PRODUCTIVITY ENHANCEMENT IN ENGINE BEARING MANUFACTURING INDUSTRY THROUGH INTEGRATED WORK SYSTEM AND JOB DESIGN: THE ERGONOMIC PERSPECTIVE

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CERTIFICATE

Certified that the thesis entitled "**PRODUCTIVITY ENHANCEMENT IN ENGINE BEARING MANUFACTURING INDUSTRY THROUGH INTEGRATED WORK SYSTEM AND JOB DESIGN: THE ERGONOMIC PERSPECTIVE**" which is being submitted by Mr. Ajay Kumar Batish, to Department of Mechanical Engineering, Thapar Institute of Engineering and Technology (Deemed University) Patiala, in fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY**, is a record of bonafide research work carried out by him under my guidance and supervision. The matter presented in this thesis has not been submitted either in part or full to any other University or Institute for the award of any degree.

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ABSTRACT

For long, the Indian industry remained protected from any international competition. The organizations were quite satisfied continuing with the old technology and working practices which were not very efficient. With the advent of globalization and liberalization and the whole world turning into a free market, many multinational companies entered the Indian market. These companies not only introduced advanced technology but also brought in world-class work practices and healthy work culture. The traditional Indian companies setup before liberalization have been left with no choice – either improve or perish. This has brought in a very welcome change. It is transforming the industry into more efficient and productive units. Higher levels of productivity, however, demand the employees to be in good physical and mental health, the working environment to be conducive to putting in hard and productive work, the work place design to be of the kind which helps in optimizing the output with minimum effort and fatigue. The subject of ergonomics has thus assumed a very important role in enhancing employee morale, his health, safety and productivity.

Cut throat competition, advanced technology and newer techniques and methods of work has increased pressure in the workplace. The whole work culture is undergoing a transformation. Now almost every one in the organization is handling not a single job but a multitude of jobs. In addition, large product mix handled in any organization has also added to the variety of jobs being done by individuals. All this demands adapting to the new skills, techniques, technology and ways of work. It also demands planning, control and accomplishment of tasks in smaller lead times, lower costs, better quality and customer satisfaction. This transformation from traditional to highly demanding and taxing working dictates that there be a parallel change in the ergonomic requirements. There is, thus, a need to study and analyze the conditions existing from ergonomic point of view, and develop and design the job and the work environment needed in the prevailing and changing manufacturing scenario. Since no generalized or universal rules and designs can be developed for all the industries, the engine bearing manufacturing industry has been taken up for detailed study.

The work has been carried out in three phases: Preliminary study of the engine bearing manufacturing organizations, detailed study of areas identified after the preliminary study, and synthesis and qualitative assessment of productivity gains and design of strategy for implementation of identified controls and validation in a phase-wise manner.

.A preliminary study was carried out to identify the extent of change which has come in jobs carried out by the employees, the resultant change which should come in

work system and job design, the status of ergonomics, and the areas needing further study and analysis. The areas identified after the preliminary study were (1) Work Postures, (2) Manual Material Handling Tasks, (3) Lifting Tasks, and (4) Job design and motivational aspects in a job.

The detailed analysis of working postures has been carried out by observing workers on all the production lines of engine bearing manufacturing units and the ergonomic risks prevalent in there work postures which result in injuries/MSD's and low productivity have been identified.. For analysis of work postures, Rapid Upper Limb Assessment (RULA) methodology has been employed. This is followed by identification of suitable provisions/ controls for implementation, as a direct outcome of the analysis.

While assessing manual material handling tasks, contributing factors that have a direct bearing on the hazards associated with such tasks have been identified and grouped. For analyzing material handling tasks, the identified factors have been used to develop an assessment technique, MHAC (Material handling assessment chart) The manual material handling tasks, which had higher need and potential for improvement have been identified and detailed analysis of these tasks has been carried out using MHAC and improvements have been made/suggested. A survey of users of handling aids has been carried out to look at safety and usability, seeking opinions on the aids currently in use and on the factors, which most affect perceptions of their usability. The outcomes of the survey results have been used to design and fabricate a four-wheeled pallet trolley for use in the representative industry. The manual-lifting tasks at all stations during the manufacturing of engine bearings/ bushings have been evaluated using the revised NISOH Lifting Equation (1991). Wherever the assessment showed that, there is a possibility of risk of injury, modifications have been made/ suggested to eliminate or reduce the risk.

Assessment of Job design has been carried out by using Job Diagnostic Survey (JDS) questionnaire (Hackman and Oldham, 1974). The study has been carried out on three job families: Production operators, Quality Staff & Inspectors, and Maintenance staff & Machine setting workers of engine bearing industry. Analysis of five measures of Motivating Potential as well as Measures of Growth Needs for the three job families has been carried out to find the number of employees in the ideal job-person match. The eight measures relating to the outcomes and satisfaction of a motivational situation have been analyzed jointly for all the operators taken together. After the analysis, the jobs needing re-design have been identified for each job family and using the cause and effect diagram and pareto technique, the root causes of problems relating to job design have been identified. Appropriate controls for the identified causes have been developed for each job family and gains in productivity and performance have been listed.

The actual and expected results of various ergonomic provisions/controls implemented/suggested after the detailed analysis as described above have been summarized in terms of productivity and performance gains. The broad findings of the preliminary study, results of the analysis of work posture, material handling (both carrying and lifting tasks), job design and their impact on muscoloskeletal disorders (MSD's) and productivity have been synthesized. The ergonomic provisions and controls implemented and suggested after the detailed analysis have been categorized into two broad categories, first where the extent of improvement in productivity is validated or calculated in quantitative terms and second, where the effect on productivity cannot be calculated precisely because it involves qualitative factors. For the second category, expert opinion has been utilized to quantify the expected gains. Productivity gains in all major areas of work postures, material handling tasks, lifting tasks and job design have been compiled from the details of implemented provisions and suggested provisions. For the purpose of synthesis and modeling for developing a strategy for implementation, the controls/ provisions identified have been grouped into broad generalized categories. The cost and productivity gains expected have then been listed for each of this generalized category of controls. Expert opinion has been utilized to identify factors and parameters affecting development of a generalized approach for implementation. The qualitative responses provided by experts to the specially designed questionnaire for the purpose has been converted to quantitative score and results have been listed in reducing order of their weighted scores. Generalization of various measures for developing an approach to be used by industry in future has been suggested using expert opinion. It has further been suggested that the implementation of the developed approach be carried out in three phases.

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Nomenclature

Af	Fatigue Allowance per cycle
AM	After Market
AM	Asymmetric Angle Multiplier
Avg.	Average
CLI	Composite Lifting Index
CM	Coupling Multiplier
DM	Distance Multiplier
FILI	Frequency Independent Lifting Index
FIRWL	Frequency Independent Recommended Weight Limit
FM	Frequency Multiplier
GNS	Growth Need Score
HM	Horizontal Multiplier
JDS	Job diagnostic Survey
LC	Load Constant
LI	Lifting Index
MHAC	Material Handling Assessment Chart
MPS	Motivating Potential Score
MSD	Muscoloskeletal Disorder
NIOSH	National Institute of Occupational Health and Safety
Ns	Number of Shifts per day
Nwd	Number of Working Days in a month
OEM	Original Equipment Manufacturer
Om	Output per month
RR	Rejection Rate
RULA	Rapid Upper Limb Assessment
RWL	Recommended Weight Limit
SD	Standard Deviation
STLI	Single Task Lifting Index
STRWL	Single Task Recommended Weight Limit
Tas	Available Time per Shift
Tcy	Cycle Time for one Operation
TIET	Thapar Institute of Engineering and Technology, Patiala
Tsu	Setup Time per Shift
VM	Vertical Multiplier
WAPS	Weighted Average Percent Score

CHAPTER 1

INTRODUCTION

Over the past couple of decades, ergonomics has assumed a great importance in manufacturing industry. The effect of ergonomic factors on employee morale, his health, safety and above all his productivity is being increasingly recognized. In the developed countries ergonomics has become an essential component of not only the work place design from anatomical, physiological and psychological points of view but from a broader perspective of all human interactions. In developing countries, however, ergonomics is used in a very restricted sense. Mostly the apparent and well-established aspects of working conditions and work place design are being considered in industry. The reasons for the present state of affairs are many: lack of awareness both on the part of employers and employees, age old practices in vogue, resistance to and risk of change, lack of awareness about the benefits that will accrue, initial expenditure etc. are some of the probable reasons.

According to Helander (1997), " ergonomics and human factors use knowledge of human abilities and limitations to the design of systems, organizations, jobs, machines, tools, and consumer products for safe, efficient and comfortable use. Application of ergonomics has evolved over time as ergonomic knowledge and research have progressed, but also as human problems emerged around the world. The emergence of macro ergonomics has strongly contributed to the increasing interest in work organization in ergonomics field (Hendrick, 1991, 1996). According to US NIOSH (2000), work organization deals with subjects such as the following: the scheduling of work (such as work-rest schedules, hours of work and shift work), job design (such as complexity of task, skill and effort required, and degree of worker control), interpersonal aspects of work (such as relationships with supervisors and co-workers), career concerns (such as job security and growth opportunities), management style (such as participatory management practices and teamwork), and organizational characteristics (such as climate, culture, and communications).

The objective of ergonomics is to improve performance as well as health and safety. Therefore, the concept of work organization is at the core of ergonomics. Some work organizations are more 'efficient' at achieving optimal performance and health and safety goals. The impact of work organization of people can be conceptualized as physical or psychosocial work factors (Cox and Ferguson, 1994). Psychosocial work factors are 'perceived' characteristics of the work environment that have an emotional connotation for workers and managers, and that can result in stress and strain (Hagberg et al., 1995). Physical work factors include typical ergonomics work factors, e.g. repetitiveness, force, poor workstation design, and unhealthy and awkward postures.

1.1 PRESENT SCENARIO AND FUTURE OPTIONS

The dawn of globalization and liberalization in India and the whole world turning into a free market has ushered in a new era in industrial working. This era of cutthroat competition has brought with it some welcome changes. It is also transforming the industry into more efficient and productive units. Higher levels of productivity, however, demand the employees to be in good physical and mental health, the working environment to be conducive to putting in hard and productive work, the work place design to be of the kind which helps in optimizing the output with minimum effort and fatigue. In addition, the human – human interactions, be it between the management and employees or between employees should be healthy, devoid of creating tensions and which promote initiative and motivation and generate a sense of belonging.

As mentioned above, globalization and liberalization has brought with it more competition, increased pressure in the workplace and newer techniques and methods of work. The whole culture is undergoing a transformation. Now almost every one in the organization is handling not a single job but a multitude of jobs. Not very long ago quality used to be the responsibility of Quality Control people. Now it is primarily the responsibility of the people producing goods and services. Similarly maintenance, upkeep of the work place and continuous improvement are becoming the responsibility of the people who produce goods. Workers and supervisors, in addition to handling these multiple jobs, are also the members of various teams working on new projects and improvement programs. In addition, large product mix handled in any organization has also added to the variety of jobs being done by individuals. All this demands adapting to the new skills, techniques, technology and ways of work. It also demands planning, control and accomplishment of tasks in smaller lead times, lower costs, better quality and customer satisfaction. This transformation from traditional to highly demanding and taxing working dictates that there be a parallel change in the ergonomic requirements. It is feared that ergonomic environment has not undergone a proportional change. This may have a detrimental effect on the employee who in his daily and social life is also subjected to more pressures because of cultural change and new life styles. There is, thus, a need to study and analyze the conditions existing from ergonomic point of view, and develop and design the work environment needed in the prevailing and changing manufacturing scenario.

Although such studies are needed in every sector and every type of industry, yet there have to be separate studies in different kinds of industries. No generalized or universal rules and designs can be developed for all the industries. Some of the requirements however, will be common to all. Comprehensive studies aimed at analyzing the problem completely, particularly in the wake of changed manufacturing scenario, have not been evidenced in the literature. In this research work, it is proposed to study the engine bearing manufacturing industry in detail, analyze the ergonomic requirements and design an ergonomic system for this kind of industry, which ensures worker safety and health as well as enhances productivity.

1.2 OBJECTIVES AND ISSUES

The proposed study is aimed at assessing the status of work system design and job design in engine bearings manufacturing industry with regard to ergonomic perspective; finding out the effect of these on performance and productivity and develop guidelines for the achievement of desired ergonomic levels for enhanced performance and productivity. The following issues have been considered in this study:

- Changed demands of work from the employees in the wake of changed manufacturing scenario.
- Changed ergonomic requirements in the wake of more demanding work
- Status of ergonomics in specified manufacturing industry.
- Productivity and performance levels.
- Effect of ergonomic initiatives on performance and productivity.
- Determination of desired work system and job design particularly with regard to
    - Work postures
    - Manual material handling tasks
    - Lifting tasks
    - Job design and redesign
- Modeling of the system to achieve the desired level in a phased manner.
- Validation of improved work system and job designs

1.3 SCOPE OF THE STUDY

The study has been carried out in automobile engine bearings manufacturing industry situated in Punjab, Haryana, Himachal Pradesh and Delhi. Further, the study has been mainly focused on analysis of work postures, material handling tasks which includes both lifting as well as carrying tasks, job design and repetitive tasks. Environmental aspects have been considered to the extent so that there is no apparent adverse impact on productivity and performance. Study was mainly conducted in actual working places in particular, the shop floor operations rather than laboratory.

1.4 OVERALL METHODOLOGY OF THE STUDY

The overall work is divided into two parts: analysis and design. Literature on the subject and its constituent aspects have been reviewed extensively to design a methodology for carrying out analysis of the current status of work design and job design in the representative industries. Long standing industrial experience of the researcher particularly of the shop floor working, also served as a useful input for study. The areas under work system design and job design needing detailed analysis were identified using the results of a specially designed questionnaire, review of literature and industrial experience. Design phase uses the results of the analysis, and along with expert opinion taken in a structured way develops strategies for future implementation of various desired ergonomic provisions and controls with an aim to improve worker health and safety as well as enhance productivity in a phased manner.

In the beginning of the work a preliminary study of engine bearings manufacturing units has been conducted to find out: (i) Changed demands of work from the employees in view of the changed and more competitive manufacturing scenario (ii) Changed ergonomic needs of the employees due to changed demands of work. (iii) Status of Ergonomics in engine bearing industry, and (iv) Identification of areas which need to be taken up for further detailed ergonomic analysis to make them more ergonomically compliant and to increase productivity. This preliminary study involved taking feedback from the employees of the four engine bearing units through a specially designed questionnaire. A review of literature and its findings formed an important input for content and design of the questionnaire.

Based on the finding of the preliminary study, detailed analysis of the identified areas has been carried out using specialized assessment techniques reported in the literature. For analysis of work postures Rapid Upper Limb Assessment (RULA) method has been employed. Material handling and lifting tasks have been analyzed using Material Handling Assessment Chart (MHAC) and NIOSH revised lifting equation (1991) respectively. Job designs have been evaluated using the Job Diagnostic Survey (JDS Model) developed by Hackman and Oldham (1974). By conducting detailed analysis of each task, those tasks, which need most urgent action with regard to ergonomic risks involved, were identified and an order of priority for the application of improvement action for the entire manufacturing line was established. Subsequently, a series of improvement actions were undertaken and implemented, analyzing whether significant improvement in productivity levels take place in parallel as a result of these ergonomic improvements. The hierarchy of controls developed has been (1) Engineering Controls, (2) Administrative Controls, and (3) Workplace modifications. The results showed that the productivity issues were more predominant for the tasks, which had ergonomic problems, than for the rest of the tasks. For that reason, the relationship between productivity and ergonomic problems associated with a task has been established analyzing one task at a time under different ergonomic conditions. This has been followed by generalization of results using expert opinions through qualitative modeling. Using the qualitative model, strategies were developed for implementation of various ergonomic provisions and controls in manufacturing industries to achieve the desired levels of performance in a phased manner.

1.5 ORGANIZATION OF THE THESIS

The thesis has been divided into nine chapters. Brief description of the contents of each chapter is as under:

Chapter 1 brings out the need and importance of work system and job design in manufacturing industry particularly in engine bearing manufacturing industries, in the light of more demanding work carried out by employees along with their impact on productivity and performance. Significant issues viz. the impact of globalization and liberalization, status of ergonomics awareness and compliance, and likely strategies for elimination of ergonomic hazards and its impact on productivity improvement have been discussed. Objectives and scope of the study and overall methodology adopted have also been briefly outlined.

Chapter 2 covers an extensive literature review on the subject and its related areas. Literature review has been divided into the following categories:

1) **Work system design**: i) Assessment of work postures and its impact on MSD's and other back injuries; ii) Repetitive tasks; iii) Arrangement of work centers in the shop floor; iv) Arrangement of various materials, tools etc. on the work centers; and v) Productivity improvement through ergonomically designed work place

2) **Material handling systems**: i) Analysis of Lifting and carrying tasks· ii) Material handling aids used in manufacturing industry

3) **Job design and redesign**: Job Design – Task identity, task significance, skill variety, autonomy, feedback from people, feedback from job, growth needs, Job contents

4) **Environment**: Study of environmental factors viz. Illumination, temperature, noise humidity to an extent to ensure their compatibility with job and work system design.

Within each category, literature regarding the importance of area as well as need and status studies carried out by various researchers has been covered. Current state of the research has been assessed, limitations of existing approaches have been outlined and areas needing further research have been highlighted.

Chapter 3 discusses the design of the study, its phases and procedural steps. A brief description of the, methodology, tools and techniques used have been covered in this chapter.

Chapter 4 presents the analysis and results of a preliminary study carried out involving employees of representative engine bearing manufacturing units to identify the extent of change which has come in jobs carried out by the employees, the resultant change which should come in work system and job design, the status of ergonomics, and the areas needing further study and analysis.

Chapter 5 covers the detailed analysis of the work postures of the workers on the production lines of engine bearing manufacturing units and the ergonomic risks prevalent in these postures which result in injuries/MSD's or low productivity. For analysis of work postures, Rapid Upper Limb Assessment (RULA) methodology has been employed. This is followed by identification of suitable provisions/ controls for implementation, as a direct outcome of the analysis and the principles of work place design. The chapter also outlines the productivity levels in an engine bearing manufacturing unit. This data has been used to establish the effect of ergonomic improvements on productivity. The level of productivity before and after the implementation of controls has also been documented at each workstation.

Chapter 6 describes the Identification of contributing ergonomic factors and parameters that have a direct bearing on the hazards associated with manual material handling tasks and grouping them into ten broad categories. The chapter further describes the development of an assessment tool, MHAC (Material handling assessment chart), for analyzing material handling carrying tasks and its application for analysis of material handling tasks prevalent in engine bearing industry. The manual material handling tasks, which had higher need and potential for improvement have been identified and detailed analysis of these tasks has been carried out using MHAC and improvements have been made/suggested. Finally, effects of these improvements on human performance and productivity have been assessed and a cost benefit analysis has been carried out. Besides this, a survey of users of handling aids has been carried out to look at safety and usability, seeking opinions on the aids currently in use and on the factors, which most affect perceptions of their usability. A four-wheeled pallet trolley has been designed from ergonomic point of view for use in the representative industry. This chapter also describes the evaluation of manual-lifting tasks at all stations during the manufacturing of engine bearings/ bushings using the revised NISOH Lifting Equation (1991). Wherever the assessment showed that, there is a possibility of risk of injury (Lifting Index greater than 1), modifications have been made/suggested to eliminate or reduce the risk.

Chapter 7 covers the aspects of job design and redesign. For carrying out the assessment of Job design, Job Diagnostic Survey (JDS) questionnaire (Hackman and Oldham, 1974) has been used. The JDS provides 21 measures of an individual's motivational situation, which enables it to give very detailed and factual information. The aims of this study have been to determine the nature and extent of any motivational problems amongst three categories of operators namely, Production operators, Quality Staff & Inspectors, and Maintenance staff & Machine setting workers of engine bearing industry, and assess their possible effects on productivity and performance. Analysis of five measures of Motivating Potential as well as Measures of Growth Needs for the three job families has been carried out to find the number of employees in the ideal job-person match. The eight measures relating to the outcomes and satisfaction of a motivational situation have been analyzed jointly for all the operators taken together. After the analysis, the jobs needing re-design have been identified for each job family and using the cause and effect diagram and pareto technique, the root causes of problems relating to job design have been identified. Appropriate controls for the causes identified have been developed for each job family and gains in productivity and performance have been listed.

Chapter 8 summarizes the actual and expected results of various ergonomic provisions/controls implemented/suggested in Chapter 5 to Chapter 7, in terms of productivity gains. This chapter synthesizes the broad findings of the preliminary study, results of the analysis of work posture, material handling (both carrying and lifting tasks), Job design and redesign and their impact on muscoloskeletal disorders (MSD's) and productivity. The ergonomic provisions and controls implemented and suggested in the preceding chapters were categorized into two broad categories, first where the extent of improvement in productivity is validated or calculated in quantitative terms and second, where the effect on productivity cannot be calculated precisely because it involves qualitative factors. While in the case of some of the suggested provisions a fairly accurate assessment of improvement in these parameters and consequent increase in productivity has been worked out, for some others jobs provisions and controls suggested are administrative or qualitative in nature. For the second category, expert opinion has been utilized to quantify the expected gains. Productivity gains in all major areas of work postures, material handling tasks, lifting tasks and job design have been compiled from the details of implemented provisions and suggested provisions. For the purpose of synthesis and modeling for developing a strategy for implementation, the controls/ provisions identified have been grouped into broad generalized categories. The cost and productivity gains expected have then been listed for each of this generalized category of controls. Expert opinion has been utilized to identify factors and parameters affecting development of a generalized approach for implementation. The qualitative responses provided by experts to the specially designed questionnaire for the purpose has been converted to quantitative score and results have been listed in reducing order of their weighted scores. Further, this chapter covers the generalization of various measures for developing an approach suggested to be used by industry in future. For this generalization and development of phased approach, expert opinion was again utilized.

Chapter 9 presents the summary of results, conclusions of the study covering its usefulness, work done, areas explored and scope for further work. Recommendations for further research and covering other closely related areas with a view to eliminate or reduce ergonomics risks associated with the performance of the job have also been made.

1.6 CONCLUDING REMARKS

While every attempt has been made to make this study exhaustive, intensive and broad based as much as possible, it may be appreciated that covering all the engine bearings manufacturers in a country as large as India, is a stupendous task. To the best of our knowledge, this study has not left out any important factors or parameters relating to ergonomic analysis of engine bearings manufacturing. Review of the literature is the first logical step in a research effort and the next chapter is devoted to the same.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A comprehensive review of literature on diverse aspects of application of ergonomics and its impact on productivity is presented here. It helps to identify the areas to be explored in this study. Thrust areas of research and limitations of existing approaches are highlighted. Need for further research is explored.

2.2 REVIEW OF LITERATURE

Ergonomics is now being recognized as a separate and vital subject in industrial working. It has a very wide domain ranging from physical factors like measurements (anatomical) to physiological, psychological and finally the human – human interactions. Each one of these areas has become a special branch of study. Work is being done in all these areas. In India, however, very limited research is being carried out.

2.3 DEFINITIONS OF ERGONOMICS

As per ISO working draft (1999), "Ergonomics produces and integrates knowledge from the human sciences to match jobs, systems, products and environments to the physical and mental abilities and limitations of people". In doing so, it seeks to safeguard safety, health and well being whilst optimizing efficiency and performance.

ILO defines ergonomics as "the application of human biological sciences in conjunction with engineering sciences to the worker and his working environment, so as to obtain maximum satisfaction for the worker, which at the same time enhances productivity".

The IEA Executive working group (2000) defines Ergonomics as a scientific discipline concerned with the understanding of interactions among humans and other elements of a system in carrying out a purposeful activity. It continues "Ergonomics contribute to the design of tasks, jobs, products and environments in order to make them compatible with the needs, abilities and limitations of people".

Wilson (2000), gave a new definition of ergonomics confirming it to be a discipline in its own right - as a theoretical and fundamental understanding of human behavior and performance in purposefully interacting socio–technical systems, and the application of that understanding to design of interactions in the context of real settings. The author brings out the role of ergonomics as the holistic approach to understanding complex interacting system involving people and the use of such understanding to improve people's well being, performance and productivity.

2.4 ERGONOMIC PERSPECTIVE

In the early days, ergonomics was often applied to "unitary problems", one person interacting with one machine or job, or behaving within an environment notable for one particular factor (heat, noise, temperature, pressure etc.). What distinguished ergonomics from its constituent disciplines of anatomy, physiology and psychology was the notion that it must be applied. However, this is no longer the case. Wilson (2000) says that we must have a fundamental ergonomics and an applied ergonomics – both related to real world experiences with multiple complex interactions. In working with this perspective, ergonomists became experienced in producing frameworks to examine and measure interactions, providing insights and a body of knowledge on which to base improvements.

Jensen et al. (2001), discuss the results of a national survey conducted in Denmark for workplace assessment for occupational assessment and safety management in small firms. The study discusses the capability of the small firms to comply with legislative demands on work environment. The results show that only a small fraction of small firms comply. The firms, which show more compliance to ergonomics requirements, are shown to have better work environment, satisfied people and higher productivity levels.

Suri and Marsh (2000) point out that ergonomics must achieve a balance between its valuable but retrospective, problem driven activities and its prospective life enhancing contributions. Woods (1999) also suggests that we must move from living in the age of ergonomics problems to a world where ergonomics is central and fundamental requirement for all systems development. Burns and Vicente (1999) feel that too often, ergonomics is relegated to being a "post-design" evaluation, leaving ergonomists little opportunity to make significant and important design changes. They go on to describe the findings from a participant-observer study of the relationship between ergonomics and engineering design and conclude that designers and ergonomists must negotiate through a changing web of constraints from many sources.

Singh and Batish (2003) presented an approach for ergonomic investigation of manufacturing units and design of an effective industrial/production system for all-round productivity improvement. The approach includes ergonomic investigation of the existing work system prevalent in a representative manufacturing unit to study. The investigation includes man-machine relationship on work centers which encompasses types of displays, time-sharing, decision making, types of control devices and their compatibility with displays and working postures; material handling and the arrangement of work centers in the production shop floor; psychological aspects regarding job contents, task analysis, job rotation, multiple jobs and multiple skills, interruptions in jobs etc.; environmental aspects to ensure their compatibility with job design and work system design; worker capabilities (response time, reaction time, two hand co-ordination etc.) through specially designed experimental equipment and other standard psychological tests viz a viz the job performed by them. These details of the prevalent systems are compared with the requirements of an efficient ergonomically designed system based on the principles of balance theory and theories of job design and in order to work out the gaps in the present system (Smith, 1989) a new system would evolve by removing these gaps. The approach also includes carrying out of a cost benefit analysis indicating the initial expenditure for ergonomic compliance and benefits to be accrued in terms of productivity enhancement and reduction in wastage by modeling of the system to achieve the desired levels in a phased manner.

Considering the diverse nature of application of ergonomics in industry, the areas covered in this literature review encompass work system design, job design and redesign, material handling which includes analysis of both lifting as well as carrying tasks, and environmental aspects.

2.5 CATEGORIZATION OF LITERATURE REVIEW

The review of literature has been divided into following categories:

1) Work system design

- Assessment of work postures and its impact on MSD's and other back injuries
- Repetitive tasks
- Fatigue
- Arrangement of work centers in the shop floor
- Productivity improvement through ergonomically designed work place

2) Material handling system

- Analysis of Lifting and carrying tasks
- Material handling aids used in manufacturing industry

3) Job design and redesign

Job Design – Task identity, task significance, skill variety, autonomy, feedback from people, feedback from job, growth needs, Job contents, task analysis, rotations, multiple jobs and multiple skills, interruptions in jobs, shift hours, part of the job or complete job, manual and mechanized work, extent of use of principles of job design and work study in existing jobs, routine or development work, job rotation, job enrichment, and job enlargement.

4) Environment

Limited study of environmental factors viz. Illumination, temperature, noise humidity to ensure their compatibility with job and work system design.

2.6 WORK SYSTEM DESIGN

2.6.1 Work postures and muscoloskeletal disorders (MSD's)

Injuries and illness due to muscle, joint, and bone disorders from physical jobs account for more than 34% of all injuries that results in lost workdays, costing employers $15-$20 billion a year in worker compensation charges (OSHA, 1999). The relationship between awkward working postures and the risk of musculoskeletal disorders has been widely studied in the past. Wely (1969) discussed the relation between inadequate work postures and probable sites of pain, and Armstrong et al. (1993) reported a comprehensive review of epidemiological studies examining the relationship between work postures and musculoskeletal disorders. Heinsalmi (1986) and Burdorf et al. (1991) pointed out that a significant relationship was found between poor working postures and musculoskletal-related lost workdays or low-back disorders. Bhatnagar et al. (1985) indicated that a working posture affects postural discomfort and inspection performance for printed board reproductions. Awkward, extreme, and repetitive postures can increase the risk of musculoskeletal disorders. Therefore, cost effective quantification of the magnitude for physical exposure to poor working postures is important and needed, if the potential for injury as a result of postures is to be reduced (Andrew et al., 1998). Since the development of the Posturegram, a technique for numerically defining a posture proposed by Priel (1974), various postural classification methods have been developed to identify and quantify postural stress during work. These schemes can be classified into two basic categories depending upon the methods used for quantifying postural stresses: instrument-based and observational techniques. The latter is more widespread in industry, because it does not interfere with the worker during observations, and does not require use of expensive equipment for estimating the angular deviation of a body from the neutral position (Genaidy et al., 1994). The instrument-based method using bioinstrumentation such as electromyography has been rarely used as a major tool for quantifying postural stresses in industry because it is expensive, obtrusive and limited due to the nature of the production process in industrial sites. Most postural classification schemes developed use the observation methods. These include the posture targeting (Corlett et al., 1979), OWAS (Karhu et al., 1977), PATH (Buchholz et al., 1996), and RULA (McAtamney and Corlett, 1993), etc.

U.S., Department of Labour, OSHA (1999) define work-related musculoskeletal disorders as injuries or disorders of the muscles, tendons, joints, spinal discs, nerves, ligaments or cartilage. MSDs develop as a result of repeated exposure to ergonomic risk factors. Work related MSD's are those disorders to which the work environment and the performance of work contribute significantly. Ergonomic risk factors are the aspects of a job or task that impose biomechanical stress on the worker. Ergonomic risk factors are the synergistic elements of MSD hazards. OSHA discusses a large body of evidence supporting the finding that exposure to ergonomic risk factors in the workplace can cause or contribute to the risk of developing an MSD. This evidence, which includes thousands of epidemiologic studies, laboratory studies and extensive reviews of the existing scientific evidence by NIOSH shows that the following ergonomic risk factors are most likely to cause or contribute to and MSD :

1. Force (i.e. forceful exertions, including dynamic motions).
2. Repetition
3. Awkward postures
4. Static postures
5. Contact Stress
6. Vibration
7. Cold temperature

2.6.2 Work Posture Assessment

McAtamney and Corlett (1993) developed a survey method called RULA (Rapid upper limb assessment) for use in ergonomic investigations of work places where work related upper limb disorders are reported. This tool requires no special equipment in providing a quick assessment of the postures of the neck, trunk and upper limbs along with muscle function and the external loads experienced by the body. The method uses diagrams of body postures and three scoring tables to provide evaluation of exposure to risk factors. The risk factors under investigation are those described by McPhee (1987) as external load factors which included (1) numbers of movements, (2) static muscle force, (3) Force, (4) work postures determined by the equipments and furniture, and (5) time worked without a break. In an effort to assess the first four external load factors described above, RULA was developed to:

1. Provide a method of screening a working population quickly, for exposure to a likely risk of work related upper limb disorders;
2. Identifying the muscular effort which is associated with working posture, exerting force and performing static or repetitive work, and which may contribute to muscle fatigue;
3. Give results, which could be incorporated in a wider ergonomic assessment covering epidemiological, physical, mental, environmental and organizational factors.

A coding system is used to generate an action list, which indicates the level of intervention required to reduce the risks of injury due to physical loading on the operator. The requirement of action into which the grand scores after assessment by RULA are divided is summarized in Action levels as shown in Table 2.1:

Table: 2.1
Recommendations for each action level

Action Level	Grand Score	Generic recommendations
1	1 to 2	Posture is acceptable if it is not maintained or repeated for long periods.
2	3 to 4	Further investigation is needed and changes may be required.
3	5 to 6	Investigation and change are required soon.
4	7	Investigations and changes are required immediately.

Kee and Karwowski (2001) presented a technique for postural loading on the upper body assessment (LUBA). The method is based on the new experimental data for composite index of perceived discomfort (ratio values) for a set of joint motions, including the hand, arm, neck and back, and the corresponding maximum holding times in static postures. Twenty male subjects participated in the experiment designed to measure perceived joint discomforts. The free modulus technique of the magnitude estimation method was employed to obtain subjects' discomforts for varying joint motions. The developed postural classification scheme was based on the angular deviation levels from the neutral position for each joint motion. These were divided into groups with the same degree of discomforts based on the statistical analysis. Each group was assigned a numerical discomfort score relative to the perceived discomfort value of elbow flexion, which exhibited the lowest level among all joint motions investigated in this study, and, therefore, was set as a reference point. The criteria for evaluating stresses of working postures were proposed based on the four distinct action categories, in order to enable practitioners to apply appropriate corrective actions. The technique is very useful for evaluating and redesigning static working postures in industry.

One of the most widely used methods of observation in working posture studies is the Ovako Working Posture Analysis System (OWAS) (Karhu et al., 1977). It is used to identify and evaluate harmful working postures. The OWAS method is based on sampling from typical working postures for the whole body. OWAS codes are used to make up the 84 different posture combinations - four back postures, three arm postures and seven leg postures (three additional leg postures are included in the extended OWAS). The use of strength or the weight of loads handled is classified by a three-class scale. Taking these three loads levels into account, the basic OWAS has 252 (4×3×7×3) posture and load combinations.

The method produces the frequency and relative proportion of time spent in the individual positions and an assessment on a four-grade scale of the harmfulness of the postures as well as the urgency to correct these postures. From the beginning, the OWAS method was manual and the registrations and calculations were performed on special pre-printed forms. Nowadays, several semi-computerized systems based on the OWAS method have been developed for making the work less demanding for the operator by automation of the input and output procedures (Kant et al., 1992; Long, 1992; Leskinen and Tonnes, 1994; Pinzke, 1994; Vedder, 1998).

Pinke & Kopp (2001) performed two experiments to examine the usability of different marker-less approaches in image analysis and computer vision for automatic registration of OWAS (Ovako working posture analysis system) postures from video film. In experiment 1, a parametric method based on image analysis routines is developed both for separating the subject from its background and for relating the shapes of the extracted subject to OWAS postures. All 12 analyzed images were correctly classified by the method. In experiment 2, a computer neural network is taught to relate postures of a subject to OWAS postures. When the network was trained with 53 images the rest of the set of 138 images was correctly classified. The experiments show promising results regarding the use of image analysis and computer vision for tracking and assessing working postures. However, the authors felt that further research is needed including tests of different human models, neural networks, and template matching for making the OWAS method more useful in identifying and evaluating potentially harmful working postures.

Westgaard (2000) discusses three themes that are likely to be important within health-related ergonomics in the coming years. The first two themes concern methods for risk analysis of low-level biomechanical and psychosocial exposures. The third theme is approaches to successful implementation of ergonomics interventions. Evidence on the assessment of low-level biomechanical and psychosocial exposures by instrumented measurements is also discussed. In this paper, it is concluded that, despite recent advances in our understanding of exposure-effect associations under these exposure conditions, we must at present rely on more subjective methods, employed in collaboration between expert and worker. This approach to risk analysis identifies in most cases critical exposures in a work situation. The focus should then be on the successful implementation of measures against those exposures, as identification alone does not solve problems. The aim of improved health for the workers further requires that the full complement of risk factors be considered, including work, leisure time and person-based risk factors. Finally, the need to put ergonomics intervention initiatives in an organizational context are emphasized, the examples of approaches used by companies is presented.

Mortimer et al. (1999) conducted a study to validate interview data concerning the duration of four work postures (1) sitting, (2) standing/walking with hands above shoulder level (3) standing/walking with hands between shoulder and knuckle level, and (4) standing/walking with hands below knuckle level. The self-reported time spent in each posture was tested in relation to observations and technical measurements in 20 subjects during two full working days. The linear relationships between self-reports and observations were strong for the three postures; sitting (r^2=0.55), hands above shoulder level (r^2=0.58) and hands below knuckle level (r^2=0.69). Thus using this interview technique, self-reports concerning time spent in (1) sitting, (2) standing/walking with hands above shoulder level and (3) standing/walking with hands below knuckle level may be accurate enough for studying these work postures in epidemiological studies. The experience from the interviewers is that the interview model makes it easy for respondent to comprehend the different descriptions of work postures and it seems to be easy for the subjects to assess duration of the respective work posture as well. The authors, thus, concluded that interview data concerning the following work postures, may be accurate enough for studying health effects in epidemiological studies - Time per day spent sitting; Time per day spent with hands above shoulder level; Time per day spent with hands below knuckle level.

Rose et al. (2001) conducted a study to investigate the effects of low loads in fully flexed postures. Thirteen men who were unused to the postures participated. Thirteen professional construction workers with long experience of suchlike postures were also studied. Pain reactions during and after loading were observed, as well as endurance time and the recovery process, hereby studying the resumption time. The authors concluded that endurance and resumption times differed little from those given by models used for more common postures. Also, pain from the legs and not from the back limited the working ability in 86% of the endurance tests. Thirdly, the construction workers had significantly longer endurance time and shorter resumption time.

2.6.3 Ergonomic analysis of workplace using ergonomic software

Feyen et al (1999) presented a case study for ergonomic analysis of work place design using computer-aided ergonomics software. According to the authors, one of the primary goals of computer-aided ergonomics is to develop software tools that allow ergonomics information to be accessed at the earliest stages of design. The case study discusses a PC-based software program that allows a designer to quantify a worker's biomechanical risk for injury based on a proposed workplace design. The program couples an established software tool for biomechanical analysis, the Three-Dimensional Static Strength Production Program (3DSSPP), with a widely used computer-aided design software package, AutoCAD. The use of this "3DSSPP/AutoCAD interface" in the proactive analysis of an automotive assembly task is described and the results compared with an independent assessment using observations of workers performing the same task. Both studies yield similar conclusions suggesting that proactive use of software such as the 3DSSPP/AutoCAD interface is a valid tool in evaluating proposed workplace designs. In this context, issues in the analysis of workplace designs regarding the use of supporting ergonomic tools, assumptions, and posture selection are also discussed.

Johansson et al (2001) present a method for psychological evaluation of potentially stressful or unsatisfactory situations in manual work. The studies conducted by them using a computer software focus on subjective responses regarding specific situations and are based on interactive worker assessment when viewing video recordings of oneself. The results obtained are helpful in participatory ergonomic process of change. A comprehensive ergonomic evaluation of retail ice cream shops, including field and laboratory data collection was conducted by Dempsey et. al. (2000) using a human workplace model approach to ergonomic practice (Leamon, 1988) to guide a comprehensive ergonomics evaluation (Dempsey and Leamon, 1999; Leamon, 1996). The goal of the evaluation was to provide recommendations to enhance the health, safety and productivity of the employees. Active and passive surveillance and facility walk through were used to guide the selection of analyses.

2.6.4 Measurement of gripping forces

McGorry (2000) describes a device for measuring gripping forces and the moments generated by a hand tool since quantification of the forces applied with or by hand tools can be a difficult but important component of an ergonomic evaluation. Laboratory characterization indicated that the device had good linearity ($r^2=0.999$) with minimal hysteresis or creep. The working range exceeds 700 N for gripping forces and 28 and 16 Nm fore the two applied moment axes. The device, configured as a boning knife, was sensitive to differences in grip forces and applied moments in a simulated meat-cutting task requiring distinct levels of precision. Significant individual variation in the efficiency of grip force was also observed. The system design is flexible, allowing for additional tool configurations.

2.6.5 Repetitive tasks

Arbejdstilsynet (Labour Inspectorate, 1994) considers repetitive work as hazardous if it lasts for more than 3-4 hours a day with a cycle time of less than 30 seconds, or the same movements are repeated more than 50% of cycle time. In addition, the risk can be increased by reinforcing factors such as high demands for precision; high demands on vision; low level of influence; heavy lifting and carrying; awkward work postures and large use of force. Work with a cycle time of less than 30 seconds or the same movement more than 50% of cycle time may also be considered hazardous repetitive work based on a concrete evaluation of the work and reinforcing the factors.

Hasle and Molla (2001) presented an action plan against repetitive work and discussed as a possible new strategy for regulating repetitive work as well as other complicated working environment problems. The article is base on an empirical evaluation of the action plan. The assessment of the action plan indicates that a measurable reduction of repetitive work has been achieved, while recognizing that new management strategies focusing on human resource development have also played an important role.

A summary of Danish Action Plan to combat repetitive work referred by the authors is as under:

Objective:

- Reduction of hazardous repetitive work by 50% before the year 2000.

General Activities:

- Research and analysis aimed at defining hazardous repetitive work, methods to reduce repetitive work, economic consequences of reduction of repetitive work;
- Improving the registration of repetitive strain injuries;
- An investment program for companies wishing to reduce repetitive work.
- Involvement of the works council in reducing repetitive work.
- Considering repetitive work issues in general bargaining;
- Development of education and information about repetitive work.

Sectional Activities:

- 11 Sectoral Working Environment Councils shall prepare industry-specific action plans and follow-up on received company action plans.

Company activities:

- Companies with repetitive work shall make a company action plan. This plan must be forwarded to the Industrial Environment Council.

In addition, the Labour Inspectorate is asked to place priority on guidance to the companies rather than enforcement. It was also stipulated that a mid-term and a final evaluation of the plan should be carried out.

Shikdar and Das (1995) presented the results of an experimental industrial field study conducted to improve worker productivity through various interventions in a repetitive production task performed under ergonomic working conditions. The authors conclude that worker productivity was found to improve most as a result of participative standard setting with feedback and monetary incentives. In general, standard setting with feedback, with or without monetary incentives, improved worker productivity. The performance without interventions was far below the normal standard. The authors concluded that under good working conditions, challenge and incentives may be advantageously applied to improve worker productivity in industry.

Shikdar and Das (2003) carried out further investigation to determine the manner by which production standards or goals, performance or production feedback and monetary or wage incentive affected or moderated the relationship between worker satisfaction and productivity in a repetitive production task in a fishing industry. The industrial study was conducted to measure worker satisfaction and productivity under various experimental conditions involving production standards, performance feedback and monetary incentive. Only the participative standard and performance feedback condition affected the worker satisfaction-productivity relationship significantly for the fish-trimming task. The positive correlation coefficient (0.87) for this condition was found to be highly significant. This has an important implication for setting a strategy for achieving higher worker satisfaction and productivity in such an industry. Production standards with feedback generally improved worker satisfaction and productivity. Monetary incentive further improved worker performance but added no incremental satisfaction gain. The incorporation of production standards, performance feedback and monetary incentive affected worker satisfaction and productivity differently and this had an effect on the worker satisfaction-productivity relationship. In an earlier laboratory study, no significant worker satisfaction-productivity relationship was found when subjects (college students) were provided with similar experimental conditions. The investigation was performed in a fishing industry where the operators were performing a repetitive fish trimming operation. An important implication of this research suggests a strategy for achieving higher worker satisfaction and productivity through the incorporation of participative standard or goal and performance feedback in such an industry. The authors are of opinion that the finding of this research can be used advantageously in other industries where the operators are engaged in a repetitive production task. The authors further added that in the future, it will be desirable to develop a model to describe the relationship between the independent factors, such as production standards, performance feedback, monetary incentive and other work design aspects and the dependent factors, such as, worker satisfaction, job attitudes and performance.

Singh and Batish (2004) presented the results of a study carried out to improve productivity of workers performing highly repetitive tasks through various interventions. The study was conducted in an engine bearing manufacturing facility at the hole punching station, which is highly repetitive. Motivating workers to improve productivity has been a major agenda for the management on this operation. The study was conducted after ensuring proper ergonomic conditions. The subjects were randomly divided into four groups. Each group was given training and subsequently working sessions were assigned. The groups were given different targets. Worker productivity was found to improve most as a result of participative target setting and the management providing continuous feedback on performance. The performance without such controls was far below the normal standard. It is concluded that good working conditions, challenge and ongoing feedback can be advantageously applied to improve worker productivity in industry for repetitive tasks.

Laring et al. (2002) conducted a study to develop an ergonomic complement to a modern MTM system called SAM that gives the production engineer a first insight into the future ergonomic quality of a planned production. A method was developed that requests the engineer to supply two additional pieces of information to the analysis; the zone relative to the operator's body in which the movement takes place or ends, and the weight or force involved in the operation. It was concluded from the study that ErgoSAM can predict high load situations from the different tasks during the work sequence. Repetitive tasks are prevalent in manual industrial work and the source of many work related diseases, and ErgoSAM has the potential of being a tool for early detection of such risks. The method is proven to estimate correctly biomechanical load occurrence. When comparing different alternatives for technical and organizational design of a future production, it will be possible to optimize with respect to productivity and biomechanical load simultaneously. The authors further add that if ErgoSAM is to be used as a future tool by production engineers, it is of vital importance to point out what type of musculoskeletal strains that are not identified by ErgoSAM. This can be done in the form of a checklist that is presented to the engineer in a suitable manner during the ErgoSAM analysis.

2.7 UNDERSTANDING FATIGUE

Ergonomics and work measurement literature streams, although drawing from similar sources, fail to manifest a common definition of fatigue, although some common ground is reached. According to Mital, physical fatigue can be distinguished from psychological fatigue, which he terms "an aversion to work" (Mital et al., 1994). Niebel (American Institute of Industrial Engineers, 1992, Chapter 62, p.1621) similarly terms fatigue "a lessening in the will to work". The work measurement literature apparently adopts the subdivision of fatigue into physical, psychological and environmental components - either as a contributing factor or one in its own right. Rohmert (1973a) defines fatigue (perhaps more narrowly) as the "reduction of the functional capacity of an organ or of the organism as a result of action; fatigue is eliminated by recovery, fatigue and recovery being understood as time processes." There is clearly significant common ground in terms of defining fatigue in terms of the need for recovery time to offset it.

The ergonomics literature has devoted considerable effort to devising appropriate rest and recovery intervals to offset the effects of physiological fatigue. The literature focuses primarily on recommended standards or limits of work-related energy expenditures (Mathiassen and Winkel, 1992). It is from this literature stream that the third methodology (objective physiological assessment of fatigue) flows. Waters et al (1993b), in attempting to construct a guideline for repetitive lifting (particularly applicable to grocery warehouse order selectors), utilized a maximum energy expenditure ceiling and then adjusted it to account for the location of the repetitive lifting and the maximum duration of the repetitive lifting episode, expressing this criterion in terms of kilocalories per minute expended.

2.7.1 Fatigue Allowance Standards

Cornman (1970) while, noting the lack of consensus among engineers concerning how fatigue allowances should be set and the lack of "a formula or even a basis from which to start", proposed a basic yardstick for "daily use of the plant engineer". Cornman also argues that fatigue allowances are purely for fatigue and are unrelated to any considerations made with respect to personal and unavoidable delay allowance; thus his protocol stands independent of personal and unavoidable delay allowance determination. Cornman argued that any allowance must satisfy three basic criteria (1) it must be as uniform as possible, (2) it must be understood by all concerned and (3) it must be verifiable.

Page's (1964) overall methodology is somewhat similar to Cornman's although it lacks clear factor definitions, degrees and degree definitions. However, it does provide benchmark comparisons of how certain jobs should be rated. In addition, Page's work states clearly that the factor definitions and corresponding fatigue allowance should only be applied to those relevant job elements (parts of the job versus the entire job); in other words, a weight allowance is only applied to those elements of the job in which the individual is actually lifting, pushing, pulling or carrying.

Williams (1973) reported a study of his employer to attempt to validate a particular formula for determining fatigue allowance, as part of an effort to evaluate gender pay equity gaps. Like Cornman and Page, he dismissed attempts to more rigorously link fatigue allowance determination to the research literature on fatigue as "codified folklore", concluding that not enough is known at the time about fatigue. His working group confirmed that there is a basic minimum level of fatigue allowance applicable to any form of work to cover for normal, mental and/or physical fatigue and personal needs and a fatigue allowance should be applied individually to each job element.

Ashberg et al (2000) conducted a study to analyze the effects of shift work on different dimensions of perceived fatigue, as well as to study if fatigue changes over an entire shift cycle, using the Swedish Occupational Fatigue Inventory (SOFI). The participants, 48 men and 44 women, worked on a rotating three shift in a paper mill Fatigue was rated at the end of each shift, using the SOFI, the Karolinska Sleepiness Scale, and the scale Accumulated Time with Sleepiness. Reaction time tests were also carried out at the end of each shift. The results showed that the reported fatigue was primarily expressed on terms of Sleepiness, and to some extent also in terms of Lack of energy and Lack of motivation. These dimensions also discriminated most between work shifts, where the highest levels of fatigue were reported during the night shifts. Longer reaction times coincided with increasing ratings of the mental aspects of fatigue. The study results add that Lack of energy and Lack of motivation also form part of the perceived fatigue after night shifts. In addition, fatigue tends to accumulate during night shifts.

2.8 MATERIAL HANDLING

Low back pain (LBP) and injuries attributed to manual lifting activities continue as one of the leading occupational health and safety issues facing the manufacturing industry. Despite efforts at control, including programs directed at both workers and jobs, work-related back injuries still account for a significant proportion of human suffering and economic cost to any organization. The extent and scope of the problem has been summarized in a report entitled Back Injuries, prepared by the Department of Labor's Bureau of Labor Statistics of USA [DOL9BLS)], Bulletin 2144, published in 1982. The DOL's conclusions are consistent with current workers' compensation data indicating that "injuries to the back are one of the more common and costly types of work-related injuries" (National Safety Council, 1990). According to the DOL report, back injuries accounted for nearly 20% of all injuries and illnesses in the work place, and nearly 25% of the annual workers' compensation payments. Another study indicated that overexertion was the most common cause of occupational injury, accounting for 31% of all injuries. The back, moreover, was the body part most frequently injured (22% of 1.7 million injuries) and the most costly to workers' compensation systems.

2.8.1 Analysis of Lifting Tasks

In 1981, National Institute for Occupational Safety and Health (NIOSH) recognized the growing problem of work-related back injuries and published the Work Practices Guide for Manual Lifting (NIOSH WPG, 1981). The NIOSH WPG (1981) contained a summary of the lifting-related literature before 1981; analytical procedures and a lifting equation for calculating a recommended weight for specified two-handed, symmetrical lifting tasks; and an approach for controlling the hazards of low back injury from manual lifting. The approach to hazard control was coupled to the Action Limited (AL), a resultant term that denoted the recommended weight derived from the lifting equation.

In 1985, NIOSH convened an adhoc committee of experts who reviewed the current literature on lifting, including the NIOSH WPG (1981). The literature review was summarized in a document entitled Scientific Support Documentation for the Revised 1991 NIOSH Lifting Equation: Technical Contract Reports, May 8, 1991. The literature summary contained updated information on the physiological, biomechanical, psychophysical, and epidemiological aspects of manual lifting. Based on the results of the literature review, the adhoc committee recommended criteria for defining the lifting capacity of healthy workers. The committee used the criteria to formulate the revised lifting equation. The equation was publicly presented in 1991 by NIOSH staff at a national conference in Ann Arbor, Michigan, USA entitled "A National Strategy for Occupational Musculoskeletal Injury Prevention - Implementation Issues and Research Needs". Subsequently, NIOSH staff developed the documentation for the equation and played a prominent role in recommending methods for interpreting the results of the lifting equation.

The revised lifting equation reflects new findings and provides methods for evaluating asymmetrical lifting tasks, and lifts of objects with less than optimal couplings between the object and the worker's hands. The revised lifting equation also provides guidelines for a more diverse range of lifting tasks than the earlier equation (NIOSH WPG, 1981).

The rationale and criterion for the development of the revised NIOSH lifting equation are provided in a separate journal article entitled : Revised NIOSH Equation for the Design and Evaluation of Manual Lifting Tasks, by Waters, Putz-Anderson, Garg, and Fine, 1993 [Appendix I].

Thus, NIOSH Work Practices Guide for Manual Lifting - 1991 Revised Equation is based on a combination of biomechanical, epidemiological, psychophysical, and physiological data. It establishes acceptable lifting limits based on selected task parameters and specifies recommended engineering controls. Proper application of the equation requires an appreciation of assumptions/limitations that underlie the equation and that characterize the job being evaluated. They are categorized as:

A) Equation related assumptions -

1. Phychophysical laboratory studies provide the basis of much of the equation. These studies are based on perceived lifting stress as opposed to the potential for low back injury.
2. Physiological guidelines focus on preventing whole body fatigue.

B) Job Related Assumptions

1. Lifting and lowering tasks have the same level of risk for low back injuries. This assumption is invalid if the worker actually drops the load instead of lowering it all the way to the destination.
2. Activities other than lifting are minimal and do not require significant energy expenditure. These include holding, pushing, pulling, walking, climbing etc.
3. There are no unpredictable conditions such as an unexpected heavy load.
4. Lifting and lowering is performed with two hands.
5. Lifting and lowering is limited to no more than eight hours.
6. The worker is standing while performing the lifting/lowering.
7. The lifting/lowering occurs at a moderate pace, characterized by slow and smooth movements with constant velocity.
8. The load is stable (center of mass does not shift).
9. Equation does not apply to one-handed lifting, lifting while seated or kneeling, lifting wheelbarrows or shoveling.
10. The workers are physically fit and accustomed to physical labour.
11. Favourable environmental conditions exist involving temperature (66-79° Fahrenheit) and humidity (35 to 50%).
12. The floor surface is even.
13. The surface between the shoe sole and the floor has a 0.4 static coefficient of friction.
14. The work space is not restricted.

Recommended Weight Limit (RWL) and Lifting Index (LI)

The NIOSH equation computes the RWL, which is assumed to be safe for 99% of the male population and 75% of the female population for the given task being evaluated. The lifting index (LI) is computed by dividing the actual weight being handled (numerator) by the RWL (denominator). If this resulting number is less than one (1) the task is considered to be safe. If the LI is greater than one it exceeds the recommended weight limit and results in increased risk of injury to employees.

Snook and Ciriello (1991) developed push/pull hazard tables which provides psycho-physical data useful in predicting the percentage of male and female industrial workers who are considered safe (at low risk for MSD injuries)

Yeung et al. (2002) felt that although the development of the National Institute for Occupational Safety and Health (NIOSH) equation was partly based on the expertise of committee members convened under the auspices of NIOSH, there is no study reported in the published literature that examined the role of professional expertise in determining the relative contribution of different lifting task variables to effort exertion. They conducted a study to explore whether professional expertise can be relied on, through the use of a systematic procedure, to quantify the effects of lifting task parameters on perceived effort and risk of injury outcome measures. Three international experts participated in the research and evaluated the interactive effects of 6 lifting variables (a) weight of load, (b) horizontal distance (c) frequency of handling (d) work duration, (e) twisting angle, and (f) height of lift. They predicted the lifting effort and the injury risk of a large number of lifting configurations. A linguistic approach was used to describe the lifting activities. Logistic regression analyses were employed to model effort as a function of various lifting task variables. The results showed that all three experts rated the weight of load as the most dominant variable and the height of lift as the least important variable. Furthermore, they differed slightly in ranking the relative importance of other variables. In general, the effect of weight of load on physical effort was, at a minimum two times more important than other lifting task variables. The horizontal distance, work duration, frequency and twisting angle variables were considered to be more important than the height of lift by 25% to 33%. Collectively, these findings indicate that the experts agreed on the most and least important variables. In between, the relative importance of other variables was dependent on the professional training of the expert. The results further demonstrated that an increase in perceived physical effort was associated with an increase in the perceived risk of injury in the moderate-to-high-range values. There was a large variance, however, at the lower levels of physical effort and perceived risk. Collectively, the findings confirm the notion that low-level effort exertion activities are not perceived by the experts as risky. As the level of exertion increases to moderate values, however, the experts start to be conscious about the risk involved in the manual lifting activities. Therefore, one should not treat these two variables as equal, because they may reflect two separate dimensions in the low range. In the moderate to high range, they have some common variance but they may still reflect some differences to a certain extent.

2.8.2 Handling Aids

Mack et al. (1995) conducted a survey of users to show that many of the aids currently used are poorly designed or inappropriate for the tasks performed. The information gained during the survey was analyzed to identify the most important design features and to provide guidance for their selection and evaluation, in order to ensure that aids are suitable for the tasks for which they are used and that they are effective and safe. The authors conclude that the first stage in establishing design criteria and guidelines should be developing an understanding of the task requirements and environmental conditions under which materials have to be transported in industry. The authors conclude that there is an increasing demand for manual handling aids, but the survey has shown that many of the aids currently in use are poorly designed from the user's point of view. Moreover, the provision of such aids has not guaranteed that stress levels on the body are reduced and some of the design faults identified can actually increase the risk of injury, defeating the primary objective for the introduction of the aid. If manufacturers and purchasers of aids paid more attention to ergonomic design factors, a significant improvement in efficiency and reduction in the number of injuries could be achievable. Given the range of design factors identified during the user survey, and the fact that these tend to interact and be affected by task factors, it is important to address the usability of the aids through task analysis and user trials in order to identify the most important design features for the different types of aids and the different jobs for which they are used. The aim should be to make the handling of loads easier and safer, and in so doing reduce musculoskeletal stresses and the number of handling injuries.

2.8.3 Use of Symbols to Promote Correct Handling

Burt et al (1998) conducted three studies to examine the use of a symbol to prompt the adoption of correct lifting posture. Study 1 used an appropriateness test to evaluate nine symbols designed to encourage the adoption of correct lifting posture. Four symbols met the appropriateness criteria and were tested for comprehension in Study 2. Study 3 examined the effect of best performing symbol from Study 2 in a field setting, which involved subjects lifting a small box. Results indicate significant increases in the adoption of the use of correct lifting posture when the symbol was present compared to a control condition. The study also identified the placement of a lifting criterion symbol onto packaging as a useful technique for communicating safety information.

2.9 JOB DESIGN AND REDESIGN

Stahl et al. (2000) emphasize that job design is one of the key elements in the design of production systems. It links other activities, such as machine tool selection to personnel planning and therefore largely to the characteristics of the required personnel. They present a method that allows a task structure to be generated early, when information is still poorly defined, to be continuously adapted to the increasing level of detail, and to be used to deduce personnel needs. First, requirements for such a method with respect to the necessary modeling elements, scope, and ease of use are derived. Second a variety of existing methods, ranging from job analysis to object-oriented modeling tools, is judged with respect to these requirements. Since no existing method fulfills the requirements satisfactorily, a new method was developed. This method is a combination of a modeling method with a job analysis method and is especially suited to deal with poorly defined information.

Hackman and Oldham (1974) developed a comprehensive model of motivation, which incorporates the insights of the traditional theories: The Job Characteristics Model. The strength of this model is that it is simple enough to be used effectively while being comprehensive enough to detect a wide range of different motivational problems. The Hackman and Oldham model concentrates on the relationship between the person and the job. Six measures describe the motivating features of a job; they are called Core Job Dimensions. These are aggregated into a single measure called the Motivating Potential Score (MPS) of the job. Two measures describe the person's motivational preferences, and they are aggregated into a single measure called the Growth Needs Strength (GNS) of the individual. If the MPS of a job matches closely the GNS of the person then the individual is likely to be highly motivated. This relationship between the person and the job results in an internal psychological situation (three measures called Internal Psychological States), which in turn influences the outcome in terms of a person's satisfaction or dissatisfaction with their working situation (eight measures). These in turn influence the practical outcomes such as productivity, quality of work, absenteeism and staff turnover. Figure 2-1 shows the relationship between these four factors, the MPS of the job, the GNS of the person, the psychological states resulting from the match and the satisfaction outcomes. The measurements are taken by individual completing the Job Diagnostic Survey (JDS) questionnaire. The JDS is not a psychometric test. Differences between people are not the issue. However, it is the relationship between the person and the job, which is studied. Hackman and Oldham do not try to change the person to match the job rather they seek change the job to match the person. Most people do not want their employers to find out that they are unsuitable for the job they are doing. They are not likely to admit to being discontented if this will mean that they will be less likely to gain promotion or more likely to be made redundant. On the other hand it is to their advantage to explain how their job could be changed to make a better match with the person.

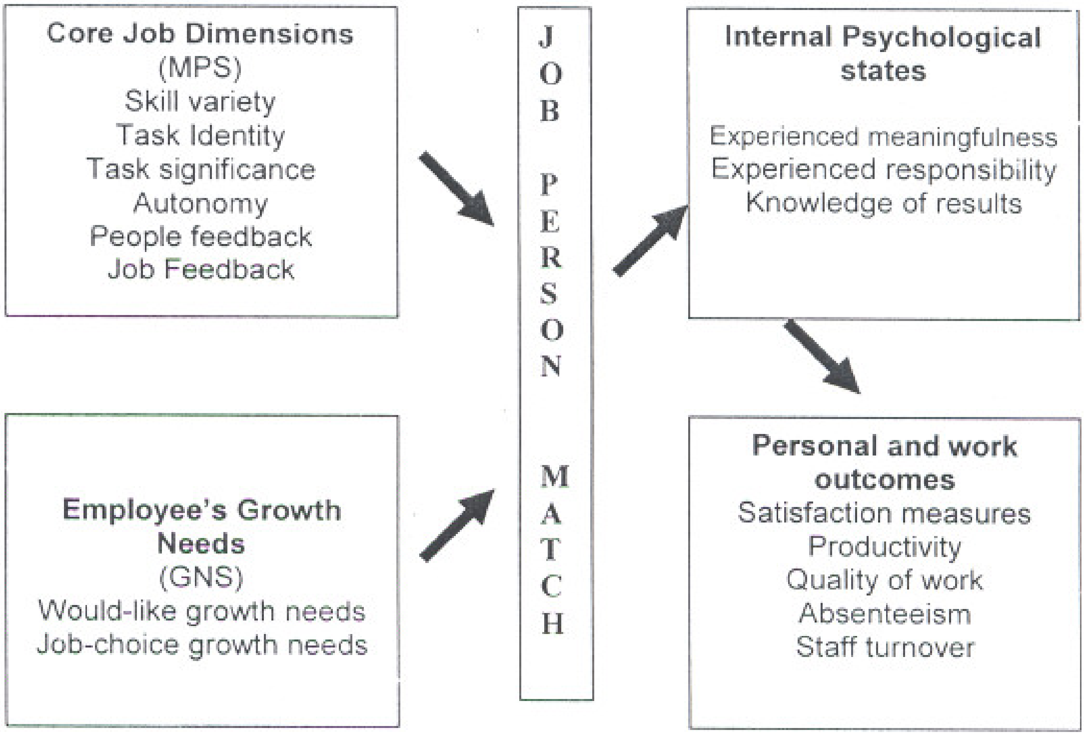


Figure 2.1: Relationship between MPS of the job, GNS of the person, psychological states resulting from the match and satisfaction outcomes.

Holman et al. (2002) reviewed the field of job design from three paradigmatic perspectives, namely, functionalism, interpretivism and critical theory. They point out that the core of job design theory, across all paradigms, has traditionally been concerned with the outcomes of job design, the role of key factors such as control, demand, and skill, and how jobs can be changed. By outlining two scenarios about how work is changing, they argue that, although job design still has a lot to offer (its traditional core concerns are still relevant), it must develop to have a wider appeal and to have more relevance. Finally, they propose how job design can develop as a field. These proposals are based on their belief that job design theory can progress most fully if it draws on a wide range of theories from across different paradigms and from grounded studies of the changing nature of work in diverse occupational contexts.

2.9.1 Job design in socio-technical system

Matsunaga and Nakazawa (1999) point out that we are all part of a socio-technical system consisting of individual persons, organizations, and technology. Therefore, a methodology of synthesizing and balancing technological, organizational, and human factors becomes necessary as a discipline. The authors have proposed a design method that takes human satisfaction into consideration, and to this end, have developed a satisfaction measurement system using a neural network that estimates human satisfaction from electroencephalogram measurements. They have discussed a design method and the satisfaction measurement system, and describe the development of a real-time adaptive human-machine interface based on satisfaction measures as an example of the design method proposed.

Clegg(2000) offers a set of socio-technical principles to guide system design and some consideration of the role of principle of this kind. The principles extend earlier formulations by Cherin (1976). They are intended to apply to the design of new systems, including those incorporating new information technologies and a range of modern management practices and ways of working. The principles are of three broad types: Meta, content and process, though they are highly interrelated. They are for use by System Manager, users and designers and by the technologists and social scientists. The paper highlights that industrial and commercial environments have changed enormously over the recent period. The rate of technological change has increased and has become dominated by new information and communication technologies. Further more, not only are the new technologies becoming more prevalent and powerful, they also offer opportunities to work in more inter-connected ways, providing the scope and catalyst for new working arrangement. The organization of the work is also changing at unprecedented rates, partly as a result of growth of a range of new management practices and techniques (Dean & Snell 1993). Team working, supply chain partnering, empowerment, cell based working, process based working, Just-in-Time procedures, and Total Quality Management and others all constitute change in work organization and working practices. Because of these changes, it is felt that new amended underlying design principles are required. Socio-technical theory has at its core the notion that the design, performance and productivity of new systems can be improved and indeed can work satisfactorily, if the 'social' and 'technical' are brought together and treated as independent aspects of the work system. Improvement in Socio-technical design principals and practices should contribute to the enhanced level of the performance, where this can be taken to include operational measures such as effectiveness and productivity, along with psychological indicators concerned with well being and attitudes.

Carayon and Smith (2000) examine the impact of the socio-technical and business trends on the work organization and ergonomics. This analysis is performed with the use of balance theory (Smith and Carayon 1989). The impact on work organization and the work system of the following socio-technical and business trends is discussed: restructuring and reorganizing of companies, new forms of work organization, workforce diversity and information and communication technology. An expansion of Balance theory from the design of work systems to the design of organizations is discussed. The paper highlights the important emerging areas in ergonomics, methodology to change work organization and design. Organizational design and psychosocial work organization are important areas cited and discussed. According to the NIOSH (2000), work organization deals with the subjects such as the following: the scheduling of work (such as the work-rest schedules, hours of work and shift work), job design (such as complexity of tasks, skill and effort required, and degree of worker control), inter-personal aspects of work, (such as relationships with supervisors and co-workers) career concerns (such as job security and growth opportunities), management styles (such as participatory management practices and team work), and organizational characteristics (such as climate, culture and communications). The objective of ergonomics is to improve both performance and health and safety. Therefore, the concept of work organization is at the core of ergonomics. According to the balance theory of Job design (Smith & Carayon, 1989), work organization results in the design of a work system that has five elements: the individual, task, tools and technologies, physical environment and organization. The five elements of the system interact to produce a stress load. The interplay and interactions between these different factors can produce various (physical and physio social) stresses on the individual that then produces a stress load, which has both physical and psychological components. "Loads" on the person challenge biological resources (energy, expenditure, biomechanical strain, physical status), psychological resources (perception, cognition, decision-making, emotion) and behavioral resources (motivation, coping behaviors). The individuals react to the load. The result is increased or decreased performance, quality of working life, strain and health. Balance theory emphasizes a system's approach in which all elements to the work system should be considered in order to improve performance, and health & safety.

Corlett (2000) talks about the changed organization structures by quoting – " over recent decades the number of levels in many organizations have become fewer. Where once a Senior Manager would rarely face member of the work force directly the wider distribution of responsibilities and the breakdown of hierarchies has increased such contacts among the personnel of the enterprise. Where advise or decisions could have assumed to be impersonal and relatively private, the impact of them can now be seen, experienced and in many cases has to be justified by the decision maker to those who face the consequences.

Employee participation in the development & improvement of their own work activities and daily production tasks has been strongly emphasized by the 'quality movement'. From this point of view, the quality perspective, and in particular development work, are supportive of improved working conditions and ergonomics, Eklund (2000) proposes a classification of development work in relation to participative problem solving. Further, the introduction of development work was found from a theoretical point of view to be consistent with improvement in the characteristics that represent good and rewarding work. Several empirical studies in the field confirm that improvements in work and company performance and productivity take place as a result of better job designs which include both routine and development work.

The literature on ergonomics in work design has largely focused on production and the design of good and rewarding work Das (1999), Di Martino and Corlett (1998), Hackman and Oldham, (1980). The socio-technical approach, for example, aims for increased physical and mental variation through horizontal and vertical integration of production tasks as means to improve work and working conditions. The concept of development work has largely been made well known by the Japanese production system, in particular kaizen and the TQM philosophy. There are two kinds of activities, namely production activities and improvements (or development) the TQM philosophy sees the dual function if work, which means that everyone should work on both daily standard work and on improvements.

Abrahamsson (2000) presents a production economics analysis of investments initiated to improve working environment. A development project was initiated in order to come to grips with the difficult working environment and problems associated with absenteeism due to illness and occupational injuries. It shows that the new workplace considerably improved the working conditions and increased both the quality and efficiency of production. The profitability calculations show that an investment initiated to improve the working environment can yield good profitability.

The effects of interruptions in work activity have been examined by Eyrolle and Cellier (2000), through field and laboratory results. The interruptions due to customers' calls in the work of an operator engaged on card-index data about customers phone lines resulted in an increase of the processing time of the current task and in the use of several management strategies. A laboratory study was designed in order to study the effects of temporal strain, complexity and similarity on time-sharing efficiency and to clarify the psychological mechanisms underlying the shifting from one task to the other. The results showed especially a significant effect of temporal strain on performance and a strong increase in the mean error rate at the very beginning of the processing of the second task.

2.10 ENVIRONMENT

Ahsan et al. (1999) present a study of metal workers in Bangladesh. Stresses caused by thermal factors (heat and humidity), poor air quality (Inorganic dust, welding fumes) awkward body postures and noise were found. They were identified through a comprehensive ergonomic approach encompassing classification of jobs and integrating cultural and socio-economic factors. Simple low cost practical solutions were advocated. The constraints many of which are interrelated included (i) negative attitude and acceptance of unsafe practices, (ii) poor access to information and training, (iii) the poverty cycle (low wages, poor nutrition etc.), (iv) weak trade unions and corruption and (v) lack of support from the international community.

Parsons (2000) provides a review of the principles methods and models used in environmental ergonomics, in terms of the effects of heat and cold, vibration, noise and light on the health, comfort, performance and productivity of the people. The paper presents a summary of the useful models employed and standards devised/developed for health, comfort, performance and productivity related to the individual components of heat, cold, vibration, noise and light.

2.11 PRESENT STATUS

The literature review reflects that awareness about the need for consideration of ergonomic factors in the job and work design is building up. Investigative studies aiming at finding out the existence of various factors in the work area and their effect on the working, health and safety as well as performance and productivity, are being carried out both in the field as well as in the laboratories.

The researchers have studied the change in ergonomic requirements because of increased complexity of the productive systems and because of use of newer concepts. A number of tools and techniques have been developed to analyze a work place. These techniques have been classified into two basic categories depending upon the methods used for quantifying postural stresses: instrument-based and observational techniques. The latter is more widespread in industry, because it does not interfere with the worker during observations, and does not require use of expensive equipment for estimating the angular deviation of a body from the neutral position. The instrument-based method using bioinstrumentation such as electromyography has been rarely used as a major tool for quantifying postural stresses in industry because it is expensive, obtrusive and limited due to the nature of the production process in industrial sites. Most postural classification schemes developed are the observation methods. These include the posture targeting, OWAS, PATH, RULA, LUBA etc. A great deal of literature is available on assessment of body postures to identify ergonomic deficiencies in a task for reducing MSD's.

A number of strategies have been reported in the literature to combat hazardous repetitive tasks. Studies have been reported for improving worker productivity through various interventions in a repetitive production task. Further studies have been reported to establish relationship between worker satisfaction and productivity in repetitive production tasks. However, linking of repetitive tasks to worker capability and aptitude has not been seen in literature.

The ergonomics literature has devoted considerable effort to devising appropriate rest and recovery intervals to offset the effects of physiological fatigue. The literature focuses primarily on recommended standards or limits of work-related energy expenditures. Referencing to recognized fatigue standards have been widely reported in ergonomics literature.

Analysis of lifting tasks has been adequately reported in literature although no formal techniques could be seen for manual load carrying tasks. The carrying tasks have been referred to in bits and pieces and a formal technique similar to the ones available for postural analysis has not been developed/ reported. The use of handling aids and their design has been adequately reported and literature pertaining to these aspects is readily available.

Effects of temperature, noise, vibrations and psychological aspects of human-human interactions because of one's job content and other conditions of working have also been investigated either separately or in an integrated manner in some sectors. Because of the rapid change in the working styles, technology, competition levels and other such factors the thrust of the latest literature on ergonomics can be seen to be tilting towards job and environment design in order to make the job of the employee conducive to achieving high performance and productivity levels.

2.12 LIMITATIONS OF EXISTING APPROACHES

Some of the limitations of the existing approaches for ergonomic analysis of a batch type production manufacturing facility in Indian engine bearing industry are highlighted as follows:

- There has been a heavy emphasis on development of postural assessment techniques to reduce the compensation claims of organizations. However, there are hardly any studies relating this ergonomic analysis to enhancement in productivity on individual workstations or as a whole.
- There are no formally reported assessment techniques available for analysis of manual material handling load-carrying tasks.
- An approach to carry out investigation of a manufacturing facility relating to ergonomic perspective has not been adequately reported in the literature. Most studies reported are specific to a particular task and does not consider the manufacturing facility as a whole.
- Most of the work on ergonomic analysis of a manufacturing facility is reported from the developed countries where the awareness level of both employees and employers is considerably higher and where even some legislations and standards have come up. However, in developing countries like India, there is very little work reported with regard to ergonomic analysis of a manufacturing facility and its impact on productivity.

- There have not been many surveys and reviews especially in India, conducted in this area, which may be one of the major causes of lack of appreciation of the status and potential of ergonomic compliance.
- In majority of the studies on Job design, very little or no emphasis has been placed on matching the job to the person. The efforts have been the other way round i.e. trying to match the person to the job.
- Using the Job diagnostic survey developed by Hackman and Oldham (1974), the match between the Motivating potential score and the Growth needs strength has not been adequately established in the published studies.
- Ergonomic analysis of an engine bearing manufacturing facility has not been reported in literature.

2.13 NEED FOR RESEARCH AND AREAS OF STUDY

Based on the literature survey and its limitations, priority areas needing immediate research attention are as follows:

- Since most of the studies on ergonomic analysis and its application in a manufacturing facility is reported from developed countries, there is a need to conduct studies on similar lines taking the regional factors and present levels into consideration. It is hoped such investigations will not only help the employee in the form of a better job and environment to work in but will also help the employers to achieve better performance by the employees resulting in higher productivity and profitability.
- Research efforts are required to develop a comprehensive approach to study the improvement in productivity as a result of ergonomic compliance.
- Implementation of the developed approach of synthesizing the work system design and job design in a manufacturing facility and its impact on productivity and worker satisfaction.
- There is a great need to develop a comprehensive observational technique to analyze the material handling (carrying) tasks.
- In developing countries like India ergonomics is used in a very restricted sense. Mostly the apparent and well-established aspects of working conditions and work place design are being considered in industry. This research work is indented to establish the benefits accrued to an organization as a result of improvement of work system design and job design.

2.14 CONCLUDING REMARKS

A selective review of available literature in the field brings out a few points relating to ergonomics and its compliance quite cogently. These include lack of a comprehensive approach for analyzing tasks with respect to ergonomics compliance and its impact on productivity and worker satisfaction. The present work is an attempt in this direction to cover a few of these points, particularly those relating to ergonomic compliance with regard to work system and job design.

CHAPTER 3

DESIGN OF STUDY

3.1 INTRODUCTION

This chapter introduces overall design of study, which includes the methodology adopted for carrying out the work. Details of work done in each phase and tools, techniques, and models used have also been covered here.

3.2 METHODOLOGY

The study has been divided into two major parts namely Analysis and Design as shown in figure 3.1. 'Analysis' includes finding out the status of ergonomics in engine bearing manufacturing industry from work system design and job design point of view as well as current productivity and performance levels. It also involves identification and evaluation of critical and potential areas and sub-areas to be taken up for improvement by application of ergonomic provisions and controls. 'Design' deals with evolving and implementation of appropriate ergonomic provisions or controls in the identified areas and their validation. Design also includes development of a generalized strategy for implementation of ergonomic provisions in manufacturing industry in a phased manner for productivity improvement.

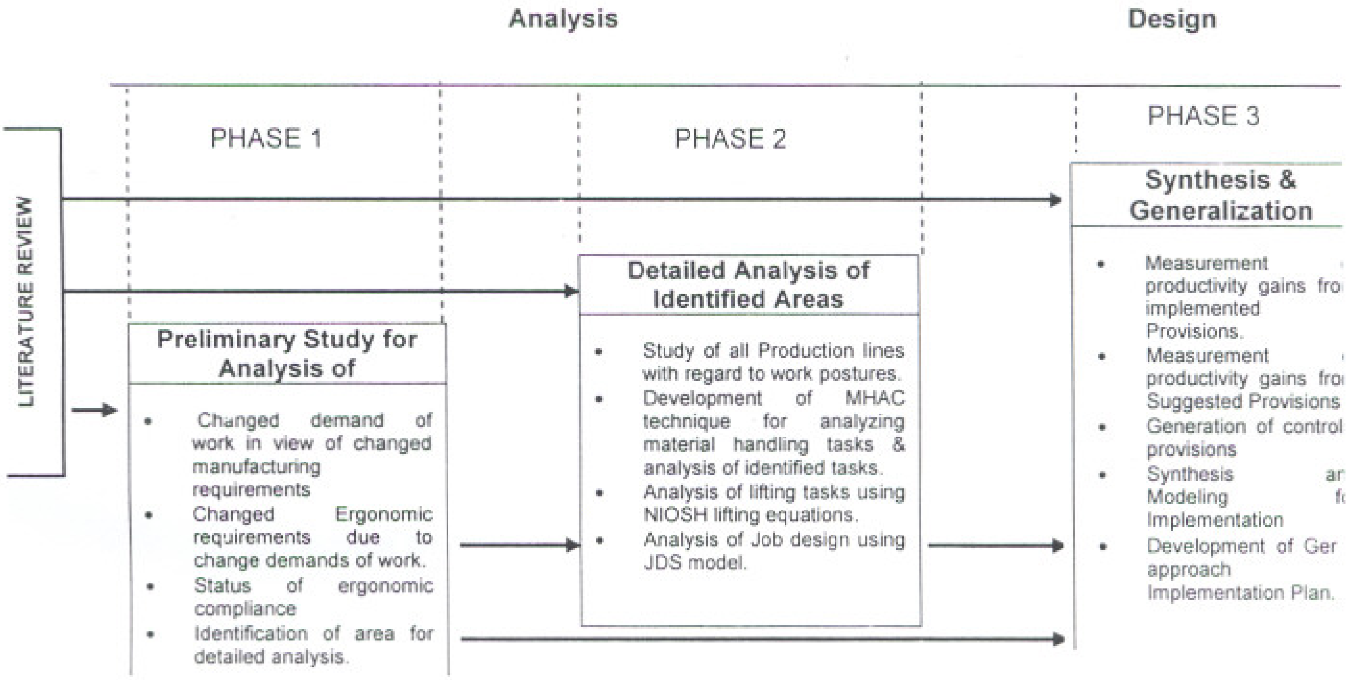


Figure 3.1: Phases of Study

The work has been carried out in three phases:

Phase-I: Preliminary study aimed at collecting feedback from the employees through a specially designed questionnaire to find out the changed demands of work, the resultant desired change in ergonomic requirements and the status of ergonomics in the representative industry. The results of the preliminary study have been used to identify areas, which need to be taken up for further detailed ergonomic analysis.

Phase-II: Detailed studies of the areas identified through the preliminary study in the representative organizations.

Phase-III: Synthesis and qualitative assessment of productivity gains and design of strategy for implementation of identified controls and validation in a phase-wise manner.

Figure 3.1 depicts the relevance and importance of each phase for meeting the objective of productivity enhancement in engine bearing manufacturing industry through integrated work system and job design using the ergonomic perspective. By conducting a preliminary study aimed at collecting feedback from the employees of the specified industry through a specially designed questionnaire, the information on the changed demands of work, the resultant desired change in ergonomic requirements and the status of ergonomics has been gathered and analyzed. Response of the employees to Section II and Section III of the questionnaire has clearly brought out that the areas of working postures, material handling, lifting tasks, job design and feedback need to be taken up for detailed analysis. Following this, observations of activities being carried out by employees pertaining to these broader areas were made over a period of one week. These observations confirmed the findings of the response of the employees.

The areas identified as a result of the initial survey have been taken up for detailed analysis. In general, the steps involved have been:

- Statement of objectives of the production line of the representative industrial units
- Separation of functions into various tasks
- Identification of ergonomic risks/ hazards in each of these tasks
- Implementation of appropriate controls to eliminate or reduce the effect of ergonomic deficiencies observed in these tasks.
- Establishing the impact of these controls on performance and productivity
- Measuring performance and productivity improvement
- System Integration

The information collected from the preliminary study and detailed observational analysis of bearing production lines has been used for developing and generalizing the various course of action for implementation using qualitative modeling. The development of this model has been a team effort. The team comprised of executives and supervisors from the engine bearing industry as well as the researcher and his supervisor. A questionnaire was prepared based on the outcomes of literature review, survey and detailed observational studies and was deliberated upon in a brainstorming session attended by all experts. Based on the comments received from experts during the session qualitative modeling was completed. The outcome of the qualitative modeling is a phase wise implementation strategy proposed to be adopted by manufacturing industry for productivity enhancement through integrated work system and job design.

3.3 DESCRIPTION OF THE MANUFACTURING FACILITY

Engine Bearings are used in all types of engines and mechanisms for supporting and controlling the motion of the rotating, sliding or reciprocating parts. Bearings are designed to serve the purpose with minimum friction, power loss and generation of heat and are aided in serving these requirements through suitable lubricants.

3.3.1 Classification of Bearings

Depending on the type of application the engine bearings can be classified as crankshaft bearings, connecting rod bearings, camshaft bearings and bushings. In any engine, a complete set comprising of the above classifications are used. A complete set for an engine contains varying quantities of these parts depending upon number of cylinders. These bearings are generally used as split halves and a combination of one lower and one upper part during assembly generates the complete bore. The engine bearings are precision components, manufactured in extremely close tolerances, and under normal operating conditions the bearing and moving parts it supports, do not touch and the two are separated by a thin oil film of about 0.002/0.003mm.

3.3.2 Manufacturing

The process of manufacture of these parts is highly specialized considering the intended application of the bearings. The parts are manufactured using a bimetallic strip, which consists of a bearing alloy bonded through sintering to mild steel strip. The I.D. surface of the bearing possesses the necessary bearing material properties like embed ability, strength, and corrosion resistance. The bearing material used is generally non- ferrous alloy like Cu-Pb-Sn or Al-Sn or Lead based Babbitt material. The alloy is manufactured using the powder metallurgy process where in ingots of the basic raw material are melted in an induction furnace and slurry is atomized, pumped to dryers for drying and then classified into powder particles of desired size after blending. The fine powder is then sintered at around 850° C to form a strong bond with a mild steel strip and is finally rolled in a rolling mill to achieve desired thickness and compaction of grains. The bimetallic strip is blanked on a suitable pneumatic press with identification stamp embossed on the steel side of the blank. The balnks undergo a number of forming and machining operations to form a bearing which is finally plated with a 0.015 to 0.020 mm thick coating of Lead, Tin and Copper before it is inspected and packed in sets comprising of desired matching parts.

There are many features of this kind of industry, which make it highly complex. The type of machinery and equipment used in such an industry ranges from large induction furnaces and other specialized equipment in the Powder plant to 25 to 30 feet long sintering furnaces along with Nitrozen-Hydozen generation plant to prevent oxidation of strip during sintering besides heavy duty rolling mills and slitting machines. The equipment in the production shops include power presses, special purpose machining centres, broaches and milling machines, and a state of art Tool Room. Plating shop includes an automatic plater with specialized loading racks for bearings besides the tin flash facilities. The manufacturing of powder, sintered bimetallic strip and plating are grouped under the category of special processes since it is impossible to inspect the output without destructive testing, strict adherence to process parameters like temperature, current, time, speed etc. is necessary to achieve the desired quality and productivity levels. The process parameters are qualified by way of experimentation periodically. Close tolerances need to be maintained at all other shearing, forming and machining operations.

The other distinct feature of this industry is the large product mix that is handled. To compete in the market as well as to have a larger market share, these companies manufacture parts for all types of engines. These companies, thus, manufacture close to 1500 different part numbers each month. The packing is done in sets comprising of 2 to 6 different part numbers and non-availability of any one of these, means all other parts, comprising the set can not be packed and have to be stored. Because of the large product mix, very frequent changeovers are necessary meaning thereby that job design, task analysis and overall work system design is an extremely important function for such an industry.

A review of the scrap rate and customer complaints reveal that most of the rejects are due to damages caused due to mishandling, or mix-up of parts either during processing or during packing, thereby resulting in customer receiving defective parts.

The layout of machines/equipment, material handling and movement of parts through the production line, tooling and fixtures control, identification of parts to prevent mix up, setup times, changeovers and multi-skilling of employees is required to be of very high order. The work environment and job design should be developed on scientific lines to promote systematic and careful working. Job design and overall work system design satisfying ergonomic considerations can help a great deal to achieve this. The process flow charts depicting the manufacturing of engine bearings from basic raw material to packing are shown in figure 3.1 and 3.2.

3.4 PRELIMINARY STUDY

The study has been conducted using a specially designed questionnaire containing multiple-choice questions. The steps involved in the initial study are:

1. Design of a suitable questionnaire
2. Standardization of the questionnaire by pre-testing and incorporating the suggestion of the experts from industry.
3. Conducting the study.
4. Compiling the response and performing the analyses to find out:
    - Changed demands of work from the employees in view of the changed and more competitive manufacturing scenario.
    - Changed ergonomic requirements due to changed demands of work.
    - Status of Ergonomic compliance in engine bearing industry.
    - Identification of areas, which need to be taken up for further, detailed ergonomic analysis to make them more ergonomically compliant and to increase productivity.

3.5 DETAILED STUDY OF THE IDENTIFIED AREAS

The aim of this study has been to investigate the contribution of the ergonomic design of workplace to increase in productivity in terms of production volumes, quality and reduction in machine downtime. The studies have been carried out in four different engine bearing manufacturing companies. These companies are manufacturing engine bearings and bushings for almost all reputed original equipment manufacturers. The organizations selected are QS 9000 and/or ISO 9001 certified firms, which ensured that adequate quality and other productivity records, were readily available.

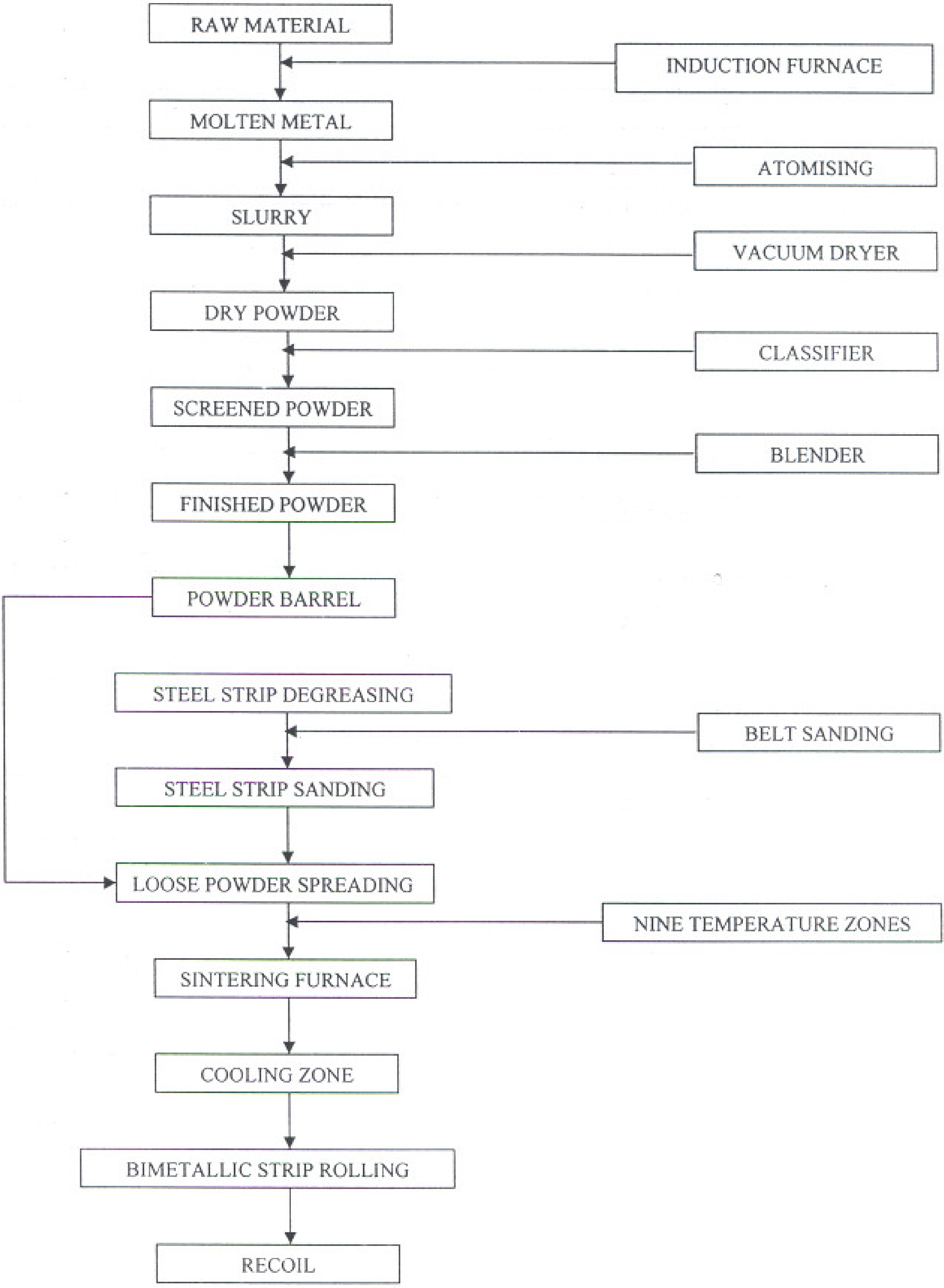


Figure 3.1: Process Flow Chart – Powder and Strip Manufacturing

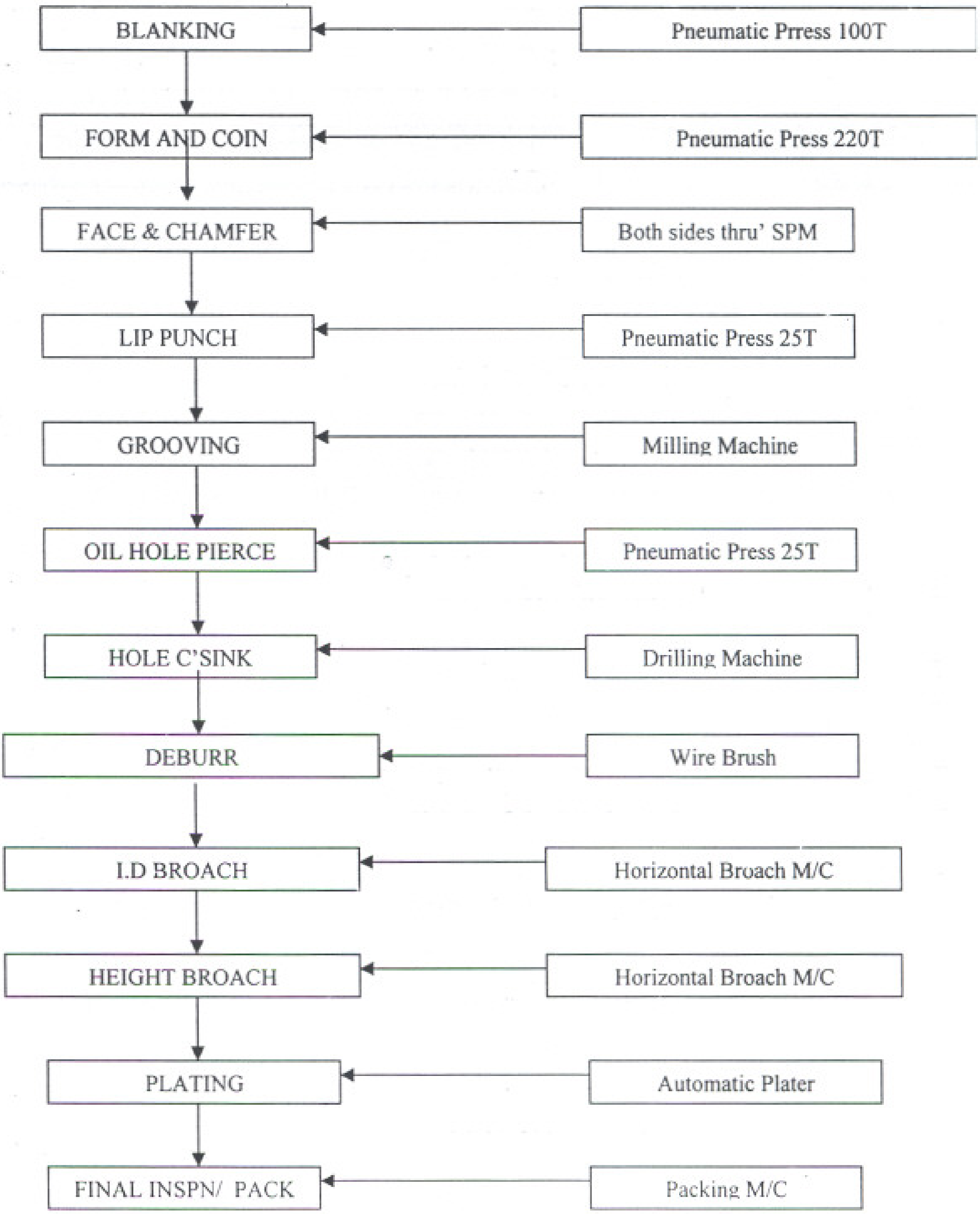


Figure 3.2: Process Flow Chart – Bearing Manufacturing

3.6 STEPS OF DETAILED ANALYSIS OF IDENTIFIED AREAS

Applying a functional criterion to the firms selected, the jobs were grouped together in workplaces in the shop. The next step was to select the production line and the workplace that was most important in keeping with the aims of the evaluation. Subsequently, studies were carried out on all the production lines beginning from the bimetallic strip manufacturing till packing of all types of bearings. The office and store workplaces were not studied since productivity is more directly measured in production shop floors. Care was taken to ensure that the timing of the study does not coincide with any abnormal happening in the company, e.g. intentional slow-down by workers, long term wage settlement negotiations etc. Observation and record sheets were prepared in advance and the data from the daily production and other reports was recorded on a daily basis.

3.6.1 Ergonomic assessment of the workplace with regard to work postures

For analysis of work postures, Rapid Upper Limb Assessment (RULA) methodology was employed. The steps of analysis and resultant implementation of various provisions and controls are as under:

1. Direct observation of tasks on all lines. This involved
   - Breaking the job into tasks.
   - Breaking the task into observable elemental operations
   - Evaluation of elemental operations using RULA methodology
2. Identification of tasks needing most urgent action
   - Calculation of RULA score for all elemental operations
   - Identification of those elemental operations with a RULA scores of 5 or above. (As recommended in the technique).
3. Evolving suitable provisions/ controls for implementation, as a direct outcome of the analysis and the principles of work place design.
4. Implementation of evolved provisions/ controls.
5. Collection of past/ existing data of productivity and quality indicators.
6. Measurement/ assessment of expected improvements in fatigue allowance, wastages, quality, available time as a result of implementation of provisions.
7. Comparison of before and after productivity levels and assessing the improvement.

3.6.2 Ergonomic Analysis of Manual Material Handling Tasks

The steps included in analysis of manual material handling tasks are:

1. Analyze the tasks to identify the ergonomic hazards present in a job. The analysis involved carrying out a variety of activities, which included:
    - Observing the worker performing the task
    - Interviewing and discussing with workers
    - Making measurements related to carry distance, carry frequency etc.

   The observation of the material handling tasks has been made over a period of two weeks covering all the four weeks of a month. The observations were spread over all the three shifts to ensure that any differences in material handling activities during the course of the day are also captured.
2. Identification of contributing ergonomic factors, parameters that have a direct bearing on the hazards associated with these tasks and grouping them into categories. The exercise was carried out by brainstorming amongst two experts drawn from each of the four different manufacturing units and the researcher. As a result of brainstorming, the contributing factors were grouped into ten broad categories.
3. **Development of Study technique:** To evaluate the combined effect of the ten factors identified by the brainstorming team, a survey technique has been developed which has been named as 'Material Handling Assessment Chart' (MHAC). For development of MHAC the following steps were undertaken:
    - An experimental study carried out in the workshop of Thapar Institute of Engineering and Technology, Patiala for assessment of effect of load weight under different carrying frequencies.
    - Incorporation of expert opinion for assessing the effect of factors, which were qualitative in nature by considering the 'worst-case scenario'.

MHAC has been developed to:

- Provide a method of screening the working population quickly, for exposure to a likely risk of work related MSD's;
- Assessing the risk associated with employees lifting and carrying loads over distances, sometimes on uneven and slippery surfaces;
- Give results, which could be incorporated in a wider ergonomics assessment covering epidemiological, physical, mental, environmental and organizational factors.

4. **Application of MHAC:** The MHAC technique has been used to evaluate all the material handling tasks in the representative firms by direct observation of workers who performing material handling tasks in the production lines, inspection operations and packing.
5. Development of appropriate controls for problematic carrying tasks considering the accepted hierarchy of controls as: (1) engineering improvements, (2) administrative controls and (3) work practice modifications.
6. Design and fabrication of a four-wheeled pallet trolley using the parameters and factors already reported in literature from time to time as a control.
7. Analysis of Manual Lifting Tasks as under.
    - Using the NIOSH revised lifting equation for assessment of possible risk of injury. (Lifting Index greater than 1).
    - Modification of task to reduce risk.
8. Survey of users of material handling aids: A survey of users of handling aids has been carried out to look at safety and usability, seeking opinions on the aids currently in use and on the factors, which most affect perceptions of their usability. The aim has been to make the handling of loads easier and safer, and in doing so reduce muscoloskeletal stresses and the number of handling injuries. The steps involved are:
    - Designing of a special questionnaire
    - Getting the questionnaire filled up.
    - Carrying out task analysis and user trials in order to identify the most important design features for the different types of aids and different jobs for which they are used.
9. Listing of Benefits Accrued/Expected in performance and productivity as a result of implementation of appropriate controls.

3.6.3 Job Analysis and Design

For carrying out this study, the Job Diagnostic Survey (JDS) questionnaire (Hackman and Oldham, 1974) has been chosen. The JDS provides 21 measures of an individual's motivational situation, which enables it to give very detailed and factual information. The aims of this study have been to determine the nature and extent of any motivational problems amongst production workers of engine bearing industry, and assess their possible effects on productivity and performance. The study involved the following steps:

1. Briefing and motivating the participating employees.
2. Grouping the participants into categories based on the job family.
3. Filling of questionnaire by the employees.
4. Plotting of frequency plots for each of the 21 measures of the JDS instrument as histogram and calculation of average and standard deviation for each measure.
5. Carrying out analysis separately for the five measures of Motivating Potential as well as Measures of Growth Needs for the three different job families. Carrying out joint analysis of the eight measures relating to the outcomes and satisfaction of a motivational situation.
6. Identification of jobs needing re-design for each job family.
7. Development of Cause & Effect Diagram for each job family to examine the factors that may be contributing to the problems with regard to Job Design.
8. Development of a Pareto chart to identify the vital few causes of the problems identified for job redesign.
9. Analysis and development of appropriate controls for tasks needing job redesign.
10. Listing of benefits accrued/ expected in performance and productivity as a result of implementation of controls.

3.7 ASSESSMENT OF PRODUCTIVITY ENHANCEMENT

Following work has been carried out for this assessment:

1. Compilation of productivity gains in all major areas of work postures, material handling tasks, lifting tasks and job design from the details of implemented provisions.
2. Using expert opinion to assess the extent of productivity gains for those provisions and controls, the results of which are qualitative.
3. Determining the impact of various provisions and controls on the overall productivity separately for different product groups.

3.8 SYNTHESIS AND MODELING FOR DEVELOPMENT OF STRATEGY FOR IMPLEMENTATION

The steps employed in the synthesis and qualitative modeling has been as under:

1. Identification of experts from the engine bearing industry
2. Dissemination of results of analysis to experts.
3. Generalization of the provisions/controls identified under each of the above area, by the experts.

4. Compilation of costs and productivity gains for the suggested provisions and controls.
5. Identification of factors and parameters influencing development of a generalized approach by brainstorming and idea generation.
6. Collection of qualitative responses from the experts for each factor using a specially designed format.
7. Converting the qualitative score to a quantitative score using the scoring scale and the number of responses to a choice.
8. Listing the results of various generalized provisions/ controls in reducing order of their cumulative scores, separately for work postures, lifting tasks, material handling tasks, and job design.
9. Using expert's opinion for implementation of these provisions and deciding an order of priority to the four major areas studied.
10. Formulation of a phased implementation approach by picking up the provisions which had higher weighted scores in the above four major areas.

3.9 CONCLUDING REMARKS

In this chapter the methodology adopted along with the step-by-step approach employed has been described. Tools and techniques employed for analysis of various areas and activities and design of ergonomic provisions and controls as well as for development of implementation strategy have also been briefly described. The next four chapters cover the detailed analysis employing the methodology described.

CHAPTER 4

ERGONOMIC ANALYSIS OF ENGINE BEARING INDUSTRY

4.1 INTRODUCTION

This chapter presents an account of the changed demands of work carried out by employees in engine bearing industry, due to efforts of the organizations to become more cost effective, efficient and competitive; changed ergonomic requirements as a result of the changed demands of work and the status of ergonomics in the industry. Detailed analysis of working postures and design of appropriate controls for ergonomically hazardous tasks are also covered in the chapter.

A specially designed questionnaire has been used to find out the changed demands of work, the resultant desired change in ergonomic requirements and the status of ergonomics. A number of employees from the identified units of engine bearing industry were asked to fill up the questionnaire. The employees were randomly selected from all functional areas of the organizations. The questionnaire was also pre-tested on a representation sample of the employees (Appendix 4.2). A copy of the Questionnaire is appended (Appendix 4.1). Prior to requesting them to fill up the questionnaire, they were briefed about the objective of information collection and subsequent analysis. A total of forty employees filled up the questionnaire completely. The response was compiled as a raw score and then summarized and analyzed to find out the following:

i) Changed demands of work from the employees in view of the changed and more competitive manufacturing scenario.

ii) Changed ergonomic requirements due to changed demands of work.

iii) Status of ergonomic compliance in engine bearing industry.

(iv) Identification of areas, which need to be taken up for further, detailed ergonomic analysis to make them more ergonomically compliant and to increase productivity.

4.2 CHANGED DEMANDS OF WORK

In Section 1 of the questionnaire, 12 questions, all of multiple-choice type have been designed with the objective of collecting information from the employees to assess changed demands of work in the last few years. The compiled and summarized response to these 12 questions is shown in Table 4.1.

Table 4.1
Summary of responses to assess the changed demands of work

S. No	Short Phrasing of the question	No. of Responses (n_i)				$\frac{\sum n_i c_i}{4 \times \sum n_i} \times 10$
		C_1(4)	C_2(3)	C_3(2)	C_4(1)	
1.	Change in job requirements	A lot of change	Fair degree of change	Some change	Practically no change	93.75
		32 80%	6 15%	2 5%	0 0%	
2.	Actual time spent in 8 hour shift	Appreciably more	Fairly more	Slightly more	Not at all more	93.75
		31 77.5%	8 20%	1 2.5%	0 0%	
3.	Quality Requirements & acceptable level of scrap %age	Great improvement	Fair improvement	Some improvement	No improvement	94.3%
		33 82.5%	5 12.5%	2 5%	0 0%	
4.	Production targets per shift	Tremendous increase	Fair degree of increase	Some increase	No increase	87.5%
		25 62.5%	10 25%	5 12.5%	0 0%	
5.	Pressures due to quality & quantity requirements	Great pressure	Fairly high degree of pressure	Some pressure	No pressure	83.12%
		20 50%	15 37.5%	3 7.5%	2 5%	
6.	Variety of jobs and multiple jobs	A large variety & many jobs	Fairly larger variety & multiple jobs	Some change	Practically no change	76.87%
		18 45%	14 35%	5 12.5%	3 7.5%	
7.	Small part of the job or complete job	A lot of change	Fair degree of change	Some change	No change	74.37%
		15 37.5%	13 32.5%	8 20%	4 10%	
8.	Inclusion of areas like maintenance, quality control and report making	Absolutely	To a great degree	To some degree	Not at all	72.5%
		14 35%	12 30%	10 25%	4 10%	
9.	Supervision reduction	Absolutely	To great degree	To some degree	Not at all	67.5%
		10 25%	13 32.5%	12 30%	5 12.5%	
10.	Control on leaves discipline & performance	Very strict control	Appreciably more control	Some difference is there	Practically no difference	75%
		15 37.5%	12 30%	11 27.5%	2 5%	
11.	Performance appraisal	There is a tremendous change	A fair degree of change	Some change is there	No change	65.62%
		10 25%	11 27.5%	13 32.5%	6 15%	
12.	Accountability of job and its results	Increased to a high degree	Appreciable increase	Some Increase	No increase	78.75%
		17 42.5%	14 35%	7 17.5%	2 5%	

4.2.1 Analysis of Responses - Changed Demands of Work

As depicted in Table 4.1, 80% of the employees feel that their job has undergone a lot of change in the last few years, while the remaining feels that there has been a fair degree of change. About 78% of the employees report that now they spend appreciably more time on the performance of their job out of the 8-hour shift as compared to earlier. The remaining 22% feel that there has been a fair to slight degree of change. For most employees (82.5%) the quality requirements of the jobs have greatly improved and scrap levels have to be maintained much lower. 62.5% of the employees have reported that over the years there is a tremendous increase in production targets per shift while 37.5% have reported some increases to a fair degree of increase. About 50% of the employees feel that the enhanced production targets and stringent quality requirements have put a great degree of pressure on them, 37.5% experience a fairly high degree of pressure, 7.5% some pressure and 5% no pressure.

Regarding contents of jobs, 45% of the responding employees have reported that now they perform a large variety of jobs and multiple jobs. About 7.5% report practically no change in job contents while the remaining 47.5% report some change to a fair degree of change. Further, about 38% feel that now their job is more complete as compared to earlier when they were performing only a small part of the job, 32.5% feel a fair degree of change in this regard, 20% some change and 10% practically no change. Activities of Maintenance, quality control and report writing have been made an integral part of the employee's jobs to an absolute extent as reported by 35% of the employees. Another 30% report that this change has come to a fairly great degree while the remaining 35% have experienced some change to no change in these aspects. In the earlier production systems, a lot of supervision was employed over the workers/operators. 25% of the responding employees feel that this supervision has been absolutely removed, 32.5% report reduction to a great degree, and 30% to some degree and 12.5% report a negligible reduction.

Regarding leaves, absenteeism, discipline and performance 37.5% of the employees experience a very strict monitoring and control over these now, 30% an appreciably more control, 27.5% some control and 5% feels there is practically no control. Employees feel that over the last few years, performance appraisal system has changed. 25% report a tremendous change, 27.5% a fairly large degree of change, 32.5% some change and 15% experience practically no change. Employees have been made more accountable for the jobs they are performing and results thereof. This accountability has increased to a high degree as reported by 42.5% of the employees. 35% report appreciable increase, 17.5% some increase and 5% practically no increase.

From the above discussion, it is concluded that jobs have become more demanding in industrial organizations in their efforts to perform better and become more competitive. The employees now spend appreciably more time, out of an 8-hour shift on actual performance of their jobs, quality requirements and production targets have become more stringent, bringing a lot of pressure on employees to perform better. Employees now handle more variety of jobs and multiple jobs. Their jobs are more complete now. Functions like maintenance, quality control and report writing etc. are becoming integral parts of their jobs. Supervision over them has been reduced and they are being made more accountable for the activities to be performed by them. There is a more strict control over their leaves, absenteeism and discipline and their performance appraisal has become more logical and demanding.

Further to access which areas have contributed the most towards making the jobs demanding, a weighted average score of response to each question has been calculated in percentage. This has been calculated by using the following equation:

$$WAP_S = \frac{\sum_{i=1}^{4} n_i c_i}{4 \times \sum n_i} \times 100 \qquad \ldots 4.1$$

WAP_S is the weighted average percentage score of a question.

c_i is the weight given to a choice of a question i.e. 4 to the best choice, 3, 2 and 1 to the next choices in order and n_i are the number of responses received for the each choice from the responding employees.

The final calculated weighted average percentage scores of all questions are given in the last column of the Table 4.1. As can be seen that the change in quality requirements has got a maximum score of 94.37%, followed by change in job requirements (93.75%), actual time spent on job (93.75%), increase in production targets (87.5%), pressures due to quality and quantity requirements (83.12%) and others. These have emerged to be the most important areas on account of their scores being in the range of above 80%. Other areas following in the next level of importance (in 70 to 80%) are job accountability (78.75%), performance of variety of jobs and multiple numbers of jobs (76.87%), more strict control over leaves, absenteeism etc. (75%), whole job (74.37%) and inclusion of other functions in the job (72.5%). Two remaining areas i.e. reduction in supervision (67.5%) and performance appraisals (65.62%) have not changed to a large extent.

4.3 CHANGED ERGONOMIC REQUIREMENTS

The results of the survey presented in the previous section depict that the jobs of the employees have definitely become more demanding. In the light of this change it appears necessary to make corresponding changes in job design, environment and other aspects of human working to enable the employees to perform more demanding jobs with ease with an aim to achieve higher level of performance and productivity.

Section II of the questionnaire filled up by employees seeks information for the assessment of need in different aspects of working in the organization. The feedback given by employees is compiled in Table 4.2.

4.3.1 Analysis of Responses - Changed Ergonomic Requirements

Analysis of response of feedback given by employees and presented in Table 4.2 depicts the following:

A large percentage of employees (55%) feel that there is an absolute need for analyzing and changing the hazardous working postures. Another 45% employees have felt this need to an appreciable degree (30%) and fair degree (15%). 57.5% of the employees are of the opinion that there is an absolute need of looking into and changing the material handling system. The remaining has realized this need to an appreciable to a fair degree. For performance of jobs there are many lifting tasks involved. A very large percentage of employees (65%) feel that lifting tasks needs to be analyzed. The remaining 35% also advocate some change to a fair degree of change. Location and types of controls employees in an organization affect the human working to a great deal. This aspect seems to have been taken care of in engine bearing industry as depicted by the response. Only 20% of the employees feel an absolute need of change in this area followed by a 30% who feel a fair to an appreciable degree of need. But a large chunk (50%) does not feel any need of change in location and types of displays and controls.

Regarding job allocations based on interest, aptitude and skills, the response in general, depict a very low degree of need of a change with 47.5% of the employees feeling that there is no need of change. However, the remaining 52.5% feel a fair degree to an absolute level of change required. Another area where employee does not feel much of a change required is communication and information flow with 22.5% finding the present system good enough, while 20% feeling a fair degree of need to change it, 25% an appreciable need and 32.5% an absolute level of change. Regarding good interpersonal relationships and support by the management nearly 75% of the responding employees have registered an absolute need or an appreciable degree of need while for the remaining 25%, there is hardly a need to bring change in this aspect. 45% of the employees want a change in the aspects of provision of training and avenues for personal growth followed by 27.5% wanting an appreciable level of change, another 20% wanting fair degree of change and the remaining 7.5% contented with the present system.

Table 4.2
Feedback on Changed Ergonomic Requirement

S. No	Area/Aspect of Human Working	Extent of need to change in view of more demanding works No. of Responses n_i				$\frac{\sum n_i c_i}{4\times\sum n_i}\times 100$
		Absolute need	Appreciable degree of need	Fair degree of need	No need	WAPs
		$C_1(4)$	$C_2(3)$	$C_3(2)$	$C_u(1)$	
1.	Working posture i.e. sitting, standing, bending, moving etc.	22	12	6	0	85%
2.	Material handling including manual material handling and use of material handling devices	23	13	4	0	86.87%
3.	Lifting task (Force requirements) as a part of the job.	26	12	2	0	90%
4.	Location and types of displays and controls	8	7	5	20	50%
5.	Job allocation based on interest aptitude and skills	10	8	3	19	55.6%
6.	Communication and information flow in the organization, particularly from top downwards.	13	10	8	9	60.62%
7.	Good interpersonal relationships and support by the management	15	15	8	2	76.87%
8.	Provision of training, avenues for personal growth	18	11	8	3	77.5%
9.	Scientifically evolved job designs	25	8	7	0	86.25%
10.	Autonomy, information feedback, etc.	24	7	7	2	83.25%

The response depicts that most of the employees (62.5%) need the jobs to be designed more logically on scientific basis. The remaining 37.5% have felt a varying degree of need. The area assumes a great importance as no responding employee has ticked the 'no need' choice meaning thereby that 100% of the employees want better job design. On the same lines, employees want more autonomy, feedback, recognition, motivation and rewards. This is depicted by the response: 60% feel it absolutely necessary followed by 17.5% (appreciable need) 17.5% (some need) and 5% (no need).

To assess the relative importance of all these areas of human working, based on the response of the employees, weighted average percentage score of all aspects have been calculated and presented in the last column of Table 4.2.

It is seen that the WAPS for Lifting tasks is highest (90%) followed by Material handling (86.87%), Scientific job design (86.2%), Working postures (85%), Autonomy, information feedback etc. (83.1%), Provision of training (77.5%), Good inter-personal relations (76.9%), Communication and information flow (60.6%), Job allocation (55.6%) and Displays and Controls (50%). Based on the above data, the following five areas have emerged to be the one's needing immediate change.

i) Working Postures.

ii) Material Handling.

iii) Lifting Tasks

iv) Scientifically evolved Job Designs with autonomy and feedback, etc.

These areas are proposed to be taken up for detailed analysis in this thesis work. Further, to strengthen the feedback given by the employees and to identify specific areas for analysis, the response given by the employees to section III of the Questionnaire has been compiled and analyzed.

4.4 STATUS OF ERGONOMICS IN ENGINE BEARING INDUSTRY

Section III of the questionnaire seeks information on two aspects. First of this is the areas of human work. For example, in material handling the aim is to find out how many material handling jobs need to be analyzed, how many types of materials are handled and what kind of handling aids are used? The second aspect is to assess the current status of these areas and efforts made by the management towards ergonomic improvement of these areas.

The response received by the employees is compiled in Table 4.3.

From the number of responses to each choice, WAPS for all aspects have been calculated separately for existence of areas and status. This is depicted in columns 11 and 20 of Table 4.3. For a quick comparison the WAPS scores have been plotted as histograms as shown in figure 4.1. The light coloured bars depict the existence of the identified areas in engine bearing manufacturing organizations, whereas the darker bars

Table 4.3
Status of Ergonomics in Engine Bearing Industry

S. No	Area	Part A									Part B								
		Existence Of areas/ activities									Status and Effort								
		Many		Fair		Same		No		WAPS %	Great		Good		Fair		Negligible		WAPS %
		n_i	%	n_i	%	n_i	%	n_i	%		n_i	%	n_i	%	n_i	%	n_i	%	
1.	Working Postures (WP)	25	62.5	7	17.5	6	15	2	5	84	6		7	17.5	13	32.5	14	35	53
2.	Material Handling (MH)	23	57.5	8	20	8	20	1	2.5	83	5	12.5	10	25	15	37.5	5	25	56
3.	Lifting Tasks (LT)	22	55	7	17.5	9	22.5	2	5	80	7	17.5	12	30	10	25	2	27.5	59
4.	Location & Types of Displays & Controls (C&D)	10	25	8	20	9	22.5	13	32.5	59	19	47.5	14	35	6	15	1	2.5	82
5.	Job Allocations (JA)	11	27.5	9	20	10	25	11	27.5	64	20	50	15	37.5	5	12.5	0	0	84
6.	Communication & Information Flow (CI)	12	30	12	30	10	25	6	15	69	18	45	14	35	7	17.5	1	2.5	80
7.	Interpersonal Relationships, Support by Management (IP)	12	30	12	30	8	20	8	20	67	16	40	10	25	11	27.5	3	7.5	74
8.	Provision of Training, avenues for personnel growth (TR)	14	35	14	35	9	22.5	3	7.5	74	18	45	10	25	10	25	2	5	77
9.	Scientifically evolved job design (JD)	24	60	8	20	7	17.5	1	2.5	80	9	22.5	11	27.5	10	25	10	25	62
10.	Autonomy Information feedback, recognition, motivation and reward (FB)	22	55	8	20	9	22.5	1	2.5	82	10	25	10	25	9	22.5	11.	27.5	62

shows the existing status and current efforts being put in for implementation by the engine bearing industry.

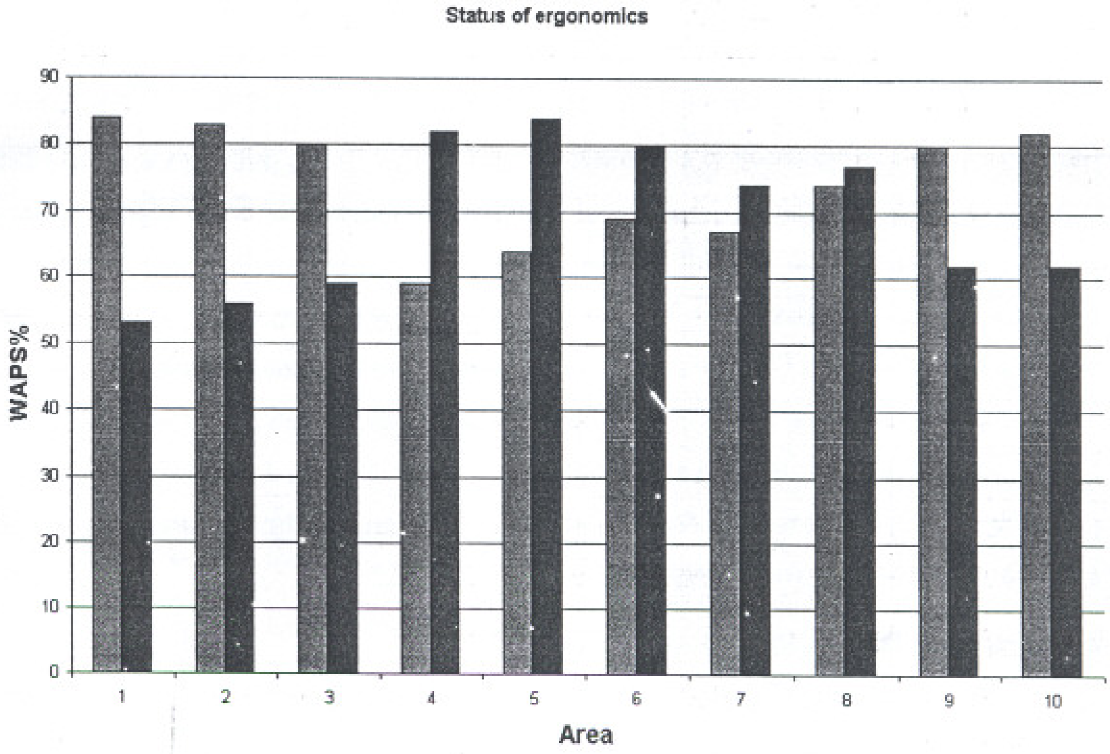


Figure 4.1: WAPS% Score for areas shown in Table 4.3

4.4.1 Analysis of Responses - Status of Ergonomics in Engine Bearing Industry

Figure 4.1 brings out following important points.

i) Four areas have scores above 80% in Part A of the questionnaire i.e. existence of activities. These areas are working postures, material handling, lifting tasks, job designs and feedback. It shows that in these areas form an inportnat and integral part of working of an engine bearing industry. The response to these five aspects in the second part of the question is ranging from 56% to 62%. It shows the poor status of ergonomic implementation of these aspects. Thus, the important finding is that these areas, which are very important, as these affect most of the employees in performance of their tasks, have not evinced much attention from the management and their current status is regarded as poor.

ii) The other five areas namely location and types of controls, job allocations, communication and management, interpersonal relationships and provision of training avenues are being adequately looked after and their present status is reported as good. Their score in part B range from 74% to 84%, which is indicative of better status compared to the four areas identified above. Also, as per employees, these areas/activities have a relatively lower priority, and as such does not warrant immediate ergonomic considerations.

4.5 IDENTIFICATION OF AREAS TO BE TAKEN UP FOR DETAILED STUDY

Response of the employees to Section II and Section III of the questionnaire has clearly brought out that the areas of working postures, material handling, lifting tasks, job designs and feedback should be taken up for detailed analysis. Following this, observations of activities being carried out by employees pertaining to these broader areas were made over a period of one week. These observations confirmed the findings of the response of the employees. Thus, it was decided to explore these areas further. In the subsequent chapters details of analysis carried out in these areas are presented along with the modifications made/suggested, validations and improvements expected/achieved in productivity.

4.6 CONCLUDING REMARKS

A preliminary study was carried out in four engine bearing manufacturing organizations and the results were analyzed to identify the extent of change which has come in jobs carried out by the employees, the resultant change which should come in work system and job design, the status of ergonomics, and the areas needing further study and analysis. The next three chapters describe the detailed analysis of the identified areas after the preliminary study.

CHAPTER 5

ERGONOMIC ASSESSMENT OF THE WORKPLACE WITH REGARD TO WORK POSTURES

5.1 INTRODUCTION

The aim of this study was to investigate the contribution of the ergonomic design of workplace to increase in productivity in terms of production volumes, quality and machine downtime. The initial ergonomic analysis was carried out employing the RULA (Rapid Upper Limb Assessment) method. The method breaks down the various activities carried out in the workplace into elemental tasks. The movements of each task are evaluated by dividing the body into segments, which form two groups, A and B. Group A includes the upper and lower arm and wrist and Group B includes the neck, trunk and legs. Once all the individual movements are evaluated, the results are integrated so as to obtain the evaluation of the task. In this way definitive scores are obtained for each part of the body, which in turn give rise to an overall ergonomic score or evaluation of the task carried out, ranging from value 1(acceptable movement) to 7(changes immediately required). By conducting this analysis for each task, the tasks, which need most urgent action with regard to ergonomic improvement in the workplace design, were detected and an order of priority for the application of improvement for the entire manufacturing line was identified.

After identifying the tasks with ergonomic problems, a series of improvement actions were then undertaken and implemented, analyzing whether significant improvement in productivity levels take place in parallel as a result of these ergonomic improvements. Also, the results showed that the productivity issues were more predominant for the tasks, which had ergonomic problems, than for the rest of the tasks. However, it must be clarified that it is difficult to compare different tasks due to different characteristics of each one. For that reason, the relationship between productivity and ergonomic problems associated with a task was checked by analyzing one task at a time under different ergonomic conditions.

5.2 BRIEF DESCRIPTION OF THE 'RULA' METHODOLOGY

In order to assess the four external load factors namely number of movements, static muscle work, force and postures, RULA (McAtamney, L and Corlett, E.N.) was developed to:

1. Provide a method of screening a working population quickly, for exposure to a likely risk of work related upper limb disorders;
2. Identifying the muscular effort which is associated with working posture, exerting force and performing static or repetitive work, and which may contribute to muscle fatigue;
3. Give results, which could be incorporated in a wider ergonomic assessment covering epidemiological, physical, mental, environmental and organizational factors.

The development of RULA occurred in three phases.

Stage 1: Development of method for recording working posture

To develop a method which is quick to use, the body is divided into segments which formed two groups, A and B. Group A includes the upper and lower arm and wrist and Group B includes the neck, trunk and legs. This ensures that the whole body posture is recorded so that any awkward or constrained posture of the legs, trunk or neck is included in the assessment. The range of movement for each body part is divided into sections which are numbered so that number 1 is given to the range of movement or working posture where the risk factors present are minimal. Higher numbers are allocated for more difficult postures.

Scoring for Group A

The range of movements for ***upper arm*** were assessed and scored as under:

- 1 for 20° extension to 20° flexion;
- 2 for extension > 20° or 20-45° flexion;
- 3 for 45-90° flexion;
- 4 for 90° or more flexion

The range of movements for ***lower arm*** were assessed and scored as under:

- 1 for 60 - 100° flexion;
- 2 for < 60° and > 100° flexion

The guidelines for the ***wrist*** are:

- 1 if in neutral position;
- 2 for 0 - 15° in either flexion or extension;
- 3 for 15° or more in either flexion or extension

Pronation and supination of the wrist (***wrist twist***) are defined as under:

- 1 if the wrist is in the mid range of twist
- 2 if the wrist is at or near the end range of twist

Scoring for Group B

The score and posture ranges for the ***neck*** are:

- 1 for 0 - 10° flexion;
- 2 for 10-20° flexion;
- 3 for 20° or more flexion;
- 4 for if in extension.

The score and posture ranges for the ***trunk*** are:

- 1 when sitting and well supported with a hip-trunk angle of 90° or more;
- 2 for 0 - 20° flexion;
- 3 for 20-60° flexion;
- 4 for 60° or more flexion

The ***leg*** posture score are defined as:

- 1 if the legs and feet are well supported when seated with weight evenly balanced;
- I if standing with the body weight evenly distributed over both feet, with room for change of position;
- 2 if legs and feet are not supported or the weight is unevenly balanced.

Stage 2: Development of the system for grouping the body part posture scores

The first step is to rank each posture combination from the least to greatest loading as described in stage 1. When the posture scores for each body part are recorded, they are used in Table 5.1 and Table 5.2 to find the combined scores called score A and score B. A scoring system was developed to include the additional load on the muscoloskeletal system caused by static muscle work, repetitive motions and the requirement to exert force while working.

The ***muscle use*** score is given as under:

Give a score of 1 if the posture is

- Mainly static
- Repeated 4 times/minute

The ***force or load score*** while working is given as under:

- 0 for No resistance or less than 2 kg
- 1 for 2-10 kg intermittent load or force
- 2 for 2-10 kg static load or repeated load
- 3 for: 10 kg or more static load or repeated load

After the scores A and B have been calculated from tables 1 and 2, muscle use and force score are added to them as shown below:

Score A + muscle use and force scores for Group A = Score C

Score B + muscle use and force scores for Group B = Score D

Table 5.1
Table A into which individual posture scores for the upper limbs are entered to find posture score A

Upper Arm	Lower Arm	Wrist Posture Score							
		1		2		3		4	
		Wrist twist		Wrist twist		Wrist twist		Wrist twist	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table 5.2
Table B into which the individual posture scores for the neck, trunk and legs are entered to find posture score B

Neck Posture Score	Trunk Posture Score											
	1		2		3		4		5		6	
	Legs		Legs		Legs		Legs		Legs		Legs	
	1	2	1	2	1	2	1	2	1	2	1	2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Table 5.3

Table C where score C and Score D are entered to find the grand score

		Score D (neck, trunk, leg)						
		1	***2***	***3***	***4***	***5***	***6***	***7+***
Score C (Upper Limb)	***1***	1	2	3	3	4	5	5
	2	2	2	3	4	4	5	5
	3	3	3	3	4	4	5	6
	4	3	3	3	4	5	6	6
	5	4	4	4	5	6	7	7
	6	4	4	5	6	6	7	7
	7	5	5	6	6	7	7	7
	8	5	5	6	7	7	7	7

Stage 3: Development of the grand score and action list

The third stage is to incorporate both score C and Score D into a single grand score using Table 5.3 whose magnitude provides a guide to the priority for subsequent investigations.

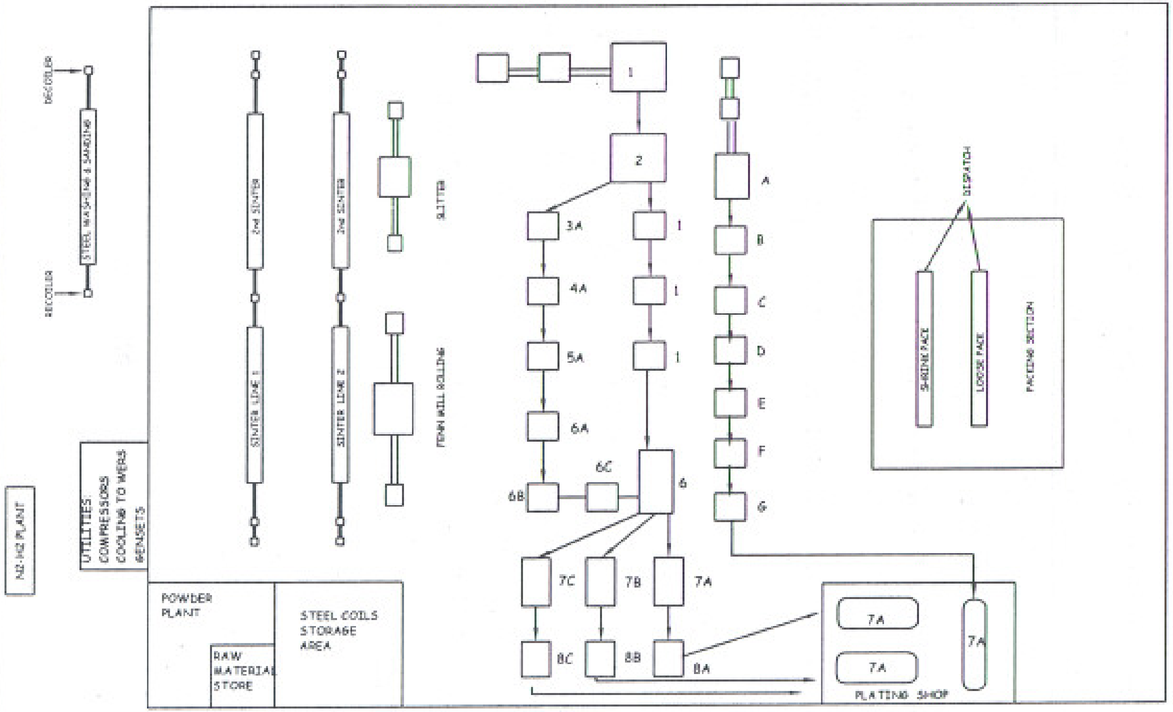
The requirement of action into which the grand scores are divided is summarized in Action levels as follows:

- Action level 1: A score of 1 or 2 indicates that the posture is acceptable if it is not maintained or repeated for long periods.
- Action level 2: A score of 3 or 4 indicates that further investigation is needed and changes may be required.
- Action level 3: A score of 5 or 6 indicates that the investigation and change are required soon.
- Action level 4: A score of 7 indicates that investigations and changes are required immediately.

5.3 EMPIRICAL ANALYSIS

The study has been carried out on all the production lines beginning from the bimetallic strip manufacturing till packing and dispatch of all types of bearings. The office and store workplaces have not been studied since productivity is more directly measured in production shop floor and profitability of the whole organization depends primarily on the productivity of operations carried out on the shop floor. Based on the preliminary study of various operations carried out in selected engine bearing firms, a broad classification of major operations (Figure 5.1) can be made as under:

1. Powder manufacturing plant
2. Sinter Lines(s) for bimetallic strip manufacturing



BEARING PRODUCTION LINE

1- BLANKING
2 - FORMING &
3/3A - FACING & CHAMFERING
4/4A - LIP PUNCHING
5 - LIP MILLING
6 - WIRE BRUSHING & WASHING
5A - HOLE PUNCHING
6A - LIP MILLING
6B - GROOVING
6C - HOLE COUNTERSINKING
7A/7B/7C - ID BROACHING
8A/8B/8C - HEIGHT BROACHING
9A/9B - LTC PLATING

BUSHING LINE

A - BLANKING
B - COUNTERSINKING
C - FIRST FORMING
D- FINAL CONNING
E - FACING & CHAMFERING
F - OD GRINDING
G - ID BORRING
H - TIN PLATING

Figure: 5.1 Layout of bearing manufacturing facility

3. Bearing Line(s) - manual/automatic
4. Bushing Line(s)
5. Packing
6. Dispatch stores

To begin with, the bushing line workplace was selected and direct observation of the work was started. The job was broken down into tasks, and further into observable elemental operations. These elemental operations were subsequently evaluated using the RULA methodology. Raw score of sample set of observations and calculations carried out for bushing line to arrive at a grand score using RULA methodology is presented in Appendix 5.1, wherein each operation function (column 1) was broken down into tasks (column 2) and then the postures of the workers were studied as described above for the two body segments, Group A and B, by direct observation of the worker performing each task. Subsequently, the ergonomic assessment using the RULA methodology was carried out on all the remaining production lines namely (1) Bearing line, (2) Sintering and powder manufacturing line, (3) Plating shop, and (4) Packing and Dispatch Section. The raw scores of these four areas are not included in this thesis. However, their compilation has been used for further analysis as described below.

Thus, applying the RULA methodology to analyze the job or job task at the workplace for ergonomic assessment in order to determine the ergonomic problems, those tasks that had a grand score of more than 5 (those that need most urgent action) were identified. A breakdown of tasks needing immediate changes or an in-depth study was thus carried out. The main causes of the ergonomic problems for those tasks that had a grand score of more than 5 are presented in Table 5.4 to Table 5.8.

5.3.1 Current Productivity Data

The past data on productivity and quality indicators were collected from the relevant records, which has been used as a basis for measuring any quantitative improvement as a result of the improvement actions on the identified problem tasks. The productivity and quality data for Bushing Line, Bearing Line including Plating shop, Powder Plant and Sintering Lines, and Packing and Dispatch Section respectively are given in the Tables (Table 5.9 to 5.12).

Table: 5.4

Resultant operator stress factors for potentially stressful tasks for Bushing line

Operation/ Function	Potentially stressful task	RULA Score	Resulting operator stress factor
Loading of coil on de-coiler	Placing the three strip supports on the floor	5	• Awkward posture • Sustain exertion
	Pulling the loose end of the strip up to the Straightener	6	• Forceful exertion
Blanking of parts	Set up of Die and Punch	6	• Constrained work space • Awkward posture
	Unloading of blanked parts into the pan	5	• Manual lifting • Forceful exertion • Awkward posture
First forming of bushes	Tooling set up and ejecting out the first formed piece out of the punch	5	• Constrained work space • Forceful exertion
Final forming of bushes	Holding of ID Core Plug during forming	6	• Very forceful exertion • Twisting of wrists • Contact stress
Facing/ Chamfering of bushes	Set up of cutting tools	5	• Constrained work space
	Loading of bushes on the shuttle	5	• Awkward posture
OD Grinding	Loading of bushes at input magazine feeder after each grinding pass	5	• Contact stress • Forceful exertion
	100% checking of parts after grinding	6	• Repetitive job • Forceful exertion
ID Boring	Application of clamping load	6	• Sustain exertion • Awkward posture

Table: 5.5

Resultant operator stress factor for potentially stressful tasks for Bearing Line

Operation/Function	Potentially stressful task	RULA Score	Resulting operator stress factor
Loading of coil on de-coiler	Placing the three strip supports on the floor	5	• Awkward posture • Sustain exertion
	Pulling the loose end of the strip up to the Straightener	6	• Forceful exertion
Forming and Coining of parts	Loading of parts into the Magazine Feeder	5	• Awkward posture • Contact stress
Face and Chamfer of bearings	Set up of 4 single point cutting tools on each of the two chucks	5	• Constrained work space • Awkward posture
	Holding of two half bearings in the fingers so as to load as a circular bearing	5	• Contact stress • Forceful exertion
	Loading of bearings on the lower half of the shuttle	5	• Awkward posture • Sustain exertion
Hole piercing	Set up of die and punch	5	• Constrained work space
	Injuries due to accidents at hole piercing	6	• Repetitive job • Forceful exertion
Lip Punching	Loading of parts with correct orientation into lip punching die	6	• Repetitive job • Forceful exertion
Wire brushing of the bearing back	Unloading of parts into the pan after wire-brush	5	• Awkward posture • Contact stress
ID Broaching and Height Broaching	Set up of master nest block and the broach cutters	6	• Very forceful exertion • Twisting of wrists
	Loading of parts into the die block	5	• Contact stress

Table: 5.6
Resultant operator stress factor for potentially stressful tasks for Plating Shop

Operation/Function	Potentially stressful task	RULA Score	Resulting operator stress factor
Plating loading station	Shifting of plating racks to the Loading station	5	• Manual lifting • Sustain exertion
	Loading and Unloading of parts in the plating rack	6	• Repetitive job • Forceful exertion

Table: 5.7
Resultant operator stress factor for potentially stressful tasks for Powder Plant and Sintering Lines

Operation/Function	Potentially stressful task	RULA Score	Resulting operator stress factor
Sintering of steel coils	Loading the steel/bimetallic strip on the De-coiler	5	• Awkward posture • Sustain exertion
Steel issue area	Layout of the steel coil storage area and handling of coils	6	• Forceful exertion • Constrained work space
Sintering of steel coils	Monitoring of process parameters on the sintering line	6	• Excessive travel between stations

Table: 5.8
Resultant operator stress factor for potentially stressful tasks for Packing section

Operation/Function	Potentially stressful task	RULA Score	Resulting operator stress factor
Packing of parts meant for Original equipment manufacturers	Use of themocole inserts as separators:	5	• Contact stress and injuries to fingers
After Market or AM parts shrink packing station	Placing of trays for set packing	5	• Awkward posture • Sustain exertion
Oiling of parts before packing	Dipping of parts into oiling tank	5	• Accidents due to slippage

Table 5.9
Productivity and Quality data (Existing) for Bush Line (Average of Jun-Dec 2002)

	Blank	Counter sink	First form	Final form	Face/ Chamfer	OD Grind	ID Bore
Output per shift	8100	6000	13200	4500	4700	6000*	2700
Output per month per machine in lac pieces	4.05	3.00	6.60	2.25	2.35	1.00	1.35
Average good output per month	3.90 lac parts per month						
Cycle time norm (1 part per min)	0.029	0.065	0.023	0.075	0.057	0.053	0.120
Set up time norm min.	20+30	10	20	25	40	10	60
Downtime %	6.8	0.6	2.4	4.5	9.6	6.1	7.5
Average Rejection per month (Parts)	4500	300	730	1850	3550	3050	700
%Rejection to good output	1.12	0.03	0.18	0.46	0.88	0.75	0.17
Number of reworked parts	4360	-	-	-	6141	8450	1260
Rework %age	1.12	-	-	-	1.59	2.19	0.07
Percentage of lots needing 100% sorting/ month	-	-	-	8.6	3.4	42.0	7.6
Number of customer complaints registered	2 for stamp	-	-	3 for OD	1 for chamfer	7 for OD	2 for finish
Sales returned per month Rs lacs	0.20	-	-	0.86	-	4.64	0.68
Warranty claims	Exact data not available						
Percent of lots offloaded to vendors because of capacity constraints	4	60	34	15	2	40	-
Accident rate – Major	-	-	1	0.4	1	-	-
Accident rate – Minor includes MSD's reported	4	-	4	10	4	1	-
% Absenteeism rate	16	9	21	28	11	10	9

** Each bushing at grinding is finished to the final outside diameter after three to four grinding passes. Thus the final output is about 2000 parts per shift.*

Table 5.10
Productivity and Quality data (Existing) for Bearing Line including plating shop (Average of Jun-Dec 2002)

	Blank	Form/ Coin	Face/ Chmfer	Hole Punch	Lip Punch	Grooving	ID Broach	Height Broach	Plating***
Output per shift	9200	10800	8200	7900	7900	3500	4700	4700	8050
Output per month per machine in Lac pieces	6.90	8.10	4.10	3.95	3.95	1.75	2.35	2.35	6.04
Average good output per month	6.56 lac parts per month								
Cycle time norm (1 part per min)	0.029	0.029	0.065	0.039	0.052	0.068	0.065	0.065	-
Set up time norm min.	20+20	35	40	25	25	18	40	40	45
Downtime %	4.2	4.6	8.4	3.6	2.4	5.8	6.6	5.4	4.5
Average Rejection per montn (Parts)	2800	4500	5650	950	900	1200	7450	6500	4400
%Rejection to good output	0.41	0.66	0.82	0.14	0.13	0.18	1.08	0.94	0.64
Number of reworked parts	2040 Burr	-	4450 Chf.	-	-	3143 Chf.	7672	6418	-
Rework %age	0.38	-	0.82	-	-	0.58	1.41	1.18	-
Percent of lots needing 100% sorting/ month	-	3.5	6.2	2.0	1.4	-	4.4	26.3*	45**
Number of customer complaints registered	-	1	-	1	-	3	-	8	4
Sales returned per month Rs lacs	-	-	-	0.15	-	0.36	-	1.42	0.94
Warranty claims	-	-	-	0.2	-	-	-	0.14	0.68
Accident rate – Major	-	-	-	0.5	0.5	-	-	1	-
Accident rate – Minor includes MSD's reported	2	1	4	6	4	2	7	11	3
Absenteeism rate percent	9	11	17	16	19	9	24	21	18

* *Height is checked 100% for some OE customers*

** *Wall Thickness of bearings is checked 100% after plating for OE manufacturers*

*** *Blanking, Forming and Coining and Plating run all three shifts*

Table 5.11
Productivity and Quality data (Existing) for Powder plant and sinter line (Average of Jun-Dec 2002)

	Powder mfg	Steel sanding	1st sinter	2nd sinter	Fenn mill rolling*	Slitting
Output per shift	1500 kg per day	2000 mtr	600 mtr.	600 mtr.	Used for finishing	1200 mtr
Output per month per line	1500 kg	2000 mtr	2400 mtr	2400 mtr	-	2400 mtr
Average output per month	28940 kg	72000 mtr	72000 mtr	72000 mtr	3104 mtr	34617 mtr
Cycle time norm	NA	-	0.525	0.525	-	12.19 mtr/min
Set up time norm min.	64	20+10	20+30		18	35
Downtime %	11	8.6	14.8	12.4	3.1	7.6
Rejection per month	640 kg	131 mtr	-	967 mtr	46 mtr	188 mtr
%Rejection to good output	2.2	0.31	-	1.98	1.48	0.54
Rework quantity	850 kg	-	-	-	2106 mtr	-
Rework %age	2.93	-	-	-	4.3	-
Number of customer complaints registered		-	-	4	-	-
Sales returned per month Rs lacs	-	-	-	0.44	-	-
Warranty claims	-	-	-	0.58	-	-
Accident rate – Major	-	1	-	-	-	2
Accident rate – Minor includes MSD's reported	2	2	6	4	-	9
Absenteeism rate	20	16	18	21	-	14

** Fenn mill rolling is carried out only for washers where the final thickness is finished at strip rolling*

Steel Sanding, Fenn mill rolling and Slitting is carried out in two shifts and Powder manufacturing and sintering is carried out in all three shifts.

Table 5.12
Productivity and Quality data (Existing) for Packing and dispatch section
(Average of Jun-Dec 2002)

Productivity parameter	Loose packing	Shrink Packing	Skin Packing	Shipment
Output per shift	8000	7300	7000	25000
Avg. output/r month in Lac pieces	4.00	3.65	1.00	12.00
Set up time norm min.	Nil	10 mins	15 mins	NA
Downtime %	NA	4%	11%	NA
Rejection per month	Nil	Nil	Nil	Nil
%Rejection to good output	0	0	0	0
Rework quantity	Nil	10000 parts per month (avg)	1000 parts per month (avg)	0
Rework %age	Nil	2.5%	1.0%	0
Number of customer complaints registered	1 in a quarter	10 in a quarter for size mix-up or wrong packing	Nil	2 in a quarter for invoicing and other defects
Sales returned per month Rs lacs	Nil	0.10	Nil	0.20
Warranty claims	Nil	0.20	Nil	Nil
Accident rate – Major	Nil	Nil	Nil	2 in one year (Back Pain)
Accident rate – Minor includes MSD's reported	2 every month (avg)	1 every month	Nil	2 every month (avg)
Absenteeism rate	18%	15%	15%	17%

5.4 ANALYSES AND DEVELOPMENT OF APPROPRIATE CONTROLS FOR PROBLEM TASKS

Efforts to develop appropriate controls included suggestions by employees performing the job in question and the researcher who performed the analysis. Engineering controls were generally preferred because they eliminate or reduce employee's exposure to potentially hazardous conditions. These controls included changing the workstation layout or tool design, or changing the way the materials, parts, and products are transported to reduce hazards. However, wherever it was difficult to fix the problem using Engineering controls, Administrative controls or Work Place Modifications were also suggested.

Administrative controls include work practices and policies to reduce or prevent employee exposure to hazards, such as scheduling rest breaks, rotating workers through jobs that are physically tiring, training workers to recognize ergonomic hazards, and providing instructions in work practices that can ease the task demands or burden. Understanding the ergonomic risk associated with each operation can help management develop effective job rotation schedules, and rotate operators from high-risk operations to low-risk operations. Provision of rest breaks for operators throughout a shift performing high risk tasks to decrease the exposure to the risk and to provide the body time to heal between the more demanding tasks.

Concurrent improvements to work practices ensure that employees understand the ergonomic benefit of the changes and promote proper use of the equipment. Work practices modifications may include proper use of work procedures and training operators in the principles of ergonomics to allow them to understand the proper techniques to use while performing tasks. Familiarity with these procedures can reduce operator exposure to ergonomic risk. After training employees in any work practice, it is important to develop a method to positively reinforce the practice. When operators learn a new work practice, it takes some time to develop the new habit. Therefore, management and supervisors must actively work with operators to ensure the compliance of work procedures and practices.

5.4.1 Analysis of Bushing Line

The detailed analysis of ergonomic problem tasks that have been identified after the assessment by RULA for the bushing line is as under:

1) Loading of Bimetallic Strip on De-Coiler

i) Task Description: Remove and put the three strip supports on the floor.

For loading the bimetallic strip on the De-coiler, the operator has to remove the three strip supports provided on the De-coiler. The operator after opening each support, places them on the floor one by one, although his posture at work is standing position. After loading the strip, the operator is required to fix the three supports back at their position.

Ergonomic Deficiencies identified for this task: The operator has an awkward bending posture six times in each cycle. The posture adopted by the operator requires the forearm to be rotated while the wrist is bent. Also, since the strip supports are to be placed at the floor level, the trunk angle is > 60° flexion, which is an extremely awkward posture position for the trunk. Again while fixing the supports in position after the strip has been loaded, the trunk bending and rotation of forearm takes place.

Controls Implemented: A fixture has been provided on the de-coiler body at a height of 4 feet to place the three strip supports, after these are removed from the De-coiler The revised RULA score is shown in Table 5.18.

ii) Task Description: Pulling the loose end of the strip to the Straightener

After loading the strip on the De-coiler the loose end of the strip is pulled by the operator up to the Straightener, which straightens the wound coil. The strip is then clamped between the Straightener rollers. After the Straightener is switched on, it starts pulling the coil towards the Blanking Press mechanically.

Ergonomic Deficiencies identified for this task: The manual pulling of the strip by the operator up to the Straightener necessitates the operator to work with elbow above the mid-torso height or requires work with the hands down behind the shoulder line in the sagittal plane, although, it is recommended that the elbow should remain at the side of the body to avoid extreme rotation of the forearm or extreme deviation of the wrist side to side. In addition, the operation requires a pulling force/load of 10 Kg by the operator, which is dependent upon weight of the loose end of the strip, length of holding as well as adopted posture.

Controls Implemented: A strip clamping vice has been installed between the De-coiler and the Straightener, which will hold the strip till the loose end is fixed in the rollers of the Straightener, which resulted in reduction of the force/load score given. Also, the push-button control of the Straightener has been re-located at a more appropriate position which is easily accessible to the operator while he is holding the one end of the coil. The revised RULA score is shown in Table 5.18.

Benefits Accrued/Expected: The existing norm for loading of strip was 20 minutes, which included a fatigue allowance of 14% (as per Page's fatigue allowance determination table). After implementation of controls as above the fatigue allowance has been re-calculated as under:

Basic fatigue Allowance: 3%; Standing allowance: 2%; Weight allowance: 3%

Total fatigue allowance: 8%

The cycle time for loading of strip was, therefore, revised to 15 minutes as against a norm of 20 minutes earlier.

2) Blanking of Strip

i) Task Description: Set-up of Die/Punch on the 225T Pneumatic Press

For each bushing type, specialized tooling particular to each bushing application is set-up on the press. The tooling consists of standard die and punch besides the spacers and locator guides. A progressive die set is used in which a number of forming and shearing operations are carried out during each press stroke. Also, set-up of the tooling requires a number of hand tools like nut runners (Allen Keys), screw drivers, spanners, impact wrenches etc. Besides these, hammers and pinch clinchers are also used for setting the steel stamp for identification of the blanks. The numbers of pieces that can be blanked per shift as per the productivity data are 8200 pieces per 8-hour shift, which also includes three set-ups for different application of bushings. The current set-up time norm is 30 minutes which means that a total of about 90 minutes are spent in machine set-up each shift.

Ergonomic Deficiencies identified for this task: The operator performing the task was observed over three complete shifts of eight hours duration each for making an ergonomic assessment. The most awkward postures were observed to be while using the hand tools for the set-up of the die/punch. It was observed that while using hand tools like nut runners the wrist is flexed while the forearm is pronated. Also, the work area is constrained by the shut height of the press which means that the posture is affected by work location, work position, tool shape and worker size. It was subsequently revealed that the operator on the machine had reported discomfort or had requested assistance in the form of helper(s).

Controls Implemented: After observing the task for a number of cycles and also collecting information from operators, a number of controls were developed and implemented including introduction of pre set-up dies. The tooling was pre set-up in the Tool Room where the posture was not constrained because of the press shut height and also the hand tools could be re-positioned according to the comfort of the operator concerned. The pre set-up die was moved to the Blanking press prior to the start up of the new production lot requiring this die.

Benefits Accrued/Expected: The set-up time reduced from 30 minutes to 15 minutes, as only minor adjustment of spacers and strip guides were required after installing the pre set-up dies. The productivity data for the press showed improvement in terms of number of parts produced and also the additional number of set-ups that could be taken up during the 8-hour shift. The defect rate due to rejection of set-up pieces dropped significantly, thereby, improving the quality of parts produced. Table 5.13 shows the improvement that has taken place before and after the implementation of the controls.

The pre set-up dies were introduced on trial basis for three bushing applications, which ran most frequently, and the proposal needs to be extended to all applications over the next year. The revised RULA score is shown in Table 5.18 at the end of this section.

Table: 5.13

Productivity improvement before and after the implementation of the controls on blanking

Application	Set - up time		Avg number of parts per shift		Number of parts rejected		Employees reports regarding fatigue
	Before	After	Before	After	Before	After	
Camshaft bush	35	15	8200	10900	1.12 %	0.77 %	**Before:** Number of informal reports; request for a helper **After:** No reported discomfort
Connecting Rod bush	24	14					
Steering Knuckle bush	38	20					

The drop in the rejection percentage was primarily due to the reduction in the number of parts used up during set-up. After the introduction of pre-set up dies, only two parts were used during setup as against 12 to 15 parts with the earlier arrangement.

ii) Task Description: Unloading of blanked parts into the pan

After blanking, the parts are unloaded into a pan placed on the floor through a combination of a chain link conveyor and a gravity chute installed as shown in figure 5.2 (Existing). Each pan can accommodate up to about 200 blanked parts and for a typical lot size of 2000, a total of 10 pans are needed. The pans filled with parts are first removed and replaced by an empty pan.

Ergonomic Deficiencies identified for this task: The task needs to be carried out on an average 40 to 50 times in an 8-hour shift resulting in high trunk flexion of more than 60° besides the side-bending of the trunk. The pans filled with parts are then subsequently manually lifted to the next operation.

Controls Implemented: A roll conveyor was installed at a height of 3 feet at the blanking press as shown in figure 5.2 (Proposed Change), and connected to the countersinking machine, which is the next operation after blanking. The horizontal travel distance of the motorized chain link conveyor was extended up to the roll conveyor on which the empty pans were placed. After the pan is loaded with blanked parts, it is pushed to the next station of countersinking or first forming. The revised RULA score is shown in Table 5.13 at the end of this section.

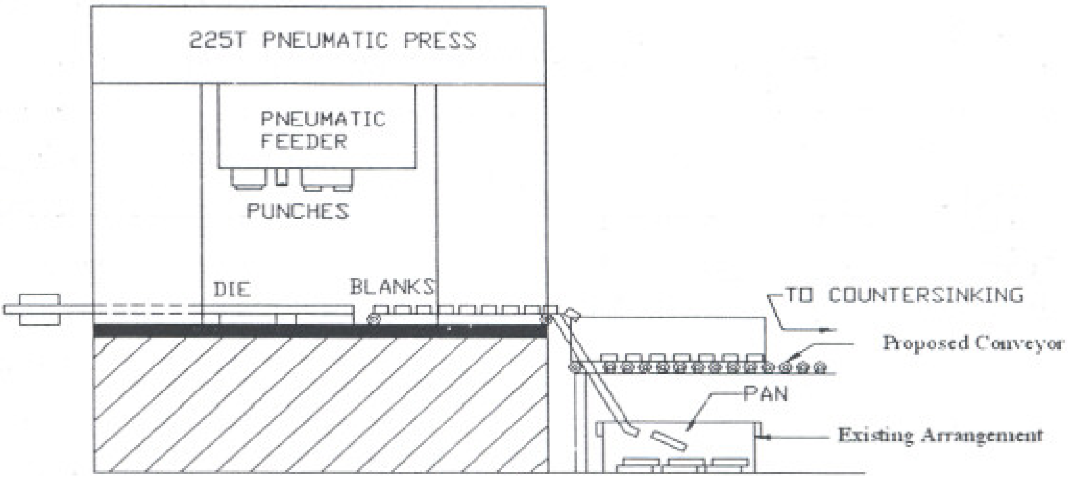


Figure 5.2: Existing and Proposed unloading method

Benefits Accrued/Expected: After implementation of the above controls, manual lifting of the pans from floor to the Counter-Sinking station was eliminated.

The fatigue allowance thus has been reduced to 12% compared to 20% earlier. The blanking operators will also not need a helper for moving pans, which was being provided earlier.

3) First Forming or Semi Forming of Bushings

Task Description: Set-up of die/punch and ejection of the first formed piece punch

The set-up issues on the first forming station with regard to operator posture are similar to the ones already discussed above for blanking operation.

Ergonomic Deficiencies identified for this task: As shown in figure 5.3, the operator has to work in a constrained workspace because of the limitation imposed due to press shut height. However, the tooling used for first forming is much simpler, compared to blanking, requiring far less number of tool sub-parts.

The other peculiar ergonomic problem associated with the first forming operation was ejection of the first formed part, which remains struck in the punch after the completion of the stroke and has to be manually pushed out using hand force, to the gravity chute through to the pan. The operator is required to exert a pushing force at his maximum capacity which causes detrimental fatigue. The fatigue allowance thus, allocated for this task as per Page's fatigue distribution table, was 20%.

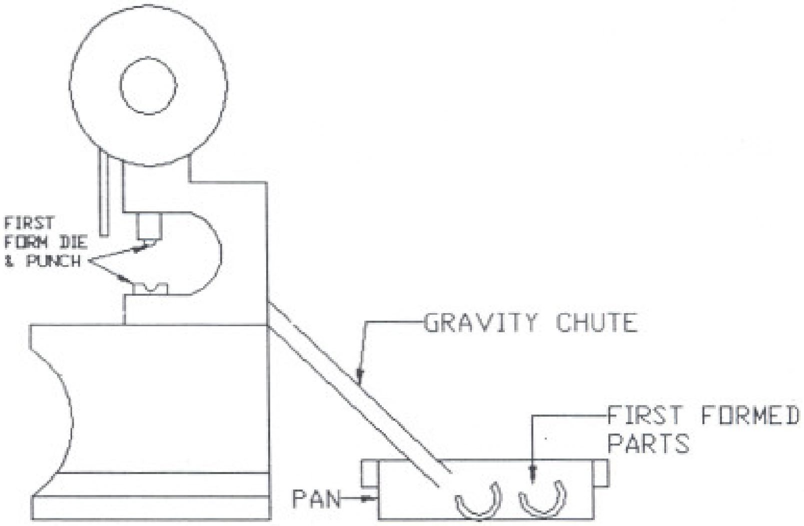


Figure 5.3: First Forming of bushes

Controls Implemented: The neck bending and the trunk bending had a score rated at 3 because of the forward bending angle was in excess of 40°. This awkward posture combined with the high hand push force required resulted in grand score of > 6 requiring immediate action. In order to correct the bending posture of the neck and the trunk, the press has been inclined at an angle of 30° with the vertical as shown in figure 5.4. Since the force required to push the part out of the punch is affected by the body position and the direction of exerted force relative to the body, the operator's strength and capability to exert force also improved thereby reducing the force score as per RULA methodology. The revised RULA score is shown in Table 5.18 at the end of this section.

Benefits Accrued/Expected: After the implementation of the controls listed as above, the fatigue allowance was re-calculated at 14% as against 20% earlier and the cycle time for the task was thus revised to 0.016 minutes for manufacturing per part. The production output per shift is expected to go up to 14500 parts. (Table 5.14).

Table: 5.14

Productivity improvement after implementation of controls at first forming

Operation	Fatigue allowance		Cycle time for one part (Mins)		Output per shift	
	Before	After	Before	After	Before	After
First form	20%	14%	0.023	0.016	13200	14500

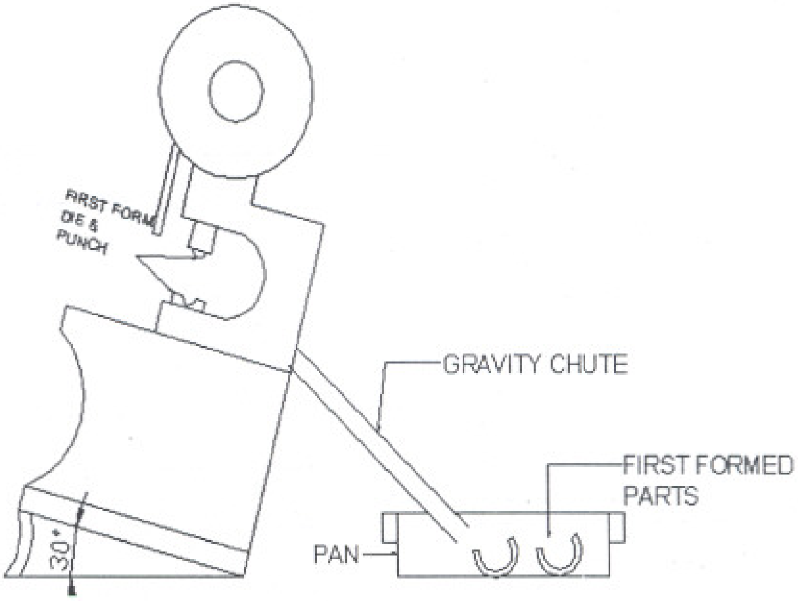


Figure 5.4: First Forming Press after the implementation of controls

4) Final forming bushings

i) Task Description: Final forming of the bushing while holding the ID Core to get a hollow bushing

During the final forming operation, the first formed piece is held in a core plug of diameter equal to the inside diameter (ID) of the bushing. The bush is fully formed after load is applied using a pneumatic press, while still holding the plug core inside the bush ID with the left hand. The process is repeated twice for each part when during the second stroke the part is rotated at 90° to control ovality of the outside diameter of the bush.

Ergonomic Deficiencies identified for this task: This process was identified as the most stressful task in the entire bushing manufacturing operation because of the flexing of the wrist, while the forearm was pronated. While rotating the bushing at 90° to control ovality, the twisting of the upper and lower arm also takes place. The production line capacity is directly proportional to the capacity at the final coining and there were large number of requests for assistance or reports of discomforts for this task.

The final forming operation necessitates that the operator possess the ability to adequately support the plug core in a particular position, while reacting against forces produced by the press operation. The capacity to produce forces is usually referred to as strength. Strength at final forming is therefore the maximum force an individual can produce. An operator normally cannot work on this machine for long without being fatigued, as he is required to exert force at maximum capacity. The ratio of the required force to an individual's strength approaches unity as the force requirement approaches an operator's strength capability. This proportion is related to the ability to sustain a given exertion, and to the onset of localized muscle fatigue. The greater the proportion of strength that a repeated exertion requires, the quicker the operator will be unable to sustain that exertion, and the more rapid the onset of fatigue. The core plug must be used in such a way that it maximizes the operator's strength.

The cycle time for this operation is 0.075 minutes for one part. The output per shift for bushes of diameter 2 inches or less is 4500 parts per shift. The cycle time has been calculated using a fatigue allowance of 25% as per Page's fatigue determination tables.

Controls Implemented: The strength is affected by body position, the direction of the exerted force relative to the body, the type of grip for holding the core plug and the handle size. Operator strength capabilities change as the position of the limbs and the body changes.

- It is recommended that the plug core be pushed away from the body as the press stroke applies load because the arm muscles are strongest when pushing in the direction away from the body.
- For maximizing the grip strength, the thumb, index finger and the middle fingers, which are the strongest fingers, should be utilized for producing the grip force. The ring and the small finger should only be used for stabilizing handles.
- Grip strength has been known to decrease when the handle diameter exceeds 50mm. The handle diameter was reduced to 45mm to maximize the gripping force. The shape of the handle was changed from circular to oval to maximize the grip strength.
- It has also been suggested to rotate the operators on this station in such a way that no single worker operates this press for more than two days in a week. The suggestion is possible to implement because most of the workers are skilled on one workstation ahead and one workstation behind their own workstation.

The revised RULA score is shown in Table 5.18 at the end of this section.

Benefits Accrued/Expected: The above controls were implemented for one bushing application on a pilot study and the resultant improvement observed is as under (Table 5.15):

- The fatigue allowance reduced marginally to 18%
- The cycle time was re-calculated accordingly and was observed at 0.071 minutes
- Absenteeism rate at the operation showed a marked improvement reducing from 28% to 10%. This however, could also be attributed to the high motivation of the employees because majority of the suggestions for this task came from them and they owned them while implementing.
- The anticipated drop in the health related issues related to the MSD's is likely to drop by 50%. This needs to be validated and verified by conducting an experimental study on the number of injuries related to MSD's reported over a longer period of time. (Say 2 to 3 years)

Table: 5.15

Productivity improvement after implementation of controls at final forming

Operation	Fatigue allowance		Cycle time per part		Output per shift		Absenteeism rate	
	Before	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
Final form	24%	18%	0.075	0.071	4500	4750	28%	10%

5) Face and Chamfer of bushings

i) Task Description: Set-up of 4 single point cutting tools on each of the two chucks

The facing and chamfering operation is carried out using a special purpose machine on which four single point HSS cutting tools are mounted on each of the two chucks provided to machine the two ends of the bushings. Out of the four tools mounted on each chuck, two are for facing and one each is for providing OD and ID chamfer. The bushings are alternatively loaded at two loading stations on the shuttle, which reciprocates up and down between the two chucks as shown in figure 5.5.

Ergonomic Deficiencies identified for this task: Since the working space available between the two chucks is very small, extreme wrist extension (> 45°) and wrist twist takes place. The elbow is pronated greater than 70° and the neck flexion angle is also greater than 45°.

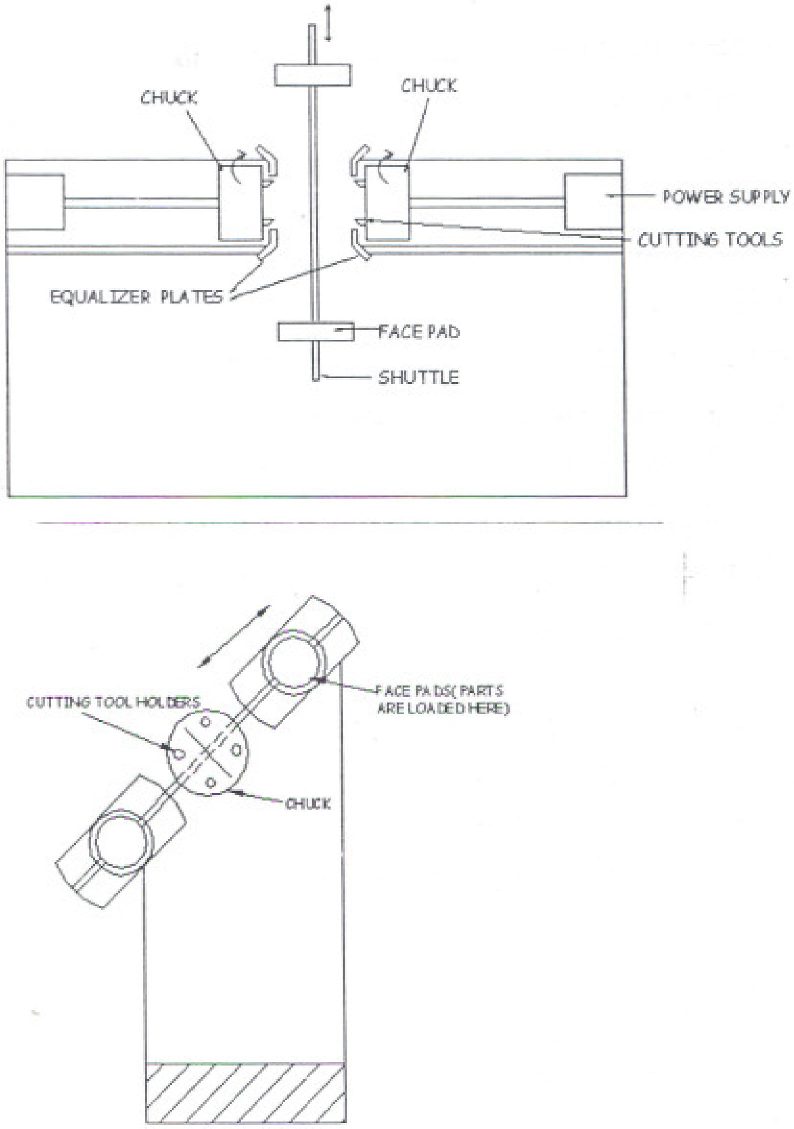


Figure 5.5: Face and Chamfer Machine – Equalizer Plates have been installed

Controls Implemented: After brainstorming by the operators performing the job in question and the team members performing the analysis, it was felt that it is not possible to eliminate the ergonomic issues by implementing some kind of engineering controls without any major change in the design of the machine, which would need a major investment. Also, since the focus has been on low technology, low cost engineering controls, going in for a major investment for this study purpose was not possible although suitable design changes could be incorporated for new machines as and when these are acquired. Administrative controls like job rotation have been recommended till such time.

ii) Task Description: Loading of the bushings on the lower half of the shuttle

The shuttle on the machine is inclined at an angle of 30° with the vertical and has two loading stations as shown in figure 5.5 in the side view of the loading shuttle.. While there is practically no discomfort reported while loading the bushes on the top loading station, considerable discomfort has been reporetd while loading parts on the bottom loading station.

Ergonomic Deficiencies identified for this task: The neck flexion angle was observed to be greater than 20° and the trunk flexion angle was greater than 30° because the operator is required to see that the bush is loaded in the bottom face pads, of the shuttle, at the correct location with approximately equal projection outwards on each side. This resulted in an uncomfortable posture. The two stations are loaded alternatively for machining the bush face. The production output at this operation is 4700 parts per 8-hour shift, which means the operator attains this posture at least 2350 times, each shift.

Controls Implemented: After brainstorming with the line operators, two sets of equalizer plates have been installed for both the top and the bottom half of the shuttle to equalize the outward projection of the loaded bush in the face pads (Figure 5.5). This ensures that equal amount of cutting takes place on both sides of the bush. The equalizer plates had an end taper of 45° to prevent jamming of the bush with the shuttle in case of unequal loading by the operator. The revised RULA score is shown in Table 5.18 at the end of this section.

Benefits Accrued/Expected: After installation of the equalizer plates, the operator is no more required to look at the bottom face pads and this has resulted in reducing his fatigue due to a stressed posture.

6) Grinding of Outside diameter of bushings (OD)

Task Description: The outside diameter of the bushes is ground on a Centre-less Grinder. The parts are fed through a magazine feed and after grinding, are transferred through a gravity chute into a pan located on the floor. Each bush requires three to four grinding passes to achieve the required finishing diameter. After each grinding pass, the parts are collected in a pan, and are manually lifted for re-loading at the magazine feeder on the machine for the next pass. Each pan can accommodate up to 200 parts and for a typical lot size of 2000, a total of 10 pans are needed. The pan filled with parts are first removed and then replaced by an empty pan.

Ergonomic Deficiencies identified for this task: The task needs to be carried out on an average 50 times in an 8-hour shift resulting in high trunk flexion of more than 60°, besides the side bending of the trunk.

A review of the quality problems associated with this operation shows that there have been number of complaints of mix-up of parts of different OD sizes mixed during work in progress (WIP). This has been primarily due to semi-ground parts falling on the floor and then getting mixed up with the final ground parts. There have been number of instances when the lots had to quarantined and then checked 100% for OD because of mix-up. Since number of such parts mixed up with the finished lot is usually low, the probabilities of such parts to be found, even in the extended sample size, is very less and are subsequently reported by the customer during fitment of parts into the engine housing. There have been number of such complaints from the customers in the past, and the line supervisor has been resorting to 100% checking of all parts for OD, before final packing. This has usually led to dissatisfied customers, unsure of the quality of the finished product, as the defect may result in stoppage of customer's production lines on account of a supplier's quality issues. A number of lots have been returned by the customer in the past adding to the cost and at times 100% checking of parts had to be carried out at customer's premises because of urgency. The number of defectives observed and the customer complaint data is shown in Table 5.16.

Controls Implemented: A roll conveyor was installed at a height of 3 feet at the output station of the machine and was extended up to the input station of the machine for re-loading of parts for the subsequent grinding passes. The bushes after each grinding pass are collected in pans located on the roll conveyor and are then pushed by hand force to the input station or to the next operation in case the final diameter has been achieved.

Benefits Accrued/Expected: Since the parts will not roll down to the pan placed on the floor by a gravity chute, the possibility of some parts tumbling out of the pan on to the floor has been eliminated which was the primary reason for the mix up of parts at the grinding station. The quality data after implementation of this control is shown in Table

5.17. The data will, however, need to be reviewed and verified over a longer period of time to formally close the quality concern. The revised RULA score is shown in Table 5.18.

Table 5.16
Quality concerns because of parts mix up before implementation of controls

Application	Outcome of in-house 100% check **(Jan-Mar 2003)**				Customer Complaint	Cost of sales return	Customer Concerns
	No of lots	Total no of parts	No of Defective		No of lots rejected	(Rs lacs)	
Camshaft bush	9	26140	227	0.87%	3	2.68	1) One customer has quarantined supplies and suspended supply of pending orders 2) Delivery dates of parts are not met because of delay
Spring eye bush	3	5872	57	0.97%	1	0.81	
Connecting rod bush	11	46520	348	0.74%	2	1.74	

Table: 5.17
Quality concerns because of parts mix up after implementation of controls

Application	Outcome of in-house 100% check **(May - Jun 2003)**				Customer Complaint	Sales return	Customer Concerns
	No of lots	Total no of parts	No of Defective		No of lots rejected	(Rs lacs)	
Camshaft bush	7	21660	64	0.29%	-	-	1) No complaints received for lots supplied in April and May 2003
Spring eye bush	4	7640	13	0.18%	-	-	
Connecting bush	9	37885	91	0.24%	-	-	

7) Boring of Inside diameter of bushings (ID)

i) Task Description: Application of clamping pressure on the split brass bore

The parts are bored using a split brass bush bored in-line using a diamond cutting tool. The parts to be bored are then placed in the brass bush and clamped by a tightening screw by application of load of 10kg. After boring, the clamping load is removed and the bushes are unloaded from the split brass bush. Thus, in each boring cycle the clamping load is applied and removed before and after the boring operation.

Ergonomic Deficiencies identified for this task: The upper arm is flexed at an angle of 90° and also because of the force application of 10kg, the score by RULA assessment is very high. The problem is all the more acute for spindle 2, which is farther from the spindle 1 by 1.5 feet as shown in figure 5.6.

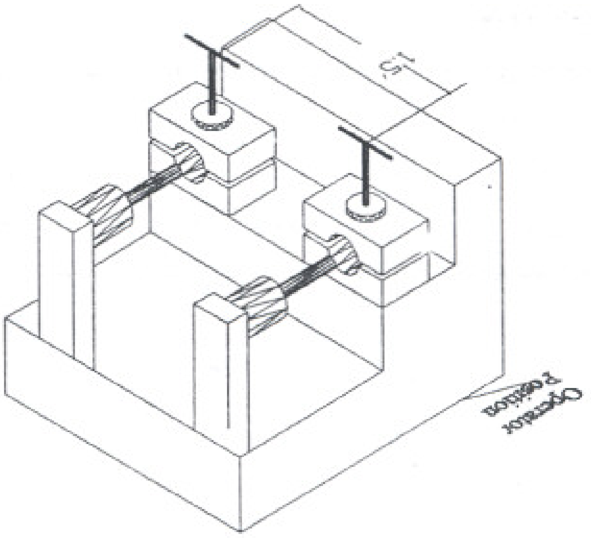


Figure 5.6: Fine Boring Machine

Controls Implemented: When frequent exertions are necessary, the required forces should be reduced. Force was reduced by provision of mechanical aids for the handheld clamping rod. The friction between the hand and the clamping rod was increased by using a knurled rod. This has helped in reduction of force. To reduce slippage and the grip force requirement, a flange at the end of the clamping rod was provided. A platform of 9 inches height was provided specifically for loading of parts into spindle II of the boring machine. The revised RULA score is shown in Table 5.18.

Table 5.18
Revised RULA Score after the implementation of controls

Operation/ Function	Potentially stressful task	Revised RULA Score
Loading of coil on de-coiler	Placing the three strip supports on the floor	3
	Pulling the loose end of the strip up to the Straightener	3
Blanking of parts	Set up of Die and Punch	2
	Unloading of blanked parts into the pan	4
First forming	Tooling set up and ejecting out the first formed piece out of the punch	4
Final forming	Holding of ID Core Plug during forming	4
Facing/ Chamfering	Set up of cutting tools	5
	Loading of bushes on the shuttle	3
OD Grinding	Loading of bushes at input magazine feeder after each grinding pass	3
	100% checking of parts after grinding	3
ID Boring	Application of clamping load	4

5.4.2 Assessment of Bearing Lines

The analysis of ergonomic problem tasks that have been identified after the assessment by RULA for the bearing line is as under:

1) Loading of Bimetallic Strip on De-Coiler

The problem tasks identified after the assessment by RULA on the de-coiler and the blanking press are similar to the one already discussed in Section 5.4.1 of this chapter.

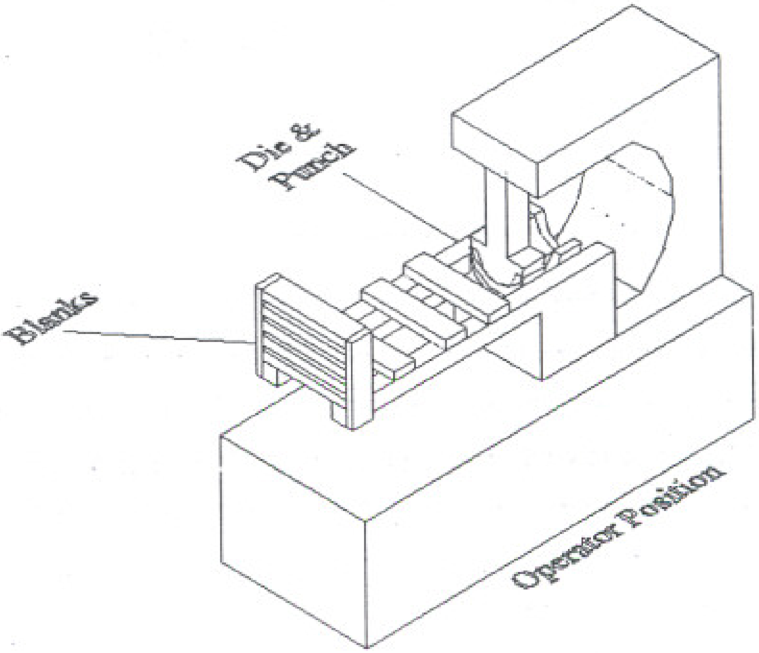


Figure 5.7: Forming and Coining of bearings

2) Forming and Coining of parts

i) Task Description: Loading of parts into the Magazine Feeder

The operator at this station is required to load the stacked parts after blanking into a vertical magazine feeder while simultaneously keep looking at the coining operation, as a mis-fed part into the die can cause accidents, which generally results in damage to the tooling. Replacement of tooling was reported to be expensive and usually takes 3 to 4 weeks. The operator loads the parts with his left hand as shown in the figure 5.7, and simultaneously looks at the coining operation.

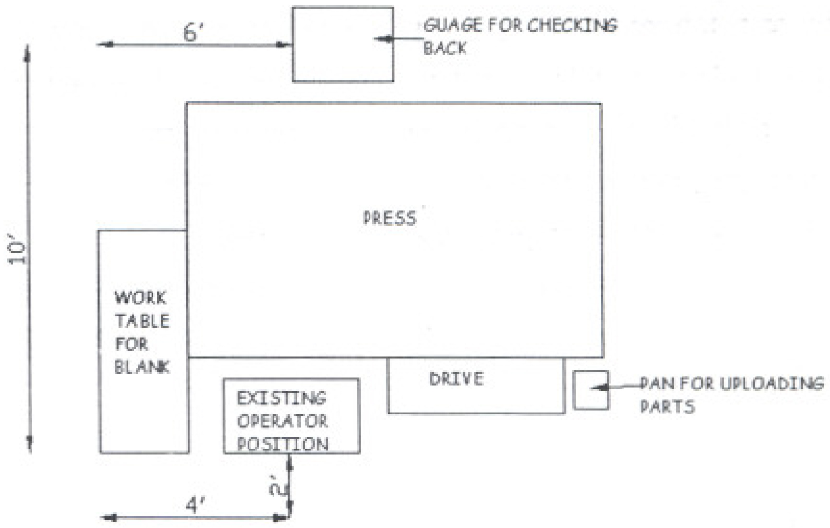


Figure 5.8: Existing operator work position on Form and Coin Press

Ergonomic Deficiencies identified for this task: The position of the operator as shown in figure 5.7 and 5.8 with respect to the feeder results in a neck flexion angle of 45° along with side bending of the neck, which results in a uncomfortable posture. Also, the loading of parts is done with the left hand with lower arm flexion of 90°+, resulting in a high RULA ranking needing immediate attention.

Controls Implemented: After brainstorming, the following controls were implemented:

- The work position of the operator has been re-located from existing sideways with respect to the press to the front of the press as shown in the figure 5.9. Thus, the sideways neck bending of the operator to enable him to always look into the die block for any wrong-feeding of parts into the coining die block has been eliminated. A wooden platform of height 9 inches has been provided at the new feeding station to reduce the arm flexion angle to < 60°, minimizing the discomfort caused due to loading of parts into the feeder.
- The change in the location of the loading station on the press also resulted in another advantage. The operator at the earlier loading station had to travel a distance of 44 feet after every 15 minutes to inspect the back geometry of the bearing by applying blue colour on the back and then inspecting the back contact percentage under load. The operators working on the press had suggested that the blue checking gauge be shifted closer to his workstation. The gauge however, could not be shifted, because the same gauge is used at all the subsequent operations also, although, the checking frequency at the subsequent operations is at set-up only. This meant that the operators of subsequent machines traveled to the gauge

once, or at the most twice, in the shift in normal operating circumstances. The new loading station shown in figure 5.9 on the machine helped reduce the travel time to 12 feet only. The existing cycle time for the process was calculated considering this aspect of the operator traveling about 25 times each shift to the blue checking gauge and necessary allowances were given accordingly.

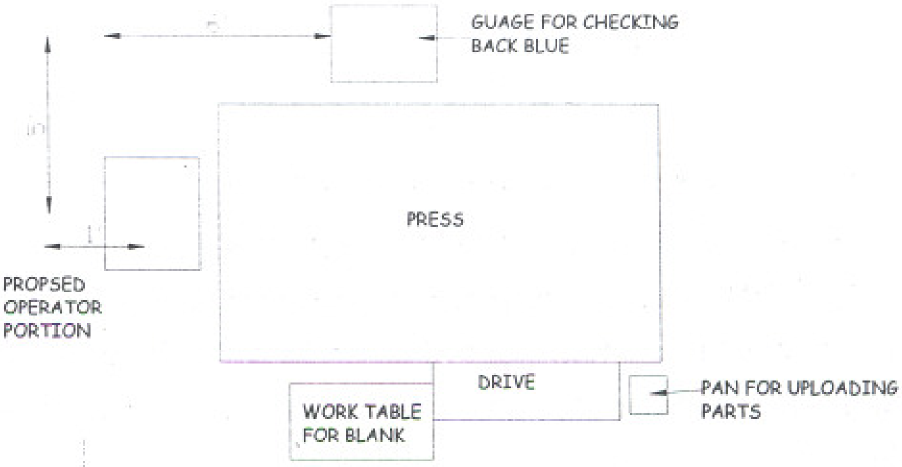


Figure 5.9: Proposed operator work position at Forming and Coining

Benefits Accrued/Expected: The revised cycle time for the process reduced from 0.029 minutes to 0.026 minutes for one part. The fatigue allowance was re-calculated at 14% against 20% earlier. See Table 5.19.

Table: 5.19

Productivity improvement after implementation of controls at forming & Coining

Operation	Fatigue allowance		Cycle time for one part (Mins)		Output per shift	
	Before	After	Before	After	Before	After
Form/Coin	20%	14%	0.029	0.026	10800	12400

3) Face and Chamfer of bearings

i) Task Description: Set up of 4 single point cutting tools on each of the two chucks

The problem has already been discussed in section 5.4.1(5).

ii) Task Description: Holding of two half bearings in the fingers so as to load as a circular bearing

The difference between a bushing and an engine bearing is that while the bushes are manufactured as full round, the bearings are manufactured as half shells and one lower half shell assembled with another upper half shell makes one bearing set. For loading the parts in the face and chamfer shuttle two half shells are assembled between the fingers and then loaded as a full circular shell in the loading shuttle.

Ergonomic Deficiencies identified for this task: While assembling the parts between the fingers, the wrist thus get flexed and twisted while the forearm is pronated which may irritate tendon attachments at the epicondyle. The loading of parts in this way is a highly repetitive task and risk of developing hand or wrist disorder is significantly increased for operators performing this task. Also, since the parts are handled between the fingers and the thumb in extended posture, contact stresses are induced at the thumb, index and the middle fingers because of the repeated pressure exerted against the skin. These results in pain and detrimental stress to the hand and also, many times the parts rotate or slide out of the hands of the operator.

Controls implemented: The following controls were implemented:

- Equalizer plates were installed on the machine as described during the discussion on facing and chamfering of bushes in section 5.4.2 of this chapter.
- Acute contact pressure and the resultant mechanical stress on the hand can be reduced by elimination of sharp edges on the bearings. This would mean that the machining or shearing tools used in the previous operations are sharp and do not leave any burr or sharp edges on the parts. Although this aspect has been well addressed in the part drawing and process sheets, strict compliance needs to be re-emphasized by issuing modified control plans for this operation.
- The operators were advised to wear fingertips although it would be necessary to study the affect of these on gripping of bearings between the fingers. While fingertips did increase friction, they did negatively affect hand forces by adding to the force necessary to oppose the resistance of the fingertips. Although, it was anticipated that there would be a decrease in the grip strength because of the fingertips, on the other hand, increase in the ability to prevent bearings from rotating or sliding out of the hand was expected. A study was conducted on five facing and chamfering operators over a period of three shifts for each operator to investigate the affect of fingertips on handling of parts between fingers for loading into the shuttle. The study was conducted assuming that the use of fingertips has no significant affect on the grip strength in this case. Each of the five operators was observed continuously during the shift for three consecutive days. Table 5.20 shows the results of the experiment and as can be observed, the use of fingertips resulted in significant drop of number of instances of rotation and sliding out of bearings from the hand during loading.

The revised RULA score after the controls were implemented is shown in Table 5.25 at the end of this section.

Table: 5.20

Affect of use of fingertips while loading parts into face and chamfer machine

	Shift	No. of loadings per shift on each face pad *	Rotating or sliding out of bearings out of the fingers		No. of loadings per shift	Rotating or sliding out of bearings out of the fingers	
			Loading without fingertips			Loading with fingertips	
			No of parts	Percentage		No of parts	Percentage
Operator 1	Day 1	2248 x 2	34 x 2	1.51	2180 x 2	8 x 2	0.37
	Day 2	2605 x 2	21 x 2	0.81	2470 x 2	2 x 2	0.08
	Day 3	2422 x 2	42 x 2	1.73	2050 x 2	3 x 2	0.15
Operator 2	Day 1	2087 x 2	26 x 2	1.24	2280 x 2	6 x 2	0.26
	Day 2	2450 x 2	48 x 2	1.96	2440 x 2	6 x 2	0.24
	Day 3	2175 x 2	31 x 2	1.42	2180 x 2	1 x 2	0.05
Operator 3	Day 1	2710 x 2	19 x 2	0.70	2610 x 2	9 x 2	0.34
	Day 2	2108 x 2	27 x 2	1.28	2540 x 2	4 x 2	0.16
	Day 3	1904 x 2	40 x 2	2.10	2450 x 2	5 x 2	0.20
Operator 4	Day 1	2540 x 2	25 x 2	0.98	2250 x 2	1 x 2	0.04
	Day 2	2480 x 2	18 x 2	0.72	2755 x 2	2 x 2	0.07
	Day 3	2350 x 2	38 x 2	1.62	2380 x 2	7 x 2	0.29
Operator 5	Day 1	2440 x 2	33 x 2	1.35	2305 x 2	-	0.00
	Day 2	2310 x 2	19 x 2	0.39	2480 x 2	1 x 2	0.04
	Day 3	2550 x 2	24 x 2	0.94	2610 x 2	-	0.00
		35379 x 2	445 x 2	**1.26**	35980 x 2	55 x 2	**0.15**

**There are two facing pads on the machine on which parts are loaded. The figures shown above are for top facing pad.*

iii) Task Description: Loading of bearings on the lower half of the shuttle

The problem has already been discussed in section 5.4 of this chapter.

4) Hole piercing

i) Task Description: Set up of die and punch

The hole is pierced on the part at the specified location using a universal die block in which the necessary set up is made on the press both for the angular as well as for the axial location of the hole as specified in the part drawing. Physical stressors associated with this process include awkward posture, repetitive motion and contact stress. The number of parts that can be pierced per shift are 7900 which includes three types of set ups for different bearing applications. The current norm for setup time is 25 minutes. Thus, about 75 minutes are used up for set up in each shift.

Ergonomic Deficiencies identified for this task: The operator was observed over three complete shifts of 8-hours duration for the posture assessment. The awkward posture was observed to be due to the restricted work space on the press constrained by the shut height between the base and the ram, thus leading to bending of neck by 20° and trunk by > 60°.

The review of the quality data also showed that there have been large rejections due to the shift of angular location of the hole with respect to the centerline of the bearing. This has been mainly due to the use of a universal die (common to many applications of engine bearings within a specified range of diameter). The fittings of the die tend to loosen after some time of the press operation resulting in shift in central axial location of the hole. The dies, thus, needed frequent adjustment and minor setup changes.

Injuries due to accidents at hole piercing

A large number of job related injuries have been reported at this workstation resulting in a high compensation cost to the workers injured while working on the press. The exact data pertaining to the compensation cost paid could not be retrieved since a substantial part of the compensation is paid through a government scheme under ESI, which is directly paid to the employee. Many times the injury at the workstation had resulted in either lost fingers or deep cuts/wounds on the fingers or thumb. Most of the operators who had injured hands are presently working only on light jobs like visual inspection or light rework jobs. The total number of injuries reported as per records at two different firms is as shown in table 5.21.

Table 5.21

Number of Injuries, lost mandays and Compensation Cost

Year	No. of accidents / MSD'S reported		Number of lost mandays		Compensation cost paid
	Major Injuries*	Minor Injuries**	Restricted days	Lost days	
1997-98	2	32	240	127	Data not available
1998-99	1	44	187	88	
1999-00	1	41	96	104	
2000-01	1	55	164	78	
2001-02	3	28	115	166	

* *Permanent disability*

** *Mostly MSD's or minor injuries*

All the accidents had taken place while loading the part into the die block. The part is first picked from the pan placed on right side of the operator in the right hand & loaded into the die. The press is operated using both the hands, a precaution, which had been earlier introduced with limited success, to ensure that both the hands are out of press operation area while the ram takes the piercing stroke. The part is then unloaded with the left hand while simultaneously loading the next part with the right hand. The entire sequence of operations needs excellent two-hand coordination and most of the accidents have been as a result of error in judgment while coordinating the motion of two hands. Despite the fact that the operator needed to press the two control push buttons simultaneously with both hands, still accidents took place because of the rate at which the operators are expected to load and unload the parts.

Controls Implemented: After observing the task and discussion with the operators working on the press, the following controls were implemented:

Dedicated hole piercing die for each application

It was suggested that the universal die be replaced with a dedicated die, which will be specific to the bearing application with fixed angular and linear location for the hole. Such a die will need no adjustment for the hole angular location. It was also suggested that those applications which run most frequently and those which had the largest lot sizes be taken up first and subsequently all applications be covered under this kind of tooling over next one to two years. Consequently, the team as a first step developed the dedicated tooling for TATA 697 Engine bearing application based upon the above criteria.

Benefits Accrued/Expected: Since no major set up was involved on the press after providing a dedicated die, the set up time reduced from 25 minutes to 8 minutes on the press. Since no adjustments were required on the press, the use of hand tools that required working with the wrist flexed and hyper extended and extreme rotation of forearm during the setup has been avoided.

Controls for injuries due to accidents at hole piercing: The following controls were implemented after detailed discussions:

i) Two Hand Coordination Test

The organizations may conduct tests to match the capability of the operators using two-hand coordination test on several operators with a given set of variables with the requirement of the process steps. It has also been suggested that those operators who had the best capability be assigned on this job.

ii) Safety Arms

Two safety armbands were hooked to steel ropes and attached vertically through two pulleys hanging overhead and then connected to the press ram. The motion of the ram was synchronized in such a way that as the ram went down to complete a punching stroke, the rope attached through the pulleys pulls the two hands of the operator wearing the armbands, away from the work area.

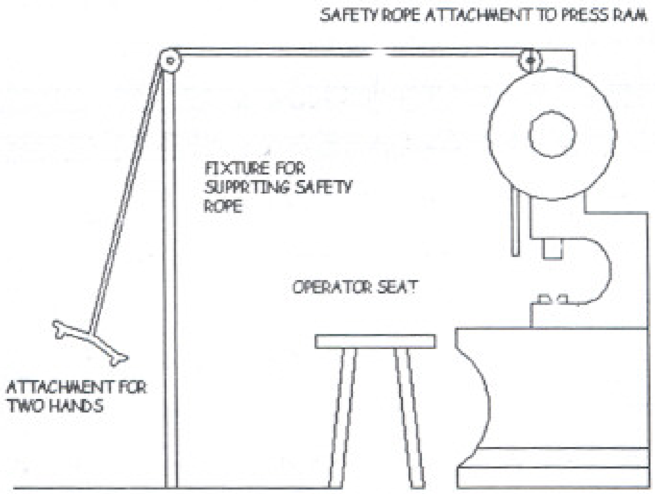


Figure 5.10: Safety Arms attached to Hole Piercing Press

Benefits Accrued/Expected: The safety arrangement as explained above ensured that the hands of the operator were always away from the die block when the press ram is completing the stroke. The safety arrangement was subsequently installed on all the hole piercing and lip punching presses as shown in figure 5.10. The operator initially did report inconvenience, but understood the necessity. The effectiveness of the system needs to be validated over a longer period of time although no accidents were reported till two months after the installation of the safety ropes. No significant affect on the cycle time and productivity of the process was observed. The control is expected to significantly bring down the cost of compensation and other adverse affects of accidents on productivity and worker morale.

The revised RULA score after the controls were implemented are shown in Table 5.25

5) Lip Punching

i)Task Description: Loading of parts with correct orientation into lip punching die

The loading of parts into the lip punching die must be done in such a way that the hole and the lip orientation, as specified in the part drawing supplied by the customer, is always maintained. The resultant requirement is that the parts must be loaded only from one particular side to prevent reversal of hole and lip orientation.

Ergonomic Deficiencies identified for this task: The operator is required to always ensure that the loading of parts is always done as specified in the process control plan. The customer's views defects such as incorrect orientation of lip and hole very seriously as it is impossible to segregate one such part in a big lot and usually the part is noticed during engine assembly at customer's production line. The customers are known to take extreme precautionary steps, which generally results in returning of all lots supplied as well as those pending for fitment in their stock, besides, quarantining the pending supplies. This generally results in a serious loss of face for the bearing manufacturers. Because of this, the operators working on this process rate the task as very stressful. The manufacturers are resorting to 100% checking of all parts for hole and lip orientation to eliminate chances of serious repercussions of the after affects of such a defect occurring.

The operator while loading the part in the die first checks the side of parts for correct orientation and has been asking for a helper to stack the parts with correct orientation. On any given day, if no such help is provided, the press operators do not produce more than 1/3rd of the normal output. The helper stacks the parts at the loading station with correct orientation and the operator loads the parts into the die thereafter.

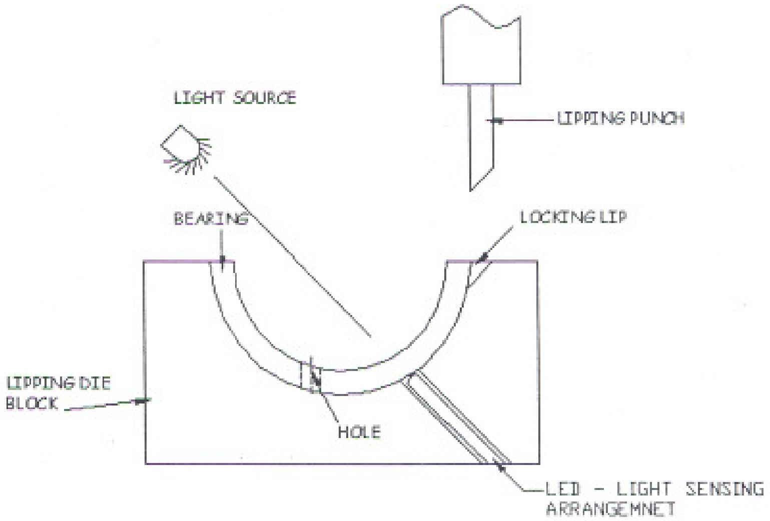


Figure 5.11: Incorrect Loading of bearing- Hole reversed with respect to Lip

Controls Implemented: The operators view this task as stressful because they have to visually check the parts before loading into the lip punching die and the only way to reduce this stress was to develop a poke-yoke or a mistake proofing system which will eliminate the need for visual inspection of parts for loading from the correct side. It was decided to take the help of the in-house Engineering Section of the companies to work on developing such a system. The task team proposed a light-sensing device, which could be installed in the Lip punching die block and send signal through the limit switches to the ram in case of reversed on incorrect orientation of the part. The system was tested on one lip punching press and it worked on the principle that if the part is correctly loaded into the die, then the hole punched on the part will exactly match the LED-sensing device fitted in the die. The light, which passes through the hole to the sensor, actuates the ram of the press. However, if the part is loaded in any other orientation or reversed, the LED will not get a signal and the press will not operate. The arrangement is shown in figure 5.11 and 5.12. As can be seen in the two figures, if the bearing is loaded into the die in reversed position, the bearing blocks the light and no signal is passed for actuation of the press.

The revised RULA score after the controls were implemented are shown in Table 5.25.

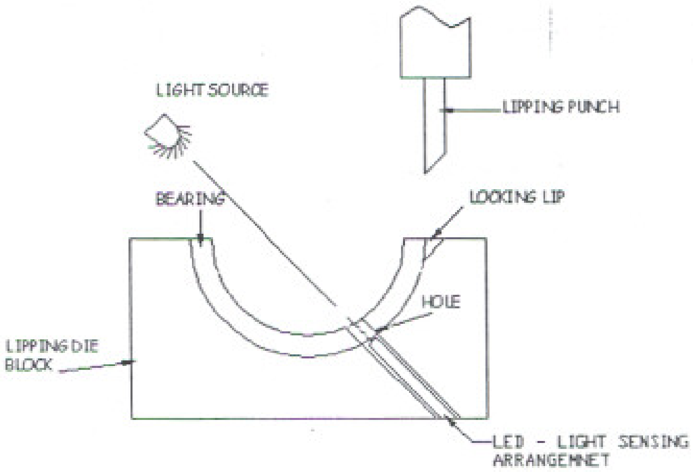


Figure 5.12: Installation of Mistake Proofing Device

Benefits Accrued/Expected: A study was conducted to investigate the affect on the production output per shift for the Lipping process using two skilled operators on five different days using the following variables:

1. Production output per shift **without** provision of a helper to stack parts with correct orientation

2. Production output per shift **with** provision of a helper to stack parts with correct orientation
3. Production output per shift without provision of a helper, **but after installing the light-sensing device (Poke-yoke)** to check for any incorrect orientation of hole and lip.

After the analysis of the production data subsequent to implementation of the above control, it was concluded that production output achieved after installation of the Light sensing device was similar to the one achieved when a helper was provided to stack parts with correct orientation before the operator loads the parts into the die. The new system thus eliminated the need for engaging a helper to visually check orientation. (Table 5.22).

Table: 5.22

Affect on output without helper, with helper and after mistake proofing

Day	Production output per shift					
	Without helper		With helper		After installation of Light-sensing device	
	Operator 1	Operator 2	Operator 1	Operator 2	Operator 1	Operator 2
Day1	3460	2980	5715	6118	5825	5740
Day2	3175	2450	6080	5822	6053	5954
Day3	3108	2716	5540	5734	5274	5509
Day4	2614	3115	5366	5584	5775	5815
Day5	3247	3048	5820	5924	5826	5670
Total	15604	14309	28521	29185	28753	28688
Average	3120.8	2861.8	5704.2	5837.0	5750.6	5737.6

6) Wire brushing of the bearing back

i) Task Description: Unloading of brushed parts into the pan

After wire brushing of the bearing back, the parts are unloaded into a pan placed on the floor through a gravity chute. Each pan can accommodate up to about 200 parts and for a typical lot size of 2000, a total of 10 pans are needed.

Ergonomic Deficiencies identified for this task: The pans filled with parts are first removed and replaced by an empty pan. The task needs to be carried out on an average 40 to 50 times in an 8-hour shift resulting in high trunk flexion of more than 60° besides the side-bending of the trunk. The pans filled with parts are then subsequently manually moved to the next operation.

Controls Implemented: A roll type magnetic conveyor was installed at a height of 3 feet at the wire brush station, and connected to the countersinking machine, which is next operation after wire brushing. The parts are raised with the help of a motorized magnetic roll conveyor and the parts are unloaded into the pan placed at a height of 3 feet. After the pan is loaded with parts, the pan is pushed to the next operation. The revised RULA score is shown in Table 5.25 at the end of this section.

7) ID Broaching and Height Broaching

i) Task Description: Set up of master nest block and the broach cutters

The parts are broached for control of wall thickness and crush height using horizontal broaching machines. The tooling for each type of bearing is application specific and is mounted on the base of the broaching machine. The broach cutters are mounted on the horizontal slide, which cuts in the forward stroke, while, the return stroke is idle.

Ergonomic Deficiencies identified for this task: The operator uses a trial and error method for setup of the tooling for crush height, by which a part is first loaded on to the tooling, broached and then measured for size. Necessary adjustments in the setup are made based on the results of the broached parts, for which the operator is required to go to the back of the machine traveling a distance of 36 feet each time. The set up is generally completed after three to four iterations and the operator has to travel that much distance as many number of times. Besides this, the holding bolts of the nest block needs to be adjusted after every 500 parts to compensate for the wear out of the broach cutters. The operator uses a long handle nut runner for adjustment of the bolts. The forces acting on the hand while operating a nut runner include (1) push or feed force (2) holding force and (3) torque reaction force. Feed force is necessary for starting the fastener and keeping the bit engaged during the securing cycle, and it is affected by the work material and design of the fastener. Holding force is the force necessary for supporting the nut runner. Reaction torque is produced by rotation and is affected by the tool length. These forces require a reaction from the operator to control the tool and keep it stable.

Controls Implemented: After brainstorming with the operators performing the job in question it was concluded that it is not possible to eliminate the ergonomic issues by implementing some kind of engineering controls without any major change in the design of the machine, which would necessitate a major investment. Administrative controls like job rotation have been recommended till such time.

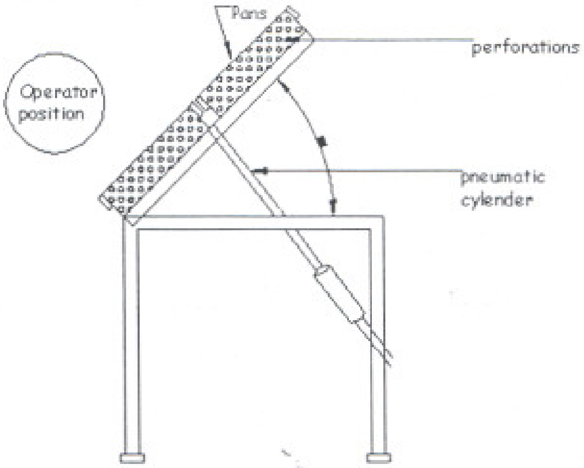


Figure 5.13: Loading station inclined at ID and Height Broach

ii) Task Description and Ergonomic Deficiencies identified for: Loading of parts into the die block at Height and Wall Broaching machines.

The review of loading and unloading task at the broaching machines depicts the following sequence as shown in Table 5.23.

Controls Implemented:

- To reduce the stress caused by the neck bending sideways and neck flexion angle of 35°, the pan was inclined at an angle of 45° on the loading table by installing a pneumatically operated cylinder to the top plate of the table placed in the right side of the operator as shown in figure 5.13. After placing the pan on the tabletop, the top was inclined at an angle of 45° to reduce the neck flexion angle to 10°. This arrangement also resulted in reducing the stress caused by sideways bending of neck.
- To eliminate or reduce the stress caused by the unloading of parts into the pan placed on the left of the operator, another intermediary unloading station was fabricated on the top of the slide of horizontal broach, which could accommodate up to 500 parts as shown in figure 5.14. The operator after unloading the parts from the die block was asked to place them on the tray provided on the top of the slide and subsequently unload the parts after every 30 to 45 minutes into the pan placed on the left hand side. This has helped reduce the fatigue caused because of asymmetrical turning for putting of each single part into the pan placed on the left hand side. To further eliminate the stress factor, the operators were provided with a

20 inches long magnetic catcher, which could lift 40 to 50 parts at one time and release these parts into the unloading pan after de-magnetizing.

Table 5.23

Sequence of tasks while loading and unloading on broaching machines

Task	Location	Posture Assessment
Pick up part for loading	- Right of the operator using right hand	- Neck bending sideways and neck flexion angle of > 20° - Other body parts in normal position.
Load part into the die block	- Uses right hand and presses two control switches simultaneously	- Neck flexion 20° - Body posture normal
Unloading of parts	- Unloading pan placed on the left of the operator - Uses left hand	- Right hands picks up next part for loading - Left hand removes the finished part
Put in unloading pan	- Uses left hand	- The unloading pan is 1.5 feet sideways on the left as shown in figure because of machine drive - Operator has to turn asymmetrically at an angle of 75° to place the part

Benefits Accrued/Expected: After implementation of the above controls the fatigue allowance was re-calculated using Page's fatigue determination table. The revised allowance allocated was 13% as against 16% existing. The resultant improvement in the cycle time led to an increase in output per shift to 5150 parts per shift. See Table 5.24.

Table: 5.24

Productivity improvement after implementation of controls at ID & Height broach

Operation	Fatigue allowance		Cycle time for one part (Mins)		Output per shift	
	Before	After	Before	After	Before	After
ID / Height Broach	16%	13%	0.065	0.059	4700	5150

The revised RULA score is shown in Table 5.25 at the end of this section.

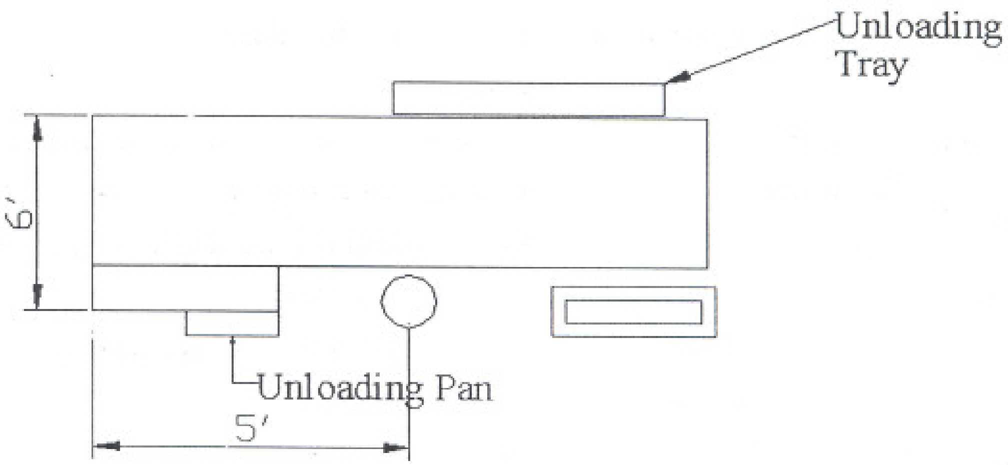


Figure 5.14: Intermittent unloading tray on broaching machines

Table 5.25

Revised RULA Score after the implementation of controls – Bearing Line

Operation/Function	Potentially stressful task	Revised RULA Score
Loading of coil on de-coiler	Placing the three strip supports on the floor	3
	Pulling the loose end of the strip up to the Straightener	3
Forming and Coining of parts	Loading of parts into the Magazine Feeder	3
Face and Chamfer of bearings	Set up of 4 single point cutting tools on each of the two chucks	5
	Holding of two half bearings in the fingers so as to load as a circular bearing	4
	Loading of bearings on the lower half of the shuttle	3
Hole piercing	Set up of die and punch	3
	Injuries due to accidents at hole piercing	3
Lip Punching	Loading of parts with correct orientation into lip punching die	2
Wire brushing of the bearing back	Unloading of parts into the pan after wire-brush	3
ID Broaching and Height Broaching	Set up of master nest block and the broach cutters	5
	Loading of parts into the die block	4

5.4.3 Analysis of Plating Section

The ergonomic problem tasks that have been identified after the detailed assessment by RULA for the plating shop are as under:

1) Plating loading station

i) Task Description: Shifting of plating racks to the Loading station

The bearings after the completion of all the machining operations are plated with a 0.020/0.025mm thick layer of Lead, Tin and Copper plating. The pans containing the machined parts are placed on the worktable at the loading station and appropriate racks for plating are identified and moved from the storage area to the loading station. The selection of a particular type of rack is dependent on the bearing free diameter and as such three combinations of racks are available which can be used of all the diameters within the bearing range except the bearings characterized as large size bearings used generally for heavy engines like turbines or locomotives. The racks are further characterized as single column or double column depending upon how many columns of bearings are loaded at one time.

Ergonomic Deficiencies identified for this task: After selection of the appropriate rack for a given type of bearing application, the plating racks are moved from the storage area located at a distance of 35 feet from the loading station. The plating machine can accommodate 40 such racks in one cycle of 50 minutes duration. For a typical lot size of 2000 parts, the bearings can be plated in three to four cycles depending upon the number of parts loaded in one rack. Depending upon the diameter of the subsequent bearing application, the racks may need to be replaced and a review of the number of applications which ran in the plating shop for a period of two months suggest that the racks need to be changed on an average three to four times in each shift. Each time the racks have to be replaced, the old racks first need to be shifted to the storage area and the new racks are then moved to the loading station as shown in figure 5.15. The total time used up for this activity is about 15 minutes resulting in a time loss of about 45 to 60 minutes per shift just on account of change of racks.

The force requirement for the task is related to the weight of the plating racks being handled. Also, the distribution of the weight of the rack affects how force is transmitted to the user. The racks used in the plating shop did not have grips for handling them and repeated force over a small surface area of the fingers and the palm for moving the racks resulted in pain and detrimental stress to the hand and the fingers.

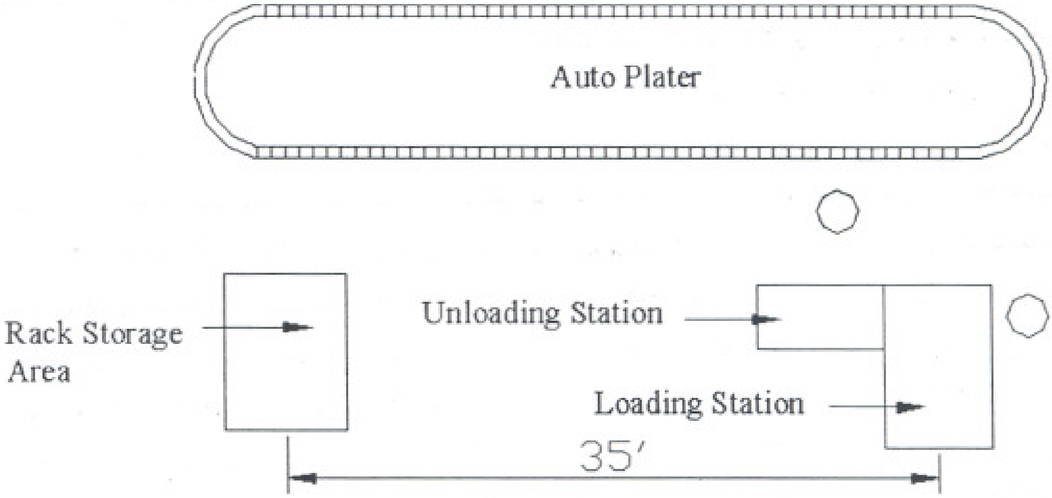


Figure 5.15: Layout of Plating Section

Controls Implemented: The team after brainstorming decided to fabricate a trolley in which slots were provided to hang the plating racks on two sides. Each trolley could accommodate 20 racks, 10 on each side and a total of six trolleys for three types of racks were fabricated. 40 racks of each type were hanged on two trolleys each and at every setup change in the plating shop, two trolleys with appropriate rack sizes were moved to the loading station.

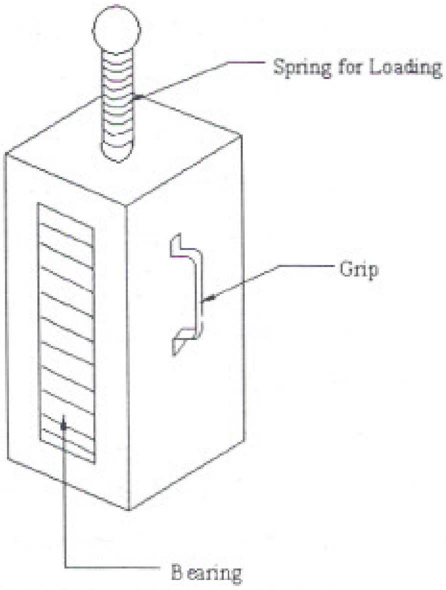


Figure 5.16: Provision of grips on plating racks

In order to reduce the force/exertion on the hands and fingers, 9 inches gripping handles on two sides of the racks were provided to permit a comfortable fit in the hands as shown in figure 5.16. The gripping handles were provided with soft compliant coverings. Also, it was ensured that sufficient friction was present between the handle and the hand to provide a secure grip and prevent slippage. The amount of friction depends upon the coefficient of friction between the hand and the material of the grip. It was further recommended that the centre of gravity of the plating rack should be aligned with the center of the grasping hand. The centre of gravity is the intersection of the plumb line dropped when the rack is suspended from two different points. The centre of gravity should be determined with the rack fitted with all its attachments including the loading springs.

The revised RULA score is shown in Table 5.27 at the end of this section.

ii) Task Description and ergonomic deficiencies for: Loading and Unloading of parts in the plating rack

The review of the loading and unloading task depict the following sequence. (Table 5.26) The task is completed by two operators one for loading and the other for unloading of parts.

Table: 5.26
Loading and unloading task on the Plating Machine

Task	Activity	Posture Assessment
1. Place parts on the base rods provided on worktable	- Lift parts from the pan with left hand - Place parts on base rod with right hand	- Neck front bending with flexion angle > 20° - Contact stress on fingers
2. Move plating rack into position in the slot provided	- Lift with both hands	- Forceful exertion
3. Pull loading spring with spanner & simultaneously lift the base rods by the foot operated pneumatic system	- Pull spring with spanner held in left hand - Holds rack in position by applying hand pressure on rack - Press foot operated control for lifting parts	- Lower arm flexion > 60° - Wrist twisted - Frequent forceful exertion
4. Release spring held with spanner so that parts are firmly held under spring tension	- Remove spanner	- Normal working posture
5. Lift rack and load on the hooks at the plating station	- Hold rack from grips provided and load on plater	- Frequent forceful exertions - Upper arm flexion angle > 90°

For unloading of parts after plating the following sequence is followed:

→ 5 → 3 → 4 → 2 → 1

Controls Implemented: The following controls were implemented:

1. **Adjustable Work-table Height**: The two worktables for loading and unloading of parts were provided with an arrangement to adjust their heights according to the requirement of the operator concerned. The adjustable worktable height helped reduce the neck-bending flexion angle to 10°.
2. **Use of fingertips to reduce contact stress**: The operators were advised to wear fingertips although it would be necessary to study the affect of these on gripping of bearings between the fingers. While fingertips did increase friction, they did negatively affect hand forces by adding to the force necessary to oppose the resistance of the fingertips. Although, it was anticipated that there would be a decrease in the grip strength because of the fingertips, on the other hand, increase in the ability to prevent bearings from rotating or sliding out of the hand was expected. The study conducted while implementing controls for the face/chamfer loading process did validate that the use of fingertips helped reduce the contact stress.
3. **Force requirement to pull the rack spring:** If the bearings are not held against the rack column with adequate spring tension pressure, the bearings collapse in the plating racks because of the vibration or jerks to the plating racks while lowering or raising in the plating tanks. The operator needs to produce force to pull the spring adequately so that the bearings column is held against the wall of the plating rack under spring tension. The capacity to produce force is the required strength of the operator. Strength is therefore the maximum force an individual can produce. The ability of the loading operators to produce the required forces should be taken into account while selecting the appropriate springs for the racks. An operator normally cannot use a rack for long without becoming fatigued, if required to exert force at maximum capacity. The ratio of the required force to an individual's strength approaches unity as the force requirement approaches an operator's strength capability. This proportion is related to the ability to sustain a given exertion, and to the onset of localized muscle fatigue. The greater the proportion of strength that a repeated exertion requires, more rapid is the onset of fatigue. Racks should therefore be selected so that this proportion is minimized. This can be accomplished by

selecting racks requiring less spring force, without compromising on the ability of the spring to hold the bearing column against the wall of the rack.

The revised RULA score is shown in Table 5.27 at the end of this section.

Table 5.27
Revised RULA Score after implementation of controls

Operation/Function	Potentially stressful task	Revised RULA Score
Plating loading station	Shifting of plating racks to the Loading station	3
	Loading and Unloading of parts in the plating rack	4

5.4.4 Analysis of Packing and Dispatch Section

Brief Introduction of Packing Section:

Engine bearings are generally packed in three different types of packing:

1. **Loose packing**: Bearings are directly packed after oiling in cardboard cartons with thermocole separators to avoid bearing-to-bearing contact. All OE parts are generally loose packed as individual part numbers although these are always shipped as complete sets.
2. **Shrink packing**: The parts are shrink wrapped using a shrink wrapping machine and are always packed in matched sets. This packing is primarily used for packing of replacement parts.
3. **Skin Packing**: The parts are skin wrapped on a cardboard and is generally done for parts which are to be transported through ship. Thus this type of packing is used mostly for parts meant for export orders and the parts are always packed as matched sets.

The detailed analysis of each of the task with respect to the ergonomics problems is as under:

1) OE parts loose packing station

i) Task Description: Use of thermocole inserts as separators

Almost all the parts meant for original equipment manufacturers are packed as individual part numbers in cardboard box cartons. All the parts are oiled by dipping the complete pan in an oiling tank. The parts are then packed in cardboard cartons after wrapping a polythene sheet around the parts. Each carton may contain 10 or 20 parts depending upon the size and diameter of the bearing. In order to avoid bearing-to bearing contact, which may cause damages, a thermocole insert as shown in figure 5.17

separates the parts. The sequence of operations for this task as observed is as shown in figure 5.18.

Ergonomic Deficiencies identified for this task: The review of the ergonomic problems associated with this task shows that a wide finger and hand span is needed to grip/hold the parts before packing the parts into the box. The wrist is bent repetitively up and down during the completion of the task. Also, number of minor injuries has been reported while inserting the thermocole separators between parts as the finger nails rubs against the bearing parts repetitively. The operators find this particular task stressful on account of these fingernail injuries. The operators face number of problems with the design of locking arrangement while preparing carton boxes as many times the box remains loosely assembled and they have to staple the box at loose ends to ensure that it does not open up during transit.

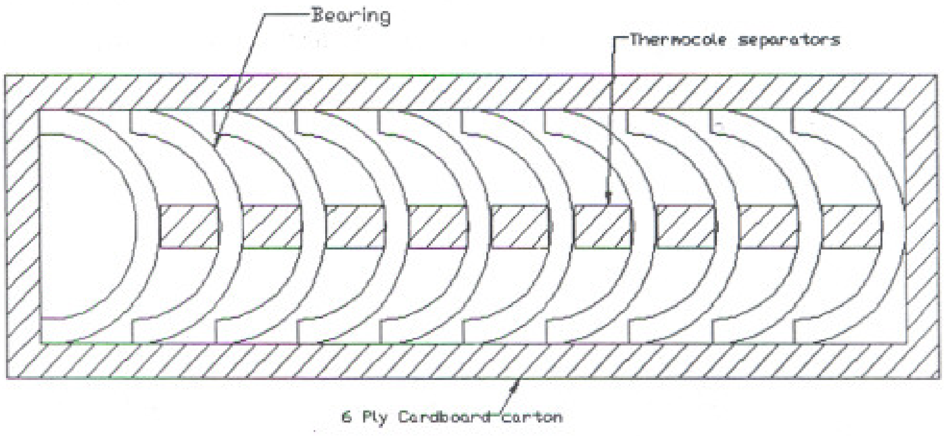


Figure 5.17: Packing with thermocole inserts

Besides the ergonomic problems associated with this job, a large number of customer complaints are also received from time to time because of damages caused to parts due to bearing-to bearing-contact. Since these bearings are thin-walled, the thermocole separator, many times caves in and the parts get scrambled/jammed into each other causing damages/scratches as well as loss of free spread of bearings. The problem has been very acute with large diameter bearings such as Cummins NH/NT engine bearings.

Controls Implemented: After brainstorming and discussions with the employees working on the job, the following controls were implemented.

Change of packing design:

Two new designs have been suggested for loose packing of parts to reduce the ergonomic risks associated with the job as well as eliminate the problem of damages and loss of free spread of parts due to packing related issues.

Option 1: It has been suggested that the use of thermocole inserts as separators be discontinued and replaced with a cardboard separator, which may be placed in the box prior to placing the parts in the box. The outer box will however, remain the same as before. To test its usefulness, boxes for two applications namely TATA 697 Main bearings Part number 3520330001, 3520330002 and TATA 697 connecting rod bearings part number 3520380610 were manufactured. The parts were packed in the boxes with the cardboard separator instead of thermocole and 5 sets of boxes were sent to the customer for his approval. The design was approved by the customer and was then introduced for sending pilot supplies in June 2003.

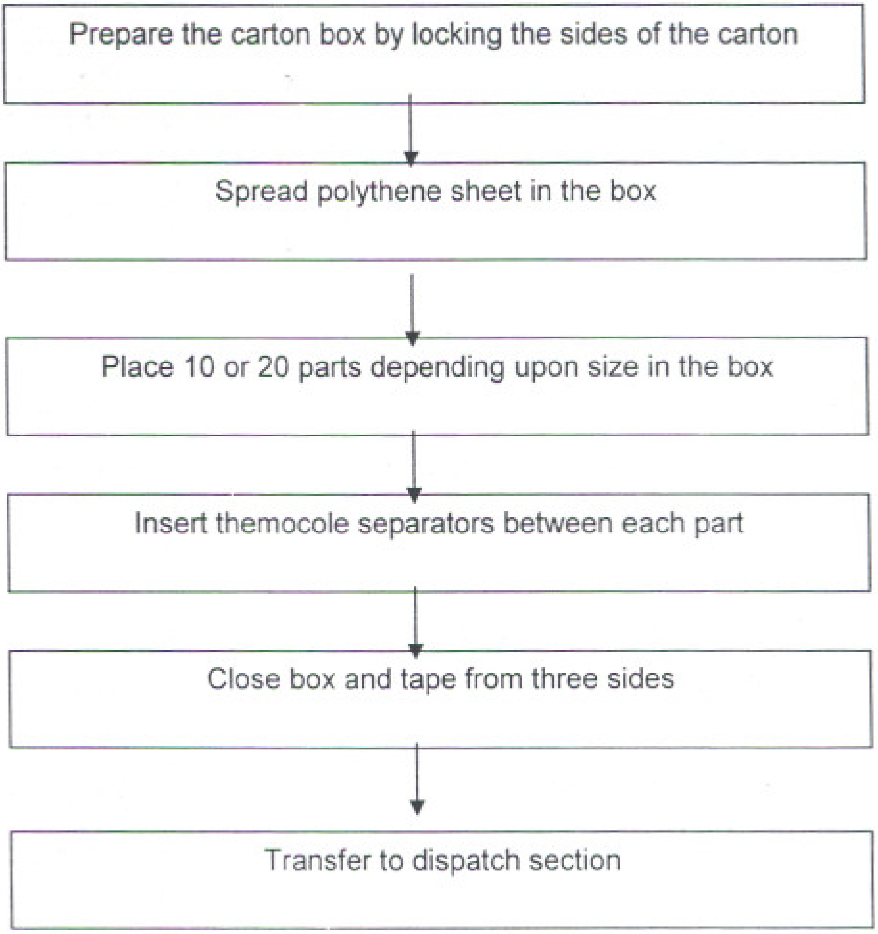


Figure 5.18: Sequence of tasks carried out for OE packing

Benefits Accrued/Expected: Since the packing operators does not have to insert the thermocole separators between the parts, the injuries caused to fingernails due to repetitive motions has been reduced to a large extent. A review of the customer complaints for a period of July 2003 to October 2003 shows that no quality related issues associated with packing damages has been reported. In fact, the customer has requested other supplier of these parts also to follow the same packing design. The design can be easily replicated on the other parts where the customer requires such packing.

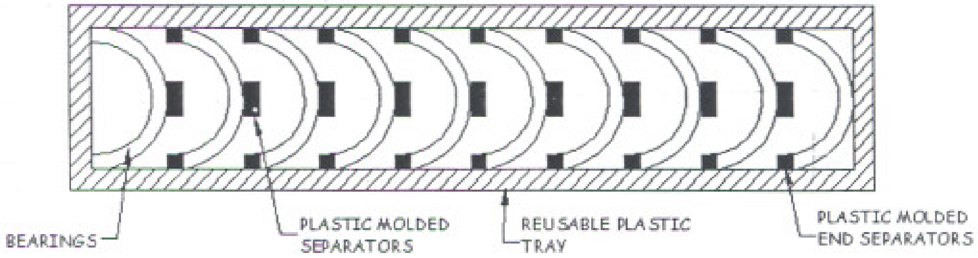


Figure 5.19: Packing for Cummins parts using plastic tray

Option 2: The option 2 was suggested by the customer (Cummins in this case) for the parts supplied to them. This design requires the packing carton box be replaced with a plastic tray with slots made in the tray to act as stoppers so as to avoid bearing to bearing contact The tray is specific to the diameter of the bearings and 10 parts can be packed in each tray. (Figure 5.19). The trays are re-usable and an arrangement can be worked out with the customer(s) to return the trays after the parts have been used up in their engine assembly lines. Thus, such trays require a one-time investment and some recurring expenditure. Sample trays have been manufactured and sent to Cummins for trials.

Benefits Accrued/Expected: If the organizations decide to accept this design, the following ergonomic improvements can be expected:

- Eliminate the need to assemble carton boxes
- Eliminate visual demands of the task to view fine details such as placing separators
- Reduction of injuries caused to fingernails
- Prevention of defects caused due to damages etc.

Since there is considerable investment required for implementation of option 2, it has been suggested that option 1 be explored for all OE customers except Cummins for whom option 2 may be implemented because of their specific request.

After the implementation of option 1 for TATA 697 bearings, the productivity indicators namely (1) cycle time, (2) output per shift, (3) discomfort, (4) injuries, and (5) quality complaints were compared to same productivity indicators with the existing packing design using thermocole separators. The results are shown in Table 5.28. As can be seen from the table, a positive impact on productivity indicators as described above can be seen. The data shown under the heading 'before' is the average for the period January to May 2003, whereas the data shown under 'After' in the table is the average for the period June to September 2003.

Table: 5.28

Productivity indicators for loose packing after implementation of option 1 for two applications

	Cycle time (seconds)		Output/shift (Number of parts packed)		Discomfort		Injuries to fingernails (Avg/ month)		Quality Complaints (Avg/ month)	
	Before	After	Before	After	Before	After	Before	After	Before	After
Tata 697 Engine Main bearing	0.046	0.035	7500	9500	Acute	Moderate	14	2	2	0
Tata 697 Engine Con rod bearing			8500	11000	Acute	Moderate				

Each carton box contains 20 parts

The revised RULA score is shown in Table 5.29.

2) After Market (Replacement market) or AM parts shrink packing station

Task Description: Packing of matched sets

Unlike the OE parts, the parts for the replacement market are packed in matched sets. Each bearing set typically consists of a combination of Upper half bearings and Lower half bearings. The upper and lower half may have further series depending upon the location of fitment in the engine block. Thus each bearing set may consist of 4 to 6 different part numbers. For example a Cummins NH/NT main bearing set consists of 6 different part numbers namely: Front Upper and Lower half with part numbers 3019174 & 3019180; Intermediate Upper and Lower half with part numbers 3019186 and 3019192; and Rear Upper and Lower half with part numbers 3019198 and 3019204. Thus for a set of Cummins main bearings to be packed all the six parts need to be available in the packing section.

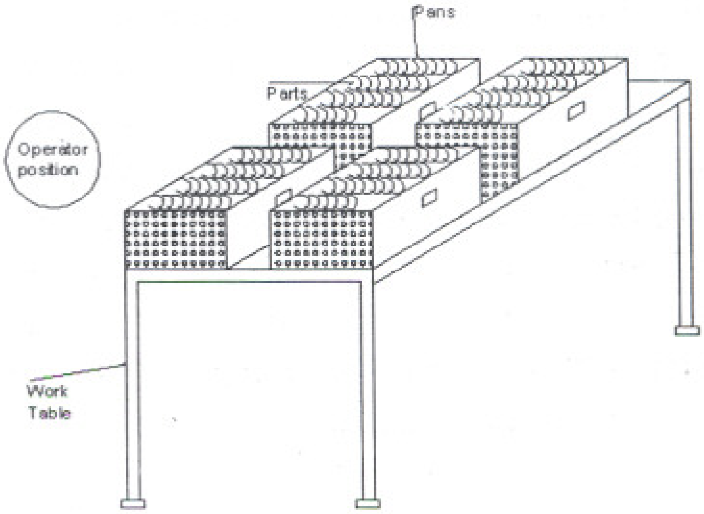


Figure 5.20: Loading station at shrink packing machine

Ergonomic Deficiencies identified for this task: The operator while packing such sets on a shrink wrapping machine places the six pans on a work table placed sideways as shown in figure 5.20. He then picks up all the six parts as per set requirement and places these on the shrink-wrapping machine. As can be seen from the layout of the shrink wrapping station, the operators finds it extremely difficult to pick parts from the last three pans located behind the first three pans. While picking up parts from these pans, the operator has to repetitively move the upper arms out to the side of the body. The job involves awkward reaching of the arms across the body. The wrist is bent repetitively and the fingers and the hand span have to be spread out wide to grip/hold the parts for placing them on to the shrink-wrapping machine. The operator at the loading station always demand a helper who is expected to pick up parts from the last three pans and handover to the loading operator. The management was providing a helper to push up the packing rate at this station during high output days or when a large volume had to be packed.

Controls Implemented: After discussions with the operators working at this station, following controls have been implemented:

Provision of an inclined worktable: The worktable placed sideways from the operator as shown in figure 5.20, was replaced with another worktable, which can be inclined at an angle depending upon convenience of the operator. The top of the table was attached to a pneumatic cylinder as shown in figure 5.21, and the angle of inclination can be adjusted anywhere from 10° to 60° with the base. The operator, who had to stretch earlier to pick up parts from the last three trays, could now conveniently pick up parts for packing. The angle of inclination can be re-adjusted as the material is consumed from the pans. The sideways stretching of the arms and shoulders has thus been reduced to a large extent thereby reducing the stress levels associated with this task. The revised RULA score is shown in Table 5.30.

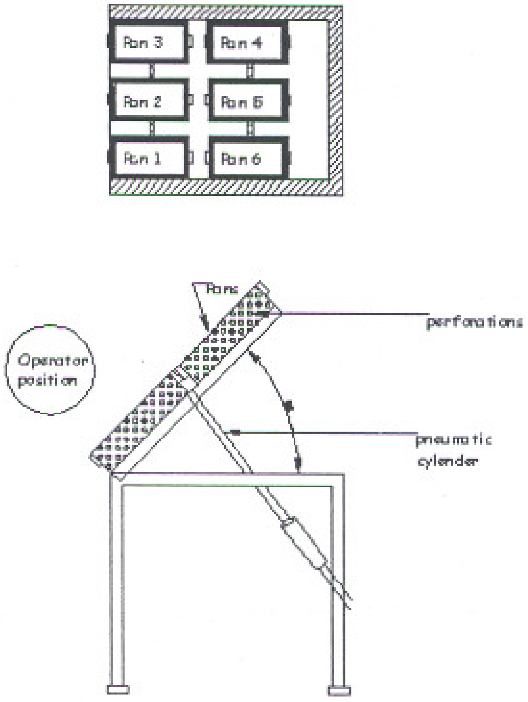


Figure 5.21: Modified Shrink packing loading station

Benefits Accrued/Expected: The existing norm on shrink-wrapping machine for loading one set was 1 minute, which included a fatigue allowance of 14% (as per Page's fatigue allowance determination table). After implementation of controls as above the fatigue allowance was re-calculated as under:

Basic fatigue Allowance: 4%; Sideways bending allowance: 3%; Weight allowance: 5%

Total fatigue allowance: 8%

The implementation of control also eliminated the need of a helper for loading of parts for shrink-wrapping.

3) Oiling of parts before packing:

Task Description: Dipping of pans into oiling tank

All the parts prior to packing are oiled using a rust preventive oil to prevent corrosion of parts during its shelf life. The current method of packing requires the pans, fabricated out of perforated mild steel sheet, be dipped into an oiling tank using a pneumatic cylinder arrangement. The pans are then allowed a soaking period of about 30 minutes so that the extra oil moves out of the pan through the perforations and re-used.

Ergonomic Deficiencies identified for this task: Because of dipping of pans into the oiling tank a large quantity of oil spills over from the pans to the floor surface, since

- many times the soaking period time norm is not adhered to because of urgency of material.
- and, at other times where the soaking period is provided, a relatively smaller quantity of oil still spills out to the floor while shifting the pans to the packing station.

The oil, which spills over to the floor, creates a dangerous safety hazard for the employees of this area and a number of accidents related to slippages have been reported in the past.

The customers have also reported that the parts have a very thick layer of oil and at times they have to wash the parts before assembling them on the engine. Thus it can be concluded that there is a lot of wastage of oil primarily due to spilling as well as due to excess quantity used though the requirement is a very thin fine layer of oil which should preferably be sprayed. This provides an opportunity for saving of cost resulting out of the reduction of consumption of oil if it can be sprayed instead of dipping.

Also, since all the pans are dipped into the oiling tank and the same pans then go back to the production shop floor after packing, the oil on the pans lead to quality concerns especially in the plating shop where even a tiny droplet of oil on to the bearings before plating can lead to poor plating quality generally leading to plating bond failure. The Plating Manager has been very vocal on this issue and has been requesting that action be taken urgently so that the pans are not dipped into oil. The degreasing station at the plating shop needs replacement of the degreasing solution every second day on account of this problem.

Controls Implemented: This problem has also been discussed in detail while suggesting controls for the motivational and growth related problems associated with quality inspectors engaged in 100% visual inspection of parts before packing.

The existing oiling station needs to be replaced with a spray type oiling machine which will have three spray controls, one for the centre of the bearing, two for each side so as to ensure that no portion of the bearings gets packed without a thin layer of rust preventive layer of oil around it. The spray method will ensure that complete pan is not dipped into the oiling tank and the parts are oiled on line after visual inspection before these are placed into pans for set packing. As already discussed during job design of visual inspectors, the visual inspection will be carried out at the plating section on line as the parts are unloaded from the Plater on to the conveyor and the spray type oiling machine may be installed on the conveyor itself. Since the pan will not be dipped into the oiling tank, large-scale spillage of oil on the floor and other areas will not occur. Another spray type machine may also be installed at the packing station for those parts lying in Store awaiting packing for some time because of non-availability of all the set part numbers.

Table: 5.29
Anticipated improvements/ cost reduction after introduction of spray type oiling machine

Floor surface		Oil Consumption		TC Vapour Consumption		Plating bond failures	
Before	After	Before	After	Before	After	Before	After
Oil spilled on floor; hazardous slippages. Large number of accidents	Clean floor with minimal probability of accidents due to slipping	400 litres per month @ Rs 200/- per litre = Rs 80000/-	200 litres per month @ Rs 200/- per litre = Rs 40000/-. Net saving of Rs 40000/- per month	800 litres per month @ Rs 150/- per litre = Rs 96000/-	300 litres per month @ Rs 150/- per litre = Rs 45000/-. Net saving of Rs 41000/- per month	0.74% of total bearing rejection per month	0.20% of total bearing rejection per month

Benefits Accrued/Expected: The consumption of oil is expected to be half of the 400 liters consumed in the existing set-up although the exact quantity will need to be established after the spray-type oiling machine is installed. Similarly, the quantity of Trichloroethylene vapour (TC) solution used for degreasing of parts and pans is expected to reduce to one third of the current consumption. The rejection of parts due to plating bond failure, which happens because of oil, or due to power failure during plating will be eliminated. The expected improvements after the installation of spray type oiling machine are shown in Table 5.29. The data shown under the heading 'Before' is the average for the period January to May 2003, whereas the data shown under 'After' in the table are the anticipated results.The revised RULA score is shown in Table 5.30.

Table 5.30
Revised RULA Score after Implementation of Controls – Packing and Dispatch Section

Operation/Function	Potentially stressful task	Revised RULA Scre
Packing of parts meant for Original equipment manufacturers	Use of themocole inserts as separators:	3
After Market or AM parts shrink packing station	Placing of trays for set packing	4
Oiling of parts before packing	Dipping of parts into oiling tank	4

5.4.5 *Analysis of Powder Plant and Sinter Line*

Brief Introduction about Powder Plant and Sintering Lines:

Production of sintered strip is a highly mechanized process where the role of the operators is to load the steel coils on the de-coiler and unload the finished bimetallic strip from the re-coiler at the other end of the sintering line. At all other times the job of the line operator is to monitor the process parameters like temperatures of the different zones of the sintering furnace, line speed, Nitrogen-Hydrogen mixture supply to prevent oxidation and inspecting strip samples for bond, thickness control and hardness.

The ergonomic problem tasks that have been identified after the assessment by RULA for the Powder Plant and Sintering Lines are as under:

1) Loading the steel/bimetallic strip on the De-coiler

The ergonomic problem tasks identified after the assessment by RULA at the strip loading station on the de-coiler are exactly similar to the one already discussed for loading of coiled strip for bush blanking in Section 5.4.1 of this chapter.

2) Layout of the steel coil storage area and handling of coils

i) Task Description: The first task of a sintering line front-end operator is to identify and get a steel coil issued as per the requirement of the strip production order issued by the Production Planning and Control department. The steel coils are located in areas clearly identifying the sizes of the coil (i.e. width, thickness and length of the coil). However, because of the way the coils are stored their withdrawal from the storage area is considered to be very stressful task. The coils are located one over the other separated by wooden planks in order to move the Fork-lifter forks into the planks for shifting the coil to the production area. (figure 5.22).

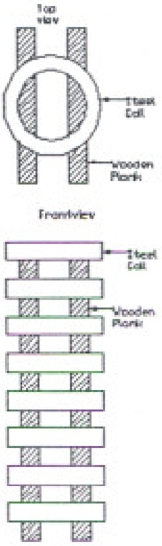


Figure 5.22: Existing method of storing steel coils

Ergonomic Deficiencies identified for this task: If the coil is lying on top of the stack, it is fairly easy to remove the coil, on the other hand, if the coil is lying at the bottom or close to the bottom of the stack, it becomes an extremely tedious task to remove the coil. The operator has to first remove all the coils lying on top of the required coil, and then after taking out the required coil, is also required to put all the other coils back in the same order. Since the steel stock at any given point of time is a minimum of three weeks, (about 45000 meters stock which is equivalent to about 150 coils of different sizes for a typical coil length of about 300 meters), it is extremely tedious and time consuming to first remove the unwanted coils lying on top of the required coil and then re-locate them back on the stack of coils each separated by wooden planks.

The task is considered to be highly stressful by the operators on the front-end of the Sintering lines. A review of the downtime record for the month of February 2003 shows that the front-end operators spend on an average 46 minutes locating coils from the steel store. There have been numerous requests from the concerned operators as well as line supervisors to re-arrange the coils so that these are easily retrievable.

Controls Implemented: Since the problem at hand was closely related to layout design and housekeeping, the team consisting of Sintering line supervisor, Steel stores incharge, and line operators, were introduced to the concept of 5-S improvement technique. After provision of this training, the team members arrived at the following solution:

Re-design of the storage method:

A new coil stand was fabricated as shown in figure 5.23, in which the coils would be placed horizontally side by side instead of vertically one over the other as in the existing design. The coils would be stacked in these racks and can be easily taken out of the rack by locating the hook of the hoist in the inside diameter of the coil. This way each coil stacked in the rack remains accessible. The rack size was kept as 8 feet length and 6 feet width with the vertical height of the stacker limited to 4 feet. The storage area available for the steel coils was of size 40 feet by 40 feet. Four rows with five racks in each row were designed to be accommodated in the existing steel storage area. Each rack can accommodate 8 coils, thereby meaning that 40 coils can be adjusted in one row and with a total of 4 rows planned in the available space, a total of 160 coils can be adjusted in the storage racks. The hoist facility to lift the coils already existed for handling the coils. 5 feet wide aisle space was provided between each row. The racks were fabricated with 1-inch diameter hollow mild steel round pipe. The racks were fabricated in April and May 2003 and were put in place in end May 2003. Also, in the new layout with the re-designed racks, the use of forklift to remove coils has been eliminated.

Benefits Accrued/Expected: Table 5.31, shows the impact of the change in layout and the re-design of racks on the strip production as well as reduction in waiting time.

Table: 5.31
Impact of change in steel store layout and storage rack re-designs

Steel store layout and storage rack re-design			
Average waiting time for coils		Extra bimetallic strip likely to be produced	
Existing	After implementation of the recommendations	Existing	Expected
46 minutes	10 minutes ↓	70000 meters	74400 meters ↑

The finished strip production in the month of June 2003 was reported as 72400 meters. This is after the implementation of the above controls and the initial set in period. This data however will need to be reviewed over an extended period of time and also needs to be validated that the improvement in strip production is due to the implementation of these controls as described above. The revised RULA score after the implementation of controls is shown in Table 5.32 at the end of this section.

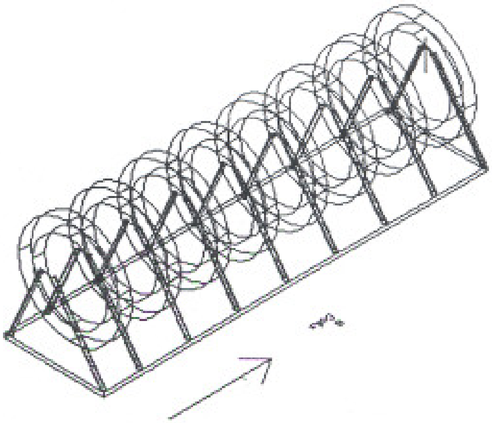
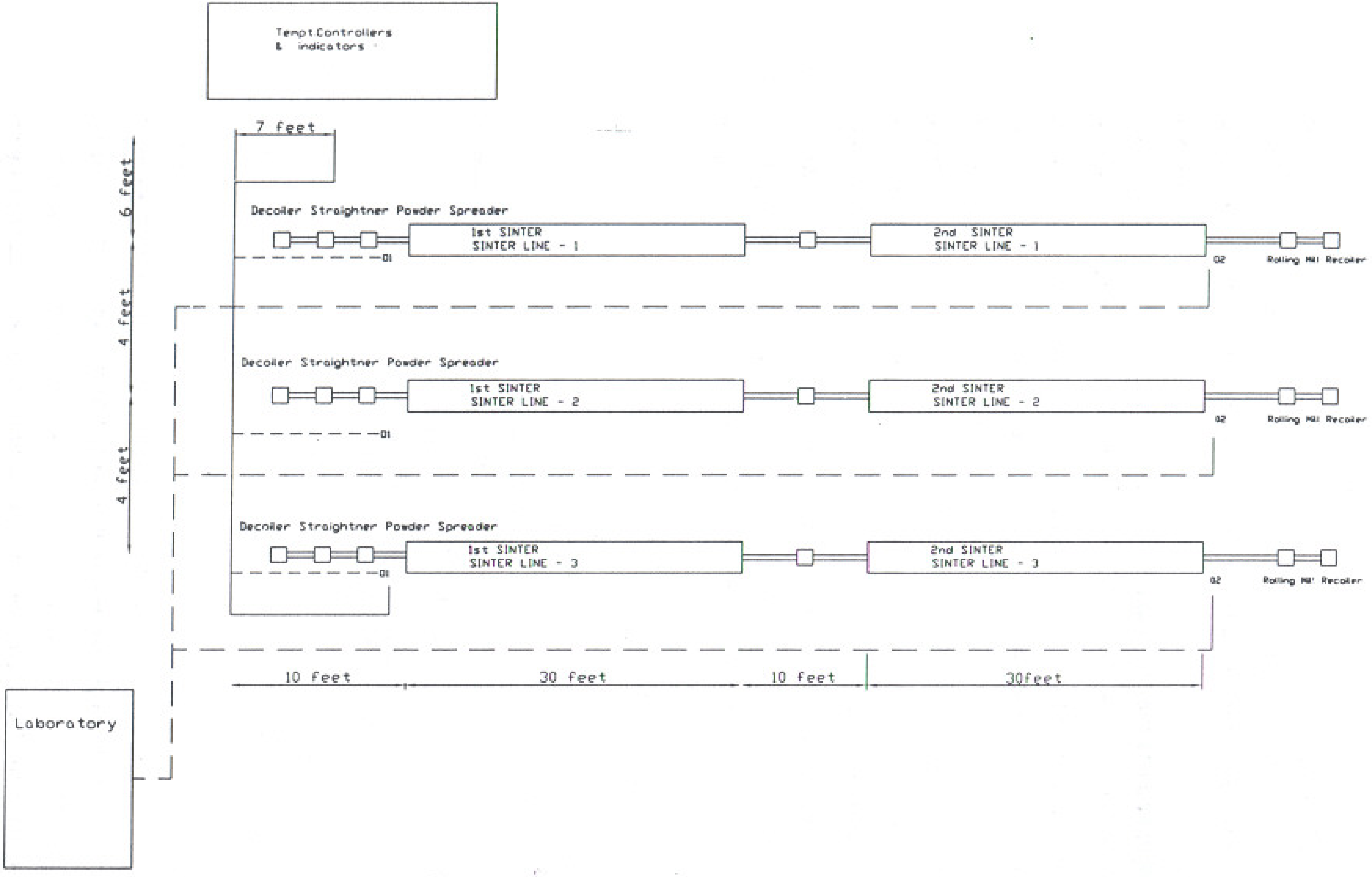


Figure 5.23: Modified steel coil storage stand

3) Monitoring of process parameters on the sintering line

Task Description: As already described above, the primary responsibility of the line operators at the sintering line is to monitor process parameters after the coil has been loaded and fed into the muffle furnace for sintering. Each line has two operators. The one on the front side of the furnace is identified as Front-end operator and the other is stationed at the back of the line is called Back-end operator. The responsibilities of the front-end operator include setting of the loose powder spreader as well as monitor and record process parameters such as temperature of the nine zones of the sintering furnace. He is also responsible for the control of line speed. The operator at the back-end is responsible for controlling thickness of the coil, by adjusting the rolling mill periodically as well as inspection of strip bonding, hardness and finally the re-coiling of the bimetallic strip as coil.

Ergonomic Deficiencies identified for this task: Both the front-end and the back-end operators are required to monitor the process and dimensional parameters after every 20 meters of coil. The layout of the sinter line is shown in figure 5.24. As can be seen



O1- Front End Operator
O2- Back End Operator

----------- Front End Operator path for monitoring temperature

- - - - - Back End Operator path for carrying out lab tests

Figure:5 24 Existing Layout Chart of Sintering lines from the figure, the temperature controllers and indicators for all the three lines are located at the following distances from the operator position:

- Front-end operator on Sinter Line I: 46 feet to and fro
- Front-end operator on Sinter Line II: 54 feet to and fro
- Front-end operator on Sinter Line III: 62 feet to and fro

As can be seen from above data, that the operator is required to travel the above distances after every 20 meters of coil production to monitor and record the temperature of the nine zone furnace. With average line speed at one meter per minute, the operator is required to travel the above distances every 20 minutes for monitoring the temperature. It was decided to observe the activities of the front-end operator over complete one shift and it was found that it was virtually impossible to follow the process guidelines of temperature monitoring every 20 meters and the operators were actually recording on an average twice in an hour and sometimes even once only. The operators, though, recorded the temperature measurements after every 20 meters. When the same was checked with the line supervisor, he also expressed that it is not possible to follow the process guidelines with the temperature controllers lying at a distance from the operator and felt that these must be shifted closer to the operator work station.

Similarly, the back-end operator is required to check the strip thickness after rolling as well as inspect a sample for bond strength by bending a one inch diameter sample taken out by piercing the coil using an on line die/punch arrangement. The sample is clamped in a bench vice and bent at 90°. The sintered lining material of Copper, Lead and Tin alloy is chipped off using a chisel and hammer. If the material does not chip off, the bond is considered to be good. The other test that the operator is required to carry out is dipping the chiseled portion into solution of Hydrogen peroxide and if the bond strength is good, the portion turns into red (copper) colour which is an indicator that the copper based lining material has bonded perfectly with steel. The back-end operator also checks hardness of the bi-metal coil every 20 meters. Since all these tests are not available on line, the sample has to be taken to the Chemical Laboratory located at a distance of 88 feet, which implies that the operator has to travel a to and fro distance of 176 feet after every 20 minutes. On observing the operator, it was found that the defined frequency is not being complied to and the tests were being done only once in an hour.

Controls Implemented:

Front-end operator: The temperature controllers have been re-located in front of the three lines. Although, ideally these should have been located next to the operator position, but due to shortage of space between the two lines (only 4 feet is available between the two lines) these were placed in front of the line. The distance traveled thus reduced from maximum 62 feet to 20 feet and since the operator is required to keep on moving between the de-coiler and the powder spreader area which is at the front end portion of the sintering furnace, the new location of the temperature controllers is very convenient.

Back-end operator: A working table of size 4'x4'x3' has been placed on the back end portion of the sinter line, with a bench vice and a hardness tester installed on one side of the table. A hammer and a chisel have also been provided along with hydrogen peroxide solution for checking the bond. The table has been located at a distance of 7 feet from the operator, which means that the operator now needs to travel only 14 feet to and fro as against 176 feet earlier.

Benefits Accrued/Expected: Table 5.32, shows the improvement that has taken place with regard to monitoring and recording of process parameters after the change in layout and provision of resources on line.

Table: 5.32

Improvement in sintering process parameter monitoring after implementation of controls

Front-end of Sinter Line				Back-end of Sinter Line			
Parameter	Process standard	Check frequency		Parameter	Process standard	Check frequency	
		Actual existing	After layout changes			Actual existing	After layout changes
Loose Powder Thickness	Check every 20 meters	20 meters	20 meters	Finished coil thickness	Check every 20 meters	20 meters	20 meters
Temperature of 9 zones	Check every 20 meters	50 meters	20 meters	Hardness	Check every 20 meters	60 meters	20 meters
Line Speed	Check every 20 meters	50 meters	20 meters	Bond strength	Check every 20 meters	60 meters	20 meters

The revised RULA score after the implementation of controls is shown in Table 5.33.

Table 5.33
Revised RULA Score after the implementation of Controls – Powder Plant and Sinter Line

Operation/Function	Potentially stressful task	Revised RULA Score
Sintering of steel coils	Loading the steel/bimetallic strip on the De-coiler	3
Steel issue area	Layout of the steel coil storage area and handling of coils	3
Sintering of steel coils	Monitoring of process parameters on the sintering line	4

5.5 Concluding Remarks

In this chapter detail of analysis of work postures has been presented. Application of Rapid Upper Limb Assessment (RULA) technique on all workstations in the production lines brought out the areas needing further detailed analysis and ergonomic provisions. Subsequently, more in-depth analysis was carried out and controls were suggested/ implemented. The benefits accrued in terms of productivity were assessed. The benefits in productivity from these provisions will be integrated with the benefits from other areas of material handling, lifting tasks and job design and are presented in Chapter 8. Next chapter contains the detailed analysis of material handling and lifting tasks.

CHAPTER 6

ERGONOMIC ANALYSIS OF MANUAL MATERIAL HANDLING TASKS

6.1 INTRODUCTION

Moving raw materials and finished products through a facility is a common process in engine bearing industry. Throughout the process, operators working in a variety of manufacturing tasks routinely lift/lower, push/pull and carry an object, where risk factors leading to Musculoskeletal Disorders (MSD'S) may be present. When investigating manual material handling, health and safety professionals must determine the most practical ways to move objects while decreasing ergonomic risk and positively affecting productivity and cost.

This chapter describes the development of an assessment tool for analyzing material handling carrying tasks and its application for analysis of material handling tasks prevalent in Engine Bearing Industry. After a close observation of material handling tasks spread over many days, a list of various tasks and parameters/variables affecting these tasks was made. Ergonomic conditions present in these tasks and deficiencies involved in them were then identified and based on the interrelationships of tasks and their affinities, categories were developed. Using the data of these categories and various conditions and parameters, an assessment tool called MHAC (Material handling assessment chart), was developed. Using this tool, the manual material handling tasks which had higher need and potential for improvement were identified. A detailed analysis of these identified tasks was then carried out using MHAC and improvements were made/suggested. Finally, effects of these improvements on human performance and productivity were assessed and a cost benefit analysis was carried out.

6.2 ASSESSMENT OF MATERIAL HANDLING TASKS

The first step in eliminating the hazard related to manual material handling tasks has been to analyze the tasks to identify the ergonomic hazards present in a job. The analysis involved a variety of activities, which included:

1. Observing the worker performing the task
2. Interviewing and discussing with workers
3. Making measurements related to carry distance, carry frequency etc.

The observation of the material handling tasks was made for 15 days spread over all the four weeks of a month. Table 6.1 shows the list of the material handling tasks observed at various times during the day, and number of observations taken.

Table 6.1
List of Material Handling Tasks observed for assessment

	Location	Task details	Time of observation	No. of observations
1	Powder Plant	Carrying Raw material ingots of Copper, Lead and Tin to the induction furnace	• 6.00 am to 8.00 am (Twice) • 3.00 pm to 5.00 pm	3
2	Bearing Line	Carrying blanks from Blanking press to Forming and Coining press	• 12.00 noon to 12.30 pm • 5.00 pm to 5.30 pm • 11.15 pm to 11.45 pm	3
3	Bearing Line	Transfer of pans from the Forming and Coining press to the 3 facers	• 1.00 pm to 1.30 pm • 6.00 pm to 6.30 pm • 11.45 pm to 12.45 am	3
4	Bearing Line	Transfer of pans from the Wire brush station to ID Broach	• 10.00 am to 10.30 am • 5.00 pm to 5.30 pm	2
5	Plating Shop	Transfer of pans from Height Broach to Plating Degreasing section	• 11.30 am to 12.15 pm • 7.00 pm to 7.30 pm • 9.00 pm to 9.30 am	3
6	Plating Shop	Transfer of pans from Degreasing section to Loading station on machine	• 8.00 am to 8.30 pm • 7.00 pm to 7.30 pm • 10.00 pm to 11.00 pm	3
7	Packing section	Transfer of finished parts from Bearing Awaiting Packing (BAP) store to shrink-wrap station	• 10.30 am to 11.30 am • 2.30 pm to 3.15 pm • 4.00 pm to 4.30 pm	3
8	Dispatch Section	Transfer of cartons from packing section to dispatch section and loading on trucks	• 11.00 am to 12.15 pm • 2.00 pm to 3.00 pm • 4.00 pm to 5.00 pm	3

In order to identify the ergonomic factors, parameters that have a direct bearing on the hazards associated with these tasks, affinity diagram was used. An affinity diagram is a creative process, used with or by a group, to gather and organize ideas, opinions, issues, etc. on the factors affecting these tasks. The exercise was carried out by brainstorming amongst experts, two drawn from each of the four manufacturing units where study was carried out, and the researcher. The researcher coordinated the brainstorming session. The technique has been used to identify by consensus the factors affecting the material handling tasks and putting them into broad categories.

6.2.1 Contributing factors in assessment of material handling tasks

The following factors were identified by consensus:

1. Load Weight and frequency of handling
2. Hand distance from lower back
3. Asymmetrical trunk load
4. Postural constraints
5. Grip on load
6. Operator capabilities
7. Floor surface
8. Carry distance
9. Obstacles en route
10. Other environmental factors

6.3 DEVELOPMENT OF *'MHAC'*

In order to evaluate the affect of the above factors on the manual material handling tasks, the team described above developed a survey technique called Material handling Assessment Chart (MHAC). MHAC has been developed to investigate the exposure of individual workers working separately or in team to risk factors associated with manual material handling tasks. The technique has been developed in engine bearing manufacturing industry, after making an assessment of operators who performed material handling tasks in the production lines, inspection and packing section. The MHAC technique has been used to evaluate all the material handling tasks listed in Table 6.1.

In an effort to assess the factors described above, MHAC was developed to:

1. Provide a method of screening the working population quickly, for exposure to a likely risk of work related MSD's;
2. Assessing the risk associated with employees lifting and carrying loads over distances, sometimes on uneven and slippery surfaces;
3. Give results, which could be incorporated in a wider ergonomics assessment covering epidemiological, physical, mental, environmental and organizational factors.

MHAC has been developed as a technique to be used without need for special equipment. This provides an opportunity to a number of investigators to conduct assessments without additional equipment expenditure. As the investigator only requires a pen and a writing notebook, MHAC assessment can be done in confined workplaces without disruption to the workforce.

6.4 STAGES OF DEVELOPMENT OF MHAC

MHAC has been developed in two stages. The first stage is the development of the method for assessment and recording the parameters and conditions like, load weight and frequency of handling, working posture, grips on load, operator capabilities, floor surface, carry distance, obstacles en route and other environmental factors. The second stage involves the development of a scale of action levels, which provides a guide to the level of risk and need for action to conduct more detailed assessment.

6.4.1 Stage 1: Development of a method to assess and record the status of contributing factors and conditions

As an outcome of the brainstorming session in which experts from four different organizations participated, it was concluded that for carrying out risk assessment of the manual material handling tasks, the following factors needs to be taken into account:

(a) **The Load**

1. **Weight***:* The weight of the load is a significant factor, but one that must be looked at in conjunction with all other elements of the assessment. Where there is a heavy load, it may be possible to split this into two lighter loads. The assessment must consider whether the benefits of a reduced weight are justified when compared to the increased risks caused by creating twice as many lifting/lowering movements.
2. **Stability***:* Is the load unstable, or filled with contents that may shift? Where the contents of a load shift, such as when handling liquid containers, there may be unexpected and injury-causing stresses imposed on the body.
3. **Shape of the object:** Is the load hot, cold, slippery, and sharp or otherwise potentially damaging to hold? If yes, appropriate personal protective equipment should be readily available.

(b) **Working posture:** Various working postures may involve:

1. **Holding or handling loads away from the body:** The risk of injury is reduced where the load is held close to the body, and where the weight is within the center of gravity of the user.
2. **Awkward movements or awkward posture, such as twisting the trunk, stooping or reaching upwards:** The risk of injury is increased when the handler is unable to gain a secure footing and evenly distribute body weight. Twisting the trunk, particularly whilst supporting the load significantly increases stress on the back. Reaching upwards imposes an additional stress and renders the load more difficult to control.
3. **Excessive lifting or lowering distances or excessive carrying distances:** The risk of injury is increased where loads have to be lifted from below knuckle height whilst standing. A load that has to be lifted from, or to, a height above the shoulder will also present an increased risk.

4. **Excessive pushing and pulling:** Pushing or pulling actions present an increased risk where the forces are exerted below the knuckle height or above shoulder height.
5. **Risks of sudden movements of loads:** Where the load suddenly moves, there is increased physical strain and a risk of losing balance. For example, freeing a jammed machine part can cause an unpredictable stress on the body.
6. **Frequent or prolonged physical effort:** When a reasonably modest load is handled frequently, there is a risk of fatigue and of cumulative strain injuries.
7. **Insufficient time for workers to rest/recover:** Rest periods should be provided to prevent the onset of fatigue rather than to aid recovery. Set break times may not be always appropriate, and workers should have as much discretion over rest pauses as possible.
8. **A work rate imposed by a process**: Where the handler has no control over the work rate, such as when removing material from automated conveyor delivery system, the risk of fatigue and subsequent injury is increased.
9. **Limited space that prevents the posture**: Loads that have to be handled in restricted space forcing the adoption of an unsuitable posture, or where there is inadequate head height so the worker will be required to stoop, a known risk factor.

(c) **Grip on load:** Do the containers have well designed handles or handholds, which are fit for the purpose? Is the grip comfortable?

(d) **Operator capability**: Performance of various manual material handling tasks may:

1. **Require a person of unusual strength or height:** There is a certain amount of self-selection for jobs involving handling of loads, but the employer must still ensure that the task is within the ability of the worker. In general, there is a great deal of variations in individual capability. Women are generally shorter than men, and some lifting task may be better suited to workers within a given height range. Physical capability varies with age; teenagers and older workers may be more susceptible to injury and, in the case of older workers, the recovery is longer. The benefits of experience and mature judgment may adequately compensate for declining physical ability.
2. **Create a hazard to workers who may have a health problem:** An employee is obliged to advise the employer of any condition that is likely to put him or her at a greater risk of injury. Conditions will include pregnancy, recent surgical operations and any relevant previous medical history (both occupational and non-occupational).

It is appropriate to seek relevant health information at the pre-employment stage where a person is being considered for a job that includes manual handling operations with a risk of injury.

(e) **Floor surface:** Floor Surface is also an important factor. The floor surface may have the following:

1. **Slippery, uneven or unsuitable floors or surfaces**: Some floors may be wet, in poor repair, or unsuitable. Workers are more likely to fall on unsuitable floor surface when they are carrying a load.
2. **Variations in the level of work or floor surfaces, for example stairs or slopes**: Carrying a load up a slope or staircase will increase fatigue. The load may impede visibility and make the worker more susceptible to tripping.

(f) **Carry distance:** Where a load has to be carried for a distance of over 10-metres, the physical demands are likely to outweigh those of lifting and lowering the load.

(g) **Obstacles en route:** If the route on which the material-handling task is performed involves carrying a load up a steep slope or steps or around tripping hazards or climbing up a ladder, the risk of fatigue and subsequent injury is increased.

(h) **Other environmental factors:** These may include the following:

1. **Unusually low or high temperatures or extremes of humidity**: Grip, dexterity and the speed of reaction are all reduced in low temperatures. High temperatures result in rapid fatigue and perspiration can affect the ability to securely grip a load.
2. **Poor lighting conditions:** Both excessive lighting, which may cause glare, and reduced light levels, which increases likelihood of accidents occurring. Dramatic contrast variations, such as when moving from a dark interior to bright sunlight, may cause temporary visual impairment and render the worker at risk.
3. **Ventilation problems:** Inadequate ventilation will speed up fatigue.
4. **Weather problems, such a wind or rain**: Outdoor conditions can have a significant influence upon the risk assessment of a handling activity. For example, wet weather conditions may result in wet shoes or floors inside a building, increasing the likelihood of slips, trips and falls.

6.4.2 Assigning Rating Scores to Factors

The rating for the affect of each of the above factor has been given in such a way that the number 1 is given to the range of activities where the risk factors present are minimal. Higher rating scores are given to the activities with more difficult work conditions as discussed above indicating an increasing presence of risk factors causing load on the structures of the body segments. This system of scoring for each of the above factors provides a sequence of numbers, which is logical and easily remembered. The ratings have been developed based on the brainstorming session amongst the experts drawn from four organizations manufacturing engine bearings.

a) Rating scores for load/weight: The rating to assign scores for the load/weight handled during the lifting and carrying task were assessed and scored on the basis of an experimental study carried out on the operators of the Central Workshop (also referred to as Training-cum-Production Centre TCPC) of Thapar Institute of Engineering and Technology, Patiala. The experiment was conducted to study the affect of carrying load on the onset of discomfort rated on a scale of 1 to 5 at various carrying frequencies. The carrying task was standardized to ensure that the experiment would be conducted under the same working conditions and methods. The subjects were asked to lift pan containing parts of known weight and carry to a destination at a distance 8 feet away. The workplace was designed considering ergonomic guidelines with respect to layout, posture, design of grips on load, floor space, and ensuring there were on obstacles en route. The subjects identified for the study had almost similar individual capabilities.

1. **Work environment:** The physical environment with regard to temperature, humidity and light was within normal levels. The temperature was 28 °C, relative humidity 56%, and light 2500 Lx on the workstation. The sound level was below 85 dba, thus the subjects did not use earplugs.
2. **Subjects:** Twelve operators from among the regular employees were selected on a voluntary basis as subjects for the experiment. The criteria of screening were based on following parameters:
    - At least 6 months on the job experience
    - At least 8th Grade education

The participants were given adequate demonstration and instructions before starting the experiment. To familiarize them with the standard method of task performance, the subjects were given adequate training on proper motions to perform the task. The subjects performed the same task in the experimental sessions under specified experimental conditions.

Experimental Design: The subjects were asked to lift a pan containing standard mild steel samples of known weight, used for testing on Universal testing machine in the Strength of Materials laboratory at different carrying frequency. The experimental conditions for each group were explained to all the subjects. The subjects performed one training and two experimental sessions. In every session the subjects were reminded about their experimental condition. All the participants were requested not to discuss their results amongst themselves. The experimental conditions for each subject are as under.

i) **I oad weight to be carried (Kgs)**

10; 20; 30; 40; and 50

ii) **Number of carries per hour**

Each of the above weights was to be carried to a destination 8 feet away at the following carry frequencies:

- 1 carry per day (1 carry per 8-hours)
- 1 carry per 30 minutes (2 carries per hour)
- 1 carry per 5 minutes (12 carries per hour)
- 1 carry per 2 minutes (30 carries per hour)
- 1 carry per 1 minute (60 carries per hour)
- 1 carry per 30 seconds (120 carries per hour)

iii)

Table 6.2
Method for rating load/weight discomfort

Condition	Rating Score
Practically no discomfort	1
Mild discomfort	2
Heavy discomfort	3
Severe discomfort	4
Extreme discomfort	5

3. **Recording of discomfort rating score:** The assessment commenced by observing the operator during several work cycles. Based on the criteria described in Table 6.2, the day's discomfort rating was noted at the end of the day's work on a checklist provided to each subject. The data for all the 12 subjects has been compiled to get an overall discomfort rating score as shown in Table 6.3. Also, mean discomfort-rating score for each of the 12 subjects has been calculated by dividing the sum of all ratings for each weight by the number of subjects who participated in the study. Using figures 6.1 to 6.7 the observer records the discomfort rating scores for the load/weight in the respective columns provided in figure 6.8. The experts during the brainstorming session also

concluded that if the discomfort rating score is greater than 3, the task should be examined very closely. Such operations may represent a serious risk of injury and should come under close scrutiny, particularly when one person carries the entire weight of the load.

Table 6.3
Individual and mean discomfort scores for various loads and carry frequency combinations

Operator	Weight Kg	Operator												
		O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12	Mean Score
1 carry per day	10	1	1	1	1	1	1	1	1	1	1	1	1	1
	20	1	1	2	1	1	2	1	1	1	2	1	1	1.3
	30	1	1	2	1	2	2	2	1	1	2	2	1	1.5
	40	3	3	2	2	2	2	3	2	2	3	3	2	2.4
	50	4	4	5	4	4	3	3	4	4	4	5	4	4.0
2 carries per hr	10	1	1	2	1	1	1	1	1	1	1	1	1	1.1
	20	2	2	2	1	1	2	2	1	1	2	1	2	1.6
	30	3	3	3	2	3	3	2	3	2	3	3	2	2.7
	40	3	4	4	4	4	4	3	4	4	4	5	4	3.9
	50	5	5	5	5	5	5	4	5	5	5	5	5	4.9
12 carries per hr	10	2	3	2	2	2	3	2	2	3	2	2	2	2.3
	20	2	3	3	3	3	4	3	3	4	3	4	3	3.2
	30	4	4	4	3	4	4	4	3	4	4	4	4	3.8
	40	4	5	5	5	5	4	5	4	5	5	5	4	4.7
	50	5	5	5	5	5	5	5	5	5	5	5	5	5.0
30 carries per hr	10	3	2	3	3	3	2	2	3	3	3	3	3	2.8
	20	3	3	3	4	3	3	3	4	4	3	3	3	3.3
	30	4	4	4	5	4	4	4	4	5	4	4	4	4.2
	40	5	5	5	5	5	5	5	5	5	5	5	5	5.0
	50	5	5	5	5	5	5	5	5	5	5	5	5	5.0
60 carries per hr	10	3	3	3	4	3	3	3	3	3	3	3	4	3.2
	20	4	4	4	4	4	3	4	4	3	4	4	4	3.8
	30	4	4	5	5	5	4	5	4	4	4	5	5	4.5
	40	5	5	5	5	5	5	5	5	5	5	5	5	5.0
	50	5	5	5	5	5	5	5	5	5	5	5	5	5.0
120 carries per hr	10	3	3	3	3	4	3	3	3	3	3	4	3	3.2
	20	4	4	4	5	4	4	4	5	4	4	4	4	4.2
	30	5	5	5	4	4	4	4	5	4	4	5	5	4.5
	40	5	5	5	5	5	5	5	5	5	5	5	5	5.0
	50	5	5	5	5	5	5	5	5	5	5	5	5	5.0

The mean discomfort rating score has been plotted for each load carried at carry frequencies as shown in figure 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, and 6.7.

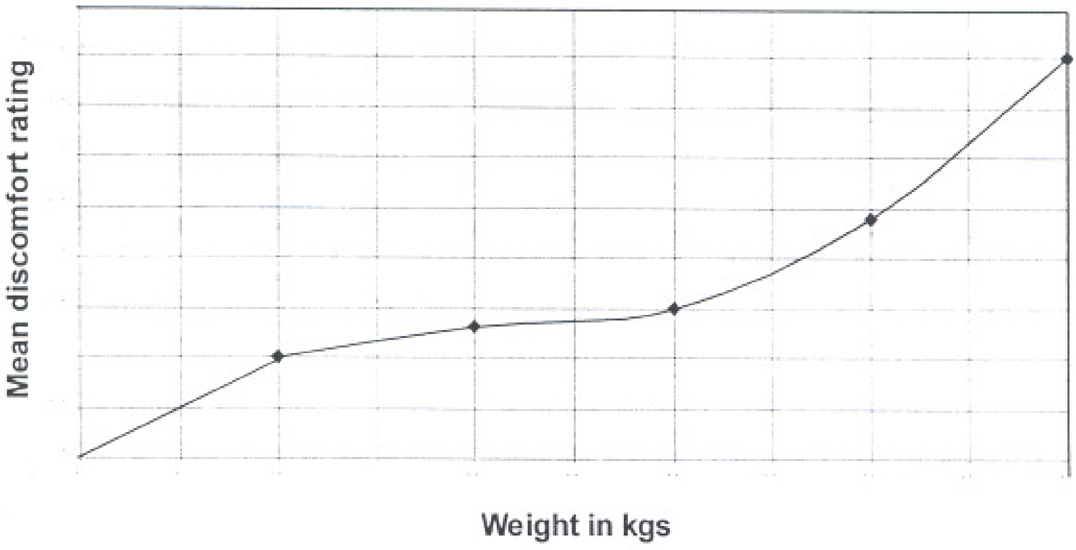


Figure: 6.1: Mean discomfort-rating score for 1 carry per day

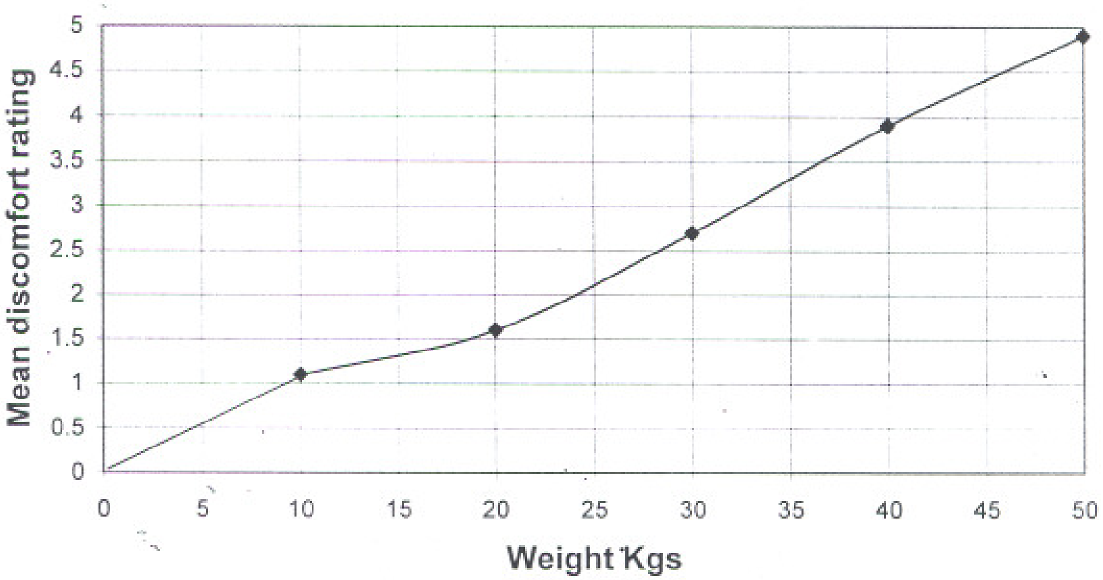


Figure: 6.2: Mean discomfort-rating score for 2 carries per hour

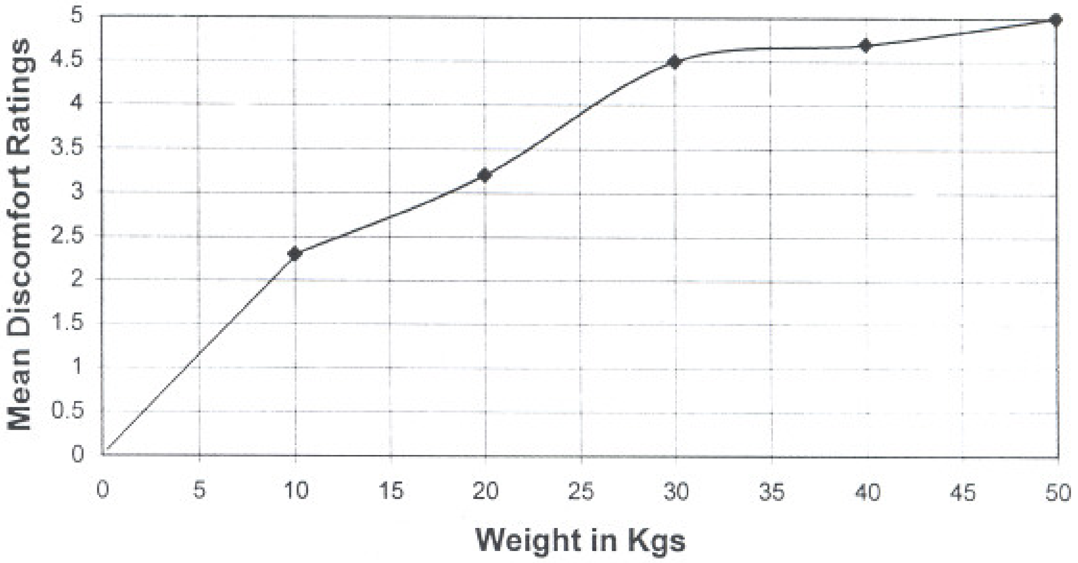


Figure: 6.3: Mean discomfort score for 12 per hr

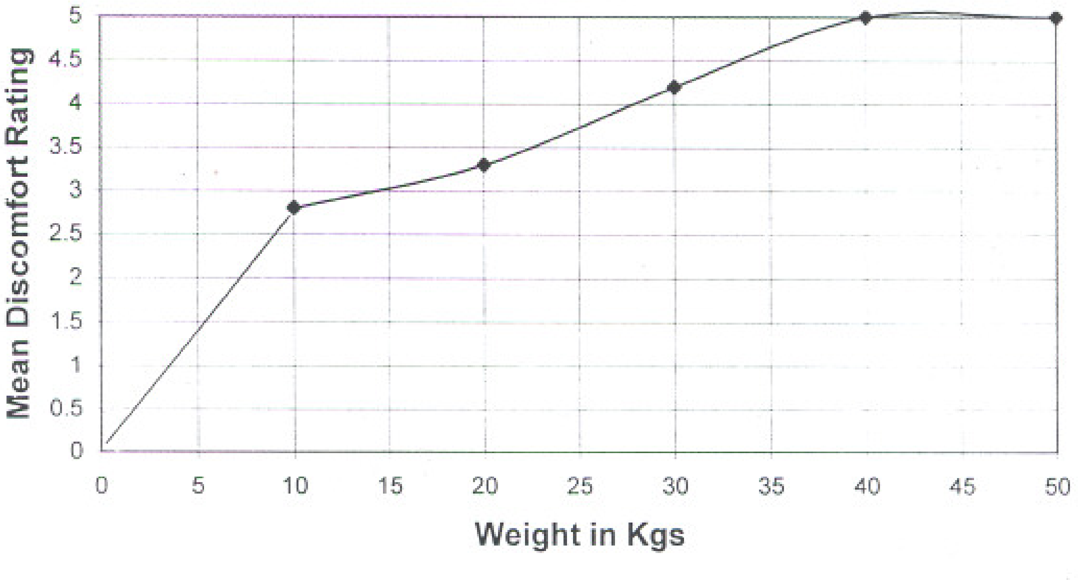


Figure: 6.4: Mean discomfort score for 30 carries per hour

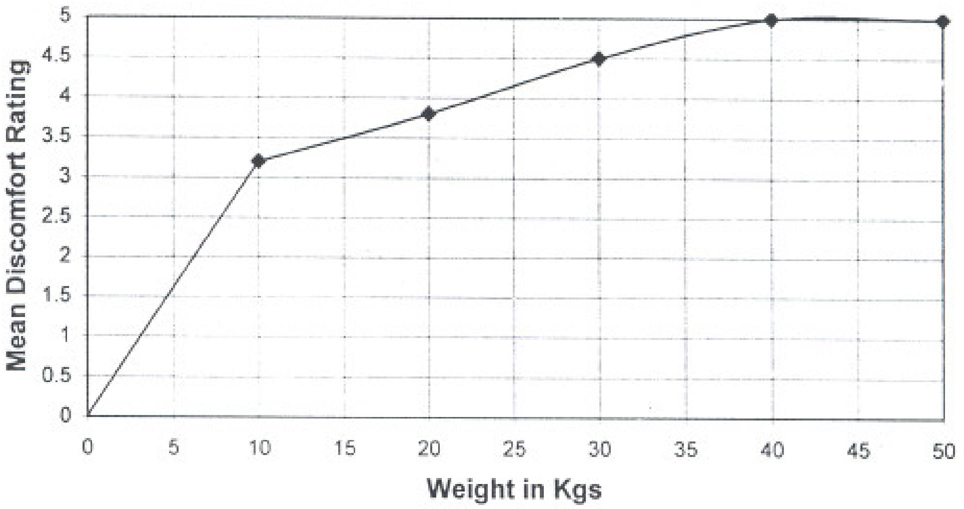


Figure: 6.5: Mean discomfort score for 60 carries per hour

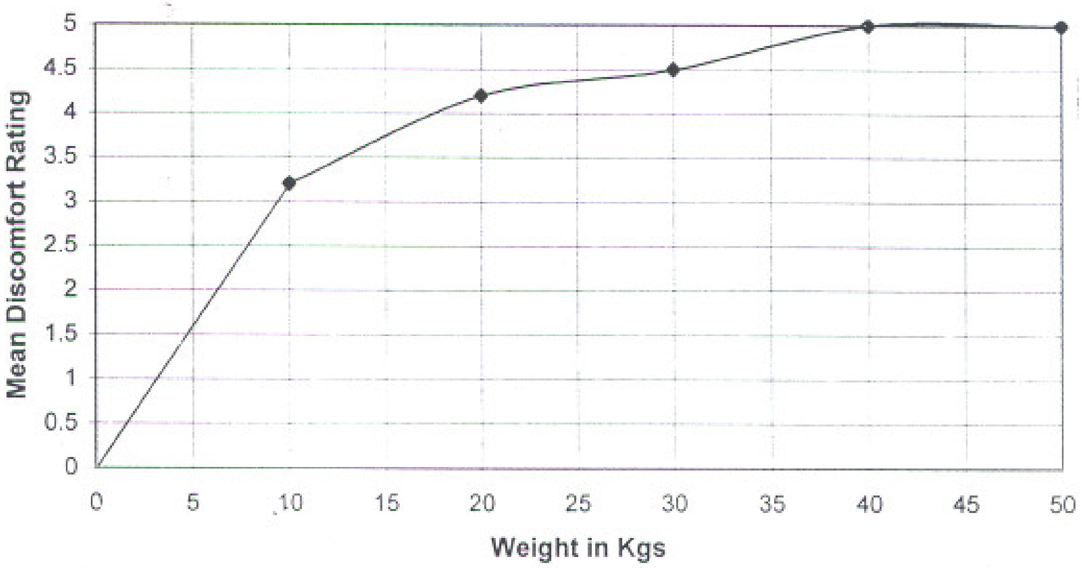


Figure: 6.6: Mean discomfort score for 120 carries per hour

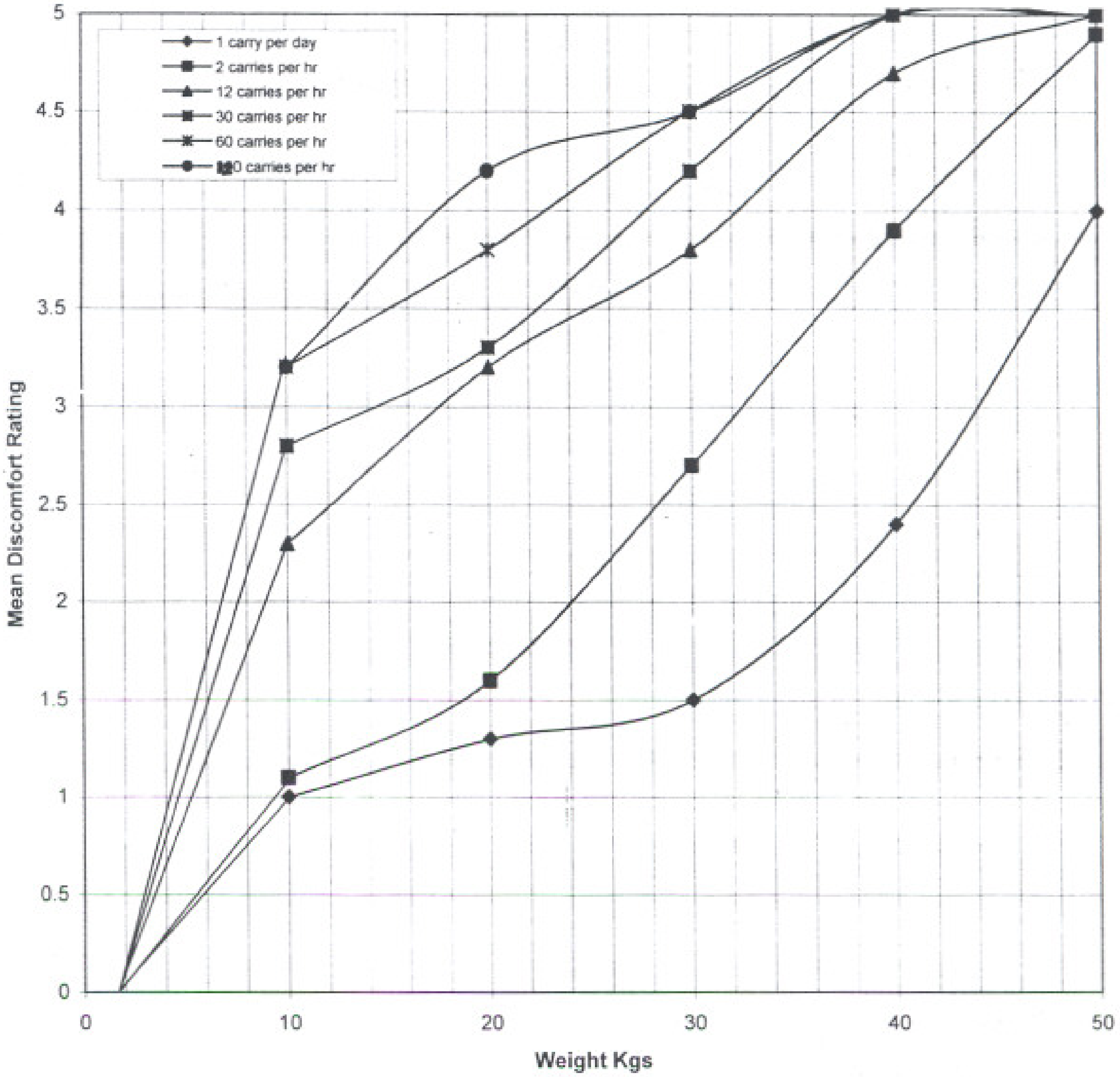


Figure: 6.7 Mean discomfort score at different carry frequencies

Task Description:

____

____

Insert the numerical score value for the load /weight in the boxes below referring to your assessment using figures 6.1 to 6.7.

1) Load weight=_________ 2) Carry frequency= __________ 3) Discomfort rating= _______

Figure 6.8: The Load discomfort rating score sheet

b) Rating score for hand distance from the lower back: The hand distance from the lower back is found by observing the task and examining the horizontal distance between the operative's hands and their lower back. The assessment is always based on the 'worst case scenario' and the rating method given in Table 6.4 has been used to assess the affect of hand position from the lower back. The experts during the brainstorming session also concluded that if the discomfort rating score is greater than 3, the task should be examined very closely. The experts also felt that such operations may represent a serious risk of injury and should come under close scrutiny, particularly when one person carries the entire weight of the load. The discomfort score of 3 is therefore shown in bracket in Table 6.4. In discussion of subsequent parameters contained in Tables 6.5 to 6.12, the bracketed score and above represents the criticality i.e. warranting close examination and immediate improvement action.

Table: 6.4

Discomfort rating score for hand distance from the lower back

S.No.	Hand distance from the lower back	Discomfort score
i)	Upper arm aligned vertically and upright trunk with weight within center of gravity of body	1
ii)	Upper arm above shoulder height	2
iii)	Upper arm angled away from the body	[3]
iv)	Upper arm angled away from the body and trunk bent forward	4
v)	Upper arm angled away from the body, trunk bent forward and weight not aligned with center of gravity of body	5

c) Rating scores for asymmetrical trunk load: Operative's posture and the stability of the load, which are known to be risk factors associated with musculoskeletal injuries, are observed and the assessment is always based on the 'worst case scenario'. The rating method given in Table 6.5 has been used to assess the asymmetrical trunk load.

Table: 6.5

Discomfort rating score for Asymmetrical trunk/load

S.No.	Asymmetrical trunk/load	Discomfort score
i)	Load and hands symmetrical in front of the trunk	1
ii)	Load and hands asymmetrical up to an angle 35° and upright body position.	2
iii)	One handed carrying to the individual's side	[3]
iv)	Load lifted from or to a height above the shoulder with asymmetrical angle up to 100° but greater than 35°.	4
v)	Load lifted from or to a height above the shoulder with asymmetrical angle greater than 100°.	5

d) Rating scores for postural constraints: By observing the task and examining the operative's posture, the experts decided on the posture constraints and their ratings are given in Table 6.6.

Table: 6.6
Discomfort rating score for posture adopted during carrying tasks

S.No.	Posture constraints	Discomfort score
i)	Unhindered movement of the operator	1
ii)	Adopts restrictive postures while carrying (e.g. narrow doorway making operator turn or move load to get through) (eg narrow doorway making operator turn or move load to get through)	[2]
iii)	Heavily restricted posture while carrying (e.g. carrying loads in a forward bent posture in areas with a low ceiling)	3

e) Rating score for grip on load: Different conditions of grip on the handle and their scores as decided by the experts are given in Table 6.7.

Table: 6.7
Discomfort rating score for grip on handle

S.No.	Grip on handle	Discomfort score
i)	Containers with well designed handles or handholds, fit for purpose or when handling loose parts enabling comfortable grip	1
ii)	Containers with poorer handles or handholds or which require fingers to be clamped at 90° under the container	[2]
iii)	Containers of poor design used for carrying loose parts, irregular, bulky or difficult to handle objects or non-rigid sacks/objects	3

f) Rating score for individual operator capability: Table 6.8 contains the states of operator's capability and discomfort score as decided by the experts.

Table: 6.8
Discomfort rating score for individual operator capability

S.No.	Operator capability	Discomfort score
i)	Does not require a person of unusual strength or height	1
ii)	Requires a person of unusual strength or height	[2]
iii)	Creates a hazard to workers who may have a health problem or medical condition	3

g) Floor surface: The experts decided that by observing the task and examining the floor surface on which the load/weight is carried, the discomfort rating score can be given as shown in Table 6.9.

Table: 6.9
Discomfort rating score for floor surface

S.No.	Floor surface	Discomfort score
i)	Dry and clean floor in good condition	1
ii)	Dry floor but poorer condition, worn or uneven	[2]
iii)	Contaminated/wet or steep sloping floor or unstable footing	3

h) Rating score for other environmental factors: By observing the work environment the discomfort rating score decided by the experts is given as shown in Table 6.10. The environmental conditions considered are: if the carrying operation takes place (1) in extremes of temperature; with strong air movements; (2) in extreme lighting conditions (dark, bright or poor contrast); (3) in high humidity; or (4) in high noise levels measured in decibels.

Table: 6.10
Discomfort rating score for other environmental factors

S.No.	Environmental factors	Discomfort score
i)	If only one environmental risk factors is present	1
ii)	If two environmental risk factors are present	[2]
iii)	If more than two environmental risk factors are present	3

i) Rating score for carry distance: By observing the task and estimating the total distance that the load is carried the discomfort rating is assigned as described in Table 6.11.

Table: 6.11
Discomfort rating score for carry distance

S.No.	Carry distance	Discomfort score
i)	If the carry distance is up to 4 metre	1
ii)	If the carry distance is between 4 metre to 10 metre	[2]
iii)	If the carry distance is greater than 10 metre	3

j) Rating score for obstacles en route: Observe the route over which the carrying task is performed. If the route involves carrying a load up a steep slope or steps or around tripping hazards, enter 1 for the numerical score on the score sheet. If the task involves carrying the load up the ladder, enter 2 for the numerical score. If the task involves more than one of the risk factors (i.e. steep slope and then up ladders) enter a score of 3 on the score sheet. The rating method developed by experts is given in Table 6,12.

Table: 6.12
Discomfort rating score for obstacles en route

S.No.	Obstacles en route	Discomfort score
i)	No obstacles or carry route is flat	1
ii)	Steep slope	[2]
iii)	Trip hazards or steps	3

6.4.3 Stage 2: Development of Grand Score and Action Plan

The second stage of MHAC and thus of its development, is to incorporate all the scores listed in section 6.4.2 into a single grand score whose magnitude provides a guide to the priority for subsequent investigations.

Each possible combination of all the above ten factors were added to get a grand score of 10 to 34. For a grand score of 10 to 16 the carrying task would have scored 2 or less for load weight and asymmetrical trunk and 1 for all other factors. Thus, those carrying tasks, which have a grand score from 10 to 16 are considered acceptable if not maintained or repeated for long periods. A grand score of 17 to 22 will mean the tasks are moderately exerting and the load and the working postures are within suitable ranges but if the task is repetitive or exertions of force are required, further investigation is needed for these tasks and changes may be required. A grand score of 23 to 28 indicates that the load and work postures and other factors are not within suitable ranges of motion. It suggests that the operator is required to perform tasks involving heavy load with large repetitive movements and other factors as listed in section 6.4.1 also have high discomfort scores. It is suggested that these operations are investigated soon and changes are made in the short term while long term measures to reduce the level of exposure to risk factors are planned. A grand score from 29 to 34 would be given to any task at or near the end of the range of all the ten factors listed in the previous section. Investigation and modification of these operations is required immediately to reduce excessive loading of the musculoskeletal system and the risk of the injury to the operator.

However, it is strongly emphasized that, since human body is a complex and adaptive system, no single method can deal with all the situations that may come across in any carrying or loading task. What the MHAC system provides is a guide, and it has been developed to draw boundaries around the more extreme situations. However, the combination of factors, which influence any carrying task but vary between operators and factors, which alter the individual's response to a particular task, may contribute to increasing the risk from within acceptable boundaries to being a serious problem for some people. For these reasons the action list leads, in most cases, to proposals for a more detailed investigation. To draw the limits too tightly would lead to an undue expense in changing jobs without any guarantee that those still within the boundary would be safe. Hence, the use of MHAC will give a priority order for jobs which should be investigated while the magnitude of the individual scores for all the ten contributing factors listed in section 6.3 indicate which aspects of the carrying task are likely to be those where trouble will be expected. It should be noted that while MHAC provides a guide to the risk associated with carrying tasks there is no substitute for some understanding of occupational ergonomics if sound decisions are to be made on the basis of the information, when redesigning operations. A score sheet developed by experts for recording the rating for the factors and calculating grand scores is given in Table 6.13.

Table: 6.13

MHAC score sheet to get a grand score

MHAC: *Score Sheet*		
Company Name:	Insert the numerical score for each of the risk factors in the boxes below, referring to your assessment, using the tool	
Task description:	**Risk factors**	**Score**
	1. Load weight & carry frequency	
	2. Hand distance from lower back	
	3. Asymmetrical trunk/load	
	4. Postural constraints	
Are there indications that the task is high risk ***(Tick in appropriate boxes)*** ☐ Task has a history of manual handling incidents (e.g. accident record) ☐ Task is known to be hard work or high risk ☐ Employees doing the work show signs that they are finding it hard work (e.g breathing heavily, sweating) ☐ Other indications, if so what? ___________ Date:	5. Grip on load	
	6. Individual operator capabilities	
	7. Floor surface	
	8. Other environmental factors	
	9. Carry distance	
	10. Obstacles en route	
	Total score Signature:	

6.5 IDENTIFICATION OF JOBS FOR IMPROVEMENT USING MHAC

In order to make planned and practical manual material handling task improvements in an engine bearing facility, the ergonomic risk in a job has been quantified by gathering three pieces of data:

- Ergonomic risk based on force, frequency, posture and duration using MHAC
- Previous musculoskeletal disorders data
- Operator discomfort reports

From this data, a prioritized assessment of list of task (Table 6.1) has been developed for analysis. Other factors that have been used to determine priority for improvement are the number of operators exposed to the manual material handling tasks, the number of shifts during which the tasks are performed and how often the tasks are completed (daily, weekly, monthly or annually). The MHAC has been used to determine the manual material handling tasks, which involve the highest ergonomic risk, and practical solutions to address those risks have been developed. Some of the important considerations that have been taken into account while implementing practical material handling solutions on the identified tasks are as under:

- Ergonomic risk reduction
- Cost – Benefit trade off
- Productivity improvement
- Number of operators affected
- Time frame
- Ease of implementation

The most critical of these considerations is reducing the amount of ergonomic risk experienced by the operator. The prioritized task list was generated by the MHAC, which has helped to determine the magnitude of the material handling challenge in the facility by quantifying the ergonomic risk by task. However, it must be noted that if there are numerous high-risk tasks, appropriate capital must be budgeted to make improvements. All the potential solutions have been evaluated, based on the time and resources required to implement them. It is expected that changes can be in place within 30 to 60 days, with limited staff involvement.

6.6 ERGONOMIC ASSESSMENT OF CARRYING TASKS USING MHAC

Applying the MHAC methodology to analyze the carrying task listed in Table 6.1 for ergonomic assessment in order to determine the ergonomic problems, those tasks that had a grand score of more than 23 (those that imply most urgent action) were identified and listed in Table 6.14.

Table: 6.14
Identification of critical Tasks using MHAC

	Operation/ Function	Potentially stressful task	MHAC Score
1	Bearing Line	Transfer of pans containing parts from the Forming & Coining press to the three Facers.	23
2	Bearing to Plating shop	Transfer of pans containing parts from the Height Broaching machine to the Plating machines.	25
3	Plating shop	Transfer of pans containing parts from the Degreasing station to the Loading station	23
4	Powder Plant	Transfer of raw material ingots for the incoming material store to the induction furnace for melting.	26
5	Packing Line	Transfer of finished parts from the Bearing awaiting packing (BAP) store to the On-line shrink wrap station	25
6	Merchandizing Section	Transfer of Color cartons and Master cartons from the packing line to dispatch and load on trucks.	25

6.7 ANALYSES AND DEVELOPMENT OF APPROPRIATE CONTROLS

Efforts to develop appropriate control included brainstorming by employees performing the task in question and the researcher. When developing solutions to ergonomic issues, the hierarchy of controls has been: (1) engineering improvements, (2) administrative controls and (3) work practices modifications.

6.7.1 Task 1: Transfer of pans containing parts from the Forming & Coining press to the Facers.

The ergonomic problem tasks that have been identified after the assessment by MHAC at the transfer station are:

Task Description: In the bearing production line, the forming and coining press feeds parts to two facers as shown in the figure 6.9. The pans containing parts are lifted and carried to the facing loading station by the operator for carrying out the next operation.

Ergonomic Deficiency observed: The analysis of the carrying task as per the MHAC score sheet is given in Table 6.15. The weight of the pan when filled to full capacity with ten different bearing applications was measured and average weight of the load was calculated to be 22 kg. Each face and chamfer operator used to manually carry the loaded pans to their respective workstations at a carry frequency of about 2 carries per hour. Also, since the pans were placed on the floor at the Forming & Coining station, the worker had to lift the parts in an awkward posture leading to bent trunk and upper arm. The pans grip holders were made of mild steel and in the absence of any cushioning used to put a lot of stress on the grip of the operator. The general environmental conditions in the shop had high noise value (> 85 dBa) and temperature goes up to 38°C in summers.

Table: 6.15
MHAC Sheet for Task1

MHAC: *Score Sheet*			
Company Name:	*Insert the numerical score for each of the risk factors in the boxes below, referring to your assessment, using the tool*		
Task description:	***Risk factors***	***Measured value***	**Score**
Transfer of pans containing parts from the Forming & Coining press to the three Facers.	1. *Load weight & carry frequency*	30 kg; 2 carries/hr	3
	2. *Hand distance from lower back*	Trunk bent forward and upper arm bent	4
	3. *Asymmetrical trunk/load*	Load and hands asymmetrical at 25° and upright body position.	2
	4. *Postural constraints*	Adopts restrictive postures while carrying	2
Are there indications that the task is high risk (Tick in appropriate boxes) ☐ *Task has a history of manual handling incidents (e.g. accident record)* ☐ *Task is known to be hard work or high risk* ☐ *Employees doing the work show signs that they are finding it hard work (e.g breathing heavily, sweating)* ☐ *Other indications, if so what?* ________	5. *Grip on load*	Containers of poor design	3
	6. *Individual operator capabilities*	Requires a person of unusual strength or height	2
	7. *Floor surface*	Dry floor but uneven	2
	8. *Other environmental factors*	High Noise and extremes of tempertaure	2
	9. *Carry distance*	5 meters	2
	10. *Obstacles en route*	No obstacles	1
	Total score		**23**

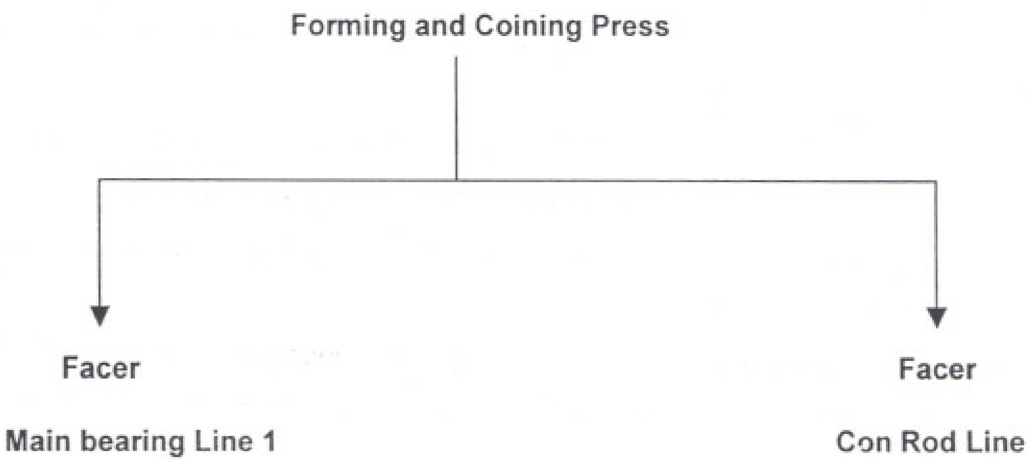


Figure 6.9: Distribution of material from Forming and Coining press to Facers

Controls Implemented: After brainstorming, the following controls were implemented:

- **Trolley design:** Four wheeled trolleys were designed for the bearing lines with a provision to keep eight pans on each trolley. The four-wheeled trolleys were designed using the recommendations reported in literature on design of trolleys. The trolley was designed during the course of the study using ergonomic considerations. The detailed design characteristics and the factors affecting the performance of the trolleys are discussed in detail in section 6.8 of this chapter.
- **Size:** The size of the trolley was designed to accommodate the largest size of the pan although most of the pans available in each organization were fairly consistent in dimensions.
- **Number of pans on trolley:** Four pans were placed side by side as shown in figure 6.12. The size of the pan and the four-wheeled trolley designed to accommodate 8 pans of these type are as under:
    - ➢ Dimensions of the pan: Length = 24 inches; Width = 12 inches; Height = 4 inches, Mild steel perforated sheet of thickness 22 SWG.
    - ➢ Dimensions of the trolley: Length = 25 inches; Width = 25 inches; Height from ground level = 6 inches; Height of the side-on handle = 40 inches; Trolley handle diameter = 1.5 inches.
- **Handle Height:** The height of the handle was so selected that it should allow the individual user to adopt a comfortable posture, although the optimum height of handle differs depending on whether the aid is being pushed or pulled. This factor has been considered while designing and fabricating a trolley as explained in Section 6.8.

- **Force required:** The four-wheeled trolleys for the line were designed to reduce push forces as well as to ensure a neutral hand/wrist posture. This aspect is described in detail in Section 6.8 of this chapter.
- **Wheels:** Wheels and castoring greatly influence both the maneuverability of trolleys and the forces required to move them. The trolleys were fitted with smaller diameter wheels although these can be harder to push, pull or steer, but are helpful while operating in tight aisles.
- **Location of trolleys:** The new trolleys were located at the Forming and coining station and empty pans were placed on them. After the pans were filled with the parts the trolleys were pushed to the respective facing and chamfering machines for subsequent operation.
- **Grip on Pans:** The pan grip holders were provided with rubber grips rolled over the mild steel handle to provide a cushioning affect to the hands and fingers on a pilot basis. Also, since the pans are now placed one over the other, the chances of overfilling was totally eliminated which resulted in excessive weight in some pans earlier.

The firms had been employing at least two casual manpower for manually carrying the pans to the three facing and chamfering stations and after the introduction of the four-wheeled trolleys at these stations the requirement of additional manpower for material handling has been eliminated. Also, since the task was performed by casual manpower, which was, employed for a fixed period of 3 months, no data on any MSD's or other related injuries or accidents were available with regard to this task as this kind of manpower was rarely re-employed as per the company policies. It can however, be safely concluded that all normal workers performing such tasks over a prolonged period of time, are likely to suffer from MSD's.

6.7.2 *Task 2:* Transfer of pans from the Height Broaching machine to the Plating machines

The ergonomic problem tasks that have been identified after the assessment by MHAC (Table 6.16) at the transfer station are:

Task Description: The bearings are handled manually at the first operation of blanking, forming and coining and then move in a single piece flow from the facing and chamfering station up till height broaching station, which is the last of the machining operation carried out on parts.

Table 6.16

MHAC Sheet for Task 2

<table>
<tr><td colspan="4">MHAC: <i>Score Sheet</i></td></tr>
<tr><td><i>Company Name:</i></td><td colspan="3"><i>Insert the numerical score for each of the risk factors in the boxes below, referring to your assessment, using the tool</i></td></tr>
<tr><td rowspan="5"><i>Task description:</i>
Transfer of pans containing parts from the Height Broaching machine to the Plating machines</td><td><i>Risk factors</i></td><td><i>Measured value</i></td><td><i>Score</i></td></tr>
<tr><td><i>1. Load weight & carry frequency</i></td><td>27 kg; 12 carries/hr</td><td>4</td></tr>
<tr><td><i>2. Hand distance from lower back</i></td><td>Upper arm angled away from the body</td><td>3</td></tr>
<tr><td><i>3. Asymmetrical trunk/load</i></td><td>Load and hands asymmetrical at 25° and upright body position.</td><td>2</td></tr>
<tr><td><i>4. Postural constraints</i></td><td>Adopts restrictive postures while carrying</td><td>2</td></tr>
<tr><td rowspan="7"><i>Are there indications that the task is high risk (Tick in appropriate boxes)</i>
☐ <i>Task has a history of manual handling incidents (e.g. accident record)</i>
☐ <i>Task is known to be hard work or high risk</i>
☐ <i>Employees doing the work show signs that they are finding it hard work (e.g breathing heavily, sweating)</i>
☐ <i>Other indications, if so what?</i> ____________</td><td><i>5. Grip on load</i></td><td>Containers of poor design</td><td>3</td></tr>
<tr><td><i>6. Individual operator capabilities</i></td><td>Requires a person of unusual strength or height</td><td>2</td></tr>
<tr><td><i>7. Floor surface</i></td><td>Dry floor but uneven</td><td>2</td></tr>
<tr><td><i>8. Other environmental factors</i></td><td>High Noise and extremes of temperature</td><td>2</td></tr>
<tr><td><i>9. Carry distance</i></td><td>12 meters</td><td>3</td></tr>
<tr><td><i>10. Obstacles en route</i></td><td>Obstacles</td><td>2</td></tr>
<tr><td><i>Total score</i></td><td></td><td>25</td></tr>
</table>

Ergonomic deficiencies observed: All parts, with Copper, Lead and Tin alloy lining material are moved to the Plating section for electroplating. The parts were manually carried to a distance of 12 meters to the plating shop. The average weight of each pan was observed to be 22 kg with a carry frequency of 12 carries per hour. All other problems associated with the carrying of the pans were similar to the ones already discussed above.

Controls Implemented

Provision of four wheeled trolleys: The four-wheeled trolleys introduced at the forming and coining stations were moved after the facing and chamfering station to the height broaching station from where the parts were unloaded into the pans again and moved to the plating section in the trolleys. The detailed design of the trolley is discussed in Section 6.8 of this chapter. The trolleys after unloading the parts in the plating section were moved back to the Forming and Coining station. The additional manpower, which was used for moving parts at the forming and coining station, was also carrying pans between the height broach and the Plating section. The need for the additional manpower for these jobs was thus eliminated.

6.7.3 Task 3: Transfer of pans from the Degreasing station to the Plating Loading station

The ergonomic problem tasks that have been identified after the assessment by MHAC (Table 6.17) at the transfer station are:

Task Description: The pans are unloaded from the trolleys at the Degreasing station of the Plating shop. All parts are degreased in Tricholoroethylene (TC) vapour before plating. The Degreasing section has been designed in such a way that one complete pan at a time can be degreased by dipping in the TC liquid vapour. The pans are then allowed to cool for 15 minutes before being moving them to the plating loading station.

Ergonomic deficiencies observed: The operator carries the pans weighing about 22 kg at a distance of 5 meters with a carry frequency of about 1 carry every 5 minutes. The upper arm remains angled away from the body and the load and the hands are asymmetrical at 25°. The task requires an operator of unusual strength and height and high temperatures and noise from the tumbling machine are a major irritant and distraction.

Table 6.17

MHAC Sheet for Task 3

<table>
<tr><td colspan="4">MHAC: Score Sheet</td></tr>
<tr><td>Company Name:</td><td colspan="3">Insert the numerical score for each of the risk factors in the boxes below, referring to your assessment, using the tool</td></tr>
<tr><td rowspan="5">Task description:
Transfer of pans containing parts from the Degreasing station to the Loading station</td><td>Risk factors</td><td>Measured value</td><td>Score</td></tr>
<tr><td>1. Load weight & carry frequency</td><td>27 kg; 12 carries/hr</td><td>4</td></tr>
<tr><td>2. Hand distance from lower back</td><td>Upper arm angled away from the body</td><td>3</td></tr>
<tr><td>3. Asymmetrical trunk/load</td><td>Load and hands asymmetrical at 25° and upright body position.</td><td>2</td></tr>
<tr><td>4. Postural constraints</td><td>Adopts restrictive postures while carrying</td><td>2</td></tr>
<tr><td rowspan="7">Are there indications that the task is high risk (Tick in appropriate boxes)
☐ Task has a history of manual handling incidents (e.g. accident record)
☐ Task is known to be hard work or high risk
☐ Employees doing the work show signs that they are finding it hard work (e.g breathing heavily, sweating)
☐ Other indications, if so what? ____________</td><td>5. Grip on load</td><td>Containers of poor design</td><td>3</td></tr>
<tr><td>6. Individual operator capabilities</td><td>Requires a person of unusual strength or height</td><td>2</td></tr>
<tr><td>7. Floor surface</td><td>Dry floor but uneven</td><td>2</td></tr>
<tr><td>8. Other environmental factors</td><td>High Noise and extreme temperature</td><td>2</td></tr>
<tr><td>9. Carry distance</td><td>5 meters</td><td>2</td></tr>
<tr><td>10. Obstacles en route</td><td>No obstacles</td><td>1</td></tr>
<tr><td>Total score</td><td colspan="2">23</td></tr>
<tr><td></td><td></td><td colspan="2"></td></tr>
</table>

Controls Implemented

After brainstorming the following controls were implemented:

Provision of Roller Conveyor: Degreasing unit and the Plating loading station were connected with the help of roller conveyor. Each pan after degreasing was placed on the conveyor and pushed with hand pressure on to the plating loading station thereby eliminating the necessity of carrying pans. The Degreasing machine was also re-located closer to the plating machine to facilitate the use of a roll conveyor.

Productivity improvement has been measured in terms of output, and ergonomic gains like reduction in accident/ injury rates. The existing output data as well as information regarding accident/injury rates and absenteeism were collected and comparison of data for three months before and after the implementation of the controls was made. Table 6.18 shows the effect on productivity due to improvement in manual material handling practices.

Although the above data shows an improvement in all the three aspects measured after the implementation of controls, it will be necessary to study the affect over a longer period of time to quantify the net gain. However, from the above data, it is clear that productivity gains are enormous with regard to improvement in ergonomic aspects in manual material handling.

Table: 6.18

Productivity improvement before and after implementation of controls

	Before Implementation of controls in 2003				After Implementation of controls in 2003				Improvement
Parameter	Jan	Feb	Mar	Avg (b)	Apr	May	Jun	Avg (a)	(b-a)/a x 100
Output per shift	10400	9140	10210	9917	10550	10310	10450	10437	5.24%
Absenteeism Rate (%).	18.2	22.7	20.4	20.5	11.8	15.9	10.0	12.6	38.5%.
Accidents / Injuries data	2	1	1	1.3	-	-	-	-	100%

Calculation of output per shift and absenteeism:

1. Controls were implemented in the month of April 2003.
2. Output per shift has been calculated by: $\frac{TotalOutputforthemonth}{Numberofavailableshiftseachmonth}$

3. Absenteeism rate has been calculated as under:

$$AbsenteesimRate = \frac{Averagenumberofwor\ker sabsenteachday}{Totalmanpowerofthe\sec tion}$$

6.7.4 *Task 4:* Transfer of raw material ingots from the incoming material store to the induction furnace for melting

The ergonomic problem tasks that have been identified after the assessment by MHAC (Table 6.19) at the powder plant are:

Task Description: Engine bearings are manufactured using a non-ferrous alloy lining sintered onto a mild steel strip. The alloy powder is manufactured using powder metallurgy by melting the raw material ingots of Copper, Lead and Tin in an induction furnace of 500 kg capacity. The metals are mixed usually in the ratio of 80:10:10 for Cu, Pb and Sn respectively.

Ergonomic deficiencies observed: The raw material is moved from the online stores in the correct proportion and then carried to the induction furnace for melting. The weight of the ingot during each carry is about 40 kg and the operator carries the stock at least 12 times per hour. The powder plant has an online store located at a distance of 8 meters and considering the layout and the space available it was not possible to move the store closer than this. The raw material was stacked on the floor in the online store and the operator had to bend his trunk in the forward direction to lift the material before carrying the stock. As the ingots were received from suppliers in varying sizes and were also required to be cut to appropriate sizes depending upon the weight of the material required for each melting. Because of this, it was not possible to conveniently grip the load while carrying. The task required workers of sufficient strength and height to carry the load. The work area had high temperature as well as noise.

Table 6.19

MHAC Sheet for Task 4

<table>
<tr><td colspan="4">MHAC: <i>Score Sheet</i></td></tr>
<tr><td><i>Company Name:</i></td><td colspan="3"><i>Insert the numerical score for each of the risk factors in the boxes below, referring to your assessment, using the tool</i></td></tr>
<tr><td rowspan="5"><i>Task description:</i>
Transfer of raw material ingots for the incoming material store to the induction furnace for melting.</td><td><i>Risk factors</i></td><td><i>Measured value</i></td><td><i>Score</i></td></tr>
<tr><td><i>1. Load weight & carry frequency</i></td><td>40 kg; 12 carries/hr</td><td>5</td></tr>
<tr><td><i>2. Hand distance from lower back</i></td><td>Upper arm angled away from the body and trunk bent forward</td><td>4</td></tr>
<tr><td><i>3. Asymmetrical trunk/load</i></td><td>Load lifted with asymmetrical angle up of 80°.</td><td>4</td></tr>
<tr><td><i>4. Postural constraints</i></td><td>Adopts restrictive postures while carrying</td><td>2</td></tr>
<tr><td rowspan="7"><i>Are there indications that the task is high risk (Tick in appropriate boxes)</i>
☐ <i>Task has a history of manual handling incidents (e.g. accident record)</i>
☐ <i>Task is known to be hard work or high risk</i>
☐ <i>Employees doing the work show signs that they are finding it hard work (e.g breathing heavily, sweating)</i>
☐ <i>Other indications, if so what?</i> ____________</td><td><i>5. Grip on load</i></td><td>Containers of poor design</td><td>3</td></tr>
<tr><td><i>6. Individual operator capabilities</i></td><td>Requires a person of unusual strength or height</td><td>2</td></tr>
<tr><td><i>7. Floor surface</i></td><td>Dry and clean floor in good condition</td><td>1</td></tr>
<tr><td><i>8. Other environmental factors</i></td><td>High Noise and extreme temperature</td><td>2</td></tr>
<tr><td><i>9. Carry distance</i></td><td>8 meters</td><td>2</td></tr>
<tr><td><i>10. Obstacles en route</i></td><td>No obstacles</td><td>1</td></tr>
<tr><td>Total score</td><td colspan="2" align="right">26</td></tr>
<tr><td></td><td></td><td colspan="2"></td></tr>
</table>

Controls Implemented

After brainstorming the following controls were implemented:

1. **Provision of trolleys:** Three four-wheeled trolleys were provided between the powder online store and the melting station. The design of trolleys has been discussed separately in section 6.8 of this chapter.
2. **Provision of storage rack with shelves:** To ease the ergonomic problems associated with handling and storage of raw material a storage rack with three shelves was provided in the online store. The operator after the implementation of this control will not be required to stoop and bend to pick material from the floor. The height of the lowest shelf was kept at 2 feet.

Productivity improvement has been measured in terms of ergonomic gains like reduction in absenteeism and accident/ injury rates. The comparative data with regard to productivity improvement for a period of six months is given in Table 6.20.

Table: 6.20

Productivity improvement before and after implementation of controls

	Before Implementation of controls in 2003				After Implementation of controls in 2003				Improvement
Parameter	Jan	Feb	Mar	Avg (b)	Apr	May	Jun	Avg (a)	(b-a)/a x 100
Absenteeism Rate (%)	27.4%	30.6%	22.5%	27%	14.7%	12.6%	11.8%	12.1%	55%
Accidents/ Injuries data	2	1	1	1.3	-	-	-	-	100%

Calculation of Absenteeism rate

1. Controls were implemented in the month of April 2003.
2. Absenteeism rate has been calculated as discussed in Section 6.7.3

Although the above data shows an improvement all the three aspects measured after the implementation of controls, it will be necessary to study the affect over a longer period of time to quantity the exact gain.

6.7.5 *Task 5:* Transfer of finished parts from the Bearing awaiting packing (BAP) store to the On-line shrink-wrap station

The ergonomic problem tasks that have been identified after the assessment by MHAC (Table 6.21) at the packing section are:

Task Description: Engine bearings are always packed in matched sets which generally includes upper and lower bearing shells which may further be subdivided into front, rear, and intermediate bearings depending upon the engine type. Thus, one bearing set for an engine bearing usually contains at least four different part numbers. The bearings are shrink-wrapped after all the part numbers for the set are available in matched numbers. Since lead-time for manufacturing is different for the different part numbers of a set, some of the parts, which have smaller lead times, are stored in Bearings Awaiting Packing (BAP) store till the matching parts are produced. Even after all the parts are transferred to Packing section for set packing, left over quantity of some part numbers have to be retained in the BAP store because of the non-availability of the matching part numbers.

Thus there is large stock of finished parts awaiting packing because of non-availability of one or more of the matching part numbers. During subsequent processing of fresh lots, Production Planning Department prepares the production plan considering the stock available for each part number in the BAP Store.

Ergonomic deficiencies observed: There is a continuous movement of stock from the stores to the packing line and back. An observation of the number of times the pans are carried to and fro and the average load carried in each shifting of stock during each shift was made over a period of one week and are listed as under.

- Average weight per pan = 15 kg
- Average carry distance = 10 meters
- Average number of carries per hour = 30
- Floor surface = Contaminated & oily

Controls Implemented

After brainstorming the following controls were implemented:

1. **Provision of trolleys:** The packing line was provided with four-wheeled trolleys similar to the one fabricated for the bearing production line as discussed above. Also, in the BAP store, simply stacking pans on a pallet whose height is raised by two empty pallets can reduce repetitive bending of the trunk. The trolley design is discussed in detail in section 6.8 of this chapter.
2. **Spray Oiling machine:** Since all the pans filled with finished parts are dipped into an oiling tank which acts as a rust preventive coating on the parts, lot of oil spill over from the pans on the floor causing hazardous working conditions. An online oiling mechanism has been suggested by the Engineering section but is yet to be procured. Such a machine as and when installed will prevent the spilling over of rust preventive oil onto the floor. The benefits that will accrue to the organizations have already been described in Chapter 5.

Table 6.21

MHAC Sheet for Task 5

MHAC: *Score Sheet*			
Company Name:	*Insert the numerical score for each of the risk factors in the boxes below, referring to your assessment, using the tool*		
Task description: **Transfer of finished parts from the Bearing awaiting packing (BAP) store to the On-line shrink wrap station**	***Risk factors***	***Measured value***	*Score*
	1. *Load weight & carry frequency*	15 kg; 30 carries/hr	3
	2. *Hand distance from lower back*	Upper arm angled away from the body and trunk bent forward	4
	3. *Asymmetrical trunk/load*	One handed carrying to the individual's side	3
	4. *Postural constraints*	Adopts restrictive postures while carrying	2
Are there indications that the task is high risk (Tick in appropriate boxes) ☐ *Task has a history of manual handling incidents (e.g. accident record)* ☐ *Task is known to be hard work or high risk* ☐ *Employees doing the work show signs that they are finding it hard work (e.g breathing heavily, sweating)* ☐ *Other indications, if so what?* __________	5. *Grip on load*	Containers require fingers to be clamped at 90° under the container	2
	6. *Individual operator capabilities*	Requires a person of unusual strength or height	2
	7. *Floor surface*	Contaminated/wet and oily floor surface	3
	8. *Other environmental factors*	High Noise and extreme temperature	2
	9. *Carry distance*	10 meters	2
	10. *Obstacles en route*	Large material stacking because of excess WIP	2
	Total score		**25**

3. In combination with engineering controls discussed above, **administrative controls** to help control exposure to ergonomic risk were also suggested. Administrative controls included simple methods such as:
   - **Job rotation** – Rotate operators through less strenuous tasks to reduce the amount of risk exposure. Understanding the ergonomic risk associated with the carrying operation can help management develop effective job rotation schedules, and rotate operators from high-risk operations to low-risk operations.
   - **Rest breaks** – Provide operators with rest breaks throughout a shift that requires high-risk manual material handling tasks to decrease the exposure to the risk and to provide the body time to recoup between the more demanding tasks.

Productivity improvement has been measured in terms of ergonomic gains like reduction in absenteeism and accident/ injury rates and manpower deployment. The BAP store was handled by one regular worker supported by two casual workers employed on temporary basis for a period of three months at a time. The comparative data with regard to productivity improvement for a period of six months is given in Table 6.22.

Table: 6.22

Productivity improvement before and after implementation of controls at BAP Store

	Before Implementation of controls in 2003				After Implementation of controls in 2003				Improvement
Parameter	Jan	Feb	Mar	Avg (b)	Apr	May	Jun	Avg (a)	(b-a)/a x 100
Absenteeism %	18.3	21.6	15.8	18.6	9.2	12.9	11.7	11.2	28.5%
Output / shift	18750	16580	17540	17623	19930	18870	20050	19616	11.3%
Manpower Deployed	3	3	3	3	1	1	1	1	66.6%

Calculation of Absenteeism rate

1. Controls were implemented in the month of April 2003.
2. Absenteeism rate and output per shift have been calculated as in Section 6.7.3.

Although the above data shows an improvement in all the three aspects measured after the implementation of controls, it will be necessary to study the affect over a longer period of time to quantity the net gain.

6.7.6 *Task 6:* Transfer of Color cartons and Master cartons from the packing line to dispatch and load in trucks

The ergonomic problem tasks that have been identified after the assessment by MHAC (Table 6.23) at the dispatch/merchandizing section are:

Task Description: The packed material is transferred to the Finished Goods Store (FGS) in the requisite packing cartons. The FGS is divided into three segments i.e. OEE, After Market and Exports. While material belonging to OEM is shipped generally in full truck loads unless there is an extreme emergency, the after market material is forwarded to Carrying and Forwarding Agents (C&F Agents) located in each major market zone. For the export customers, the merchandizing section waits till the entire order for a particular customer is completed before shipping (unless part-shipping has been accepted by the customer).

Ergonomic deficiencies observed: The material before shipment is directly packed into master cartons. The master cartons for packing are of following dimensions:

Length: 2 feet; Width: 1.5 feet and height: 1.5 feet.

The average weight of a fully packed master carton is 35 kg and the cartons have to be carried to the truck parked at a distance of 10 meters. The master cartons are transferred at a carry frequency of 30 carries per hour during peak shipment days specially the last week of every month when a lot of material is shipped.

The cartons received from packing section are stacked in storage racks consisting of four shelves, the lowest being at a height of 6 inches from the floor level. The workers while unloading parts from the shelf for transferring them to master cartons have to bend their trunk. In the absence of any grip on the cartons, the workers have to clamp their fingers under the cartons at 90°.

The task is perceived to be extremely hazardous and there have been numerous reports of MSD's and other injuries to the workers although the exact data could not be retrieved since this particular task of manual handling was being carried out by temporary contractual manpower and all the cases relating to medical problems were directly referred to ESI (A Government Agency related to providing medical treatment to industrial workers) through their contractor. The most common body part affected by manual material handling is the back, which often suffers strains, sprains, herniated discs, joint inflammation and dislocation.

Table 6.23

MHAC Sheet for Task 6

MHAC: *Score Sheet*			
Company Name:	*Insert the numerical score for each of the risk factors in the boxes below, referring to your assessment, using the tool*		
Task description:	***Risk factors***	***Measured value***	***Score***
Transfer of Color cartons and Master cartons from the packing line to dispatch and load on trucks.	1. *Load weight & carry frequency*	35 kg; 30 carries/hr	4
	2. *Hand distance from lower back*	Upper arm angled away from the body and trunk bent forward	4
	3. *Asymmetrical trunk/load*	Load lifted from or to a height above the shoulder with asymmetrical angle up to 100°	4
	4. *Postural constraints*	Heavily restricted posture while carrying	3
Are there indications that the task is high risk (Tick in appropriate boxes) ☐ *Task has a history of manual handling incidents (e.g. accident record)* ☐ *Task is known to be hard work or high risk* ☐ *Employees doing the work show signs that they are finding it hard work (e.g breathing heavily, sweating)* ☐ *Other indications, if so what?* ___________	5. *Grip on load*	Containers require fingers to be clamped at 90° under the container	2
	6. *Individual operator capabilities*	Requires a person of unusual strength or height	2
	7. *Floor surface*	Dry and clean floor in good condition	1
	8. *Environmental factors*	Extreme temperature	1
	9. *Carry distance*	10 meters	2
	10. *Obstacles en route*	Large material stacking because of excess WIP	2
	Total score		**25**

Controls Implemented

After brainstorming the following controls were implemented:

1. **Workstation Design Changes:** Changing the workstation design provides the best opportunity for improving material handling for this particular section. This includes provision of a conveyor with adjustable diverter bars to transfer the material from the shelves to the truck. Design of a U-shaped workstation has also been suggested to minimize material handling and walking distance of operators by reducing the overall work area and transfer distances. Although such suggestions are typically perceived as impractical solutions because of high cost, and longer implementation time, yet once developed with operator input and consideration for work flow, these systems can significantly reduce ergonomic risk, which helps justify the cost and installation time. Since provision of such an arrangement was not within the scope of this work, it has been left at as only a suggestion, which can be taken up at an appropriate time. However, the cost benefits and assessment of expected benefits in terms of worker health, performance and productivity has been made based on expert opinion and is described in Chapter 8.
2. Other measures suggested are changing the size, design and orientation of cartons, administrative controls like job rotation and rest breaks, work practice modifications like use of proper material handling aids and proper positioning.

6.8 DESIGN OF FOUR-WHEELED TROLLEYS FOR MATERIAL HANDLING

The use of trolleys to move items is an important strategy in reducing the holding and carrying actions. However the use of trolleys is not without risk of injury from either the movement or loading and unloading. The trolleys to be used have been designed using the parameters and factors already reported in literature from time to time. In the context of this chapter, a "trolley" refers to trolleys, which have four wheels.

6.8.1 Types of Forces

The amount of force required to move a trolley is the major issue in determining how easy or difficult it is to move a trolley. There are two types of forces, which have been considered in trolley movement:

- Initiating force i.e. the force to start a trolley moving; and
- Sustained (continuous) force i.e. the force to maintain movement of the trolley.

As reported in literature, the force required to initiate movement is normally higher than that required to maintain movement. In a study by Lawson & Potiki,(1997) the forces required to initiate movement of trolleys are about 30 - 90% higher than that required to sustain movement. The initiating force is therefore more critical when assessing forces required to move trolleys. The force used to initiate and maintain movement in a straight line increases proportionately with the total weight of the loaded trolley. The same load being moved by two different trolleys can result in very different levels of force being required due to the design of the trolley.

a) Measurement of Force*:* The measurement of force was done using a set of tension/compression measuring device. Before taking measurements, it was ensured that the device used is calibrated. The movement forces were measured by pulling rather than pushing the trolley. The device was attached to the handle of the trolley. The scale on device was positioned on the handle of the trolley in such a way that the reading on the scale is visible to the person performing the pulling. Pans full of parts were kept on two identical trolleys. Eight pans full with parts were placed on to the first trolley in two rows of four pans each. The rows were placed adjacent to each other as shown in figure 6.12. Ten full pans were placed on to the second trolley in two rows of five pans each. The two rows were placed adjacent to each other as described above.

b) Weight of the trolleys: The weight of each pan when full was 22 kgs. The weight of the empty trolley was 21 kgs. Thus, the total weight of the two trolleys was:

Trolley 1 : 197 Kgs
Trolley 2 : 241 Kgs

Prior to doing the measurements it was ensured that the test area is representative of the floor surface normally available in the organization and that there are no cracks or holes in the floor, which may influence results. The wheels/castors were also positioned in the direction of movement of the trolley.

For measurement, the device connected to the trolley was pulled. Two readings were taken and recorded: one when trolley movement starts (initiating force) and the other while the trolley is continuously moving (sustained force). The measurements were repeated 3 times. These readings were then compared to relevant push/pull criteria reported in the literature as given below. The results of the forces measured on the two trolleys are shown is Table 6.24.

c) Recommended Forces: Forces recommended for the movement of trolleys are as follows:

For mixed or female only working population

- Initial force - 17-21 kg
- Sustained force- 6-12 kg

For male only working population

- Initial force - 20-26 kg
- Sustained force- 7-16 kg

Table 6.24
Measurement of force for four wheeled trolleys

		Recommended value for male workers in Kgs	Actual force measurements (Kgs)			
			Trial 1	Trial 2	Trial 3	Average
Initial Force	Trolley 1 Wt. 197 kg	20-26	21	23	21	21.6
	Trolley 2 Wt. 241 kg	20-26	27	25	28	26.6
Sustained Force	Trolley 1 Wt. 197 kg	7-16	9	9	8	8.6
	Trolley 2 Wt. 241 kg	7-16	14	15	15	14.6

Since, the material handling tasks in the four organizations where the study was carried out are generally the responsibility of male workers, the actual measurements of force values have been compared to the recommended force value for male workers. The trolleys were thus designed to place eight pans in two rows placed adjacent to each other. The four pans in each row were placed one over the other.

d) Other factors affecting forces required to move trolleys: It must be mentioned here that besides the weight of the pans and the trolley weight there are other factors also which affect the force required to move a trolley. These factors are:

- Design of the handles;
- Design of the wheels;
- Maintenance of the trolley;
- Posture used; and
- Floor surface factors.

6.8.2 *Design of the Handles*

As reported in literature, it is generally accepted that a user's push/pull capability is at its most effective between hip height and shoulder height. Further, within this range it has been suggested that for pushing an optimum height is 70 - 80% of shoulder height, which is approximately chest height. An additional criterion is to minimize the degree of stooping.

Consequently, while designing trolleys for engine bearing industry, it was ensured that handle height is not lower than 38 inches so that tall persons do not have to stoop. The trolleys were designed with the handle height between 38 inches to 40 inches. A 40 mm diameter handle was provided so that the grip is not too large to be uncomfortable or too small so as to cramp the grip. It was also ensured that the shape of the handle did not have any sharp edges, seams or defined finger recesses.

6.8.3 Design of the Wheels

The wheel diameter, width and profile are the characteristics of trolley wheels, which will determine its ability to move easily in a straight line. Generally, the larger the diameter of the wheels on a trolley, the lower the forces required to move a trolley. It also makes it easier to roll over gaps or holes in the floor.

Lawson and Potiki (1998) recommended that trolley wheels should have a minimum diameter of 5 inches for indoor use. For outdoor use where the loads exceed 200kg, it is recommended that the diameter be increased to 8 inches. Using this information, the trolleys were provided with 6 inches diameter harder nylon wheels, since the trolleys were to be used on a smooth floor and moved over small distances.

6.8.4 Maintenance of the trolley

Even the best-designed trolley will not be effective if it is not well maintained. One of the principal areas to maintain is the wheels/castors. If the wheels are not maintained, trolleys will get progressively harder to move.

Table 6.25
Preventive Maintenance Schedule for Trolleys

Title: Preventive Maintenance Schedule for 4-wheel trolleys including history card						
Trolley Identification Number:						
Location: Production/ Plating/ Powder Plant/ Packing *(Tick as appropriate)*						
Check Frequency: Once every month						
Parameters/ Characteristics to be checked						
	Tyres/ Wheels	Bearings	Castors	Frame	Handle	Remarks
Specifications	In good condition	In good condition	Should swivel and roll easily	No missing parts or damages	No missing parts or damages	
Date						
Date						
Date						

A preventative maintenance programme carried out at a frequency related to the level and type of use of the trolley was prepared for trolley maintenance. The maintenance schedule and history card is shown in Table 6.25 above. Subsequently, it has also been suggested that once in six months, the pull forces should be measured and compared with the recommended level to determine if the maintenance has been effective.

6.8.5 Posture used

The trolleys were designed for movement by a pushing action. This allows body weight to be used to assist in moving the trolley, particularly when initiating movement.

6.8.6 Floor surface factors

The type of floor surface significantly affects the amount of force required to move a trolley. The trolley was designed for use on hard floor surface. As reported in literature, the force required to push a trolley up a ramp or incline will increase proportionately with the degree of slope. Also, sloping surfaces present problems when coming down the slope, as the trolley has to be restrained. The presence of ramps or inclines on trolley routes is not desirable. However, since the trolley has not been designed for movement on such surfaces, the use of trolleys on these should be avoided.

The other floor surface factor, which affects trolley movement, is where gaps or holes in the floor surface are present. This may sometimes require the trolley to be pushed very hard over the floor, which may require sudden high forces to be exerted. To ensure smooth movement of trolleys, elimination of such gaps or holes on the floor surface was proposed. This was subsequently done by filling up holes and minimizing gaps.

6.9 ANALYSIS OF MANUAL HANDLING AIDS USED FOR TRANSPORTATION

When an assessment by Material Handling Assessment Chart (MHAC) shows that there is a possibility of risk of injury, modifications are required to eliminate the risk or reduce it so that the level of the demand of physical effort on operators is acceptable. There are many solutions and organizations are free to choose those which are most appropriate for their circumstances. These could include mechanization or automation of tasks, but in many situations this can be achieved through less expensive improvements to the layout of the workplace or design of the task. The emphasis in the present work has been on using an ergonomic approach as the key to removing or reducing the risk of injury using engineering controls, with administrative controls like instruction and training as a complement to but not a substitute for designing a safe material handling system.

The immediate and most attractive solution to eliminate or reduce ergonomic risk related with manual material handling tasks is to use manual handling aids, which can assist lifting or avoid the need for carrying loads over distances. Such aids are relatively cheap, necessitating a minimum of modifications to other equipment or plant and require little skill or training to use. However, despite the attractions of this solution in reducing the risk of manual handling and the widespread use of equipment such as trucks or trolleys or pallet lifters, very little attention seems to have been paid to ergonomic aspects of their design.

The present study described in this section has been undertaken to see whether handling aids are providing a successful solution to manual material handling problems in an engine bearing manufacturing industry and to determine which features are most important for their usability. There is a vast range of handling aids which are available like hoists for lifting all types of materials, pallet tables for raising, lowering or rotating stacks of components, and trolleys for transporting goods. The focus of this study has been on the problems encountered during use of transport aids (trucks and trolleys), since the need to move materials around a plant is common to almost all engine bearing manufacturing organizations.

6.9.1 Survey of Users of Handling Aids

A survey of users of handling aids was carried out to look at safety and usability, seeking opinions on the aids currently in use and on the factors, which most affect perceptions of their usability. The survey was conducted in four engine bearing manufacturing firms using survey form as shown in Appendix 6.1. Thirty employees, who most frequently used manual material handling aids during their work were identified and interviewed individually at their work sites. The most commonly used handling aids were identified as four wheeled trolleys (available in many different forms), followed by hand pallet trucks and sack trucks. Most of the respondents used the aids frequently in their work. Load reported to be carried in each trip varied from 10 kg on a flat platform trolley to 800 kg on a pallet truck. The average distance traveled per trip ranged from 5 meters to about 200 meters. The aids were used on a variety of surfaces such as concrete and tiled floors as well as tarmac. Some of these surfaces were reported to be in poor condition.

Interview with the users and analysis of the responses received from the four firms provided a good understanding of the tasks for which manual handling aids are being used and helped in identification of factors believed to affect the usability of these aids. Table 6.26 shows the percentage of respondents identifying the factors such as

(1) Force requires, (2) Stability, (3) Steerability, (4) Interface, (5) Starting and Stopping, (6) Field of View, (7) Loading or Unloading and (7) Security of Load, affecting performance of each type of handling aid. It can be seen from Table 6.26 that problems were experienced with all types of aid, the ones causing most problems being the flat platform four wheeled trolleys, hand pallet trucks and cylinder trolleys. Many of the problems were compounded by environmental factors as shown in Table 6.27 and illustrated by comments quoted in Table 6.28. The environmental factors pointed out in the survey include the Floor surface, Restricted Space, Corners or Turning, Steps and Slopes or Ramps. The condition of the floor surface seemed to be a major problem. Rough and bumpy surfaces not only increased the force required, but also make it difficult to move at all.

Table 6.26
Factors affecting performance of each type of handling aid

	Percentage of users identifying each factor (Rounded off)							
	Force required	Stability	Steerability	Interface	Starting or stopping	Field of view	Loading or unloading	Security of load
4-wheeled trolleys								
• Flat platform	65	12	75	13	5	5	33	7
• Tall trolleys	35	6	42	4	21	31	6	8
• Mini-movers	7	5	9	57	2	-	-	18
Hand pallet trucks	55	6	18	9	23	4	47	19
Roll conveyors	61	4	2	-	9	-	25	12
Cylinder trolleys	77	54	7	23	7	14	12	43

Table 6.27
Environmental conditions affecting performance of each type of handling aid

	Percentage of users identifying conditions affecting performance				
	Floor surface	Restricted space	Corners or turning	Steps	Slopes/ Ramps
4-wheeled trolleys					
• Flat platform	33	8	12	-	4
• Tall trolleys	21	26	21	-	5
• Mini-movers	14	-	5	-	11
Hand pallet trucks	63	24	38	3	12
Roll conveyors	-	12	8	-	-
Cylinder trolleys	31	12	9	-	15

Table 6.28
Respondent's comments related to environmental conditions

Environmental conditions	Comments
Floor surface (e.g. uneven, bumpy, wet, sticky etc.)	- Difficult to steer on uneven surface - Load unbalancing due to bumpy surface - Machining chips cause interruption to free movement of four wheeled pallet trolley - If gets struck, needs lot of force to push - Difficult to stop pallet truck due to oily surface in packing - Stones from tumbler jams the castor wheels
Restricted space	- Hurt self because of less aisle space between machines in machine shop. - Too much congestion because of high inventory at stores and other places reducing maneuver.
Corners or turning	- Right angle sharp turns are a problem with most material handling aids. - Too little space at sharp corners require to take a wider circle while turning
Steps	- Hurt back while loading parts at dispatch on steps - Cannot use the material handling aids at steps
Slopes/Ramps	- Hard to pull up the slope - Security of load is a concern on slopes

6.9.2 Forces Required

From the data in Table 6.28 it can be seen that most of the aids were perceived to be heavy to operate, and operating persons had problems with the forces needed in getting them into motion, controlling the aid and stopping it. These forces can be much higher than the forces required to pull or push a handling aid while it is moving. The problem was observed on the four wheeled pallet trolleys as well as pallet trucks used to carry pans through the various sections of the bearing manufacturing facility. The user is also required to restrain the trolley if it starts to overturn or gets unbalanced.

After discussing the problem with the users, the causes of the problem of high force required could be attributed to the mechanical design of the aids as well as lack of proper maintenance. It was observed that the in-house engineering sections of the firms designed the four wheeled pallet trolleys, customized for the particular type of pans used by each of these firms. The loading data for each of these aids were simply ignored or compromised to procure the cheapest option. In other cases, users were attempting to transport loads that were too heavy for the trolley or the hand pallet truck. Overloading of trucks or trolleys seems to be a common practice because of high WIP inventory, which occupies a large number of trolleys and pans.

The main reason for lack of maintenance seemed to be staff shortages, or simply because nobody has been assigned for maintenance of these aids.

6.9.3 Stability

Stability was not a major problem with four wheeled pallet trolleys except when these were overloaded and were related to lack of security of their loaded trays. Stability was a much more significant problem with two wheeled devices, for example, the cylinder trolleys. Users were finding it difficult to find a comfortable point of balance after they had tilted the trolley off the ground for carrying the load. Many reported aching shoulders or back, as the trolley was not adequately supporting the weight of the load. Also, insecure loads can add to the problems of stability since their movement can change their center of gravity and balance of the cylinder trolley. The problem was partially overcome by providing a third wheel at the rear, which helps balancing off the instable loads.

6.9.4 Steerability

Many users reported problems with steering and controlling trolleys. The trolleys were hard to maneuver around round corners. Also, castors, which swiveled too freely made trolleys difficult to control and, moreover, this seemed to increase the force required to make the aid to do what you want it to do. Users described the problem as "wheels go the wrong way when you push or can't push it in straight line". Wheel type and size, and also level of maintenance, were all factors affecting steering. On some trolleys, nylon wheels were fixed as standard and caused considerable problems. These were reported to have the advantage of being hard-wearing, but were only effective on flat even surfaces. Any scarp or chips on the floor could bring the trolleys to complete halt and it took considerable effort to free the trolley.

6.9.5 Handle interface

Some of the problems associated with the four-wheeled trolleys were about the handle height or its design. The survey results indicated that handles were too low so they had to stoop while pushing. This is certainly a factor which will affect the biomechanical loading and risk of injury when forces have to be exerted, and should be regarded as a important design factor.

Users of two-wheeled cylindrical trolleys were more critical about the interface design although handle height on a two-wheeled device is less constraining as the trolley can be tilted to give some degree of height adjustability. It was because many two-wheeled trolleys have handles, which are too short for many users, and also problem was related to other aspects of the handle interface. For example, many handles on cylindrical trolleys are nearly straight (vertical when parked). Although these are useful when pushing the trolley, but not helpful in tilting the trolley backward when starting off. Handles with horizontal bar running between and just below the handles were found to be more helpful.

One interface was specific to the tall trolleys. When these are fully loaded. It could be very difficult for the person who is pushing the trolley to see where he is going. As a result many users tend to pull the trolley than to push them. However, no adequate handholds were provided (for pushing or pulling) and pulling was reported to be particularly difficult because the user was forced to walk backwards or to walk in a twisted posture.

6.9.6 Starting and Stopping

Many users complained of difficulties in starting and stopping. Starting seemed to be problem with heavy loads, and was usually worse if the aid had small wheels or was poorly maintained. Problems were encountered in stopping when loads had to be pushed down slopes or ramps. Stopping was also reported to be a problem around corners or when pushing on wet or oily floor surface.

6.9.7 Loading and Unloading

The largest number of problems was associated with the loading and unloading using pallet trucks. The main reason seems to be that the space between top and bottom of some of the pallet boards was too narrow for the pallet forks to pass through, and some forks were shorter than the pallets being transported, so that the wheels on the front of the forks did not make contact with the floor and the load could not be raised.

6.9.8 Security of Load

Security of load appears to be major problem with cylinder trolleys. In some cases there was no means of securing the load and the goods had the tendency to fall off in transit, especially round corners or bumps. In some cases the securing devices were not adequate to stop the load wobbling while it was in motion, and in others the mechanism was awkward or poorly maintained.

6.9.9 Discussion

The survey results show that large numbers of users are experiencing problems with their manual transport aids in engine bearing manufacturing industry. Not only were many reported to be heavy to operate, but injuries had also been caused. Hand pallet trucks were used extensively to move pans and accident record showed that the pallet trucks had caused injuries such as cuts and bruises. Some of the reasons were attributed to poor design but many others appeared to occur because the aids were inappropriate for the task being performed and many aids were being used under poor environmental conditions. Organizational factors such as lack of maintenance is another cause.

Thus, there are six main aspects, which affect usability, for determining whether an aid is suitable in a particular situation are as shown in Table 6.29 below:

Table 6.29

Table 6.29
Factors which affect usability of handling aids

1. **The Design characteristics**
    - Interface, handle type, height, orientation
    - Size
    - Weight
    - Load securing system
    - Platform height and dimensions
    - Wheel type and size
    - Castoring of wheels
2. **Load characteristics**
    - Type of load
    - Size
    - Weight
    - Weight distribution (Centre of Gravity)
    - Shape
3. **Environmental considerations**
    - Compatibility with work place and other equipment
    - Space available
    - Obstacles
    - Terrain – Floor surface
    - Surface friction
    - Slopes
    - Steps, Stairs
    - Maintenance condition
    - Lighting
    - Vibration
4. **Operational conditions**
    - Frequency and duration of task
    - Speed of work
    - Required load per trip
    - Work pressure
    - Availability of assistance
5. **User characteristics**
    - Sex
    - Age
    - Anthropometry
    - Strength
    - Training and task knowledge
    - Motivation
6. **Performance aspects**
    - Forces required
    - Steerability, Stability
    - Field of view
    - Physiological energy demands
    - Ease of loading/Unloading
    - Efficiency
    - Safety

It is felt that the improvements in usability of manual handling aids needs to be approached through at least two routes:

1. Greater attention to ergonomic aspects in their design;
2. Clear guidance for selection of aids for each handling task

6.10 ANALYSIS OF MANUAL LIFTING TASKS

Manual lifting activities are widely recognized as a major source of injuries in industrial work. Despite efforts at control, including awareness programmes directed at both workers and jobs, injuries caused due to manual lifting tasks still account for 25% of all industrial accidents (Davii and Sheppard, 1980); and approximately half of the resulting injuries are sprains or strains of the lower back. According to the Department of Labour's Bureau of Labour Statistics (DOL) of United States, back injuries accounted for nearly 20% of all injuries and illness in the workplace. Another study indicated that that over exertion was the most common cause of occupational injury, accounting for 31% of all injuries. The back, moreover, was the body part most frequently injured and the most costly to worker compensation systems.

The National Institute of Occupational Safety and Health (NIOSH) of United States has published the "Work Practices Guide for Manual Lifting" which includes analytical procedures and a lifting equaition for calculating the Recommended Weight Limit(RWL) for specified two-handed, asymmetrical lifting tasks, as an approach for controlling the hazards of low back injury for manual lifting. The approach to hazard control was coupled to the Action Limit, a resultant term that denoted the recommended weight derived from the lifting equation. NIOSH lifting equation is provided in a separate journal article entitled "Revised NIOSH Lifting equation for the design and evaluation of Manual Lifting tasks", by Waters, Putz-Anderson, Garg and Fine, 1993.

The manual lifting activities at all stations during the manufacturing of engine bearings/ bushings have been evaluated using the revised Lifting Equation. When an assessment shows that, there is a possibility of risk of injury (Lifting Index greater than 1), modifications are required to eliminate the risk or to reduce it so that the level of demand on the operators is acceptable. There are, of course, many possible solutions and the manufacturing organizations may choose the most appropriate ones for their own circumstances. Thus, there are several approaches for controlling the stressors related to manual lifting. One approach is to eliminate the manual requirement of the jobs, which could involve mechanization, or automation of the task by using aids like hoists, cranes, chutes, conveyors or lift trucks. If the manual requirement of the job cannot be eliminated, then the demands of the jobs should be reduced through ergonomic design/ re-design. As a last resort, and if re-design is not feasible, stress on the workers should be reduced by distributing the stress between two or more workers. (For example, team lifting).

Ergonomic design / re-design include:

- Physical change in the layout of the job
- Reduction in the lifting frequency rate and/or duration of the work period.
- Modification of the physical properties of the material lifted, such as type, size or weight, and/or improvement of hand-to-object coupling.

The NIOSH lifting equation has been used to identify ergonomic problems in the production lines, and to evaluate the ergonomic design / re-design solutions. By examining the value of each task multiplier, the penalties associated with each job related risk factor has been evaluated in order to determine their relative importance in consideration of alternate work place design. The task factors that cause the greatest reduction in the load constant have been considered as a first priority for job design.

6.10.1 Analysis of Manual Lifting Jobs using NIOSH Lifting Equation

The most frequently used lifting task analysis is the NIOSH 91 Guide. This has a maximum weight of 51 lbs (23 Kgs). The maximum weight limit is corrected using a manipulative model that provides a weighting for six task variables namely:

i)	Horizontal Distance, H	iv)	Asymmetry Angle, A
ii)	Vertical Distance, V	v)	Frequency/Duration of Lift, F
iii)	Vertical Travel Distance, D	vi)	Type of Coupling, C

The weightings are expressed as coefficients that serve to decrease the maximum weight limit, also referred to as load constant, which represents the maximum Recommended Weight Limit, hereafter written as, RWL, to be lifted under ideal conditions. The RWL is defined by the following equation:

$$\mathbf{RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM} \quad (1)$$

Where,

LC = Load Constant or Maximum Weight Limit and is equal to 51 lbs

HM = Horizontal Distance Multiplier

VM = Vertical Distance Multiplier

DM = Distance of Lift Multiplier

AM = Asymmetric Angle Multiplier

FM = Frequency and Duration of Lift Multiplier

CM = Coupling Multiplier

The Lifting Index (LI)

The Lifting Index is a term that provides relative estimate of the level of physical stress associated with a particular manual lifting task. This estimate of the level of physical stress is defined by the relationship of the weight of the load lifted and the Recommended Weight Limit (RWL). The LI is defined by the following equation:

For single task manual lifting:

$$LI = \frac{ActualLoadWeight, L}{RecommendedLoadWeight, RWL} \qquad (2)$$

For Multi-task manual lifting:

$$CLI \Rightarrow STLI_1 + \sum \Delta LI \qquad (3)$$

Where,

$$\sum \Delta LI = FILI_2\left(\frac{1}{FM_{1+2}} - \frac{1}{FM_1}\right) + FILI_3\left(\frac{1}{FM_{1+2+3}} - \frac{1}{FM_{1+2}}\right) + FILI_4\left(\frac{1}{FM_{1+2+3+4}} - \frac{1}{FM_{1+2+3}}\right) + \ldots$$

$$\ldots\ldots\ldots\ldots\ldots FILI_n\left(\frac{1}{FM_{1+2+3+\ldots n}} - \frac{1}{FM_{1+2+3+\ldots(n-1)}}\right)$$

Where CLI = Composite Lifting Index

FILI = Frequency Independent Lifting Index

STLI = Single task Lifting Index

ΔLI = Incremental increase in Lifting Index

Note that (1) the numbers in the subscripts refer to the new task numbers, and (2) the FM values are determined from the standard tables provided with NIOSH Lifting equation.

6.10.2 Using the RWL and LI to guide ergonomic design

The Recommended Weight Limit and the Lifting Index can be used to guide ergonomic design in several ways:

i) The individual multipliers can be used to identify specific job related problems. The relative magnitude of each multiplier indicates the relative contribution of each task factor. (For example, horizontal, vertical, frequency etc.)

ii) The RWL can be used to guide the redesign of existing manual lifting jobs or to design new lifting jobs. For example, if the task variables are fixed, then the maximum weight of the load could be selected so as not to exceed the RWL; if the weight is fixed, then the task variables could be optimized so as not to exceed the RWL.

iii) The LI can be used to estimate the relative magnitude of the physical stress for a task or job. The greater the LI, the smaller the fraction of workers capable of safely sustaining the level of activity. Thus, two or more job designs could be compared.

iv) The LI can be used to prioritize ergonomic redesign. For example, a series of suspected hazardous jobs could be ranked in order as per the value of LI and a control strategy could be developed based on the priority matrix. (i.e., jobs with Lifting Indices above 1.0 or higher would benefit the most from redesign.

Thus it can be concluded that a Lifting index of 1.0 or less is ideal, but sometimes may be unrealistic As a rule of thumb, it must be ensured that as the weight of the object to be lifted is increased (51 lbs or 23 kgs maximum), the more neutral the body position be kept. However, it must be mentioned here that those lifting tasks, which have the LI greater than 1.0, pose an increased risk for lifting related low back pain for some fraction of the work force. Hence, the goal should be to design all lifting jobs to achieve a LI of 1.0 or less.

Wherever any organization accepts a LI value greater than 1.0 (say up to 1.5), the worker selection criteria must be used to identify workers who can perform potentially stressful lifting tasks. Those selection criteria must be based on research studies, empirical observations, or theoretical considerations that include job related strength testing and/or aerobic capacity testing. Nonetheless, nearly all workers will be at increased risk of work-related injuries when performing highly stressful lifting tasks. (i.e. those tasks with LI value greater than 3.0)

6.11 THE DETAILS OF ANALYSIS OF LIFTING TASKS

Prior to assessment, it was determined (1) if the job is to be analyzed as a single task or multi-task manual lifting job, and (2) if significant control of an object is required at the destination of the lift. Significant control of an object at the destination is required if:

- The worker has to re-grasp the load near the destination of the lift.
- The worker has to momentarily hold the object at the destination.
- The worker has to position or guide the load at the destination.

Step 1: Collect data

The data needed for each task include the following:

The weight of the object to be lifted (L)

- Horizontal and Vertical distance of the hands with respect to the mid-point between the ankles at both origin and destination.
- Angle of Asymmetry at the origin and destination
- Frequency of Lift in lifts per minute (average over at least 15 minutes) based on duration, which can be short, moderate or long.
- Coupling type categorized as Good, Fair or Poor as per guidelines provided with the NIOSH Lifting equation.

Step 2: Assessment of Single task Lifting jobs

Calculate the RWL at origin and destination using equation (1) and the lower of the RWL values at the origin or destination should be used to compute the Lifting Index (LI) using equation (2).

Assessment procedure for multi-task Lifting jobs:

i) Compute the frequency independent recommended weight limit (FIRWL) and single task recommended weight limit (STRWL) for each task using equation (1).

ii) Compute the frequency independent lifting index (FILI) and single task lifting index (STLI) for each task using equation 2.

iii) Compute the composite Lifting Index (CLI) for the multi-task lifting job by using equation (3).

6.11.1 Analysis of lifting tasks on Bearing / Bushing production lines

The production lines in an engine bearing manufacturing unit follows a cell concept with regard to the layout of machines and equipment. The cells have been formed as shown in Table 6.30. The lifting tasks as indicated in column 4 of above table have been analyzed with the help of NIOSH Lifting equation to arrive at the Recommended Weight Limit and the Lifting Index.

Table: 6.30

Identification of stations where Lifting tasks needs to be analyzed

Cell Number	Operation Groupings	Machine Type	Manual Lifting	Production type
Bearing Production Line				
1	Blanking ↓ Forming and Coining	Power Press Power Press	At Form and Coin	Batch type
2	Face & Chamfer ↓ Lip Punching ↓ Hole Punching ↓ Groove milling ↓ Lip Milling	Special m/c Pneumatic press Pneumatic Press Horizontal Milling m/c Horizontal Milling m/c	At face & Chamfer station	Single piece Flow
3	Counter Sinking ↓ Wire brushing	Vertical Drilling m/c Special wire brush	At Counter Sinking	Batch type production
4	ID Broaching ↓ Height Broaching	Horizontal Broaching m/c	At ID Broach	Single piece flow
Bushing Production Line				
1	Blanking	Power Press	-	Batch type production
2	Counter sinking	Vertical Drilling m/c	At Loading station	Batch type production
3	First Forming ↓ Final Forming ↓ Face and Chamfer	Pneumatic Press Pneumatic Press Special M/c	At First form loading station	Single piece Flow
4	Final OD Grinding	Centre less Grinder	At Loading station	Batch type production
5	Final ID Boring	Boring m/c	At Loading station	Batch type production

a) Loading of parts into Form and Coin press

Job Description: The Forming and Coining operator routinely lifts pans filled with blanks placed on a four-wheeled pallet truck and places them on the worktable. The weight of the pan when full is 38 lbs. Significant Control of the load is not required at the destination of the lift. Also, the horizontal distance has been calculated for the pans, which are lying farthest from the operator position as shown in figure 6.10. The task variable data are measured and recorded on the job analysis worksheet. (Table 6.31(a)) The operator stands at a position shown in figure 6.10, and the vertical height at the origin is 13 inches and at destination is 37 inches and the maximum horizontal distance is 13 inches. This activity of placing pans on the worktable occurs about 12 times in a shift, so frequency is less 0.2 and duration is less than one hour. The asymmetric angle is 15° and the coupling has been classified as fair.

Calculation of Multipliers

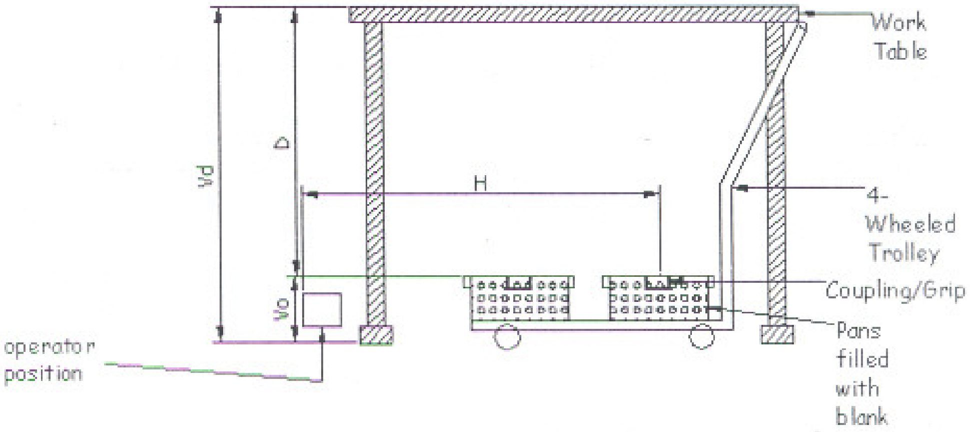


Figure 6.10: Loading station at Forming and Coining Press

- Horizontal Distance at Origin and Destination = 13 inches

  Horizontal Multiplier has been calculated as $\frac{10}{H}$ = 0.77

- Vertical Distance at Origin = 13 inches

  Vertical Distance at Destination = 37 inches

  Vertical distance Multiplier has been calculated as $1-(0.0075|V-30|)$

  VM at origin = 0.87 and VM at Destination = 0.95

- Distance D = (Vertical distance at origin) – (Vertical distance at destination) = 24 in.

  Distance Multiplier (DM) has been calculated as $0.82+\left(\frac{1.8}{D}\right)$ = 0.90

- Asymmetric Angle, A = 15°

  Asymmetric Multiplier, AM has been calculated as $1-(0.0032A)$ = 0.95

1. Frequency F = Less than 0.2 per minute (Calculated over a 15 minute period) and the duration of lift is less than one hour.

   Frequency Multiplier (FM) has beer calculated directly from the standard table provided by NISOH Lifting equation = 1.0
2. Coupling was classified as Fair.

   Coupling Multiplier has been calculated from the standard table provided by NIOSH lifting equation = 1.0

Thus, Recommended Weight Limit RWL has been calculated as under:

$$RWL = LCxHMxVMxDMxAMxFMxCM$$

RWL at origin = 29.21 lbs and RWL at destination = 30.83 lbs

Hazard Assessment:

The weight to be lifted (38 lbs) is greater than the RWL at both the origin and destination of the lift (29.21 lbs and 30.83 lbs, respectively). The LI at origin is 1.30 and at the destination is 1.23. These values indicate that this lift would be moderately hazardous for some of the industrial workers.

The measurement of task parameters, task multipliers, RWL and the LI are shown in Table 6.31(b)

Redesign Suggestions:

The worksheet shown in Table 6.31(a), indicate that the smallest multipliers (i.e the greatest penalties) are 0.77 for the Horizontal Multiplier, and 0.90 for the vertical multiplier. Since it is not possible to reduce the horizontal distance of the pans because of the four-wheeled trolley, the only modification that is possible is for the Vertical distance. The following job modifications have been suggested:

- Raise the height of the pans from current 13 inches to 25 inches by adding two rows of empty pans under the filled pans as shown in figure 6.11. This will also reduce the vertical travel distance from 24 inches to 12 inches.

The RWL and the corresponding LI values for this preferred combination of task variables are shown on the modified job analysis sheet. (Table 6.31(b)) At the origin, The RWL is 34.73 lbs and the LI is 1.09. At the destination, The RWL is 34.37 lbs and the LI is 1.10. Since the LI value of 1.10 is just marginally more than the ideal value of 1.0, the solution has been considered to be good enough.

Table 6.31(a) JOB ANALYSIS WORK SHEET

Department: Production

Job Description: Lift pans at Form & Coin Press

Step 1: Measure and Record Task Variables

Object weight lbs		Hand Location				Vertical distanceD	Asymmetric Angle		Frequency Lifts/min	Duartion (Hrs)	Object Coupling
		Origin		Destination			Origin	Destination			
L (Avg)	L (Max)	H	V	H	V						
38	38	13	13	13	37	24	15	15	0.2	< 1 hr	Fair

Step 2: Determine the multipliers and compute the RWL's

	RWL =	LC x	HM x	VM x	DM x	AM x	FM x	CM	
Origin		51 x	0.77 x	0.87 x	0.90 x	0.95 x	1.00 x	1.00 =	29.21 lbs
Destination		51 x	0.77 x	0.95 x	0.90 x	0.95 x	1.00 x	1.00 =	30.83 lbs

Step 3: Compute the Lifting Index, LI

Origin	LI =	1.3
Destination	LI =	1.23

Table 6.31 (b) JOB ANALYSIS WORK SHEET (Modified)

Step 1: Measure and Record Task Variables

Object weight lbs		*Hand Location*				*Vertical distanceD*	*Asymmetric Angle*		*Frequency Lifts/min*	*Duartion (Hrs)*	*Object Coupling*
		Origin		*Destination*			*Origin*	*Destination*			
L (Avg)	*L (Max)*	*H*	*V*	*H*	*V*						
38	*38*	*13*	*25*	*13*	*37*	*12*	*15*	*15*	*0.2*	*< 1 hr*	*Fair*

Step 2: Determine the multipliers and compute the RWL's

	RWL =	*LC x*	*HM x*	*VM x*	*DM x*	*AM x*	*FM x*	*CM*	
Origin		*51 x*	*0.77 x*	*0.96 x*	*0.97 x*	*0.95 x*	*1.00 x*	*1.00 =*	*34.73 lbs*
Destination		*51 x*	*0.77 x*	*0.95 x*	*0.97 x*	*0.95 x*	*1.00 x*	*1.00 =*	*34.37 lbs*

Step 3: Compute the Lifting Index, LI

Origin	*LI =*	*1.09*
Destination	*LI =*	*1.1*

Note: All dimensions are in inches and weight is in pounds

Change in Work Instruction: The operator work instructions at the previous blanking operation have been amended to include this aspect before transfer the material to Forming and Coining.

b) Loading of parts at Face and Chamfer Station

Job Description: After forming and coning, the pans are moved to the face and chamfer machines for facing. As in Forming and Coining, the facing operator routinely lifts pans filled with bearings placed on a four-wheeled pallet trolley and places them on the worktable as shown in figure 6.11. Since the bearings are stacked in pans, the maximum load weight of one pan is 42 lbs. No significant control is required at the destination. Since the parts are transferred from the previous station as one batch, eight pans are placed one over the other on the trolley. No twisting is required when picking up the pans. Walking and carrying are minimized by keeping the pallets close to the worktable. The vertical location, V at the origin and vertical travel distance D, vary from one lift to the next.

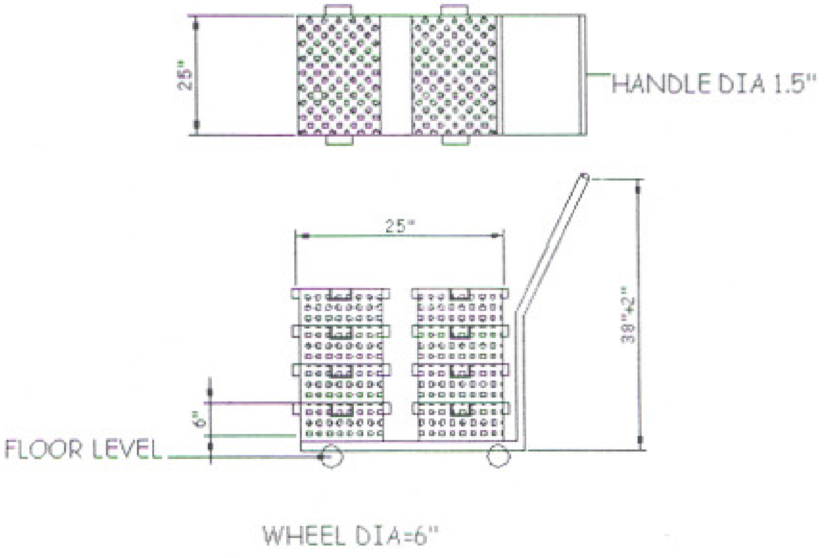


Figure 6.11: Loading of four-wheeled trolley at Face and Chamfer Station

Job Analysis: Since the job consists of more than one distinct task and the task variables change with every lift, the multi-task lifting analysis procedure has been used.

The job is divided into four tasks representing the four tiers of the loaded pans placed on the pallet trolley. Task numbering is done sequentially and reflects the order in which the tasks are performed.

The measurements/observations were made and recorded on the job analysis work sheet. (See Table 6.32(a))

The multi-task lifting analysis:

1) Frequency Independent Recommended Weight Limit (FIRWL) and Frequency Independent Lifting Index (FILI) values for each task using default Frequency Multiplier of 1.0 is given in Table 6.33.
2) The Single task recommended weight limit (SIRWL) and Single task lifting index (STLI) values for each task is shown in Table 6.33, where STRWL = FIRWL x FM. The FM value is determined by interpolation using the standard table provided by NIOSH.

Table: 6.33
RWL and LI for each task

Task	FIRWL	FILI = FIRWL x FM	STRWL	STLI	Renumbered task
Task 1	38.87	0.87	38.87	0.87	4
Task 2	36.56	0.93	36.56	0.93	3
Task 3	32.51	1.04	32.51	1.04	2
Task 4	30.57	1.11	30.57	1.11	1

The four tasks are renumbered starting with the task with the largest STLI value, and ending with the task with the smallest STLI value.

Hazard Assessment: The composite lifting index for the job has been calculated using equation 3. Using the equation the value of CLI is 1.24, which means that some healthy workers will find this job physically stressful. Therefore, redesign may be needed. Analysis of results suggest that Task 1 and Task 2 have a lifting index value of less than 1.0, which would be acceptable for nearly all healthy workers. However, when the other two tasks are added, the overall frequency increases the lifting index above 1.0. This suggests that the overall frequency should be reduced to limit the physical stress associated with this job.

Redesign Suggestions: The worksheet presented in Table 6.32(b) indicated that the multipliers with the smallest magnitude (i.e. providing the greatest penalties) are 0.77 for the HM for all the tasks; 0.87 and 0 89 for task 4 for vertical hand distance and distance respectively. The following job modifications are suggested:

The job is divided into four tasks representing the four tiers of the loaded pans placed on the pallet trolley. Task numbering is done sequentially and reflects the order in which the tasks are performed.

The measurements/observations were made and recorded on the job analysis work sheet. (See Table 6.32(a))

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Redesign Suggestions: The worksheet presented in Table 6.32(b) indicated that the multipliers with the smallest magnitude (i.e. providing the greatest penalties) are 0.77 for the HM for all the tasks; 0.87 and 0.89 for task 4 for vertical hand distance and distance respectively. The following job modifications are suggested:

- Bring the pans closer to the worker to increase the HM value to 1.

A reduction in these multipliers would decrease the CLI to about 0.80.

c) Analysis of lifting tasks for the production lines and plating shop: The Lifting index and the recommended weight limit have been calculated at two stations on the production line. Since similar trolleys and pans with similar vertical heights are used in any given organization, the RWL and LI values calculated above can be used for all the production lines. Thus, it can be concluded that once the redesign suggestions listed above are implemented, the lifting tasks will not lead to any physical stress to a normal healthy worker.

6.11.2 Analysis of lifting jobs at stations other than production area

During the course of the study, lifting jobs at stations other than handling of pans on the production line were also studied. These tasks were identified after discussions with experts from the engine bearings manufacturing organizations. These tasks were identified on the basis of (1) Load/weight handled, (2) High lift frequency and /or duration, and (3) Perceived difficult lifting tasks based on experience.

The jobs thus identified for detailed analysis are:

1. Loading of plating racks on the plating machine
2. Handling of tools, dies, fixtures in the tool storage area.

1.) Analysis of loading of plating racks on the plating machine

Job Description: As already explained in Chapter 5 while discussing the ergonomic problems with regard to the plating shop, all bearings with Copper, Lead and Tin alloy lining are plated with a 0.001" thick layer of Lead, Tin and Copper solution. For plating, the parts are loaded in a single or a double column rack and the rack is subsequently loaded on to a hook slot on the automatic plating machine. The study has been carried out for double column racks used for TATA application, which are perceived to be physically stressful. Significant control of the rack is required at the destination of the lift. Also, the worker must crouch at the destination of the lift to support the rack in front of the body, but does not have to twist.

Job Analysis: The task variables are measured and recorded on the job analysis work sheet (Table 6.34(a)). The vertical location of the hand is 39 inches at the origin and 58 inches at the destination. The horizontal distance of the hands is 10 inches at the origin and 15 inches at destination. The asymmetric angle is 0 degrees at both origin and

Table 6.32(a) JOB ANALYSIS WORK SHEET

Department: Production **Job Description: Lift pans at Face and Chamfer Machine**

Step 1: Measure and Record Task Variables

Task No.	Object weight lbs		Hand Location				Vertical distanceD	Asymmetric Angle		Frequency Lifts/min	Duartion (Hrs)	Object Coupling
			Origin		Destination			Origin	Destination			
	L (Avg)	L (Max)	H	V	H	V						
1	34	34	13	31	13	37	6	0	0	0.2	1	Fair
2	34	34	13	25	13	37	12	0	0	0.2	1	Fair
3	34	34	13	19	13	37	18	0	0	0.2	1	Fair
4	34	34	13	13	13	37	24	0	0	0.2	1	Fair

Step 2: Compute Multipliers and FIRWL, STRWL, FILI, and STLI for each task

Task No	LC x	HM x	VM x	DM x	AM x	CM x	FIRWL x	FM	STRWL	FILI	STLI	New task No.
1	51	0.77	0.99	1	1	1	38.87	1	38.87	0.87	0.87	4
2	51	0.77	0.96	0.97	1	1	36.56	1	36.56	0.93	0.93	3
3	51	0.77	0.92	0.9	1	1	32.51	1	32.51	1.04	1.04	2
4	51	0.77	0.87	0.89	1	1	30.57	1	30.57	1.11	1.11	1

Step 3: Compute Composite Lifting Index (Using equation 2 and 3)

CLI $STLI_1 + \Delta FILI_2 + \Delta FILI_3 + \Delta FILI_4 + \Delta FILI_5$ = 1.24

Table 6.32(b) JOB ANALYSIS WORK SHEET (Modified)

Step 1: Measure and Record Task Variables

Task No.	*Object weight lbs*		*Hand Location*				*Vertical distanceD*	*Asymmetric Angle*		*Frequency Lifts/min*	*Duartion (Hrs)*	*Object Coupling*
			Origin		*Destination*			*Origin*	*Destination*			
	L (Avg)	*L (Max)*	*H*	*V*	*H*	*V*						
1	34	34	10	31	10	37	6	0	0	0.2	1	Fair
2	34	34	10	25	10	37	12	0	0	0.2	1	Fair
3	34	34	10	19	10	37	18	0	0	0.2	1	Fair
4	34	34	10	13	10	37	24	0	0	0.2	1	Fair

Step 2: Compute Multipliers and FIRWL, STRWL, FILI, and STLI for each task

Task No	*LC x*	*HM x*	*VM x*	*DM x*	*AM x*	*CM x*	*FIRWL x*	*FM*	*STRWL*	*FILI*	*STLI*	*New task No.*
1	51	1	0.99	1	1	1	50.49	1	50.49	0.67	0.67	4
2	51	1	0.96	0.97	1	1	48.96	1	48.96	0.69	0.69	3
3	51	1	0.92	0.9	1	1	46.92	1	46.92	0.72	0.72	2
4	51	1	0.87	0.89	1	1	44.37	1	44.37	0.77	0.77	1

Step 3: Compute Composite Lifting Index (Using equation 2 and 3)

CLI $STLI_1 + \Delta FILI_2 + \Delta FILI_3 + \Delta FILI_4 + \Delta FILI_5$ *= 0.80* destination, and the frequency is 3 lifts per minutes during the 8-hour shift. The coupling is classified as poor because of lack of a gripping handle on the racks and also because the worker has to reposition the hands at the destination of the lift. Since significant control is required at destination, the RWL and LI are to be calculated both at origin as well as destination. The multipliers have been calculated using the standard tables and formulae provided with the literature on analysis using NIOSH lifting equation.

Hazard Assessment: The RWL value for this activity is 21.36 lbs at origin and 12.16 lbs at destination. The weight to be lifted is 24 lbs, which is greater than the RWL, at both the origin and the destination of the lift (21.36 lbs and 12.16 lbs respectively). The LI at the origin is 1.12, and at the destination is 1.97. These values indicate that this job is only slightly stressful at the origin, but moderately stressful at the destination of the lift.

Redesign Suggestions: The task multipliers with the smallest magnitude are 0.55 for frequency and duration of lift, 0.67 for HM at destination, 0.79 for vertical distance at destination and 0.9 for the coupling/grip. The following modifications are suggested:

1. **Reduce the lifting frequency** for a single worker by providing for recovery time (light work) after continuous loading of racks of at least 0.3 times the work time. For example, if a worker continuously lifts for 2 hours, then a recovery period of at least 36 minutes would be required before initiating a subsequent lifting session. Thus this job must be rotated between the plating operators at least 4 times in each shift so as to restrict the lifting duration per person to less than 2 hours per shift. After implementation of this suggestion, the FM multiplier value will increase to 0.79 as against 0.55 earlier.
2. The vertical distance at the plating machine where the rack is to be loaded cannot be altered because the tank has to accommodate the height of the rack as well as maintain the required volume of salt solution.
3. **Provision of coupling/grip:** A grip has already been provided on the racks to improve the multiplier value for coupling as already described in Chapter 5. The grip can be categorized as good after the implementation of controls described in Chapter 5. The new CM multiplier value is 1.0.

Thus the final RWL value would be increased from 12.16 lbs to 19.40 lbs, and the LI at the destination would decrease from 1.97 to 1.24 and the job can now be categorized as only slightly stressful to some workers. See Table 6.34(b).

2) Handling of tools, dies, fixtures in the tool storage area

A worker unloads tooling dies and fixtures returned after use in the production line. He unloads the tools from a cart to three storage shelves. Although the tools, dies and fixtures (hereafter referred to as 'tools') are lifted in the sagittal plane when moved between shelves, they are usually lifted asymmetrically, from one side of the body to the other, when lifted from the cart onto the shelves. The worker whenever required takes a step when placing the tools into the shelf. The tools do not have grips or handholds, so the worker slides his hand under the tool to lift it. When lifting to the top shelf, workers usually reposition their grip near the end of the lift. The work pattern is cyclic, meaning that the job is carried out at the beginning of each shift when all the tools after use in the production line are brought back and placed at their designated places on the shelves. The lifting frequency during the 1-hour work session is 1 tool per minute. The task is repeated at the beginning of each shift, which means there is enough recovery time between the two lifting sessions.

Job Analysis: Since the job consists of more then one distinct tasks and the task variables change often, the multi-task lifting procedure has been used for analysis. The job is divided into three tasks. Task 1 is defined as lifting from the cart to the lower shelf. Task 2 is defined as lifting to the centre shelf, and Task 3 is defined as lifting to the upper shelf. The left and right shelf positions are considered to be equivalent, since the worker can step towards the shelf during the lift. The task variables were measured and recorded on the job analysis worksheet. See Table 6.35(a). Tools are maximum 6 inches in height. Cart height is 24 inches high. The bottom shelf is 6 inches high, the middle shelf is 24 inches high and the top shelf is 42 inches high. At the origin, the horizontal distance H is 12 inches, the vertical height 30 inches high, and the angle of asymmetry is 30° for all lifts. At the destination, H is 16 inches, and A is 30° for all lifts.

The multi-task lifting analysis:

1) Frequency Independent Recommended Weight Limit (FIRWL) and Frequency Independent Lifting Index (FILI) values for each task using default Frequency Multiplier of 1.0 is given in Table 6.35(a).
2) The Single task recommended weight limit (SIRWL) and Single task lifting index (STLI) values for each task is shown in Table 6.35(a), where STRWL = FIRWL x FM. The FM value is determined by interpolation using the standard table provided by NIOSH.

Table 6.35(a): JOB ANALYSIS WORK SHEET

Department: Tool Room **Job Description: Tool Storage area**

Step 1: Measure and Record Task Variables

Task No.	Object weight lbs		Hand Location				Vertical distanceD	Asymmetric Angle		Frequency Lifts/min	Duartion (Hrs)	Object Coupling
			Origin		Destination			Origin	Destinatior			
	L (Avg)	L (Max)	H	V	H	V						
1	26	33	12	30	16	12	18	30	30	0.2	1	Poor
2	26	33	12	30	16	30	0	30	30	0.2	1	Poor
3	26	33	12	30	16	48	18	30	30	0.2	1	Poor

Step 2: Compute Multipliers and FIRWL, STRWL, FILI, and STLI for each task at Destination

Task No	LC x	HM x	VM x	DM x	AM x	CM x	FIRWL	x FM	STRWL	FILI	STLI	New task No.
1	51	0.63	0.87	0.92	0.9	0.9	20.83	0.91	18.95	1.58	1.74	2
2	51	0.63	1	1	0.9	0.9	26.02	0.91	23.68	1.27	1.39	3
3	51	0.63	0.87	0.92	0.9	0.9	20.83	0.91	18.95	1.58	1.74	1

Step 3: Compute Composite Lifting Index (Using equation 2 and 3)

CLI $STLI_1 + \Delta FILI_2 + \Delta FILI_3 + \Delta FILI_4 + \Delta FILI_5$ = 1.80

Table 6.35(b): JOB ANALYSIS WORK SHEET (Modified)

Step 1: Measure and Record Task Variables

Task No.	Object weight lbs		Hand Location				Vertical distanceD	Asymmetric Angle		Frequency Lifts/min	Duartion (Hrs)	Object Coupling
			Origin		Destination			Origin	Destinatior			
	L (Avg)	L (Max)	H	V	H	V						
1	34	34	9	30	10	12	18	15	15	0.2	1	Poor
2	34	34	9	30	10	30	0	15	15	0.2	1	Poor
3	34	34	9	30	10	48	18	15	15	0.2	1	Poor

Step 2: Compute Multipliers and FIRWL, STRWL, FILI, and STLI for each task

Task No	LC x	HM x	VM x	DM x	AM x	CM x	FIRWL	x FM	STRWL	FILI	STLI	New task No.
1	51	1	0.87	0.92	0.95	0.9	34.9	0.91	31.76	0.97	1.07	2
2	51	1	1	1	0.95	0.9	43.6	0.91	39.68	0.78	0.86	3
3	51	1	0.87	0.92	0.95	0.9	34.9	0.91	31.76	0.97	1.07	1

Step 3: Compute Composite Lifting Index (Using equation 2 and 3)

CLI $STLI_1 + \Delta FILI_2 + \Delta FILI_3 + \Delta FILI_4 + \Delta FILI_5$ = 1.11

3) The four tasks are renumbered starting with the task with the largest STLI value, and ending with the task with the smallest STLI value.

Hazard Assessment: The Composite Lifting Index CLI using the multi task analysis is 1.90, which indicates that there is a significant level of stress associated with this job. It can be also be concluded that strength is a problem with all the three tasks, since the FILI value exceed 1.0. Therefore, the overall physical demands of the job are primarily the result of excessive strength, rather than the lifting frequency rate.

Redesign suggestions: Table 6.35(b) shows that the multipliers with the smallest magnitude are 0.63 for the HM at the destination, 0.87 for the VM at the destination and 0.90 for the CM. The following job modifications are suggested:

1. Bring the tools placed on the cart closer to the worker to increase HM by bringing the tools between the worker's legs.
2. Reduce the angle of twist to increase AM by moving the origin and destination further apart.
3. However, it is not possible to provide any grip or coupling on to the tools.

After implementation of the above suggestions the Horizontal distance is expected to reduce to 9 inches (HM = 1) and the Asymmetrical Angle to 15° (AM = 0.95). The modified Job Analysis Worksheet is shown in Table 6.35(b). The CLI (modified) = 1.11 which is only marginally higher than the ideal value of 1.0.

6.12 Concluding Remarks

This chapter describes the development of MHAC (Material handling assessment chart) as a survey method for use in ergonomic investigations of workplaces This instrument requires no special equipment in providing a quick assessment of a manual carrying task on ten different factors. A scoring system has been used to generate an action list, which indicates the level of intervention required to reduce the risks of injury due to manual carrying tasks on the operator. The technique has been used to analyze the risks involved in manual material handling tasks. This chapter further describes the results of a survey of manual transport aids (trucks and trolleys) are in widespread use in engine bearing manufacturing industries. However, their use does not always result in anticipated reduction of workload or muscoloskeletal stresses and disorders. It has been concluded that most of these aids are poorly designed. In the last section of this chapter, a detailed analysis of manual lifting task was carried out using the revised NIOSH Lifting equation (1991). Those tasks, which have Lifting Index greater then 1, appropriate controls have been suggested and implemented.

CHAPTER 7

JOB ANALYSIS AND DESIGN

7.1 INTRODUCTION

Job design identifies what work must be performed, which includes the content of the job, how will it be performed, where is it to be performed and the competencies required by the person who will perform it. Job design also facilitates the achievement of organizational goals and performance of the work, the job was established to accomplish. A well-designed job can help to maximize productivity and job performance. The symptoms of poor job design include absenteeism, turnover, low productivity and poor morale and often these symptoms are treated rather than the cause. The benefits derived by a good job design are shown in Table 7.1.

Table: 7.1
Benefits of Job design

Benefits to Organization	**Benefits to employees**
Highly skilled workforce	Increased job satisfaction
Flexible and responsive workforce	Increased skills and training
Increased productivity and efficiency	More opportunity to participate in decision making and planning
Improved quality	A safer workplace
A reduction in occupational health and safety problems	More career opportunities
Elimination of unnecessary levels of supervision, checking and control	Improved quality of working life
Organizational effectiveness	
Increased customer service standards	
Improved efficiency by reducing costs associated with waste, delays and accidents	

People are far more effective in their work and get more satisfaction if their job interests them and offers a challenge. Hence job design based on scientific principles, while helping employees in efficient performance of their tasks, also results in higher productivity.

7.2 JOB DESIGN

Job design for the purpose of this thesis work has been carried out covering two aspects:

1. Ergonomic job design: eliminating and reducing risk factors for musculoskeletal disorders (MSD's)
2. Job Design for increasing employee motivation and productivity.

7.2.1 Ergonomic Job Design has two Major Components:

- Eliminate exposures to physical risk factors (Force, Repetition, Awkward Posture, Static Posture, Vibration, Contact Stress and Environment)
- Change how work is organized (so that the structure or set-up of the job or task promotes or protects against exposure to ergonomic risk factors)

This aspect has already been covered in detail in Chapters 5 and 6 for ergonomic analysis and design at individual workstations and manual material handling respectively.

7.2.2 Increasing employee motivation and productivity

Increase in productivity can manifest itself in various forms. For example, the focus can be that of improving quality and quantity of goods and services, reduce operation costs, and/or reduce turnover and training costs. Research has shown that there are several key factors that need to be included in a job to make it fully meaningful and satisfying. These factors include:

- Variety
- Responsibility for the Job
- Autonomy
- Task Identity
- Feedback
- Participation in Decisions
- Recognition and Support
- Work Environment

For carrying out this study the Job Diagnostic Survey (JDS) questionnaire (Hackman and Oldham, (1974) was chosen because it has been widely employed/used. The JDS provides 21 measures of an individual's motivational situation, which enables it to give very detailed and factual information. The aim of this study has been to determine the nature and extent of any motivational problems amongst production workers of engine bearing industry, and assess their possible effects on productivity and performance.

7.3 MODELS AND METHODS

7.3.1 The Hackman & Oldham model of motivation

Hackman and Oldham (1974) developed a comprehensive model of motivation, which incorporates the insights of the traditional theory, The Job characteristic Model. The model concentrates on the relationship between the person and the job. Six measures describe the motivating features of a job; they are called core job dimensions. These are aggregated into a single measure called the Motivating Potential Score (MPS) of the job. Two measures describe the person's motivational preferences, and they are aggregated into a single measure called the Growth Needs Strength (GNS) of the individual. If a MPS of a job matches closely the GNS of the person, then the individual is likely to be highly motivated.

This relationship between the person and the job results in an internal psychological situation, (three measures called Internal Psychological States) which in turn influence the outcome in terms of a person's satisfaction or dissatisfaction with their working situation (eight measures). These in turn influence the practical outcomes such as productivity, quality of work, absenteeism and staff turnover. Individuals completing the Job Diagnostic survey questionnaire take these 21 measurements. In JDS, the differences between people are not the issue. However, it is the relationship between the person and the job, which is under study. Hackman and Oldham do not try to change the person to match the job; rather they seek to change the job to match the person.

The JDS instrument uses a seven-point response scale (1 = low; 7 = high). The five job characteristics, the three critical psychological states and the affective reactions to the job and other terms measured by the JDS instrument are defined as follows:

7.3.2 Individual Measures

a) Measures of Motivating Potential

- **Skill Variety:** The degree to which a job requires a variety of different activities in carrying out the work, which involve the use of a number of skills and talents of the employee.
- **Task Identity:** The degree to which the job requires the completion of a "whole" and an identifiable piece of work – that is, doing a job from beginning to end with a visible outcome.
- **Task Significance:** The degree to which the job has a substantial impact on the lives and work of others – whether in the immediate organization or in the external environment.
- **Autonomy:** The degree to which the job provides a substantial freedom, independence and discretion to the employee in scheduling his or her work and in determining the procedures to be used in carrying it out

- **Feedback from Job itself:** The degree to which carrying out the work activities required by the job results in the employee obtaining information about the effectiveness of his or her own performance.
- **Feedback from people:** The degree to which the employee receives information about his or her performance effectiveness from supervisors and co-workers.
- **Motivating Potential Score (MPS):** A score reflecting the potential of a job for eliciting positive internal work motivation on the part of the employees. MPS is derived from the above six core job dimensions.

Motivating Potential Score (MPS) =

$$\left[\frac{\text{Skill variety} + \text{Task identity} + \text{Task significance}}{3}\right] \times (\text{Autonomy}) \times (\text{Feedback})$$

b) Measures of Growth Needs

- **Would-like Growth needs:** An individual's preference for motivational elements in his or her work.
- **Job-choice Growth Needs:** An individual's choice between different motivational elements.
- **Growth Need strength (GNS):** This scale taps the degree to which an employee has a strong versus weak desire to obtain growth satisfaction from his or her work. It is derived from the above two measures.

c) Measures of Internal Psychological States

- **Experienced Meaningfulness:** This scale is a measure of how worthwhile or important the work is to the employees.
- **Experienced Responsibility:** The scale measures the employee's beliefs that they are personally accountable for the outcomes of their efforts.
- **Knowledge of Results:** The scale measures the employee's beliefs that they can determine, on some fairly regular basis, whether the outcomes of their work are satisfactory.

d) Measures relating to outcomes and satisfaction of a motivational situation

- **General satisfaction:** An overall measure of the degree to which the employee is satisfied and happy in his or her work.
- **Growth satisfaction:** The degree to which the organization meets the need of the employees to grow and develop as people.
- **Internal Motivation:** The degree to which the employee is self-motivated to perform effectively on the job.

- **Pay satisfaction:** The degree to which the employee believes that his or her pay is equitable.
- **Job security:** The degree to which the employee feels secure in the organization.
- **Social satisfaction:** The degree to which the organization meets the needs of the employee to interact with other employees.
- **Dealing with Others:** The degree to which the job requires the employee to work closely with other people, whether other organization members or the organization's clients.
- **Supervisory Satisfaction:** The degree to which the employees are satisfied with their supervisors.

7.4 JDS MEASURES

The JDS model was used for re-designing the job characteristics in four different engine bearing manufacturing organizations. In all organizations, the initial technical know-how had been a foreign collaborative effort. Today, these organizations have adapted the original product designs and operational procedures to suit indigenous needs. Thus the manufacturing companies approached were mature in areas of technological and managerial competence. Fifty persons from the four organizations completed the Job Diagnostic Survey. The survey form and rating scores are appended at Appendix 7.1. The participants were grouped into three categories depending upon the job family they belonged to. The three categories of employees formed were (1) Production shop operators, (2) Inspectors and Quality Control Staff, and (3) Machine setters and Maintenance staff. The summary of the participants from each organization is shown in Table 7.2. Table 7.3 shows the same participants re-arranged in job families. Also included in these tables are some related statistics gathered from their biographical data. With a few exceptions, all participants had a high school education. A majority had a technical trade diploma. This advanced training is equivalent to a minimum of three to four years of education and work experience. In most cases, the participants had undergone technical training in training centres run by the organizations themselves. Thus, the participants had a fairly diversified competence with high level of training in basic job skills. The participants were mostly in the age group of 30's or 40's.

Table 7.2
Summary of Participants by Organization

	Engine Bearing manufacturing organizations				
	A	B	C	D	Total of Study
Sample size	23	17	13	16	69
Number of Groups in each organization	4	4	4	4	4
Male/Female ratio	17/6	15/2	13/0	14/2	59/10
Average Salary	8000	6250	7000	6800	7012
Average years at job	12.4	8.9	7.2	4.2	8.2

Table 7.3
Summary of participants by Job family

Job family	Production shop operators	Inspectors/ Quality control	Machine setters & Maintenance
Sample size	36	17	16
Male/Female ratio	33/3	12/5	14/2
Average salary	6900	6600	8100
Average years at job	10.9	7.3	11.4

7.5 DATA COLLECTION

All the participants were assured that their participation is voluntary, that the study was of an exploratory nature, and that respondent must be motivated to answer truthfully. All the participants were assured that their responses would be kept confidential. During the preliminary discussions, copies of the questionnaire were made available to supervisors of the participating groups. The primary purpose here was to pre-test the questions for clarity and applicability to the organization. Secondly, it gave the supervisors an opportunity to gauge the level of English level comprehension required and thus enabled them to identify and select the participants. In some instances the questionnaire was translated into Hindi for convenience of the respondents. During its administration, this translation was available to those who wished to consult it for further clarification. There was little difficulty with the use of JDS in the English language.

The employees completed the questionnaire during their regular working hours in a separate room away from their workplace. No management personnel from the organization were present during the administration of the JDS. Each group was given a briefing on the responses scale, before they began writing their answers.

7.6 MEASUREMENTS

This section contains the frequency plots for the 21 measures of the above four job families. All the measures except Motivating Potential Score (MPS) are measured with the same scale where 1 indicates the lowest response and 7 the highest. MPS is measured on a scale where 0 is the lowest value and the theoretical maximum value is 343. With core job dimensions, the higher the value of the dimension, the greater that attribute is present in the job. MPS itself is a consolidation of all six measures. With Growth Needs Strength (GNS), the higher the value the greater the person's motivational preferences.

It is the match between the GNS and MPS that is most important for the purpose of this study. Where the motivating potential of the job fails to meet the growth needs of the person then the person is being de-motivated by a lack of these key motivating factors. As a guide, for people with high growth needs, job dimensions with values of less than 5 are starting to become a problem, and values of 3 or less indicate a significant problem. Where the motivating potential of a job greatly exceeds the growth needs of a person then the very high values for job dimension indicate areas where the job is excessively demanding in motivational terms. These would typically be dimensions with values in the range of 6 to 7.

GNS is an inherent characteristic of a person, and while it may change over time it cannot be changed easily by design, unlike the motivating potential of a job. Low GNS values, 4.5 and below, indicate people who are more cautious and require jobs with lower MPS values. High GNS values, 5.5 to 6.5 indicate people who like more risk in their work that needs to be matched by jobs that offer higher motivating potential. While high GNS staff may seem preferable, i.e. low GNS staff is less, so in any organization the jobs to be performed will vary considerably in MPS. Some jobs may have naturally low MPS values that cannot be increased, e.g. 100% visual inspection jobs. Consequently it is necessary to employ staff with a range of GNS values. Many studies report that placing lower GNS people in lower MPS jobs produces a good motivational outcome in terms of productivity and quality of work.

The values of Internal psychological states (IPS) can be assessed on a more absolute scale. A well-motivated person i.e. where the MPS/GNS match is good, would be expected to have high IPS values of 5 or greater. The higher the values the better the person feels about the job. As a guide, IPS values of less than 4.5 indicate that the person does not feel good with his job, and values of less than 3 indicate a significant lack of good feeling. It has been reported that when there is a poor MPS/GNS match yet the person's IPS values are higher than would be expected. This indicates the use of coping strategies to make up for the job deficiencies. The value of satisfaction outcomes can be assessed in the same way as IPSs. A good MPS/GNS match should generate high values of 5 or more. However, some of the outcomes measured do not relate to core job dimensions, e.g pay satisfaction and job security. If these measures score low values, less than 4.5, then they represent negative de-motivating factors that reflect on an organization's environment and not on the job itself. As long as they persist the individual may under perform. When they are solved than the person will focus on the core job dimensions. As with IPSs, outcome measures can show higher than expected values due to coping strategies.

7.7 ANALYSIS OF SURVEY RESULTS

7.7.1 Analysis of survey findings for 21 measures

This section presents the analysis of the frequency plots of all the 21 measures of JDS. The analysis has been done separately for the five measures of Motivating Potential as well as measures of Growth Needs for the three different job families of Production operators, Inspectors/Quality Control Personnel and Machine setters/Maintenance personnel. The eight measures relating to the Outcomes and Satisfaction of a motivational situation have been analyzed jointly as these aspects affect one and all the same way in an organization irrespective of the area the people work in.

I) Analysis of measures of Motivating Potential for Production Operators

- **Skill Variety:**

  The jobs performed by the production operators participating in this survey show a very high skill variety. (Figure 7.1) Whilst there are some members scoring below 4, the distribution is fairly small around the high mean value. Consequently, we can say that lack of, or excessive skill variety is not a problem with production operators in an engine bearing manufacturing industry.

- **Task Identity:** Figure 7.2 shows that task identity is widely spread with a larger concentration in the 3 to 5 range. This indicates that the task identity is becoming a problem for some members of this group. Low task identity represents a job that is either defined in vague terms, or consists of very small tasks that are not a complete piece of work. High task identity represents a job that is well defined but tasks that are too large for one person to perform.

  Further analysis of the jobs where the task identity was rated as low was identified as wire brushing and washing of the bearing back just before height and inside diameter (ID) broaching. Some other jobs where task identity was rated as low were (1) Corner Chamfering of bearing, (2) Burr removal after ID broaching, and (3)

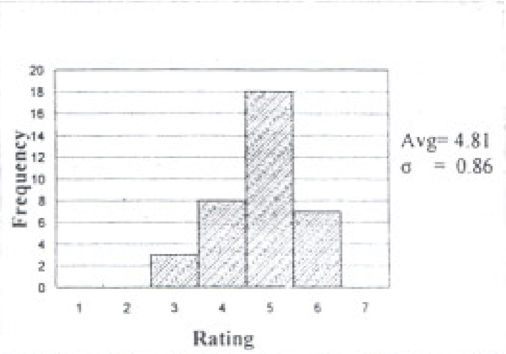


Figure 7.1 : Skill variety - Production staff

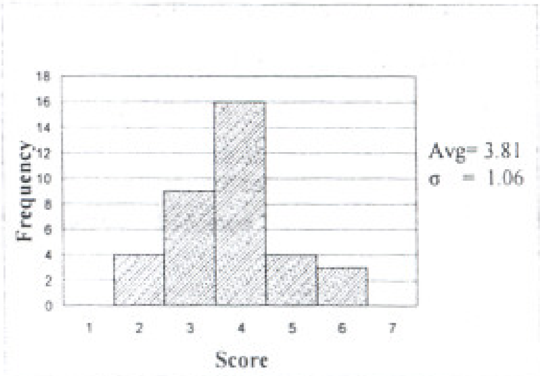


Figure 7.2: Task Identity Production Staff

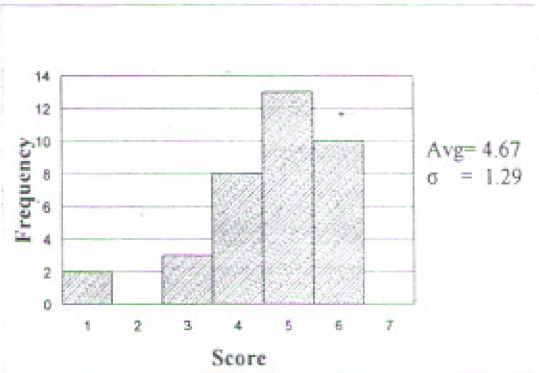


Figure 7.3: Task significance Prodn Staff

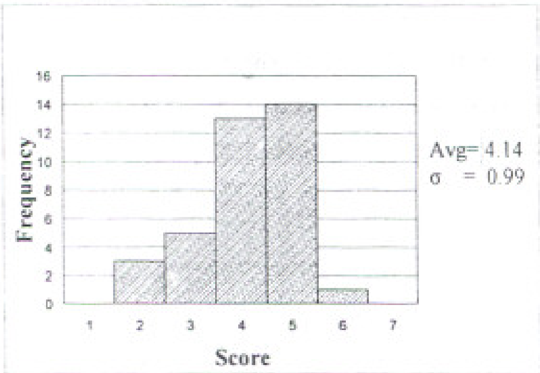


Figure 7.4: Autonomy Prodn Staff

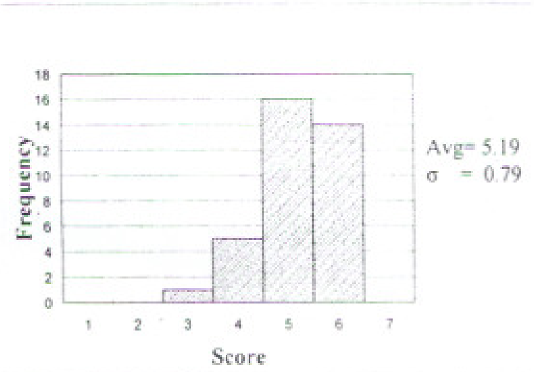


Figure 7.5: Feedback Prodn Staff

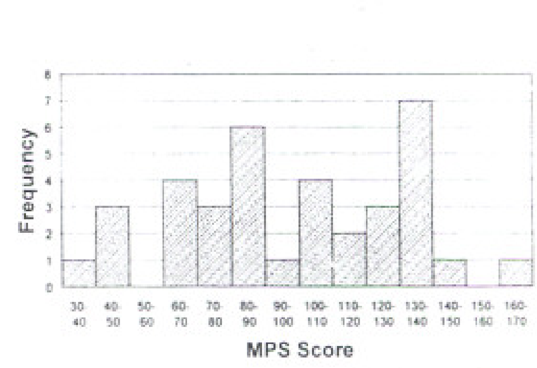


Figure 7.6 : MPS Scores - Prodn staff

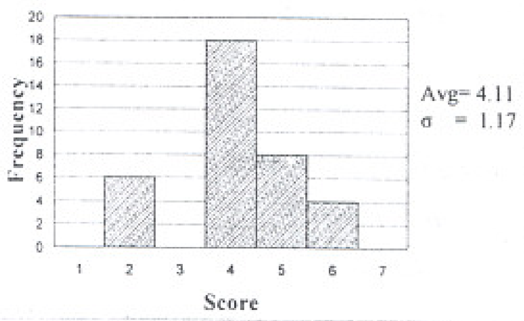


Figure 7.7: 'Would like' Prodn Staff

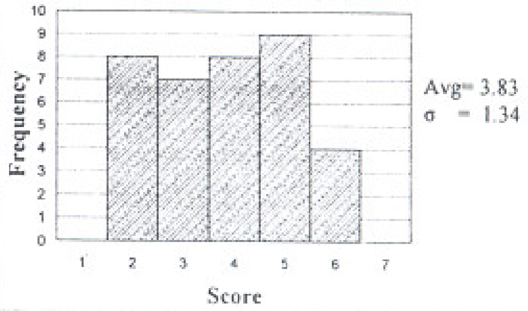


Figure 7.8: 'Job Choice' Prodn Staff

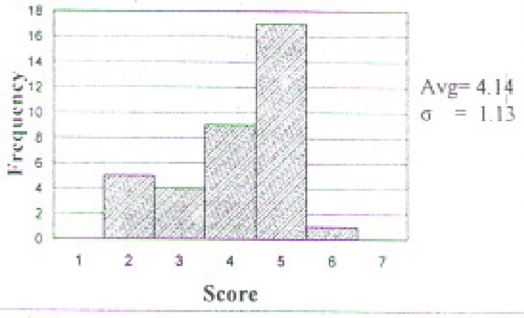


Figure 7.9: 'GNS' Prodn Staff

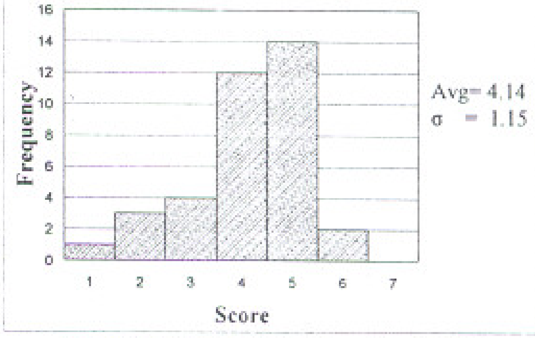


Figure 7.10: 'Exp. Meaningfulness' Prodn Staff

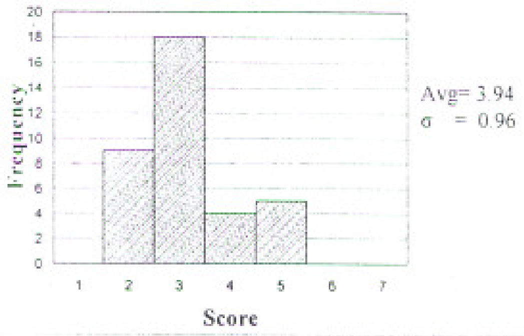


Figure 7.11: 'Exp. Responsiblity' Prodn Staff

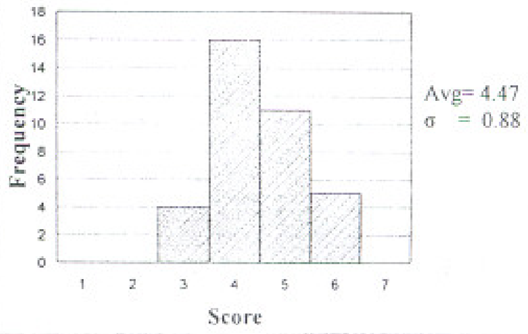


Figure 7.12: 'Knowledge of Results' Prodn Staff

Counter-sinking. These operations require negligible skill and the operators performing this task feel they are under utilized.

- **Task Significance:** There is wide spread of values indicating that low significance affects about one third of the group. (Figure 7.3) This is a significant problem for this group. A job with low task significance is one that an organization does not attach much importance to. A job with high task significance may be so critical to an organization that the person doing it feels a great deal of pressure or stress.

  A similar analysis as done for identifying the jobs with low task identity reveals that jobs such as (1) Material Handling, (2) Stacking of parts after blanking or burr removal, (3) Wire brushing and washing and (4) Corner Chamfering have low task significance.
- **Autonomy:** Figure 7.4 shows that for nearly half the group, autonomy is a significant problem. Low autonomy means that the operators perceive that the job does not provide substantial freedom, independence and discretion to the employee in scheduling his/her work and in determining the procedures to be used in carrying it out. Interviews and personal discussions with the group blame it on the supervisors who are not giving them enough freedom with regard to work methods. Discretion to schedule work has never been a strong point in most Indian organizations especially at the lowest level at which the production operators work.
- **Feedback:** Everyone needs information of some kind about how is he doing - about what he has achieved, otherwise there is no way of getting any real satisfaction from performing effectively. Performance feedback helps the jobholder to learn on the job and keep on learning. The supervisor has the main responsibility for giving feedback, but another person (eg. a co-worker) may also give it or it may result from the job itself. It is important that when feedback is given it is genuine. The feedback should also include information on the standard of their performance, the employee needs to know what their particular targets are and how they relate to the overall operation of the organization. This feedback should provide employees with an equitable capacity for ongoing learning and advancement. A job should provide an opportunity for interaction with other employees. Figure 7.5 shows that for all but a few job feedback is very high. It is the strongest in the core job dimensions for this group. Since these organizations were practicing single piece flow concept in most of the machining operations, every next station served as an internal customer for the operator and immediate feedback was available on performance and quality parameters.

- **Motivating Potential Score:** Motivating Potential Score is a consolidation of the previous five measures as listed above. As a guide people with higher growth needs would require jobs with MPS values in the range of 100 to 170. (See figure 7.6) As can be seen in the figure, the MPS values are wide spread with 50% of the jobs scoring outside this range.

  For the 22%, scoring 70 or less, the work is de-motivating. It is expected that such people may be actively seeking another role in their organizations, or even looking for a new job although probability of this is scarce because of limited number of opportunities available in India at these levels. There are no scores beyond 170, which means that none of the production jobs in such organizations are overly demanding.

- **Would-Like Growth Needs:** The would-like growth needs of this group are high, with only 19% of the people below the score of 5. (Figure 7.7) This suggests that most of the people prefer high motivational elements in their jobs.
- **Job-Choice Growth Needs:** Job-Choice growth needs of the group surveyed are relatively lower with about 64% of the people having scores less than 4. This suggests that most of these people prefer roles with less risk. (Figure 7.8) This trend seems to be recent since the opening of Indian economy, the hold of the labour unions have gradually gone down and persons at the operator level tend to prefer low risk jobs because of insecurity. The same can also be seen in figure 7.41, for assessment under Job security.
- **Growth Needs Strength:** Growth Needs Strength is an average of the previous two growth needs. This measure shows the degree to which an employee has a strong versus weak desire to obtain growth satisfaction from his or her work. (Figure 7.9)
- **Experienced Meaningfulness:** Experienced meaningfulness is related to the first three core job dimensions namely Skill variety, task identity and task significance. The distribution as shown in figure 7.10 is better than expected, given the problems with task identity and task significance. This may be due to the underlying enthusiasm of the group towards the growth of the organization, despite problems with the work itself.
- **Experienced Responsibility:** Experienced responsibility is related to autonomy, and the distribution of responses shown in figure 7.11 agrees well with that of figure 7.4 for Autonomy. Normally high experienced responsibility will be good, but with low feedback this can create problems. The scores under this measure show that the

persons believe that to an extent they are personally accountable for the outcomes of their efforts.

- **Knowledge of Results:** Knowledge of results is related to the two feedback job dimensions namely from people and from the job. The distribution of responses as shown in figure 7.12, agrees well with the results obtained for feedback under the core job dimensions measure as shown in figure 7.5.

II) Analysis of measures of Motivating Potential for Inspectors/Quality Control Operators

- **Skill Variety:** The distribution of scores for skill variety as shown in figure 7.13, shows that while for some persons the measure is very strong and for others, which are about 50%, the score is low to moderate. An analysis of the kind of jobs being undertaken by this group show that about 50% of the Quality Control Inspectors are required to carry out 100% visual inspection of all types of bearing applications for visual defects like damages or burrs etc. This particular job, along with some of the 100% dimensional checks resorted to by the companies for critical dimensions are considered to be very de-motivating and lack skill variety. Consequently, it can be said that lack of skill variety is a problem with quality roles in bearing manufacturing organizations.
- **Task Identity:** The distribution for task identity for this group is wide spread with the rating values fairly distributed over the seven-point scale. As already discussed in the previous chapter, low task identity represents a job that the operators perceive to be consisting of several small tasks that are not a complete piece of work. (Figure 7.14) Thus while those who are involved in pre-dispatch audit and inspection of parts have rated the task identity high and some others involved in 100% visual checking rate it much lower thereby indicating that task identity is a problem for these members of the group.
- **Task significance:** The average value for task significance being less than 4 indicates a significant problem of task significance for this group. (Figure 7.15) The operators feel that the companies do not attach much importance to mundane or non-productive jobs such as 100% checking and these persons often feel left out of the mainstream. On the other hand, some jobs like pre-dispatch audit and gauge calibration have a very high task significance and are so critical to the organization that the person doing it feels a great deal of pressure.

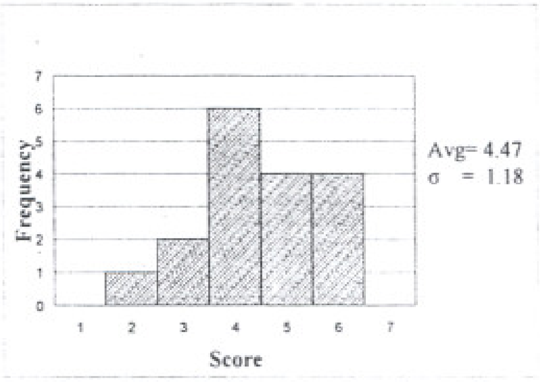


Figure 7.13 : Skill variety - Quality staff

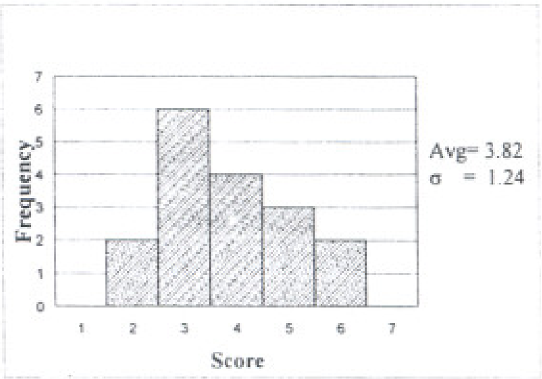


Figure 7.14 : Task Identity Quality staff

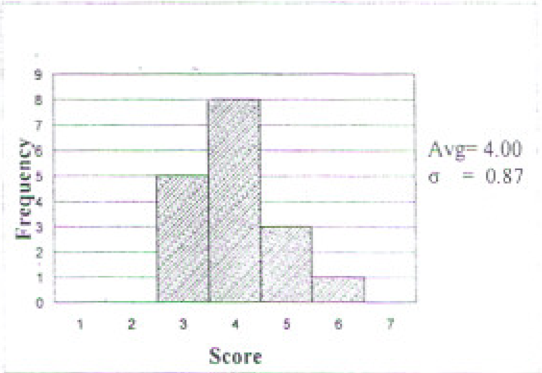


Figure 7.15 : Task significance Quality staff

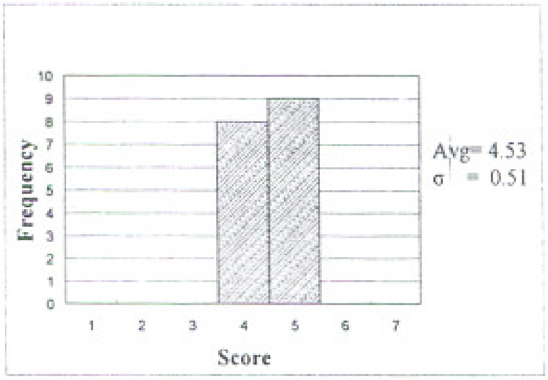


Figure 7.16 : Autonomy Quality staff

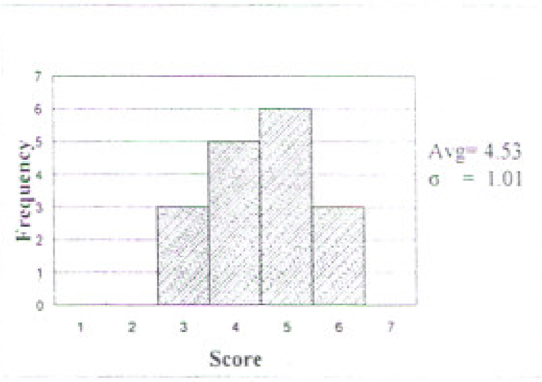


Figure 7.17 : Feedback Quality staff

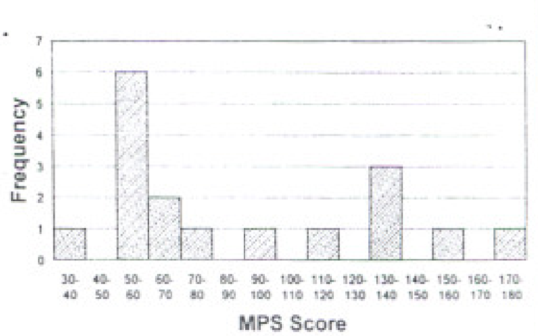


Figure 7.18 : MPS Score for Quality Staff

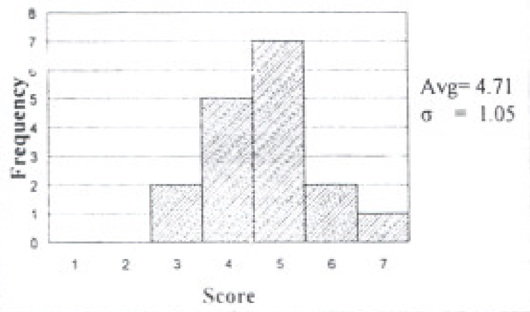


Figure 7.19 : Would Like Quality staff

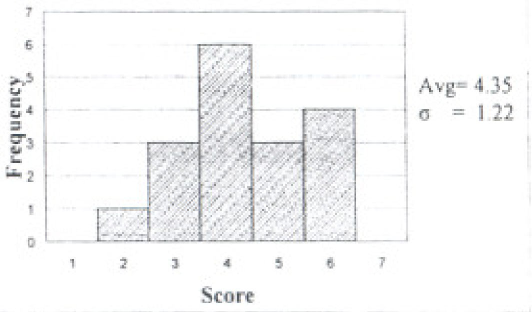


Figure 7.20 : Job Choice Quality staff

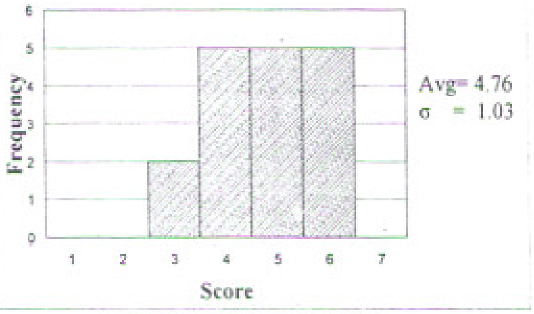


Figure 7.21 : GNS Quality staff

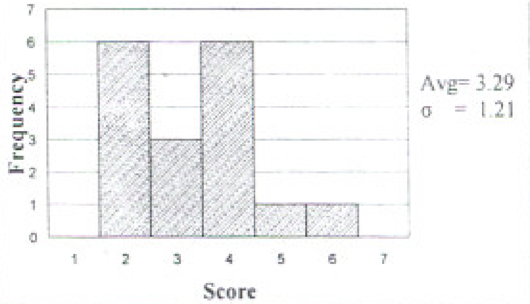


Figure 7.22 : Experienced Meaningfulness Quality staff

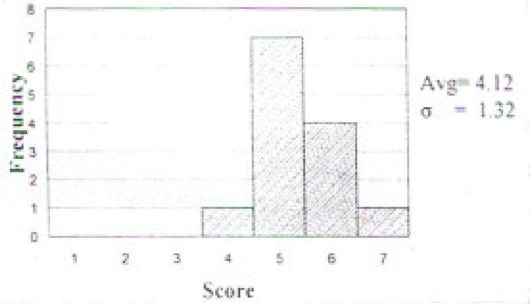


Figure 7.23 : Experienced Responsibility Quality staff

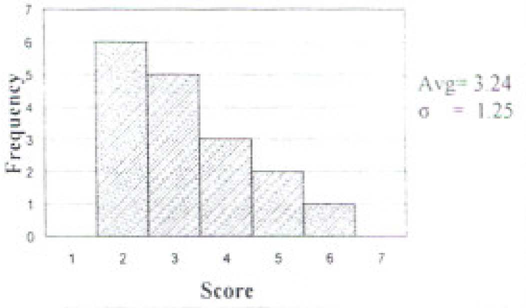


Figure 7.24 : Knowledge of Results Quality staff

- **Autonomy:** Figure 7.16 shows that for almost all, autonomy is very high in quality roles. It is the strongest of the core job dimensions for this group. However, high autonomy can be a problem for those who lack the feedback to know when they have made a sound decision. The quality operators/Inspectors have substantial freedom and discretion in scheduling their work during the day.
- **Feedback:** Figure 7.17, shows that half of the Quality Inspectors are suffering from a serious lack of feedback from the work they are performing. Some feedback is available through pre-dispatch and pre-packing audits but most of the time feedback comes directly from the customers that too in case of defective consignments. This is a very significant problem for this group. Their jobs are set so they do not contain feedback mechanisms or performance milestones within the tasks being performed. There is an apparent lack of feedback from other people, supervisors or other staff also. If quality staff is not told how well they are performing, they cannot learn where they need to improve or how they can improve. For high GNS people, which this group is, lack of people feedback is frustrating and de-motivating.
- **Motivating Potential Score:** The MPS score presented in figure 7.18 is a consolidation of the five core job characteristics. The point to note in this figure is the extreme wide spread of values with about 65% of the jobs outside the accepted values from 100 to 170.

  For the 59% scoring 80 or less the work is very de-motivating. A further analysis of the persons with low MPS score shows that a majority of these are engaged in 100% visual inspection. The remaining are also involved in routine 100% dimensional checking for critical parameters like wall thickness and crush height of parts. From this analysis, it can be concluded that quality inspectors involved in 100% inspection of parts are actively seeking other roles within the organization and many preferring roles like set-up approval inspections or pre-dispatch audit of parts or gauge calibration activities. The remaining 35% who have a good MPS/GNS match are primarily associated with auditing or calibration activities including maintenance of Quality System.
- **Would-like Growth Needs:** The would-like growth needs of this group are high as shown in figure 7.19. This indicates that most of the quality persons prefer high individual motivational elements in their jobs.
- **Job-Choice Growth Needs:** In the job-choice format, the respondents indicate their relevant preferences for pairs of hypothetical jobs. As for production operators group,

the Job-choice growth needs for this group is relatively lower than would-like, but are still high. (Figure 7.20) As a guide, it can be assumed that those scoring 4 or less prefer roles with less risk. The reasoning for this again lies in the insecurities attached with jobs of high task significance.

- **Growth Need Strength (GNS):** The GNS score is the average of the "would-like" and "job-choice" scores and is shown in figure 7.21. The distribution shows a strong desire to have growth relevant conditions present in their jobs. However, at present the Management of the four organizations participating in this survey does not seem to define a clear carrier path for its employees. The GNS score can be helpful in estimating whether people are likely to prosper on enriched jobs.
- **Experienced Meaningfulness:** The distribution of scores for this measure as shown in figure 7.22, shows a low average because of the problems with task identity and task significance for inspectors involved in 100% checking as already discussed above. Also, most of the employees in this job family have been promoted from the ranks of machinists or production operators, both of which have high MPS score compared to this job family. This job offers little or low task identity and task significance, which directly affects this measure.
- **Experienced Responsibility:** This measure is related to autonomy, and the distribution of responses shown in figure 7.23, agrees well with that of figure 7.16, for Autonomy. Normally high experienced responsibility would be good, but with low feedback this can create problems since for this group scoring on feedback has been relatively low, lower than for the other two groups we have looked at. Task significance is also low for some of the jobs under this family, so some operators, besides, not knowing HOW they are doing a job, are also not clear WHY they are doing it.
- **Knowledge of Results:** Knowledge of results is related to the last core dimension Feedback. Figure 7.24, shows a serious lack of feedback from job, the distribution, shows correspondingly similar results here as shown in figure 7.17. Perhaps Quality personnel view feedback as a measure of success. If feedback is not forthcoming they know this is a disappointing work.

III) Analysis of measures of Motivating Potential for Machine Setters/Maintenance Staff

- **Skill Variety:** The jobs performed by the employees in this group show a strong skill variety. (Figure 7.25) Although, the score for some employees is moderate, there number is low and consequently it can be safely concluded that lack of, or excessive, skill variety is not an issue with this group.

- **Task Identity:** People receive more satisfaction from doing a 'whole' piece of work. This is likely to happen when the job has a distinct beginning and end, which is clearly visible to the jobholder and others. Thus, it is important that people see the end results of the work they have produced either on their own or as a part of a team. Figure 7.26, shows that task identity for this group is widely spread which indicates that task identity is a problem for some members of the group. From personal observation and information gathered about this job family, task identity is an issue with some employees involved in routine preventive maintenance. Task identity, however, is not an issue with the Machine Setters.
- **Task Significance:** The task significance values are also wide spread indicating that low task significance values affects about one third of the group. (Figure 7.27) The analysis of the tasks reveals that task significance is a significant problem for some employees of the maintenance section in this group. A further breakdown suggests that the problem may be confined to employees handling routine breakdowns during the shift.
- **Autonomy:** This goes hand in hand with responsibility. Autonomy means giving more scope to people to regulate and control their own work. The jobholder ought to have some areas of decision-making that they can call their own within the framework of their job. Figure 7.28 shows that for all employees in this group autonomy is very high. It is one of the strongest core job dimensions for this group.
- **Feedback:** Feedback is another strong core job dimension for this group. The nature of jobs itself contain an inbuilt feedback mechanisms or performance milestones. Consequently, we can conclude that feedback is not a problem with group in general. (Figure 7.29)
- **Motivating Potential Score:** The motivating potential score for this group shows the best results compared to the scores of the other two groups. (Figure 7.30) Since there are no scores less than 80, it can be concluded that the work is motivating for all the employees in this group. Also, none of the scores are more than 180, which signifies that none of the tasks carried out by this group is overly demanding. However, it must be noted here that 37% of the employees in this group are between a score of 80 to 100, which is considered low although it is not a very significant

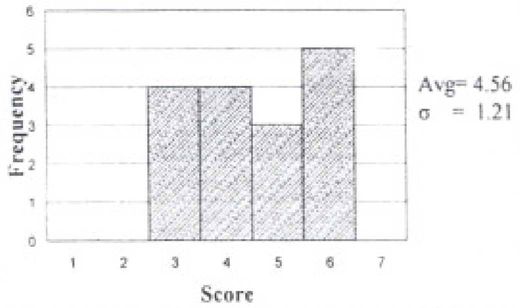


Figure 7.25 : Skill variety - Machine setters

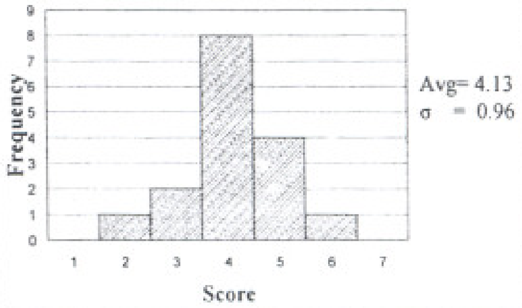


Figure 7.26 : Task Identity - Machine setters

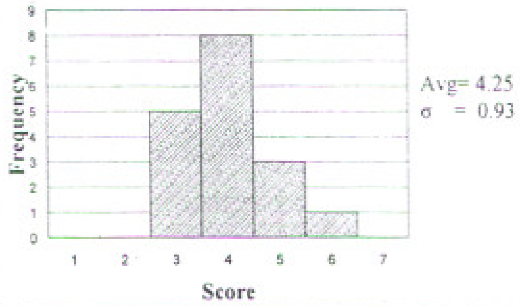


Figure 7.27 : Task Significance - Machine setters

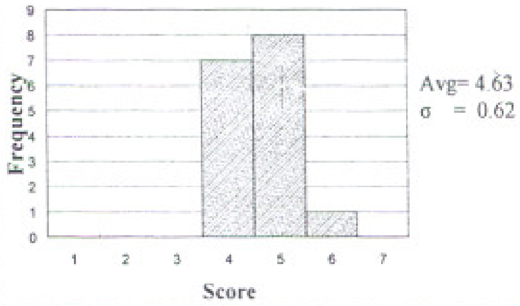


Figure 7.28 : Autonomy - Machine setters

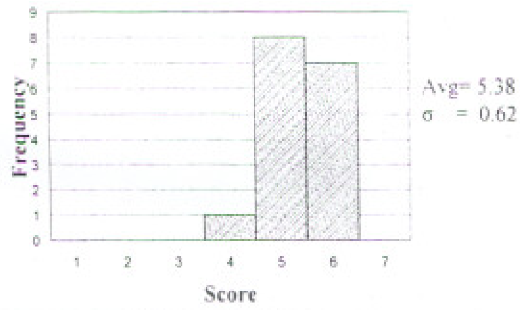


Figure 7.29 : Feedback - Machine setters

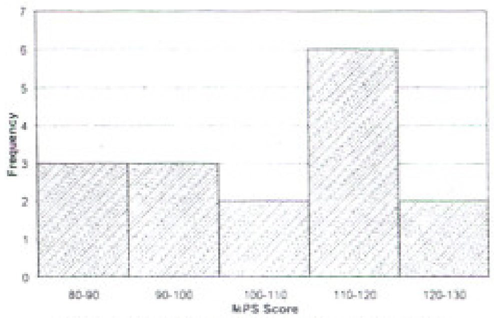


Figure 7.30 : MPS Scores for Maintenace staff and setters

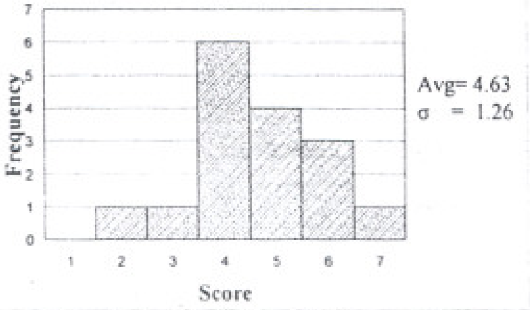


Figure 7.31 : Would Like - Machine setters

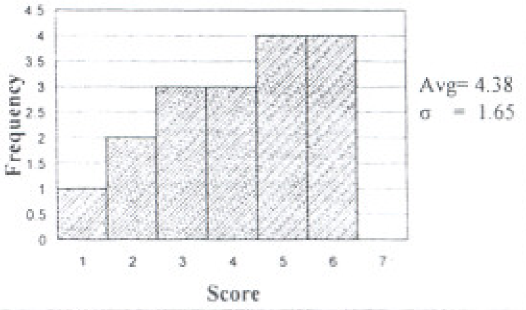


Figure 7.32 : Job Choice - Machine setters

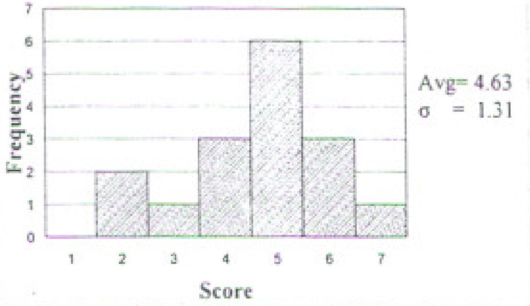


Figure 7.33: GNS - Machine setters

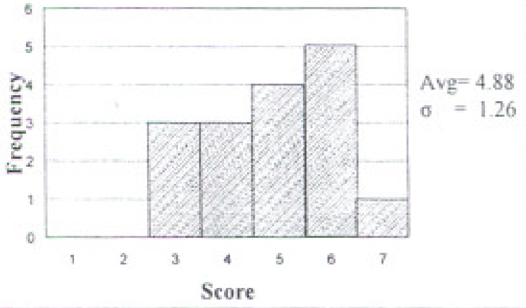


Figure 7.34: Experienced Meaningfulness Machine setters

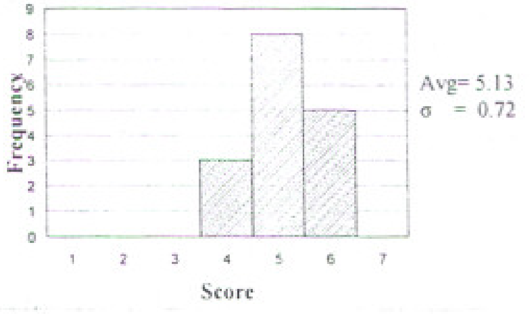


Figure 7.35 : Experienced Responsibility - Machine setters

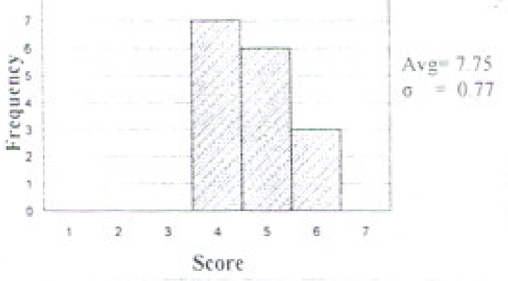


Figure 7.36 : Knowledge of Results - Machine setters

problem. A relative comparison within the three groups show that MPS values for Maintenance staff and Machine Setters is the highest.

- **Would-Like Growth Needs:** This group indicates a moderate to strong desire to have growth relevant conditions present in their jobs as indicated by the GNS scores for would-like choice. (Figure 7.31) At present there is not a clear path defined by the management of these organizations. Furthermore, there are no organized programmes of Job design, which build in motivators. Job promotion in most instances is based on seniority to a limited supervisory positions and at times act as de-motivator.
- **Job-Choice Growth Needs:** Job Choice growth needs are lower in comparison to Would-like growth needs, which indicate that many employees in this group prefer roles with low risk. (Figure 7.32) The explanation for this is similar to the one presented under this measure for production operators group.
- **Growth Need Strength:** Growth need strength is the average of the previous two growth needs. As can be seen in figure 7.33, nearly half of the maintenance and machine-setters staff has high growth needs of 4 and above with a small number outside this band.
- **Experienced Meaningfulness:** Experienced meaningfulness is related to the first three core job dimensions. This distribution, as shown in figure 7.34, is better than expected given some problems with task identity for the preventive and breakdown maintenance staff. This result also points to the underlying enthusiasm of this group towards the importance of their tasks, despite some problems with the job itself.
- **Experienced Responsibility:** People need to feel responsible for a significant part of the work they are doing, either individually or as part of a team. Their work should be clearly identified so they can see that they are personally responsible for the successes and failures that occur as a result of their own actions. The employee should understand the significance of the work and where it fits into the purpose of the organization. Experienced responsibility is related to autonomy, and the distribution of responses shown in figure 7.35, matches with the distribution of responses for autonomy shown in figure 7.28.
- **Knowledge of Results:** Knowledge of results is related to feedback, and the distribution of responses shown in figure 7.36, matches with the distribution of responses for feedback shown in figure 7.29. Thus it can be concluded that experienced responsibility and knowledge of results is not a problem for this group.

7.7.2 Consolidating a view for the other 8 measures relating to the Outcomes and Satisfaction of a motivational situation

These measures as already described above have been analyzed jointly for all the three as these aspects affect one and all the same way in an organization irrespective of the area the people work in. The data presented below is for all the 69 respondents analyzed together.

- **General Satisfaction:** This represents an overall measure of degree to which the employee is satisfied and happy in his or her work. As can be seen for the distribution plot of the scores, 60% of the combined group of three families shows a high growth satisfaction in the range of 4 to 7. (Figure 7.37). Considering the problems identified with the core job dimensions and other measures, this distribution indicates that the group is bearing up quite well despite some problem with motivating potential of their jobs.
- **Growth Satisfaction:** This measure is generally good for the combined group, again indicating that despite the other issues identified, employees feel that their work offers significant potential for personal growth. (Figure 7.38)
- **Internal Motivation:** Internal motivation shows high value for the combined group. Two-third of the scores are in the range from 4 to 6, with a small percentage outside this range. This measure is perhaps the clearest indication of the feelings the group has about the importance of their work. (See figure 7.39)
- **Pay satisfaction:** This measure shows the degree to which the employees believe that his or her pay is equitable. The widely distributed scores in figure 7.40, shows that pay is clearly an area of dissatisfaction for nearly half of the combined three groups. For one-third of the group, scoring less than 3, pay is a major de-motivating factor. Pay is an important way in which an organization indicates the value on an individual's work. This figure also highlights the differing views between individuals and their organizations on the value of their work.
- **Job Security:** Perceived threat of job security is the most serious problem facing this group, with about two-thirds highlighting concerns from moderate concern to extreme worry. The insecurity is more prevalent in the employees of the Quality Function, which indicates that they believe that their jobs are the first in line should there be redundancies in the organization at any given point of time. This reflects the lack of support they feel from the senior management. (Figure 7.41)

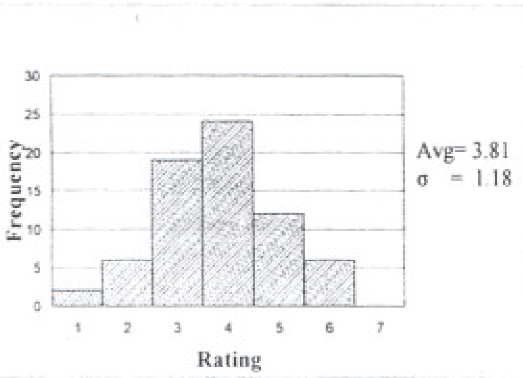


Figure 7.37 : General Satisfaction - All staff

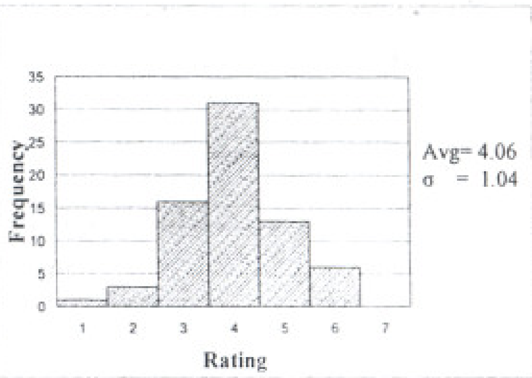


Figure 7.38 : Growth Sati-faction - All staff

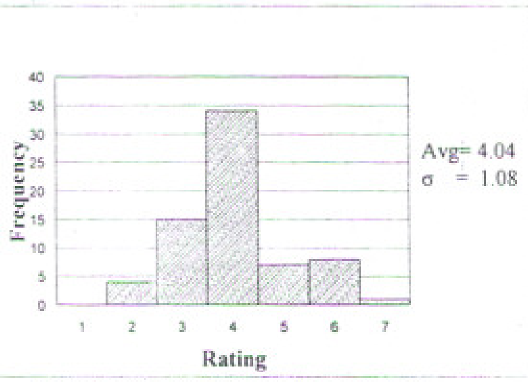


Figure 7.39 : Internal Motivation - All staff

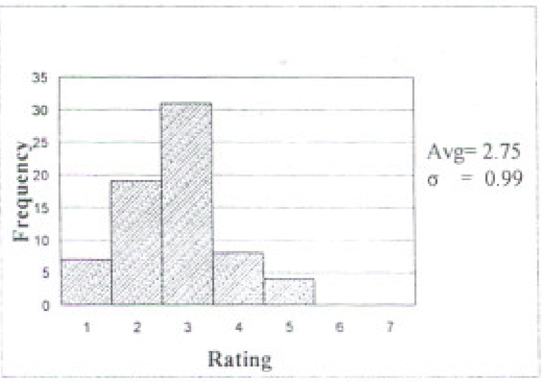


Figure 7.40 : Pay satisfaction - All staff

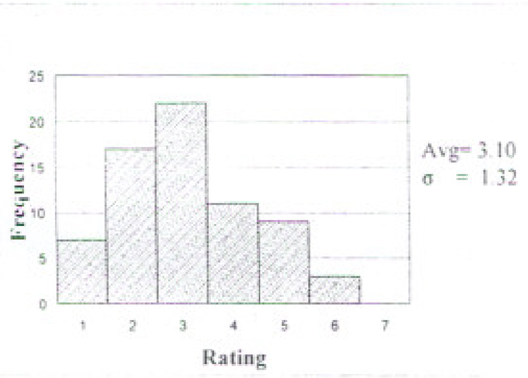


Figure 7.41 : Job Security - All staff

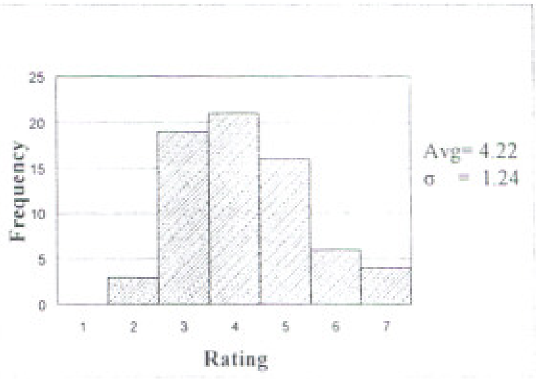
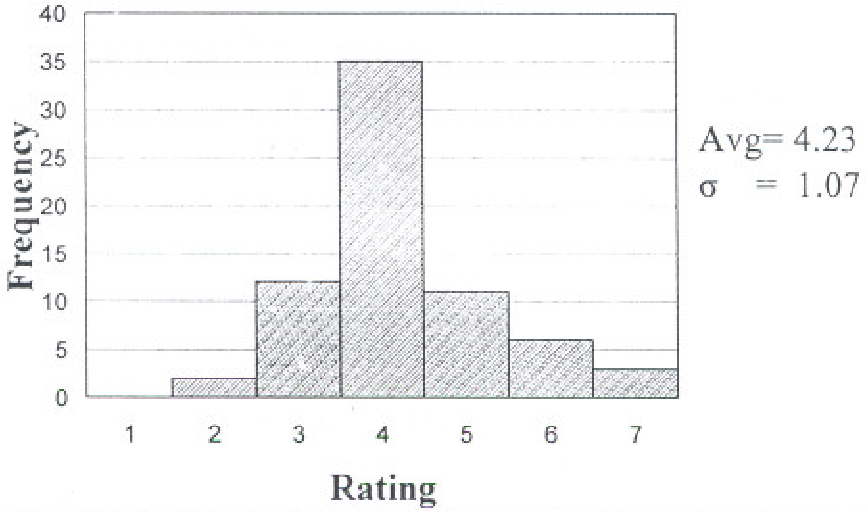
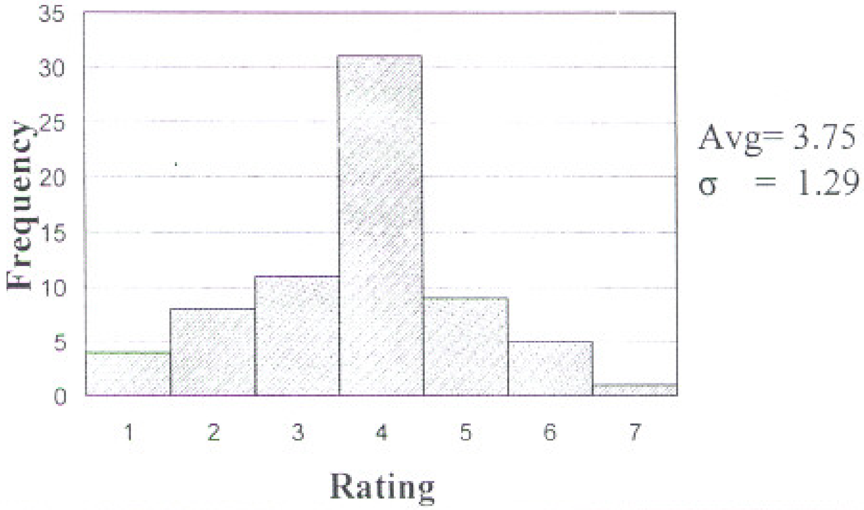


Figure 7.42 : Social Security - All staff



Avg= 4.23
σ = 1.07

Figure 7.43 : Dealing with others - All staff



Avg= 3.75
σ = 1.29

Figure 7.44 : Supervisory satisfaction - All staff

- **Social Satisfaction:** As can be seen in figure 7.42, social satisfaction is generally high within the group, indicating that employees work with other people with whom they can establish good social relationships.
- **Dealing with others:** Figure 7.43 shows that the groups are very satisfied with their professional dealings with other staff.
- **Supervisory Satisfaction:** Half of the group shows dissatisfaction with their supervisors, with many very dissatisfied. This contrasts sharply with the degree of satisfaction that the group shows both socially and in professional dealings with others. The figure 7.44 supports the view that poor feedback, low pay and poor job security are related to the degree of supervisory support (or lack of it) they receive.

7.8 PROBLEMS WITH JOB-PERSON MATCH

A key concept behind the Job Characteristic Model of Motivation is that for a person to be well motivated their Growth Needs (GNS) should be in balance with the Motivating Potential Score (MPS) of their job. The degree to which they are in balance is known as job-person match. As the ideal relationship between MPS and GNS is known, an attempt is made in this work to look at the actual relationship for every participant in the survey. One of the following three cases may result:

- **Case 1:** Match of MPS and GNS is good, indicating that the person is well motivated. All participants with MPS score of 100 to 170 and GNS from 4.5 to 6 will fall in this group.
- **Case 2:** The person is de-motivated because the job lacks the motivational content they need. All participants with MPS score of less than 100 and GNS either less than 4.5 or greater than 6 will fall in this group.
- **Case 3:** The person is de-motivated because the job has too high a motivational content. All participants with MPS score of greater than 170 and GNS either less than 4.5 or greater than 6 will fall in this group.

The average responses for each of the 21 variables measured by JDS are summarized in Table 7.4.

Table: 7.4

JDS Measured by Job families

Measure – Average rating on a scale of 1-7	Production Operators	Inspectors/ Quality Staff	Maintenance Staff/ M/c setters	Average
Skill Variety	4.81	4.47	4.56	4.61
Task Identity	3.81	3.82	4.13	3.92
Task Significance	4.67	4.00	4.25	4.31
Autonomy	4.14	4.53	4.63	4.43
Feedback from Job	5.19	4.53	5.38	5.03
MPS	96	88	106	96.67
Growth 'would-like'	4.11	4.71	4.63	4.48
Growth 'Job-Choice'	3.83	4.35	4.38	4.19
GNS	4.14	4.76	4.63	4.51
Experienced Meaningfulness	4.14	3.29	4.88	4.10
Experienced Responsibility	3.94	4.12	5.13	4.40
Knowledge of Results	4.47	3.24	4.75	4.15
General Satisfaction				3.81
Growth Satisfaction				4.06
Internal Motivation				4.04
Pay Satisfaction				2.75
Job Security				3.10
Social Security				4.22
Dealing with others				4.23
Supervisory satisfaction				3.75

7.8.1 Methods of Re-design of Tasks with poor MPS/GNS Match

There are four methods of job design and re-design reported in the literature.

The first, **job enlargement**, can be used to increase motivation by giving employee's more and varied tasks. Tasks that reduce the amount of specialization required by the employee, as well as, extending the length of time he or she has to complete them.

The second, **job rotation**, allows an employee to work in different departments or jobs in an organization to gain better insight into operations. This, in itself, does not modify or redesigns the employee's job, but allows the opportunity to increase his/her skills and knowledge about other jobs.

Job enrichment, the third method, allows the employee to take on some responsibilities normally delegated to management. The risk here is that the employee would be transferred too much responsibility and autonomy in the planning and control aspects of the job. Done right, however, the new found control would invigorate the employee to work more effectively.

Lastly, **work simplification** is the analysis of a job's most basic components to restructure or redesign them to make the job more efficient.

Additional aspects that can be considered when analyzing and (re)-designing a job are the policies, incentives, and feedback that inevitably affect the efficiency and motivation of the employee responsible to the job.

7.8.2 Job-person match for Production operators

Case 1: The ideal match. Approximately 50% of the participants are in this category.

Case II: Low motivating potential for approximately 20% of the participants and significantly low motivating potential for the rest 30% of the participants.

Case III: None of the participant fall in this category, which means none of the jobs have too high, motivating potential.

Thus, it can be concluded that Job-person match for the production operators in engine bearing manufacturing organizations is poor for about 50% of the people. Even if the marginal cases (those having MPS score between 80 to 100 and GNS score between 4.5 to 6) are ignored, there are still about 30% people who may have significant motivational problems. (Table 7.5)

Historically, the major problem with jobs in production was they lack the motivating potential to satisfy high growth needs people. From personal interviews and observations in the shop floor, the reasons for low motivating potential in some jobs were identified. Such jobs include tasks like Countersinking on ID and OD of the bearing, wire brushing and washing operations prior to height broaching, manual material handling tasks and some highly repetitive tasks such as hole punching. All these jobs are viewed as routine, unchallenging, too small or insignificant, highly repetitive that lacked motivational stimuli.

Table 7.5
Production Operator Scores

Operator No.	Skill Variety A	Task Identity B	Task significance C	Autonomy D	Feedback E	MPS		Would like F	Job choice G	GNS (F+G)/2
						(A+B+C)/3	(A+B+C)/3xDxE			
1	3	4	5	3	4	4	48	2	2	2.0
2	5	4	1	5	5	3.3	83	5	5	5.0
3	5	5	6	5	5	5.3	133	4	6	5.0
4	6	3	3	5	4	4.0	80	5	5	5.0
5	3	3	5	4	5	3.7	73	2	2	2.0
6	4	2	4	4	5	3.3	67	4	3	3.5
7	5	3	5	4	5	4.3	87	5	5	5.0
8	3	4	6	5	6	4.3	130	4	2	3.0
9	6	5	4	4	4	5.0	80	5	5	5.0
10	5	2	5	3	5	4.0	60	2	2	2.0
11	4	3	4	5	4	3.7	73	2	2	2.0
12	5	4	6	5	5	5.0	125	4	5	4.5
13	5	4	6	5	5	5.0	125	4	5	4.5
14	5	3	5	4	6	4.3	104	4	3	3.5
15	6	2	3	2	6	3.7	44	2	4	3.0
16	4	4	5	3	5	4.3	65	4	2	3.0
17	5	3	6	5	5	4.7	117	4	6	5.0
18	5	4	6	2	3	5.0	30	2	2	2.0
19	4	5	4	5	6	4.3	130	5	4	4.5
20	5	3	5	5	6	4.3	130	5	4	4.5
21	5	4	3	5	5	4.0	100	4	4	4.0
22	4	4	5	4	6	4.3	104	4	3	3.5
23	6	3	6	2	4	5.0	40	4	3	3.5
24	5	4	4	6	5	4.3	130	4	6	5.0
25	5	2	5	3	5	4.0	60	4	3	3.5
26	6	5	5	4	6	5.3	128	5	5	5.0
27	4	4	6	4	5	4.7	93	4	3	3.5
28	4	4	5	4	6	4.3	104	4	6	5.0
29	5	4	4	5	6	4.3	130	5	5	5.0
30	6	6	5	4	5	5.7	113	6	4	5.0
31	4	3	6	3	6	4.3	78	4	2	3.0
32	5	4	1	4	6	3.3	80	4	4	4.0
33	5	4	5	5	6	4.7	140	6	5	5.5
34	6	6	4	5	6	5.3	160	6	4	5.0
35	5	6	6	4	6	5.7	136	6	4	5.0
36	5	4	4	4	5	4.3	87	4	3	3.5

In order to find out whether the organizations are making positive efforts to match jobs to individuals, scatter plot between the MPS and GNS values was generated and examined for any relationship between the two. In case a relationship is established, this will provide evidence that job design is being practiced. Figure 7.45, shows the distribution of MPS/GNS for the 36 participants from amongst the production operators. Analysis shows that there is no relationship. Thus the existing Job-Person match is random. The present job design or lack of it has been based on the use of best practice guides made available by the technical collaborators. These guides help organizations define the jobs that need to be done whenever any technological know-how is acquired. These guidelines also specify the content and the skills and experiences required. While all these make an important contribution, they were not written to address the dynamics of motivation. This provides a clue as to why there is such poor job-person match.

7.8.3 Identification of Jobs Needing Re-Design in the Production Shop

i) Problems with task identity and task significance:

As already discussed in previous sections, task identity and task significance is very low for some individuals amongst the production staff. So even if the average of some of the measures may seem to be acceptable, the results cannot be used to predict the situation of an individual operator. Thus, it is necessary to identify some of these tasks with low significance and identity and suggest certain controls. So, the averages and standard deviation for each of the 21 measures can be used to alert us about problems, which are common enough for the organization to worry about first. The simplest method used to suggest controls while redesigning jobs was personal interaction or discussions with the respondents. The discussions had been highly productive, but there were some problems like:

- The respondents concentrated on complaints, with very little emphasis on solutions
- Some respondents concentrated to allocating blame, within the group or beyond
- Some respondents were unwilling to discuss motivational issues

Thus, the people who are closest to the problems suggested approaches to solve the problem, which are more effective for their circumstances.

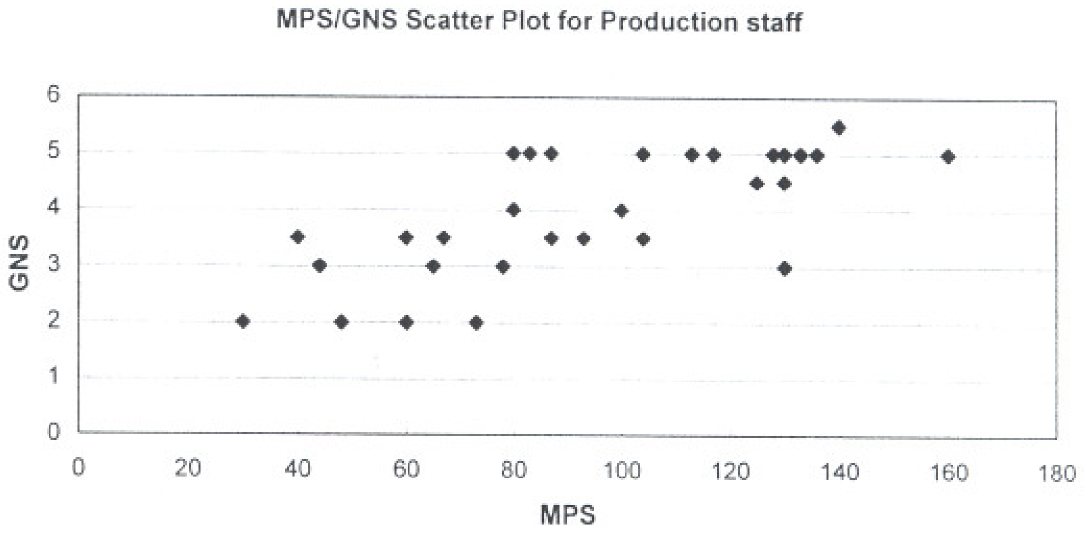


Figure 7.45: MPS/GNS Scatter Plot for Production Staff

ii) Problems with task identity, task significance:

As discussed above the jobs, which had low task significance or task identity, were identified and were taken up first for redesigning. The tasks identified are:

- Counter-Sinking of punched holes both on ID and OD of bearings
- Wire brushing and washing of bearings before ID and Height broaching
- Some manual material handling tasks

Cause and Effect Diagram

A Cause & Effect Diagram was developed to examine the factors that are contributing to the problem. The Cause-and-Effect Diagram, (Figure 7.46) was developed through four steps, namely:

1. Identify the problem's characteristics
2. Brainstorm the reasons why the problem is occurring using a Causal Table (also known as the Why-Because Technique)
3. Group the causes by relationship
4. Create a Cause-and-Effect Diagram

The causes are grouped under the following headings:(1) Policy, (2) Operator, (3) Machine, (4) Methods/procedures, (5) Environment, and (6) Measurement

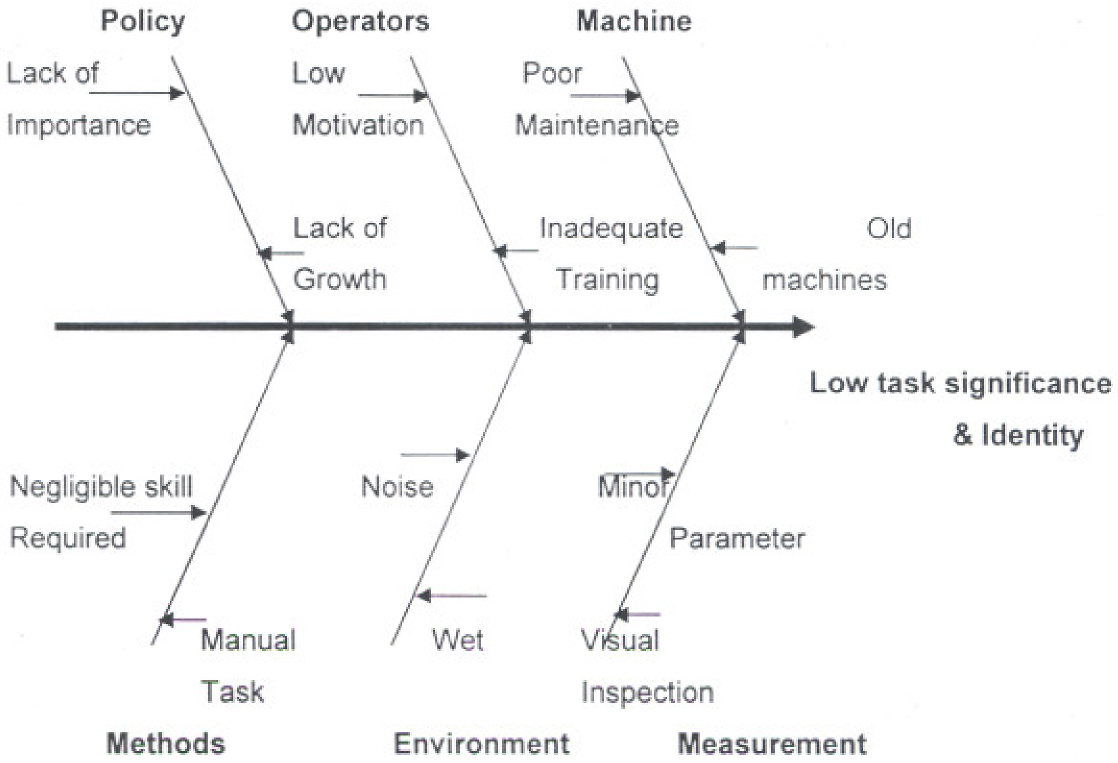


Figure 7.46: Cause and Effect Diagram for production tasks

Figure 7.46 makes it easy to see the many possible root causes of the issues that may be leading to low task significance and task identity. Looking over all the list of causes created in the Cause-and-Effect Diagram, it was decided to gather some more data on the frequency of the different possible causes. A sample of 23 operators of the production line was interviewed to determine which of the possible causes happen most frequently. The results of the survey are presented in Table 7.6.

Pareto Analysis

The Pareto Principle states that focusing on solving the most frequently occurring causes can solve a problem more efficiently and economically. As can be seen in Table 7.6, the top three causes lead to 78% of the problems. These are the "vital few" causes. (Table 7.7)

Table 7.6

Frequency of occurrence of causes of low task significance for production operators

Low task significance causes in production jobs	Frequency
Lack of Importance	6
Lack of Growth	1
Low Motivation of employees	1
Inadequate Training	-
Poor Maintenance	2
Old Machines	8
Negligible Skills required	4
Manual Task	1
Noise	-
Wet	-
Minor parameter	-
Visual Inspection	-

Table: 7.7

Possible causes of low task significance and identity in production tasks

Possible causes of low task significance and task identity	Percentage of total
Manual task whereas there is a considerable amount of automation on the other tasks in the line	35%
Company does not attach importance to these jobs resulting in inadequate growth opportunities for employees	26%
These jobs require negligible skill and anybody can do it with little on the job training	17%
Others	14%

Re-Design of selected Production tasks

Thus, looking at the causes as listed in Table 7.7, that are contributing to the problems with these tasks the following controls have been recommended:

Cause: Manual task whereas there is a considerable amount of automation on the other tasks in the line

Controls Suggested/Implemented: The most contributing factor has been the manual nature of wire brushing and countersinking tasks. Thus, it has been suggested that that the two tasks of wire brushing/ washing and the countersinking be combined so as the operator has to feed the parts only once. For this to be done, considerable amount of automation needs to be incorporated into the design of the machines and will need a good transfer mechanism by which the parts will first be counter-sunk and then transferred through an automated transfer mechanism to washing and wire brush section. Such an arrangement will reduce the requirement of at least one operator and also enlarge the job with fair bit of automation. The setting of transfer mechanisms and specialized tools will induce requirement of reasonable level of skill, which may be helpful in improving the task identity.

Benefits accrued or expected: Although the suggestion has not yet been implemented on the production line, the benefits can clearly be visualized and the expected productivity improvement is shown in Table 7.8:

Table: 7.8

Likely productivity Improvement on production jobs

Operation	Number of operators		Cycle time for one part (Mins)		Output per shift		Absenteeism rate	
	Before	After	Before	After	Before	After	Before	After
Counter-Sinking	**2**	**1**	**0.026**	**0.020**	**4500**	**6000**	**24%**	**7%**
Wire brushing and Washing			**0.018**		**7000**		**21%**	

Note: Data shown under 'before' is from "as is" process whereas the data under 'after' is as anticipated.

iii) Problems with Autonomy

The average score for autonomy on production jobs is 4.19 although there are a few jobs where the respondents have reported a lack of autonomy in the performance of jobs. Most of these jobs have been those where the companies feel that the control of specifications is of utmost importance. (Critical parameters like height broaching, wall thickness broaching and electroplating) The companies have deployed inspectors for control of these specifications who fill up observations on the SPC control charts and provide periodic feedback about the quality performance. The operators are not allowed to start production of parts till the in-process inspection staff has not granted a set-up approval on about five parts. The machine operators have been provided little or no training on filling up of control charts and also how to read them and make conclusions. This has resulted in waiting time and also poor autonomy on these jobs.

The following controls have been recommended:

Promoting use of SPC by line operators: Training of all operators on Statistical Process Control (SPC)/ Statistical Quality Control (SQC) and gradually removing the in-process line inspectors so as to build in quality during manufacturing. As reported by the line staff, currently there is a tendency to shift the blame on each other between the operators and the line inspectors. In order to ensure that quality is in-built into the parts, this step needs to be urgently implemented. However, adequate training of operators is absolutely essential before making the recommended changes. It is anticipated that this change as and when implemented will improve the autonomy scores on these jobs. Also, the production operators will have more variety in their jobs.

7.8.4 Job-person match for Inspectors and Quality Control Staff

Case 1: The ideal match. Approximately 41% of the participants are in this category.

Case II: Low motivating potential for approximately 59% of the participants and no participant has significantly low motivating potential.

Case III: None of the participant fall in this category, which means none of the jobs have too high, motivating potential. (Table 7.9)

Table 7.9
Quality Inspectors Scores

Operator	Skill Variety	Task Identity	Task significance	Autonomy	Feedback	MPS		Would like	Job choice	GNS
No.	A	B	C	D	E	(A+B+C)/3	(A+B+C)/3xDxE	F	G	(F+G)/2
1	3	3	3	4	3	3.0	36	3	2	2.5
2	4	4	3	4	4	3.7	59	3	3	3.0
3	2	2	4	5	4	2.7	53	4	4	4.0
4	4	3	3	5	3	3.3	50	4	4	4.0
5	5	4	4	4	4	4.3	69	4	4	4.0
6	5	4	4	4	4	4.3	69	5	4	4.5
7	3	2	3	4	5	2.7	53	4	3	3.5
8	4	3	4	5	6	3.7	110	5	5	5.0
9	6	6	6	5	5	6.0	150	5	5	5.0
10	6	6	5	5	6	5.7	170	6	6	6.0
11	5	3	3	4	4	3.7	59	4	3	3.5
12	4	3	4	4	5	3.7	73	5	5	5.0
13	5	4	4	5	6	4.3	130	5	6	5.5
14	4	5	4	4	3	4.3	52	5	6	5.5
15	6	5	5	5	5	5.3	133	6	6	6.0
16	4	3	4	5	5	3.7	92	5	4	4.5
17	6	5	5	5	5	5.3	133	7	4	5.5

Thus it is concluded that Job-person match for the Quality Staff and Inspectors in engine bearing manufacturing organizations is poor for about 59% of the people, and the problem is very acute for those whose MPS score is less than 80. From personal interviews and observations in the shop floor, the reasons for low motivating potential in some tasks were identified. Such jobs include jobs like 100% visual inspection as well as

100% dimensional checks for critical parameters. All these jobs are viewed as routine, unchallenging, too small or insignificant, highly repetitive that lacked motivational stimuli.

Figure 7.47, shows the distribution of MPS/GNS for the 17 participants from amongst the Quality Staff. Analysis shows that there is no relationship. Thus the existing Job-Person match is random. Just like jobs of production operators, the present job design or lack of it has been based on the use of best practice guides made available by the technical collaborators. As discussed for the production staff, that while all these makes an important contribution, they were not written to address the dynamics of motivation. This provides a clue as to why there is such poor job-person match.

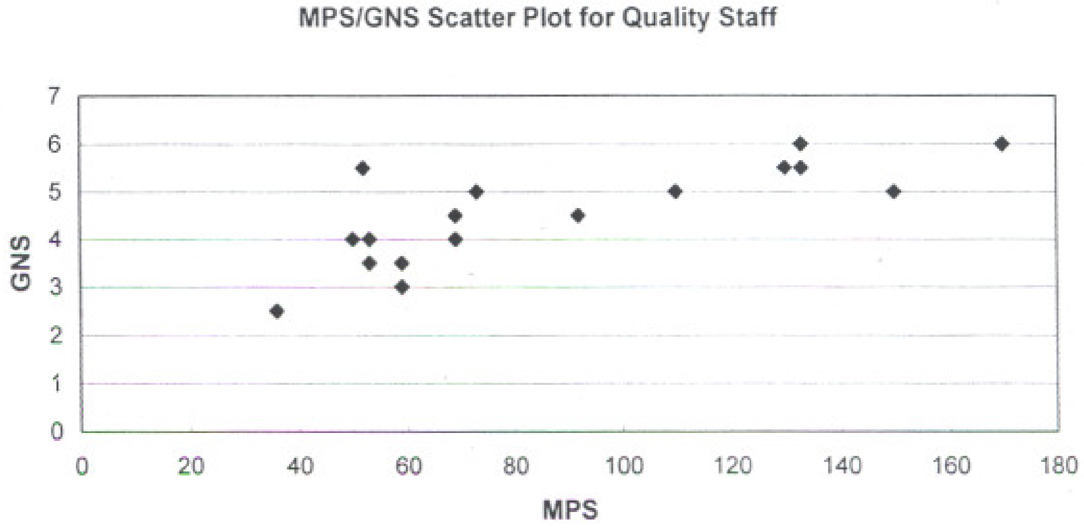


Figure 7.47: MPS/GNS Scatter Plot for Quality Staff

Identification of jobs needing re-design in the Quality Functions:

Problems with Low Motivating Potential Score:

The distribution of scores for MPS shows that nearly one third of the respondents had significant problems. An analysis of the kind of jobs being undertaken by this group show that about 50% of the Quality Control Inspectors are required to carry out 100% visual inspection of all types of bearing applications for visual defects like damages or burrs etc. This particular job, along with some of the 100% dimensional checks resorted to by the companies for critical dimensions are considered to be de-motivating and thus lacks motivation for the employees leading to low MPS score.

Cause and Effect Diagram:

A Cause & Effect Diagram was developed to examine the factors that are contributing to the problem. (Figure 7.48)

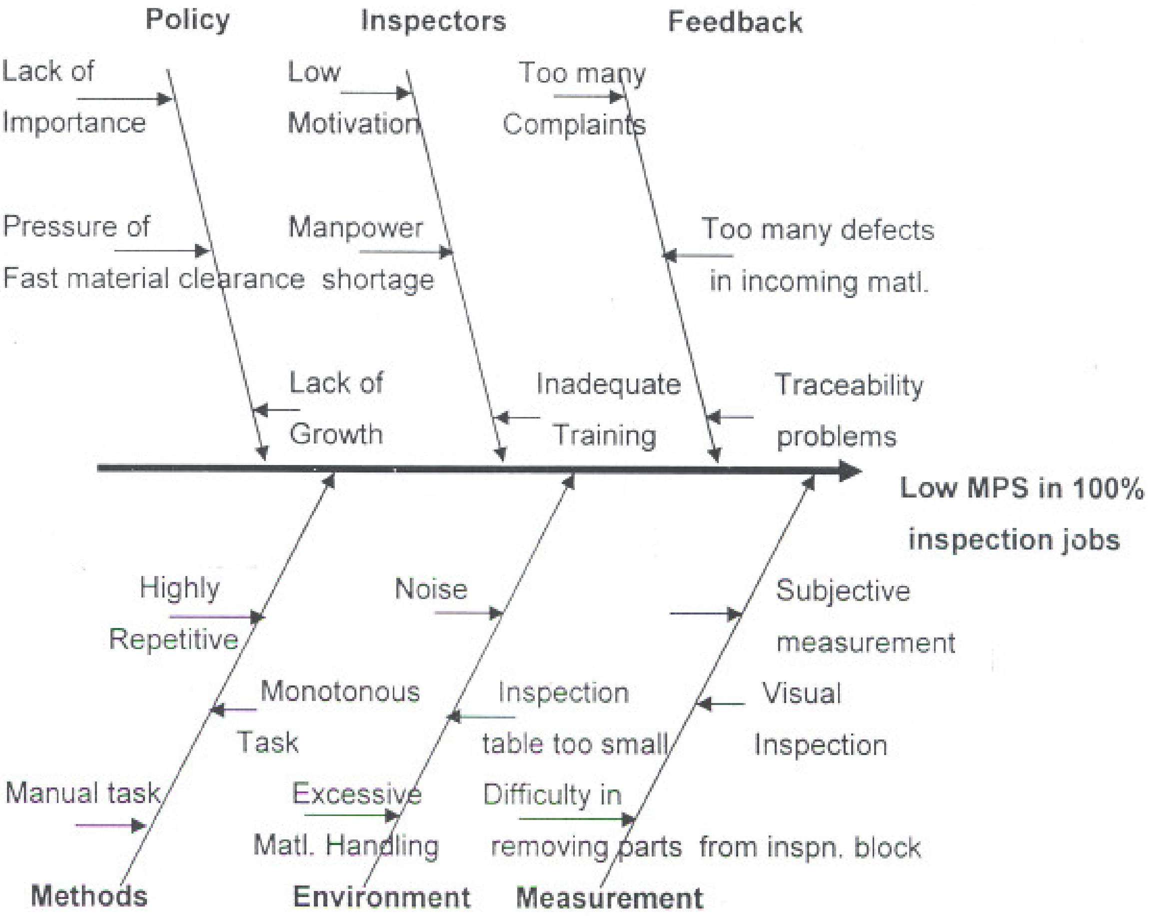


Figure: 7.48: Cause and Effect Diagram for Quality inspectors

Pareto Analysis

Figure 7.48 makes it easy to see the many possible root causes of the issues that may be leading to low MPS in 100% inspection jobs. By looking at the list of causes created in the Cause-and-Effect Diagram, it was decided to gather some more data on the frequency of the different possible causes. A sample of 20 inspectors working on 100% checking jobs was interviewed to determine which of the possible causes happen most frequently. The results of the study are presented in Table 7.10.

Table 7.10

Frequency of occurrence of causes of low task significance for Quality Inspectors

Low task significance causes in production jobs	Frequency
Lack of Importance	-
Lack of Growth	-
Low Motivation of employees	-
Inadequate Training	-
Manual Task	-
Noise	-
Visual Inspection	-
Pressure of fast material clearance	3
Manpower Shortage	1
Too many complaints	4
Too many defects in incoming material	3
Traceability problems	-
Highly repetitive and monotonous	2
Excessive Material Handling	-
Inspection Table too small	1
Subjective measurement	-
Difficulty in removing parts from inspection block	6

Table: 7.11

Possible causes of low MPS in quality inspectors job

Possible causes of low MPS	Percentage of total
Difficulty in removing parts from the height test block while carrying out 100% checking.	30%
Complaints from the market regarding visual defects have put too much pressure on the inspectors.	20%
Too many handling defects including mix-up of part under sizes	15%
Highly monotonous and repetitive	10%
Pressure of fast clearance and manpower shortage	05%
Others	20%

As can be seen in Table 7.11, the top five causes lead to 94% of the problems. These are the "vital few" causes.

Re-Design of selected Quality tasks:

Thus looking at the causes as listed in Table 7.11, that are contributing to the problems with these tasks, the following areas have been taken up for improvement:

i) Removal of parts from the Height test Block after measuring crush height:

Task description: For all major original equipment manufacturers (OEMs) the crush height of the bearings is checked 100% prior to transferring of material for packing. Each part is located in a height test block whose diameter is equal to the gauge diameter of the part. The bearing is pressed against a stopper on one side of the block and a known load, equal to the torque pressure while assembling in the engine, is applied on to the other side of the bearing. The height above the half gauge point is indicated on a dial.

Problems with this task: The quality control inspectors find the task of removal of the part from the height test block as very demanding as it puts lot of stress on fingers and is extremely tiring because the part gets jammed in the height test block after the application of load.

Controls Implemented: After brainstorming with the employees to find out a possible solution for this problem, the following changes were made in the drawing of the height test block. A through hole, at an angle of 45° was provided in the height test block in which a knockout pin could be located. The base of the height test equipment (fixture) was provided with a cam attachment exactly underneath the knockout pin so that when the cam handle is pressed the knockout pin pushes out the bearing out of the height test block. The arrangement was tested on one height test block used for one of the most frequently run TATA applications and a height testing fixture. The problem of removal of parts from the test block after removal of the load was eliminated after implementation of the above controls. The implementation of this control is likely to be done on all height test blocks and height fixtures in a phased manner over a period of time.

Benefits accrued/ expected: The most likely productivity benefits are as shown in Table 7.12.

Table: 7.12

Likely productivity improvement due to re-design of Height measuring equipment

Operation	Fatigue allowance		Cycle time for one part (Mins)		Output per shift	
	Before	After	Before	After	Before	After
100% Height inspection	16%	7%	0.030	0.025	3500	5000

ii) Visual Inspection:

Task Description: The other category of tasks with low MPS in Quality functions is the 100% visual inspection that is carried out on all parts prior to packing. The inspection is carried out to segregate visual defects like damages, dents, scratches, missing operations, burrs etc.

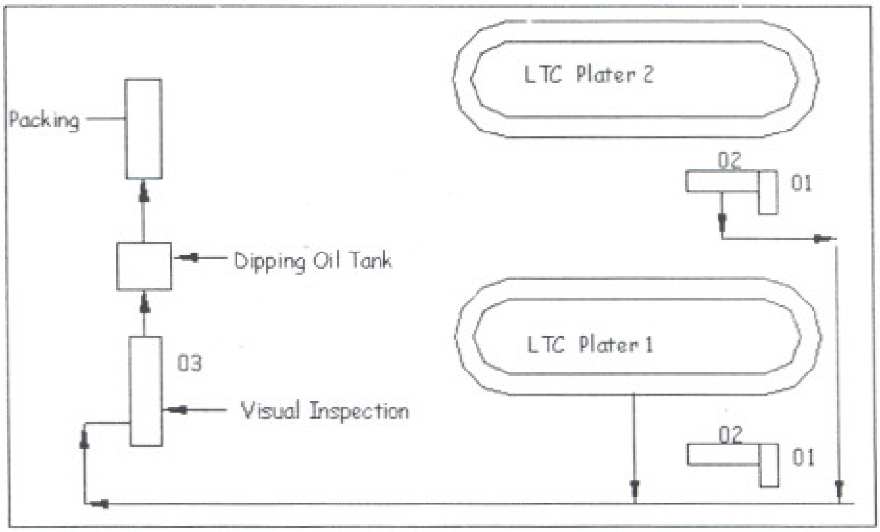
Problems with Visual Inspection: Since the inspection is subjective in nature, workmanship standards have been developed by companies to make decisions regarding acceptance of marginal parts. A review of quality complaints received from the customers reveals that there have been many complaints regarding visual defects observed in parts. The visual inspectors had been under tremendous pressure due to this but despite efforts from the Line Managers and others concerned, not much has been achieved. After discussions with the inspectors, the following reasons have been found to be the main contributors to the problem:

- Too many defects in the incoming material and while they have been removing large number of parts as defectives, still some pieces are missed and are subsequently reported by the customer.
- The management does not give adequate time for completing this task and feels once the part has been produced, it should immediately be moved for packing. Also, since the companies have been generally employing female workforce for this job, who are not allowed to work beyond 10.00 pm by labour laws, there is accumulation of material for visual inspection in the night shift. The visual inspectors feel lot of pressure for clearance of this backlog and are known to rush up.
- Since the material is inspected subsequent to the completion of the final operation in the plating shop, the material has to be unloaded from pans for inspection and re-loaded and many defects are caused during this activity as well. The inspection is carried out at separate stations after the completion of finishing plating operation as shown in figure 7.49.

Controls Suggested/Implemented: After brainstorming with the employees to find out a possible solution to this problem, the task may be re-designed as under:

It has been recommended that the visual inspection should be part of the plating operation and as and when the plating shop runs there must be one inspector on the line to check parts in a 'single piece flow'. (Figure 7.50) This is expected to solve another problem. The Quality team when made responsible for 100% visual inspection gets involved into material clearance activities, which is strictly a production shop activity. There have been number of instances when the inspectors have come under undue pressure to clear parts even when they may not be sure about the quality level of the lot.

The irony of the situation is that during high production days like during month-ends, people make compromises with quality.



O1 - operator at loading station
O2 - operator at unloading station
O3 - on-line Visual Inspector

Figure 7.49: Existing material flow – Plating to Inspection to packing

Other Recommendations: The Quality department should restrict itself to carrying out sample pre-dispatch audits, training of employees on quality aspects and solving problems related to internal and external failures in the product or process. The other activities of the Quality Department may include quality assurance activities like gauge calibration, besides supplier quality checks and other jobs. The quality function as of today seems an extension of the production line and they succumb to similar pressures as applicable to production operators.

Thus, it is recommended to transfer all the visual inspectors to the plating shop, who should be made responsible to ensure that visual inspection is carried out directly as the parts are unloaded on to a conveyor in a single piece flow. Also, the parts can be oiled

on line before putting them into pans. The plating shop may train its entire male employee on visual inspection for doing the job during the night shifts.

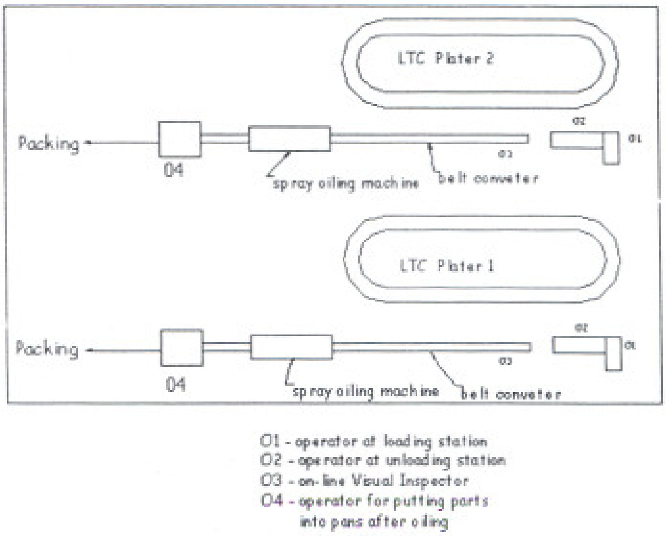


Figure 7.50: Proposed material flow in plating section – Online inspection

7.8.5 Job-person match for Maintenance Staff and Machine Setters

Case 1: The ideal match. Approximately 62% of the participants are in this category.

Case II: Low motivating potential for approximately 38% of the participants and no participant has significantly low motivating potential.

Case III: None of the participant fall in this category, which means none of the jobs have too high, motivating potential. (Table 7.13)

Thus, it can be concluded that Job-person match for the Machine Setters and Maintenance staff in engine bearing manufacturing organizations is poor for about 38% of the people, although it must be mentioned here that the problem is not very significant for this job family as none of the respondents had MPS score lesser than 80. From personal interview and observations on the shop floor, the reasons for low motivating potential in some tasks were identified. Such jobs include jobs like breakdown maintenance and some preventive maintenance tasks. However, it must be mentioned here that this job family has the least problem as far as motivational issues are concerned.

Table 7.13
Maintenance Staff and Machine Setters Scores

Operator	Skill Variety	Task Identity	Task significance	Autonomy	Feedback	MPS		Would like	Job choice	GNS
No.	A	B	C	D	E	(A+B+C)/3	(A+B+C)/3x DxE	F	G	(F+G) /2
1	3	3	6	4	5	4.0	80	2	2	2.0
2	4	4	4	5	5	4.0	100	4	3	3.5
3	6	6	3	5	5	5.0	125	5	4	4.5
4	5	4	3	5	6	4.0	120	3	1	2.0
5	3	2	6	5	5	3.7	92	4	5	4.5
6	6	5	4	4	5	5.0	100	5	4	4.5
7	4	4	3	4	6	3.7	88	4	3	3.5
8	5	4	5	4	6	4.7	112	5	5	5.0
9	3	3	6	4	6	4.0	96	4	6	5.0
10	6	5	4	5	5	5.0	125	6	5	5.5
11	5	4	5	5	5	4.7	117	5	5	5.0
12	4	5	5	5	5	4.7	117	7	6	6.5
13	6	4	5	4	6	5.0	120	6	6	6.0
14	3	4	6	4	6	4.3	104	4	2	3.0
15	6	5	4	6	4	5.0	120	6	6	6.0
16	4	4	2	4	6	3.3	80	4	3	3.5

Figure 7.51, shows the distribution of MPS/GNS for the 16 participants from amongst the Maintenance staff and Machine Setters shows that there is no relationship. Thus the existing Job-Person match is random. Just like jobs of production operators, the present job design or lack of it has been based on the use of best practice guides made available by the technical collaborators. As discussed for the production staff, that while all these makes an important contribution, they were not written to address the dynamics of motivation.

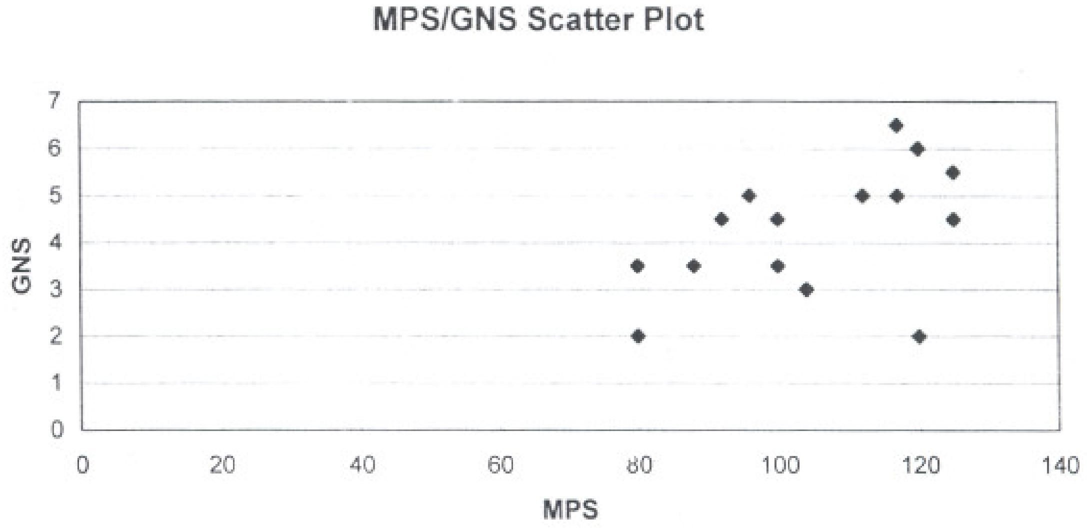


Figure 7.51: MPS/GNS Scatter Plot for Maintenance staff and Machine setters

Identification of jobs needing re-design in the Maintenance and Setters tasks:

Although there are no apparent significant motivational or other issues with this job family, still some jobs especially in the maintenance function are considered to be less motivating compared to others. Since the employees of this job family carry a large number of varied tasks, job enlargement is not an issue here. However, job rotation can be employed as one of the strategies for improving employee motivation. Job rotation, allows an employee to work in different departments or jobs in this job family to gain better insight into operations under various jobs. This, in itself, although does not modify or redesign the employee's job, but allows an opportunity to increase his/her skills and knowledge about other jobs.

7.8.6 Job-person match for all employees

Case 1: The ideal match. Approximately 49% of the participants are in this category,

Case II: Low motivating potential for approximately 51% of the participants which includes 19% employees for whom the problem is not very significant. (Those with MPS > 80)

Case III: None of the participant fall in this category, which means none of the jobs have too high, motivating potential. (Figure 7.52)

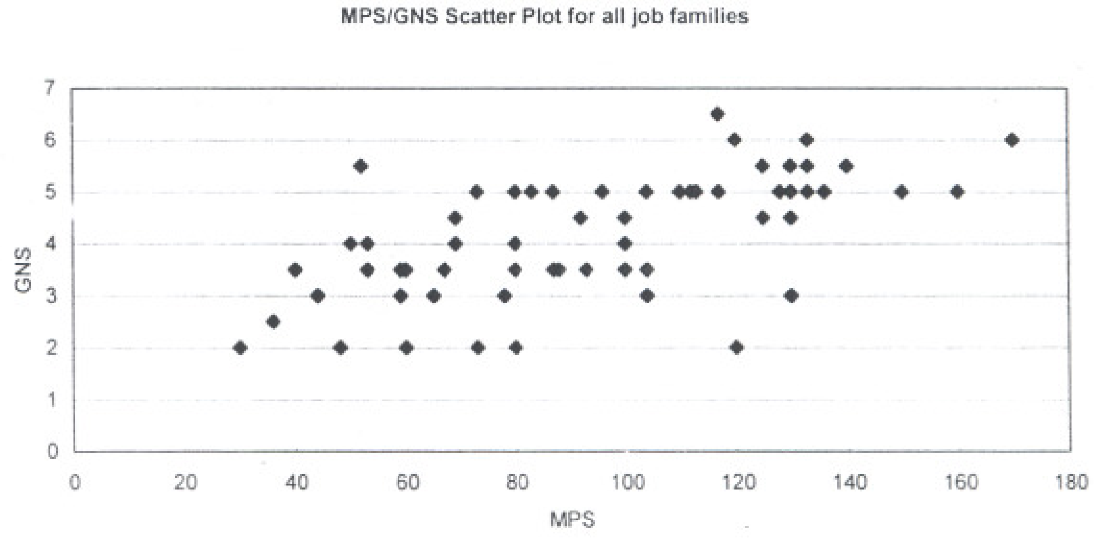


Figure 7.52: MPS/GNS Match for all employees

As already discussed in previous sections the job-person match is random. Any attempts at job design are not taking into account the need to balance a person's growth needs with the motivating potential of their job. Informal discussions with the managers and supervisors also show that they are not aware of the need to achieve a motivational match between jobs and people. However, they are highly aware of the difficult problems and poor work outcomes that result from the mismatch.

Designing jobs is a two-stage process. The first step requires the use of best practice for initial job design. The second step is monitoring and implementation of these jobs, and understanding whether people doing them can deliver the work performance required. The second step provides the vital information necessary to understand problems, re-design jobs and start on a path of motivation improvement.

7.8.7 Problems with general JDS measures

Problems with Pay satisfaction and job security: Pay is one of the tangible ways by which an organization values a person's work. Pay satisfaction for the employees across the job families was low and was recorded as a problem for more than 50% of the total number of respondents. Low pay will de-motivate staff and draw their attention away from more important aspects of their jobs.

Job security is another indicator of the value that an organization attaches to that job. Two thirds of the employees felt insecure; some felt that redundancy was certain. These findings support the view that some jobs are not valued highly by the management and if jobs are to become redundant those working on such jobs will be high on the list. Such jobs include those where a fair amount of automation has been introduced in recent years. Also, there were many in Quality Functions who felt insecure. If the organizations were under pressure to perform better and improve productivity than reducing investment in quality management would seem illogical. Thus, it would be necessary for the organizations to ensure that the employees feel important and are able to contribute meaningfully to the betterment of the organization.

7.9 DISCUSSION

All job families indicate a strong desire to have growth relevant conditions present in their jobs as indicated by "would – like" choice. At present there is not a clear path defined by management in most job families. Furthermore, there are no organized programmes of job design, which build in motivators. Job promotion in most instances is based on seniority to supervisory positions and acts as a de-motivator since there is a perception amongst the operating staff that once somebody is promoted as a supervisor, he moves out of the Labour Union and thus becomes susceptible to job insecurities normally associated with supervisory staff.

The inspectors/quality staff is a case in point. This job family has a low MPS score. Most of the employees in this position are promoted from the ranks of machinists and calibration/testers both of which have higher MPS scores. This job family especially 100% inspection offers little skill variety and the task is low in autonomy and feedback. Another job family in which the participants do not experience job satisfaction and can experience and could benefit from career development through job re-design is washing and wire brushing machine operators. The job is highly monotonous, and requires a very little skill and has poor task identity and task significance.

The total growth needs strength (GNS) scores of JDS can also be helpful in estimating whether people are likely to prosper on enriched jobs. Given the training, skill and knowledge of the participants, if those aspects of the job that contain the motivating potential (say skill variety and autonomy) are in fact changed, it is possible that workers will respond positively.

Job redesign is not the only answer to organizational problems, many of which are rooted in economic, social, political and cultural factors of the work environment. Although the general outcomes of work satisfaction indicated in this study are relatively low, the participants do feel a strong growth satisfaction in their jobs. Thus the participants see a challenge and opportunity in their work environment, yet do not feel a strong internal work motivation. All these variables diagnose the need to improve job design by building recognition, achievement, and responsibility into their tasks.

Positive outcomes of job satisfaction are reflected in the scores of job families with built in motivators. Job families in which recognition and responsibility are designed as part of the task have higher MPS scores. Machine setters have the highest scores for the five core job characteristics and for all the critical psychological states. From personal observation and information gathered about this job family, the job design has many features desired in an ideal enriched job. Such jobs are high on skill level and individuals experience a good deal of autonomy in their task assignments. Another point of interest is to recognize that inspectors/quality staff and machine setters are two job families promoted from within the same job family (production operators). However, in case of machine setters, the built in motivators of skill variety, growth satisfaction recognition (dealing with others) have resulted in positive outcomes for the individuals. Thus, it can be concluded that the presence of critical psychological states did result in higher MPS scores and a positive identification with job design. In cases where good core job characteristics were present, the employees responded positively to enriched and challenging jobs. The lack of clearly defined growth opportunities coupled with poor job design appears to act as a de-motivator. Also, there is a critical need to align the ability requirement of the jobs with the abilities possessed by the employees in each job family. This is especially significant for core job characteristics of skill variety, autonomy and feedback.

7.10 CONCLUDING REMARKS

This chapter describes the use of the JDS Model for analysis of job design of three different job families namely (1) production operators, (2) Quality Inspectors, and (3) Machine setters and Maintenance Staff. Bases on the data collected, diagnostic analysis for the motivational situation for each group has been carried out. After identification of tasks needing re-design, the root causes have been identified using the Cause and Effect Diagram, and Pareto approach. Controls/ provisions have been suggested for each job family to get an ideal match of Motivating Potential and Growth Needs. The benefits in productivity from these provisions have been integrated with the benefits from other areas of material handling, lifting tasks and are presented in the next chapter.

CHAPTER 8

PRODUCTIVITY ENHANCEMENT THROUGH ERGONOMIC PROVISIONS/CONTROLS

8.1 INTRODUCTION

This chapter summarizes the actual and expected results of various ergonomic provisions/controls implemented/suggested in Chapter 5 to Chapter 7, in terms of productivity gains. The increase in productivity due to ergonomic provisions and controls would come by the following:

1. Increase in ***available time on machine*** due to
    - Reduced relaxation and fatigue allowance achieved through better job design, work place layout, simplification of task and design of support equipment.
    - Reduced setup time as a result of ergonomic provisions and also by converting the internal setup time on machine to external time, e.g. Provision of pre-setup dies.
    - Reduced cycle time due to methods improvement
    - Reduced non conformities in products resulting in higher good output

    The reduction in all or some of the above has resulted in more time available for actual productive jobs, thereby increasing productivity.
2. Less number of ***accidents*** because of better work place design and better job design.
3. Less ***wastage.***
4. Increased ***morale of workers and job involvement.***

Some of the provisions evolved in previous chapters have actually been implemented in full or in part during the course of the study and expected improvement in productivity in terms of output or non-conformities or accidents/injuries etc. have been validated. In some other cases, the improvements have been suggested as a direct outcome of the detailed analysis carried out. In this case the expected benefits in productivity have been estimated from the expected improvements in various parameters. Also, a number of qualitative measures like job enrichment, or enlargement have been suggested. It is expected that once implemented these measures will result in productivity improvement. However, assessment of quantitative value of productivity enhancement from these measures is quite difficult. For this purpose, opinion of experts (employees and officers of the organizations where the study was carried out) has been gathered in a structured way within the boundaries of qualitative modeling. The productivity gains actually realized or expected have then been compiled for each individual job and the whole production line. From these values of productivity increase in these areas, expected increase in overall productivity of various major products of the organizations has been worked out considering the capacities of various work centers and the flow of products between various work centres. From the productivity gains of the individual work centers as well as of the whole of the organizations realized in the studied organizations, an attempt has been made to generalize the results with an aim to develop an implementation plan.

8.2 PRODUCTIVITY GAINS FROM THE IMPLEMENTED PROVISIONS AND CONTROLS

Tables 8.1 to 8.4 summarize a brief account of provisions/controls actually implemented in part or full after the analysis of job postures, material handling tasks, lifting tasks and job design. The data for these tables has been taken from analysis carried out in Chapter 5 to 7. From the demonstrated reduction in cycle times, setup times or improvement in work method etc., an assessment of increase in productivity increase at each station on the production lines have been made and tabulated. It may be pertinent to point out here that some of the controls have not been implemented in full and the impact on productivity has been calculated by part implementation of the control. The difference in productivity before and after implementation of controls has been used to predict the overall effect on productivity after the controls are implemented in full. For example, dedicated punching dies have been suggested for each application as one of the controls on hole piercing operation on the bearing production line. But since there are about 100 different applications of bearings, which are manufactured every month, it was not possible to procure all the dies for each application. The net productivity gains were thus measured on three applications whose dies were procured during the period of the study and the benefits accrued have been estimated for the production lines using this data.

8.2.1 Calculation of Output per Month from each Production Line

Output per month (refer Table 8.1 to 8.4) has been calculated both for the earlier existing system and after the ergonomic improvement of the workplace as under:

$$Om = \left(\frac{0.95\ Tas - nTsu}{Tcy + Af} \right) \times (1 - RR) \times Ns \times Nwd \qquad \text{-----------------------------} \ (8.1)$$

Where,

- Om is the output per month
- Tas is the available time per shift

- Tsu is the setup time per shift
- n is the number of setups per shift
- Tcy is the cycle time of one operation
- Af is the fatigue allowance per cycle
- RR is the rejection rate calculated in fractions
- Ns is the number of shifts per day
- Nwd is the number of working days in a month.
- The factor of 0.95 is the down time multiplier to net off the available time with regard to a considered down time of 5%.

Tables 8.1, 8.2, 8.3, and 8.4 show the productivity gains as a result of implementation of provisions after the detailed analysis of working postures on each work center of the bushing line, bearing line, packing Section and sintering line respectively. The controls undertaken as a result of the analysis are listed in the first column and the areas of improvement with data for existing practices and after the implementation of controls are shown in the middle columns. The combined impact of the improvements due to reduction of cycle time and setup time or other factors have been used to measure the increase in productivity parameters i.e. output per month and drop in rejection % and these appear in the last two columns. The data presented in Table 8.1 to 8.4 is based on following considerations:

Table 8.1: For Bushing Line

1. About 85% of the total bushing output is directly packed after the facing and chamfering operation and are not required to go through OD Grinding and ID Boring. Thus, the output requirements from these machines are not more than 1.00 lac parts per month per line.
2. Number of shifts per day is 2.
3. Number of working days considered in each month is 25.
4. The existing output production from each bushing line was 4.05 lac parts constrained by the output from blanking. After the implementation of controls identified as a result of ergonomic analysis, the output production is expected to go up to 4.73 lac parts. (Now constrained by maximum output from Final Forming presses).

Table 8.2: For Bearing Line

1. Bearings are manufactured with two different kind of alloy lining materials namely (1) Cu-Pb-Sn Alloy and (2) Al-Sn alloy. While all Cu-Pb-Sn alloyed bearings are plated, the Al-Sn bearings are directly packed after the last machining operations. Al-Sn alloyed

Table 8.1: Productivity Improvement through implemented provisions – BUSHING LINE

Controls/ Provisions implemented at each work station	Cost incurred Rs. Lacs Per annum	Areas of Improvement										Good output per month on two shift basis in Lac pieces	
		Fatigue Allowance		Operation time (Mins.)		Setup time (Mins.)		Available m/c time (Mins.)		Rejection %			
		Earlier	Now	Earlier	Now	Earlier	Now	Earlier	Now	Earlier	Now	Earlier	Now
1. OPERATION - BLANKING • Provision of attachment on de-coiler to place supports • Installation of strip clamping device • Introduction of pre set-up dies • Installation of roller conveyor up to countersinking operation	0.04 0.01 0.90 0.08 1.03	20%	12%	0.029	0.027	50	30	237.5	294.5	1.12	0.77	4.05	5.41
2.OPERATION-FIRST FORMING • Press inclined at 30°	-	20%	14%	0.023	0.016	20	20	304	304	0.18	0.10	6.59	7.24
3.OPERATION-FINAL FORMING • Improvement suggested for grip strength • Push plug core away from body during forming	-	25%	18%	0.075	0.071	25*	25*	337	337	0.46	0.40	4.48	4.73
4.OPERATION- FACING & CHAMFERING • Installation of 2 sets of equalizer plates for both top and bottom face pads of the loading shuttle	0.06	18%	10%	0.057	0.053	40	40	266	266	0.88	0.50	4.66	4.97
5. OPERATION- OD GRINDING • Installation of a roller conveyor from grinding output station to input station	0.10	23%	12%	0.053	0.048	10	5	323	351.5	0.75	0.45	1.00	1.20
6. OPERATION- FINAL BORING • Clamping rod knurled to improve friction. • Provision of a platform	0.02	22%	13%	0.120	0.111	60	60	323	323	0.17	0.10	1.34	1.44
TOTAL	1.21 lacs												

*Number of setups per shift have been considered to be 3, except those marked * where these are considered as 2.*

Table 8.2

Productivity Improvement through implemented provisions – BEARING LINE

Controls/ Provisions implemented at each work station	Cost incurred Rs Lacs Per annum	Areas of Improvement										Good output per month on 2/3 shift basis in Lac pieces	
		Fatigue Allowance		Operation time (Mins.)		Setup time (Mins.)		Available m/c time (Mins.)		Rejection %			
		Earlier	Now	Earlier	Now	Earlier	Now	Earlier	Now	Earlier	Now	Earlier	Now
OPERATION – BLANKING Provision of attachment on de-coiler Installation of strip clamping device Introduction of pre set-up dies	0.04 0.01 4.00	20	12	0.029	0.027	40	25	266	308.7	0.41	0.25	6.83**	8.55**
OPERATION-FORMINGAND COINING Work position re-located to front of the press. Provision of a wooden platform	0.04	20	14	0.029	0.026	35	30	313.5	323	0.66	0.25	8.04**	9.28**
OPERATION- FACING & HAMFERING Installation of equalizer plates Provision of finger tips to reduce contact stress	0.06 0.12	16	7	0.065	0.060	40	40	266	266	0.82	0.60	8.13	8.75
OPERATION- HOLE PIERCING Dedicated hole piercing die for each bearing application Installation of safety attachment	4.03 0.30	15	9	0.039	0.037	25	8	308.7	357.2	0.14	0.05	3.60	4.30
OPERATION- LIP PUNCHING Installation of Light sensing fool proofing device	2.50	15	8	0.043	0.039	25	15	308.7	337.2	0.13	0.05	7.19	8.59
OPERATION- WIRE BRUSH & OUNTERSINK Installation of roller magnetic conveyor	0.12	18	10	0.026	0.022	5	5	365.7	365.7	0.08	0.00	6.99	8.30
OPERATION- ID BROACHING AND EIGHT BROACHING Pans inclined at 45° using a pneumatic cylinder; Provision of an intermediary unloading station	0.24	16	13	0.065	0.059	40	40	304	304	1.08 and 0.94	1.00 and 0.90	6.91	7.57
PLATING Fabrication of a trolley to move racks; Provision of grip handles on racks Provision of adjustable work table height; Use of finger tips to reduce contact stress	0.20 0.06 0.03 0.12	20	12	0.046	0.043	45	35	370.5	389.5	0.64	0.50	6.00**	6.77**
	11.87												

*Number of setups per shift have been considered to be 3, except those marked * where these are considered as 2.*

*** Number of shifts worked in a day are considered as 2 except those marked as ** where the number of shifts are 3*

Table 8.3
Productivity Improvement through implemented provisions – Packing Section

Controls/ Provisions implemented at each work station	Cost incurred Rs Lacs per annum	Areas of Improvement										Good output per month on two shift basis in lac pieces	
		Fatigue Allowance		Operation time (Mins.)		Setup time (Mins.)		Available m/c time (Mins.)		Rejection %			
		Earlier	Now	Earlier	Now	Earlier	Now	Earlier	Now	Earlier	Now	Earlier	Now
1. OPERATION –PACKINGOF OE PARTS AND LOOSE PACKING OF BUSHES • New packing designed replacing themocole for OE bearings	Rs 1.2 lac recurring cost	22%	16%	0.046	0.035	-	-	370.5	389.5	Customer complaints = 2 to 3 per month	-	8.00	10.50
2. OPERATION- SHRINK PACKING IN MATCHED SETS FOR REPLACEMENT MARKET • Provision of inclined work table	Rs 0.03 lac	20%	12%	0.048	0.043	30	30	351.5	351.5	-	-	3.65	4.53

*Number of setups per shift have been considered to be 3, except those marked * where these are considered as 2.*

Table 8.4:
Productivity Improvement through implemented provisions – SINTERING LINE

Controls/ Provisions implemented at each work station	Cost incurred Rs Lac per annum	Areas of Improvement										Good output per month on three shift basis	
		Fatigue Allowance		Operation time (Mins.)		Setup time (Mins.)		Available m/c time (Mins.)		Rejection %			
		Earlier	Now	Earlier	Now	Earlier	Now	Earlier	Now	Earlier	Now	Earlier	Now
1. OPERATION – SETUP OF STEEL COIL FOR SINTERING • Provision of attachment on de-coiler to place supports • Installation of strip clamping device	Rs 0.05 lacs	20%	12%	0.525	0.520	50	45	313.5	327.5	2.29	1.50	70000 mtrs.	74300 mtrs.

*Number of setups per shift have been considered to be 3, except those marked * where these are considered as 2.*

bearings contribute about 20% of the total output. Thus the output of 6.77 lacs from the plating section is considered enough.

2. The Lower half of bearings do not have oil holes, that is why the output from the hole piercing station is not required to be more than 3.50 lac parts per month per line.
3. Number of working days considered in each month is 25.

Table 8.4: For Sintering Lines

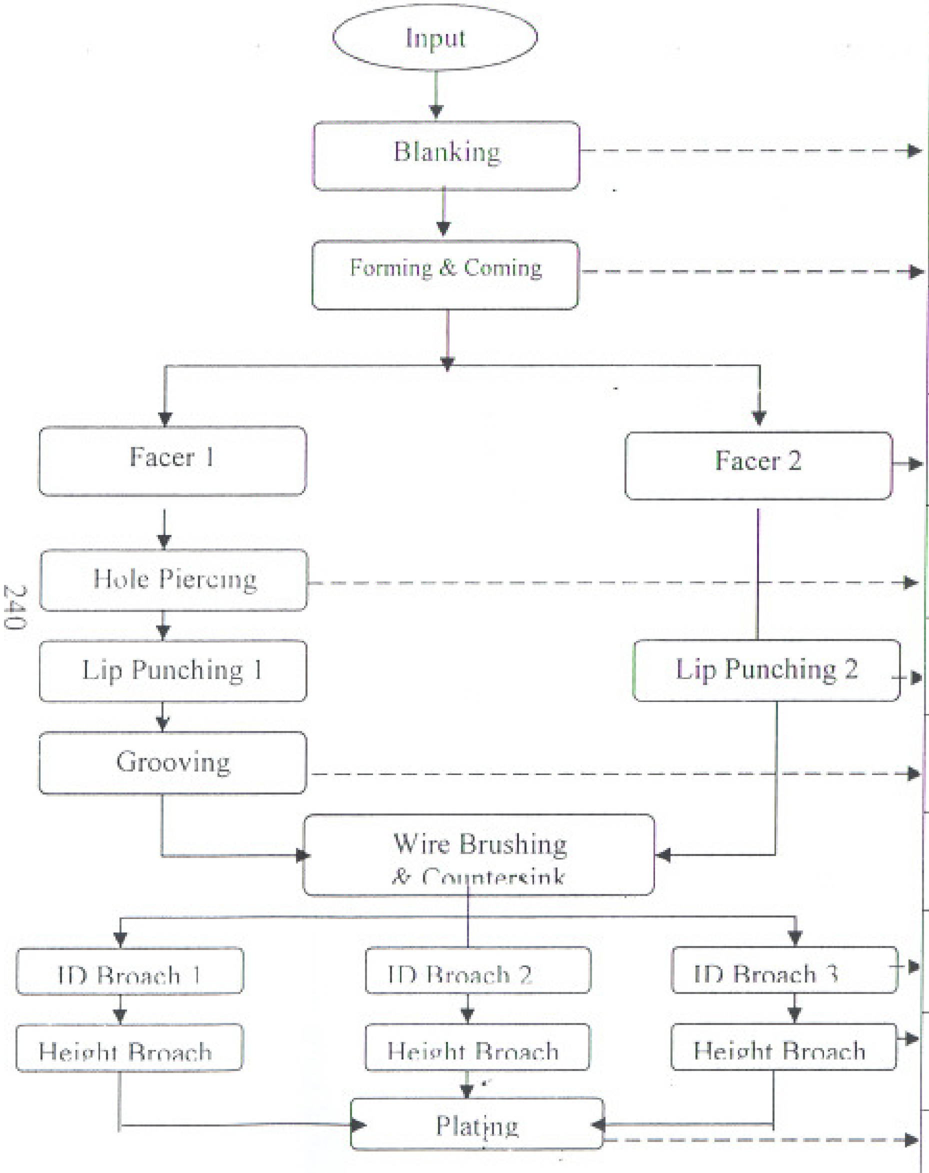
1. Number of working days considered is 20 as lines are shut down on every Saturday nights and are restarted on Monday 2nd shift for preventive maintenance.

8.3 GAINS FROM IMPLEMENTED PROVISIONS FOR EACH LINE

From the output values of each work center shown in Tables 8.1 to 8.4, output of various lines have been worked out. For this the sequence of operations carried out in each line to convert the bimetallic strip into finished product are considered and drawn in the form of flow charts as shown in figures 8.1 and 8.2. In these figures, it is shown with the help of tables drawn alongside, that the output of the line is determined by the output of the work centre having least output (bottleneck work center). As can be seen in the two figures, the existing bushing output (before the implementation of controls) was 4.05 lac parts, constrained by the output from blanking, which had minimum output. After the implementation of controls, the production is expected to go up to 4.73 lac parts. (constrained by maximum output from Final Forming presses, which is now the bottleneck work centre). Similarly, for the bearing line, the output production is expected to increase to 7.57 lac parts per month as against 6.81 lac parts existing before the study. The output before the implementation of controls was constrained by the output from blanking and after the implementation of controls is constrained by maximum output from ID and Height broaching machines.

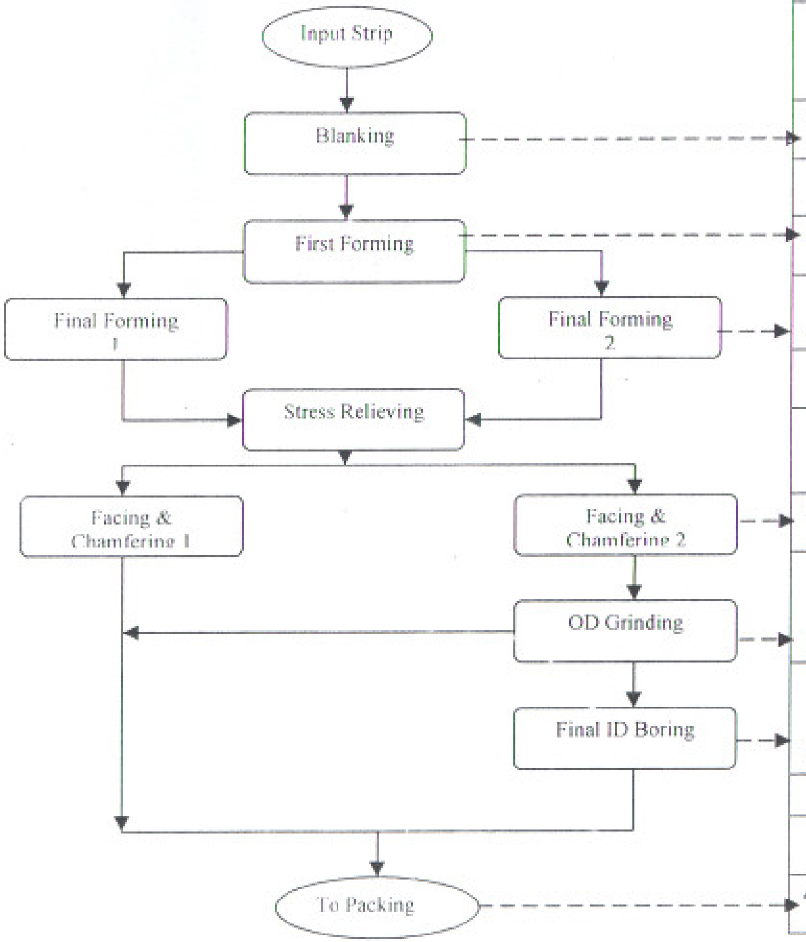
8.4 PRODUCTIVITY GAINS FROM THE SUGGESTED PROVISIONS

In addition to the implemented provisions as described in the previous section, there are many other provisions and controls suggested as a result of ergonomic analysis in Chapter 5 to Chapter 7 with which the productivity is expected to increase. During their analysis in the previous chapters, expected change in factors like fatigue allowance, rejections, cycle time, setup time, accidents/injuries, lost/restricted days etc. have been calculated. While in the case of some provisions a fairly accurate assessment of improvement in these parameters and consequent increase in productivity can be worked out, for some others jobs provisions and controls suggested are administrative or qualitative in nature. The actual gains will depend upon how the employees accept them, how the managements support them, the



pcs lac		of shifts			Benefits
Earlier	Now		Earlier	Now	
6.83	8.55	3	0.41	0.25	-
8.04	9.28	3	0.66	0.25	-
8.13	8.75	2	0.82	0.60	Reduced contact stress on fingers
3.60	4.30	2	0.14	0.05	No accidents
7.19	8.59	2	0.13	0.05	Mistake proofing
3.50	3.50	2	0.10	0.10	-
6.99	8.33	2	0.08	0.00	-
6.91	7.57	2	1.08	1.00	-
6.91	7.57	2	0.94	0.90	-
6.00	6.77	3	0.64	0.50	-

Figure 8.1: Process Flow Chart of Bearing Line



Output per month		Number of shifts	Rejection %		Other Benefits
Earlier	Now		Earlier	Now	
4.05	5.41	2	1.12	0.77	-
6.59	7.24	2	0.18	0.10	-
4.48	4.73	2	0.46	0.40	-
4.66	4.97	2	0.88	0.50	-
1.00	1.20	2	0.75	0.45	-
1.34	1.44	2	0.17	0.10	-
4.05	4.73				

Figure 8.2: Process Flow Chart of Bushing Line

general working environment existing in the organization and some other extraneous factors. It was felt that in such cases the employees of the organizations could make a fairly good and realistic assessment of the effects of such provisions. It was, therefore, decided to seek the opinion of experts (employees of the organizations) in a structured way. In all, a total of ten experts consisting of two Managers three Supervisors, three Operators, one Inspector and one Mechanic were selected. The experts were briefed about the findings of the ergonomic analysis and the purpose of getting their feedback. All the experts who were selected had requisite amount of experience, education level and a realistic bent of mind. Based on the ergonomic analysis and the qualitative provisions suggested therein a short questionnaire (Appendix 8.1) was developed. The experts filled up the questionnaire while sitting separately in the conference room of one of the organizations in the presence of the researcher.

The filled up questionnaire was compiled and analyzed and based on that an assessment of expected improvements in various parameters was worked out as shown in Table 8.5. These expected benefits are converted in terms of savings in cost and utilized for working out the productivity gains in Table 8.6.

8.5 SYNTHESIS AND MODELING FOR IMPLEMENTATION

This section presents a synthesis of the analysis carried out in the preceding chapters, results thereof in terms of provisions and controls implemented or suggested, cost involved with these and productivity improvement accrued or expected. The purpose of this synthesis is to see a comparative effect of the implemented and proposed strategies with an aim to generalize them for any industry and develop a set of guidelines for the implementation of proposed measures in a phased manner taking into account the costs involved, productivity gains expected and other related parameters. For the purpose of synthesis and development of implementation plan through generalization and ranking of various measures, experts from the organizations where studies were carried out were involved. The experts gave their qualitative opinion/ scores on the factors, which are otherwise fuzzy and quite difficult to quantify. The synthesis has been done in a structured way under the framework of qualitative modeling. In the following sections various steps of synthesis, generalization of actions taken and modeling for development of a phase- wise implementation plan are discussed.

8.5.1 Synthesis and Generalization

Synthesis and generalization exercise involved seeking and incorporation of expert opinion in a brainstorming and idea generation session. Ten experts were involved in the exercise. In

Table 8.5
Expected gains in parameters through ergonomic provisions

Provision suggested	Identified improvement parameter	Present level	Expected level	Expected gains in					
				Output	Reducing Rejection	Reduction in manpower or material cost	Reduction in accidents/ injuries	Reduction in compensation costs	Lost / restricted days
1. Manual material handling carrying tasks • Design and provision of 4-wheeled trolley (of design demonstrated) in production lines	• Manpower • High MSD's, back pain/ injuries	2	0	-	-	Saving of two casual manpower = Rs 0.5 lac per annum	-	Compensation cost paid by ESI	Saving of 36 mandays per annum = Rs 0.11 lac per annum
2. Transfer of pans from degreasing to plating loading station • Installation of roller conveyor transfer mechanism between the two stations.	• Absenteeism rate • Accidents/ Injuries per month • Output / month	20.5% 1.3 6.80 lac	10% 0 6.90 lac	Increase of 10000 parts/ month = Rs 15.6 lac per annum	-	Saving of one casual manpower = Rs 0.24 lac per annum	No accidents	-	Saving of 20 mandays per annum = Rs 0.06 lac per annum
3. Powder plant – Transfer of raw material for melting • Design and provision of four-wheeled trolley • Height and surface of load platform raised by 2 feet	• Absenteeism rate • Accidents/ Injuries per month	27% 1.3	10% Nil	-	-	Saving of one casual manpower = Rs 0.24 lac per annum	No accidents	-	Saving of 12 mandays per annum = Rs 0.04 lac per annum
4. Transfer of finished parts from the BAP store to shrink wrap station Design and provision of 4-wheeled trolleys	• Absenteeism rate • Manpower deployment	18.6% 3	10% 1	-	-	Saving of two casual manpower = Rs 0.5 lac per annum			Saving of 20 mandays per annum = Rs 0.06 lac per annum
5. Constrained workspace, wrist extension and twist during setup at face and chamfer • Job rotation of workers	• Output per month • Job variety • Increase in Motivating Potential score (MPS)	4.75 lac Poor MPS = 70	4.80 lac Enhanced MPS > 130	Increase of 5000 parts/ month = Rs 6.0 lac per annum	-	-	-	-	Saving of 30 mandays per annum = Rs 0.09 lac per annum

6. Set up of master nest block and broach cutter on broaches - Job rotation of workers	- Output per month - Job variety - Increase in Motivating Potential score	7.72 lac Poor MPS = 82	7.75 lac MPS > 130	Increase of 3000 parts/ month = Rs 4.7 lac per annum	-	-	-	-	Saving of 30 mandays per annum = Rs 0.09 lac per annum
7. Oiling of parts before packing - Provision of a spray type oiling machine	- Accidents - Oil consumption - Rejection % due to bond failure - Degreasing solution consumed	3 per month 400 lts/ month 0.74% 800 ltr/ month	0 200 ltrs/ month 0.20 % 300 ltrs/ month			Cost of oil consumption reduced = Rs 4.80 lac per annum Cost of degreasing solution consumption reduced = Rs 5.40 lac per annum	No accidents	-	-
8. Loading of plating racks on plating machine - Reduce lifting frequency by rotating workers on line - Provision of a coupling/ grip	- Output per month - Absenteeism rate - Stressed worker - Poor job variety	18% MPS = 65	10% MPS > 130	Additional 1500 parts per month = Rs 2.3 lac per annum	-	-	-	-	Saving of 30 mandays per annum = Rs 0.09 lac per annum
9. Handling of tools, dies, fixtures in tool storage area - Bring the tools placed on the cart closer to the worker - Reduce the angle of twist	- Stressed worker - Poor job variety	MPS = 60	MPS > 130	-	-	Saving of one casual manpower = Rs 0.24 lac per annum	-	-	-
10. Lifting of filled pans at forming and coining station - Height of the pans raised by adding two rows of empty pans under the filled pans.	- Additional manpower - MSD's/ Back pain injuries	1 3 lost days avg./ month	0 1 lost day / month	-	-	Saving of one casual manpower = Rs 0.24 lac per annum	-	-	Saving of 12 mandays per annum = Rs 0.04 lac per annum
11 Lifting of pans at Face and Chamfer station - Bring the pans closer to the worker position to reduce horizontal distance	- Additional manpower - MSD's/ Back pain injuries	1 3 lost days avg./ month	0 1 lost day / month	-	-	Saving of one casual manpower = Rs 0.24 lac per annum	-	-	Saving of 12 mandays per annum = Rs 0.04 lac per annum

12. Transfer of cartons from packing line to dispatch and onto trucks • Provision of on-line conveyor and adjustable diverter bars to transfer cartons from shelves to truck.	• Fatigue Allowance • Additional Manpower on large shipment days	20% 6	8% 2	-	-	Saving of 4 additional manpower hired on peak load days (about 15 days/ month) = Rs 1.44 lac per annum	-	-	-
13. Countersinking and wire brush station Automation of wire brushing station and combining of the two tasks	• Manpower • Skill Variety	2 MPS = 50	1 MPS > 130	-	-	Reduction of 1 regular manpower = Rs 0.96 lac per annum	-	-	-
14. Critical work stations e.g. height and wall broach • Self-inspection by line operators on all stations after training on Quality improvement techniques.	• Rejection rate / month • Rework / month • Manpower deployed	4.9% 2.5% 8 line inspectors	1.0% 0.5% 2 inspectors for setup approval	-	Increase in good output by 25000 parts per month = Rs 39.0 lac per annum Reduction of rework = Rs 1.65 lac per annum	Reduction of 6 regular manpower = Rs 5.8 lac per annum	-	-	-
15. Visual Inspection stations • Merge visual inspection with the plating section. Inspection tol be carried out on line, as the parts are unloaded on to a conveyor. The parts after this directly go the packing section.	• Rejection due to damages • Additional WIP lead time • Customer sales return = Rs 1.3 lac average per month (Rs 13.2 lac per annum)	1.3% 1 day	0.2% 0		Additional good output = Rs Rs 2.4 lac per annum Customer sales returns = 1.0 lac per annum	-	-	-	-

16. Dimensional checking of parts for crush height - Provision of a knockout on the height test fixture to remove parts out of the block	- Injuries on fingers - Output per shift	6 / month 3000 parts	0 5000 parts	-	-	-	No injuries	-	Saving of 30 mandays per annum = Rs 0.09 lac per annum
17. Steel storage area - Fabrication of new coil stands for their horizontal placement in steel storage area	- Average waiting time for steel coils (8 coils handled per day)	46 minutes for each coil = (368 minutes per day)	10 minutes for each coil = (80 minutes per day)	-	-	Saving of one regular manpower & casual manpower for 15 days = Rs 0.75 lac per annum	-	-	-
18. Sinter Line controls - Re-location of temperature controls and laboratory test equipment closer to operator work station at the Sinter Lines	- Prescribed monitoring frequency - Strip rejection	20 mtrs. 2.29%	50 mtrs. 1.50%	-	Additional strip output due to reduction of rejection – 200 meters per month = Rs 4.80 lac per annum	-	-	-	-

the beginning of the session the results of the studies carried out in bearing manufacturing organizations were displayed and discussed. Subsequently, the results of each area namely (1) work postures, (2) manual material handling tasks, (3) lifting tasks, and (4) results of JDS Survey for Job Design were separately displayed and the experts were requested to generalize the provisions/controls identified under each area, separately. The researcher and his supervisor acted as coordinators. After discussion, a consensus was reached on the following generalizations of the controls identified during detailed ergonomic analysis.

Area: Work Posture

1. Provision of additional controls on machines
2. Provision of conveyors, worktables with adjustable heights, platforms etc.
3. Change in operator position on the work station, re-location of machine
4. Convert internal setup time to external time
5. Additional work instructions, changes in procedures and methods
6. Provision of safety attachments, injury prevention aids
7. Integrating ergonomic principles into equipment design

Area: Lifting Tasks

1. Change in load/ weight orientation
2. Raise/ Lower height of load at origin or destination
3. Reduce lifting frequency
4. Improvement in grip/ coupling on load
5. Reduce angle of twist

Area: Manual Material handling Carrying Tasks

1. Provision of handling aids
2. Workstation design changes like conveyors etc.
3. Automation to reduce manual work
4. Reduce carrying distances, carrying frequency and weight of load
5. Promote use of handling signs and symbols

Area: Job Design

1. Job Rotation
2. Job Enlargement
3. Job Enrichment
4. Operator training and education
5. Employee involvement

After categorization of implemented/ suggested measures into the above categories, the costs and productivity gains from the previous chapters were complied for the suggested provisions and controls into generalized heads shown above. These are shown in Table 8.6. The details of costs and productivity gains associated with each generalized provision were displayed to the experts in another brainstorming session aimed at developing a generalized approach for implementation of ergonomic improvements in any bearing manufacturing industry in a phased manner.

Table 8.6
Costs and productivity gains associated with generalized categories

Area	Generalized category of provision/ control	Total cost of provisions in Rs Lacs	Total gain in productivity (Converted to cost benefit in Rs. Lacs)
1. Work Postures	1. Provision of additional controls on machines 2. Provision of conveyors, worktables with adjustable heights, platforms etc. 3. Change in operator position on the work station, relocation of machine 4. Convert internal setup time to external time 5. Additional work instructions, changes in procedures and methods 6. Provision of safety attachments, injury prevention aids 7. Integrating ergonomic principles into equipment design	3.30 0.37 0.02 8.93 - 0.54 11.2	1. Increase in bush production from 4.05 lac parts earlier to 4.73 lac parts after implementation ≈ saving of Rs 81.6 lac per annum 2. Increase in bearing production from 6.83 lac parts earlier to 7.57 lac parts after implementation ≈ saving of Rs 115.44 lac per annum
2. Lifting tasks	1. Change in load/ weight orientation 2. Raise/ Lower height of load at origin or destination 3. Reduce lifting frequency 4. Improvement in grip/ coupling on load 5. Reduce angle of twist	- - - 1.06 -	1. Saving in Manpower cost = 0.72 lacs per annum 2. Saving of cost of lost/ restricted days = 0.16 lacs per annum 3. Additional bearing output = Rs 1.56 lac per annum
3. Manual Material Handling tasks	1. Provision of handling aids 2. Workstation design changes like conveyors etc. 3. Automation to reduce manual work 4. Reduce carrying distances, carrying frequency and weight of load 5. Promote use of handling signs and symbols	1.17 0.40 3.50 - -	1. Saving in Manpower cost =3.88 lacs per annum 2. Saving of cost of lost/ restricted days = 0.45 lacs per annum 3. Additional bearing output = Rs 20.08 lac per annum 4. Saving in material cost = 10.20 lacs 5. Saving due to reduced rejection = 5.72 lcs
4. Job Design	1. Job Rotation 2. Job Enlargement 3. Job Enrichment 4. Operator training and education 5. Employee involvement	- 1.5 0 5.0 5.0	1. Reduction in rejection % from 4.9% to 1% through SQC, Self Inspection ≈ Rs 40.65 lacs 2. Sales return down from 13.2 lac /annum to 2.4 lac
	TOTAL	**41.99 lacs**	**282. 86 lacs**

8.6 DEVELOPMENT OF GENERALIZED APPROACH

For developing a generalized approach, the costs associated with a provision and productivity gains expected have been taken as the most important input. However, in the brainstorming session the experts were requested, to first of all, identify factors and parameters, other than cost and productivity gains which must be considered for developing an implementation approach.

8.6.1 Factors and Parameters influencing Development of a Generalized Approach

The experts after discussion and brainstorming converged on the following factors and parameters influencing development of a generalized approach.

1. Costs associated with the implementation of a provision
    - High (H) – If pay back period is more than one year
    - Medium (M) – If payback period is between six months and one year
    - Low (L) – If payback period is less than six months
2. Productivity gains after the implementation of the provision
    - High (H); Medium (M); Low (L)
3. Ease of implementation
    - Easy (E); Not Easy (N); Difficult (D)
4. Types of Controls
    - Engineering (E); Administrative (A); Work Simplification (W)
5. Effect on other areas (Can be positive complimentary or negative) Further the effect can be
    - High (H); Medium (M); Low (L)
6. Training required
    - High (H); Medium (M); Low (L)
7. Time frame for results: Time frame can be
    - Long (L); Moderate (M); Immediate (I)
8. Mandatory or otherwise
    - Absolutely (A); May be (M); No (N)

After identifying these parameters a blank proforma was prepared (Appendix 8.2). In this proforma, all the generalized categories of provisions/ controls described in the previous section were listed in the first column. Blank spaces were provided in other columns each reserved for response to be provided by an expert to each factor and parameter with regard to each general provision/ control. These proformas were circulated to experts who filled up the information in the requisite columns in qualitative terms for e.g. High (H), Medium (M) or Low (L). These qualitative scores were then converted into a quantitative score using the scoring scale and the number of responses to a choice. The scoring scale is shown in Table 8.7:

Table 8.7

Scoring Scale for states of parameters

S.No	Parameter	State (Qualitative response)	Score
1	Costs associated with the implementation of a provision	• High (H) – If pay back period is more than one year • Medium (M) – If payback period is between six months and one year • Low (L) – If payback period is less than six months	1 2 3
2	Productivity gains after the implementation of the provision	• High (H) • Medium (M) • Low (L)	3 2 1
3	Ease of implementation	• Easy (E) • Not Easy (N) • Difficult (D)	3 2 1
4	Types of Controls	• Engineering (E) • Work Simplification (W) • Administrative (A)	3 2 1
5	Effect on other areas	• + High (H) • + Medium (M) • + Low (L) • - High (H) • - Medium (M) • - Low (L)	3 2 1 -1 -2 -3
6	Training required	• High (H) • Medium (M) • Low (L)	1 2 3
7	Time frame for results	• Long (L) • Moderate (M) • Immediate (I)	1 2 3
8	Mandatory or otherwise	• Absolutely (A) • May be (M) • No (N)	3 2 1

Table 8.8 depicts a summary of the response received from the experts. In this table number of experts responding to a particular choice in a factor or parameter has been compiled from the individual responses of the experts. Number of responses to a particular choice has then been multiplied by the score of that choice in every factor as listed in Table 8.7. Those weighted scores have then been summed up against each generalized control or provision

Table 8.8
Summary of the response received from the experts

Generalized Provision	Number of Responses n_i																									Cumulative score
	Cost			Productivity gains			Ease of Implementation			Effect on other areas						Training required			Time frame for results			Mandatory				
	H	M	L	H	M	L	E	N	D	H	M	L	H	M	L	H	M	L	L	M	I	A	M	N	$\sum n_i S_i$
s_i	1	2	3	3	2	1	3	2	1	+3	+2	+1	1	2	3	1	2	3	1	2	3	3	2	1	
													(-) Values												
Work Postures																									
Provision of additional controls on machines	1	8	1	8	2	0	2	7	1	0	0	2	0	1	7	1	7	2	1	1	8	-	2	8	122
Provision of conveyors, worktables with adjustable heights, platforms etc.	1	9	0	9	1	0	5	5	0	0	2	8	0	0	0	0	3	7	1	1	8	0	2	8	151
Change in operator position on the work station, relocation of machine	0	2	8	1	7	2	0	2	8	1	8	1	0	0	0	7	1	2	2	8	0	0	1	9	123
Convert internal setup time to external time	7	2	1	8	1	1	0	2	8	1	8	1	0	0	0	8	1	1	9	1	0	0	0	10	107
Additional work instructions, changes in procedures and methods	0	1	9	0	1	9	9	1	0	1	8	1	0	0	0	2	7	1	8	2	0	0	3	7	133
Provision of safety attachments, injury prevention aids	1	8	1	0	1	9	1	8	1	8	2	0	0	0	0	1	8	1	1	7	2	8	2	0	146
Integrating ergonomic principles into equipment design	1	9	0	1	8	1	0	1	9	8	2	0	0	0	08	1	1	7	3	0	0	1	4	5	120

Lifting Tasks																								
Change in load/ weight orientation	1	9	0	0	3	7	8	2	0	0	2	8	0	0	0	8	2	0	1	8	1	0	1	9	124
Raise/ Lower height of load at origin or destination Reduce lifting frequency	0	2	8	0	2	8	2	8	0	0	2	8	0	0	0	8	1	1	1	8	1	0	1	9	119
Improvement in grip/ coupling on load	0	2	8	0	2	8	1	1	8	0	0	0	1	8	1	1	8	1	7	2	1	0	1	9	78
Reduce angle of twist	0	2	8	1	8	1	0	8	2	0	2	8	0	0	0	0	8	2	0	8	2	0	1	9	105
Manual Material Handling tasks																								
Provision of handling aids	0	8	2	8	2	0	0	8	2	8	2	0	0	0	0	0	8	2	0	2	8	9	1	0	175
Workstation design changes like conveyors etc.	0	8	2	0	8	2	1	8	1	2	8	0	0	0	0	0	9	1	0	8	1	0	2	8	134
Automation to reduce manual work	8	2	0	0	2	8	1	9	0	0	2	8	0	0	0	8	2	0	0	2	8	0	1	9	96
Reduce carrying distances, carrying frequency and weight of load	2	8	0	0	2	8	1	8	1	1	8	1	0	0	0	1	8	1	9	1	0	0	1	9	112
Promote use of handling signs and symbols	0	1	9	2	5	3	9	1	0	0	5	5	0	0	0	0	8	2	6	4	0	0	1	9	139
Job Design																								
Job Rotation	0	8	2	0	2	8	0	1	9	0	0	0	0	1	9	8	2	0	8	2	0	0	0	10	68
Job Enlargement	0	7	3	0	1	9	0	1	9	0	1	9	0	0	0	8	2	0	2	8	0	0	0	10	96
Job Enrichment	0	8	2	0	1	9	0	8	2	0	1	9	0	0	0	8	2	0	2	8	0	0	0	10	102
Operator training and education	0	8	2	0	1	9	8	2	0	0	1	9	0	0	0	8	2	0	2	2	6	8	2	0	136
Employee involvement	0	1	9	0	1	9	8	2	0	0	8	2	0	0	0	0	2	8	8	1	1	0	1	9	138

and have been listed in the last column of the Table 8.8. The highest score of a provision in this column, depicts that considering all the above eight factors and parameters, this generalized provision should be taken up first for implementation.

8.7 SUGGESTED IMPLEMENTATION PLAN

From the results of Table 8.8, various generalized provisions/ controls have been listed again in Tables 8.9 to Table 8.12, in reducing order of their cumulative scores, separately for Work Postures, Lifting Tasks, Material Handling Tasks, and Job Design.

Table 8.9

Preferred Provisions based on Cumulative Score – Work Postures

S.No.	Provision/ Control	Cumulative Score
1	Provision of conveyors, worktables with adjustable heights, platforms etc.	151
2	Provision of safety attachments, injury prevention aids	146
3	Additional work instructions, changes in procedures and methods	133
4	Change in operator position on the work station, relocation of machine	123
5	Provision of additional controls on machines	122
6	Integrating ergonomic principles into equipment design	120
7	Convert internal setup time to external time	107

Table 8.10

Preferred Provisions based on Cumulative Score – Lifting Tasks

S.No.	Provision/ Control	Cumulative Score
1	Change in load/ weight orientation	124
2	Raise/ Lower height of load at origin or destination; Reduce lifting frequency	119
3	Reduce angle of twist	105
4	Improvement in grip/ coupling on load	78

Table 8.11

Preferred Provisions based on Cumulative Score – Manual Material Handling

S.No.	Provision/ Control	Cumulative Score
1	Provision of handling aids	175
2	Promote use of handling signs and symbols	139
3	Workstation design changes like conveyors etc.	134
4	Reduce carrying distances, carrying frequency and weight of load	112
5	Automation to reduce manual work	96

Table 8.12

Preferred Provisions based on Cumulative Score – Manual Material Handling

S.No.	Provision/ Control	Cumulative Score
1	Employee involvement	138
2	Operator training and education	136
3	Job Enrichment	102
4	Job Enlargement	96
5	Job Rotation	68

The expert's opinion was again sought for implementation of these provisions. The experts recommended that in any engine bearing manufacturing industry these generalized provisions should be implemented in a phase-wise manner. The experts cited the following reasons for the recommendation of phase implementation approach:

- All provisions cannot be implemented simultaneously at the same time because of resource, cost and time constraints.
- A phase-wise approach will facilitate feedback and corrections needed, if any, as a result of problems faced with implementation of provisions from the previous phase(s).
- The success of the measures taken up in Phase 1 would motivate to go to Phase 2 and Phase 3, which requires comparatively higher cost, more effort and longer time for results.

Further, after brainstorming the experts gave the following order of priority to the four major areas studied while carrying out the ergonomic analysis of manufacturing facilities:

1. Work Postures
2. Material Handling
3. Lifting Tasks
4. Job Design

It was then decided to formulate a phase-wise implementation approach by picking up the provisions which had higher weighted scores in the above four major areas. For deciding the number of provisions taken up for implementation in a phase, out of the total provisions under a major area, the proximity or differences of scores around the cut offs were considered i.e. there should be a considerable difference between the score of the last provision in Phase 1 and the first provision of Phase 2 and so on. It was also decided that if more than five experts have rated a particular provision absolutely mandatory, that will taken up on priority in Phase 1, irrespective of its cumulative score. Based on all these considerations, the implementation of the provisions has been divided into three phases as an order of priority for implementation in any engine bearing manufacturing industry. The three phases of the suggested approach are presented in Table 8.13

Table 8.13
Suggested Implementation Plan

	Work Postures	Material Handling	Lifting Tasks	Job Design
Phase 1	• Provision of conveyors, worktables with adjustable heights, platforms etc. • Provision of safety attachments, injury prevention aids	• Provision of handling aids • Promote use of handling signs and symbols	• Change in load/ weight orientation • Raise/ Lower height of load at origin or destination	• Employee involvement • Operator training and education
Phase 2	• Additional work instructions, changes in procedures and methods • Change in operator position on the work station, relocation of machine • Provision of additional controls on machines	• Workstation design changes like conveyors etc. • Reduce carrying distances, carrying frequency and weight of load	• Reduce lifting frequency	• Job Enrichment • Job Enlargement
Phase 3	• Integrating ergonomic principles into equipment design • Convert internal setup time to external time	• Automation to reduce manual work	• Improvement in grip/ coupling on load	• Job Rotation

The provisions or controls suggested to be implemented in Phase 1, will in general be less costly, easy to implement, result in almost immediate gains, and would have a positive and complimentary effect on many other areas in the organization. In addition, these will also satisfy the absolutely necessary ergonomic requirements and would give a feeling to the employees that management has really started caring or them. As a result, direct and indirect productivity rise from these inexpensive measures is likely to be quite high. Successful implementation of measures in Phase 1, will also serve as a motivator for the management, which will more readily commit resources and efforts for implementation of the controls and provisions suggested to be taken up in Phase 2 and Phase 3. The inclusion of employee training, education and involvement in Phase 1 will help in effectively communicating to the employees the management's commitment to the cause of worker's health and safety. Seeing this commitment from the top, the workers will also respond positively and start participating in the implementation process.

Phase 2, includes measures which are slightly more difficult to implement, involve reasonably higher costs, which may require some kind of budgetary provisions and approvals. However, the payback period for the investment made would not be more than one year and the management will be able to foresee the results, particularly in the light of success of Phase 1. There are, in general, good productivity gains but sustained efforts are needed, as the results may not come immediately.

Phase 3 includes provisons, which are more related with hard-core technical changes in machinery, equipment and tooling. Implementation of these provisions will involve substantial capital investment and may require a number of iterations and trials before implementation. High productivity gains can be expected although large a number of teething and adjustment problems may be encountered. Phase 3, in general, consists of long-term measures.

8.8 CONCLUDING REMARKS

In this chapter the actual and expected results of various ergonomic provisions/controls implemented/suggested in Chapter 5 to Chapter 7, in terms of productivity gains have been summarized. The broad findings of the study described in Chapters 5 to 7, and their impact on muscoloskeletal disorders (MSD's) and productivity have been synthesized. For the purpose of synthesis and modeling for developing a strategy for implementation, the controls/ provisions identified have been grouped into broad generalized categories. The cost and productivity gains expected have then been listed for each of this generalized category of controls. Expert opinion has been utilized to identify factors and parameters affecting development of a generalized approach for implementation.

Further, this chapter also covers the generalization of various measures for developing an approach suggested to be used by industry in future. For this generalization and development of phase-wise approach, expert opinion was again utilized.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

9.1 INTRODUCTION

This chapter covers the summary of the research work, its results, conclusions and recommendations. The phases of analysis carried out in the study, tools and techniques used, the results of the initial survey, observational studies carried out in representative industries and inferences from them are summarized. Results of analysis and inferences drawn have been utilized to design a phase-wise approach for implementation of ergonomic initiatives in an engine bearing manufacturing industry. Conclusions have been drawn and recommendations made for use of the industry in future. The limitations along with scope for future work are also covered in this chapter.

9.2 SUMMARY OF THE WORK

The research work was undertaken for analyzing engine bearing manufacturing industry with an aim to design strategies for developing and implementing ergonomic provisions and controls in engine bearing manufacturing industry for worker health and safety as well as for improvement in performance and productivity. The study has been carried out in a phased manner (Sushil, 1997). Various phases of the study have been: clarifying the context through a review of literature on various areas of ergonomics and productivity; understanding and assessing the current status of ergonomics by conducting a preliminary study of engine bearing manufacturing units and identifying the areas which need to be taken up for further detailed ergonomic analysis to make them more ergonomically compliant and to increase productivity. Subsequently, detailed studies were carried out to assess the status with regard to the factors identified after the preliminary study, on all the production lines beginning from the raw material manufacturing till packing of all types of bearings. The tasks needing most urgent action with regard to ergonomic risks involved were identified using appropriate techniques selected through extensive review of literature and appropriate ergonomic provisions and controls were developed. While developing solutions to ergonomic issues, the following hierarchy of controls has been used: (1) engineering improvements, (2) administrative controls and (3) work practices modifications. The actual and expected results of various ergonomic provisions/controls implemented or suggested in terms of productivity gains were summarized. Synthesis of the ergonomic controls implemented or suggested after the detailed analysis and its impact on productivity was carried out with an aim to generalize them for any industry and develop a set of guidelines for the implementation of proposed measures in a phased manner taking into account the costs involved, expected productivity gains and other related parameters.

The preliminary study was conducted through a specially designed questionnaire. The review of literature provided an insight into various aspects of ergonomic status and its compliance that was helpful in deciding the contents and the format of the questionnaire. The questionnaire was standardized after pre-testing. The study was then carried out by personal visits to the engine bearing manufacturing units. The purpose of the study was to identify those areas and aspects of ergonomic compliance in the organizations, which need to be taken up for further detailed analysis. The areas identified after the preliminary study were (1) Work Postures, (2) Manual Material Handling Tasks, (3) Lifting Tasks, and (4) Job design and motivational aspects in a job.

9.3 APPROACH USED IN EACH MAJOR AREA

In each of the four major areas of work postures, manual material handling tasks, lifting tasks and job design the approach used involved the following steps:

- Identification of appropriate assessment techniques reported in the literature.
- Development of assessment technique typically useful for an engine bearing manufacturing facility.
- Ergonomic assessment of the workplace with regard to work postures, material handling, both carrying and lifting tasks and job design.
- Collection of past data on productivity and quality indicators from the relevant records, which formed basis for measuring any quantitative improvement as a result of the improvement actions on the identified problems.
- Separation of various operations of the production lines into elemental tasks.
- Identification of ergonomic risks/ hazards in each of these tasks.
- Implementation of appropriate controls to eliminate or reduce the effect of ergonomic deficiencies observed in these tasks.
- Measuring the effect of these controls on output, performance and productivity.
- Measuring performance and productivity improvement.

After the detailed analysis of the production lines, the actual and expected results of various ergonomic provisions/controls implemented or suggested during the course of the study were summarized to quantify the net gain in terms of productivity and cost benefits accrued to the organization. Synthesis of the provisions or controls implemented or suggested was carried out to study the comparative effect of the implemented and proposed strategies with an aim to generalize them for any industry and develop a set of guidelines for the implementation of proposed measures in a phased manner taking into account the costs involved, expected productivity gains and other related parameters. For carrying out this analysis, qualitative modeling technique was used. The modeling was carried out using the expertise and wisdom of the employees of the manufacturing units in a structured way within the boundaries of the system. The experts provided generalizations of the implemented and suggested provisions and controls in the four major areas. The experts further helped to identify the factors and parameters influencing development of a generalized approach. Thus, the factors other than cost and productivity gains, which must be considered for developing an implementation approach, were identified. Each generalized provision was rated by the experts and given a quantitative score. Finally the cumulative score of each category was calculated by adding the scores for each factor. The cumulative scores were then listed in reducing order. It was also decided that if more than five experts have rated a particular provision absolutely mandatory, that will taken up on priority in Phase 1, irrespective of its cumulative score. Based on all these considerations, the implementation of the provisions has been divided into three phases as an order of priority for implementation in any engine bearing manufacturing industry.

9.4 RESULTS OF THE STUDY

The results of the study are summarized separately for each phase of study.

9.4.1 Preliminary Study

The preliminary study was carried out to find the changed manufacturing scenario, its impact on ergonomics requirements and the status of ergonomics in engine bearing manufacturing industry. The study carried out through a specially designed questionnaire on employees of the studied organizations revealed the following:

Changed demands of work

- 80% of the respondents amongst the employees from the four organizations feel that their job has undergone a lot of change in the last few years, while the remaining feel that there has been a fair degree of change.
- About 78% of the employees report that now they spend appreciably more time on the performance of their job out of the 8-hour shift as compared to earlier

times. The remaining 22% feel that there has been a fair to a slight degree of change.

- For most employees (82.5%) the quality requirements of the jobs have greatly improved and scrap levels have to be maintained much lower.
- 62.5% of the employees have reported that over the years there is a tremendous increase in production targets per shift while 37.5% have reported some increases to a fair degree of increase.
- About 50% of the employees feel that the enhanced production targets and stringent quality requirements have put a great degree of pressure on them, while the remaining feel no pressure to fairly high pressure.
- 45% of the responding employees have reported that now they perform a large variety of jobs and multiple jobs. The remaining report a fair degree of change to no change.
- 38% of the responding employees feel that now their job is more complete as compared to earlier times when many of them were performing only a small part of the job. However, for the remaining there is not much change.
- 35% of the employees feel that activities of maintenance, quality control and report writing have been made an integral part of the employee's jobs to an absolute extent. The remaining 65% have been performing jobs like before with marginal diversification into other areas.
- Only one-fourth of the responding employees feel that supervision has been absolutely removed. In the remaining the change is minor to a fair degree.
- 37.5% of the employees experience a very strict monitoring and control over leaves and absenteeism now. The remaining have also experienced some change in this regard.
- 42.5% of the employees have reported that accountability has increased to a high degree while for others it has increased to an appreciable extent.

Based on the response to individual dimensions of expected change in employee's jobs, cumulative response of the employees to a dimension was calculated which was used to identify the areas that have contributed the most towards making the jobs demanding. The dimensions are (1) change in quality requirements which have got a maximum score of 94.37% followed by (2) change in job requirements (93.75%), (3) actual time spent on job (93.75%), (4) increase in production targets (87.5%), (5) pressures due to quality and quantity requirements (83.12%) and others.

Change in ergonomic requirements as a result of changed demands of work

Part II of the questionnaire used for preliminary study seeks information regarding the ergonomic requirements of the workplace in the wake of changed demands from the employee's jobs. Results of compilation of the response of the employees are:

- 55% of the respondents feel that there is an absolute need for analyzing and changing the hazardous working postures. Another 45% employees have felt this need to an appreciable degree.
- 57.5% of the employees are of the opinion that there is an absolute need of looking into and changing the material handling system.
- 65% of the responding employees feel that there is an immediate and urgent need to assess the lifting tasks being carried out on each operation.
- More then 80% of the responding employees feel that displays and controls on machines have been taken care off to a large extent by the manufacturer's as most machines have been imported from the collaborators.
- 52.5% of the employees feel a fair level to an absolute level of change required in job allocations based on interest, aptitude and skills.
- A majority of the employees report not much change required in communication and information flow.
- 75% of the responding employees have registered an absolute need or an appreciable degree of need to have good interpersonal relationships and support by the management.
- 62.5% of the employees want the jobs to be designed more logically on scientific basis.
- A weighted average percent score for all the above reveals that working postures, material handling, lifting tasks, and scientifically evolved job design are the areas where employees feel that analysis and modifications are required.

Status of Ergonomics in Engine Bearing Industry

Four areas namely working postures, material handling, lifting tasks, job designs and feedback had importance scores above 80% and status score from 55% to 62% as per feedback of the employees when asked about existence of ergonomic compliance activities. This registered the need for their further analysis in this research work. According to the respondents all other areas including controls and displays, communication and management, inter-personal relationship and provision of training are adequately looked after by the representative organizations.

9.4.2 Analysis with regard to Work Postures

This analysis was carried out using the Rapid Upper Limb Assessment (RULA) technique. All work centres in the organizations were analyzed using RULA. The jobs having scores above the acceptable level, as per RULA technique were taken up for more detailed analysis. Subsequently problems were analyzed and ergonomic provisions/ controls were implemented or suggested. The results of this analysis are:

- A total of 74 elemental tasks on 30 work centres/ tasks were studied using the RULA technique out of which 26 (35%) were found to have scores more than the minimum acceptable level.
- Further, in each major area of bushing line. bearing line, plating section, sintering line and packing section the percentage of work centres having acceptable score were 33%, 36%, 50%, 25%, and 33% respectively. It shows that the maximum problems existed in the bearing and plating lines.
- The problems found in all these areas were awkward postures, sustained or forceful exertions, constrained work space, manual lifting, twisting of wrists, contact stresses, repetitive jobs, excessive travel between stations and accidents.
- On bushing line, a total of seven work centres were taken up for detailed analysis by RULA. On these work centres, controls and provisions were applied on ten tasks. Out of the controls suggested or implemented 83% were engineering controls, and 17% were administrative controls.
- On other lines i.e. bearing line, plating section, sintering line and packing section the percentage of engineering controls are 86%, 90%, 100%, and 100%respectively;
- Out of a total of 28 controls developed on all lines taken together: 78% were implemented in full and validated because of their importance, ease of implementation and low cost involved. Some controls (8%) were implemented in part because these involved long time and resources for full implementation.
- Out of the total developed provisions/ controls 70% were low cost, 18% were medium cost and 12 % were high cost.
- The implemented controls resulted in reduction of fatigue allowance, wastages, setup times, accidents, and thus improving cycle time and output. In addition, reduction of manpower and other cost savings due to control of rejections have taken place.

- The percentage of controls developed under each of the categories under work posture and its resultant effect on productivity and cost are as shown in Table 9.1.

Table 9.1
Percent of controls developed under each category under work postures

Generalized category of provision/ control under work postures	Percentage of controls developed under each category	Total gain in productivity (Converted to cost benefit in Rs. Lacs)
1. Provision of additional controls on machines	39%	• Increase in bush production from 4.05 lac parts earlier to 4.73 lac parts after implementation ≈ saving of Rs 81.6 lac per annum • Increase in bearing production from 6.83 lac parts earlier to 7.57 lac parts after implementation ≈ saving of Rs 115.44 lac per annum
2. Provision of conveyors, worktables with adjustable heights, platforms etc.	22%	
3. Change in operator position on the work station, relocation of machine	13%	
4. Convert internal setup time to external time	8%	
5. Additional work instructions, changes in procedures and methods	8%	
6. Provision of safety attachments, injury prevention aids	8%	
7. Integrating ergonomic principles into equipment design	2%	

- In case of all implemented provisions/ controls, the RULA score was calculated again and found to be within the acceptable level. This will help improve the worker health and safety in addition to the above gains in productivity.
- The production output on the bushing line is found to increase by as much as 17% as a result of elimination of hazardous postures on machines and implementation of controls.
- Bearing output on each production line is expected to increase by about 13%. The output of the packing and dispatch section will increase by 10% as a result of implementation of controls.
- The bimetallic sintered strip production output is expected to rise by about 4% after the implementation of controls on ergonomic risk tasks.
- Safety attachments were provided on manual repetitive tasks such as hole piercing or lip punching to prevent accidents, which generally result in major injuries to hands. The study of these operations for a period of three months after the installation of safety arms, showed no injuries or accidents.

9.4.3 Material Handling Tasks

Material handling tasks carried out in bearing manufacturing units were observed over a period of time. The contributing factors to the ergonomic risks in material handling tasks were identified by experts through consensus. Subsequently, a technique was developed and the tasks were analyzed in detail using this technique. Provisions/ Controls were then developed and implemented wherever feasible. The effect of various performance parameters and output was assessed. The results include:

- The factors that contribute to ergonomic hazards in manual material handling tasks are Load Weight and frequency of handling; Hand distance from lower back; Asymmetrical trunk load; Postural constraints; Grip on load; Operator capabilities; Floor surface; Carry distance; Obstacles en route; and Other environmental factors.
- The observational technique MHAC developed for analysis of material handling tasks in an engine bearing manufacturing industry provides a method of screening the working population quickly, for exposure to a likely risk of work related MSD's, assessing the risk associated with employees lifting and carrying loads over distances, and give results, which could be incorporated in a wider ergonomics assessment covering epidemiological, physical, mental, environmental and organizational factors.
- A total of eight manual material handling tasks were analyzed using the evolved MHAC technique. Out of these, six (75%) tasks were identified to be critical requiring immediate detailed analysis and corrective action.
- Out of the six tasks analyzed in detail the problems, which occurred most frequently, were identified. Listed in the order of occurrence, the identified factors are Higher Load weight, carry frequency, awkward posture, grips, high noise and temperature on the shop floor, and carry distance and floor surface.
- The provisions/ controls developed and implemented are primarily under the category of engineering controls, which include provision of conveyors and design of four-wheeled trolley considering all loading conditions and other parameters. In one case, where engineering controls were difficult to implement, administrative controls were suggested which was primarily job rotation.
- Out of all the developed provisions/ controls all but one have been implemented and validated. The one, which has not been implemented, is provision of a conveyor in dispatch section owing to high initial investment.

- Implementation of provisions/ controls resulted in reduction of injuries, absenteeism, and manpower deployment, thereby improving output and saving costs. The details of improvements made are given in Chapter 6.
- The survey carried out in engine bearing manufacturing industries has shown that many of the handling aids currently being used are poorly designed from the user's point of view. Moreover the provision of these aids has not ensured that stress or discomfort level of the users has reduced considerably. If adequate attention is paid to the ergonomic aspects while procuring these aids, a significant improvement in efficiency and reduction of injuries is achievable.
- By providing ergonomically designed handling aids, it is expected that the output will increase by 10000 parts per month resulting in an annual saving of Rs 15.6 lacs. The manpower cost (casual manpower employed for material handling) is likely to go down by Rs 1.50 lac per annum.
- There is an expected saving of 15 to 30 mandays due to reduced number of lost or restricted days.
- Among the developed solutions for elimination of risk in hazardous material handling tasks, provision of appropriate handling aids, and promoting use of handling signs and symbols, have emerged to be most common.
- Four lifting tasks were analyzed which are representative of eight different work centers where lifting of material is carried out. The Lifting Index in all the four cases was more than 1.0. In two cases, it was even more than 1.8 depicting that some of the lifting tasks are very unsafe and are likely to cause MSD's to the workers.
- After modification, within the limitations of the existing system, the Lifting Index could be brought below 1.0 only in one case. In other three cases, it came down between 1.1 to 1.24.
- Contrary to the recommendations of Lifting Index to be below 1.0, it is observed that, in the conditions existing in bearing manufacturing units in particular and Indian conditions in general, a Lifting Index of up to 1.5 may have to be accepted. However, it must be pointed out here that wherever organizations accept LI value greater than 1.0 (say up to 1.5), the worker selection criteria must be used to identify workers who can perform potentially stressful lifting tasks. Those selection criteria must be based on research studies, empirical observations, or theoretical considerations that include job related strength testing and/or aerobic capacity testing.

- After implementation of provisions identified after analyzing the lifting tasks, it is expected that absenteeism and injury rate is likely to go down substantially. The tasks involving frequent lifting currently have an absenteeism rate of about 18% and this rate is expected to improve to a more acceptable level of 10%.
- The compensation costs payable because of injuries caused due to lifting, could not be ascertained as the amount is directly paid by a Government agency, ESI. However, as per information gathered by discussing with experts, this amount is expected to reduce by 50%.
- The most preferred controls for elimination of risk in hazardous lifting tasks as revealed by the study are (1) Change in load/ weight orientation, and (2) Raise/ Lower height of load at origin or destination.

9.4.4 Job Design

This analysis includes the application of Job Diagnostic Survey Technique developed by Hackman and Oldham (1974), on three different job families namely, production operators, quality staff and inspectors, and machine setters and maintenance staff. The aim is to find out the deficiencies in jobs based on the preferences and desires of the workers and the contents of the jobs being performed by them. The results of the analysis show:

- 22% of the production operators have Motivating Potential Score (MPS) less than 70 indicating that for these employees the work is not motivating. Further it was found that the MPS was low for those jobs, which had problems with task identity and task significance.
- Three jobs were identified on the production line where the scores for the task identity and significance were low. These are countersinking of OD/ID holes, wire brushing, and manual material handling tasks. The causes were identified using cause and effect and pareto analysis.
- 35% of the respondents felt that the problem with task identity is due to the manual and repetitive nature of the job on the identified tasks while there is considerable amount of automation on other machines.
- Another 26% felt that the problem is because the company does not attach importance to these jobs while 17% felt that problem with these jobs are that they do not require any skill to operate.

- Lack of autonomy is another problem identified for some employees contributing to low MPS of some production operators. Requiring authorization to start production for some critical work centres like ID and Height broach is one such problem. Self-Inspection using Statistical Process Control (SPC) has been suggested to be implemented immediately after operator training.
- Introducing self-inspection during the manufacturing process is expected to bring down the bearing rejection from 4.9% to 1.0% resulting in an additional sale of Rs 39.0 lac in bearings alone. The bushing rejection will also come down from 3.0% to 0.5%.
- For 59% of the quality staff and inspectors having MPS of less than 80, the work is very de-motivating because of lack of task identity, task significance, and lack of feedback from job. A majority of the employees having these low scores were inspectors involved in 100% visual inspection and dimensional checking. Some of the causes identified contributing to poor MPS are difficulty in removing parts from the inspection block (30%), pressure on employees due to complaints (20%), too many defects in some lots (15%), and others.
- The survey results showed that none of the machine setters and maintenance staff had any serious motivational problems with no employee having scored less than 80. Also, the results show that since no scores are above 180 also, none of the jobs are overly demanding.
- The provisions/ controls suggested in this area are primarily administrative controls, which include job rotation, job enlargement and job enrichment.
- 60% of the combined group of three job families shows a high general satisfaction indicating that the group is bearing up quite well because of good motivating potential of their jobs.
- Growth satisfaction is generally found good indicating that the employees feel that their work offers significant potential for personal growth.
- Internal motivation shows high value for the combined group which is a clear indication of the feelings of the employees about the importance of their work.
- Widely distributed score about pay satisfaction show that pay is clearly an area of dissatisfaction.
- Perceived threat of job security is the most serious problem facing the employees with about two-thirds highlighting concerns from moderate concern to extreme worry.

- Social satisfaction is generally high in the employees and also they are satisfied with their professional dealings with other staff.
- Half of the group shows dissatisfaction with their supervisors. Poor feedback, low pay and poor job security are related to degree of supervisory support, or lack of it.

9.4.5 *Productivity Enhancement through Ergonomic Provisions/Controls*

- All implemented provisions on each line i.e., Bushing Line, Bearing Line, Packing Section and Sintering Line have resulted in substantial increase in output. Details of the increase because of individual provisions are given in Tables 8.1 to 8.4
- The increase in output has been achieved because of reduction in fatigue allowance, improvement in cycle time of operation, set-up time, rejection or increase in available processing time. Details are given in Table 8.4
- Considering the sequence of operations on the lines, the capacities of each work center and the bottleneck work centers the output of bushing line has increased from 4.05 lac parts to 4.73 lac parts a rise of 17%, bearing line from 6.81 lac parts to 7.57 lac parts, a rise of 11%, packing section from 11.65 lac parts to 15.03 lac parts, a rise of 29% and sintering line from 72000 meters to 74300 meters, a rise of 3%.
- Further for a number of provisions and controls, which were only suggested and not implemented an assessment of various savings was made using expert opinion. It is seen that the improvements take place through saving in manpower, reduction in injuries, reduction in absenteeism, increase in motivation potential, reduction in rejection percentages and increase in output per shift. The details are given in Table 8.5. The total cost on all implemented and suggested provisions is expected to be Rs.41.99 lacs, which would result in a saving of Rs.282.86 lacs right in the first year.
- All the implemented and suggested measures were categorized by experts into 22 categories of provisions for developing a general approach for use by the industry at large. These categories are given in Table 8.6.
- Factors identified by the experts for prioritizing the implementation of. various ergonomic provisions/controls are: cost of implementation, productivity gain, ease of implementation, types of control viz. engineering, administrative or work simplification, effect on other areas, training required, time frame for results and legal/statutory requirements.

- Based on the expert opinion on all above factors, the priority of various ergonomic provisions was decided which is given in Tables 8.9 to 8.12 for work postures, manual material handling tasks, lifting tasks and job designs.
- The order of priority given to the four major areas for implementation is work postures, material handling, tasks and job design.
- Based on expert opinion and qualitative modeling a phase-wise implementation plan for engine bearing industry was developed which is given in Table 8.13.

9.5 CONCLUSIONS AND RECOMMENDATIONS

1 In the past few years the jobs of the employees have become more demanding. The factors, which have contributed to this phenomenon, include stringent quality requirements, job content like multiple jobs and job diversification, higher percentage of working time and higher production targets.

2 For the changed job requirements and changed manufacturing culture and conditions a corresponding change in work systems and job designs is necessary. This change is particularly required in the areas of work postures, manual material handling tasks, lifting tasks and job designs.

3 Areas of working postures, manual material handling tasks, lifting tasks and job designs are not adequately being looked after in engine bearing industry while some other areas like controls and displays, interpersonal relations, communication etc. are at satisfactory level.

4 The ergonomic investigation is best carried out by observational techniques instead of instrument-based techniques. The reason for such widespread use of observational techniques in industry is because it does not interfere with the worker during observations, and does not require use of expensive equipment.

5 In engine bearing manufacturing industry nearly every third work center has some posture related problem, which can adversely affect worker health and safety.

6 Among the most commonly existing posture related problems are awkward postures, sustained or forceful exertions, constrained work space, manual lifting, twisting of wrists, contact stresses, repetitive jobs and excessive travel between stations.

7 For rectifying posture related problems the provisions or control to be evolved would be the engineering controls related to equipment etc. in 80% to 100% of the cases. Administrative controls and work simplifications would be of a very limited use in posture related problems.

8 Most of the posture related problems (70 to 80%) are easy to solve with a small effort in a short time frame and with low cost. Only small percentages of the problems require medium to high cost and time frame for rectification.

9 In case of material handling tasks about 75% tasks have ergonomics related critical problems. The problems, listed in the order of their occurrence are: higher load weight, carry frequency, awkward posture, unsuitable grips, high noise and temperature, carry distance and floor surface. The problems can be solved primarily by engineering controls. Most of the controls can be implemented in a short period of time and with a small effort and low cost.

10 Handling aids generally used in bearing manufacturing industry are poorly designed and give inadequate protection against stress and discomfort.

11 In case of manual lifting task, after the calculation of lifting index, it can be concluded that almost all tasks have ergonomic risks in them. Even after implementation of controls, the recommended Lifting Index of 1.0 could not be achieved. Further, considering the state of technology and other conditions in Indian context, some improvement is possible but not to the extent that the tasks would be made totally non-hazardous. The Lifting Index thus in Indian context may be accepted up to 1.5. However, in such cases only those workers who have the strength of performing potentially stressful tasks should be employed.

12 The most preferred controls for reducing risk in hazardous lifting tasks prevalent in engine bearing industry are change in load/weight orientation and raise or lower the vertical height of load at origin or destination.

13 Jobs, which have low task identity and task significance, have very low motivating potential. Routine and repetitive job and low-level jobs like wire brushing and manual material handling etc. do not motivate.

14 Regarding job-person match out of the three categories of employees it can be concluded that maintenance persons have the highest job-person match followed by employees in inspection and quality control and production operators. Their motivation potential also follows the same order.

15 Low pay, poor job security and low degree of supervisory support are among the major de-motivators.

16 Implementation of ergonomic provisions/controls in all areas of work postures, material handling. lifting task and job design have resulted in reducing hazards involved in a job thereby making the job of the employee safer which would

definitely improve his health, well being, morale and safety. Although this is coming at a slight initial cost, the benefits would outweigh in the form of performance and productivity. The productivity is expected to go up by at least 10%. It can be thus concluded that employers should not shirk from spending on the well being of the employees. This is in fact an investment, which will show up in the form of immediate and long-term enormous benefits.

17 The low productivity issues are more prominent for the tasks, which have ergonomic problems than for the rest of the tasks. There is a definite relationship between low productivity and ergonomic risk involved in a task.

18 Converting machine internal set-up time into external time not only results in increased production but it also eliminates the hazardous work postures necessitated by constrained workspace on the machine.

19 The most preferred controls for elimination of hazardous work postures are (1) Provision of conveyors, worktables with adjustable heights, platforms etc, and (2) Provision of safety attachments, injury prevention aids.

20 The maximum productivity benefit is expected to come by integrating ergonomic principles into equipment design and converting internal setup time to external time. However, implementation of these controls involves maximum cost input.

21 Provision of additional controls on machines, providing additional work instructions and changes in procedures and methods, and relocation of operator position or machine are simple but very useful provisions.

22 The implementation plan of the provisions after the detailed analysis has been divided into three phases starting from less expensive, less effort involving, more productive and simpler ergonomic provisions. This will facilitate feedback and correction, and will provide immediate and encouraging results for motivation for continuing with the implementation process of the subsequent phases.

23 The provisions or controls suggested in phase 1 are, in general, less expensive, easy to implement, results in immediate gains in productivity or other related parameters. These will also satisfy the absolutely necessary ergonomic requirements, which are identified as mandatory.

24 The provisions undertaken for implementation in phase 2 are slightly more difficult to implement, involves higher initial capital investment. The gains in productivity may not be directly measurable but will have a positive effect on employee motivation and morale.

25 Phase 3 includes provisions, which are more related with hard-core technical changes in machinery or tooling. Large capital investment will be necessary, although it must be pointed out here that maximum productivity gains will come after implementation of these provisions.

26 Following controls and provisions are suggested to be undertaken for implementation in each of the three phases:

Phase 1:

Area	Provision or Control
Work Postures	• Provision of conveyors, worktables with adjustable heights, platforms etc. • Provision of safety attachments, injury prevention aids
Material Handling	• Provision of handling aids • Promote use of handling signs and symbols
Lifting Tasks	• Change in load/ weight orientation • Raise/ Lower height of load at origin or destination
Job Design	• Employee involvement • Operator training and education

Phase 2:

Area	Provision or Control
Work Postures	• Additional work instructions, changes in procedures and methods • Change in operator position on the work station, relocation of machine • Provision of additional controls on machines
Material Handling	• Workstation design changes like conveyors etc. • Reduce carrying distances and frequency, and weight of load
Lifting Tasks	• Reduce lifting frequency
Job Design	• Job Enrichment • Job Enlargement

Phase 3:

Area	Provision or Control
Work Postures	• Integrating ergonomic principles into equipment design • Convert internal setup time to external time
Material Handling	• Automation to reduce manual work
Lifting Tasks	• Improvement in grip/ coupling on load
Job Design	• Job Rotation

9.6 LIMITATIONS OF THE STUDY

The main limitations of the study are as follows:

- The study has been limited to manufacturers of engine bearings in North India only.
- The study has been carried out using observational techniques only.

- The study has been conducted, involving all major areas of ergonomic compliance. Separate studies taking one area at a time may be necessary for more detailed analysis of the deficiencies.
- As such no mathematical model or equation has been derived to calculate the effect of ergonomic compliance on productivity and also to relate it to research variables.
- The areas identified for detailed analysis after the initial questionnaire may differ from organization to organization. For this larger sample of industry for preliminary study may be employed in future.

9.7 SCOPE FOR FUTURE WORK

While carrying out this study, a number of areas have come in focus where detailed research can be taken up. Such areas, demanding attention, further exploration and analysis through research work are mentioned below:

- The present study has been concentrated on engine bearings manufacturing alone. The work can be extended to carry out generalized studies covering all other categories of industries such as process industry, engineering industry, and service industry.
- The study of work postures has been mainly restricted to analysis of upper body limbs using observational techniques only. Detailed analysis of MSD's caused due to awkward or difficult posture may be taken up using specialized equipment and advanced methods/ techniques.
- A detailed study can be undertaken over a longer period of time for finding out the effect of making various changes in suggested job design on performance and productivity.
- The present study has suggested provisions and generalized approach for bearing manufacturing organizations in India. Considering this as the basis, other areas can be studied to generalize the results and make recommendations for use by any type of industry.
- Separate studies for each area taken one at a time may be undertaken for more detailed analysis of the deficiencies.

9.8 CONCLUDING REMARKS

It is generally agreed that for an ergonomics programme to be effective, it should include a core set of elements or provisions to ensure management commitment, employee involvement, identification of problem jobs, development of controls for problem jobs and training and education for employees. These core elements are said to be typical of any comprehensive ergonomic implementation programme, and, together they can help an employer ensure that ergonomic hazards are identified and controlled and that employees are protected. The implementation of controls on the identified jobs leads to positive correlation with productivity gains in terms of either increase in output or reduced rejection.

It is concluded that in this new millennium, the organizations can use the phase-wise approach for ergonomic compliance described in this thesis work to improve employee health and safety and at the same time avail benefits of enhancing productivity and other gains.

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APPENDIX – 4.1

QUESTIONNAIRE FOR EMPLOYEES

This questionnaire contains questions on the following three aspects of human working in engine bearing industry:

i) Changed demands of work from the employees in the last few years due to changed manufacturing scenario.

ii) Changed ergonomic needs of the employees due to changed demands of work.

iii) Status of ergonomics in engine bearing industry

All the questions are of multiple choices. You are requested to tick (√) the most appropriate choice. You are also requested to give your suggestions at the end of the Questionnaire.

SECTION - I

1. Do you think your job requirements have undergone a change in the past few years?

A lot of change ☐ Fair degree of change ☐ Some change ☐ No change ☐

2. Do you think that the actual time out of 8 hour shift, which you spend on a job now is more than what you used to spend earlier?

Appreciably more ☐ Fairly more ☐ Slightly more ☐ Not at all more ☐

3. Do the quality requirements of the product and acceptable level of scrap percentage improved in the last few years?

Great Improvement ☐ Fair improvement ☐ Some improvement ☐ No improvement ☐

4. Do your production targets per shift increased in the last few years?

Tremendous increase ☐ Fair degree of increase ☐ Some increase ☐ No ☐

increase

5. Have the quality and quantity requirements as depicted in question numbers (3) and (4) above, brought mental and physical pressures on you?

Great pressure ☐ Fairly high degree of pressure ☐ Some pressure ☐ No pressure ☐

6. Are you performing more variety of jobs and multiple jobs now as compared to what you were performing few years back?

A large ☐ Fairly larger ☐ Some change Practically variety and many jobs   variety and multiple jobs ☐   no change ☐

7. Have there been changes in your jobs like that you were earlier performing only a small part of the job but now you are performing complete job.

A lot of change ☐   Fair degree of change ☐   Some change ☐   No change ☐

8. Do most of the areas like Maintenance, Quality Control, filling up of the reports etc. which earlier used to be separate functions have now been made part of the product job.

Absolutely ☐   To a great degree ☐   To some degree ☐   Not at all ☐

9. In the earlier production systems a lot of supervision was employed over the worker/operator. Has this supervision been reduced and the operator/worker made more responsible?

Absolutely ☐   To a great degree ☐   To some degree ☐   Not at all ☐

10. Is there a more control on your leaves absenteeism, discipline and performance?

Very strict control ☐   Appreciably more control ☐   Some difference is there ☐   Practically no difference ☐

11. Is there a more logical and regular performance appraisals now as compared to earlier times.

There is a tremendous change ☐   A fair degree of change ☐   Some change is there ☐   No change ☐

12. Have your accountability towards your job and its outcomes (results) increased over the period of time.

Increased to to high degree ☐   Appreciable increase ☐   Some change ☐   No increase ☐

SECTION - II

CHANGED ERGONOMIC REQUIREMENTS

1. Assuming that the jobs of the employees have become more demanding do you think that there is a need to make a corresponding change in the following areas of human interactions in your organization?

Sr. No.	Area	Extent of need to change in view of more demanding work			
		Absolute need	Appreciable need	Fair degree of need	No need
1.	Working posture i.e. sitting, standing, bending, moving etc.				
2.	Material handling including manual material handling and use of material handling devices				
3.	Lifting task (Force requirements) as a part of the job.				
4.	Location and types of displays and controls				
5.	Job allocation based on interest aptitude and skills				
6.	Communication and information flow in the organization, particularly from top downwards.				
7.	Good interpersonal relationships and support by the management				
8.	Provision of training, avenues for personal growth				
9.	Scientifically evolved job designs				
10.	Autonomy, information feedback, recognition, motivation and rewards				

SECTION III

Status of Ergonomics in Engine Bearing Industry

The following question is divided into two parts. Part 1 seeks information on the existence of various areas of human work and Part II attempts to get feedback on the initiatives taken by the management in these areas/status of these areas.

S. No.	Area	Part A Existence of Areas/activity				Part B Status and Efforts			
		Many	Fair	Some	No	Great	Good	Fair	Negligible
1.	Working Postures (WP)								
2.	Material Handling (MH)								
3.	Lifting Tasks (LT)								
4.	Location & Type of Controls & Displays (C&D)								
5.	Job Allocations (JA)								
6.	Communication & Information Flow (CI)								
7.	Interpersonal Relationships, support by the management (IP)								
8.	Provision of Training Avenues for personal growth (TR)								
9.	Scientifically evolved Job Designed (JD)								
10.	Autonomy, information feedback, recognition, motivation & reward (FB)								

Appendix 4.2

Pre-testing of the Preliminary Study Form

Following tasks were undertaken for pre-testing of the preliminary study form:

Suggestions received from the following were included:

1. Managing Director of M/s Kads, Enterprises, Patiala
2. Deputy General Manager at M/s Gabriel India Limited, Parwanoo
3. Senior Manager at M/s Gbariel India Limited, Patiala
4. General Manager of M/s FAG Bearings, Pune
5. Personnel Manager of M/s Gates India Limited, Lalru
6. Two faculty members from Thapar Institute of Engineering and Technology, Patiala
7. Assistant Professor from National Institute of Technology, Jalandhar

The feedback received from them was duly incorporated.

Appendix 5.1

Ergonomic Assessment of Bushing Line – RULA Methodology

Operation Function	Activity	Group 'A'								Group 'B'							Grand Score A&B	Grip	Sitting/ Standing
		Upper Arm	Lower Arm	Wrist	Wrist twist	Posture Score A	Muscle use	Force score	Total Score A	Neck	Trunk	Legs	Posture ScoreB	Muscle use	Force score	Total Score			
Load Strip on Decoiler	Bring OH Hoist Crane to site	3	1	1	1	3	0	0	3	1	1	1	1	0	0	1	3	NA	Standing
	Open Decoiler Strip supports	2	1	1	1	2	1	0	3	2	3	1	4	0	0	4	4	Wrap	Standing
	Put strip supports on ground	1	1	1	1	1	1	1	3	3	4	1	5	0	1	6	5	Wrap	Standing
	Fix hoist hook into coil	2	1	1	1	2	1	0	3	2	3	1	4	0	0	4	4	Hook	Standing
	Lift coil using OH Hoist Crane	3	1	1	1	3	0	0	3	1	1	1	1	0	0	1	3	C	S
	Load on decoiler	2	2	2	2	3	1	3	7	2	2	1	2	1	1	4	6	C	ST
	Reset ID of Decoiler to tighten coil	2	1	1	1	2	1	0	3	2	3	1	4	0	0	4	4	W	ST
	Pick up strip supports & fix them on decoiler	1	1	1	1	1	1	1	3	3	4	1	5	0	1	6	5	W	ST
	Tighten supports	2	1	1	1	2	1	0	3	2	3	1	4	0	0	4	4	W	S
	Cut coil winding wires to loosen strip	1	1	1	1	1	0	0	1	1	1	1	1	0	0	1	1	W	S
	Pull loose end of coiled strip to straightener	3	2	1	1	3	1	2	6	2	2	1	2	1	2	5	6	W	S
Straightenin	Adjust	2	1	1	1	2	1	1	4	2	1	1	2	e0	1	3	3	-	ST

g of coiled strip	straightener to hold st rip																		
Blanking-200T Pneumatic Pres	Switch on to pull strip thro' straightener	1	1	1	1	1	0	0	1	1	1	1	1	0	0	1	1	C	ST
	Bring tools (Punch, Die etc) from Tool Store	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	W	-
	Set up Die & Punch	2	2	2	1	3	1	1	5	3	3	1	4	1	1	6	7	W	ST
	Set up of hydraulic feeder	2	2	2	2	4	1	1	6	3	2	1	3	1	1	5	6	W	ST
	Setup of Dead Stopper	2	2	2	2	4	1	1	6	3	2	1	3	1	1	5	6	W	ST
	Operate m/c in manual mode for setup	2	1	1	1	2	0	0	2	1	1	1	1	0	0	1	2		ST
	Place large pan for blanked Pcs.	2	2	2	1	3	1	2	6	3	4	1	5	1	2	8	7	H	ST
	Check set pieces	1	2	1	1	2	0	0	2	1	1	1	1	0	0	1	2	W	ST
	Reset if necessary	2	2	2	1	3	1	1	5	3	3	1	4	1	1	6	7	-	-
	Locate QC Inspector for setup approval	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Start Blanking by switching to auto mode	1	1	1	1	1	0	0	1	1	1	1	1	0	0	1	1	-	ST
	Locate piece on m/c.	1	2	1	1	2	0	1	3	2	2	1	2	0	1	3	3	W	ST
	Start operation	1	1	1	1	1	0	1	2	2	1	1	2	0	1	3	3	W	ST
	Remove & put in unload pan	1	2	1	1	2	0	1	3	2	1	1	2	0	1	3	3	W	ST
First Forming or	Load raw material on	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	ST

Semi-forming (45T Pneumatic Press)	conveyor																		
	Setup first form die & punch	3	3	3	2	5	1	3	9	3	3	2	5	1	3	9	7	W	ST
	Locate blanked pcs. on table in front	1	1	1	1	1	0	1	2	1	1	1	1	0	1	2	2	W	ST
	Locate pc. on die	1	2	1	1	2	0	1	3	2	2	1	2	0	1	3	3	N	ST
	Press 2 push buttons on both sides of m/c. to operate	1	1	1	1	1	0	1	2	1	1	1	1	1	1	3	3	P	ST
	Push the Ist formed pc out of punch to the pan.	2	3	2	1	4	1	2	7	3	3	1	4	1	3	8	7	P	ST
Final forming on coining - Press pneumatic 250T	Die settings	2	3	2	1	4	1	3	8	3	3	2	5	1	3	9	7	W	ST
	Hold the first formed pc in a plug rod and locate on button die	3	3	2	2	4	1	2	7	1	2	1	2	1	2	5	7	P	SI
	Operate Press by presisng push button while still holding plug.	1	3	2	2	3	1	3	7	2	2	1	2	1	3	6	7	W	SI
	Repeat press stroke after rotating the plug	2	3	3	2	4	1	3	8	2	2	1	2	1	3	6	7	W	SI
	Knockout bush from plug by hitting die	2	3	3	2	4	1	3	8	3	3	1	4	1	3	8	7	P	SI
	Check ID by using plug gauge	1	2	1	1	2	1	1	4	1	1	1	1	0	1	2	3	W	SI
Face & Chamfer (SPM)	Change tooling on top & bottom of shuttle as per	1	2	1	1	2	1	1	4	1	1	1	1	0	1	2	3	W	ST

	bush OD																		
	Setup facing tool, ID Ch f. tools & OD Chf. tools on both sides on chucks	2	3	2	2	4	1	e2	7	3	1	1	3	1	2	6	7	P	ST
	Load bush on top half of shuttle	2	1	1	1	2	0	2	4	1	1	1	1	1	1	3	3	P	ST
-	Press push button with both hands on 2 sides to operate machine	1	1	1	1	1	0	1	2	1	1	1	1	0	1	2	2	C	ST
	Load bush on lower half of shuttle	1	2	1	1	2	0	2	4	3	1	1	3	1	1	5	5	P	ST
	Repeat above steps	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Unload bushing from top half & put in pan	2	1	1	1	2	0	2	4	1	1	1	1	0	1	3	3	P	ST
	Check length using GO/NDGO gauge	1	1	1	1	1	0	1	2	1	1	1	1	0	1	2	2	P	ST
St ress-Relieving	Open furnace door after setting	1	2	1	1	2	1	1	4	1	1	1	1	0	1	2	3	W	ST
	Lift pans with folk lifter	2	1	1	1	2	0	1	3	1	1	1	1	0	1	2	3	-	ST
	Shift pans into furnace	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Close door	1	1	1	1	1	0	1	2	1	1	1	1	0	1	2	2	W	ST
	Remove pans after 2 hours	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OD - Grinding	M/c.setup according to	1	1	1	1	1	1	2	4	2	2	1	2	1	2	5	5	W	ST

(Centreless Grinder)	bush OD																		
	Wheel Dressing	1	1	1	1	1	1	2	4	1	2	1	2	0	1	3	3	-	ST
	Load pcs.	1	2	1	1	2	1	1	4	2	1	1	2	0	1	3	3	W	ST
	Bending to lift pans for subsequent passes	3	3	1	2	4	1	3	8	2	3	2	5	1	3	9	7	P	ST
Final boring (Exceilo Boring M/c.)	On-line boring of brass bushes as per bush OD	1	2	1	1	2	1	2	5	1	2	1	2	1	1	4	5	W	ST
	Loosen clamp pressure	2	1	1	2	3	1	3	7	2	1	1	2	1	3	6	7	W	ST
	Fix bush in brass bore	2	2	1	2	3	1	2	6	2	1	1	2	1	2	5	6	P	ST
	Fix diamond tool on spindle	1	1	1	1	1	1	1	3	2	1	1	2	0	1	3	3	P	ST
	Tighten clamp after fitting bush in bravo bore	2	1	1	2	3	1	3	7	2	1	1	2	1	3	6	7	W	ST
	Switch on the m/c. spindle to operate.	1	1	1	1	1	0	1	2	1	1	1	1	0	1	2	2	P	ST
	Loosen clamp after completion of boring opn.	2	1	1	2	3	1	3	7	2	1	1	2	1	3	6	7	W	ST
	Remove bush	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ST
	Check wall thickness	1	2	1	1	2	0	1	3	3	1	1	3	0	1	4	4	P	ST
	Put in pan	1	1	1	1	1	0	1	2	2	1	1	2	0	1	3	3	P	ST

Appendix 6.1

SURVEY FORM

Survey of users of manual handling aids in Engine Bearing manufacturing industry

Name of the Company: ____
Address: ____

1. Name of the user:
2. Age: *(Pl tick appropriately) in years*
3. Under 25 ☐ 25-39 ☐ 40-50 ☐ > 50 ☐
4. Hand Used: Left ☐ Right ☐
5. Types of handling aids used. *(Pl tick appropriately)*

S.no	Type of aid	'Yes' if used and 'No' if not used	If 'Yes', then how many of each type
1	**4-wheeled trolleys** • Flat platform • Tall trolleys • Mini-movers		
2	**Hand pallet trucks**		
3	**Roll conveyors**		
4	**Cylinder trolleys**		

6. What is the frequency of use of each aid? *(Pl tick appropriately)*

S.no	Type of aid	>10 per day	5 – 10 per day	1 – 4 per day	1 per week	< 1 per week	Variable
1	**4-wheeled trolleys** • Flat platform • Tall trolleys • Mini-movers						
2	**Hand pallet trucks**						
3	**Roll conveyors**						
4	**Cylinder trolleys**						

7. Any specific difficulties faced while using these aids. Please indicate in the space provided below:

8. Is there any affect of the following environmental conditions while handling each type of aid? Please answer in Yes or No.

S.no	Type of aid	Floor surface	Restricted space	Corners or turning	Steps	Slopes/ Ramps
1	**4-wheeled trolleys** • Flat platform • Tall trolleys • Mini-movers					
2	**Hand pallet trucks**					
3	**Roll conveyors**					
4	**Cylinder trolleys**					

9. Any specific difficulties faced due to environmental factors while using these aids. Please indicate in the space provided below:

APPENDIX 7.1

JOB DIAGNOSTIC SURVEY

SECTION ONE

This part of the questionnaire asks you to describe your job, as objectively as you can.

Please do not use this part of the questionnaire to show how much you like or dislike your job. Questions about that will come later. Instead try to make your descriptions as accurate and as objective as you possibly can.

1. To what extent does your job require you to work closely with other people (either "clients" or people in related jobs in your own organization:?

1------------2------------3-------------4-------------5------------6-------------7

Very Little : dealing with other people is not at all necessary in doing the job	Moderately some dealing with other is necessary	Very much: dealing with other people is an absolutely essential and crucial part of doing the job.

2. How much autonomy is there in your job? That is, to what extent does your job permit you to decide on your own how to go about going the work?

1------------2------------3-------------4------------5------------6-------------7

Very Little : The job gives me almost no personal "say" about how and when the work is done	Moderate autonomy: many things are standardized and not under my control, but I can make some decisions about the work.	Very much: the job gives me almost complete responsibility for deciding how and when the work is done.

3. To what extent does your job involve doing a "whole" and identifiable piece of work? That is, is the job a complete piece of work that has an obvious beginning and end? Or is it only a small part of the overall piece of work, which is finished by other people or by automatic machines?

1-----------2-----------3------------4------------5-----------6------------7

My job is only a tiny part of the overall piece of work; the results of my activities cannot be seen in the final product or service.	My job is a moderate-sized "chunk" of the overall piece of work; my own contribution can be seen in the final outcome.	My job involves doing the whole piece of work, from start to finish; the results of my activities are easily seen in the final product or service.
4. How much variety is there in your job? That is, to what extent does the job require youto do many different things at work, suing a variety of your skills and talents?		
1------------2------------3-------------4-------------5------------6-------------7		
Very little : the job requires me to do the same routine things over and over again.	Moderate Variety	Very much : the job requires me to do many different things, usinga number of different skills and talents.
5. In general, how significant or important is your job? That is, are the results of your work likely to significantly affect the lives or well-being of other people?		
1------------2------------3-------------4-------------5------------6-------------7		
Not very significant: the outcomes of my work are not likely to have important effects on other people.	Moderately significant.	Highly significant; the outcomes of my work can affect other people in very important ways.
6.To what extent do managers or co-workers let you know you well you are doing on your job?		
1------------2------------3-------------4-------------5------------6-------------7		
Very little; people almost never let me know how well I am doing.	Moderately; sometimes people may give me "feedback"; other times they may not.	Very much; managers or co-workers provide me with almost constant "feedback" about how well I am doing.
7. To what extent does doing the job itself provide youwith information about your work performance? That is, does the actual work itself provide clues about how well you are doing – aside from any "feedback" co-workers or supervisors may provide?		

1------------2------------3-------------4-------------5------------6-------------7		
Very little: the job itself is setup so I could work forever without finding out how well I am doing.	Moderately; sometimes doing the job provides "feedback" to me; sometimes it does not.	Very much; the job is set up so that I get almost constant "feedback" as I work about how well I am doing.

SECTION TWO

Listed below are a number of statements which could be used to describe a job.

You are to indicate whether each statement is an accurate or an inaccurate description of your job.

Once again, please try to be as objective as you can in deciding how accurately each statement describes your job-regardless of whether you like or dislike your job.

Write a number in the blank beside each statement, based on the following scale:

1	2	3	4	5	6	7
Very Inaccurate	Mostly Inaccurate	Slightly Inaccurate	Uncertain	Slightly Accurate	Mostly Accurate	Very Accurate

1. The job requires me to use a number of complex or high-level skills.
2. The job requires a lot of cooperative work with other people.
3. The job is arranged so that I do not have the chance to do an entire piece of work from beginning to end.
4. Just doing the work required by the job provides many chances for me to figure out how well I am doing.
5. The job is quite simple and repetitive.
6. The job can be done adequately by a person working alone – without talking or checking with other people.
7. The supervisors and co-workers on this job almost never give me any "feedback" about how well I am doing in my work.
8. This job is one where a lot of other people can be affected by how well the work gets done.
9. The job denies me any chance to use my personal initiative or judement in carrying out the work.
10. Supervisors often let me know how well they think I am performing the job.
11. The job provides me the chance to completely finish the pieces of work I begin.

12. The job itself provides very few clues about whether or not I am performing well.
13. The job gives me considerable opportunity for independcence and freedom in how I do the work.
14. The job itself is not very significant or important in the broader scheme of things.

SECTION - THREE

Now please indicate how you personally feel about your job.

Each of the statements below is something that a person might say about his or her job. You are to indicate your own personal feelings about your job by marking how much you agree with each of the statements.

Write a number in the blank for each statement, based on this scale :

How much do you agree with the statement?

1	2	3	4	5	6	7
Disagree Strongly	Disagree	Disagree slightly	Neutral	Agree Slightly	Agree	Agree Strongly

1. It's hard, on this job, for me to care very much about whether or not the work gets done right.
2. My opinion of myself goes up when I do this job well.
3. Generally speaking, I am very satisfied with this job.
4. Most of the things I have to do on this job seem useless or trivial.
5. I usually know whether or not my work is satisfactory on this job.
6. I feel a great sense of personal satisfaction when I do this job well.
7. The work I do on this job is very meaningful to me.
8. I feel a very high degree of personal responsibility for the work I do on this job.
9. I frequently think of quitting this job.
10. I feel bad and unhappy when I discover that I have performed poorly on this job.
11. I often have trouble figuring out whether I am doing well or poorly on this job.
12. I feel I should personally take the credit or blame for the results of my work on this job.
13. I am generally satisfied with the kind of work I do in this job.
14. My own feelings generally are not affected much one way or the other by how well I do on this job.
15. Whether or not this job gets done right is clearly my responsibility.

SECTION FOUR

Now please indicate how satisfied you are with each aspect of your job listed below. Once again, write the appropriate number in the blank beside each statement.

How satisfied are you with this aspect of your job?

1	2	3	4	5	6	7
Extremely Dissatisfied Strongly	Dissatisfied	Slightly Dissatisfied	Neutral	Slightly satisfied	Satisfied	Extremely satisfied

1. The amount of job security I have.
2. The amount of pay and fringe benefits I receive.
3. The amount of personal growth and development I get in doing my job.
4. The people I talk to and work with on my job.
5. The degree of respect and fair treatment I received from my boss.
6. The feeling of worthwhile accomplishment I get from doing my job.
7. The chance to get to know other people while on the job.
8. The amount of support and guidance I receive from my supervisor.
9. The degree to which I am fairly paid for what I contribute to this organization.
10. The amount of independent thought and action I can exercise in my job.
11. How secure things look for me in the future in this organization.
12. The chance to help other people while at work.
13. The amount of challenge in my job.
14. The overall quality of the supervision I receive in my work.

SECTION FIVE

Now please think of the other people in your organization who hold the same job you do. If no one has exactly the same job as you, think of the job which is most similar to yours.

Please think about how accurately each of the statements describes the feelings of those people about the job.

It is quite all right if your answers here are different from when you described your own reactions to the job. Often different people feel quite differently about the same job.

Once again, write a number in the blank for each statement, based on this scale :

How much do you agree with the statement?

1	2	3	4	5	6	7

Disagree Strongly	Disagree	Disagree slightly	Neutral	Agree Slightly	Agree	Agree Strongly

1. Most people on this job feel a great sense of personal satisfaction when they do the job well.
2. Most people on this job are very satisfied with the job.
3. Most people on this job feel that the work is useless or trivial.
4. Most people on this job feel a great deal of personal responsibility for the work they do.
5. Most people on this job have a pretty good idea of how well they are performing their work.
6. Most people on this job find the work very meaningful.
7. Most people on this job feel that whether or not the job gets done right is clearly their own responsibility.
8. People on this job often think of quitting.
9. Most people on this job feel bad or unhappy when they find that they have performed the work poorly.
10. Most people on this job have trouble figuring out whether they are doing a good or a bad job.

SECTION SIX

Listed below are a number of characteristics which could be present on any job. People differ about how much they would like to have each one present in their own jobs. We are interested in learning how much you personally would like to have each one present in your job.

Using the scale below, please indicate the degree to which you would like to have each characteristic present in your job.
Note : The numbers on this scale are different from those used in previous scales.

4	5	6	7	8	9	10
Would like Having this Only a Moderate Amount (or less)			Would like having this very much			Would like having this extremely much

1. High respect and fair treatment from my supervisor.
2. Stimulating and challenging work.
3. Chances to exercise independent thought and action in my job.
4. Great job security.
5. Very friendly co-workers.
6. Opportunities to learn new things from my work.

7. High salary and good fringe benefits.
8. Opportunities to be creative and imaginative in my work.
9. Quick promotions.
10. Opportunities for personal growth and development in my job.
11. A sense of worthwhile accomplishment in my work.

SECTION SEVEN

Please differ in the kinds of jobs they would most like to hold. The questions in this section give you a chance to say just what it is about a job that is most important to you.

For each question, two different kinds of jobs are briefly described. You are to indicate which of the jobs you personally would prefer – if you had to make a choice between them.

In answering each question, assume that everything else about the jobs is the same. Pay attention only to the characteristics actually listed.

JOB A			**JOB B**	
1. A job where the pay is very good			A job where there is considerable opportunity to be creative and innovative	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B
2. A job where you are often required to make important decisions			A job with many pleasant people to work with	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B
3. A job in which greater responsibility is given to those who do the best work			A job in which greater responsibility is given to loyal employees who have the most seniority.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

4. A job in an organization which is in financial trouble-and might have to close down within the year	A job in which you are not allowed to have any say whatever in how your work is scheduled, or in the procedure to be used in carrying it out.

1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

5 A very routine job.	A job where your co-workers are not very friendly

1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

6. A job with a supervisor who is often very critical of you and your work in front of other people.	A job which prevents you from using a number of skills that you worked Hard to develop.

1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

7. A job with a supervisor who respects you and treats you fairly.	A job which provides constant opportunity for you to learn new and interesting things.
8. A job where there is a real chance you could be laid off.	A job with very little chance to do Challenging work

1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

9. A job in which there is a real chance for you to develop new skills and advance in the organization.	A job which provides lots of vacation time and an excellent fringe Benefit package.

1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

10. A job with little freedom and independence to do your work in the way you think best	A job where the working conditions are poor

1---------------------2--------------------3---------------------4------------------------5

Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

11. A job with very satisfying team work	A job which allows you to use your skills and abilities to the fullest extent

1---------------------2--------------------3---------------------4------------------------5

Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

12. A job which offers little or no challenge	A job which requires you to be completely isolated from co-workers

1---------------------2--------------------3---------------------4------------------------5

Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

SECTION EIGHT

Biographical Background

1. Sex: Male _______ Female ______
2. Age (check one)
   _________under 20 ______40-49
   ________ 20-29 ______50-59
   _________30-39 ______60 or over
3. Education (Check one)
   - Grade School
   - Some high school
   - High School Degree
   - Some Business College or Technical School Experience
   - Some College Experience (Other than business or technical school)
   - Business College or Technical School Degree
   - College Degree
   - Master's or Higher Degree
4. What is your brief job title? ______________________________________

Appendix 8.1

Expected gains in parameters through ergonomic provisions (Suggested)

Provision suggested	Identified improvement parameter	Present level	Expected level	Expected gains in					
				Output	Reducing Rejection	Reduction in manpower or material cost	Reduction in accidents/ injuries	Reduction in compensation costs	Lost / restricted days
1. Manual material handling carrying tasks • Design and provision of 4-wheeled trolley (of design demonstrated) in production lines	• Manpower • High MSD's, back pain/ injuries	2							
2. Transfer of pans from degreasing to plating loading station • Installation of roller conveyor transfer mechanism between the two stations.	• Absenteeism rate • Accidents/ Injuries per month • Output / month	20.5% 1.3 6.80 lac							
3. Powder plant – Transfer of raw material for melting • Design and provision of four-wheeled trolley • Height and surface of load platform raised by 2 feet	• Absenteeism rate • Accidents/ Injuries per month	27% 1.3							
4. Transfer of finished parts from the BAP store to shrink wrap station Design and provision of 4-wheeled trolleys	• Absenteeism rate • Manpower deployment	18.6% 3							
5. Constrained workspace, wrist extension and twist during setup at face and chamfer • Job rotation of workers	• Output per month • Job variety • Increase in Motivating Potential score (MPS)	4.75 lac Poor MPS = 70							

6. Set up of master nest block and broach cutter on broaches • Job rotation of workers	• Output per month • Job variety • Increase in Motivating Potential score	7.72 lac Poor MPS = 82							
7. Oiling of parts before packing • Provision of a spray type oiling machine	• Accidents • Oil consumption • Rejection % due to bond failure • Degreasing solution consumed	3 per month 400 lts/ month 0.74% 800 ltr/ month							
8. Loading of plating racks on plating machine • Reduce lifting frequency by rotating workers on line • Provision of a coupling/ grip	• Output per month • Absenteeism rate • Stressed worker • Poor job variety	 18% MPS = 65							
9. Handling of tools, dies, fixtures in tool storage area • Bring the tools placed on the cart closer to the worker • Reduce the angle of twist	• Stressed worker • Poor job variety	MPS = 60							
10. Lifting of filled pans at forming and coining station • Height of the pans raised by adding two rows of empty pans under the filled pans.	• Additional manpower • MSD's/ Back pain injuries	1 3 lost days avg./ month							
11. Lifting of pans at Face and Chamfer station • Bring the pans closer to the worker position to reduce horizontal distance	• Additional manpower • MSD's/ Back pain injuries	1 3 lost days avg./ month							
12. Transfer of cartons from packing line to dispatch and onto trucks Provision of on-line conveyor	• Fatigue Allowance • Additional Manpower on	20% 6							

and adjustable diverter bars to transfer cartons from shelves to truck.	large shipment days								
13. Countersinking and wire brush station Automation of wire brushing station and combining of the two tasks	• Manpower • Skill Variety	2 MPS = 50							
14. Critical work stations e.g. height and wall broach • Self-inspection by line operators on all stations after training on Quality improvement techniques.	• Rejection rate / month • Rework / month • Manpower deployed	4.9% 2.5% 8 line inspectors							
15. Visual Inspection stations • Merge visual inspection with the plating section. Inspection tol be carried out on line, as the parts are unloaded on to a conveyor. The parts after this directly go the packing section.	• Rejection due to damages • Additional WIP lead time • Customer sales return = Rs 1.3 lac average per month (Rs 13.2 lac per annum)	1.3% 1 day							
16. Dimensional checking of parts for crush height • Provision of a knockout on the height test fixture to remove parts out of the block	• Injuries on fingers • Output per shift	6 / month 3000 parts							
17. Steel storage area • Fabrication of new coil stands for their horizontal placement in steel storage area	• Average waiting time for steel coils (8 coils handled per day)	46 minutes for each coil = (368 minutes per day)							
18. Sinter Line controls • Re-location of temperature controls and laboratory test equipment closer to operator work station at the Sinter Lines	• Prescribed monitoring frequency • Strip rejection	20 mtrs. 2.29%							

Appendix 8.2

Response received from the experts

Generalized Provision	Number of Responses n_i																								
	Cost			Productivity gains			Ease of Implementation			Effect on other areas						Training required			Time frame for results			Mandatory			Cumulative score
	H	M	L	H	M	L	E	N	D	H	M	L	H	M	L	H	M	L	L	M	I	A	M	N	
Work Postures																									
Provision of additional controls on machines																									
Provision of conveyors, worktables with adjustable heights, platforms etc.																									
Change in operator position on the work station, relocation of machine																									
Convert internal setup time to external time																									
Additional work instructions, changes in procedures and methods																									
Provision of safety attachments, injury prevention aids																									
Integrating ergonomic principles into equipment design																									

Lifting Tasks																									
Change in load/ weight orientation																									
Raise/ Lower height of load at origin or destination Reduce lifting frequency																									
Improvement in grip/ coupling on load																									
Reduce angle of twist																									
Manual Material Handling tasks																									
Provision of handling aids																									
Workstation design changes like conveyors etc.																									
Automation to reduce manual work																									
Reduce carrying distances, carrying frequency and weight of load																									
Promote use of handling signs and symbols																									
Job Design																									
Job Rotation																									
Job Enlargement																									
Job Enrichment																									
Operator training and education																									
Employee involvement																									