ANALYSIS OF DEFECT IMPROVEMENT AT LG COMPRESSOR ASSEMBLY PLANT

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF REQUIREMENTS

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BY

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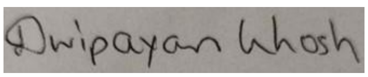
DECLARATION

I, Dwipayan Ghosh, hereby declare that the Project work entitled “ANALYSIS OF DEFECT IMPROVEMENT AT LG COMPRESSOR ASSEMBLY PLANT” is an authentic record of my own work carried out at LG Electronics India Pvt. Ltd as a part of the Internship/Training that has been done during my final year of M.E. I declare that I have successfully completed my Industrial Major Project, under the guidance of my industrial mentor, Mr. Achal Goel, from 02^{nd} Sept 2021 till 31^{st} July 2022.

Signature of the candidate



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CERTIFICATE

This is to certify that the dissertation work entitled "**Analysis of Defect Improvement at LG Compressor Assembly Plant**" is an authentic record of work carried out by Dwipayan Ghosh during his engagement as a Master's student from **September 2021 to July 2022**.This project work is carried out under our supervision and guidance in partial fulfilment of the requirements for the award of the degree of "Master of Engineering in Thermal Engineering" at Thapar Institute of Engineering and Technology, Patiala, Punjab during the academic year 2022-2023.

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It is certified that the above information made by the student is correct and true to the best of our knowledge and belief.

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ABSTRACT

The objective of this practical training is to learn something about industries practically and to be familiar with a working style of a technical worker to adjust simply according to industrial environment. This report deals with the equipment their relation and their general operating principle. In this project work the layout of LG Compressor plant has been studied, right from machine shop to production line to final dispatch line. Compressors produced during this plant are hermetically sealed compressors which are fitted in refrigeration units. In addition to those compressors usage in refrigerators these are also dispatched to other industries as well as exported to other countries. Different models of compressors are manufactured depending upon the dimensions and capacity of refrigeration unit. Detailed study of various assembly line defects starting from Drop line to final line and LQC section has been done. Lock pin defect reloading rate has been reduced from 5% to 1% when the machines were set with in the specification limit, higher piston jam defect reloading rate has been reduced after the piston and c-block size chamfer has been reduced and cover silencer final bolting machine set up to specification limit. Also, for the air gap defect a comparison has been made between CMA062 and CMA069 model for checking rotor runout and was found that in some rotor's runout is above the specification limit coming from the vendor.

Keywords: Hermetically Sealed compressor, LQC section, line defects

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 ABOUT RECIPROCATING COMPRESSORS

A compressor is a mechanical device that increases the pressure of a gas by reducing its volume. Compressors are similar to pumps, both increase the pressure on a fluid and can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the quantity of a gas. Liquids are relatively incompressible; while some may be compressed, the most action of a pump is to pressurize and transport liquids. Linear compressors use pistons driven by a crankshaft. They are stationary or portable, may be single or multi-staged, and might be driven by electric motors or combustion engines. Small linear compressors within a range of 5 to 30 horsepower are commonly seen in automotive applications and are typically for intermittent duty. Larger reciprocating compressors run over 1,000 hp are commonly found in large industrial and petroleum applications. Discharge pressures can range from air mass to very high pressure. In certain applications, like air compression, multi-stage double-acting compressors are said to be the foremost efficient compressors available, and are typically larger, and more costly than comparable rotary units. In this type of compressor, the compressor and motor are enclosed within the welded steel casing and therefore the two are connected by a typical shaft. This makes the full compressor and therefore the motor one compact and portable unit that may be handled easily. The hermetically sealed compressor is different from the normal open form of compressors during which the compressor and the motor are different entities, and the compressor is connected to the motor by coupling or belt. Following are the applications of a reciprocating compressor:

1. Oil refinery.

2. Natural gas processed plant.

3. Chemical industries.

4. Refrigerators.

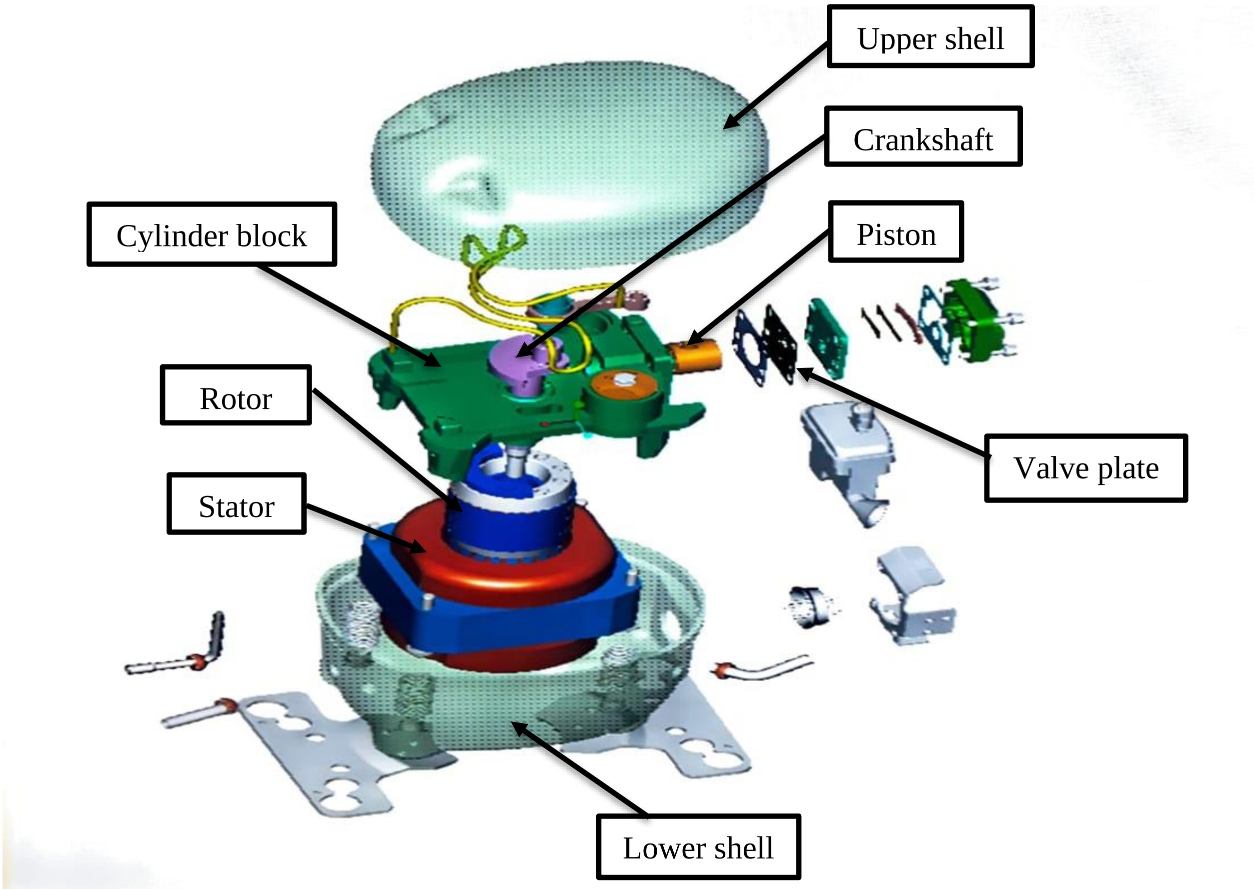


Figure 1.1 Schematic diagram of a reciprocating compressor showing its parts

Figure 1.1 represents a schematic diagram of a reciprocating compressor. The main parts of a reciprocating compressor are:

1. Cylinder block: Reciprocating compressor parts consists of cylinder blocks. These cylinder blocks accommodate both discharge and suction valve plates and are generally made from cast iron.

2. Piston: The piston is often called as the main heart of the compressor. It is made from low-weight materials such as aluminum and its alloys to reduce shaking, and the piston is responsible for the transfer of energy to the gas in the cylinder from the crankcase.

3. Piston rod: It is responsible for transmitting the reciprocating crosshead into the piston. This component is made of alloy steel. When it is passed through the cylinder block, the surface must be polished and hardened.

4. Crankshaft: Reciprocating compressors consists of crankshaft forged out of steel.

5. Connecting rod: It is manufactured of forged steel; it has a hole to allow passage of oil. This component connects the crosshead and crankshaft, converting rotary motion into reciprocating motion.

6. Valve plates: It is one of the most essential reciprocating compressor part. These are gas actuated valve plates. Two types of valve plates are sintered valve plate and structured valve plate.

7. Lubrication system: Compressors require force type lubrication for proper working. Oil act as a lubricant which lubricates piston, crankshaft body and other parts of the compressor body. Piston should be lubricated in a way that piston jam issue does not arise.

Figure 1.2 Model of a hermetically sealed compressor produced at LG compressor plant

Figure 1.2 represents a compressor model produced at LG assembly plant. This type of compressor is hermetically enclosed by an upper shell and a lower shell. Main body of compressor is fitted inside. Lower shell has 4 springs in which main body is inserted. Main body of compressor has the following parts: cylinder block in which piston, crankshaft and connecting rod is assembled, rotor and stator assembled to form the motor. Suction valve plate and discharge valve plate is attached to the head cover assembly.

1.2 TYPES OF RECIPROCATING COMPRESSOR

1. Single acting compressor.

2. Double acting compressor.

3. Single-stage reciprocating compressor.

4. Double-stage reciprocating compressor.

1.3 WORKING OF A RECIPROCATING COMPRESSOR

Process gas is drawn into the cylinder, compressed, contained and then released by mechanical valves that typically operate automatically by difference in pressure. Depending on the system design, cylinders may have one or multiple valves. The crankshaft is fitted to balance dynamic forces created by the movement of the heavy pistons. Suction gases are generally passed through suction strainers to remove particulates, moisture and liquid phase process fluid that could cause severe damage to the compressor valves and other critical components. Typically, reciprocating compressors are relatively low-speed devices, and driven by an electric motor, either with or without a variable speed drive controller. Often the motor is manufactured to be integral to the compressor, and the motor shaft and compressor crankshaft are one-piece, eliminating the need for a coupling. Following are the advantages of a reciprocating compressor:

1. It is used to produce high pressure gas.

2. It can compress refrigerant to a greater range.

3. It has high efficiency.

Following are the disadvantages of a reciprocating compressor:

1. The compressor size is large for a given capacity.

2. Problem of high noise.

3. The compressed air outlet temperature is very high.

1.4 PRESSURE-VOLUME AND TEMPERATURE-ENTROPY DIAGRAM OF RECIPROCATING COMPRESSOR

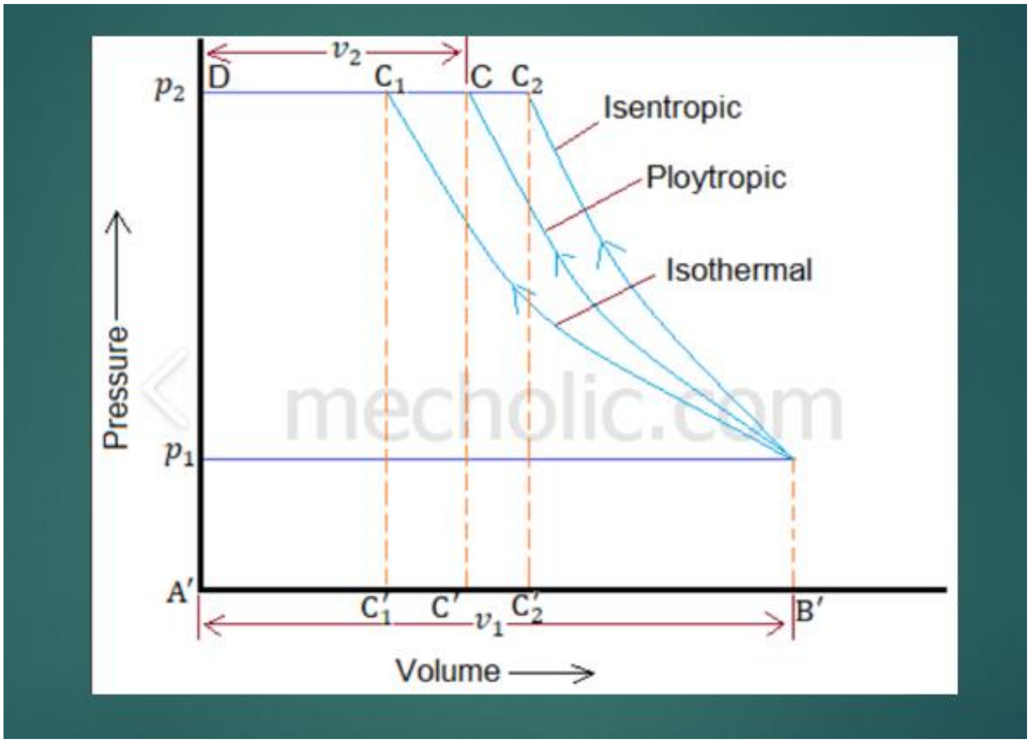


Figure 1.3 P-V diagram of a reciprocating compressor

When the piston moves from bottom dead center to top dead center air gets compresses, which increases pressure and consecutively there is a decrease in volume. The work done to compress air is converted to heat energy resulting in decrease in temperature. During compression if all the heat is taken away by the cylinder then it is known as isothermal compression. It follows the expression PV = C, where C = constant. If there is no heat transfer from the compressed air, work done is kept as heat energy. It follows the expression $PV^{\gamma} = C$, where value of γ = 1.4 for air. For polytropic compression it follows $PV^{n} = C$, where n ranges from 1.25 – 1.35.

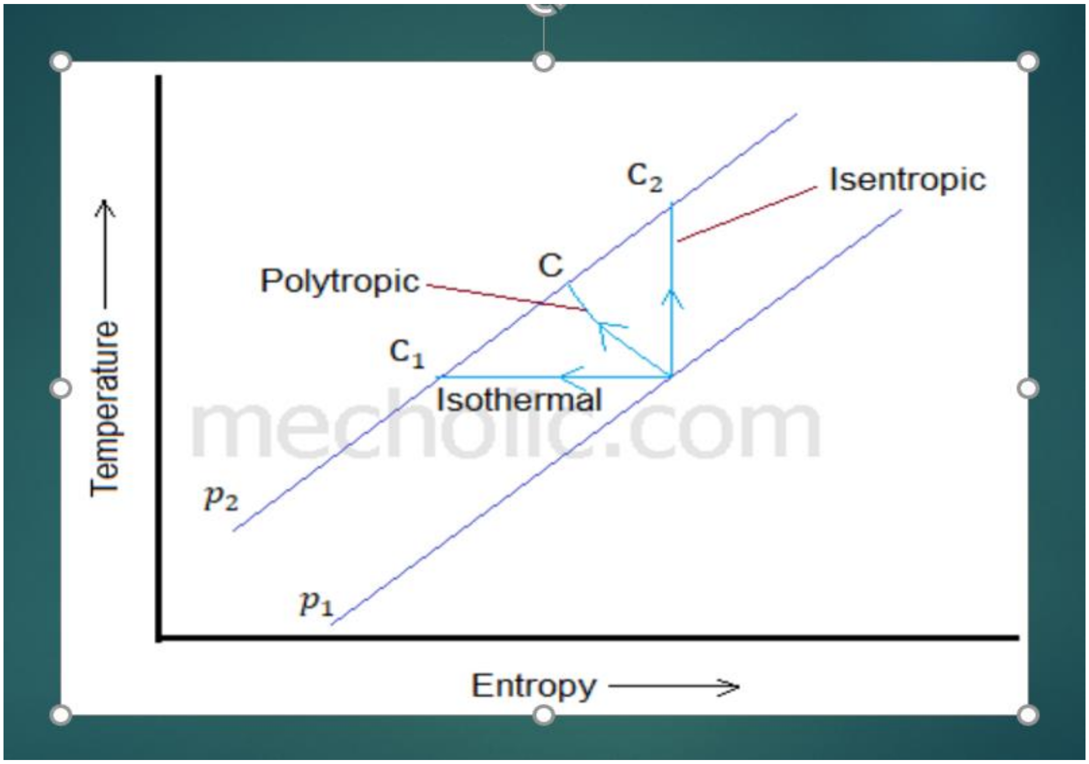


Figure 1.4 T-S diagram of a reciprocating compressor

Figure 1.4 shows a temperature vs entropy diagram of reciprocating compressor. It is used to analyze energy transfer system cycles. T-S diagram is used to represent work done by or on the system and heat added or removed to/from the system. Area under the T-S curve of the process represents the heat transferred to or from the system. Vertical line represents an isentropic process on a T-s diagram, whereas a horizontal line represents an isothermal process. Polytopic process is represented by the curved line.

1.5 KEY FEATURES

1. Less friction: Linear compressors have 1 friction point.
2. Energy Saving: Linear compressor has higher efficiency and lesser efficiency change.
3. Less Noise: LG Linear compressor contains a more stable noise.
4. Easy Application: LG linear compressor has better responsiveness of control.
5. Quality: LG linear compressors is very competitive in quality.

1.6 MODELS OF COMPRESSOR

There are many models of compressors. Few are listed below:

1. BSA057NHMV/NAMV
2. BSA075NHMVV/NAMV
3. BMG089NHMV/NAMV
4. BMKO90NHMV/NAMV
5. MA45LVJM
6. CMA069NSEM
7. CMA062NSEM
8. MB62NJEM
9. MA42LSJG
10. MA57LJKG
11. MA88LHEP

1.7 NOMENCLATURE OF COMPRESSOR MODELS

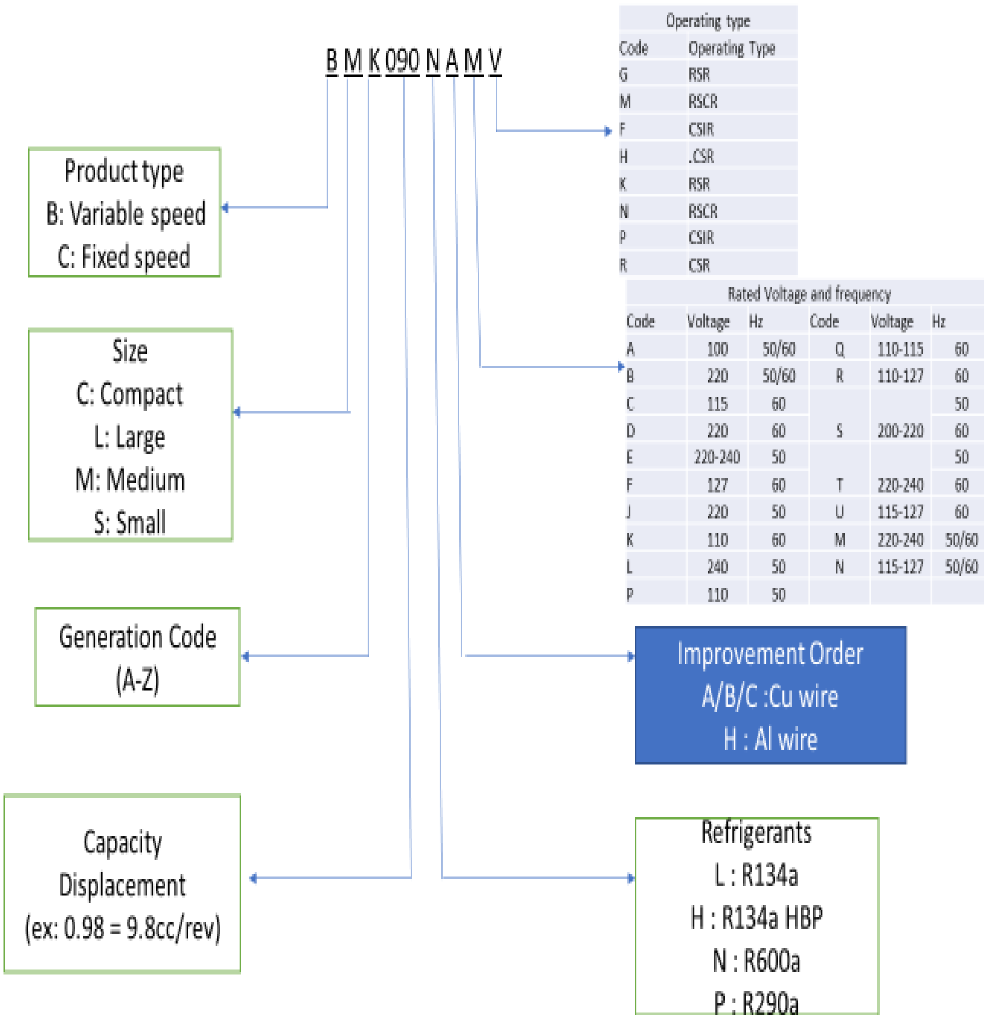


Figure 1.5 Figure representing compressor model nomenclature

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION TO COMPRESSOR DEFECTS

There are a lot of parts that work together inside of a compressor that have the potential to fail at any given time. A single failure could disrupt an entire day, knowing which parts are prone to failing and the ways in which they do fail is important. A simple valve failure can cause compressor leakage and shutdown. These valve failures occur relatively frequently. There are two different things that could be occurring with the parts inside of a compressor that result in it suddenly producing a large amount of noise. Firstly, excessive noise could be caused due to a build-up of particle matter occurring in between the piston and the valve plate. Secondly, the excessive noise could be caused due to a problem with the valve plate inside of the compressor. The valve plates play an important role if it seems to be taking a long time for the pressure to build-up inside of the compressor, then need to check the functionality of the gaskets inside. Any fluid leakage that comes from the compressor needs to be observed immediately, as it has the potential to cause many different compressor problems. It is more than likely means that one of the valves inside is not providing an efficient seal the way that it should be. Discolored valve plate, burned valve reeds, worn pistons, rings and cylinders, stator spot burn from metal debris are the causes of high discharge temperature in compressor. This is the result of temperatures in the compressor head and cylinders becoming so hot that the oil loses its ability to lubricate properly. This causes rings, pistons and cylinders to wear resulting in blow by, leaking valves, and metal debris in the oil.

Table 2.1 List of the researchers who are actively working on compressor defects

S No.	Title of research paper	Researchers	Compressor defect	Cause
1	Small hermetic compressor	Karll, B. and Josiassen, N.J., [1979]	Compressor will not operate	Low oil level, pressure switch not making contact. Pressure in the tank is below the cut-in pressure.
2	Performance enhancement of hermetic compressor	Mahmoud, I.M., Rady, M.A. and Huzayyin, A.S., [2015]	Excessive noise in operation	Lack of oil in crankcase, piston hitting the valve plate, compressor floor mounting loose.
3	Investigation on reciprocating air compressors.	Pipalia, V.F., Shukla, D.D. and Mehta, N.C., [2015]	Compressor vibrates	Mounting bolts loose. compressor not properly mounted, bent crankshaft.
4	Research on oil-free hermetic refrigeration scroll compressor	Wang, L., Zhao, Y., Li, L., Bu, G. and Shu, P., [2007]	Excessive oil consumption	Compressor tilted too much, wrong oil viscosity.
5	Thermal energy analysis in reciprocating hermetic compressors	Todescat, M.L., Fagotti, F., Prata, A.T. and Ferreira, [1992]	Oil in discharge air	Excessive oil in compressor, Worn piston rings.
6	Improving performance and development of two stage reciprocating air compressor	Ajiambo, F., Nzila, C., Namango, S., Deshmukh Ashvini, [2012]	Insufficient pressure at point of use	Leaks or restriction, restricted air intake.

2.2 GAPS IN LITERATURE REVIEW

Based on the existing literature review, the following gaps have been identified:

1. Noise arising from compressor body due to lack of oil in crankcase, piston striking the valve plate and compressor floor mounting loose.

2. Excessive oil consumption in compressor above viscosity level due to tilt of compressor, wrong oil viscosity.

3. Compressor body jam due to jam in piston, crankshaft and connecting rod.

4. Any fluid leakage from the compressor indicates that valve plates inside the compressor does not provide an efficient seal and it takes high time to build up pressure.

5. Compressor is not properly fitted into pellet due to air mounting issue. This causes noise during working.

Generally, LG compressor assembly line is divided into 4 units:

1.Drop line

2.Main body line

3.Final line and

4.Line quality control

Assembly line compressor production starts from the drop line till final line which is looked after by the production department and the final area is the LQC where quality checking of compressor is done under a series of machines such as –low voltage running tester, high voltage running tester, resistance machine, noise tester machine and so on. Defects found while passing through these machines are unloaded from LQC into a trolley. Some defects are checked visually only and unloaded. Apart from LQC, defects are detected and unloaded from the drop line also. One such common defect studied is the lock pin defect which is a common defect.

Table 2.2 List of defects detected at LQC

S No.	Defect	Treatment
1	Piston jam	Oiling is done
2	Pressure fails	Valve plate cleaned/changed
3	Power fail	Oiling done on piston/c shaft
4	Insulation resistance	Hot air supplied to the lower terminal shell
5	Sub over	Rust paper used to remove the contaminant
6	High voltage	Brush the terminals of lower shell
7	Low voltage	Oiling is done
8	Gasket jam	Gasket grade mismatch
9	Noise	Oiling is done

Table 2.3 Check sheet depicting defect types with their occurrence on day of the week

Defect types (Major/Minor)	Defects in days					Total count
	Mon	Tue	Wed	Thu	Fri	
Piston Jam	55	68	12	31	29	195
Pressure fail	38	14	11	4	2	69
Insulation resistance fail	8	2	3		3	16
Sub over			1			1
Low voltage			4	1	5	10
High voltage	2	1	3			6
Gasket jam	5		1	5		11
Contamination inside		1	1	1	2	5
Muffler noise	1			3		4
Lock pin (miss + bend) (Drop line defect)	51	47	20	38	13	169
Total count	160	133	56	83	54	486

Data collection of defects is done from drop line and LQC section on weekly basis and is found that major 2 defects arising are piston jam defect and lock pin defect. First data is collected and analyzed to check from which section the defect is arising whether there is defect in the items imported from vendor (dimensionally) or is an issue in the machine specifications which leads to piston jam at LQC. Piston is assembled into the c-block at drop line, then passed to the main body line where it is passed through a series of machines and then comes to final line and LQC. How this jam is not detected passing through out the line. It is seen that Piston jam defect unloading from LQC is quite high which leads to higher ppm rate.

2.3 MODEL WISE DEFECT

Table 2.4 List of data showing model wise defect count

Platform	Defect count	Cumulative %
BSA075	332	43
BSA057	239	73
MA	84	84
CMA	64	92
BM*	59	100

Table 2.4 shows list of various model wise defects with defect count and calculated their cumulative percentage. Data is collected for consecutive days for different model of compressors.

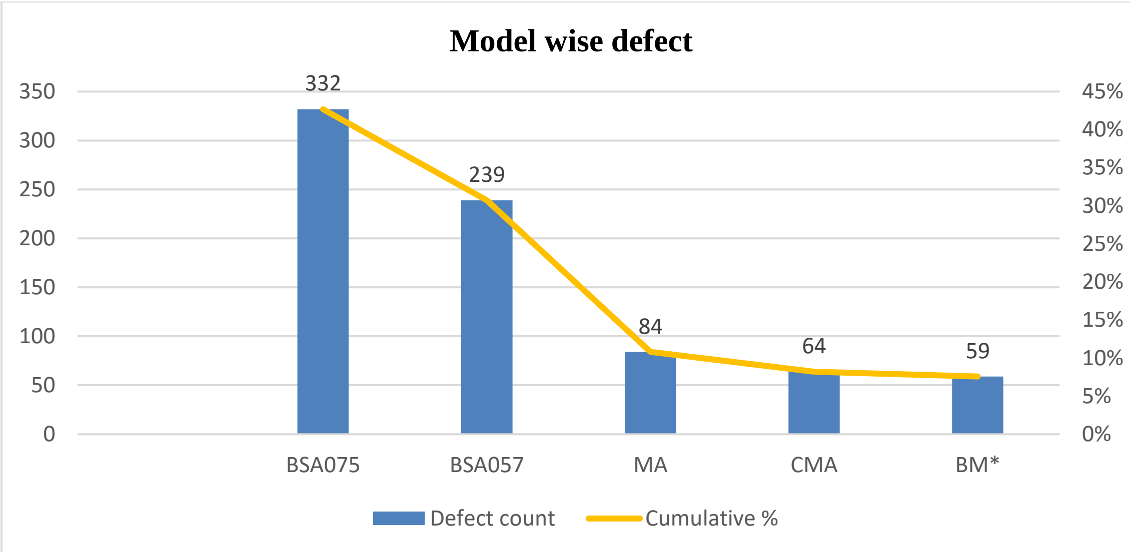


Figure 2.1 Pareto chart representing model wise defect chart

From this model wise defect chart 2.1, it is observed that almost 80% of the major defects is caused by these 2 models BSA075 and BSA075. Most common defect in BSA075 model is piston jam defect which is unloaded from LQC. Unloading data from LQC is collected on a day wise basis and actions are adopted how to reduce this defect. In this project mainly 3 defects have been studied and focused lock pin defect, piston jam defect and air gap ng defect.

2.4 THESIS OBJECTIVES

The presents work explores data collection and analysis of minimizing assembly line defects. Following are the specific objectives of thesis:

• To study and draw a schematic diagram of a reciprocating compressor, its applications, working, advantages and disadvantages.

• To calculate the performance of compressor plant with the help of key performance indices and calculate the cycle time of manpower and machine.

• To analyze the assembly line defects, from which section of line maximum defects arises and improvements taken to reduce these defects.

• To gather defect data of lock pin defect from drop line, piston jam defect from lqc section and air gap defect from main body and what action plans are taken to reduce this defect.

CHAPTER 3

METHODOLOGY

3.1 LAYOUT OF LG COMPRESSOR PLANT

Compressor Plant layout is divided into 4 units:

1. **Machine Shop:** It consists of

(a) Honing machine: Honing **i**s a process that is performed on a job to make it proper size by removing marks and roughness left on a job by the cutting tools. The Honing machine is used to make Cylinder blocks.

Figure 3.1 Honing machine

(b) Buffing machine: Buffing is the technique wherein you work upon the surface of your piston and crankshaft to enhance its shine or appeal. It can be to remove any smudge, scratches, etc to make sure that the surface looks fresh. Piston and Crankshaft comes from the vendor and buffing is done in the machine shop.

(c) Steam coating machine: After buffing is done piston and crankshaft is passed into a hot steam oven which is maintained at a very high temperature where chemical deposit is done on their surfaces.

(d) Part washing machine: In this chamber cylinder block, piston and crankshaft is washed with the help of chemicals and water and then the parts are sent to assembly line for compressor production.

Figure 3.2 Part washing machine

2. Motor line: Motor consists of 2 main components-rotor and stator. There are 3 rotor assembly lines: IR1, IR2 and IR3.Rotor which comes from the vendor are assembled and magnetized in these 3 lines. Stator is inserted into the assembled rotor in the 2 motor lines present (IM1 and IM2) and forms the assembled motor.

Figure 3.3 Motor line

3. Assembly line: There are 2 assembly lines CM1 and CM2 line where compressors are produced. Generally, in CM2 line BSA model compressors which are used in single door refrigerators are produced whereas in CM1 line MA, CMA model of compressor which are used in double door refrigerators are produced. In this line starting from cylinder block input, piston and c/shaft is inserted, rotor and stator is assembled with c-block and various parameters such as air gap, magnetizer property, leakage is tested. After quality check inspection at LQC the lower shell and upper shell of compressor is welded where compressor is loaded into the conveyor line and sent to the last section.

4. Paint shop: The compressor passing through the conveyor line is sent to a long oven where it is dipped into pool of liquid black paint and passed to a drying section. After drying, the compressor is unloaded from conveyor and loaded into line again where at LQC 2 section last phase of quality inspection is done and finally labeling of compressor is done and packed to accessories for dispatching purpose.

3.2 KEY PERFORMANCE INDICES (KPIS)

A KPI is a type of performance measurement that helps to understand how an organization is performing. Organizations use KPIs at multiple levels to evaluate their success at reaching targets. High-level KPIs may focus on the overall performance of the business, while low-level KPIs may focus on processes in departments such as sales, marketing, HR, support and others. Some of the important KPIs used are:

- Production achievement rate
- Lot completion %
- Yield Rate %
- Efficiency %
- UPH
- UPPH
- TLDR
- Idle Rate
- Conversion cost
- Cycle time

1. Production achievement rate: The following terms are used to find the production achievement rate:

Production plan: It gives the total no of quantities of a particular model to be produced each day. The production plan is set according to the demand for each day.

Total production result: It gives the actual no of quantities of a compressor model produced each day.

Not planned result: It gives the unplanned no of quantities produced each day. These are the extra quantities which are produced regardless of the daily plan sheet.

For ex: Suppose there is a shortage of some materials to produce BSA model of compressor then in place of BSA other model of compressor consider BMG model will be produced to overcome the losses in line.

Actual production result: It is the difference of production result and not planned result. There are 2 compressor lines (CM-1 and CM-2 line) to produce different compressor models. Daily plan is set to 16000 compressor each day.

For ex: Suppose there is a demand to produce 16000 compressors in a day.

Production plan = 16000.

Total production result = 16010 .

Extra parts produced (Not planned) = 50 .

Actual production (Production result) = Total production result-not planned=16010-50=15960

Production achievement rate: It is given by

$$\frac{\text{Production result(Actual production)}}{\text{Production plan}} * 100 \quad \ldots\ldots \quad (1)$$

$$= \frac{15960}{16000} * 100$$

= 99.75%

2. Lot completion %: It is also called work order. Lot size is set by the Production Planning and Control dept. It is given by the formula –

Lot completion % = $\frac{Complete\ work\ order}{Planned\ work\ order} * 100$ ……... (2)

Incomplete qty remaining % = 1-$\frac{remain\ qty}{plan\ qty} * 100$ ... ... (3)

For ex: suppose there are 28 lots of different model of compressors to be produced on a day.

Then, planned work order = 28

Complete work order = 27

Lot completion % = $\frac{27}{28} * 100$

= 96.4%

Lot size is generally a lot with order no set up with similar model of compressors. Suppose a lot of BSA057NHMV model of compressors will be grouped into a single lot id of no of compressors to be produced depending on the demand set. Another model of compressors say BSA057NAMV model of compressors will be grouped into a lot id. Each lot ids will have a unique id.

3. Yield rate %: It is the effectiveness of production regarding input working hour.

Yield Rate% = $\frac{Yield\ man\ hour}{Total\ man\ hour} * 100$ ... ... (4)

where, *Yield man hour= Prod Qty*Standard time* …... (5)

Standard time is defined as the working time to manufacture one product under standard working conditions. Standard time is different for different model of compressors.

For ex: Suppose on a day 1500 no's of BSA057 model is produced.

So, prod qty on that day =1500 no's

Standard time of BSA057 model = 2.3129s, total man hours = 8 hours.

Yield man hour=(1500*2.3129)/(8*60) = 7.22 man hour

Yield rate % = (7.22/8)*100 = 90.337 %.

Table 3.1 List of compressor models with their standard time

Models	Std time(s)
CMA	3.3925
MA	3.254
BMH	2.4195
BMK	2.511
BSA	2.3129

and *Total man hour= Direct man hour + Indirect man hour* …… (6)

Direct man hour is the time during which a manpower is directly working in line. Indirect man hour is the time during which a manpower is involved in line work but not directly. They include line Jojang and Banjang. Their main work is when there is an issue in line such as any machine breakdown/failure, manpower shortage and when there is a model change in line. Specifically, during compressor model change their work is to change the machine's jig/fixture as well as bolting machine and various other parameters.

4. Efficiency rate%: It is the ratio of yield man hour to the net man hour.

Efficiency rate%= $\frac{Yield\ man\ hour}{Net\ man\ hour} * 100$ …… (7)

Where, *Net man hour= Direct man hour-Idle man hour* …… (8)

For ex: Suppose, Direct man hour involved in line work =2 Man hours =120mins

Idle man hour (during breaks) = 10mins

Net man hour = Direct man hour – Idle man hour = (120-10) = 110mins

Considering BSA057 model,

Prod qty on that day =2500 no's

Standard time of BSA057 model = 2.3129s

Yield man hour = (2500*2.3129)/60 = 96.37

Efficiency rate % = $\frac{96.37}{110} * 100 = 87.6\%$.

5. Cycle time: Cycle time is the time taken from the start of production of a particular unit to the completion of production. Cycle time is calculated for each process whether auto or manual directly during production in line. Model wise cycle time is calculated.

Table 3.2 List of step wise operations in drop line production with their cycle time

S No.	Area	Operations	MA	CM*	BM*	BSA	Process	Max cycle Time
1	Drop	C/Block Input	2.69	2.69	2.69	2.69	Manual	2.7
2	Drop	C/Block Grading	3.01	3.01	3.01	3.01	Manual	3
3	Drop	C/Shaft Assy		2.63	2.63	2.63	Manual	2.6
6	Drop	Piston Insertion			3.07	**3.07**	Manual	3.1
7	Drop	C/Shaft Insertion	**3.17**		**3.17**	**3.17**	Manual	3.2
8	Drop	Con rod Insertion		**3.4**	3.4	**3.4**	Manual	3.4
12	Drop	Piston Pin insertion		3.2	3.2	3.2	Manual	3.2
13	Drop	Piston Pin pressing					Auto	0
14	Drop	Lock Pin Align		**2.74**		**2.74**	Auto	2.7
15	Drop	Lock Pin Insert-1		**2.85**		**2.85**	Auto	2.9
16	Drop	Lock Pin Insert-2		**2.85**		**2.85**	Auto	2.9
17	Drop	Lock Pin Pressing		**3.36**		**3.36**	Auto	3.4

The cycle time of step wise operations of drop line is noted both manually and in auto mode in the above table. If in any such operation where it is found that that cycle time is higher than line cycle time then that process is studied and objective is to reduce that cycle time. Cycle time of LG compressor plant is 3.3s. Since in lock pin pressing machine cycle time is above normal cycle time, so this process is studied.

6. UPH: UPH stands for units per hour. This index is used for measuring the workload necessary to produce one unit of a product. This is a very useful KPI to measure the man effort and cost to produce one unit.

UPH of 1 shift of LG Compressor line-

$$UPH = \frac{Total\ no\ of\ qty\ produced}{No\ of\ hours} \qquad \ldots\ldots (9)$$

For ex in a shift 8000 compressors are produced and total work hours in a shift is 8 hours.

Then, UPH = $\frac{8000}{8}$

=1000 compressors per hour.

7. UPPH: UPPH stands for units per person per hour. Productivity improvement is defined by UPPH. UPPH improvement improves production capacity which reduces investment cost & reduce manpower input which improves profit.

$$UPPH= \frac{Units}{\frac{Person}{Hour}} \qquad \ldots\ldots (10)$$

For ex: in a shift 8000 compressors are produced, work hours recorded is 8 hour and suppose 60 persons are involved in line work.

Then, UPPH = $\frac{\frac{8000}{60}}{8}$

= 17 compressors per person per hour.

8. Total line defect rate (TLDR): TLDR stands for Total line defect rate. It is given by

$$TLDR = \frac{Total\ no\ of\ line\ defects}{No\ of\ units\ produced(Prod\ Qty)} * 100 \qquad \dots\dots\dots\dots \qquad (11)$$

Line defect rate is measured in parts per million(ppm).

For ex: Suppose on 3rd June, in the assembly line there were total 40 line defects during the day shift and production qty are fixed-16000 qty then TLDR will be-

TLDR = $\frac{40}{16000} * 10^6$

= 2500 ppm.

9. Idle rate: The time for which the line production remains idle is called as idle rate. Idle rate can be of various types:

1. Controllable idle rate: The time for which the line production is idle which may be due to raw material shortage or manpower shortage, etc. is called as controllable idle rate. Controllable means this idle time can be stopped if proper planning is done from the beginning.

2. Uncontrollable idle rate: The time for which the line production is idle which may be due to unavoidable weather, or any accidental incident occurs in line which cannot be controlled is called as uncontrollable idle rate.

3. Breakdown and part shortage: The time for which the line production is idle due to some machine breakdown and part shortage is called as breakdown idle time. Generally idle rate calculation considers these 2 parameters –

Controllable idle rate% = $\frac{Controllable\ idle\ man\ hour}{Total\ attendance\ man\ hour} * 100$ ……. (12)

Uncontrollable idle rate% = $\frac{Uncontrollable\ idle\ man\ hour}{Total\ attendance\ man\ hour} * 100$ ……. (13)

Idle rate = Controllable idle rate + Uncontrollable idle rate ……. (14)

For ex: Suppose 60 manpower is involved in line production and total man hour is 8 hours per shift. So, total attendance man hour = (60*8) = 480 man hour

Idle man hour = 5 man hour.

Idle rate % = $\frac{Idle\ man\ hour}{Total\ attendance\ man\ hour} * 100$ ……. (15)

$= \frac{5}{480} * 100$

= 1.04 %.

Weekly data of production quantity and idle time in minutes per shift is taken and a scatter plot is plotted. In excel, a regression analysis is performed where a regression equation is determined using slope and intercept.

Table 3.3 List of data showing production quantity and idle time

Production quantity	Idle time (in mins)
8000	0
7840	45
7920	35
7650	60
7540	70
7420	80

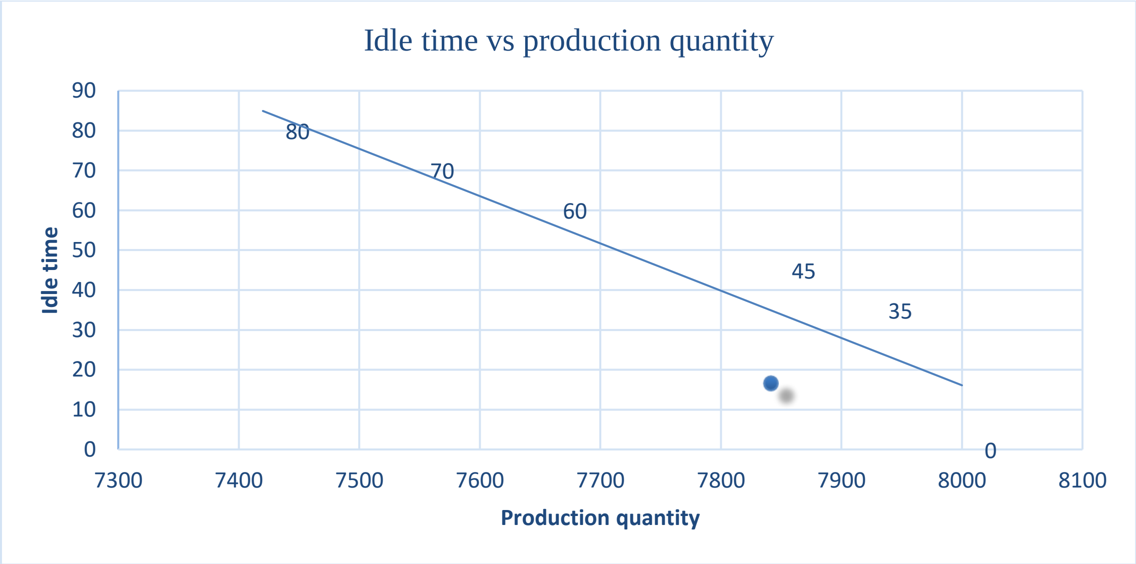


Figure 3.4 Chart showing variation of production quantity vs idle time

Figure 3.4 is a scatter type of chart. This chart is plotted by quantity produced per shift and idle time for 1 week. Production quantity is plotted in x-axis and idle time is plotted in y-axis and a scatter plot is obtained. It is observed that with the increase in idle time units produced per hour decreases. Idle time is considered in production line whenever there is an issue in machines, or manpower, etc. Issue in machines means whenever there is a break down in machine, machine failure. Manpower issue arises whenever there is a shortage in manpower or new manpower comes in place of skilled old manpower. Due to lack of skills in new manpower line production is slow and hence cycle time increases. From figure 9, regression analysis values have been found from excel and from the table of coefficient values, a regression equation has been determined from where slope and intercept has been noted. Regression analysis is a statistical method to model the relationship between a dependent (target) and independent (predictor) variables with one or more independent variables. More specifically, regression analysis helps us to understand how the value of the dependent variable is changing corresponding to an independent variable when other independent variables are held fixed.

Table 3.4 List of regression analysis values

Regression Statistics	Values
Multiple R	0.940618
R Square	0.884763
Adjusted R Square	0.855953
Standard Error	10.91231
Observations	6

One important part of this entire output is R Square/ Adjusted R Square under the above regression table, which provides information about how good our model is fit. In this case, the R square value is 0.8847, which interprets that the model has an 88.47% accuracy.

Table 3.5 List of tables of coefficients

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	965.456	165.5533	5.831693	0.004308	505.8064	1425.106	505.8064	1425.106
Production quantity	-0.11867	0.021414	-5.54175	0.005185	-0.17812	-0.05922	-0.17812	-0.05922

Now, our regression equation becomes,

Idle time = -0.11867*UPH + 965.456. ………….. (13)

where, slope value = 0.11867.

Intercept = 965.456.

From the above equations a function has been defined in which if the value of production quantity is put, the idle time can be calculated.

10. Conversion cost: A conversion cost is the amount incurred during the transformation of raw materials inventory into finished goods. In other words, this is the amount of direct labor and overhead costs that are required to turn raw materials into an actual product. Conversion costs consist of both overhead costs and direct labor. It is the ratio of total costs to buy raw material to the production cost.

For ex: suppose total no of units produced = 8000

Cost of raw materials =100000

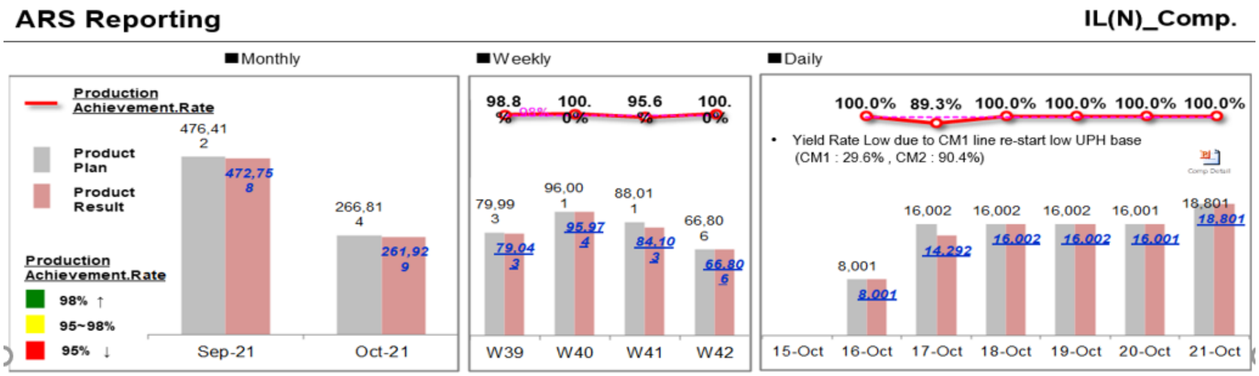
Cost on machine repair = 200000

Conversion cost = $\frac{\text{Total costs required to buy raw materials,machines}}{\text{Total no of units produced}}$ ……… (14)

$= \frac{300000}{8000}$

= 37.5.

3.2.1 SIGNIFICANCE OF KEY PERFORMANCE INDICES



[Production Index]

21.Oct →

Category	Sep	Oct	W39	W40	W41	W42	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct	21-Oct
										Week3(2021Year W42)			
Production A.Rate(%)	99.2%	98.2%	98.8%	100.0%	95.6%	100.0%		100.0%	89.3%	100.0%	100.0%	100.0%	100.0%
Production Plan	476,412	266,814	79,993	96,001	88,011	66,806		8,001	16,002	16,002	16,002	16,001	18,801
Production Result	472,758	261,929	79,043	95,974	84,103	66,806		8,001	14,292	16,002	16,002	16,001	18,801
Not Planned Result	3,656	4,905	951	27	3,928	0		0	1,721	0	0	0	0
TTL Prod. Result	476,414	266,834	79,994	96,001	88,031	66,806		8,001	16,013	16,002	16,002	16,001	18,801
Lot Completion(%)	98.4%	96.5%	98.9%	97.6%	93.3%	100.0%		100.0%	92.9%	100.0%	100.0%	100.0%	100.0%
Remain Incompletion(%)	0.8%	1.8%	1.2%	0.0%	4.4%	0.0%		0.0%	10.7%	0.0%	0.0%	0.0%	0.0%
Yield Rate(%)	88.3%	86.6%	89.6%	88.8%	89.5%	79.8%		92.0%	91.2%	89.8%	88.2%	88.9%	64.2%
Idle Work Rate(%)	0.8%	0.6%	0.7%	0.8%	0.2%	1.0%		0.0%	0.0%	0.0%	4.9%	0.0%	0.0%
Efficiency Rate(%)	96.7%	94.9%	98.3%	97.6%	97.8%	87.6%		101.7%	99.4%	97.9%	101.0%	96.9%	69.3%
UPPH	21.51	22.71	23.53	23.43	23.56	20.66		23.81	23.55	23.53	23.53	23.53	15.75
Non-Defect Rate(%)	99.9%	99.9%	99.9%	99.9%	99.9%	99.9%		99.9%	99.9%	99.9%	99.9%	99.9%	99.9%

Figure 3.5 Daily ARS report structure

The main significance of all the key performance indices is used to measure the compressor plant performance which is represented in this ARS sheet. ARS stands for Activity report sheet. ARS sheet is created daily which is attached to a daily production report. The following key performance indices that are required to create the ARS sheet are daily production plan, which is set by the production planning department, production result in actual produced, not planned result which comprises of the compressor models that are produced against the required plan, total production result is the total daily production of compressor both in day shift and night shift including overtime hours. Production rate (%) is calculated from production result and total production result. Lot completion is the actual lot of a particular model produced during the shift. Yield rate is calculated from total man hour involved in line work. Daily upph is calculated from no of units produced per person per hour directly from line. The formulas mentioned in the above key performance indices is used in this ARS report to determine the following parameters.

3.3 PROJECT-1: LOCK PIN DEFECT IN BSA057 MODEL OF COMPRESSOR

Generally, the purpose of lock pin is to hold the piston and crankshaft. Lock pin is inserted manually. There are 2 manpower both left and right side who inserts the lock pin. After lock pin is inserted manually then in auto mode lock pin pressing machine presses the lock pin to the required height. Lock pin height should be ≤ 6mm as per the specifications. The main issue is that when lock pin is inserted manually then in some cases, the machine presses it to such an extent that the pin gets bend or broken which is called as lock pin miss defect and lock pin bend defect. High reloading rate due to lock pin defect issue.

Figure 3.6 Lock pin insertion machine

Figure 3.6 depicts lock pin insertion machine in auto mode. This machine is set up in the drop line of assembly. Both left and right side of machine inserts the lock pin into c-block. First manpower inserts the lock pin and then machine presses the lock pin to an extent such that height of lock pin should be less than 6mm.

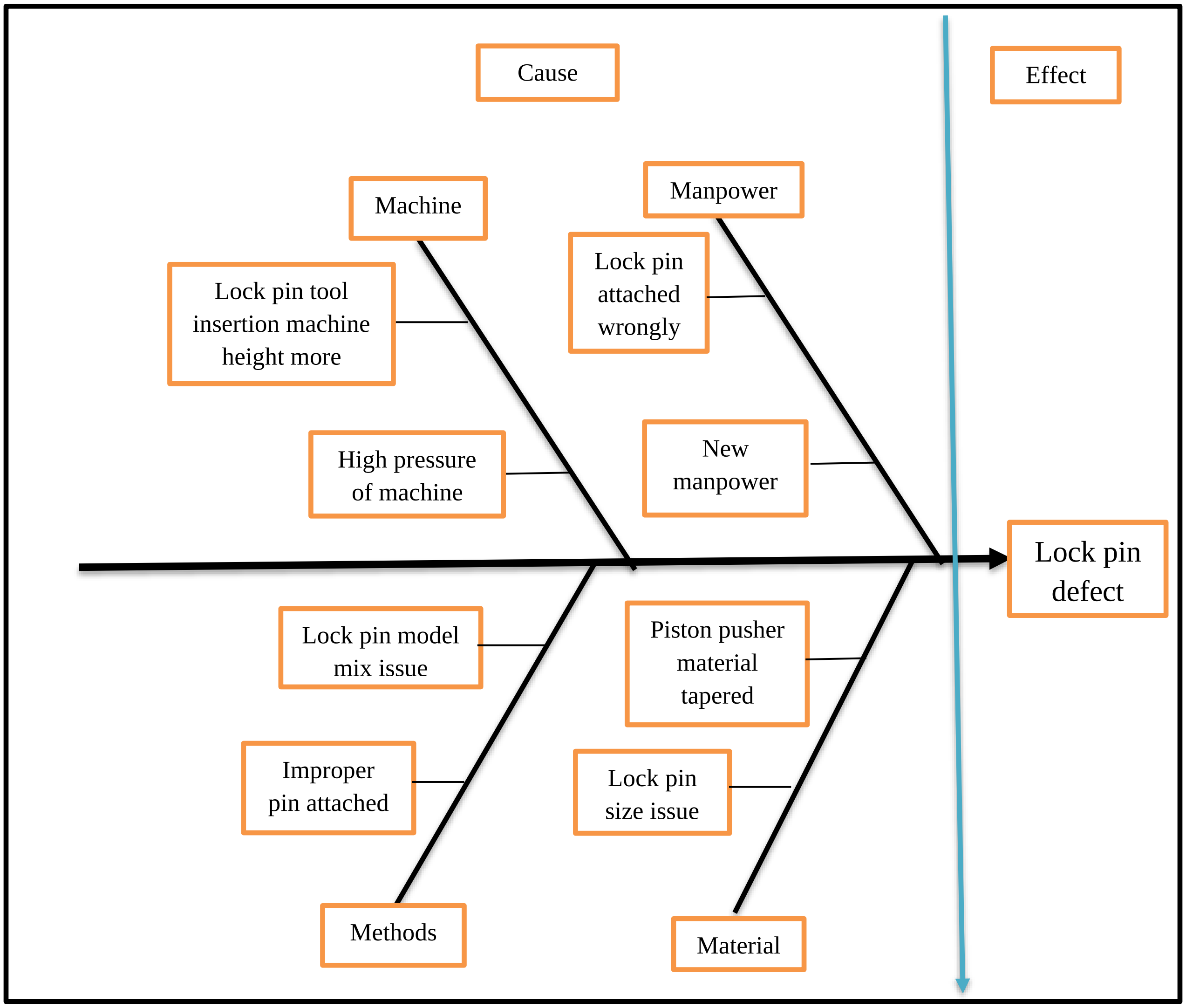


Figure 3.7 Fishbone diagram showing lock pin defect causes

A fish bone diagram is a visual tool used to categorize the potential causes of a problem. This tool is used to identify a problem's root causes. It should be efficient as a test case technique to determine cause and effect. This tool is useful in product development process. In figure the major root causes of lock pin defect are manpower, materials, machines and methods.

3.3.1 OBJECTIVES OF PROJECT-1

Following are the objectives of this project:

1. To study the specification limits of machine and identify the causes of lock pin miss/bend.

2. To gather data of daily unloading lock pin defect and implement the improvement steps to minimize this defect.

3.3.2 LOCK PIN MISS DEFECT

Lock pin miss can be because of 2 causes:

1. There is a change in the machine's parameters which are not in specification limits: Lock pin miss defect is caused by machine parameters such as machine pressure limit being above 6 bar and tool position high.

2. New manpower inserts the lock pin: Sometimes due to shortage of manpower new manpower does the job of inserting the lock pin. Due to lack of skills, pin miss problem arises and there is high unloading of lock pin miss defect.

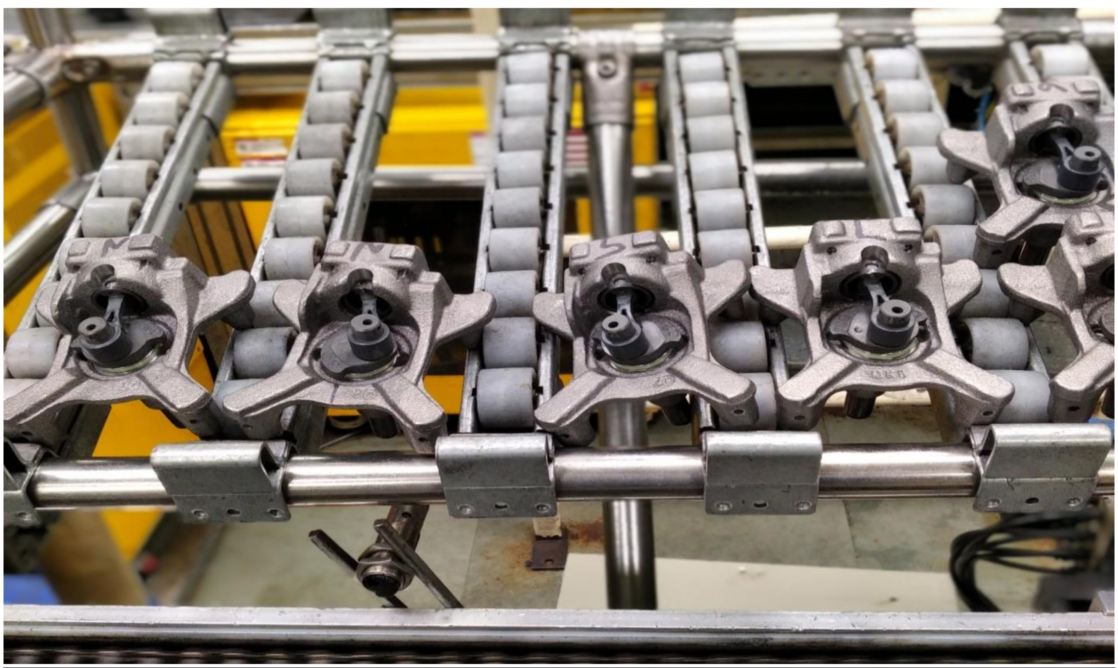


Figure 3.8 C-block with lock pin miss defect unloaded from line

Figure 3.8 represents c-block unloaded from line due to lock pin miss defect. C-block is loaded in drop line and then crank shaft and connecting rod is attached to it followed by piston and lock pin insertion which holds the piston and crankshaft. A separate trolley is attached to the lock pin insertion machine for unloading of lock pin miss defect components.

Table 3.6 List of causes which lead to lock pin miss defect with defect count

Defect cause	Defect count	Cumulative %
Piston pusher tapered	192	29
High pressure of m/c	175	55
Tool position higher	156	78
Lock pin size	77	89
Improper pin insertion	60	98
C-block chamfer, etc.	13	100

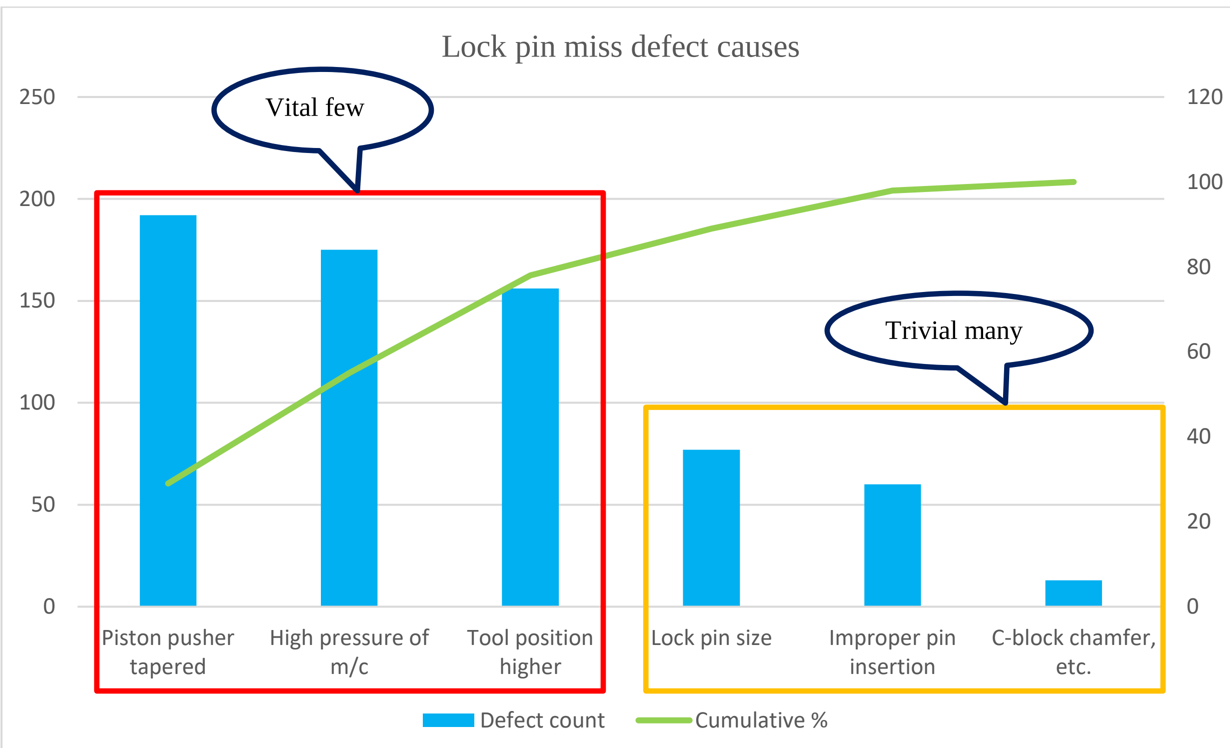


Figure 3.9 Pareto chart representing month wise lock pin miss defect trend

From figure 3.9, it is observed that 80% of the defects came from 2 out of 6 (25%) root cause types. Vital few root cause of lock pin miss defect is pusher tapered and high pressure of machine. Other significant 20% of the defects came from 4 out of 6 (75%) causes. Trivial many root causes of lock pin miss are high tool position, lock pin size improper, improper way of pin insertion and c-block chamfer less. This information is useful to establish the priorities of root causes of defects.

3.3.3 LOCK PIN BEND DEFECT

Due to out of specification limit of machine as well as improper alignment of lock pin pressing by manpower lock pin bends either upward or downward.

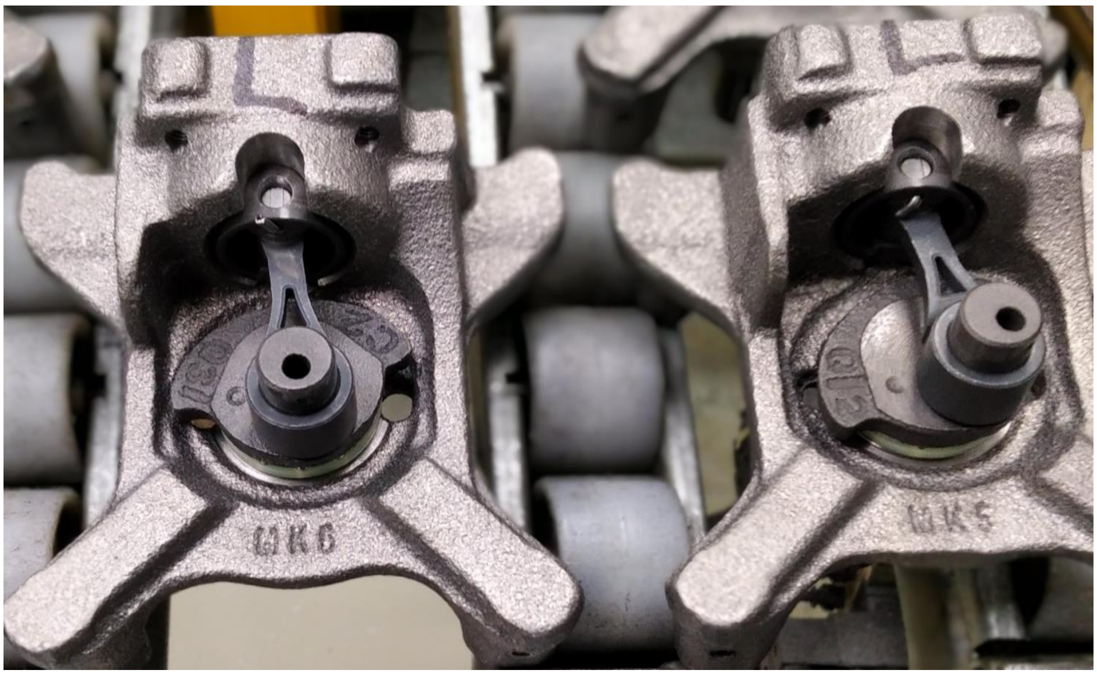


Figure 3.10 C-block with lock pin bend defect unloaded from line

Figure 3.10 represents c-block unloaded from line due to lock pin bend defect. C-block is loaded in drop line and then crank shaft and connecting rod is attached to it followed by piston and lock pin insertion which holds the piston and crankshaft. A separate trolley is attached to the lock pin insertion machine for unloading of lock pin bend defect components. Lock pin bends either upwards or downwards when it is inserted in BSA075 model.

Table 3.7 List of causes which lead to lock pin bend defect with defect count

Defect cause	Defect count	Cumulative %
Piston pusher height out of spec	122	32
Piston pusher tapered	97	57
Lock pin attached wrongly	77	77
Lock pin tool insertion m/c out of spec	52	91
Pin model mix issue	20	96
New manpower: lack of skills, etc.	15	100

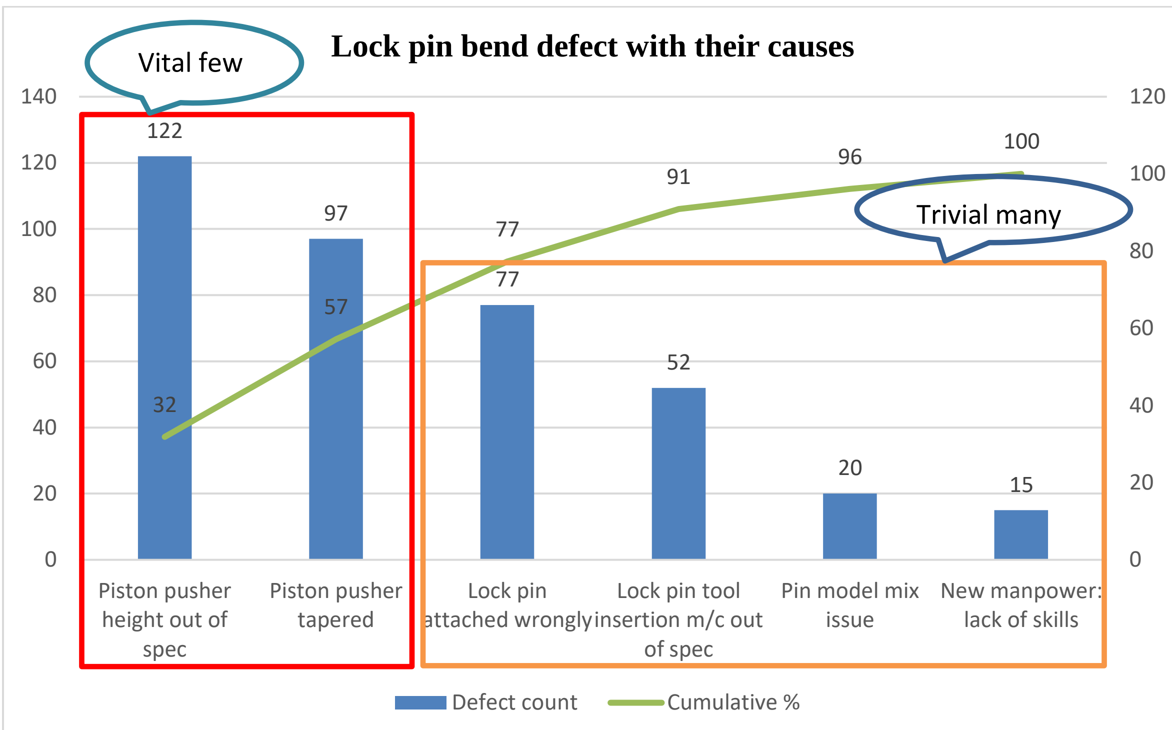


Figure 3.11 Pareto chart representing month wise lock pin bend defect trend

From figure 3.11, it is observed that 80% of the defects came from 2 out of 6 (25%) root cause types. Vital few root cause of lock pin bend defect is piston pusher height out of spec limit and pusher tapered. Other significant 20% of the defects came from 4 out of 6 (75%) causes. Trivial many root causes of lock pin bend are lock pin attached wrongly, tool insertion machine out of spec limit, pin model mix issue and new manpower with lack of skills. This information is useful to establish the priorities of root causes of defects.

3.3.4 LOCK PIN BEND DATA BIFURCATION (LHS AND RHS MACHINE SIDE WISE): TREND

Table 3.8 List of lock pin bend data unloaded from LHS and RHS side of machine

Date	LHS	RHS
12/10/2021	3	4
13/10/2021	3	2
15/10/2021	1	2
15/10/2021	1	2
22/10/2021	18	3
25/10/2021	5	18
26/10/2021	0	13
27/10/2021	5	37
28/10/2021	6	13
29/10/2021	15	18
30/10/2021	13	25
13/11/2021	3	11
15/11/2021	0	8
16/11/2021	0	7
17/11/2021	0	8
22/11/2021	1	26
30/11/2021	4	1
6/12/2021	2	0
7/12/2021	4	19
8/12/2021	4	12
10/12/2021	0	2
6/1/2022	1	2
7/1/2022	2	1
8/1/2022	0	1
14/2/2022	3	1
17/2/2022	0	0

Table 3.8 shows lock pin data bifurcation of LHS and RHS lock pin insertion machine. This graph compares the unloading of lock pin bend defect in both left and right side. It is observed that the RHS machine causes high lock pin bend defect as compared to LHS machine due to high taper of pusher on RHS which holds the piston.

3.3.5 ACTION PLAN

The following plan is adopted to reduce the lock pin defect. This plan is called as the Action plan. Action plan is implemented on machine parameters and part factors.

1. Pusher which holds the piston got tapered was changed: Pusher which holds the piston tightly is tapered due to which component is not able to stick to pellet firmly. When machine inserts the lock pin then there is lock pin miss or bend. So, new pusher is attached.

2. Pusher height was reduced by 2mm: Height of the pusher which holds the piston was 4mm due to which it is unable to hold the c-block tightly and lock pin insertion machine bends the lock pin. Thus, height is reduced by 2mm.

3. Pressure reduced from 8.5 bar to 6 bar: Lock pin insertion machine is set to initially high pressure of 8.5 bar which causes lock pin miss or bend. Thus, pressure is reduced to 6 bar which slightly reduced lock pin defect unloading from line.

4. Right and left manpower interchanged and then data taken again: Sometimes due to shortage of manpower, there is a combination of new and old manpower who inserts the lock pin. Due to lack of skills, there occurs lock pin miss and bend. So, after interchanging between left and right-side manpower pin mis and bend defect is observed and noted.

5. Position of tool which presses the lock pin changed from 117mm to 116mm: Tool which inserts the lock pin it is set to a high position set up to a height of 117mm which causes lock pin bend issue. After tool height is changed to 116mm reloading rate is reduced.

6. Pressure again reduced from 6 bar to 5 bar: Lock pin insertion machine is set to initially high pressure of 8.5 bar which causes lock pin miss or bend. Thus, pressure is reduced to 6 bar which slightly reduced lock pin defect unloading from line. To reduce unloading of lock pin defect pressure is again lowered from 6 bar to 5 bar. Following these actions Reloading rate has been reduced from 5% to nearly 1%.

3.3.6 RESULT ANALYSIS

From day wise lock pin miss + bend data unloading percentage of defects is calculated.

Considering data of 1 day,

Total nos of lock pin miss + bend: 62

Production quantity on that day: 1000

Unloading % = $\frac{62}{1000} * 100$

= 6.2 %,

After change of material parameters and (manpower interchanged, pusher changed, pusher height reduced)

Total no's of lock pin miss + bend: 14

Production quantity on that day: 1000

Unloading % = $\frac{14}{1000} * 100$

= 1.4 %,

After improvement in machine parameters (machine pressure reduced, tool position changed, piston pusher height reduced)

Considering data of 1 day,

Total nos of lock pin miss + bend: 4

Production quantity on that day: 1000

Unloading % = $\frac{4}{1000} * 100$ = 0.4 %. Overall unloading % reduced from 6.2 % to 0.4 %.

3.4 PROJECT – 2: PISTON JAM DEFECT IN BSA075 MODEL OF COMPRESSOR

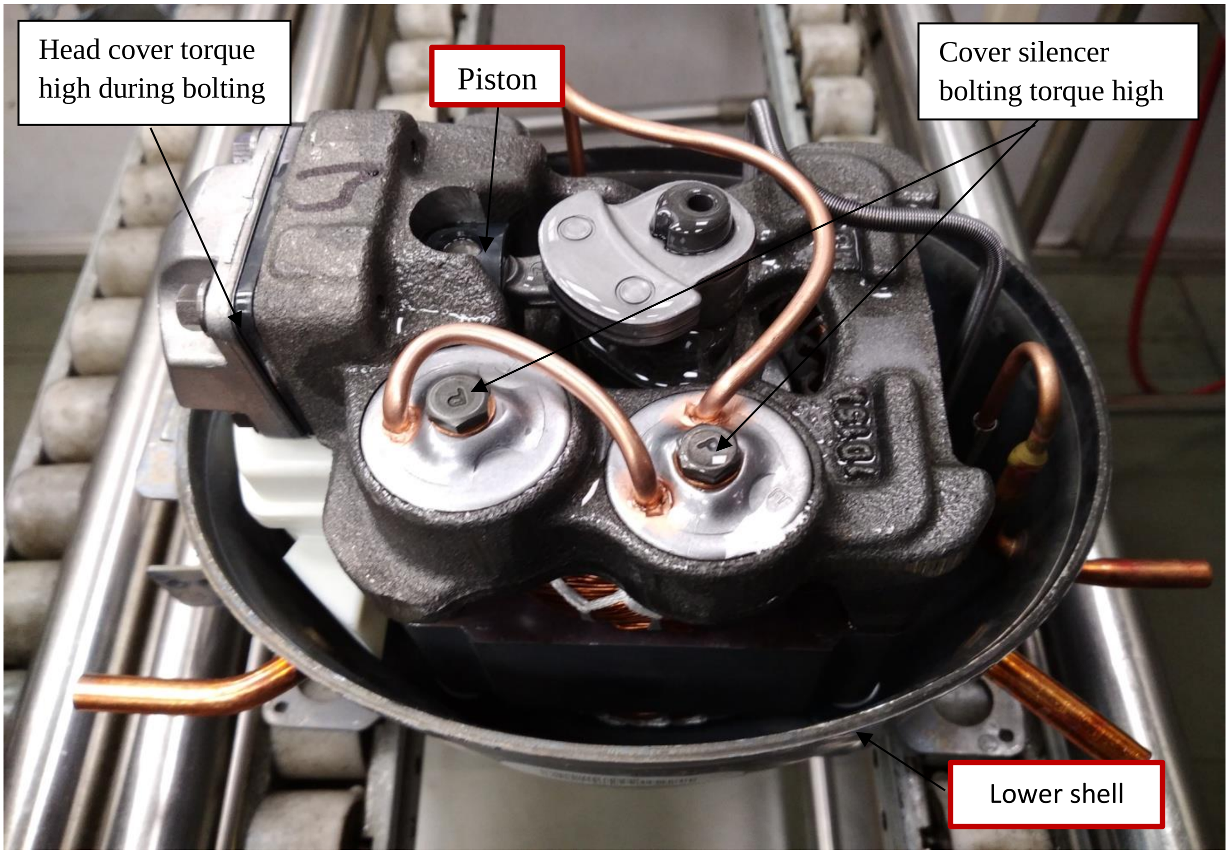


Figure 3.12 Compressor unloaded from LQC due to piston jam defect

This fig represents a compressor which is unloaded from LQC section due to piston jam defect. The main body of compressor inserted into the lower shell of compressor. Main body consists of c-block, piston, crank shaft, connecting rod, lock pin, rotor, stator, valve plate, head cover, cover silencer. Lower shell of compressor consists of springs in which the main body is attached.

3.4.1 OBJECTIVES OF PROJECT-2

Following are the objectives of this project:

1. To observe the section of assembly line from where piston is getting jam.

2. To gather data and set the machines within the specification limit.

The following has been observed during piston jam defect:

1. **Machine factors:**

    a. After cover silencer final bolting, piston getting jam: In BSA057 model cover silencer bolting machine torque limit is set at 105 kgf. But when same bolting is done in BSA075 model with torque kept at 105 kgf piston gets jam.

    b. After head cover bolting, piston getting jam: In BSA057 model, head cover bolting machine torque limit is set at 120 kgf. But when same bolting is done in BSA075 model with torque kept at 120 kgf piston gets jam.

2. **Part Factors:**

    a. Piston edge sharp/ burr: A burr is a small piece of material that remains attached to a workpiece after a modification process. It is usually an unwanted material that is removed by a deburring tool. Burrs are mostly created by machining operations such as grinding, drilling, milling, engraving, etc.

    b. C-block bore ID face chamfer less: The chamfer is a sloped or angled mainly to keep the edge safe from damage and give a more uniform look to the rough edge. Chamfers are mainly used in machining, furniture, carpentry, and to facilitate assembly of many mechanical designs.

3. **Process Factors:**

    a. Cover silencer torque higher side: Cover silencer torque is initially set to 105 kgf. When it is observed that at higher torque piston is getting jam, then cover silencer torque is reduced from 105 Kgf to 95 Kgf.

    b. Head cover torque higher side: Head cover torque is initially set to 120 Kgf. When it is observed that in BSA075 model at higher torque piston is getting jam, then head cover torque is reduced from 120 Kgf to 110 Kgf.

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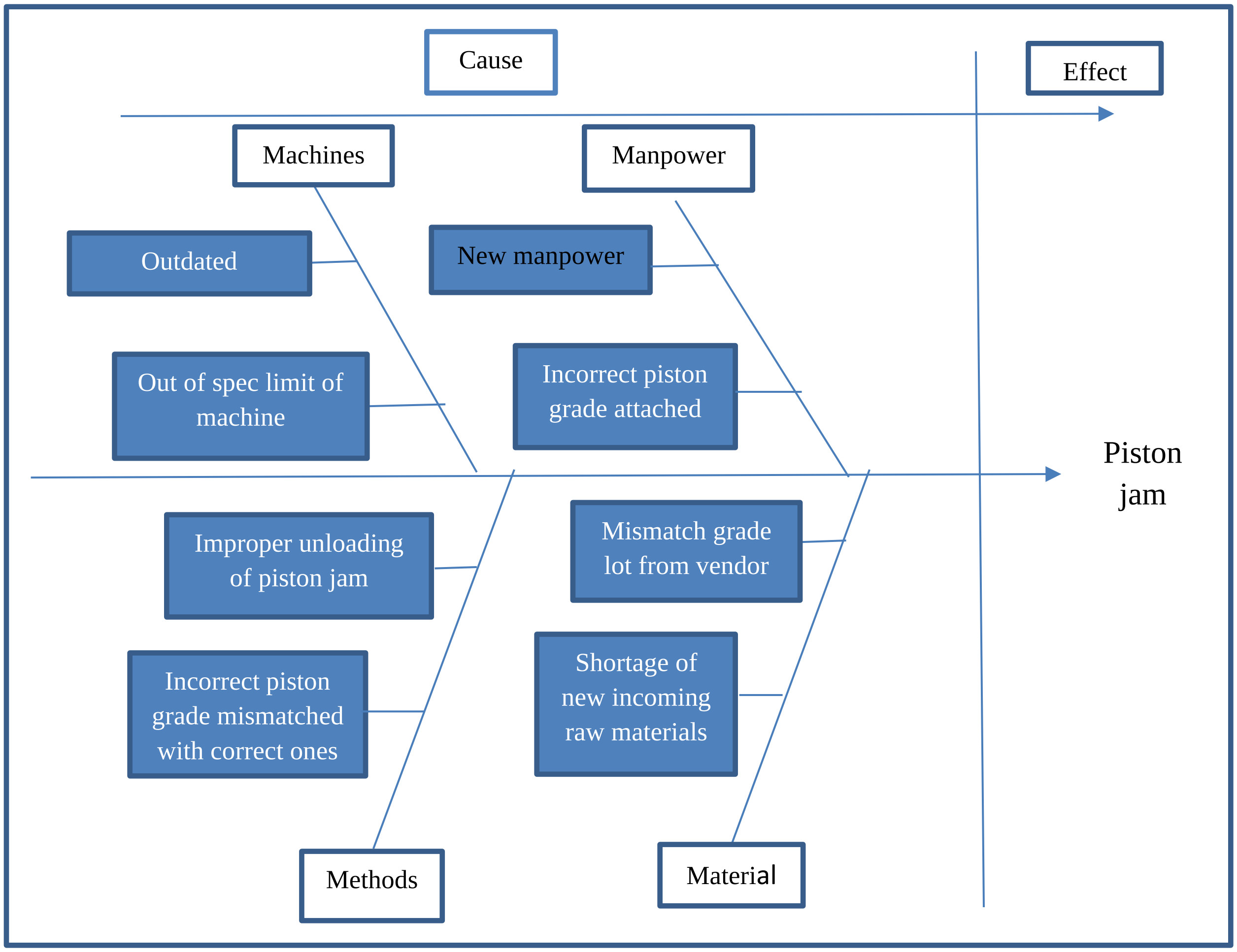

Figure 3.13 Fishbone diagram representing piston jam defect

A fish bone diagram is a visualization tool for categorizing the potential causes of a problem. This tool is used to identify a problem's root causes. It should be efficient as a test case technique to determine cause and effect. This tool is useful in product development process. In the above diagram the major causes of piston jam defect are identified and analysed. Major root causes are manpower, machines, materials and methods.

Table 3.9 List of day wise piston jam defect data

Date	Defect qty	Prod Qty	Defects per million
28/9/2021	124	1200	3432
29/9/2021	121	1225	7613
30/9/2021	108	1700	8730
1/10/2021	105	2000	9728
4/10/2021	73	2000	15952
5/10/2021	72	1800	15288
6/10/2021	68	1200	4923
7/10/2021	55	1650	17899
8/10/2021	42	1800	4374
9/10/2021	36	2000	3762
10/11/2021	35	2000	5550
10/12/2021	11	2000	9411

Table 3.9 lists day wise piston jam defect data with production quantity. The data has been taken for consecutive days and parts per million is found out. Production quantity of that day is mentioned in the table. This data is noted for BSA075 model of compressor in which commonly piston jam defect arises. PPM is a measurement which is used to measure quality performance. One PPM means one (defect or event) in a million or 1/1,000,000.

Table 3.10 Piston jam causes with defect count

Defect causes	Defect frequency	Cumulative %
Oiling issue	124	16
Piston and c/shaft surface dry	121	31
C/silencer bolting m/c torque high	108	45
H/cover bolting m/c torque high	103	59
Incorrect piston grade attached	94	71
Mismatch piston grade in lot	73	80
Machine spec not in range	61	88
C-block chamfer less	53	95
Piston surface deburring less	41	100

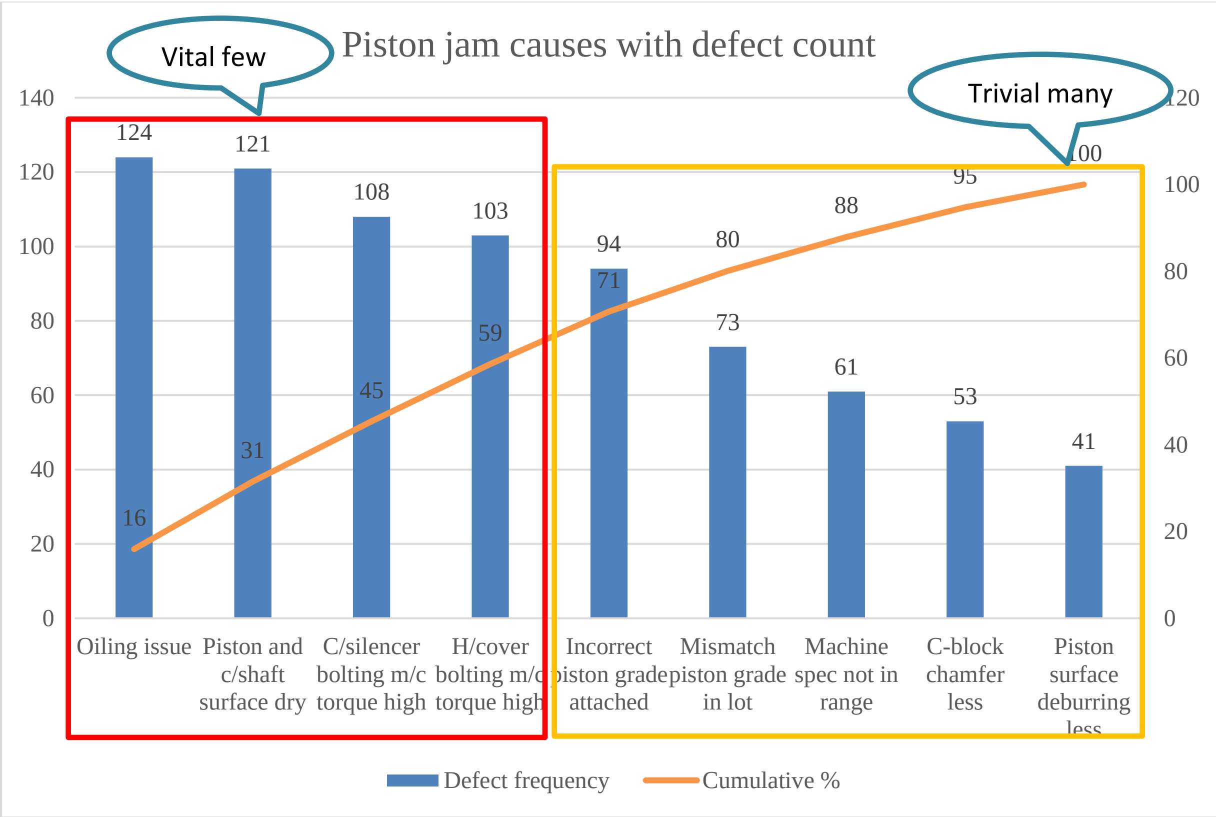

Figure 3.14 Pareto chart representing day wise unloading of piston jam defect

From figure 3.14, it is observed that 80% of the defects came from 2 out of 9 (25%) root cause types. Vital few root cause of piston jam defect is oiling issue and piston, and crank shaft surface is dry. Other significant 20% of the defects came from 7 out of 9 (75%) causes. Trivial many root causes of piston jam are cover silencer and head cover bolting machine torque high, incorrect piston grade attached, mismatch piston grade in lot, c-block chamfer less, piston surface deburring less. This information is useful to establish the priorities of root causes of defects.

3.4.2 ACTION PLAN

The following plan is adopted to reduce the piston jam defect. This plan is called as the Action plan. Action plan is implemented on machine parameters and part factors.

1. **Machine factors:** Following parameters are changed on machine to reduce this defect.

    a. Cover silencer torque reduced to 95 Kgf from 105 Kgf: In BSA075 model when cover silencer bolting torque is set at 105 kgf there is high unloading rate of piston jam defect, unloading rate nearly 10%; when torque is reduced to 95 kgf piston jam defect reduced to nearly 1%.

    b. Head cover torque reduced to 110 Kgf from 120 Kgf: In BSA075 model when head cover bolting torque is set at 120 kgf there is high unloading rate of piston jam defect, unloading rate nearly 10%; when torque is reduced to 110 kgf piston jam defect reduced to nearly 1%.

2. **Part factors:** Following actions are implemented on compressor parts to reduce this defect.

    a. Piston edge de-burring: Deburring is a machining process which enhances the final quality of the piston by removing raised edges and unwanted pieces of material, known as burrs, left by the initial machining processes.

    b. C-block bore ID face chamfer: The chamfer is a sloped corner or edge, mainly used to keep the edge safe from damage and give a more uniform look to the rough edge. C- block chamfer has been increased from 0.22mm to 0.35mm so that there is a slight gap when piston is inserted into the c-block. Following this action unloading rate has been reduced from 6% to 1%.

3.4.3 RESULT ANALYSIS

From day wise piston jam defect data, unloading percentage of defects is calculated.

Considering data of 1 day,

Total no’s of piston jam defect:124 (Highest unloading in 1 day)

Production quantity on that day: 1000

Unloading % = $\frac{124}{1000} * 100$

= 12.4 %,

After changes in compressor parts (piston edge deburred and c-block chamfer increase)

Total no’s of piston jam defect: 73

Unloading % = $\frac{73}{1000} * 100$

= 7.3 %,

After improvement in machine parameters (head cover bolting machine torque reduced)

Considering data of 1 day,

Total nos of piston jam defect: 35

Unloading % = $\frac{35}{1000} * 100$

= 3.5 %.

After cover silencer bolting machine torque reduced:

Total nos of piston jam defect: 11

Unloading % = $\frac{11}{1000} * 100$ = 1.1 %.

Overall unloading % reduced from 12.4 % to 1.1 %.

3.5 PROJECT – 3: CMA AIR GAP NG

Air Gap is manually checked by manpower. Air Gap is the distance between rotor and stator assembly. CMA069 and CMA062 are the 2 models of CMA. Air gap issue arises in both the models. Air Gap is checked by a filler gauge. The gauge is moved circularly through the slight gap between the rotor and stator. When there is no gap between rotor and stator then manpower reloads the component from line. There may be different reasons of air gap issue. One issue found is the rotor face runout. Rotor face runout data has been noted and compared separately for CMA062 and CMA069 model. Runout data has been taken.

1. Before rotor insertion into c-block by rotor pressing machine: Fresh rotor pieces has been taken from lot and before inserting into the c-block rotor run out data has been taken. Run out is checked at the top, middle and bottom surface of rotor.

2. After rotor pressing machine presses the rotor into c-block: Before pressing if in some rotors run out value is found out of specification range, those rotors are kept aside in a separate lot. After rotors are pressed into c-block by rotor insertion machine again rotor run out data is checked.

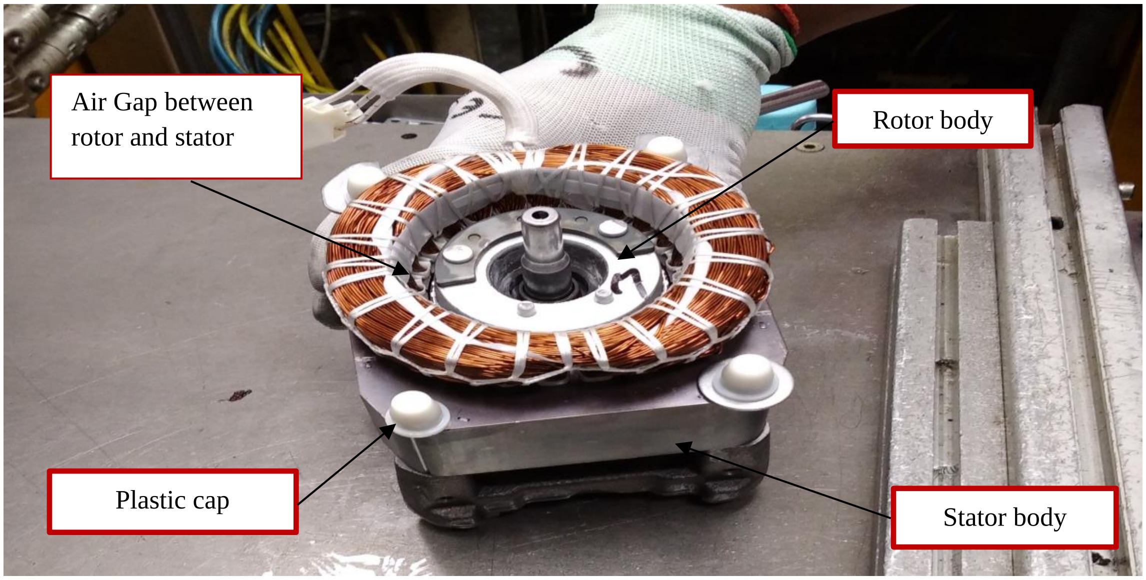

Figure 3.15 CMA069 model unloaded from line due to air Gap NG issue

Figure 3.15 shows a compressor of CMA069 model unloaded from main body line due to air gap NG issue. This figure resembles a stator inserted into rotor and copper wire winding is done on stator surface which will get magnetized. 4 plastic caps are attached on the sides of stator body. Air gap is the gap between rotor and stator. Air gap is checked in the main body line after rotor and stator insertion into c-block. It is checked by a very thin gauge. The gap is in millimetres. Fresh 8 samples of Rotor have been taken from the lot and rotor runout has been checked both before and after pressing. Rotor runout is checked at the top, middle and bottom surface by a gauge keeping the rotor fixed.

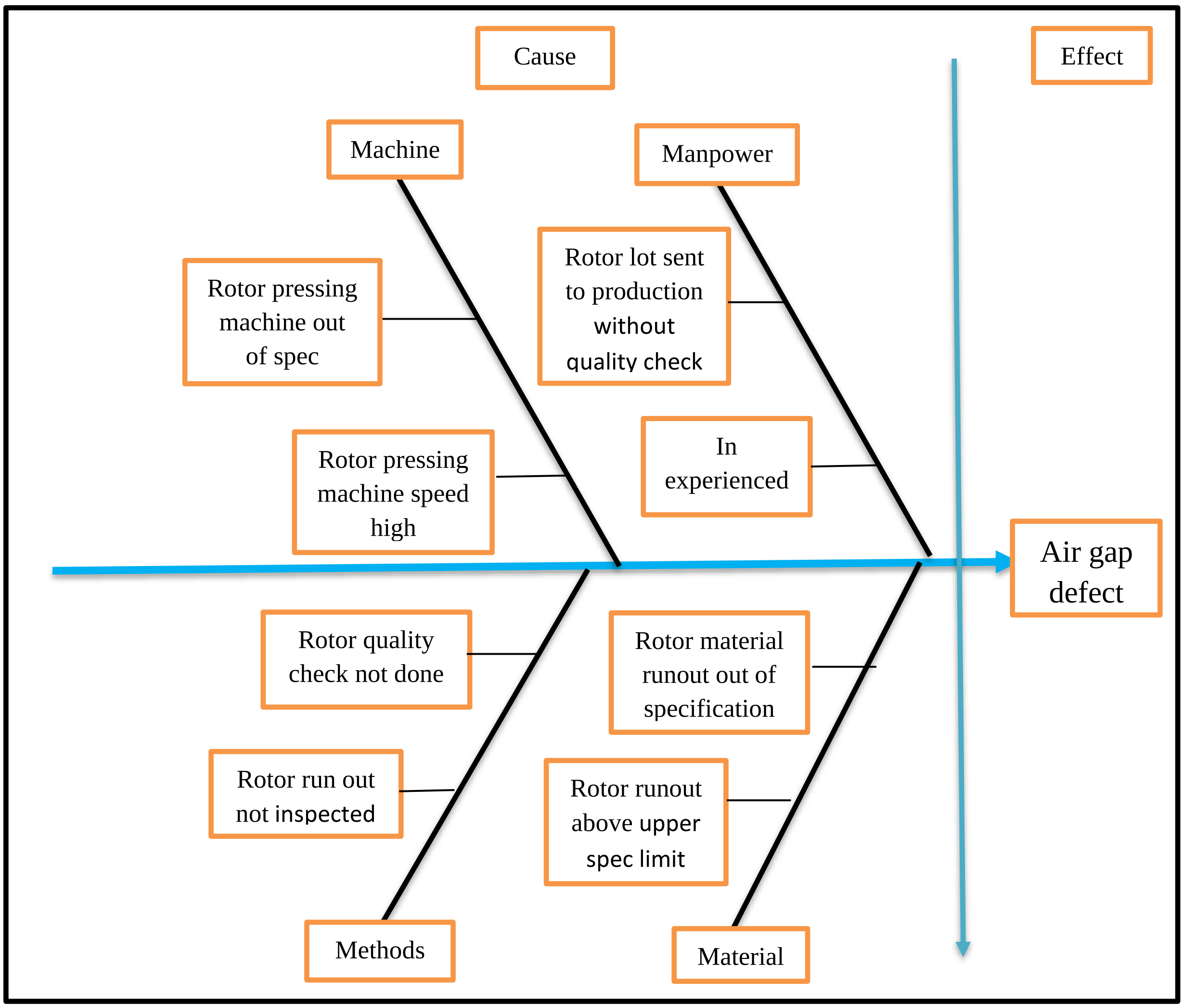

Figure 3.16 Fishbone diagram showing air gap defect causes

Figure 3.16 represents a cause and effect diagram showing air gap defect causes. A cause and effect diagram examines the reason of why something happened or might happen by organizing potential causes into smaller categories. It can also be useful for showing relationships between contributing factors.

3.5.1 OBJECTIVES OF PROJECT-3

1. To identify the root causes of air gap defect whether it is due to manpower or materials.

2. To inspect the rotor runout data and identify whether there is material issue from vendor side.

3.5.2 COMPARISON DATA TABLE

Table 3.11 List of rotor runout data in CMA062 model

	Before Pressing			After pressing		
Rotor sample	Top	Medium	Bottom	Top	Medium	Bottom
1	42	45	65	40	40	60
2	43	33	68	40	30	60
3	55	35	60	50	30	50
4	40	36	62	40	70	190
5	40	22	45	20	20	50
6	15	10	55	30	20	40
7	38	38	70	50	50	110
8	48	30	62	20	50	90

Table 3.11 shows the rotor runout data before rotor pressing and after rotor pressing. Runout is checked at the top, middle and bottom of rotor surface. Runout is checked on CMA062 model. It is observed that before pressing there is no rotor specimen whose runout is above specification limit i.e., 70 microns. After rotor pressing 3 rotor specimens have been found whose rotor runout is above specification limit i.e., 70 microns.

Table 3.12 List of rotor runout data in CMA069 model

Before Pressing				After pressing		
Rotor sample	Top	Medium	Bottom	Top	Medium	Bottom
1	80	52	200	50	40	33
2	70	50	180	40	40	80
3	50	30	70	30	40	110
4	80	40	200	60	40	90
5	70	60	110	40	30	50
6	80	50	100	60	50	90
7	60	55	120	40	40	60
8	30	16	80	40	30	40

Table 3.12 shows the rotor runout data before rotor pressing and after rotor pressing. Runout is checked at the top, middle and bottom of rotor surface. Runout is checked on CMA069 model. It is observed that before pressing there are 7 rotor specimens whose runout is above specification limit i.e., 70 microns. After rotor pressing 4 rotor specimens out of 8 have been found whose rotor runout is above specification limit i.e., 70 microns.

3.5.3 ACTION PLAN

The following plan is adopted to reduce the air gap defect. This plan is called as the action plan. Upper Specification Limit of Rotor Runout is 70 microns. From both the data tables it is seen that rotor runout is above spec limit. Higher spec limit before machine pressing indicates that rotor coming from vendor has issue. In case of CMA062, 2 samples have been found with bottom surface runout above specification limit. In case of CMA069, 6 samples have been found where rotor runout is out of spec before pressing which results in air Gap defect reloading from line. Before putting these rotors into production line quality inspection of the rotors should be thoroughly checked to avoid air gap defect.

3.6 SUMMARY OF OVERALL RESULTS

Defect	Improvement plan	Result
• Lock pin miss. • Lock pin bend.	• Piston pusher material which got tapered was changed and skilled manpower.	• Unloading rate reduced from 6.2 % to 1.4 %.
	• Machine pressure reduced from 8.5 bar to 6 bar and tool position is changed from 117 mm to 116 mm.	• Unloading rate reduced from 1.4 % to 0.4 % (Linked to page no 44).

Defect	Improvement plan	Result
• Piston jam defect.	• Improvement in parts: piston edge deburred and c-block chamfer increased from 0.22mm to 0.35mm.	• Unloading rate is reduced from 12.4 % to 7.3 %.
	• Change in machine parameters: cover silencer bolting machine torque is reduced from 105kgf to 90kgf.	• Unloading rate is reduced from 7.3 % to 1.1 % (Linked to page no 51).

Defect	Improvement plan	Result
• Air gap defect	• To improve air gap issue, first step is runout of rotor surface is checked so that it is less than 70micron.	• Rotor runout is to be within limit for air gap defect improvement. Samples whose runout is above spec limit are placed in a seperate lot and validated with the vendor.

Figure 3.17 Flowchart showing summary of overall results after improvement

CHAPTER 4

CONCLUSION

During this training programme, the whole layout of compressor line has been studied. Performance parameters of line is noted and calculated. Tact time also called cycle time is calculated for every worker at different stages of the line. During the assembly of compressor there's reloading of defect at different stages of line Drop, Main Body, Final and LQC. Lock pin defect reloading at drop line has been studied and analyzed to resolve this issue. Following are the list of conclusions:

1. Data collected from the lock pin machine features a reloading rate of 6% defect daily. This data been repeated for consecutive many days and machine parameters are changed accordingly and again data is taken, reloading rate reduced to 0.4%.

2. Reloading data collected of piston jam defect from LQC, high reloading rate. Torque is reduced in bolting machine and piston edge is deburred through deburring machine, in order that there's a slight gap when piston fits into c-block, defect reloading rate reduced from 12% to 1%.

3. Comparison of rotor runout data has been made for CMA062 model and CMA069 model and after analysis it is found that found that in some rotors there is higher specification limit of rotor surface run out.

FUTURE WORK

- More detailed analysis of lock pin defect and piston jam defect is necessary. Although unloading of these defects have reduced still sometimes there is limited unloading of these defects which needs to be minimized.

- There are various other defects from other sections of assembly line such as paint NG defect, pipe pinch defect whose data has been collected only and action plans must be analyzed.

- Air gap NG defect is frequently observed in CMA model due to rotor runout issue. In few samples rotor runout is above the specification limit due to issue from the vendor side. Though quality inspection is carried out still this problem arises. Future analysis of this defect must be carried out at a greater extent to solve this issue.

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