Thesis Report

On

Process Redesign for Chain Weight Reduction

Submitted in partial fulfillment of the requirement for the award of

Master of Engineering

IN

CAD/CAM & Robotics

Submitted By

KISHORE KASHYAP

Roll No. 801081015

Under the Guidance of

Dr. AJAY BATISH

Professor and Head

Mechanical Engineering Department,

Thapar University,

Patiala-147004

DEPARTMENT OF MECHANICAL ENGINEERING

THAPAR UNIVERSITY

PATIALA-147004, INDIA,

July-2012

DECLARATION

I hereby declare that the thesis report entitled **Process Redesign for Chain Weight Reduction** in the partial fulfillment of the requirement for the award of the degree of **Master of Engineering (CAD/CAM & Robotics)** to **Thapar University, Patiala,** is a record of work carried out by me under the supervision and guidance of **Dr.Ajay Batish**, Professor & Head-MED, Thapar University, Patiala. The matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

(KISHORE KASHYAP)

801081015

This is to certify that above declaration made by the student concerned is correct to the best of my knowledge & belief.

Dr. AJAY BATISH
PROFESSOR & HEAD-MED
THAPAR UNIVERSITY, PATIALA

Countersigned by:

Dr. AJAY BATISH~~ER~~
PROFESSOR & HEAD-MED
THAPAR UNIVERSITY, PATIALA

Dr. S.K. MOHAPATRA
DEAN, ACADEMIC AFFAIRS
THAPAR UNIVERSITY, PATIALA

ACKNOWLEDGEMENT

With deep sense of gratitude, I express my sincere thanks to my guide, ***Dr. Ajay Batish*** *Professor & Head, of Mechanical Engineering Department for his unreserved guidance, constructive suggestions, thought provoking discussions and unabashed inspiration in the nurturing work and also for providing the facilities for the completion of the work and always being a shelter in the odd days.*

In addition, I would like to thank Rockman Industries Ludhiana, who had created the necessity of the work, which help me create my basic platform and financially assisting me. Mr. A Shanmugam, Sr. Manager – R&D for assisting me whole-heartedly throughout the work. Mr. SumitUtreja – Vice President for granting such a beautiful work.

No words acknowledge the support I received from my friends for their valorous help and co-operation. I would like to thank all the members and employees of Mechanical Engineering Department, Thapar University, Patiala for their everlasting support.

Kishore Kashyap

Roll no: 801081015

ABSTRACT

The process of Drive Chain manufacturing is as important as its analyses. In today's era, it is an intelligent and profit making job to produce an optimum product. Currently, chains production is done having 1.5mm link plate thickness and it will be commendable job if we are able to produce such a chain, which have lesser link plate thickness but have equal or greater strength as the existing one.

For the same a chain has to pass tensile test, acid test, endurance test and fatigue test Machines on which a specimen is mounted and testing are available there in the company. These testing are carried out at hourly, daily or monthly rates depending upon the type of test. Changes have to be done in production procedure like heat treatment and other mechanical surface treatment and in design if possible. If it is thought to change the dimension of product, then practically we have to check the present heat treatment parameters for its hardness at variable sheet thickness

Use of computer software's can help us a lot in the field of optimization. Models for Ultimate tensile testing, Endurance Testing, and Fatigue Analysis can now days are successfully analyzed on a computer. Even our new design change in existing product can also be analyzed before actual production.

Technological advances in steels heat treatments, structure and the microstructure of most steels are well known by now, as well as the effects of the heat treatments in changing their mechanical properties, which will also be help full in increasing the strength of low carbon steels.

Table of Contents **Page No.**

LIST OF FIGURES

LIST OF TABLES

Chapter 1.

GENERAL INTRODUCTION

1.1 Power transmission devices

Power transmission devices are very commonly used to transmit power from one shaft to another. Belts, chains and gears are used for this purpose. When the distance between the shafts is large, belts or ropes are used and for intermediate distance, chains can be used. For belt drive, distance can be maximum but this should not be more than ten meters for good results. Gear drive is used for short distances [1].

1.1.1 Belts

In case of belts, friction between the belt and pulley is used to transmit power. In practice, there is always some amount of slip between belt and pulleys, therefore, exact velocity ratio cannot be obtained. That is why, belt drive is not a positive drive. Therefore, the belt drive is used where exact velocity ratio is not required. The following types of belts shown in Figure 1 are most commonly used.

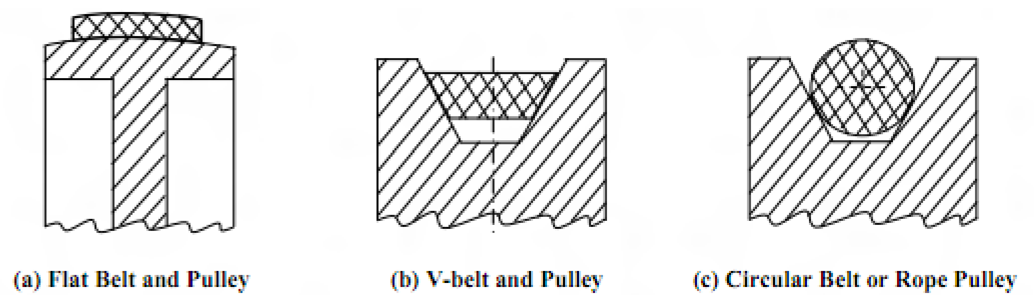


Figure 1. 1 Types of Belt and Pulley.[1]

The flat belt is rectangular in cross-section as shown in Figure 1.1(a). The pulley for this belt is slightly crowned to prevent slip of the belt to one side. It utilizes the friction between the flat surface of the belt and pulley.

The V-belt is trapezoidal in section as shown in Figure 1.1(b). It utilizes the force of friction between the inclined sides of the belt and pulley. They are preferred when distance is comparative shorter. Several V-belts can also be used together if power transmitted is more. The circular belt or rope is circular in section as shown in Figure 1.1(c). Several ropes also can be used together to transmit more power. The belt drives are of the following types [1]: (a) open belt drive, and (b) cross belt drive.

1.2 Chain Drives.

The belt drive is not a positive drive because of creep and slip. The chain drive is a positive drive. Like belts, chains can be used for larger centre distances. They are made of metal and due to this chain is heavier than the belt but they are flexible like belts. It also requires lubrication from time to time. The lubricant prevents chain from rusting and reduces wear.

1.2.1 Introduction

The chain and chain drive are shown in Figure 2. The sprockets are used in place of pulleys. The projected teeth of sprockets fit in the recesses of the chain. The distance between roller centers of two adjacent links is known as pitch. The circle passing through the pitch centers is called pitch circle [1].

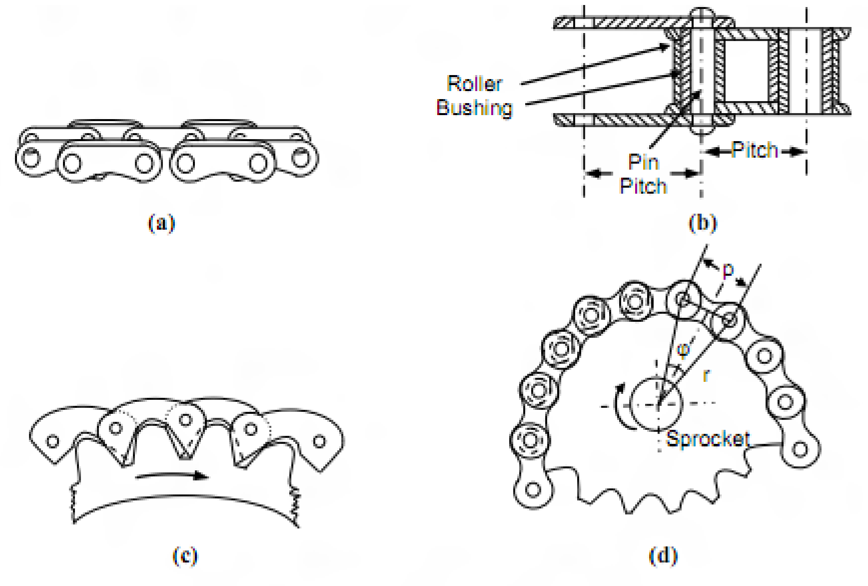


Figure 1. 2 Chain and Chain Drive [1]

The power transmission chains are made of steel and hardened to reduce wear. These chains are classified into three categories

(a) Block chain

(b) Roller chain

(c) Inverted tooth chain (silent chain)

Out of these three categories roller chain shown in Figure 1.2(b) is most commonly used. The construction of this type of chain is shown in the Figure 1.5. The roller is made of steel and then hardened to reduce the wear. A good roller chain is quitter in operation as compared to the block chain and it has lesser wear. The block chain is shown in Figure 1.2(a). It is used for low speed drive. The inverted tooth chain is shown in Figures 1.2(c) and (d). It is also called as silent chain because it runs very quietly even at higher speeds.

Roller chain is a reliable machine component, which transmits power by means of tensile forces, and is used primarily for power transmission and conveyance systems. The function and uses of chain are similar to a belt. There are many kinds of chain. It is convenient to sort types of chain by either material of composition or method of construction [2]

Chains can be sorted into five types according to their materials:

1. Cast iron chain
2. Cast steel chain
3. Forged chain
4. Steel chain
5. Plastic chain

Demand for the first three chain types is now decreasing; they are only used in some special situations. For example, cast iron chain is part of water-treatment equipment; forged chain is used in overhead conveyors for automobile factories. [1]

According to their uses, this can be broadly divided into six types:

1. Power transmission chain
2. Small pitch conveyor chain
3. Precision conveyor chain
4. Top chain
5. Free flow chain
6. Large pitch conveyor chain

The first one is used for power transmission; the other five are used for conveyance and for power transmission Roller chains are best [1]

Features of Chain Drives: [2]

Speed reduction/increase of up to seven to one can be easily accommodated.

1. Chain can accommodate long shaft-center distances (less than 4 m), and is more versatile.
2. It is possible to use chain with multiple shafts or drives with both sides of the chain.
3. It is easy to cut and connect chains.
4. The sprocket diameter for a chain system may be smaller than a belt pulley, while transmitting the same torque.

5. Sprockets are subject to less wear than gears because sprockets distribute the loading over their many teeth.

Points to notice [2]

1. Chain has a speed variation, called chordal action, which is caused by the polygonal effect of the sprockets.
2. Chain needs lubrication.
3. Chain wears and elongates.
4. Chain is weak when subjected to loads from the side.
5. It needs proper alignment.

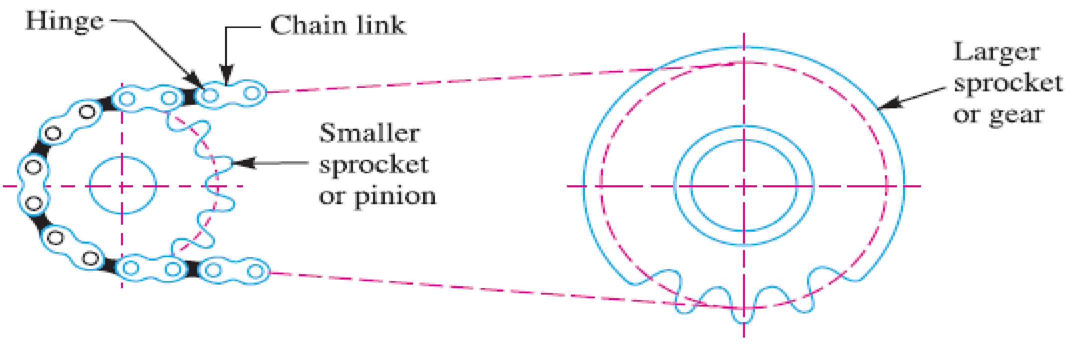


Figure 1. 3 Showing roller chain and sprockets assembly [3]

1.2.2 Advantages and Disadvantages of Chain Drive over Belt or Rope Drive [3]

Following are the advantages and disadvantages of chain drive over belt or rope drive:

Advantages

1. As no slip takes place during chain drive, hence perfect velocity ratio is obtained.

2. Since the chains are made of metal, therefore they occupy less space in width than a belt or rope drive.

3. It may be used for both long as well as short distances.

4. It gives high transmission efficiency (up to 98 %).

5. It gives fewer loads on the shafts.

6. It has the ability to transmit motion to several shafts by one chain only.

7. It transmits more power than belts.

8. It permits high-speed ratio of 8 to 10 in one step.

9. It can be operated under adverse temperature and atmospheric conditions.

Disadvantages

1. The production cost of chains is relatively high.
2. The chain drive needs accurate mounting and careful maintenance, particularly lubrication and slack adjustment.
3. The chain drive has velocity fluctuations especially when unduly stretched

1.2.3 Characteristics of Roller Chains

According to Indian Standards (IS: 2403—1991), the various characteristics such as pitch, Roller diameter, and width between inner plates, transverse pitch and breaking load for the roller chains are given in the following Table 1.1 with reference to Figure 1.4 [3]

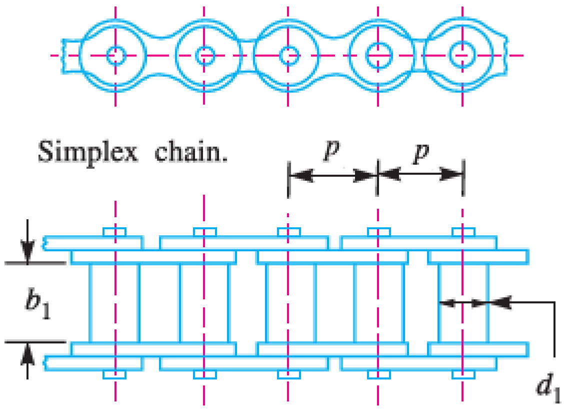


Figure 1. 4 Line diagram of joint links of roller chain referred to following Table [3]

ISO Chain number	Pitch (p) mm	Roller diameter (d_1) mm Maximum	Width between inner plates (b_1) mm Maximum	Transverse pitch (p_1)mm	Breaking load (kN) Minimum		
					Simple	Duplex	Triplex
05 B	8.00	5.00	3.00	5.64	4.4	7.8	11.1
06 B	9.525	6.35	5.72	10.24	8.9	16.9	24.9
08 B	12.70	8.51	7.75	13.92	17.8	31.1	44.5
10 B	15.875	10.16	9.65	16.59	22.2	44.5	66.7
12 B	19.05	12.07	11.68	19.46	28.9	57.8	86.7
16 B	25.4	15.88	17.02	31.88	42.3	84.5	126.8
20 B	31.75	19.05	19.56	36.45	64.5	129	193.5
24 B	38.10	25.40	25.40	48.36	97.9	195.7	293.6
28 B	44.45	27.94	30.99	59.56	129	258	387
32 B	50.80	29.21	30.99	68.55	169	338	507.10
40 B	63.50	39.37	38.10	72.29	262.4	524.9	787.3
48 B	76.20	48.26	45.72	91.21	400.3	800.7	1201

Table 1. 1 Characteristics [3] of roller chains according to IS: 2403 — 1991

1.2.4 Elements in Drive Chain.

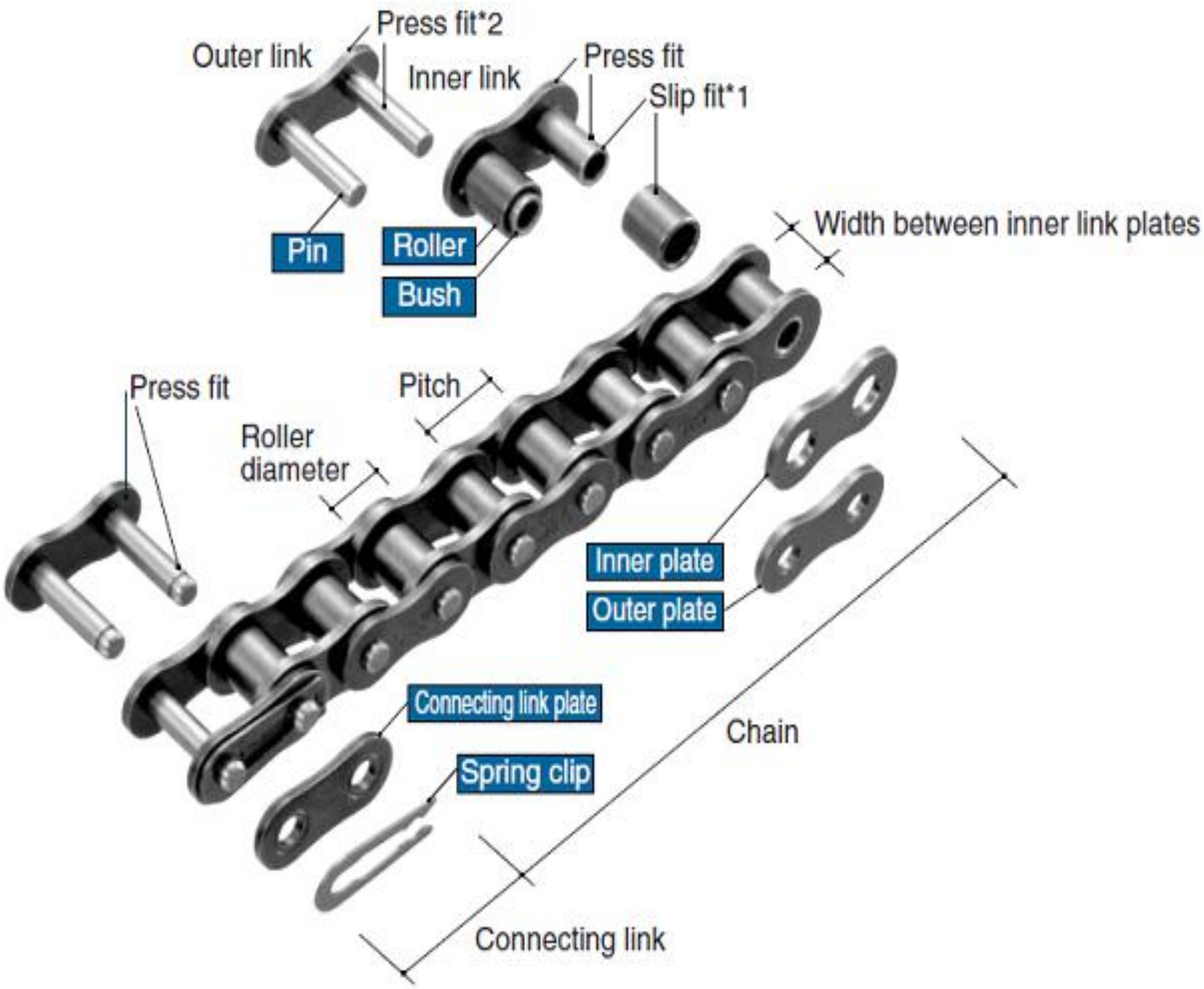


Figure 1. 5 Dimensions are not shown to kept design data safe & for material please refer Table 1.2[4]

1. **Inner/outer link Plate:-**The plate bears the tension placed on the chain. Usually this is a repetitive load, but sometimes it is accompanied by shock. Therefore, the plate must have not only great static tensile strength, but also must hold up to the dynamic forces of load and shock.

2. **Pin:-**The pin is subject to shearing and bending forces transmitted by the plate. At the same time, it forms a load-bearing part, together with the bush, when the chain flexes during sprocket engagement. Therefore, the pin needs high tensile and shear strength, resistance to bending, and sufficient endurance against shock and wear

3. **Bush: -** The bush is subject to complex forces from all parts, especially from the repetition of shock loads when the chain engages the sprocket. Therefore, the bush needs extremely high shock resistance. In addition, the bush forms a load-bearing part together with the pin, and as such requires great wear resistance.

4. **Roller:** - The roller is subject to impact load as it strikes the sprocket teeth during chain engagement with the sprocket. After engagement, the roller changes its point of contact and balance. It is held between the sprocket teeth and bush, and moves on the tooth face while receiving a compression load. Therefore, it must be resistant to wear and still have strength against shock, fatigue and compression.

1.2.5 Material for Chain Elements.

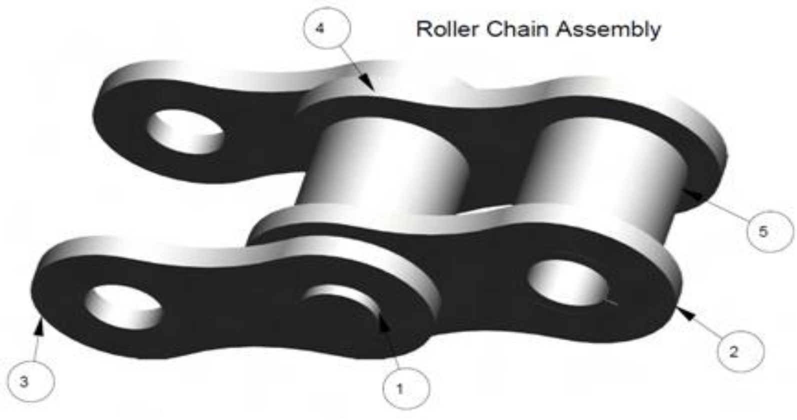


Figure 1. 6 One chain link assembly

Sr.No	Member Name	Quantity	Material
1.	Bush	2	16MnCr5
2.	Inner Plate	2	SAE1050
3.	Outer Plate	2	SAE1050
4.	Pin	1	15B25
5.	Roller	2	C1018

Table 1. 2 Showing bill of material of assembly components of roller chain

1. AISI 1040, 1045

1040, 1045 (HR, CF) - Used when greater strength and hardness is desired in rolled condition. Good for hammer forge processes. Uses include for gears, shafts, axles, bolts sand studs. 1040 is medium-carbon steel composed of 0.37 to 0.44 percent carbon, 0.6 to 0.9 percent manganese, a maximum of 0.04 percent phosphorus and a maximum of 0.05 sulphur. The remainder is iron. 1040 steel sometimes contains 0.1 to 0.35 percent silicon. [4]

Tensile Strength

Ultimate tensile strength is the maximum load a material will support before it breaks, The purpose is to find the point at which a material will fail when supporting a given load or sustaining a set force.

1040 steel will support 90,000 pounds of force per square inch before it fails, if it was hot-rolled, this strength drops to 85,500 psi. Normalizing and annealing are two examples of heat treatments. In heat treatment, the temperature of the steel is changed in order to alter its molecula structure and change its reaction to various forces during forging and fabrication

2. AISI 1050

AISI 1050 is a Standard grade Carbon Steel. It is composed of (in weight percentage) 0.48-0.55% Carbon (C), 0.60-90% Manganese (Mn), 0.04 %Phosphorus (P), 0.05 %Sulfur (S), and the base metal Iron (Fe). Other designations of AISI 1050 carbon steel include UNS G10500 and AISI 1050.

1050 - Strain hardened, stress relieving material typically 100 Ksi yield strength.1050 Steel is a plain carbon steel containing 0.50 wt. percentage of carbon.

1.3 Chain Dynamics

1.3.1 Chain under Tensile Load

How will the chain behave when it is subject to tensile loading? There is a standard test to determine the tensile strength of a chain. Here is how it works:

The manufacturer takes a new, five-link-or-longer power transmission chain and firmly affixes both ends to the jigs as shown in Figure 1.7. Now a load or tension is applied and measurements are taken until the chain breaks (JIS B 1801-1990). [2]

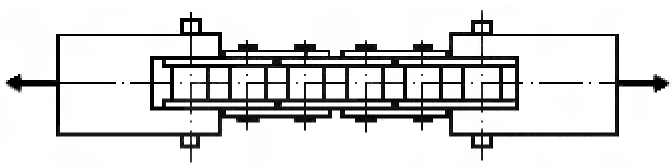


Figure 1. 7 Typical chain in tensile test.[2]

1.3.2 Chain Elongation

As a chain is subject to increasing stress or load, it becomes longer. This relationship can be graphed in Figure 1.8. The vertical axis shows increasing stress or load, and the horizontal axis shows increasing strain or elongation. In this stress-strain graph, each point represents the following: [2]

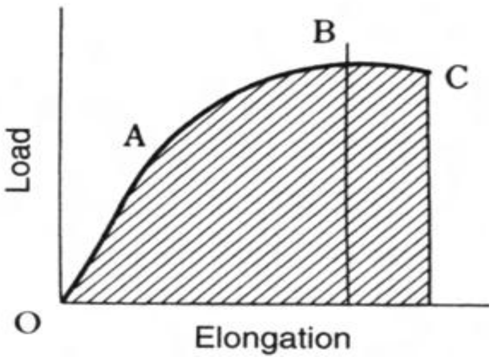


Figure 1. 8 Chain stress-strain graph.[2]

O-A: elastic region

A: limit of proportionality for chains; there is not an obvious declining point, as in mild steel

A-C: plastic deformation

B: maximum tension point

C: actual breakage

1.3.3 Elastic Elongation

Another important characteristic in practice is how much elastic elongation the chain will undergo when it is subjected to tension. When you use chains for elevators on stage, if there is a difference between the stage floor and the elevator platform, the dancers will trip on it. In an elevator parking garage, it is necessary to lower cars down to the entrance within a small difference in the level. Therefore, it is important to anticipate how long the chain's elastic stretch will be. Figure 1.9 shows elasticity/stretch for power transmission roller chains.[2]

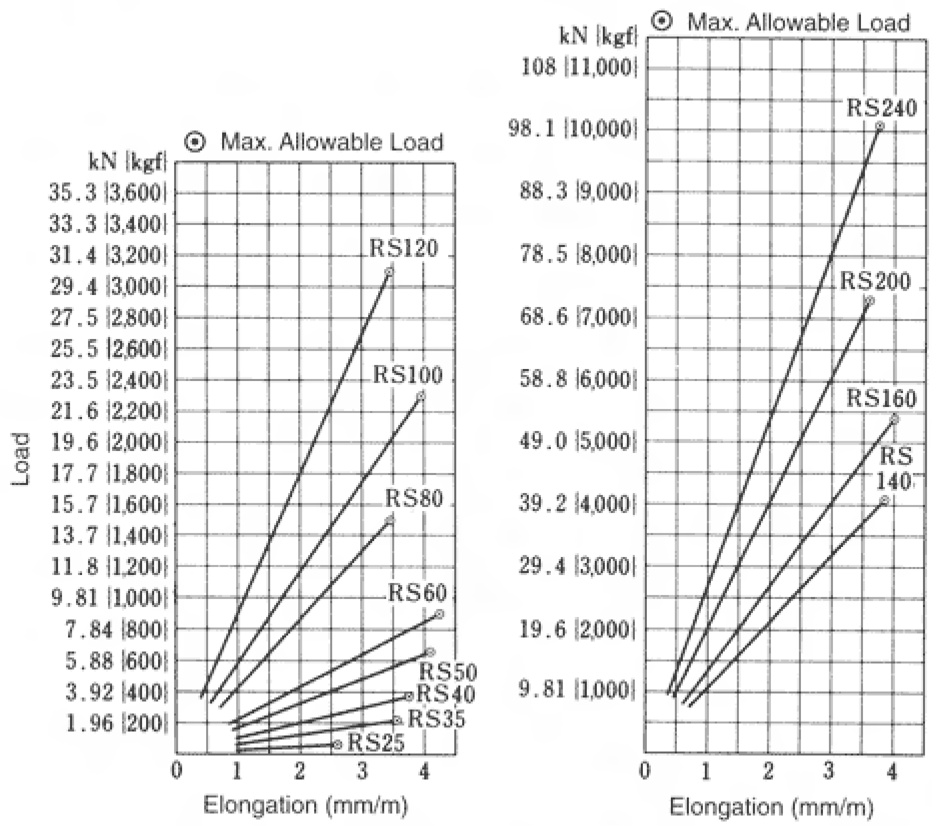


Figure 1. 9 Elastic Elongation on Roller Chain [2]

1.4 Heat Treatment of Chain elements. [5]

Heat Treatment is the controlled heating and cooling of metals to alter their physical and mechanical properties without changing the product shape so that the metal will be more useful, serviceable, and safe for definite purpose. Heat Treatment is often associated with increasing the strength of material, but it can also be used to alter certain manufacturability objectives such as improve machining, improve formability, restore ductility after a cold working operation. Thus, a very enabling manufacturing process cannot only help other manufacturing process, but can also improve product performance by increasing strength or other desirable characteristics. The various heat-treatment processes are similar in that they all involve that heating and cooling of metals. They differ, however, in the temperatures to which the metal is heated, the rate at which it is cooled, and, of course, in the result. The most common forms of heat treatment process for ferrous metals are hardening, tempering, normalizing, annealing, and casehardening. Most nonferrous metals can be annealed and many of them can be hardened by heat treatment. However, there is only one nonferrous metal, titanium, that can be casehardened, and none can be tempered or normalized

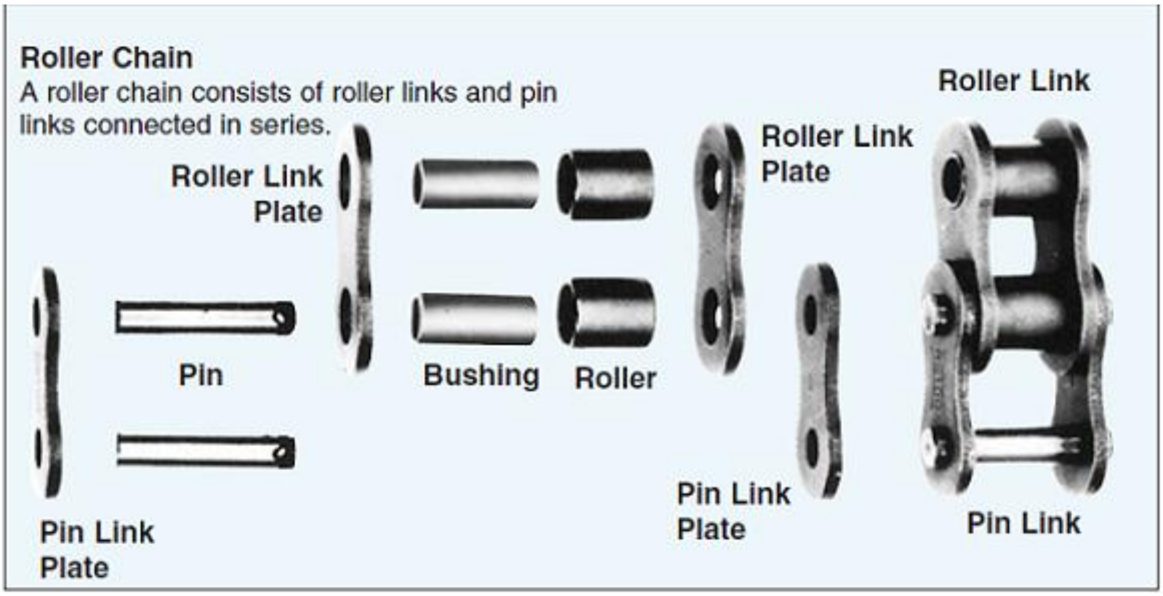


Figure 1. 10:-Various assembly components of roller chain

1.4.1 Carbonitriding (Bush, Roller and Pin)-Refer Figure 1.10.

In carbonitriding, ammonia NH3 is introduced into the carburizing atmosphere. NH3 decomposes at carburizing temperature and releases nitrogen with the ability to be absorbed by the steels. The simultaneous and competing diffusion of carbon and nitrogen leads to some particularities that are technically used. Nitrogen stabilizes the austenite, thus reducing the diffusion- controlled transformation of the austenite to ferrite and pearlite and lowering the martensite start temperature. Martensite is also stabilized by soluted nitrogen. The essential advantage of carbonitriding lies in the better harden ability (stabilized austenite) because this also allows to better control hardness profiles in steels that are not intended to be carburized as well as in sintered iron an d to use milder quenchants with less distortion. Moreover, C–N-martensite has a better tempering behavior. Whereas carburizing temperatures generally exceed 900 ℃, carbonitriding is performed at lower temperatures in the range of 815–900℃ because at temperatures of more than 900℃ ammonia decomposes too fast and the nitrogen potential becomes too high, thus causing increased contents of retained austenite and even pores. Consequently, carbonitriding is usually applied with producing case depths of less than 0.5 mm, which can be better accomplished in carbonitriding than in carburizing.

Advantages

1. It has a greater resistance to softening during tempering and increased fatigue and impact strength.

2. It is possible to use both carbonitriding and carburizing together to form optimum conditions of deeper case depths.

3. This method is applied particularly to steels with low case harden-ability, such as the seat of the valve. The process applied is initially carburizing to the required case depth (up to 2.5mm) at around 900-955°C, and then carbonitriding to achieve required carbonitrided case depth. The parts are then oil quenched, and the resulting part has a harder case than possibly achieved for carburization, and the addition of the carbonitrided layer increases the residual compressive stresses in the case such that the contact fatigue resistance and strength gradient are both increased.

Characteristics of carbonitrided parts

1. Carbonitriding forms a hard, wear resistant case, typically 0.07mm -0.5mm thick, and generally has higher hardness than a carburized case.
2. Case depth is tailored to the application, and a thicker case, increases wear life of the part. Carbonitriding alters only the top layers of the work piece; and does not deposit an additional layer, so the process does not significantly alter the dimensions of the part. Maximum case depth is typically restricted to 0.75mm; case depths greater than this take too long to diffuse to be economical.
3. Shorter processing times are preferred to restrict the concentration of nitrogen in the case, as nitrogen addition is more difficult to control than carbon.
4. An excess of nitrogen in the work piece can cause high levels of retained austenite and porosity, which are undesirable in producing a part of high hardness.

1.4.2 Through hardening (Inner & Outer Plates)

Heating of inner & outer link plates are done in rotary Furnace and then quenching them in oil (22xFQ) which is at kept in between 50-80 °C will through harden inner & outer plates and Plotted graph is shown in Figure 5 with soaking time.

1.4.1 Brief introduction to process flow in Figure 1.11

1.The inner/outer plate are manufacturing by performing piercing and blanking operation then heat treatment furnaces is used for there through hardening and tempering.

2. Wires are to be cut done into desired dimension then again heat treatment furnaces used for case hardening and tempering and then it goes for tumbling operation.

3.Roller are made by cold forging of Solid steel wires of desired diameter and then heat treated for case hardening and then tempered and then it goes for tumbling operation.

4.Bush is made by curling the steel strip of desired cutting size with the help of curling machine after which bush is obtained and then heat treatment furnaces is used for case hardening and tempering and then it goes for tumbling operation.

5.Finally these all these members of chain sent to assembly line for assembly of complete roller chain.

1.4.2 Study of Manufacturing process and assembly of roller chain is done Refer Figure 1.11

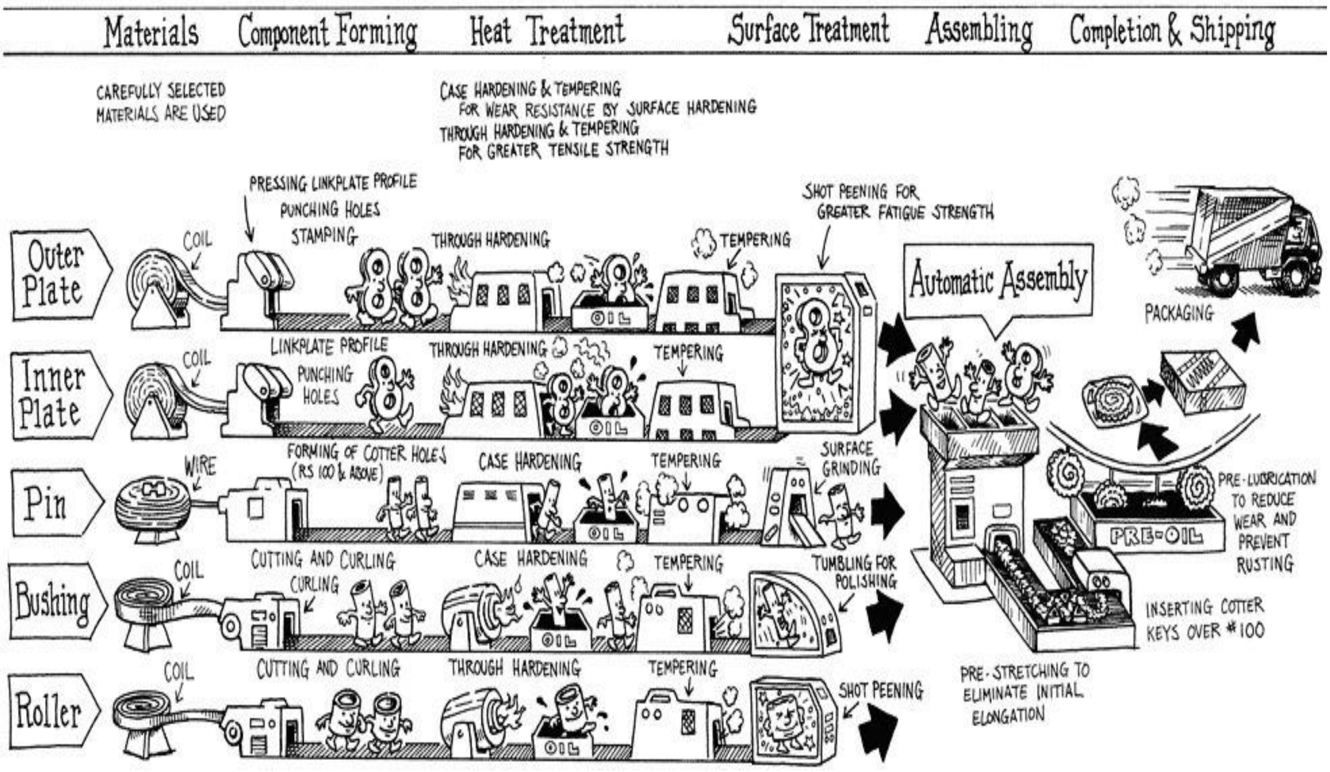


Figure 1. 11 Roller chain Manufacturing Process

Referred link: - http://chain-guide.com/breaks/roller-chain-manufacturing-process.html

1.5 Over view of Present work

In today's manufacturing world for continuous development, large efforts are taken to save the material without compromising the safety and strength of the designed component. Drive chains are manufactured and tested through various parameters like-

1. Tensile Strength
2. Chain Elongation
3. Fatigue Failure
4. Elastic Elongation

In addition, these all are discussed in chain dynamics (1.3). Out of these parameters, the most critical is Tensile strength, which is also an important factor as production & safety point of view.

To produce lightweight chain current thickness of link plates and length of Bush and riveting Pin are to be reduced and it is obvious that by doing so tensile load bearing capability of the Roller chain will reduce. On the other hand the net weight of roller chain will reduced to 15% from existing weight, in other words it is material saving act without compromising the performance of chain.

Chapter 2.

LITERATURE REVIEW

2.1 Introduction

A large work has been done on different aspects of tensile strength improvement by means of heat treatment and mechanical surface treatment. This chapter covers the literature on how the material properties can be improves by various means. This chapter also covered some design related parameters that can be implementing to strengthening the members of assembly.

2.2 Categorization of literature

Literature is divided into following three main categories:

1. Design related parameters.
2. Mechanical surface treatment.
3. Heat treatment.

2.2.1 Design related parameter

Donald W.sherman et al. [6] conducted an experimental study to prevent the metal from tearing around the opening as the embossed flange was formed. In the embossing or flanging of plates around openings it has been the practice to employed male and female die members having a difference in radius equal to the thickness of the plate so that the flange produce would be of the same thickness as the original plate.

Sadagopan et al. [7] examined effects of high velocities and transient driving torques as well as by polygonal action and rotatory impacts dominated their complex dynamical behavior. Wear reduction of existing chain used in 100cc motorcycles was considered. Elongation of chain was calculated and compared with the field results. In an alternate design developed, theoretical evaluation for elongation was made by applying the same conditions used for evaluating the existing chain. Fatigue properties of existing standard chain components were evaluated based on mathematical model as well as by using ANSYS software. Chains should also satisfy fatigue requirements. Fatigue failure of plates at the eyes was main criterion for heavily loaded high-speed roller chains. Fatigue limit was occurring between 106-107 cycles (ISO 10190:1992). When a chain was operating under load, outer surface of pins and inner surface of bushings slide against each other due to articulation, thereby causing wear.

The author also concluded that endurance limit of all components are found higher than the operating stress level and hence components will not fail during operation and have infinite life. However, fatigue strength of roller link plate was lower than other elements because of bigger hole size in the roller link plate, which reduces effective load. Chain with profile bush had an improved life than the existing chain without profile due to reduction in shrinkage of bush and the contact between pin and bush was improved in initial stages due to the profile provided in bush material. In addition, due to caulking of bushes, a small bush projection was obtained over inner links, which helps in reducing lateral movements of links and the chain moves in an almost straight path than swaying sideways. This may reduce chain noise. This is possible in modified chain due to taper profile provided and due to caulking of the bush, which facilitates wax base lubricant to enter easily pin bush clearance, thereby reducing wear of pins and bushes and hence chain elongated.

2.2.2 Mechanical Surface Treatments.

Scholtes et al. [8] studied mechanical surface treatments such as shot peening or deep rolling which are well-known processes to improve the fatigue strength of metallic components. This was due to favorable micro-structural alterations in relatively thin surface layers because of near-surface in homogeneous plastic deformations.

Figure 2. 1 Shot Peened Parts [04]

Typical examples demonstrate the fatigue-strength increase for mechanically surface-treated specimens. In the case of lightweight materials (e.g. magnesium- or aluminum-base alloys), process parameters must be well adapted in individual cases to achieve optimum near-surface material states, taking into account the wide range of mechanical properties attainable as a result of their specific material microstructure. Depth distributions of macro residual and micro residual stresses were analyzed together with micro-structural observations. An important point for the effectiveness of mechanical surface treatments is the stability of the near-surface material states during loading history. This aspect was treated for the case of fatigue loading.

E. Brinksmeier et al.[9] considered the hardness and fatigue strength achieved by strain hardening are normally noticeable lower than those attained by thermal or thermo-chemical heat treatments. Strain or deformation induced martensitic transformation of residual austenite can increase the strength achieved by mechanical surface hardening processes. In this case, study an approach was presented where work pieces with a high content of metastable austenite was used for hardening the surface layer. The microstructure had to be sufficiently stable, in order to ensure that the material can be machined without being changed by strain-induced transformation of the residual austenite. After machining, high contact stresses were introduced by deep rolling, so that a strain induced martensitic transformation of the residual austenite took place. At the same time, deep rolling produces the surface finish of the part. By this method, a surface hardening without a heat treatment process within the production line can be realized. Alternative ways of increasing wear resistance and improving fatigue strength of work pieces was thermal, thermo-chemical and thermo mechanical heat treatments, processes based on pure mechanical strain hardening. Commonly used mechanical processes to improve the fatigue strength are shot peening, deep rolling and hammering and more rarely used water-jet peening, brushing as well as ballizing of bores.

The author concluded alternative surface hardening process, where the strain induced martensitic transformation of metastable austenite was used for surface hardening by deep rolling. The pre-machined and deep rolled surface of an austenitized X210Cr12 (AISI D3) in metastable condition was investigated in terms of distribution of hardness, content of austenite, residual stresses and fatigue tests. These results allow a comparison of deep rolling and shot peening as processed to increasing wear resistance and improving fatigue strength of work pieces. From the presented results it can be concluded, that the hardness achieved by deep rolling can be enlarged extensively by mechanical activated martensitic transformation.

2.2.3 Heat treatment

Edenhofer et al. [10] described the state of the art of process technology, carbon transfer and control of the process, as well as the results achieved on various industrial applications in batch and continuous installations. From this experiment, plane open surface with fresh propane gas reaching it at a sufficient rate, the thermal dissociation effect governs the carbon transfer and the plasma activation cannot contribute to it.

Therefore, it can be concluded that in dense industrial loads components of complex geometry even when plasma carburizing with propane gas or propane gas mixtures, the carbon transfer from the plasma activated methane molecules is the decisive factor for a uniform carburizing effect.

P.F.Stratton et al. [11] concluded that carburizing can now be carried out in a more environmentally friendly way under low pressure. Author enlist range of material types being carburized under vacuum was increasing with an upward trend towards vacuum carburizing, evident in many areas. In choosing a suitable carburizing process, three main choices have to be made: which carburizing technique and gas (or gases) to employ; which type of vacuum pump system to install; and which quenching gas to use. In particular, the selection of carburizing gas has a significant impact on the efficiency and cleanliness of the process, and on deciding the most appropriate vacuum pump system. Author described the current state of the art and practical experiences with Iow-pressure carburizing techniques and examined the various options within these three essential choices. It was also considered that safety and environmental implications of these choices. A great deal of experience had now been gained operating low-pressure carburizing (LPC) systems around the world with various process parameters, different modes of operation and types of vacuum pumping equipments.

Machado et al. [12] showed technological advances in steels heat treatments. The structure and the microstructure of most steels are well known by now as well as the effects of the heat treatments in changing their mechanical properties. For instance, both martensite, obtained during rapid cooling and pearlite, obtained during slow cooling, comes from austenite. Therefore, both the steel microstructure and mechanical properties was related to steel thermal history. The main objective of this preliminary investigation was to verify the effect of the voltage applied, by using a power source, in carbon steel samples during heat treatments. The materials chosen were AISI 1020 and AISI 52100, author also concluded that a great improvement could be reached by applying voltage during heat treatments like : (1) The results showed a great improvement in the Vickers micro hardness by applying a voltage during heat treatments carried out at 750 ^{o}C. The voltage applied tripled the micro hardness in one of the steels studied after the heat treatment. (2)These modifications were also related to the current as well as to the magnitude of the current.

D.C. Lou et al. [13] investigated that strengthening of steel plates using a self-protective diffusion paste was carried out. During the surface strengthening process, a paste containing carbon, boron or similar was applied on the steel surface. In addition to serving as a source for the various diffusion ingredients, the paste protects the steel against contact with the environment, so no packing or gas protection is necessary. Thus, the handling was in general very simple, and the surface strengthening process can be performed in a conventional air furnace. The method provides the same type of surface strengthening that was obtained by more conventional methods. In this work, focus was on surface strengthening by carburizing, but also boronizing and boronizing followed by carburizing were tested out. The methods which was applied to increase the ballistic resistance of the low-strength carbon steel NVE36 (with nominal yield stress of 355 MPa) against impacts from small-arms bullets. An empirical model combining diffusion depth, heat-treatment temperature and soaking time was established on the basis of a series of experimental data. By means of this Paper, the various heat-treatment parameters can be predicted.

Shashkov et al. [14] developed a new method of low-temperature nitriding under conditions of a thermal gas cycle. Saturation cycles of flow nitriding are periodically alternated with desorption of the nitrided layer at maximum possible decrease in the saturating capacity of the atmosphere. A new process parameter, i.e., the length of a half-cycle, was suggested, which makes it possible to control efficiently the phase composition and the structure of the layer in order to obtain the required physical and mechanical characteristics.

Alvarez-Armas[15] pointed out the role of nitrogen in the accommodation of the cyclic deformation in each phase during the low-cycle fatigue of (Duplex Stainless Steels) DSS, and how it affects the cyclic response and micro crack nucleation. In this respect, a clear change of cyclic mechanisms related to plasticity in the ferrite phase appears for the three DSS at S32750, S32205 and S32900 DSS with N content of 0.26%, 0.17% and 0.06%, respectively. According to the (cyclic stress-strain curve) CSS-curves, the strong influence of the alloying element nitrogen on the cyclic behavior was evidenced in the extent of high-plastic strain ranges, The analysis of the flow-stress components at midlife stress amplitudes reveals that the back stress was responsible for the high values of stress amplitudes attained during fatigue. The great affinity of nitrogen atoms for dislocations confines the dislocations to their slip planes, increasing the number of dislocations in pile-ups, with subsequent higher values of back stress on the dislocation sources. Author characterized low-cycle fatigue behavior of high-nitrogen DSS by high values of stress amplitudes, progressive cyclic softening and improved fatigue resistance. Micro cracks nucleate preferentially in the phase where larger plastic-strain concentrations was generated. They determined the austenitic phase at low strain ranges and ferritic phase at higher ranges. The transition strain amplitude increases with nitrogen content.

Dong el. at. [16] concluded that low temperature diffusion treatments with nitrogen and carbon can used to boost the tribological performance of austenitic stainless steels. These processes produce a layer of supersaturated austenite, usually called expanded austenite or S-phase, which exhibits good corrosion and wear resistance. They pointed out novel active screen technology to provide benefits over the conventional DC plasma technology. The improvements result from the reduction in the electric potential applied to the treated components, and the elimination of such defects and processing instabilities as edge effects, hollow cathode effects and arcing. Studied, AISI 316 coupon samples were plasma carburized in DC and active screen plasma furnaces. The respective layers of carbon-expanded austenite was characterized and their tribological performance was studied and compared. Detailed post-test examinations included scanning electron microscope (SEM) observations of the wear tracks and of the wear debris, energy dispersive X-ray (EDX) mapping of the wear track, backscattered electron diffraction (EBSD) camera crystal orientation mapping of the cross sections of the wear tracks, and cross-sectional TEM. Based on the results of wear tests and post-test examinations, the wear mechanisms involved were discussed.

2.3 Summary of Literature Review.

- **Design Related**

Experimental study to prevent the metal from tearing around the opening as the embossed flange was formed was carried out [6]

Determined that wear and tear of bush and pin in derived chain can be reduced by providing angular clearance in the bush [7]

- **Mechanical surface treatment**

Study of mechanical surface treatment by means of shot peening or deep rolling which are well-known processes to improve the fatigue strength of metallic components[8],[9]

Deep rolling produces the surface finish of the part. By this method, a surface hardening without a heat treatment process within the production line can be realized [9]

- **Heat treatment based**

Conclusion was made that plasma carburizing with propane gas or propane gas mixtures, the carbon transfer from the plasma activated methane molecules was the decisive factor for a uniform carburizing effect. Low-pressure carburizing techniques and examines the various options within these three essential choices as given before. [10], [11]

Concluded that a great improvement can be reached by applying voltage during heat treatments. [12]

Effect of surface strengthening of a low carbon steel (NVE36) using a self-protecting diffusion paste was studied at different temperatures and soaking times to improve the ballistic properties [13]

Developed a new method of low-temperature nitriding under conditions of a thermal gas cycle with new process parameter, i.e., the length of a half-cycle, is suggested [14]

2.4 Gaps in Literature review

1. Practicing the embossing to improve the tensile strength of link plate of drive chain is not covered so far.
2. There is no analyses work done so for with design change in ANSYS workbench.
3. Many mathematical models and research work are already done on strengthening of low carbon alloy steels by various heat treatment methods but optimizing conventional tempering process for chain link plate is not covered.

2.5 Objective of the Present Work.

1. Experimental trials with Medium carbon steel for achieving weight reduction (Target at least 15%).
2. Improve the ultimate tensile load that chain can bear by improving material properties with the help of effective heat treatment process.
3. Process qualification for heat treatment and tempering process for the new materials proposed to be used.

2.6 Scope of present work

To produce lightweight chain the present thickness of link plates has to be reduced .The length of bush and riveting pin can be reduced which may affect the tensile load bearing capability of the chain will reduce. However the desired objective is to reduce weight without compromising the performance characteristics of the chain.

For the above task, models were made in Pro-E with different thickness of link plates with and without design change the *.igs file were imported in ANSYS to perform FEA with proper material properties and boundary conditions. On the basis of these analyses a press tool was designed and manufacture to find whether the proposed design will give the same tensile strength on the lesser thickness of link plate or not.

Tempering is another tool, which can be used by altering the temperature and soaking time. The results and conclusions of above task were studied in detail in this thesis

Chapter 3.

METHODOLOGY

3.1 Introduction

The present work was undertaken as part of sponsored project. Sponsored by m/s Rockman Industries to Thapar University, Patiala with an objective to reduce the chain weight. Rockman start its journey in early 60's with manufacturing of bicycle chains and hubs, Rockman, is a leading manufacturer of aluminum die cast parts, machined, painted assemblies and automotive chains for the automobile industry . Today Rockman Industries is producing assemblies which includes highly Critical and safety items like brake drum assemblies, brake panel assemblies, Wheel hub assemblies, crank cases and covers, Locking Bracket, Gear Shift Forks etc. The technology is continuously being improved and has been exported to Germany, France and Italy.

This chapter explains the development of a model along with the assumptions at each step for carrying out simulation. Size of the work piece, material properties, domain discretization, boundary conditions applied on the simulation model and simulation procedure has been discussed.

How the design idea comes to an existence is also explained with its proper press tool design. The change proposed in the tempering process are also discussed.

3.2 Experimental Methodology

As discussed, roller chain is subjected to tensile load, due to which riveting pin will exert force and shear on link plates at the four corners as shown in Figure3.2. So if a anti-mechanical notch is provided in the form of embossed or dimple in these areas then

- Tensile force bearing capacity of link plates is expected to improve.
- The contact area between the outer and inner plate while engaging and disengaging with the sprocket will be reduced and so there will be lesser surface wear.

Following design parameters were considered while creating outer link plate 1.2mm and 1.3mm with embossing at fracture area as shown in Figure 3.2.

1. According to Rockman Industries design reference, the embossing depth should not exceed 0.5mm.
2. Embossing would be such that there should be proper space for riveting.

3. Prevent the metal from tearing around the opening as the embossed flange was formed. During embossing of plates around openings it is a practice to employ male and female die members having a difference in radius equal to the thickness of the plate so that the flange produce would be of the same thickness as the original plate.[7]
4. Inner plate cannot be embossed as sprocket will hit the embossed surface during working of drive chain.

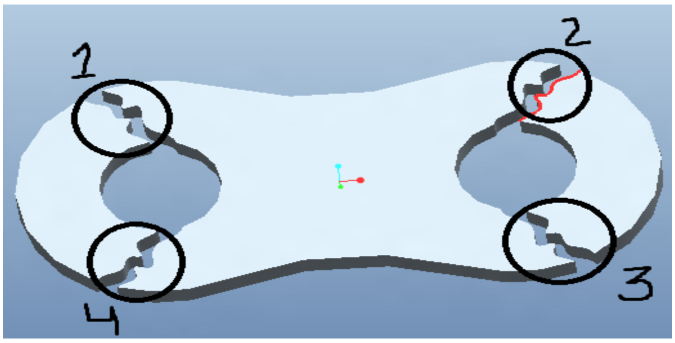


Figure 3. 1 Four area, which are under consideration.

3.2.1 Creating Outer link plate 1.2mm and 1.3mm with embossing

Embossing was provided at four corners using sheet metal-modeling in Pro-E wildfire 5 as shown in Figure 3.2 and the same model was used for calculating coordinates for 2D drafting of single cavity press tool in AutoCAD.

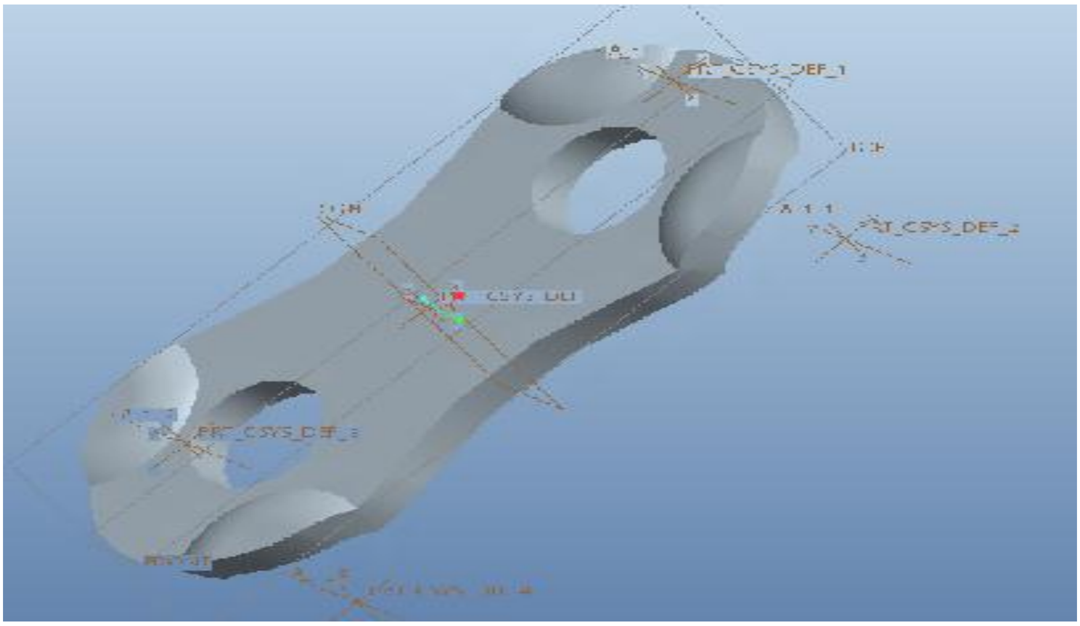


Figure 3. 2 Outer link plate 1.2mm and 1.3mm with embossing

Note: - Embossing was done only on the outer plate and not on the inner plate; the full-plotted design is attached with this thesis in the end.

3.3 CAD Model Generation

Pro-Engineer Wildfire 5.0 and ANSYS Design Modeler was used to create part as well as assembly files of 15-link chain having 1.5mm, 1.2mm and 1.3mm thick inner and outer link plates with and without design change.

The length of Bush, Pin and Roller were to be altered as per the thickness of inner-outer link plates and then assembled to form 15 links chain.

All the parts were then assembled to form a chain of 15 links with assembly module of Pro-E Wild Fire-5 and saved as a assembly file. Similarly, each assembly was formed and saved with and without variable thickness and design change respectively.

The each part file was then saved as *.igs format, to use import feature in ANSYS.

3.4 Finite element analyses (FEA)

ANSYS is a complete FEA software package used by engineers worldwide in virtually all fields of engineering. The *.igs file created by Pro-E wild fire-5 imported in ANSYS workbench to:

1. Create or import the geometry.
2. Mesh all of the contacting bodies.
3. Create the contact pair.
4. Specify the analysis type and solution controls.
5. Apply loads and boundary conditions.
6. Save the database.
7. Solve and review results.

After following the above steps the contact regions for the chain, assembly was created. A model tree after following the given steps is shown in Figure 3.3

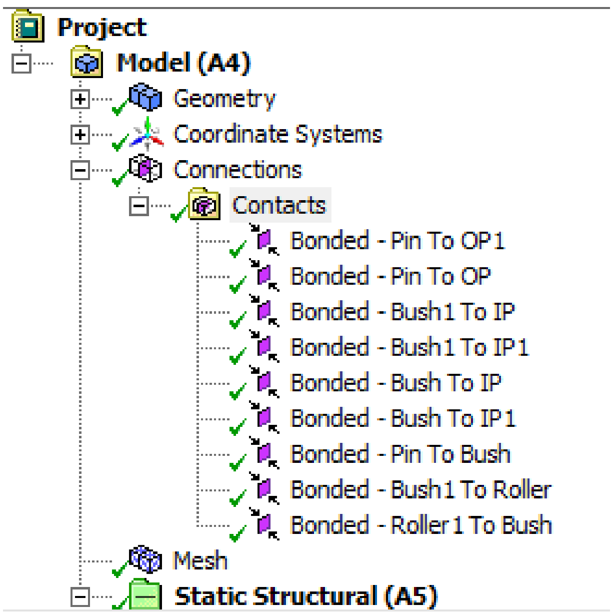


Figure 3. 3 Model tree in ANSYS after following the above said steps.

3.5 Editing the Geometry using Design Modeler

The geometry file created by Pro-Engineer cannot be directly used in ANSYS. To do this the required contact regions has to be created. Trimming of faces was done to make a face, which was used to apply constraints like boundary conditions and contact type. Design Modeler of ANSYS was used for FEA analysis.

3.5.1 Problems with current Geometry

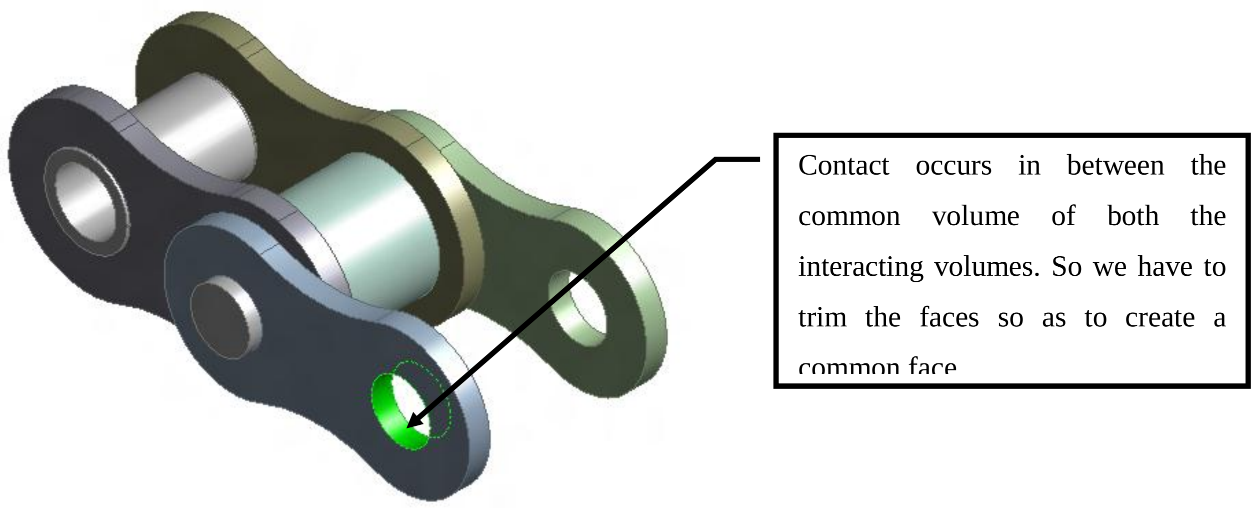


Figure 3. 4: Assembly imported for analysis purpose.

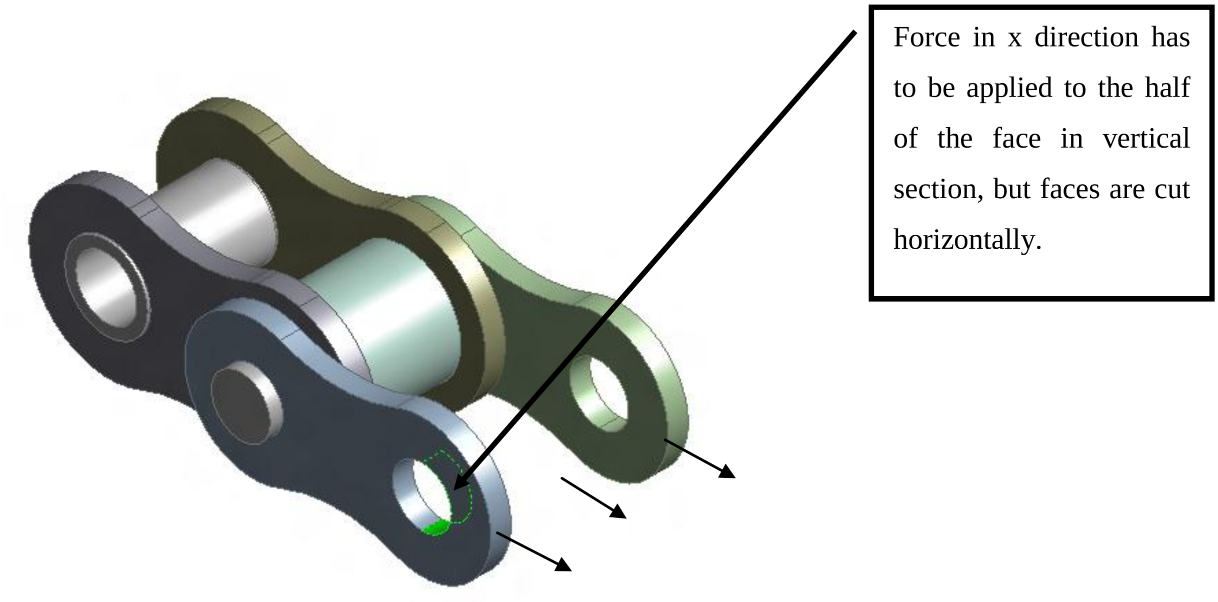


Figure 3. 5: Assembly after cutting faces and applying forces.

Figure 3. 6: Default Contact Region.

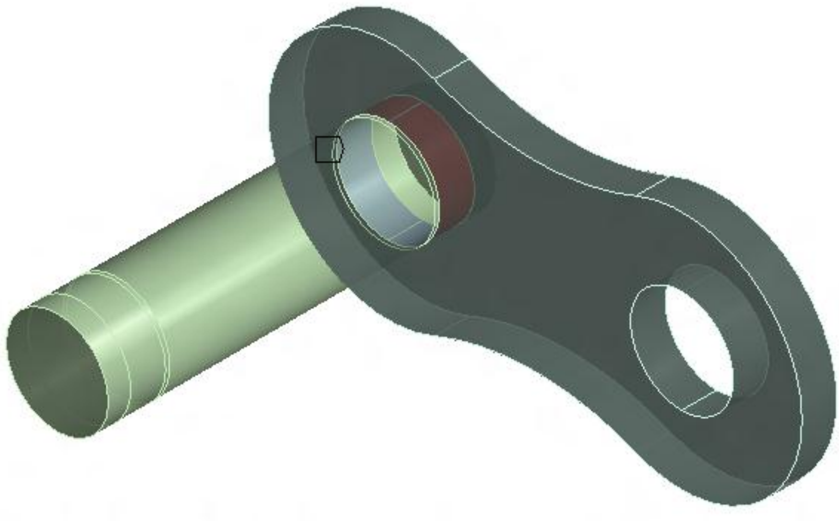


Figure 3. 7: Contact Region after Trimming Faces.

Many such contact faces were trimmed and the final model is shown below.

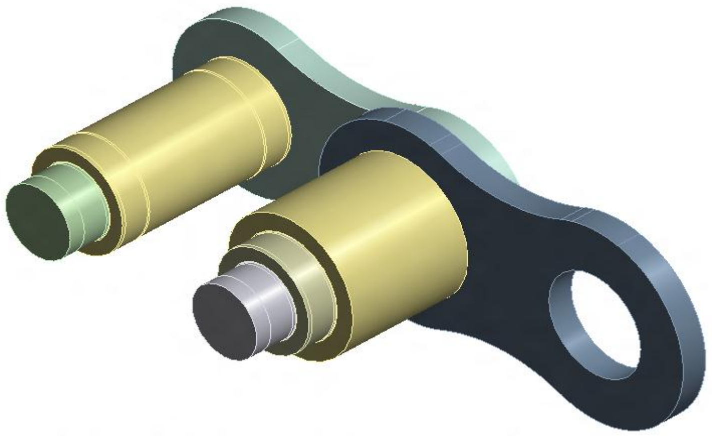


Figure 3. 8: Final Model of Assembly showing Faces Cut.

3.5.2 Generating an Optimum Model.

After checking a particular model for its boundary conditions, connections and mesh type, the results of the model were checked by the standard data available with the organization. After setting the boundary condition and connection types, the only variable remains is the number of links for a practical tensile test. The number of link used in this study varied from 2 to 15 as shown in Figure 3.9.

3.5.3 Generating an Optimum Model with Embossing.

Figure 3. 9: 15 Links chain used for Tensile Testing.

A standard 15 links chain was used for tensile testing on the Ultimate Testing Machine, this would result in analyzing a model made up of 169 bodies for chain with design change and 148 without any design change. While mounting the chain on the test machine, it was observed that the inner plates got gripped on the grippers because of greater face as compared to outer plate.

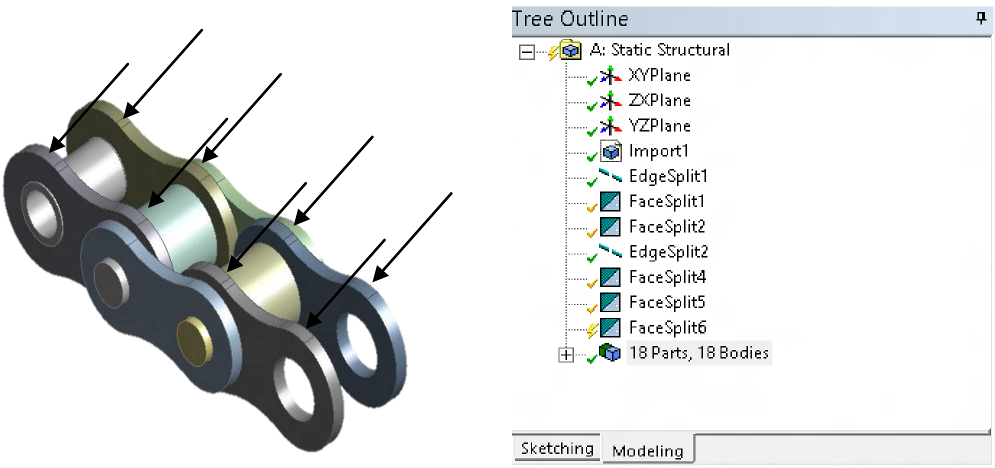
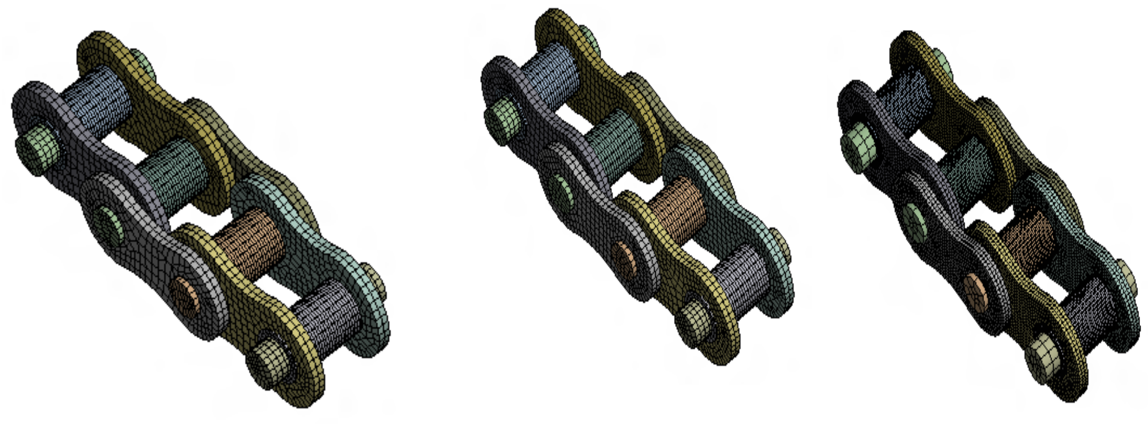


Figure 3. 10 Shows the trim faces of outer link plate where the UTM griper griped the chain both at top and bottom side.

3.5.4 Meshing

A various type of mesh levels are available. Initially, a model with fine mesh was modeled and basic results were calculated a precise result could be obtained based up on the mesh type as shown in Figure 3.11

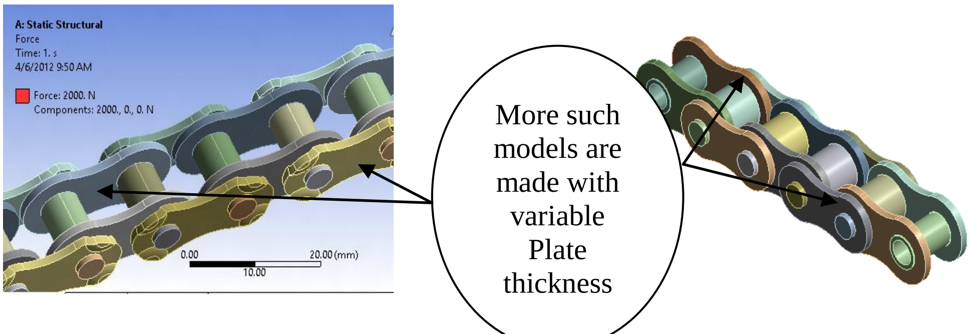


(a) (b) (c)

Figure 3. 11(a) Medium Mesh; (b) Fine Mesh and (c) Course Mesh with Proximity and Curvature

3.5.5 . Simulation using ANSYS

In present work is considering proper boundary conditions, loading and meshing type, each case was solved simultaneously to get the desired results. Model as shown in Figure 4.1(a) and 4.1(b) having bonded contacts in between the inner plate and bush, outer plate and pin. 1.5mm thick plates (existing) were compared with 1.3mm and 1.2mm thick link-plates assembly having embossed outer plate.



(a) (b)

Figure 3. 12. (a) Model with design change (b) model without design change

Figure 3.12 shows the *.igs file prepared in pro-E and imported in ANSYS for further (FEA) finite element analyses.

3.6 Die Design.

Pro-E part file as shown in Figure 3.3 was used to calculate the coordinates for 2D drafting of single cavity press tool in AutoCAD with the help of analysis tool in tool bar of Pro-E Wild Fire-5, this can be done by clicking on measure and choose the desired option in the dragged menu as shown in Figure 3.13

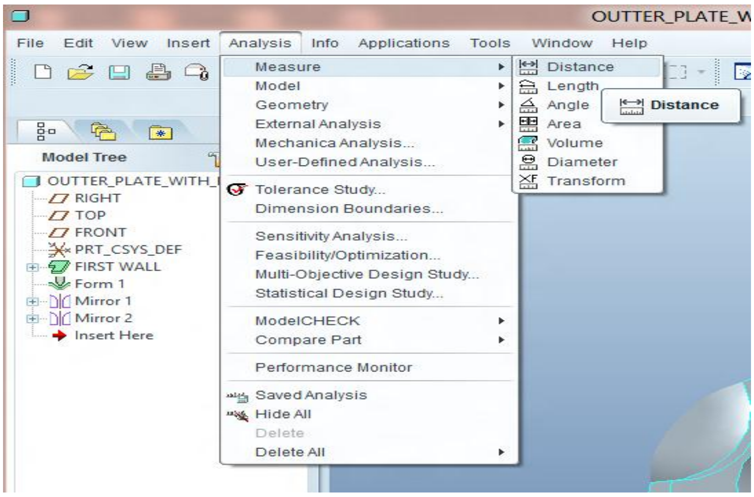


Figure 3. 13 Shows the measuring coordinate for 2D drafting in AutoCAD

Note: - The full-plotted design is attached with this thesis in the end.

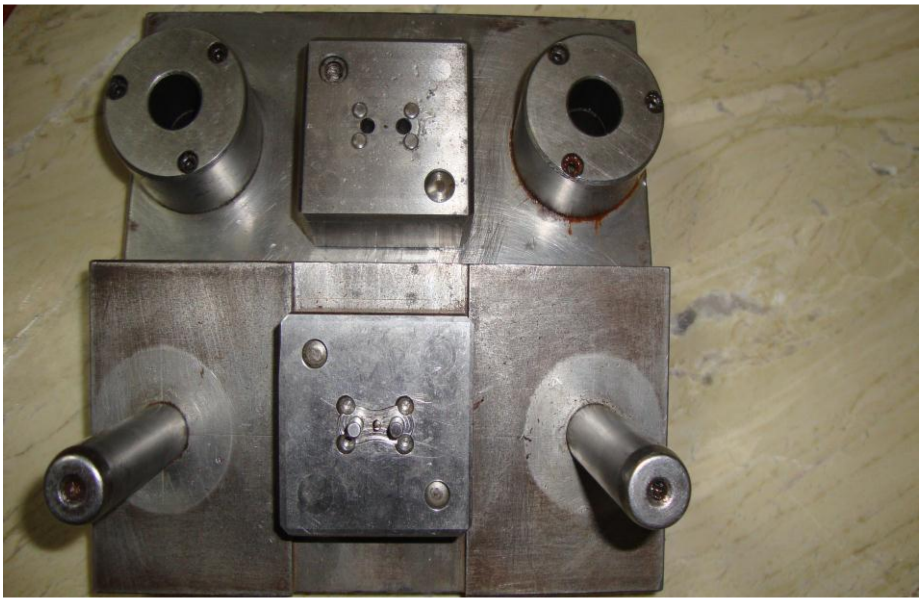


Figure 3. 14 :- Top open view of press tool manufectured at Central Tool Room ,Ludhiana.

3.7 Trials of new Press Tool at CTR, Ludhiana.

After manufacturing the embossing tool, trials were conducted using the tool to confirm the resulting embossed link plates as per the design parameters. Link plates of 1.5mm were ground to reduce its thickness 1.2mm and 1.3 mm each of outer and inner plate with surface grinder as shown in Figure 3.15.

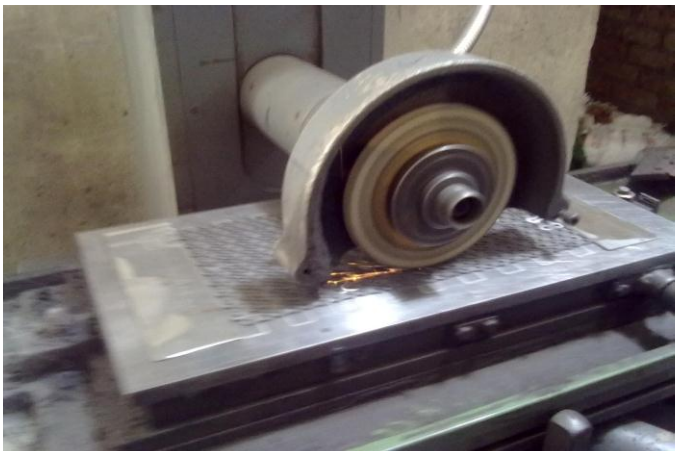


Figure 3. 15 Grinding of inner and outer link plates.

Figure 3. 16 :- Embosed outer link plates of chain after the embosing tool try-out at Central Tool Room, Ludhiana

3.8 Tempering of Inner and outer link plates.

Tempering is a process in which previously hardened or normalized steel is usually heated to a temperature below the lower critical temperature and cooled at a suitable rate. Primarily to increase ductility and toughness. Also to increase the grain size of the matrix. Steels are tempered by reheating after hardening to obtain specific values of mechanical properties and also to relieve quenching stresses and to ensure dimensional stability. Tempering usually follows quenching from above the upper critical temperature; however, tempering is also used to relieve the stresses and reduce the hardness developed during welding and to relieve stresses induced by forming and machining. [06]

Figure 3. 17 Tempering furnace at Rock Man industry, Ludhiana.

Principal Variables that affect the microstructure and the mechanical properties of tempered steel include: [06]

1. Tempering temperature
2. Time at temperature
3. Cooling rate from the tempering temperature
4. Composition of the steel. Including carbon content, alloy content, and residual elements

3.8.1 Why Heat treatment & Tempering of inner and outer plates ?

1. As the thickness of link plate reduced, it is obvious that the UTM breaking load of these plates will decrease as compared to 1.5mm thick plates so for improving the strength improvement was needed in current tempering and heat treatment process acc ordingly
2. Diameter of riveting pin, roller and bush were kept the same but their length was reduced as per plate thickness. So there strength will remain same as cross section area remains un-changed.

3.9 Measuring Equipments used

3.9.1 Rockwell Hardness Tester.

Hardness of link plates of chain to be measured at every stage i.e. after heat treatment and tempering of plates with Rockwell hardness tester as shown in Figure 3.19.

3.9.2 Universal Testing Machine (UTM).

A universal testing machine was used to test the ultimate tensile load chain can bear. The chain both ends are griped between the upper and lower gripers and the tensile load is applied which is displayed on the digital scale as shown in Figure 3.19

3.9.3 Quenching Oil Temperature Dial Gauge.

Quenching of heat-treated link plates are done with considering the Oil temperature maintained in between 50-80C.Dial gauge shown in Figure 3.19

3.9.4 Digital Micrometer

To measure the dimensions of roller chain members' digital micrometer was used.

3.10 Experimental procedure

1. **Grinding of link plates**: - Outer and inner link plates and are grinded to get 1.2mm,1.3mm size from 1.55mm as shown in Figure 3.15
2. **Embossing of link plates: -** Link plates of Chain with variable thickness was embossed with the designed press tool at CTR Ludhiana, which are shown in Figure 3.14.
3. **Heat treatment of Link plates: -** Outer link plates with new design and inner link plates passed through heat treatment in rotary furnace as shown in Figure3.18(b) at 860 °C and then quenched in a oil (22xFQ) which was at kept in between 50-80 °C.

(a) **(b)**

Figure 3. 18 (a) Link plates are coiled in wire to place them in the Furnace so that they do not mix up with the production lot at Rockman Industries Ludhiana **.(b)**Rotary furnace used in company for heat treatment of link plates

Figure 3. 19 Quenching oil temperature 50-80° C, UTM Tester and Rockwell hardness tester respectively used in rock man industries

4. **Testing hardness: -** The Rockwell hardness tester was used at C-scale 150KG load in rock man industries Ludhiana as shown in Figure 3.19
5. **Tempering of link plates: -** Tempered at three different time intervals at variable tempering temperature to achieve different hardness number ranging from 42-52 HRC. Table 3.1 to Table 3.4 shows the experimental trial of first set to forth set.
6. **Again Testing Hardness: -** Tester was used again after tempering at C-scale with 150Kg load in Rockman industries Ludhiana as shown in Figure 3.19
7. **Reducing Length of Bush and Riveting Pin: -**Reduce the length of existing bush and riveting Pin as per 1.2mm and 1.3mm link plates. Then these link plates are assembled with pin ,bush and roller to form a chain.
8. **Checking of ultimate tensile Load: -** Assembled chains with new design change and without design change tested at UTM machine.

3.10.1 Different Conditions for tempering

In 1st set, sets with heat treatment of 1.2mm and 1.3mm with embossing and using two furnaces, rotary and continues belt drive for tempering and at different temperatures and time intervals as shown in Table 3.1 and the following hardness was obtained at each condition.

SET NO.	HRC(1.2MM,1.3MM)with design change	FURNACE USED	TEMPERATURE(° C)	TIME SPENT(Hrs.)
1	50-52	Rotary	260	1
	42-43	Rotary	360	3
	47-48	Continues belt drive	360	1.5

Table 3. 1 Showing result of first set 1

After completing the Set 1 experiments, the second approach was applied based up on the results of set one. Here group of 1.5mm link plate assembly with design change,1.2mm link plates assembly without design change and 1.3mm link plate assembly without design change as shown in Table 3.2 was made and were heat treated using the best results obtained in set 1.

SET NO.	1.5mm with design change	1.2mm without design change	1.3mmwithout design change	FURNACE USED	TEMP.(° C)	TIME SPENT(Hrs.)
2	47-48 (HRC)			Continues belt drive	360	1.5

Table 3. 2 Showing result of set 2

Now by comparing the results of set one with second set, it was observed that it gave us almost the same braking load on UTM. Therefore, it was decide to decrease the tempering temperature from 360°C to 320°C and perform the tempering operation on 1.2mm and 1.3mm link plate assembly without design change as shown in Table 3.3

SET NO.	Without Design Change HRC(1.2mm,1.3mm)	FURNACE USED	TEMP.(°C)	TIME SPENT(Hrs.)
3	46-47	Continues belt drive	320	1.5

Table 3.3 Showing result of third set 3

In above experiment it was noticed that tensile load on UTM was improved but still it did not meet the desired load condition for 1.2mm and 1.3mm thick link plate's assembly.

One more trial of same experiment was carried out but with increase in sheet, thickness of link plates from 1.3mm to 1.4mm and tempered at 320°C on hardened plates as given in Table 3.4.

SET NO.	without design change HRC(1.4mm)	FURNACE USED	TEMPERATURE(°C)	TIME SPENT(Hrs.)
4	46-47	Continues belt drive	320	1.5

Table 3. 4 Showing result of fourth set 4

3.11 Destructive testing of chain with and without embossing

3.11.1 Machine used

A UTM was used to test the ultimate tensile load of the chain at Rockman Industries Ludhiana. Both ends of the chain were griped between the upper and lower gripers and the tensile load was applied which is displayed on the digital scale as shown in Figure 3.19

Figure 3. 20 Showing tested chain at UTM.

3.11.2 Method for measuring tensile strength on UTM

1. Checking the calibration status.
2. Setting up zero reading on the digital scale by pressing the re-set button.
3. Clamp one end of chain in the upper gripper.
4. Adjust the gripers distance as per the requirement of other end of chain which is clamped in the lower gripper.
5. Clamp the lower end too.
6. Apply the tensile load slowly when the digital scale reading cross the 100Kgf load release the lower clamp ensuring no slipping.
7. The digital scale shows the increasing load and when the chain fails, scale will stop the last reading displayed is the braking Load of chain in kgf.

3.11.3 Condition of testing on UTM

1. There must be 15 links in between the upper and lower grippers.
2. The digital scale must show the zero reading while clamping the chain.
3. Minimum passing load will be 1750kgf for 428 roller chain.
4. Kept one end fixed and load is applied on other end.

Chapter 4.

RESULTS & DISCUSSION

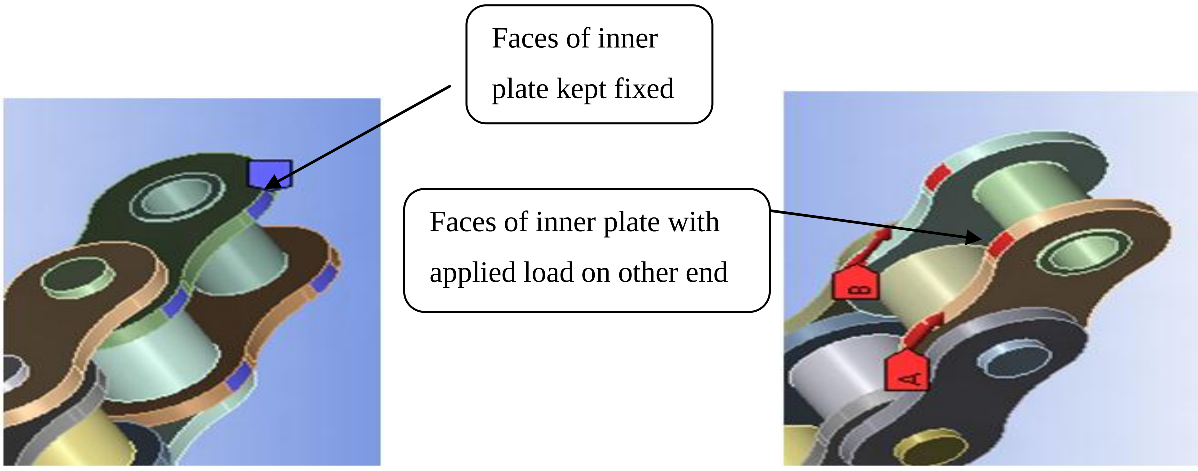
In present work following the simulation methodology and utilizing the boundary conditions as mentioned in detail in Chapter 3, simulation was completed to obtain the following sets of results:

1. Total body Equivalent stress in 1.5mm thick link plate assembly without any design change, 1.3mm thick link plate assembly with design change and 1.2mm thick link plate assembly with design change.
2. Stresses induced in others members' i.e. inner-outer link plates, pin and bush in each assembly of 1.5mm, 1.3mm and 1.2mm with and without design change.

4.1 . Input data

4.1.1 Boundary Condition

While mounting the chain on the test machine, it was observed that the inner plates got gripped on the grippers because of greater face as compared to outer plate, so due to this the inner plates faces where the four corners got gripped were trimmed.



(a) (b)

Figure 4. 1 (a) shows fixed end. (b) Loading end

The force of 2000N was applied on each inner plate summing to a total of 4000N which was applied in two parts namely 'A' and 'B' as shown in Figure 4.1(b)

4.1.2 Material data

While working in ANSYS Work Bench the material data i.e. Young's modulus, Poisson's ratio and tensile strength of respective component of each body in the assembly was provided [21] and were also confirmed as the UTM machine available in the university. The components during subsequent stages were checked in a lab at Ludhiana and based on above, the following material data was collected.

Component	Hardness	Tensile Strength (MPa)	Poisson's Ratio [21]	Young's Modulus (MPa)[21]
Inner Plate	43 (HRc)	1337	0.29	2.00E+05
Outer Plate	43 (HRc)	1337	0.29	2.00E+05
Bush	430 (Hv)	1366	0.29	2.05E+05
Roller	410 (Hv)	1303	0.29	2.00E+05
Pin	455 (Hv)	1444	0.29	2.05E+05

Table 4. 1 Material data

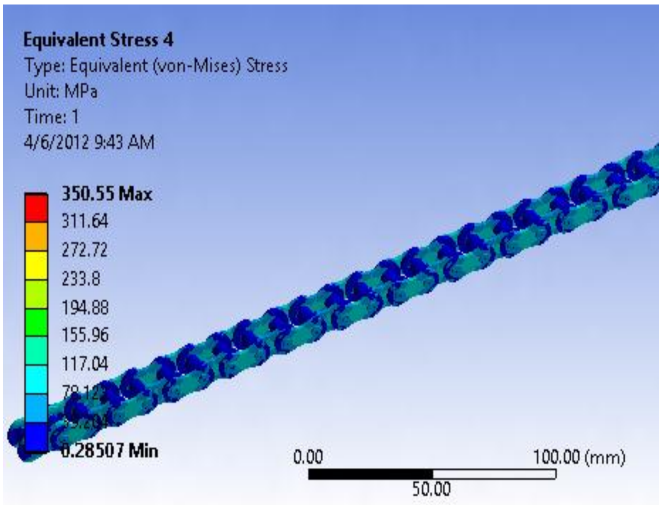


Figure 4.2 Equivalent Body stress 1.3mm thick plates embossed outer plate

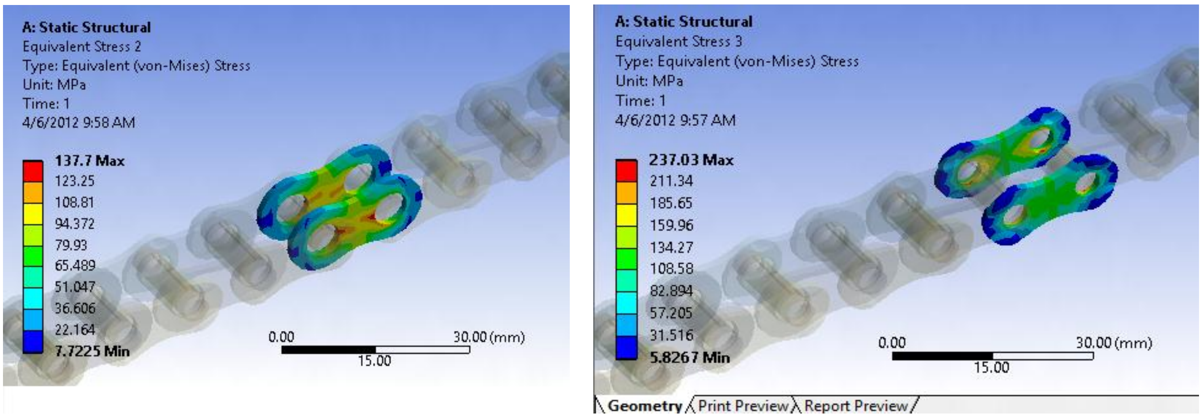
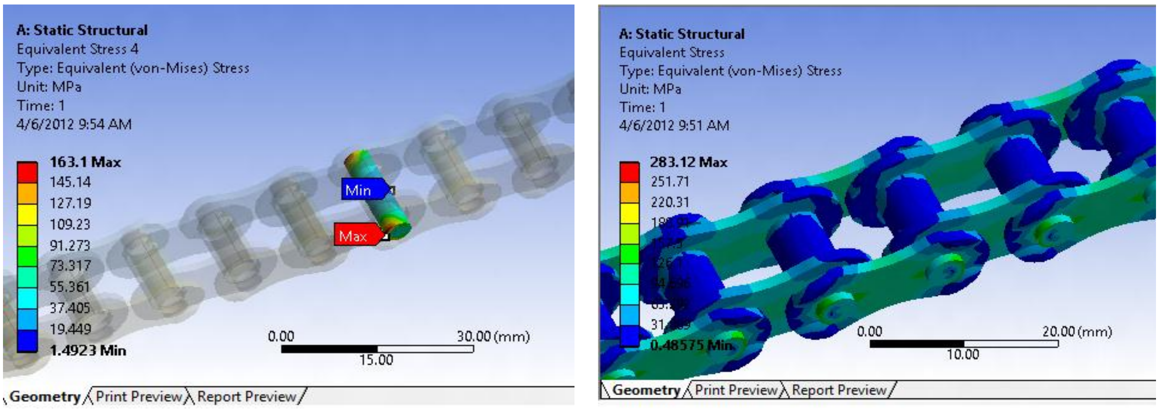
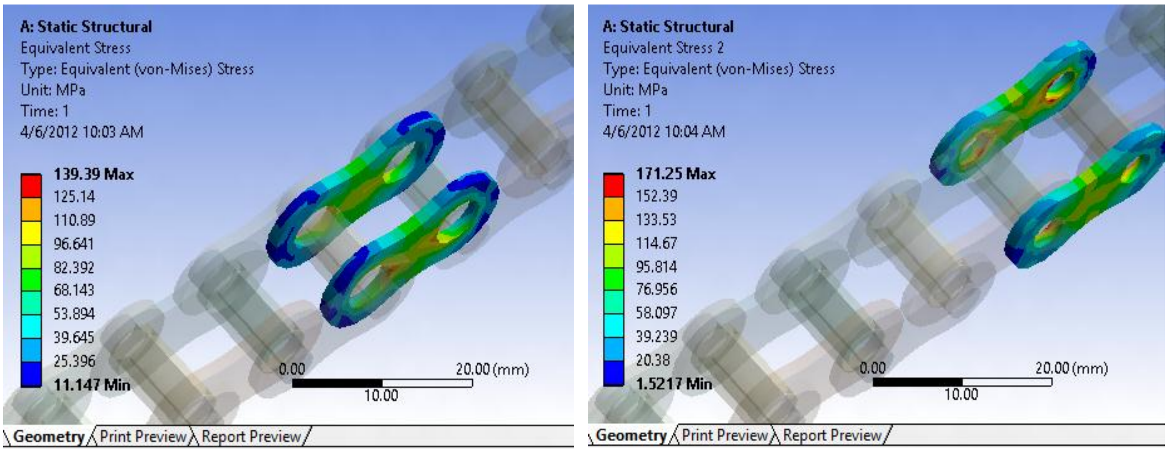


Figure 4. 3 (a) Stress in inner plate 1.3 thick. (b) Stress in outer plate 1.3 thick with design change



(a) (b)

Figure 4. 4 (a) Stress in PIN of 1.3 thick assembly. (b) Equivalent Body stress 1.5 thick plates embossed



(a) (b)

Figure 4. 5(a) Stress in inner plate of 1.5 thick assembly (b) Stress in outer plate 1.5 thick plates

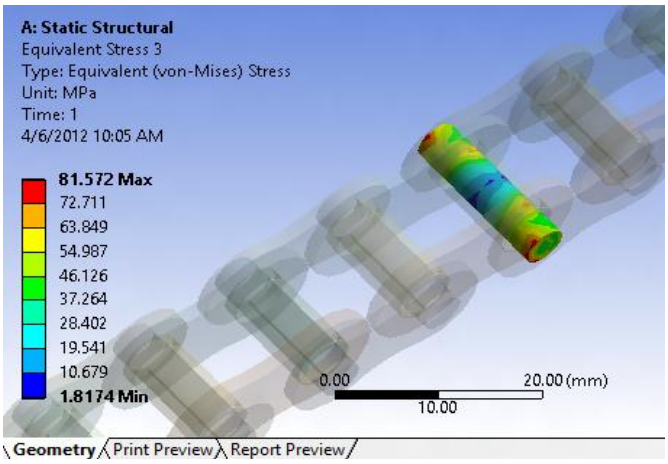


Figure 4. 6 Stress in Pin of 1.5 thick assemblies

4.2 Discussion on Figures.

Inner plate stress in 1.5mm assembly without design change is 139.39Mpa where as in 1.3mm link plate assembly with embossing on outer plate shows us 137.7Mpa and 1.2mm link plate assembly with embossing at outer plate shows us 152.9Mpa. As shown in Figure 4.5(a) and 4.3(a).

Whereas outer plate stress in 1.5mm assembly without design change give us 171.25Mpa,1.3mm link plate assembly with design change give us maximum stress in outer plate is 237.03Mpa and 1.2mm link plate with design change gives us stress of 218.8Mpa. As shown in Figure 4.5(b) and 4.3(b)

According to Table 4.1, it can be seen that 1.5mm thick plate chain provides an equivalent stress of 350Mpa. Whereas total body equivalent stress of 1.3mm and 1.2mm thick plates with design change are 297.78Mpa and 283Mpa respectively. Also shown in Figure 4.4(b) and 4.2.

Pin in 1.5mm assembly of roller chain gives the stress value of 81.57Mpa where as in 1.3mm link plate assembly with design change gives us 163.1Mpa and in 1.2mm assembly the value is much higher than previous two i.e. 167Mpa.as shown in Figure (4.6) and 4.4(a)

1.5mm Thick plate (Existing One)				1.3mm Thick plate (Embossed One)				1.2mm Thick plate (Embossed One)			
S. No	Part name	Stress Max. in Mpa	Stress Min. in Mpa	S. No.	Part name	Stress Max. in Mpa	Stress Min. in Mpa	S. No .	Part name	Stress Max. in Mpa	Stress Min. in Mpa
1	Equivalent stress of body	350	0.28	1	Eqv, stress of body	283	0.48	1	Eqv, stress of body	297.7	0.566
2	Inner plate	139.3	11.14	2	Inner plate	137.7	7.7	2	Inner plate	152.9	6.7
3	Outer plate	171.2	1.5	3	Outer plate	237	5.8	3	Outer plate	218.8	7.3
4	Pin	81.57	1.8	4	Pin	163.1	1.49	4	Pin	167	1.82

Table 4. 2 Comparing the 1.5mm thickness chain link plate’s assembly with 1.3 mm and 1.2mm thickness link plate’s assembly

4.3 Results of above simulations

While comparing the 1.5mm thickness chain link plate’s assembly with 1.3mm thickness link plate’s assembly with embossing at outer plate it was observed that:-

1. Inner link plates of 1.5mm chain without embossing gives us approximately same stress value as for 1.3mm inner link plate with embossing.
2. Stress value for outer link plate of 1.5mm without design change is lesser than that what is achieved with 1.3mm with design change by 65.78Mpa it needs to be checked how much tensile load such chains can bear.
3. Even the cross sectional area will be same as before for the pin as the same diameter pin was used with reduced length. The stress value increased by 81.53Mpa. This means that much more stress is now transferred to pin.

On the basis of above outcomes of simulation exercise, press tool was designed for embossing the outer link plate and trials were completed for the same to see the practical applicability of the observation.

4.4 Destructive testing results with and without design change.

4.4.1 Experiment for Set 1

Results of set 1 on UTM are given in Table 4.3, for different hardness value with different breaking loads of chain. Out of these results, the best one was identified as having maximum breaking load of 1212kgf for 1.2mm and 1504kgf for 1.3mm link plate chains.

SET NO.	HRC(1.2MM,1.3MM) with design change	FURNACE USED	TEMP(°C)	TIME SPENT (Hrs.)	UTM load tested 1.2(kgf)	UTM load tested 1.3(kgf)
1	50-52	Rotary	260	1	750	800
	42-43	Rotary	360	3	1098	1302
	47-48	Continues belt drive	360	1.5	1212	1504

Table 4. 3 Showing result of set 1

4.4.2 Experiment for Set 2

These test were completed to check the design changes gives any improvement or not. One set of 1.2mm and 1.3mm thick, inner and outer plate was prepared without embossing and

SET NO.	HRC of (1.5mm,1.2mm & 1.3mm thick plates)	FURNACE USED	TEMP. (° C)	TIME SPENT(Hrs.)	UTM load tested 1.5 with design change(kgf)	UTM load tested 1.2 without design change(kgf)	UTM load tested 1.3 without design change(kgf)
2	47-48	Continues belt drive	360	1.5	900	1110	1404

Table 4. 4 showing Results of set 2

tempered at 360°C on continues belt drive tempering furnace. The following readings as shown in Table 4.4 were obtained. These observation showed that there is no improvement in the tensile load of both 1.2mm and 1.3mm link plate assembly when compared to results of set 1. 1.5mm inner and outer plate assembly was also made with embossing with same parameters, which failed at 900kgf of load.

4.4.3 Experiment for Set -3

The literature review showed that for 1.5mm thick inner and outer plate manufactured with SAE-1050,the setting temperature for austempering process is 345°C [21] using this result another set was prepares of 1.2mm and 1.3mm inner and outer plates were manufactured and the tempering temperature was reduced from 360°C to 320°C the ultimate tensile load improved from 1110kgf to 1432kgf for 1.2mm & 1404kgf to 1648kgf for 1.3mm. The results are shown in Table 4.5.

SET NO.	HRC (1.2mm,1.3mm)	FURNACE USED	TEMP (° C)	TIME SPENT(Hrs.)	UTM load tested 1.2 without design change	UTM load tested 1.3 without design change
3	46-47	Continues belt drive	320	1.5	1432 and 1404	1650 and 1648

Table 4. 5 shows results of set 3

4.5 Improvement In tensile strength after tempering

4.5.1 Experiment for set -4

The acceptable load for the chain is 1750kgf which could not be achieved with 1.2mmand 1.3mm thick inner and outer plate. Since with 1.3mm inner and outer plate, the tensile load was achieved at 1648kgf, it was proposed to increase the thickness from 1.3mm to 1.4mm in the set. The process of heat treatment followed in this case was similar to one used in set 3 i.e. the parts were heat treated at 860 °C in a rotary induction furnace and then quenched in a oil at 50-80 °C, the parts were subsequently tempered at 320 °C and assembled for tensile load testing. The ultimate tensile load tested with this process was found to be 1860kgf, which is well above the minimum acceptable requirement of 1750kgf as shown in Table 4.6.

SET NO.	HRC(1.4mm)	FURNACE USED	TEMPERING TEMP.(°C)	TIME SPENT(Hrs.)	UTM load tested 1.4 without(kgf)
4	46-47	Continues belt drive	320	1.5	1860

Table 4. 6 showing results of Set 4

4.5.2 Validating results for set number-4

To confirm the results of 1.4mm thick link plates, additional sets of 21 chains was tested on UTM (Universal Testing Machine) with same heat treatment process as followed in set- 4.these chain were tested on UTM and the results are provided in Table 4.7.

SET NO.5	HRC(1.4mm)	FURNACE USED	TEMPERING TEMPERATURE(° C)	TIME SPENT(Hrs.)	UTM load tested 1.4mm without
1	46-47	Continues belt drive	320	1.5	1860
2	46-47	Continues belt drive	320	1.5	1810
3	46-47	Continues belt drive	320	1.5	1896
4	46-47	Continues belt drive	320	1.5	1878
5	46-47	Continues belt drive	320	1.5	1868
6	46-47	Continues belt drive	320	1.5	1985
7	46-47	Continues belt drive	320	1.5	1820
8	46-47	Continues belt drive	320	1.5	1848
9	46-47	Continues belt drive	320	1.5	1875
10	46-47	Continues belt drive	320	1.5	1800
11	46-47	Continues belt drive	320	1.5	1893
12	46-47	Continues belt drive	320	1.5	1798
13	46-47	Continues belt drive	320	1.5	1873
14	46-47	Continues belt drive	320	1.5	1831
15	46-47	Continues belt drive	320	1.5	1966
16	46-47	Continues belt drive	320	1.5	1989
17	46-47	Continues belt drive	320	1.5	1945
18	46-47	Continues belt drive	320	1.5	1886
19	46-47	Continues belt drive	320	1.5	1865
20	46-47	Continues belt drive	320	1.5	1826
21	46-47	Continues belt drive	320	1.5	1779

Table 4. 7 Readings of all the 21 chains of 1.4mm link plate thickness

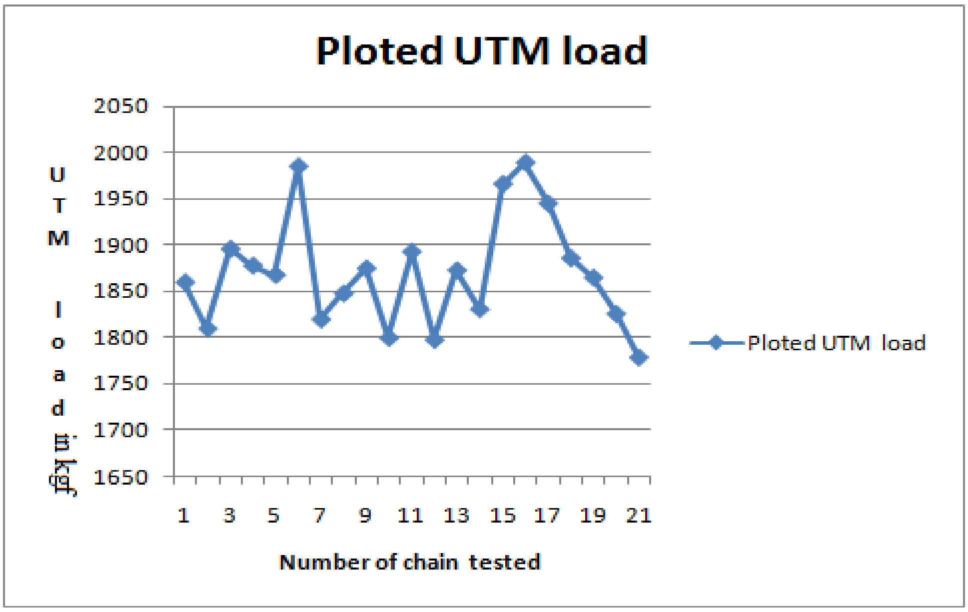


Figure 4. 7 Graph Plotted with reference to Table 4.7

Figure 4.7 clearly shows that all the observation for the 21 chains tested on UTM during this trial exhibited maximum tensile load of > 1750kgf and hence fall into acceptable category. The maximum load achieved during these trials was 1989kgf & the minimum was 1779kgf.

4.8 Discussion and summary

The present work is on power transmission roller chain weight reduction without compromising its strength. For achieving the purposed objective thickness of link plates and length of other members accordingly i.e. Bush, pin and roller were reduced. By doing so, it was natural that the tensile load bearing capacity of 428-roller chain will decrease as compared to existing one.

Various experimental trials were performed with design change as well as without design change with variable thickness of link plates as discussed earlier. Each set was passed through different tempering temperature and on the basis of successive results, it was concluded that 1.5mm thickness of link plates can be reduced to 1.4mm thickness with a valid ultimate tensile load tested on UTM, which was also validated for large sample size.

Chapter 5.

CONCLUSION & SCOPE OF FUTURE WORK

Present work was undertaken to reduce the weight of chain without compromising its strength. Pro-E Wildfire-5 was used to make the desired models as per design change. ANSYS Workbench 12.0 static structural analysis module was used to simulate stress distribution into work material due to tensile load, following the various design parameters like boundary conditions, contact type and mesh type. Different sets of simulations were completed done by varying design parameters like link plate thickness and bush, roller, riveting pin lengths. Various heat treatment and tempering trials were also performed by altering in process parameters like tempering temperature etc. For validation of the optimal process condition. 21 new chain were tested with the new process on UTM for tensile strength.

Based on the results of the present work, following conclusions were drawn :

5.1 Design change

1. Embossing on outer link plate in chain assembly shows that comparatively same ultimate tensile load as achieved without the design change on 1.2mm and 1.3mm chain assembly.
2. It was conclude that this design change just created mechanical anti notch which resists the crack but is not able to stop its progress due to high stress concentration at embossed curved surface area of outer link plate.
3. The proposed emboss on the outer link plate was dumped. Further study may be necessary to improve the design.

5.2 Tempering temperature

1. The process condition for heat treatment and tempering were altered in order to achieve the desired ultimate tensile strength.
2. Trials were made for 1.2mm, 1.3mm & 1.4mm inner and outer link plate chains with modified process conditions.
3. It was concluded that it is not possible to achieve the desired ultimate tensile load with 1.2 & 1.3mm SAE1050 material for inner and outer link plate
4. The maximum ultimate tensile load achieved for 1.2mm and 1.3mm inner and outer link plate was 1432kgf and 1648kgf respectively.
5. It was observed that with 1.4mm of inner and outer link plate chain with modified tempering process, the desired ultimate tensile load of 1750kgf was achievable.

6. The weight reduction achieved due to reduction in thickness from 1.5 to 1.4mm was calculated to be 52.84Gms.
7. Any further weight reduction is not possible until change in raw material or process parameters.
8. It was however, concluded that the parts were reduced in thickness by grinding process which may have adversely affected the material characteristics/strength. A rolled material of 1.4mm or less may provide for batter results.

5.2.1 Future work

1. Effect of mar-tempering on the heat-treated plates can be examined. [9]
2. Future tests may be made with modified work piece material.
3. Endurance and fatigue test of the 1.4mm thickness link plates chain assembly can be carried out on ANSYS to find out its performance in working conditions.
4. Results may be improved by changing the quenching medium or oil grade and its temperature.

Chapter 6.

REFERENCES

[01] Unit-3Power Transmission Devices [Online].http://www.ignou.ac.in/upload/Unit-3-56.pdf .Retrieved 2012

[02] Tsubakimoto Chain Co. The Complete Guide to Chain. [Online]. Retrieved March ,2012 from http://www.chain-guide.com.

[03] R.S Khurmi, (2005).*Machine Design* (pp. 759-775). New Delhi: Eurasia Publishing House (Pvt.) Ltd.

[04]Tsubaki Drive chain Manual[Online].Retrieved 2011from [Online]http://tsubakimoto.com/pdf/product/e_drivechain7.pdf

[05] Stainless-steel-tube.org. (n.d.). *www.stainless-steel-tube.org* Retrieved 2011, from[Online] http://www.stainless-steel-tube.org/steel.htm

[06] Bralla, J. (.-H. (2011). *eFunda, Inc. Diffusion Treatment Hardening*. Retrieved 2011, from[Online] http://www.efunda.com/processes/heat_treat/hardening/diffusion.cfm

[07] Donald W. Sherman, Shorewood .Feb. 11, 1938 United state Patent Office , Patented May 9, (1939)

[08] P Sadagopan, R. R. (2007). wear fatigue analysis of two wheeler trasmission chain. *Journal of Scientific & Industrial Research ,2007*, 912-918.

[09] Scholtes,W.Z. (1998). Mechanical Surface Treatments of Lightweight. *ASM International,Effects on Fatigue Strength and Near-Surface Microstructures 1998,145-151*, 145-151.

[10] E. Brinksmeier, M. G. (2008). Surface hardening by strain induced martensitic transformation. *Prod. Eng. Res. Devel. (2008) ,109–116*, 109-116.

[11] B. Edenhofer, W. G.-Z. (2001). Plasma-carburising a surface heat treatment process for the new century. *Surface and Coatings Technology 142-144 (2001). 225-234*, 225-234.

[12] P. F. Stratton, S. B. (2006). Low-Pressure Carburizing Systems: A Review of Current Technology. *BHM, 151. Jg. (2006), Heft 11*, 451-456.

[13] Machado, I. F. (2006). Technological advances in steels heat treatment. *Journal of Materials Processing Technology 172 (2006) 169–173*, 169-173.

[14] D.C. Lou, J. S. (2009). Surface strengthening using a self-protective diffusion paste and its application for ballistic protection of steel plates. *Materials and Design 30 (2009) 3525–3536,* 3525–3536.

[15] Shashkov, I. S. (2010). Controlled processes of nitriding underconditions. *Metal Science and Heat Treatment May, 2010 42 – 46,,* 42 – 46.

[16] Dong, S. C.(2011).Dry Sliding Wear of Active Screen Plasma Carburised Austenitic Stainless Steel. *Springer Science+Business Media, LLC 2011*.

[17] Alvarez-Armas, I. (2010). Lowcycle fatigue behavior on duplex stainless steels. *Transactions of The Indian Institute of Metals*, 159-165.

[18] Microstructures, N.-S. (2006). Low-Pressure Carburizing Systems. *BHM, 151. Jg. (2006), Heft 11*, 451-456.

[19] Morita and Teruyuki *(June 2005)* Development of High-tensile-strength Stainless Steel Wire

[20] Material Website, complete material reference. [Online]. Retrieved 2012 www.matweb.com

[21] Tempering Processes/Technology *Heat treater's guide*: *practice and procedure for iron and steels*. Copy rights ASM International 1995.