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Roller Chain Link Plate Design Based on FEA

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Abstract— Most of the time conveyor industry uses chain link assembly, the scope of this paper is to find out the areas where we can increase strength of chain, by reducing its stress concentration with reduction in weight. The paper investigates into various manufacturing features for the same. Finally Finite Element Analysis (FEA) has been used to check out the experimental and software outcomes. Later lot of effort has previously been ended in other constituents, in this development the concentration has been tapered down to specific component of chain. Inside the outer link, most dimensions in the manufacturing are parametrically well-defined. In this paper we measure the impact of change in different constraint and manufacturing methods of outer link on the stress in the structure and see if material saving is thinkable or not.

Keywords*- Roller chain, Link plate, FEA analysis, shape optimization, heat treatment.*

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I. INTRODUCTION

The most significant development made in the industrial world is conveyors [4] Conveyor is one types of material handling that existed for over 100 years. By referring to Material Handling Equipment Distributors Association or commonly known as (MHEDA, 2001), since 1795 people already used belt conveyor as a transport of bulk material from one location to another. In the 20th century, conveyors become popular with more tough and versatile. In 1902, steel conveyor belt had been manufactured by Swedish company, Sandvik. Then, around 1908, first pattern of roller conveyor received from a man named Hymle Goddard of the Logan Company. In 1910 pioneered by Henry Ford, he developed an assembly line that consist conveyor to carry the product with mass production in automotive industries. The industrial revolution in process then becomes shines when most of automotive companies began using conveyors in 1919 due to the successes of Henry Ford's innovation in assembly line.

Fig. 1.1: chain link assembly.

Conveyors provide lots of benefit that cannot be undisputed. Imagine that how many times will be wasted if the workers need to walk by holding the item from one location to another location. This situation can be handled by using conveyor to bring the item to the desired location throughout a plant. Furthermore, conveyor can be used to transport the object for a long distance. But, what will happen if the conveyor fails to operate as usual? How about the production for that day if the conveyor suddenly fails to function without giving warning to the company?

This paper only covers FEA Based Design and Study of Chain Link used in Roller Chain because that area is one of the most stressed zones. Besides, this paper will see the system in terms of chain design and operation for improvements.

II. LITERATUREREVIEW

The literature review has been presented on failure analysis of conveyor chain and is still continued. This chapter reviews the significant literature of failure analysis of chain conveyor.

- Tushar D. Bhoite, Prashant M. Pawar & Bhaskar D. Gaikwad in paper "Fea Based Study of Effect of Radial Variation of Outer Link in a Typical Roller Chain Link assembly"[1] has considered a shape optimization process for the design of roller chain link for minimization of failure modes. This process various design variables, such as wall thickness of link, breaking area of link and shape of the link.

Based on the FEA results they have successfully obtained the optimal value of radius. Though this optimization seems insignificant on its own, it must be noted that in a typical industrial application, thousands of such links will be needed. The weight saving thus achieved will have a significant impact on cost of the chain, and more importantly with a lighter chain, the cost savings during operation will also be significant.

- James C. Conwell, G. E. Johnson in paper "Experimental Investigation of Link Tension and Roller-Sprocket Impact in Roller Chain Drives"[2] presents the results from experimental investigation into the dynamic behavior of roller chain drives. A strain gage mounted on a link side plate was used to determine chain tension during normal operation over a wide range of linear chain speeds and preloads. The test machine also included specially instrumented idler sprocket that allowed the measurement of the horizontal and vertical components of the bearing reaction force. The roller-sprocket impact force was then computed by an experimental transfer function approach facilitated by a Bruel & Kjaer 2032 dual channel spectrum analyzer. Observations about the data include- The tension in a chain link increases very rapidly as the link exits the driven

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sprocket. The increase from loose side to tight side average tension occurs over less than two sprocket teeth. The tension in a chain link decreases very rapidly as the link enters the drive sprocket. The decrease from tight side to average loose side tension occurs over less than two sprocket teeth. Impact force tends to increase as chain tension increases, however the relationship is not monotonic. Impact force tends to increase as chain speed increases.

- ‘‘Troubleshooter guide” provided by the Renolds superior technology [3] highlights a series of common failure mode to give insight into the effect of application condition.

- M. D. Jagtap, B. D. Gaikwad, P. M. Pawar, B. P. Ronge(2014)[4] in paper “Use Of Strain Gages To Analyze The Behavior Ofroller Conveyor Chain Strip” focuses on the experimental demonstration of strain gage on chain strip in a Strain Rosette - 45˚ manner. Finally, experimentation is carried out on Computerized Universal testing Machine (UTM).

- NurIsmalinaBintiHaris(2013) [5]in case study“Failure Analysis Of Conveyor Chain Links”at top glove sdn. Bhd**.** focuses onthe causes of failure of chain system through characterization on the failure component. The analysis revealed that the weld defect such as crater leads the crack propagation and added with cyclic loading that cause the fatigue failure. The fatigue failure occurs due to this inherited crack at the outer circumference of the weld within chain attachment and outer chain link plate. This type of defect also can be categories as designing-in defect. Fatigue crack propagation was evident by progressive beach marks and the scanning electron microscopy (SEM) analysis revealed the types of microstructure that resulting at heat affected zone (HAZ). Hardness testing by using Rockwell Tester found the different hardness profile at three areas that are weld metal, base metal and heat affected zone. The maximum hardness values were found at heat affected zone and weld metal.

- P. Sadagopan, R. Rudramoorthy and R. Krishnamurthy (2007)[6] in paper “wear and fatigue analysis of two wheeler transmission chain” focuses on wear reduction of existing chain used in 100cc motorcycles. Elongation of chain is calculated and compared with the field result. In an alternate design developed, theoretical evaluation for elongation is made applying the same conditions used for evaluating the existing chain. Fatigue properties of existing standard chain components are evaluated based on mathematical model as well as by using ANSYS software.

- V. Kerremans1, T. Rolly1, P. De Baets1, J. De Pauw1, J. Sukumaran1 And Y. Perez Delgado1(2011)[7] in paper “Wear Of Conveyor Chains With Polymer Rollers”(2011) focuses on the wear of conveyor chain is available and there are almost no reliable test-rigs to generate and measure chain wear in a reproducible manner. In this research the different components of conveyor chains and the loading conditions are described. Additionally, the applications and disadvantages of chains with polymer rollers are discussed. The chain wear mechanisms found in literature are listed. Abrasive and adhesive wear between pin, bushing, roller and track are discussed. From the contact mechanics of the chain and pressure-velocity limit of the roller materials, the design constraints for the laboratory test-rig were derived. The capabilities and working principles of the developed test-rig are explained in this paper.

- M. Sujata, M.A. Venkataswamy, M.A. Parameswara, S.K. Bhaumik(2005) [8] in paper “Failure Analysis of Conveyor Chain Links” in this paperfocuses on failure of conveyor chain links. It was determined that the failure was caused by defects related to the metal processing. These defects were identified as surface defects in the billet, which got translated into lap or fold like defects in the final products. It was recommended that the billet be properly dressed and the surface defects are removed prior to forging operations. Failure of engineering components due to presence of defects in the material is common. These defects are either present in the material from the casting stage or get developed during subsequent hot working and thermal treatment operations. Identification of the origins of defects is an important task while analyzing failures where preexisting defects in the material are the causative factors. Systematic failure analysis can identify their origin and thereby corrective measures can be initiated to prevent the recurrence of similar defects in the final products.

III. RESEARCH GAP

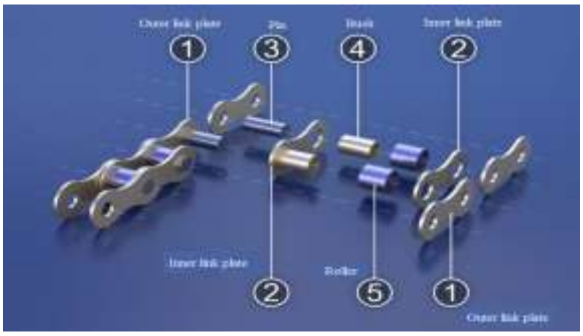

Fig. 3.1: chain link assembly.

In earlier investigation most of the person's has worked on Experimental investigation of link tension and roller-sprocket impact in Roller Chain drives, series of common failure mode, use of Strain Gauges to analyze the Behavior of Roller Conveyor Chain Strip, weld defect and fatigue failure, wear and fatigue analysis of two wheeler transmission chain, defect in chain link of conveyer related to metal processing. Since lot of work has already been done in other components of roller chain, in this paper the focus has been narrowed down to specific component of chain. Within the outer link, most dimensions in the industry are parametrically defined. In this paper we assess the impact of change in different parameter of outer link on the stress and see if material saving is possible.

Following are the ways by which we can increase the strength and reduce the stress concentration-

1) By reducing the uncertainties in manufacturing need to set optimum manufacturing processes.

2) We can make different heat treatment on link plates.

3) By choosing different material like composite for the chain link plate.

4) We can make operations such as chamfering, filleting on the link plate in order to minimize the weight of the link plate

IV. RELATED WORK

Most of the time chain is under tension which causes failure of chain assembly which is the major problem for industrial sector. Causes of this failure are improper design[1]. It is important to study the influence of these parameters. All these parameters can be considered simultaneously and chain link design optimally. Optimization is the process of obtaining the best result under given circumstances in design of system. In optimization process we can find the conditions that give the maximum and minimum value of function.

By considering the above major failure we are going to redesign the outer link plate and checking its possibility by comparing its experimental analysis with software (FEA) analysis.

In this paper a shape optimization process is used for the design of roller chain link for minimization of failure modes. This process various design variables, such as wall thickness of link, breaking area of link and shape of the link. Standard roller chains are defined as pitch proportional, which makes them different from other types of chains with rollers[1]. The ASME standards' nominal dimensions for these chains are approximately proportional to the chain pitch. The pitch of a roller chain is the distance between the centers of adjacent joint members. From the various studies, it can be noted that, even though several patents are filed on roller chains, most of the patents based on improvement of efficiency and performance. Hardly here are very few patents available which focuses on improving life of the chain and minimization of its failure. Very few researchers have explored the fatigue life estimation and stress analysis for the chain assembly. However, literature on uncertainty analysis due to improper shape of roller chain is present. The failure case studies also indicate that the birth of some failure modes is given at the time of designing stage itself.

4.1 LOAD CONSIDERATIONS*:*

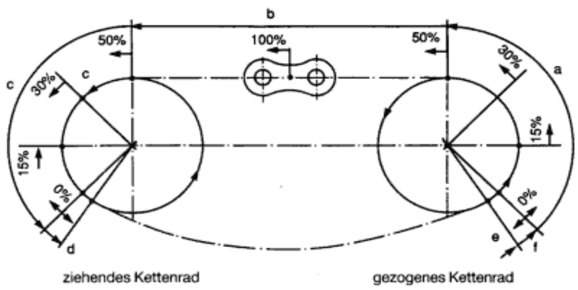

Fig4.1. Distribution of forces in chain system.

4.1.1 Tensile Load (Nominal Tensile Load):

The main consideration for all types of chain is the nominal tensile load that is required to perform the basic function[1]. The nominal tensile load generally fluctuates in a regular cycle. Figure 4.1.1 roughly shows how the tension varies in a chain that is 100 pitches long as it runs around 20-tooth sprockets. This nominal tensile load is the basic load considered in almost all chain ratings.

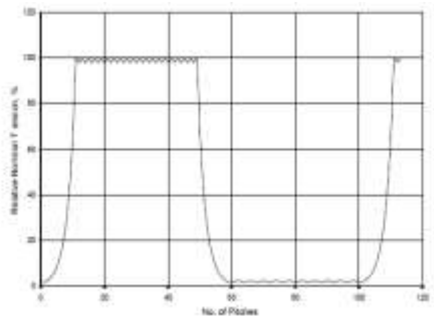

Fig. 4.1.1 : Tension varies in a chain.

4.1.2. Centrifugal Tension:

In high-speed drives, centrifugal force is generated as the chain travels around the sprockets. Centrifugal force also may be generated by the chain's travel over a curved path between sprockets.

4.1.3. Shock Load:

Shock loads are caused by the characteristics of the power source and the driven machinery. They occur repeatedly in a regular cycle, usually one or more times in each shaft revolution.

4.1.4. Vibration:

Chain vibration can cause very large increases in chain tensile loading if the vibration occurs at or near the natural frequency of the chain.

4.1.5. Inertia Load:

As the term is used here, inertia loads are different from shock loads. Inertia loads are the occasional loads imposed on the chain by unusual, and often unexpected, events. They may come from starting a heavily loaded conveyor or a drive with a large flywheel. Or they may be caused by a sudden momentary jam in the driven machine or conveyor.

4.2. Design Considerations:

Roller chains are used in a wide variety of applications, but most roller chain is used in drives. The shaft speeds of the drives range from less than 50 rpm to nearly 10,000 rpm and the amount of power transmitted ranges from a fraction of a horsepower to more than 1000 hp. The main design considerations for a roller chain to be used on a drive are the various tensile loads.

4.2.1 Ultimate Tensile Strength:

The ultimate tensile strength of a chain is the highest load that the chain can withstand in a single application before breaking. It is not a major consideration in designing roller chains. It is only important because yield strength and fatigue strength depend on ultimate tensile strength. Minimum ultimate tensile strength (MUTS) is a requirement in the ASME standards that govern roller chains. A well-made roller chain almost always meets the standard.

4.2.2 Yield Strength:

The yield strength of a chain is the maximum load from which the chain will return to its original state (length). For many

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standard chains, the yield strength is approximately 40% to 60% of the minimum ultimate tensile strength. Figure-4.2 shows a typical load elongation diagram for chain. The figure clearly shows that the yield point for the particular chain shown is at 60% of the ultimate tensile strength. Yield strength is an important consideration in designing roller chains. For standard roller chains, conforming to ASME, the yield strength is about 60% of the MUTS. Figure-4.2.2 is a diagram of how a standard roller chain elongates as a tensile load is applied.

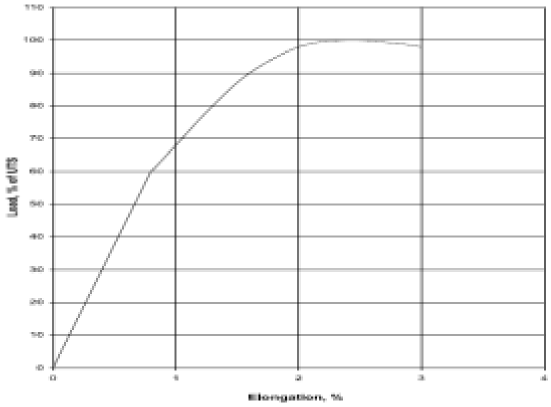

Fig. 4.2.2: Standard roller chain elongates as a tensile load is applied

4.3. Finite Element Analysis (FEA):

FEA modeling consisting of modeling of chain link, preprocessing, processing and post processing in ANSYS Workbench 12.0

4.3.1 Model Description

The model is a link with three cutouts that is created in ANSYS Design Modeler. Boundary conditions are applied as shown below.

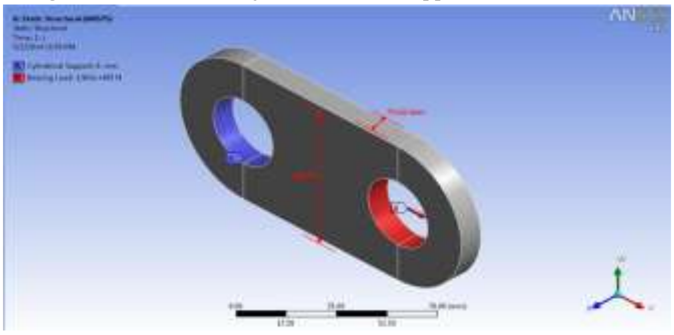

Fig.4.3link with three cutouts

Input Parameters
- Height
- Thickness

Output Parameters
- Mass
- Equivalent Stress
- Total Deformation

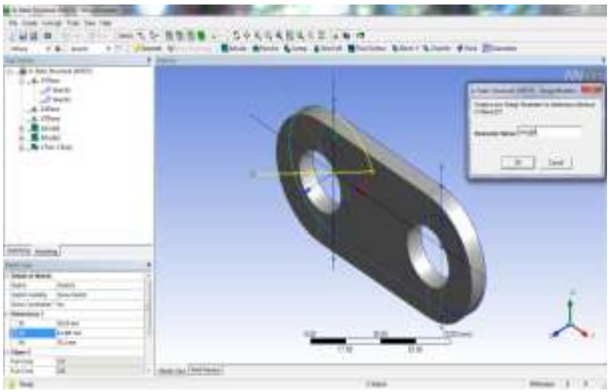

Fig.4.3.1 Defining Input parameter Height for Iteration 1

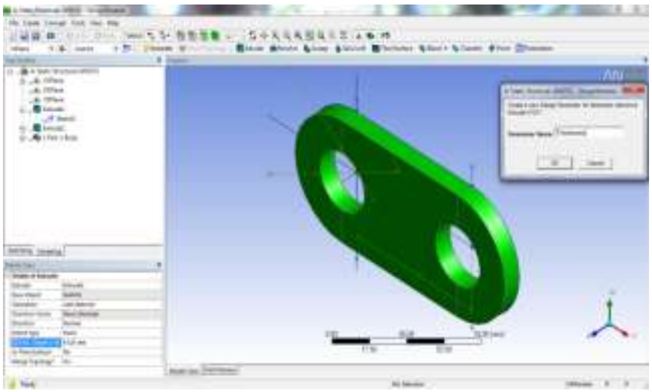

Fig.4.3.2 Defining Input parameter thickness for Iteration 1

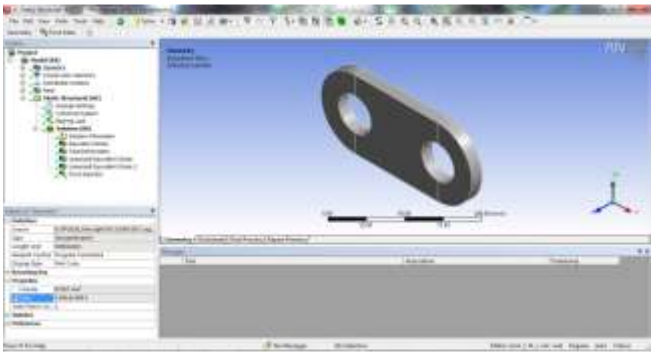

Fig.4.3.3 Defining output parameter geometry mass for Iteration 1

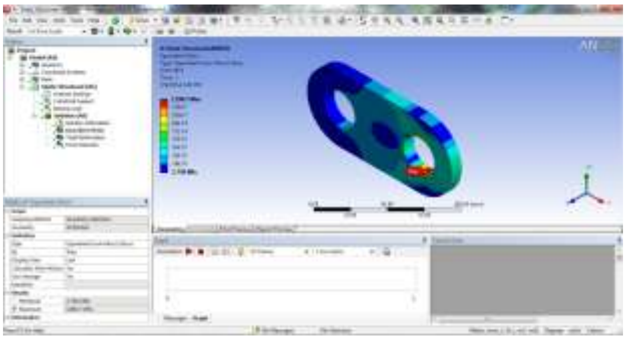

Fig.4.3.4 Equivalent Stress Plot for Iteration 1

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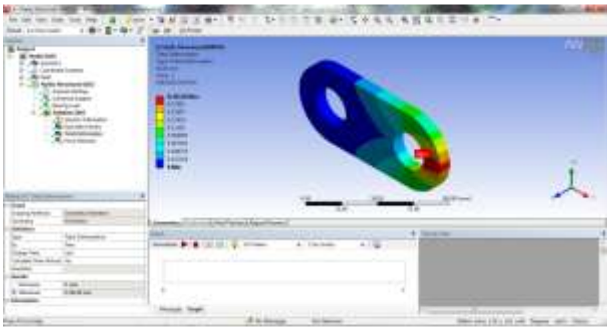

Fig.4.3.5 Displacement Plot for Iteration 1

4.4 Conclusion of 1st iteration

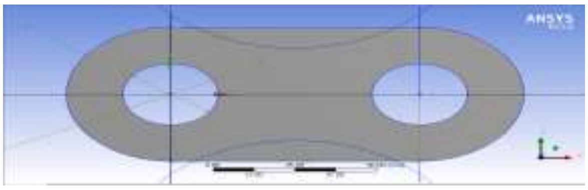

Fig.4.4: Middle height that can be changed

We observed that as per previous changes in base line iteration to iteration 1, we got better weight optimization without change in stress. So here makes good sense for geometry change.

Again we have one approach which shown in above figure to reduce weight of the link plate. We can reduce the middle height of link plate by removing material from outside. We can remove the material in curvature manner so it cannot have directly impact on stress concentration.

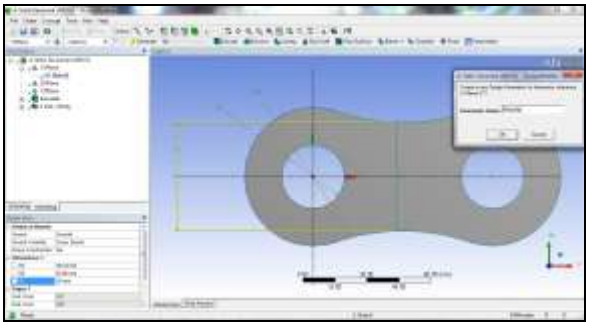

Fig.4.4.1: Middle height that can be changed

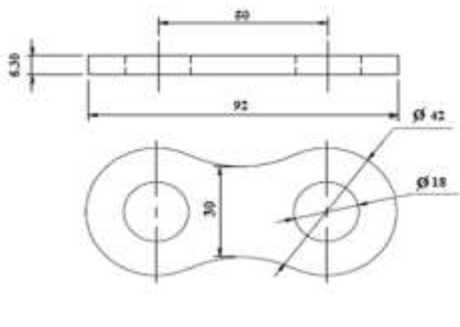

Fig.4.4.2: Shows the 2D CAD model

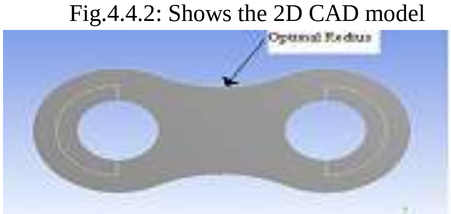

Fig.4.4.3. : Shows the optimizing radial distance

Based on the FEA Experimental results[1], it is observed that the optimal value of radius is between 45mm to 50mm.

V. CONCLUSION

The weight saving will have a major control on cost of the chain, and more principally with a lighter chain, the cost savings during procedure will also be significant. Based on the above literature and methodology used in this paper, it is detected that though this optimization looks minor on its individual, it must be well-known that in a typical industrial application, thousands of such links will be required.

By following way we can also improve the different properties of roller chain link plate, which are as follows-

1) We can make different heat treatment on link plates.

2) By choosing different material like composite for the chain link plate.

3) We can make operations such as chamfering, filleting on the link plate in order to minimize the weight of the link plate

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