A Study on "Design Optimization of Roller Conveyor Chain Link Plate by Using Topological Approach"

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Abstract— According to the relevance towards the state priorities the economy of Maharashtra state is dominated by agricultural as well as industrial sector. Sugar factories play an important role in economy of Maharashtra state. About 60 percent processes in these factories are based on roller chain conveyors. Apart from that, other industries also use these chains frequently for process atomization. However, failure of these chains is perennial problem in these industries which causes huge losses to these industries along with its dependents and in turn economic growth of the state. Material uncertainty plays an important role on formation of elastic and plastic stresses. Breakage of chain is also affected due to faulty manufacturing such as wall thickness of link, breaking area of links, bending movement of pin, inner width of chain and shape of the link and uncertainty in heat treatment. Roller conveyor chains are the critical component in sugar mills, paper mill, food processing, fertilizer industry, pharmaceutical industry, cement industry, foundry industry, heat treatment units, coal mines etc. From the previous studies, it can be noted that, even though several patents are filed on roller chains and conveyors, most of the patents are based on metallurgical investigation, improvement of efficiency and performance of chain. Hardly few patents are there on improving life of the chain and minimization of its failure. From the chain failure case studies it can be noted that the root cause of failure was faulty material processing, heat treatment and improper material selection.

Key words: Roller chain conveyor, Sugar Factory, link plate, FEA, shape optimization

I. INTRODUCTION

Chains have been used for centuries to drive machines and move materials on conveyors. A 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. They have clear advantages over belts in terms of performance and efficiency. Automation and standardization are the two major factors combined to make the roller chain industry what it is today. Roller chains have a long history as mechanical elements for transmission. From a theoretical viewpoint chain is a continuous flexible rack engaging the teeth on a pair of gears. Certainly a sprocket being a toothed wheel, whose teeth are shaped to mesh with a chain, is a form of gear. Based on its history and development, chain is a mechanical belt running over sprockets that can be used to transmit power or convey materials. Most of the time chain is under tension which causes elastic and plastic stresses which results into elongation of chain. Chain is the most important element of the industrial processes required for transmitting power and conveying of materials. As these chains operate under various forces, failure of chain assembly is the major problem. Causes of these failures are improper material selection, uncertainties in manufacturing, faulty manufacturing processes. It is important to study the influence of these parameters on the strength of the chain which governs the failure modes of the chain.

Chains are used in a variety of applications in engineering practice. In general, there are three basic types of system; hoisting and securing chains, conveying and elevating chains and power transmission chains. Conveyors chains are used when material are to be moved frequently between specific points. Depending on the materials to be handled and the move to be performed, a variety of conveyors can be used. Conveyors can be categorized on the basis of the type of product being handled (bulk or unit) and the locations of the conveyor (overhead or floor). Bulk materials such as grain, dry chemicals, ores, minerals, coal saw dust can be conveyed using a chute, belt, and bucket or vibrating conveyors. Unit materials such as castings, machined parts, and materials placed on pallets, cartons or boxes can be conveyed using chute, belt and roller wheel. Depending on the materials to be handled and the move to be performed, a variety of conveyors can be used. Conveyors can be categorized on the basis of the type of product being handled (bulk or unit) and the locations of the conveyor (overhead or floor). Bulk materials such as grain, dry chemicals, ores, minerals, coal saw dust can be conveyed using a chute, belt, and bucket or vibrating conveyors. Conveyor systems are used widespread across a range of industries due to the numerous benefits they provide.

Conveyors are able to safely transport materials from one level to another, which when done by human labour would be strenuous and expensive. They can be installed almost anywhere, and are much safer than using a forklift or other machine to move materials. They can move loads of all shapes, sizes and weights. Also, many have advanced safety features that help prevent accidents. There are a variety of options available for running conveying systems, including the hydraulic, mechanical and fully automated systems, which are equipped to fit individual needs

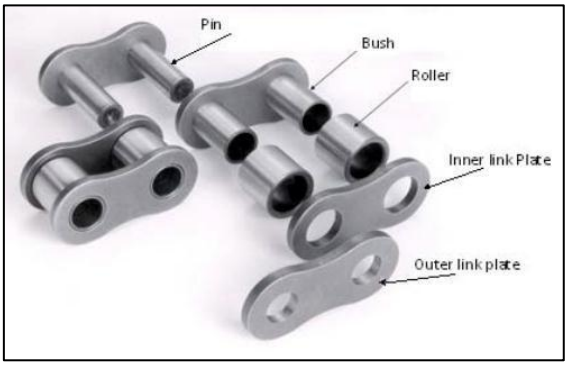


Fig. 1: Shows the typical roller chain link assembly

A. Scope of the Project

In the scope of industrialization, automation is a step beyond mechanization. Conveyor systems can also be entirely mechanized and automated for the transportation of heavier materials and for interaction with automated production lines. There are several of these types of conveyor systems available for a considerable range of applications. Automation in material handling is the use of conveyors, control system and information technologies to optimize productivity in the production of goods and delivery of services. Use of mechanization provides human operators with machinery to assist them with the muscular requirements of work, whereas the bulky and efficient use of conveyor in automation greatly decreases the need for human sensory and mental requirements while increasing load capacity, speed, and repeatability. Therefore, the reduction in cost of conveyor for same capacity will certainly affect today's market scenario.

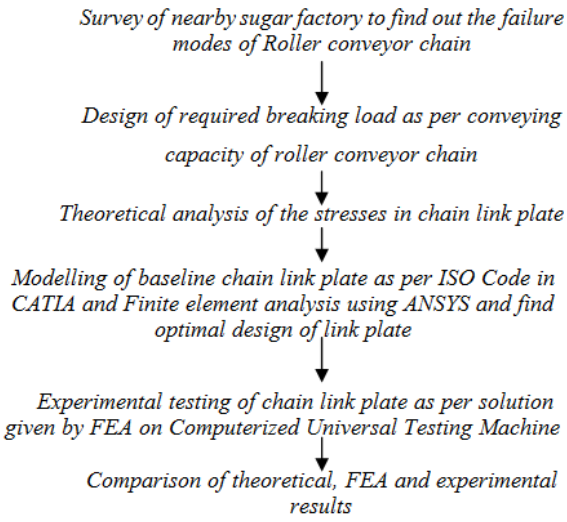
B. Objectives:

The key objectives of current work are as given below:

1) Survey of Roller conveyor chain from nearby sugar factory
2) Theoretical analysis of the stresses in chain link and estimation of required breaking load as per conveying capacity of roller conveyor chain
3) Finite element analysis of stresses in chain link using ANSYS so we got optimum conveyor chain link plate shape.
4) This optimum model from FEA analysis is used for Experimental analysis.
5) Comparison of theoretical, FEA and experimental results

II. METHODOLOGY

After deep study of available literatures it is observed that, effective implementation of optimization can result in high profit of industries. Methodology or Steps involve for optimum design of chain link plate are given below,



III. LITERATURE REVIEW

The literature gives an indication that even though a few researchers have worked on improvement of efficiency and performance of roller conveyor chain, not much amount of work is available for uncertainties in heat treatments and effect of same on the stress strain curve and mechanical properties of chain link plates. Finally, experimentation is carried out on the chain assembly to study the failure of the chain. Furthermore, as lot of work has already been done in other components of chain, my focus has been narrowed down to Finite Element Analysis (FEA) of specific component like chain link plate.

Payet et al., [1] has developed a process and conveyor device for feeding sugar cane in a Mill Train. Various known processes were used in sugar refineries for feeding sugar cane to mills or for conveying the bagses from one mill to the next. The purpose of this invention was to produce a process enabling sugar cane to be conveyed at the required speed in a mill train. Another purpose of this invention was to produce a device enabling very high conveying speeds to be obtained and a regular feed to the three-roller crushing mills. The purpose of the present invention is to impart to the crushed cane a speed independent from that of the mills which can be as high as the user required, by means of a motor independent from the mill endowed with a given power.

Ledvina and Hummel [2] have developed a randomized sprocket for roller chain. A roller Chain and Sprocket drive with a randomized sprocket which modulates the roller position on the sprocket by varying the radial seating position of the roller while maintaining a constant choral dimension between Seated rollers. The roots between teeth of the sprocket had radii that vary between a nominal radius and a maximum radius and a minimum radius. This variation or randomization was intended to provide a noise modulation effect while avoiding the negative effects of high impact from conventional randomized sprockets. Since roller fatigue was one of the prime failure modes of high speed roller chain drives, that problem presented a major obstacle to the adoption of conventional random sprockets for roller chains?

White and Fraboni [3] have demonstrated roller chain sprockets oriented to minimize strand length variation. Numerous methods have been developed to reduce the radiated noise levels generated by the engagement of roller chains with sprockets. One such method modulates the roller engagement by randomizing in a predetermined pattern the radial seating position of the rollers engaging a sprocket while maintaining a constant choral length between the seated rollers on the given sprocket. In a sprocket of that type, the interaction between engagement positions on adjacent sprockets plays a significant role in system geometry and dynamics. Another condition that could arise from changes in strand length was unwanted accelerations and decelerations of the driven shafts.

Moster et al., [4] developed a roller chain link plate profile. Material is added to the profile of the link plates at the location on the link plate where fatigue failure originates. The added material decreases the maximum stress levels effectively making the link plate stronger, which provides for a stronger chain. Although fatigue resistance is increased, the increase in the mass of the link is minimized because only the corners of the link plate were larger than a conventional link plate. The present invention has application in a power transmission system, where an

endless chain is wound between two sprockets. The present invention was directed to providing an improved strength roller chain. Each link plate of the chain has added material on a portion of the link plate in order to reduce the maximum stress levels and the likelihood of fatigue failure. As a result, the chain of the present invention has greater resistance to fatigue failure.

Noguchi et al., [5] investigated a static stress analysis of link plate of roller chain using finite element method and some design proposals for weight saving. Roller chains have a long history as mechanical elements for transmission. Although they had clear advantages over belts in terms of performance and efficiency, but their larger weight has always been a disadvantage. In that study they propose some methods of weight saving for roller chains. These methods were based on finite element method (FEM) analysis of the stress and deformation in a link plate of a roller chain. The authors also suggest some approaches for reducing stresses and weight saving in the link plate of the roller chain. The design proposal for the use of a centrally located hole in a link plate has a beneficial effect on weight saving and yields a negligible stress. Although chamfering the circumference of the link plate edge can be effective in weight saving, it is clarified that the stress increases when the circumference becomes irritated. In the link plate with a centrally located hole with the chamfering of the circumference edge, the stress increases by almost 3%. However, 10% weight saving can be realized and the design proposal is expected to be effective.

Sujata et al., [6] discovered a failure analysis of conveyor chain links. Failure of engineering components due to presence of defects in the material was common. These defects were 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 was an important task while analysing failures where pre existing defects in the material were 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. A case study on failure of conveyor chain links was presented in that paper. 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.

Bhoite et al., [7] studied FEA based effect of radial variation of outer link in a typical roller chain link assembly. Chain Link assembly is extensively used in the industry; they review the applications in the industry and explore the design considerations that go into the design of the assembly. They summarized various design variables, such as wall thickness of link, breaking area of link and shape of the link to formulate an idea of the system. While deciding the shape optimization of roller chain link raw material plays important role, so it was necessary to decide raw material. Normally medium alloy steel i.e. as per Indian Standard C45, 55C8 or as per British Standard EN8, EN9 has been used in normalized condition and after manufacturing of link it has been heat treated up to 35 to 40 HRC in order to get tensile strength up to 70 to 80 kg mm^2. Finally Finite Element Analysis (FEA) has been used to conduct shape optimization of outer link. They assess the impact of this radius on the stress in the system and saw material saving and consequently efficiency increment was possible. The weight saving thus achieved has a significant impact on cost of the chain, and more importantly with a lighter chain, the cost savings during operation was also be significant.

Sapate and Didolkar [8] discovered metallurgical investigation of failure of coal mill drag chain pin. They done metallurgical investigation of fractured connecting pins of drag chain conveyors used for coal conveying from raw coal hopper to grave gate in coal mill of a cement plant. The failure analysis of two fractured pins was carried out; the location of the fracture was near the end of the pins. Both the failed pins had reduced cross section in the immediate vicinity of the fractured surface. The chemical composition of the pins confirmed to En-19 specifications. The hardness and metallographic studies indicated that the pins were induction hardened at the surface whereas the core of the pins had tempered martensite microstructure. The visual observations of the failed pins confirmed entrapment of fine to heavy coarse coal particles on the pin surface causing mild to severe polishing wear with subsequent reduction in the cross section. The metallographic studies showed non-uniformity in the induction hardening and undesirable coarse martensite microstructure at the core. The proper induction hardening to ensure required case depth and use of En-24 steel for connecting pins has been suggested to further improve life of the connecting pins.

Hodlewsky [9] discovered a conveyor chain formed of a plurality of chain modules wherein the modules are constructed such that hinge pins are easily inserted between modules and the hinge pins are securely held in place without forming heads on the hinge pin after insertion. One of the advantages of the modular chain assembly embodying the invention was that when the conveyor chain was under tension the hinge pins joining the modules were in a position out of alignment with the hole in the module link at the edge of the conveyor. This prevents movement of the hinge pin out of the joint. The provision of elongated slots for housing the hinge pins also facilitates cleaning of the conveyor chain assembly because the slots permit entry of cleaning solution into the joint area and around the hinge pin.

Seymour T et al., [10] developed the combination of a chain and sprocket drive that allowing for reduced wear and higher speeds. This was an especially useful combination in large pitch chains and sprockets that work in abrasive environments with reduced lubrication. One such use of a chain and sprocket was in the bucket elevator portion of a continuous ship unloaded where buckets were connected to a chain and used to elevate bulk cargo such as grain from the hold of a ship. It was very important for the chain of the bucket elevator to be circulated as fast as possible since large heavy loads were undesirable. The advantages of the invention was to provide the combination of a sprocket that had cam manipulated teeth with a chain that had spring loaded hinge joints that resist hinging.

Bauman [11] invented master link for transmission chains of various types were not only widely used in

industrial apparatus for many applications, but also were commonly used on bicycles and other human or mechanically powered vehicles to transfer drive power. Frequent removal of the transmission chain from the apparatus or bicycle was desirable to allow for lubrication and cleaning of the chain, especially when operated in dusty or dirty environments. The roller elements of most transmission chains were joined by riveted links, and a master link was typically provided to enable joined the ends of the chain. This master link invented to provide a novel transmission chain which was easily connected and disconnected for lubrication and cleaning. Another objective was to provide such a transmission chain having threaded fasteners which was releasable locked in assembly to avoid inadvertently disengagement.

Pantazopoulos and Vazdirvanidis [12] discovered metallurgical investigation on fatigue failure of stainless steel chain in a continuous casting machine. They used stainless steels strips (chains) for the connection of dam blocks in belt casting machines. Thermal cycling and repetitive stressing under complex loading conditions due to tension and bending were the most frequent function modes during production. Failure analysis findings suggest strongly that the failure was caused by bending fatigue which assisted also by thermal cycling, initiated from the strip surface and followed by ductile final overload fracture. Further detailed investigation and review of the actual operation conditions was recommended to be conducted for future process improvements

C.R.F. Azevedo et al., [13] studied em-brittlement of case hardened steel chain link. They observed various steel chain links cracking during their manufacturing process, which includes induction case hardening and electro galvanizing steps. They discovered results indicated that inter granular cracking was caused by hydrogen em-brittlement. The intergranular cracking of the link was caused by hydrogen stress cracking. The results indicated that the case hardening process did not take into account the smaller ‘‘thermal mass" next to the larger bore, causing localized overheating during the austenitisation. They reviewed both case hardening and dehydrogenation treatments in order to avoid further failures.

Michael O. Ross and Kurt M. Marshek [14] developed a machine for testing and comparing chains and sprockets of various geometries and materials comprising four sprockets and two chains and having a pneumatic cylinder for loading one chain against another. This invention relates to new and useful improvements in machines for testing and comparing chain and sprocket geometries, materials, and lubricants. Moreover, the invention relates to a machine for testing and comparing not only chains and sprockets but also timing belts and timing belt pulleys of various materials and geometries. The present invention generally related to the field of chain wear measurement or chain and sprocket fatigue testing and in particular to a method and apparatus for determining the power capacity of a chain and sprocket drive system for a given life.

IV. CONCLUSIONS

While studying available literatures it is found that, FEA can be very effective tool for analyzing the system of chain link, time required by FEA for determination of stresses is very less, cost involve is low. Effective analysis methodology can save lots of efforts of industries using roller chain as it will improve working life cycle of the whole unit involving chain conveyor. 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.

REFERENCES

[1] Payet P., Combuston, Reunion, "Process and Conveyor Device for Feeding Sugar Cane in a Mill Train", U. S. Patent, (1964), 3,120,173.
[2] Ledvina T., Hummel J., "Randomized Sprocket for Roller Chain", European Patent, (2002), EP0907041.
[3] White D., Fraboni H., "Roller Chain Sprockets Oriented to Minimize Strand Length Variation", United States Patent, (2001), 6213905.
[4] Moster A., Ledvina T., "Roller Chain Link Plate Profile", European Patent, (2003), EP0833078.
[5] Noguchi S, Nagasaki K., Nakayama S., Kanada T., Nishino T., Ohtani T., "Static Stress Analysis of Link Plate of Roller Chain Using Finite Element Method and Some Design Proposals for Weight Saving", Journal of Advanced Mechanical Design, Systems, and Manufacturing, (2009), Vol. 3, No. 2.
[6] Sujata M., Venkataswamy M., Parameswara M., Bhaumik S., "Failure Analysis of Conveyor Chain Links", Engineering Failure Analysis, (2006), 13(6).
[7] Tushar D. Bhoite, Prashant M. Pawar and Bhaskar D. Gaikwad, "FEA Based Study of Effect of Radial Variation of Outer Link in A Typical Roller Chain Link assembly", International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No. 2231-6477,Vol-1, Issue-4, 2012
[8] Sapate S. G. and Didolkar V. K., "Metallurgical Investigation of Failure of Coal Mill Drag Chain Pin", Materials and Design, 30(7) 2623-2629, 2009.
[9] Willlam G Hodlewsky., "Conveyor chain assembly", U. S. Patent, (1988), 4,858,753.
[10] Timothy H. Seymour., "Chain and sprocket combination", U. S. Patent, (1991), 5,127,848.
[11] Robert C. Bauman, "Transmission Chain with radial engage able connecting pin and sprocket combination", U. S. Patent, (1993), 5,376,355.
[12] George Pantazopoulos, Athanasios Vazdirvanidas, "Metallurgical Investigation on fatigue failure of stainless steel chain in continues casting machine", Engineering Failure Analysis, 16(5) 1623-1630, 2009.
[13] C.R.F Azevedo, D. Magarotto. A. P. Tschiptschin, "Embrittlement of case hardened steel chain link", Engineering Failure Analysis, 16(5) 2311-2317.
[14] Michael O. Ross and Kurt M. Marshek, "Machine for testing chain and sprocket type drive system", U. S. Patent, (1981), 4,413,513.

