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A Review of Failure analysis found in Industrial Roller Chains

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Abstract: The basic aim of this review has been conducted on the most of the chain that is under tension which causes failure of chain assembly which is a major trouble for the industrial sector. This review paper describes the universal failure modes of chain in various engineering applications. The existing studies in the field are examined to ascertain the trends of research in the field and to identify unsolved problems. In this study, the distinction of roller chain from the leaf and conveyor chains are highlighted and the novel perspectives that are necessary for the analysis of the chain plate and bearing pin of the roller chains in particular are recommended.
Key words: Link plates; rollers; fatigue; fractography.

Introduction:

Chains are used in different applications in the engineering field. Most commonly used chains in industry are roller chains, leaf chains and conveyor chains. Roller and conveyor chains are usually used in manufacturing, automotive and agricultural industries objects require to be conveyed. Leaf chains are used for lifting purpose applications. Based on many developments, the chain is a mechanical link product running over sprockets that can be used to transmit power or conveying objects. Chains are operating under tensile cyclic load condition. The failure of a chain assembly is the most important problem in industry applications which causes failures that are of unacceptable material selection, heat treatment causing other uncertainties in the manufacturing process. The roller conveyor chains are commonly used to transport goods in production lines or assembly lines, such as pallets, automobiles or drill rig applications. They are occasionally used in dusty environments, soiled with water, foreign particles, chemicals or other contaminants. The typical use will result in wearing down of the components of the chain which can lead to unexpected failure and expensive production downtime.

Literature Review

The literature review on hand is based on failure analysis of roller chain and is a continuous process. This chapter reviews the major literature of failure analysis of a chain conveyor.

Sujata et al., (2006) have presented a case study that has a focus on failure of conveyor chain links. It is resolute that the failure was caused by defects related to the metal processing. These defects were known as surface defects in the billet which translate into a lap or fold-like defect in the final products. It is optional that the billet is to be properly dressed and the surface defects are removed prior to forging operations. Figure 1 illustrates the visual examination exposed to a shallow crack on the surface of the link.

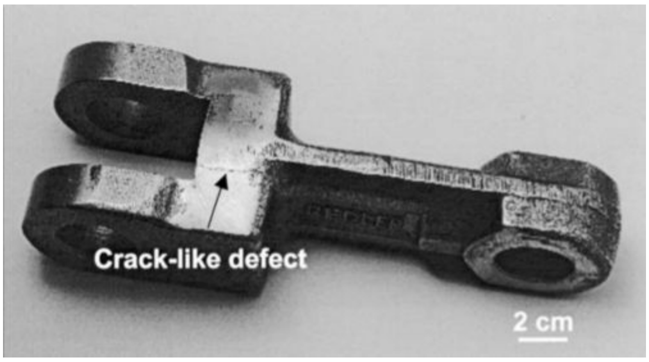

Fig.1. Photograph viewing a crack-like surface defect on a finished chain link

The failure of engineering components due to presence of defects in the material is common. These defects or whichever is present in the material from the casting stage get developed during a heated environment in progress and thermal treatment operation. Classification of the origins of defects is an important undertaking while analyzing failures where pre-existing 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 components. The chain links are forged parts made of 18MnCrB5 steel. The dealing out includes an upset forging from a bar stock followed by close die forging. The conveyor chain links have proved to be unsuccessful due to the presence of defects. The defects were known as forging laps or folds [1].

Sapate and Didolkar (2009) have reported a metallurgical study of fractured connecting pins of drag chain conveyors used for coal passing on from raw coal hopper to grave gate in a coal mill of a cement plant. Figure 2 shows the failure analysis of two fractured bearing pins of the report.

Fig. 2. Photograph of failed bearing pin 1 and pin 2. The fractured surface of the bearing pin 1 and pin 2 (lock end) is at the left of the figure.

From the results, it is found that the location of the fracture was near the end of the pins. Over here both the unsuccessful pins had been reduced to a cross section in the direct vicinity of the fractured surface. The chemical composition of the pin is definite to En-19 specifications. The hardness and metallographic studies indicate that the pins were induction-hardened at the exterior areas, whereas the core of the pins had tempered martensitic microstructure. The visual remarks of the failed pins establish an entrapment of fine to heavy coarse coal particles on the pin outside causing mild to severe polishing wear shown with following drop in the cross section. The metallographic studies show a non-equality in the induction hardening and unwanted coarse martensitic microstructure at the central part. The analysis of the fractured surface and fractographic study by SEM indicated fatigue fracture due to bending stresses and mild to reasonable torsion stresses. The proper induction hardening is shown to make a sure required case depth and use of En-24 steel for connecting pins that have been optional to further improve life of the connecting bearing pins [2].

Azevedo et al., (2009) have shown the various steel chain links obtained crack during their industrialized process, which include induction a case hardening and electro galvanizing actions. Fractographic test of the exposed crack surfaces, shown an intergranular cracking with some areas featuring a thin film of iron oxide, representing that the crack take place after the electro galvanizing action. The places of the cracks coincide with the position of the deepest case hardened film, suggestive of the occurrence of restricted overheating during the induction case hardening step. Inductive heating finite element analysis (COSMOS Design star Software) established show that during the case hardening that the austenitising temperature achieved in the crack region principles is of approximately 1050 °C. The outcome indicates that intergranular cracking was caused by hydrogen embrittlement [3].

Pantazopoulos and Vazdirvanidis (2009) have investigated fatigue failure of stainless steel chain in a continuous casting machine**.** In that, the stainless steels strips (chains) are used for the association of dam blocks in belt casting machines. The thermal cycling and cyclical stressing under difficult loading conditions due to tension and twisting are the most frequent utility modes during production. Fractured stainless steel strips samples that are used for the connection of dam blocks in a copper rod continuous casting line, were sent for an examination which showed that the optical and scanning electron microscopy for structural and fractographic valuation along with mechanical testing being used as the most important analytical techniques in the situation of the present examination for the sample as shown in Figure 3.

Fig.3. Macrograph of the failed stainless steel chain samples.

The failure analysis conclusions strongly suggest that the failure is caused by bending fatigue which is assisted by thermal cycling initiated from the strip plane and followed by ductile ending the overload fracture. The ending fracture which occurs via ductile failure (where the left over strip which is in a cross sectional area reaches a critical size) becomes incapable to sustain the operating load. The findings from the review of the service history (operating situations, e.g. process design, applied loads, thermal cycles), in arrangement to the examination of a potential substitution of the material to a extra heat (and fatigue) resistant one is recommended as further fatigue will only damage preventive actions [4].

Marcelo et al., (2009) have focused in a failure analysis of a chain link plate shown in Figure 4 and manufactured with AISI 1045 steel used for sugarcane transportation.

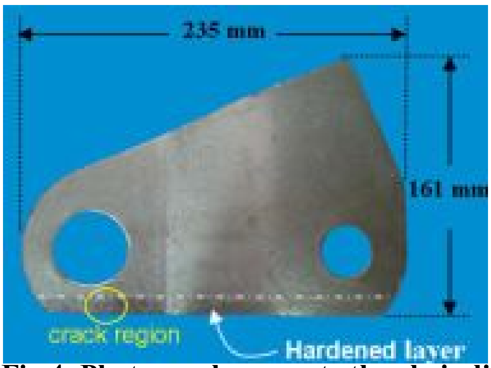

Fig.4. Photograph presents the chain link plate, indicating the crack region, the hardened layer location, and the main dimensions (thickness of 12 mm)

During the manufacturing process, this part is submitted to induction hardening, presently on one surface, before the galvanizing process. The incidence of surface cracks, during storage, disables the handling of these components. Chemical analysis and metallographic analysis, tensile, fracture toughness, and hardness tests, and fractography were conducted to classify and determine the causes of failure. The steel chemical composition was in unity with AISI 1045. The metallographic analyses and fractography did not display the presence of zinc into the cracks; this is a signal that the cracks occurred after the galvanizing method. Tensile and fracture toughness test results are as projected. The crack exterior and the fracture toughness sample surfaces showed two dissimilar fractured micro mechanisms: dimples and intergranular. The deferred fracture related with the predominance of intergranular fracture micro mechanism at the induction hardened layer and the high hardness point is a clear signal of the hydrogen embrittlement [5].

Gachet et al., have explained a forming process stage which is usually affected ending the components mechanical properties. Accounting for material processing effect is essential to analyze the final component's mechanical strength optimizing products design. Accounting for both the forming stage and the structural analysis of the final component requires dealing with complex multi-stages and non-proportional loading configurations. The development of enhanced material models and numerical methods is required. The in-use mechanical behavior of half-blanked parts is modelled by resources of the finite element method. The complete methodology to chain metal forming computations and in-use parts of the mechanical loading computations is described. An enhanced fracture criterion, suited for then on-proportional loading experiential during the products lifecycle, was developed and used to model the fracture of high-strength low-alloy steel S'420MC. Ductility is modelled by a scratch variable which can grow at some stage in the forming stage allowing the modelling of the relative loss of ductility induced by this stage. The projected fracture criterion is based on the meaning of stress state functions, by parts in the stress states space, which allow the modelling fracture under an extensive range of loading conditions. The laboratories which examine tests and industrial case computations outcomes are assessed by comparison with testing. Influence of forming phase and ductile fracture is analyzed. It is shown that accounting for the industrialized process and modeling fracture are compulsory if one needs to predict precisely the observed failure modes as healthy as the load-carrying capacity of half-blanked components [6].

Jagtap et al., (2014) have described the behaviour of the chain plate under tensile loading. In turn, it will assist in reducing losing time and the maintenance cost related to the chain assembly in various type of industries. The behaviour of a strip under tensile loading are studied by the analytical, experimental and numerical methods. In the assembly of the roller conveyor chain on the outer plates i.e. on strips where the tensile forces are applied by pins that are assembled through holes in the sidebars show the holes in the side plates as being significant stress risers.

Fig.5. Failure of Chain Plate

From Figure 5, the outer side plates are primarily tension members, and they also are subjected to considerable bending and stress concentrations in and around the region of holes. The outer side plates necessitate sufficient strength to survive the tensile forces lacking deforming or breaking, which result in having sufficient ductility to withstand considerable bending and to resist fatigue [7].

Slabbert et al., (1998) have carried out a failure analysis of carrier chain pins. In that, they have shown a sugar plant which is calculated to operate with the minimum interruption during the sugar cane harvesting season, and where the machine must be maintained in a high standard of renovation. When the failure of equipment does take place, it is important to classify the cause to minimize the possibility of any future problems. This paper deals with the analysis of a failure in the conveyor chain bearing pins as shown in Figure 6 that had functioned for only six weeks.

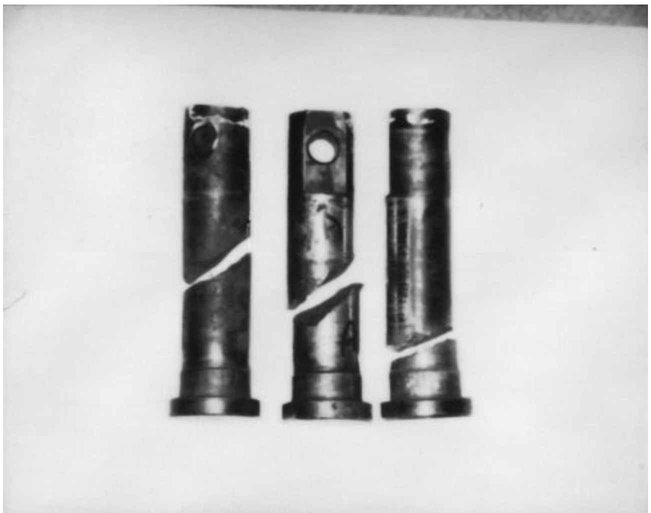

Fig.6. Three fractured bearing pins showing the position and angle of the fractures

The bearing pins had been heat-treated so that they had become susceptible to hydrogen embrittlement, and had cracked. The source of hydrogen was qualified to corrosion of other steel components in the machine system. In organization to minimize the probability of future failures, it was suggested that the source of the corroded parts be identified. In addition, it was suggested that the authors should liaise with the industry work environment in order to suggest a suitable heat treatment schedule for future bearing pins [8].

Summary

In this review the state of art of the review of the literature on the analysis of chain plate and bearing pin of the roller chain have been presented. Based on the review, the following points are summarized,

- The forged conveyor chain links have proved unsuccessful due to presence of defects. The defects were recognized as forging laps or folds.
- The induction hardened film layer on En-19 material given to improve fatigue and wear resistance has not been given equivalently on the pin surface. The use of
  En-24 with 1.25–1.75% nickel could probably get better with the wear and with corrosion resistance.
- The intergranular cracking of the chain link was caused by hydrogen stress cracking. The presence of compressive residual stress of around 450 MPa on the hardened surfaces of the link plate was not adequate to prevent a hydrogen stress cracking.
- The failure of the stainless steel strips for dam block connection takes place via the function of low cycle fatigue mechanism, due to alternating bending stresses developed during operation of the chain, followed by a ductile over-load.
- The chemical composition and the tension and fracture toughness investigate an outcome of the failed chain components which are in accord with the specification (AISI 1045) and as probable from the fabrication process. The metallographic analysis showed, as expected, tempered martensite in the hardened layer and ferritic–perlitic in the core of the part.
- Link plates used as chain basics are subjected to repetitive tensile stressing due to the succeeding load and un-loading conditions.
- When a chain is operating under loaded circumstances, the outer surface of the pin and inner surface of the bushing rub against each other, reducing the effect, diminishing the potential.
- Failure modes of the chains are of normal wear, over load and fatigue, besides failure due to poor pin bush interfering and assembly error.
- No Roller failure has been found in two wheeler automobile drive applications.
- The chain fatigue failure mostly occurs in link plates and is due to cyclic tensile loading.

Future scope of the work is fatigue strength which has been enhanced by improving the quality of the pitch holes of the link plates.

References

1. M. Sujata, M.A.Venkataswamy, M.A.Parameswara, S.K. Bhaumik., Failure analysis of conveyor chain links, Engineering Failure Analysis., 2006, 13, 914–924.
2. S.G.Sapate, V.K.Didolkar.,Metallurgical investigation of failure of coal mill drag chain pin, Materials and Design., 2009, 30, 2623–2629.
3. C.R.F. Azevedo , D. Magarotto, A.P. Tschiptschin., Embrittlement of case hardened steel chain link" Engineering Failure Analysis., 2009, 16, 2311–2317.
4. G.Pantazopoulos, A.Vazdirvanidis., Metallurgical investigation on fatigue failure of stainless steel chain in a continuous casting machine, Engineering Failure Analysis., 2009, 16, 1623–1630.
5. A.L. Marcelo, R.C. Tokimatsu, I. Ferreira., Hydrogen embrittlement in an AISI 1045 steel component of the sugarcane industry, Engineering Failure Analysis., 2009, 16, 468–474.
6. J.M. Gachet, G. Delattre, P.-O.Bouchard.,Improved fracture criterion to chain forming stage and in use mechanical strength computations of metallic parts – Application to half-blanked components, Journal of Materials Processing Technology., 2015, 216, 260–277.
7. Jagtap M.D, Gaikwad B.D,Pawar P.M., Study of roller conveyor chain strip under tensile Loading, International Journal of Modern Engineering Research., 2014, 4, 61-66.
8. G. A. Slabbert, J.J. Mcewan, R. Paton., Failure Analysis of Carrier Chain Pins, Engineering Failure Analysis., 1998, 5, 121-128.

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