Process Optimization and Stress Analysis of Link Plate of Roller Chain

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***Abstract*—The link plate of roller chain is manufactured by blanking and piercing operation. Surface finish of this sheared product is very poor. So secondary operations are required to be performed on link plate to make surface finish fine but this adds extra manufacturing time and cost. The aim of this project is to eliminate the secondary operations and increase the breaking load capacity of roller chain. This is achieved by modification in die and link plate of roller chain. The load coming on link plate of roller chain is calculated by standard analytical procedure. The link plate is modeled on Solidworks modelling software and analyzed on Ansys Workbench 16.0 by considering symmetric conditions.**

***Index Terms*—Blanking and Piercing, Clearance, Die Modification, Finite Element Analysis, Link Plate, Roller Chain.**

I. INTRODUCTION

ROLLER chains are widely used in chain drives, motorcycle, chain saw cutter and in conveyor to transfer material from one place to another as a mechanical element. It has a basic mechanism of engagement and disengagement between chain and sprocket wheel. Roller chains are widely used in industry for various purposes like for power transmission and in material transmitting conveyor chains. The capacity and efficiency of roller chain is high compared to belt drive as the slip is absent in chain drive. Any failure in the roller chain causes sudden stoppage of production of the company. This causes huge losses to the company. The main difference between power transmitting chain and conveyor chain is power transmitting chain is used to transfer the torque and conveyor chain is used to transfer the goods. The pitch of the conveyor chain is large and also the thickness of the link plate is large to withstand the high tensile and shock loads.

Roller chains of machines are subjected to severe working condition such as high tensile load, shock load and extreme working conditions. As the chains are operating under severe working condition failure of roller chain is critical problem of many industry. The improper manufacturing processes are another source failure initiation. Link Plate inner and outer, roller, bushing, pin are the important component of roller chain.

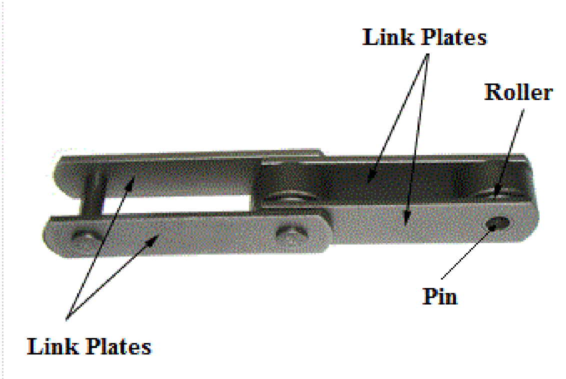

Fig. 1.Roller Chain Assembly

The roller conveyor chain consist of two types of link plate which are inner link plate and outer link plate. When span of the roller chain is large and used for conveying purpose then large driving force is required. But this increases weight of the roller chain as the greater strength is required to withstand high driving forces.

II. PROBLEM STATEMENT

The manufacturing of link plate of roller chain is done by blanking and piercing operation which gives rough surface finish on sheared surface. The hole of the link plate is most critical area as all the load is coming on this part of the link plate. As the area come in contact with the pin and hole reduces there are chances of shear failure, so there is need to improve the surface finish of sheared hole. And this is achieved by performing secondary operations like shaving, reaming and grinding. This adds extra manufacturing cost and time.

III. LITERATURE REVIEW

Kai Wang have presented in paper that die clearance has great impact on resulting edge fracture. He developed computational methodology for edge fracture prediction and carried out FE analysis of hole punching process [1]. Pusit Mitsomwang presented in paper that punch or die shearing is one of the most important method. He analyzed effect of punch and die clearance on cutting characteristic. Then he investigated the crack propagation. He also done study of the effect of feed velocity [2]. Wang Hong have determined fine blanking die clearance and designed fine blanking compound die. He mentioned that quality of fine blanking parts is directly related to quality of mold design.

He carried out analytical calculations of Layout design, fine blanking pressure and force [3]. Masao Murakawa presented a new technology to improve the surface quality of sheared product. He used combined process of finish blanking and press shaving. And found out smallest possible clearance between Punch and Die. Processes like Quenching and Tempering are eliminated and finishing processes like Grinding and Turning eliminated [4]. Ridha Hambli discussed the importance of ring indenter in fine blanking Process. He done the numerical simulation of fine blanking operation and states the importance of fine blanking process. [5]. P. R. Brage increased strength of the chain at some specific location . He given brief introduction about the types of load coming on chain and done the optimization of link plate [6]. S. Noguchi describes the methods for experimental testing of roller chain [7]. S.R. Kale carried out analysis and optimization of link plate of roller chain [8]. R.K Pathak discussed about importance of die clearance. He found out expression for die clearance considering engineering strain at proportional limit [9].

IV. LOAD CALCULATION

The blanking and piercing force coming from existing die design is calculated using standard procedure by considering shear strength and thickness of sheet material.

Breaking load of chain is calculated by,

Length of Conveyor, L = 181 ft = 55 m span

Speed of Chain = 0.45 m/s

Co-efficient of friction,

$$\mu_C = 0.15 \text{ (Normal lubrication)}$$

Estimated Mass of Chain with all assembly,

$$W_C = 30 \text{ kg/m}$$

Capacity of Conveyor,

$$W_L = 40 \text{ T/hr}$$

$$= 40 \times \frac{1000}{3600} = 11.11 Kg/s \tag{1}$$

Let,

Mass on Conveyor = W kg/m

Capacity of Conveyor (W_L),

= Mass on Conveyor kg/m (W) × Speed of Chain in m/s

$$11.11 = W \times 0.45$$

So,
$$W = 11.11 / 0.45 = 24.69 \tag{2}$$

Chain Pull,

$$P = 9.81 \times \mu_C [(2.04 \times W_C \times L) + W]$$

$$P = 9.81 \times 0.15 [2.04 \times 30 \times 55) + 24.69]$$

$$P = 4990 \text{ N} \tag{3}$$

Maximum Braking Load require,

$$W_B = P \times \frac{8}{2}$$

$$= 4990 \times \frac{8}{2}$$

$$= 19960 \text{ N} \approx 20000 \text{ N}$$

$$W_B = 20 \text{ KN} \tag{4}$$

This much load is coming on roller chain link plate and link plate is need to be withstand this much load.

V. FINITE ELEMENT ANALYSIS

There are three basic steps in Finite Element Analysis. The pre-processor, processor and post-processor. Modeling of link plate is the first step in pre-processor..

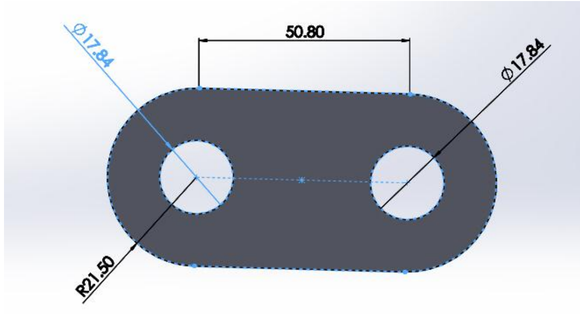

Fig. 2.Dimensions of Link Plate

As the link plate is of symmetric geometry only half of link plate is modelled on modeling software that is Solidworks. Then it is imported to Ansys Workbench 16.0.

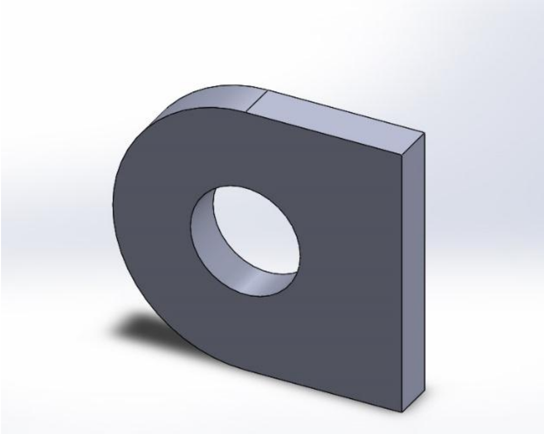

Fig. 3.Solidworks model of link plate

Above Fig. 3 shows the Solidworks model of link plate. Mesh is generated by giving appropriate relevance. The load coming on the link plate is calculated by standard procedure and which comes out to be 20 KN. Then this load is converted to pressure. Which comes out to be 119 MPa and applied on link plate as shown in Fig. 4 and symmetry condition is applied on link plate.

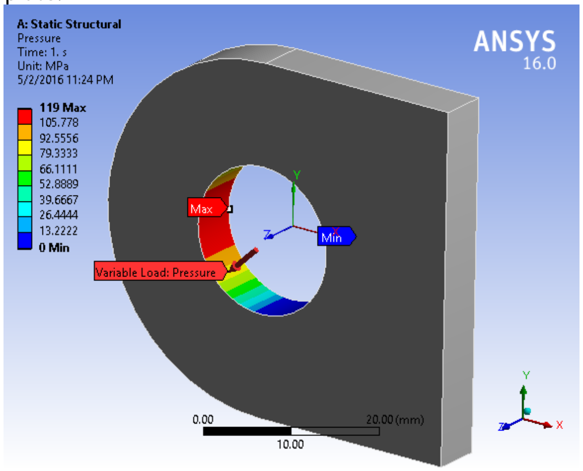

Fig. 4.Loading Diagram of Link Plate

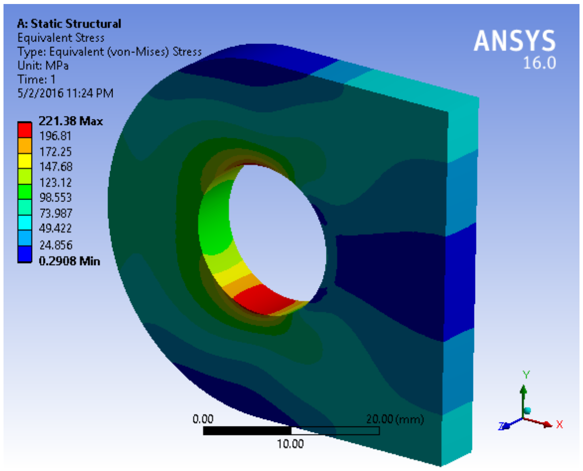

Fig. 5.Von Mises Stresses in Link Plate

Fig. 5 shows the area which shown in red color indicates max. von mises stress which is equal to 221.38 MPa and the area shown in blue color indicates min. stress which is 0.2908 MPa. Fig 6 shows total deformation in link plate. The max. deformation in link plate is 0.0215 mm.

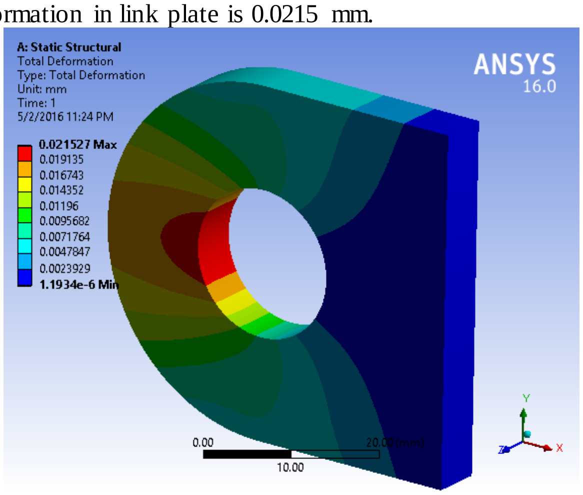

Fig. 6.Total Deformation in Link Plate

Then modification in link plate is carried out. Two cases are taken in consideration, in first case the Diameter of hole of link plate is varied. The diameter of hole is changed from 17.84 mm to 16 mm, 17 mm, 18.5 mm and 19 mm. The results are obtained from Ansys and graph is plotted for Von mises (Equivalent) stress vs Diameter of hole.

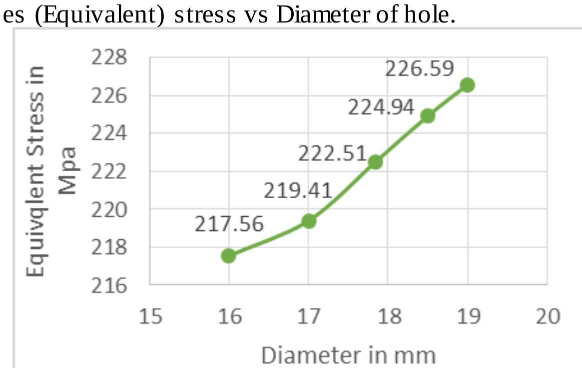

Fig. 7.Equivalent Stress vs Diameter of Hole

Then in second case changes are made in the thickness of link plate. Thickness is changed in two steps from 6 mm to 7mm and then to 8 mm. Then combined graph is plotted for Equivalent stress and diameter.

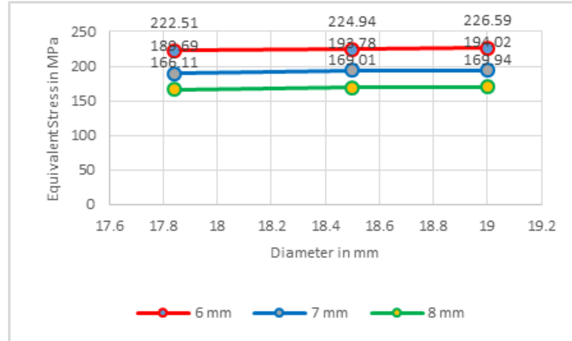

Fig. 8.Stress for varying thickness of link Plate

From Fig. 8 it is clear that if thickness of link plate is varied by just 1 mm, stresses reduces considerably. With the help of Fig. 8 it is decided to go with link plate of thickness 7 mm as stresses in this link plate are much low.

VI. SHEAR MECHANISM OF WORK-PIECE MATERIAL

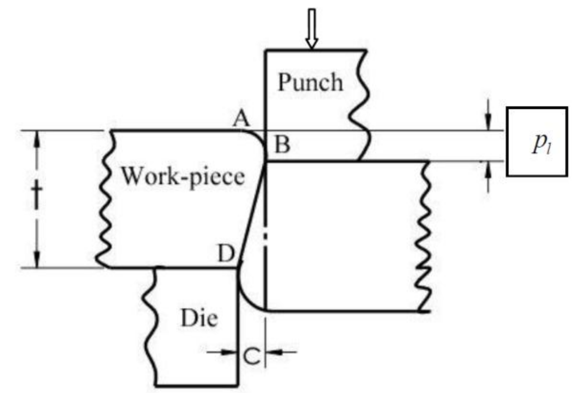

Fig. 9.Deformation of work-piece during punching

A notch subjected to shear loading gets dull on one side and pointed on the other while the crack gets initiated at the pointed tip and is deflected much like it is shown in Fig. 9. For simple analysis it is assumed that the cracks initiate at the point B and D it starts to grow as shown in Fig. 9 Consider a punch and die with the work-piece shown in Fig. 9. The work-piece material gets bend during the downward movement of the punch. Then material of workpiece is pulled down by the movement of the punch. The grain elongation take place near the corner B. Near the die corner D similar type of deformation also takes place. When the grain elongation in the surface fiber AB at B reaches a limiting value ef, the fiber ruptures at this point.

VII. MODIFICATION IN DIE

Surface finish of sheared product is depend upon various parameters like clearance, feed velocity, cutting line force, normalized depth. Out of this clearance is very important parameter. Clearance is calculated by equation developed by R. K. Pathak [9],

$$\frac{t}{c_o} = 1.36 e^{\varepsilon_f} \left[\frac{2.3 e^{\varepsilon_f} - 1}{2 e^{\varepsilon_f} - 1} \right] \quad (5)$$

Where, t = Thickness of plate

ε_f = Strain at failure $= \ln(1 + e_f)$

e_f = Engineering Strain

c_o = Clearance in Die and Punch

From this equation clearance is comes out to be 1.389 mm for 7 mm thick link plate.

Then feed velocity, cutting line force and normalized depth of indentation is found out by Pusit Mitsomwang equations [2]. Maximum Principal Stress and Minimum Principal Stress found out near punch corner and near die corner by P. Mitsomwang equation.

Max. Principal Stress (σ_1) near the punch corner,

$$\sigma_1 = -417.1 \ (c / t_s) + 425.9 \quad (6)$$

Max. Principal Stress (σ_1) near the die corner,

$$\sigma_1 = -359.1 \ (c / t_s) + 414.7 \quad (7)$$

Min. Principal Stress (σ_2) near the punch corner,

$$\sigma_2 = 82.97 \ (c / t_s) - 84.11 \quad (8)$$

Min. Principal Stress (σ_2) near the die corner,

$$\sigma_2 = 94.38 \ (c / t_s) - 88.21 \quad (9)$$

The values of Maximum Principal Stress σ_1 and Minimum Principal Stress σ_2 are calculated for clearance values starting from 0.2 mm to 2 mm with increment of 0.2 mm. Then Shear Stress (τ) near the punch corner and die corner is calculated by,

$$\tau = \frac{\sigma_1 - \sigma_2}{2} \quad (10)$$

Then shear stress obtained near punch and die corner is plotted against clearance value. As shown in fig 10.

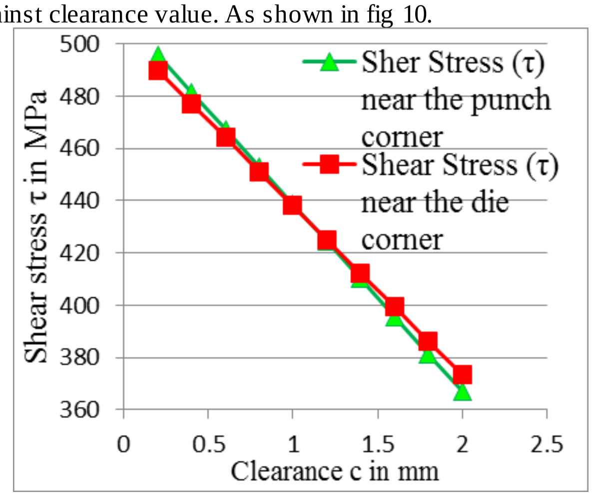

Fig. 10.Shear Stress τ vs Clearance

From Fig. 10 it can be seen that optimum clearance value is in between 1 and 1.5 mm. It has calculated already as 1.389 mm.

VIII. Conclusion

Stress analysis is carried out to obtain the stresses and deformation values in link plate of roller chain. For 6 mm thick link plate max. deformation is 0.021 mm. After modification, stresses in link plate reduced considerably hence breaking load capacity of roller chain is increased. Tension test is proposed to carry out on link plate to verify the results with finite element analysis results and Elongation test on roller chain will perform on chain testing machine. After modification in die the secondary operations need not to be carry out on link plate. And manufacturing time and cost will reduce considerably.

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