APPLICATION OF FINE PIERCING PROCESS FOR ROLLER CHAIN LINK PLATE TO INCREASE BREAKING LOAD OF ROLLER CHAIN

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ABSTRACT

The hole quality in the sheet metal manufacturing is directly dependent on the die design and process parameters. In conventional piercing process, the hole surface features normally consist of the die-roll, shear surface, cracks, and burr. The secondary operations such as shaving, reaming, and grinding are needed for achieving the smooth hole surface without any cracks. The link plate of roller chain is manufactured by conventional blanking and piercing operation. In assembly of roller chain only shear zone of hole comes in contact with pin, so less contact area between pin and bush causes uneven bending stresses as well as shear stresses in the pin while chain is in working condition. Therefore elongation in the chain due topin and bush wear, which decrease the breaking load and life of chain. The purpose of this study is to increase the contact area between bush and pin which automatically will increase the life and the breaking load of the chain. The fine-piercing process, referenced to the fine-blanking principle, is used to produce the precise-dimensioned holes in the roller chain link plate parts with smooth-cut surfaces over the whole material thickness in a single operation. In this study, the stresses on link plate and pin were investigated by finite-element method (FEM) for both conventionally piercing and fine piercing of link plate. The breaking load of chain was checked on UTM for both roller chains when conventionally pierced link plate and fine pierced link plates are used in assembly of chain.

The results showed that an application of fine piercing processes in link plates of roller chain results superior fine-pierced hole surface could be achieved. Furthermore, the use fine piercing process increases shear length in hole. The increase in shear length increases the contact area between pin and bush, therefore wear between pin and bush reduces. The reduction in wear minimizes stresses on pin and link plate and increases breaking load and life of chain.

KEYWORDS: Fine blanking, Roller chain, Link Plate, Breaking Load.

I. INTRODUCTION

Blanking and piercing are both shearing operation. The difference is only in the scrap. In blanking what you cut out is of interest. In punching what you cut from is of interest. For example: You cut a hole in a sheet metal. If you are interested in the disc that is cut out, then the process is called blanking. The sheet metal with a hole through it is the scrap. If you are interested in the sheet metal that now has a hole through it, then the process is called piercing.

Blanking is one of the basic processes in the sheet metal forming. It is one of the advanced technologies of processing materials and manufacturing products. In engineering practice, the shape of the product near the cut edge is by far the most important property. Blanking is a constrained shearing operation that involves elastic deflection, plastic deformation and fracture of the work material. In theblanking process, some factors such as the punch-die clearance, the tool geometry and the mechanical properties of the materials influence the quality [1, 3] of the cross-section and the dimension precision. In conventional metal stamping only a punch and a die set is used. A typical fine-blanking tool is a single-station compound tool used to produce a finished part in one press stroke [3, 4]. The only additional operation needed is the removal of a slight burr. The process requires a triple-action fine-blanking press that applies clamping force, blanking force, and counterforce to the fine-blanking tool, respectively [2]. In fine blanking the V-ring indenter presses into the sheet material close to the cut line, gripping the material on both sides of the cut. Compression stress occurs in the cutting zone and causes the plastic phase to affect the entire thickness of the blanked material, resulting in a quality blanked edge. Thus, the part is smoothly removed from the strip [5].

The link plate of roller chain is manufactured by conventional blanking and piercing operation. In assembly of roller chain only shear zone of hole comes in contact with pin, so less contact area between pin and bush causes uneven bending stresses as well as shear stresses in the pin while chain is in working condition.

II. PROBLEM DEFINATION

In conventional piercing process, the hole surface features normally consist of the rollover zone, shear zone, fracture zone and burr zone. The link plate of roller chain is manufactured by conventional blanking and piercing operation.
The different zones in the link plate hole are shown in (figure 1). Due to fracture zone a taper hole is observed in the link plate at the bottom side. In assembly of roller chain only shear zone of hole comes in contact with pin. Which produces uneven bending stresses as well as shear stresses in the pin while chain is in working condition. This stresses in the pin and on hole surface of link plate reduces the breaking load of chain and increases the chain elongation.

III. MECHANISM OFFINE BLANKING

Fine blanking is a specialized form of blanking where there is no fracture zone when shearing. This is achieved by compressing the whole part and then an upper and lower punch extract the blank. This allows the process to hold very tight tolerances, and perhaps eliminate secondary operations. In fineblanking, in addition to the same tool components needed for blanking, an ejector or counterpunch and a V-ring (4 and 2, respectively, in Fig. 3) are used. The main purpose of these tool components is to generate compressive stresses and hold the material against horizontal movement. Three forces V-ring force \( F_R \), counterforce \( F_G \), and blanking force \( F_S \) act on the blank. These forces are generated, as shown in Figure 1, by the V-ring (2), the ejector (4), the punch (3), and the die plate (1). \( F_R \) and \( F_G \) are applied by hydraulic cylinders.

IV. FINE BLANKING FORCE CALCULATION AND PRESS SELECTION:

During a fine-blanking cycle, three forces act upon the material: the V-ring force, the counterforce, and the blanking force. The exact interactions among the three forces have a strong influence on the quality of the part and the performance of the fine blanking process.

**Blanking Force**

\[
F_S = l_s \times s \times k_S
\]

Where,
- \( l_s \): Total length of cutting lines
- \( s \): Material thickness
- \( k_S \): Cutting resistance
- \( k_S = 0.8 \times R_m \)
- \( R_m \): Material tensile strength

\[
F_S = \pi \times D^2 \times 0.8 \times R_m
\]

\[
= 3.14 \times (17.84)^2 \times 0.8 \times 440
\]

\[
= 118.309 \text{ KN}
\]

**V-ring force**

\[
F_R = 4 \times l_R \times h_R \times R_m
\]

Where,
- \( l_R \): Length of V-ring
- \( h_R \): Overall height of V-ring
- \( R_m \): Material tensile strength

\[
l_R = \pi \times D^2
\]

Where,
- \( D \): Diameter of v-ring

\[
D = (17.84 + 2 \times 0.3\% + 2 \times 3)
\]

\[
D = 23.876 \text{ mm}
\]

\[
l_R = 3.14 \times 23.876
\]

\[
l_R = 74.97064 \text{ mm}
\]

\[
h_R = 0.7 \text{ mm}
\]

\[
R_m = 440 \text{ Mpa}
\]

\[
F_R = 4 \times l_R \times h_R \times R_m
\]

\[
= 4 \times 74.97064 \times 0.7 \times 440
\]

\[
= 92.363 \text{ KN}
\]

**Counter Punch Force**

\[
F_G = A_q \times q
\]

Where,
- \( A_q \): Cutting piece surface
- \( q \): Specific counter punch force

\[
A_q = \pi \times \left( \frac{D}{2} \right)^2
\]

\[
= 3.14 \times \left( \frac{17.84}{2} \right)^2
\]

\[
= 249.84 \text{ mm}^2
\]
Value of the specific counter punch force for small sized, thin workpieces is given by,

\[ q_G = \frac{20}{g^{3015}g^{3040}} \]

and Value of the specific counter punch force for big, thick workpieces.

\[ q_G = \frac{70}{g^{3015}g^{3040}} \]

\[ F_G = 249.84 \times 70 \]

\[ = 17.488 \text{ KN} \]

Total pressure of fine blanking

\[ P = F_S + F_R + F_G \]

\[ = 118.309 + 92.363 + 17.488 \]

\[ = 228.16 \text{ KN} \]

V. PRESS SELECTION

There are two kinds of fine blanking presses, fully hydraulic press and mechanical toggle lever press. Mechanical fine blanking presses are mainly used to manufacture relatively thin and small parts. Components with a thickness of more than 3 mm, requiring a total force of 100 tons and more, are in the majority produced with fully hydraulic fine blanking presses.

To reduce costs, the fine blanking is carried out in general presses. According to the total blanking force, JB21-63 of Two Column Fixed Bench Press Open is used.

VI. EXPERIMENTAL APPROACH

A 32B roller chain is selected for the experiment. As it is used widely in sugar industries, marine engines, paper mill, food processing, fertilizer industry, pharmaceutical industry, cement industry, foundry industry, heat treatment units, coal mines etc. The concentration is made on the outer link plate of roller chain for the analysis because of its direct contact with pin. Thickness of the outer link plate is 6 mm. The hole surface features of conventionally pierced holes and fine pierced holes are measured by using the rapid-I machine. The hole surface is examined for shear zone depth and crack depth. The link plates are cut along the diameter of hole to see the hole surface features. The below figure 5 shows the setup used to measure hole surface features of link plate hole.

For analysis of hole surface features of conventionally pierced link plate total 10 outer link plates are cut along the hole diameter and checked for length of different zones. The fine piercing operation on outer link blank plate is performed without changing the link plate material. Total 100 blank plates are used for fine piercing and 10 plate are selected randomly for analysis. Fig. 7 and 8 shows the comparison between surface features for fine piercing and conventional piercing along with its length.

Figure 5. Fine blanking/piercing die setup.

Figure 6. Setup used to measure hole surface features.

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Figure 7 Conventionally pierced link plate hole surfaces.

Figure 8 Fine pierced link plate hole surfaces.

VII. FEA ANALYSIS

Finite Element Analysis of roller chain assembly with conventionally pierced link plates.

FEA analysis is firstly carried for roller chain assembly with conventionally pierced link plates and then roller chain assembly with fine pierced link plates. The chain link plate is first modelled in CATIA V-5 as shown in Fig. 9. The shear zone length inside the hole is taken 4.26mm and fracture length is taken 1.74mm which is the average length of all shear zone length and fracture length measured for 10 conventionally pierced link plates.

Figure 9 Conventionally pierced outer link plate model in CATIA.

Chain link assembly is then modelled in CATIA software with conventionally pierced link plates and it is imported in RADIOSS, FEM package. In chain assembly of conventionally pierced plates all components are meshed by using tetrahedral element. A material property of all parts has been entered as an input. 5mm element edge length is considered. 31002 elements and 100136 nodes are generated to mesh the chain link assembly freely. The constraints and loading conditions for chain link assembly has been shown in Fig.10. One end of the assembly is...
fixed in all directions (i.e., SPC 123456). A force of 49033.25N (5ton) is applied at the other end and allows to move only in a positive x direction (spc23456).

Figure 10 Constraints and Loading for roller chain assembly with conventionally pierced link plates.

Figure shows Von misses stress plot for conventional roller chain assembly at load of 49033.25N (5 tonnes). The maximum stress value is 408 N/mm².

Figure 11 Von misses stress plot for conventionally pierced link plate Assembly.

Finite Element Analysis of roller chain assembly with fine pierced link plates.

Figure 12 Fine piercing link plate model in CATIA.

Fig.12 shows fine piercing link plate model in CATIA. The shear zone length inside the hole is taken 5.61mm and fracture length is taken 0.39mm which is the average length of all shear zone length and fracture length measured for 10 fine pierced link plates. Then new chain is modelled with fine pierced link plates in assembly. The same load, constraints, material properties are applied to chain which was applied for chain with conventionally pierced link plate in assembly.

Figure 13 Constraints and Loading for Roller Chain assembly with fine pierced link plates.

Figure 14 Von misses stress plot for fine pierced link plate chain Assembly.

Figure 14 shows Von misses stress plot for conventional roller chain assembly at load of 49033.25N (5 tonnes). The maximum stress value found in this chain is 287 N/mm².

VIII. RESULTS AND DISCUSSIONS

The objective of this project was to increase the breaking load of the roller chain by increasing the shear zone length inside the link plate hole. This is achieved by changing the manufacturing process of link plate hole from conventional piercing to the fine piercing process with reference to the fine blanking process. Total 100 blank plates were used for fine piercing and 10 plates were selected randomly for analysis. From the average length of shear zone in conventional and in fine it found that 22% increment in shear zone length. A new roller chain is assembled by replacing conventionally pierced link plates by fine pierced link plates and checked for breaking load on Universal Testing Machine. Table 1 shows the comparison of displacement and stress in chain assemblies.

Table 1 FEA and experimental results.

<table>
<thead>
<tr>
<th></th>
<th>Roller chain with conventionally pierced link plates</th>
<th>Roller chain with fine pierced link plates</th>
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</thead>
<tbody>
<tr>
<td>Displacement (mm)</td>
<td>Stress (MPa)</td>
<td>Stress (MPa)</td>
</tr>
<tr>
<td>Results From FEA</td>
<td>0.188 408.57</td>
<td>0.159 287.793</td>
</tr>
<tr>
<td>Results From Experimental</td>
<td>0.193 421.47</td>
<td>0.167 301.5</td>
</tr>
<tr>
<td>% variation in results (Analysis v/s Experimental)</td>
<td>2.5% 3.05%</td>
<td>4.79% 4.54%</td>
</tr>
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Figure 15 Stress-Strain relation of roller chain assembly

The above fig.15 shows the graph of stress v/s strain for both roller chains. The max load of 7.41 tonne load was taken by the roller chain with conventionally pierced link plates and 7.85 tonne by chain with fine pierced link plates. The maximum tensile strength of 408 N/mm² and 287.79N/mm² was gained by the conventional chain and fine roller chain respectively.

CONCLUSION

The holes in the roller chain link plates are typically generated using ‘stamping’ process. The pierced hole in this conventional process has three distinct zones - rollover, shear band and fracture region. The prominence of a burnished band over the cross-section of the pierced hole helps to offer higher contact area for the mating pin.

From the experimental result it is found that when fine piercing process is used for link plate then there is 22% increment in the shear zone length. From the FEM simulation results, In the case of roller chain assembly with conventionally pierced link plates, the errors for displacement and stress were 2.5% and 3.05% respectively and roller chain assembly with
fine pierced link plates, the errors for displacement and stress were 4.79% and 4.54%. Thus an alternative process of stamping i.e. fine piercing process can be used for roller chain link plates.

REFERENCES