SHEARING PARAMETER EFFECT ON PUNCHING PROCESS OF ROLLER CHAIN LINK PLATE

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Abstract
The link plate of roller chain is manufactured by blanking and piercing operation on Press Machine. Surface finish got from this processes is very poor. Hole of the link plate is important part as all the load coming on this sheared part of link plate. As the surface finish is poor, the actual area come in contact between hole and link is less so there is uneven shear stresses are generated. 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 study is reduced secondary operations. And this is achieved by modifying different parameters of die. This paper is focused on effect of different shearing parameters like clearance, feed velocity, cutting line force, and normalized depth of indentation during piercing operation of link plate on die.
Index Terms: Blanking and Piercing, Clearance, Die Modification, Link Plate, Roller Chain.

I. INTRODUCTION

The link plate is manufactured on Press Machine. And made by Blanking and Piercing operations. Blanking and piercing are both shearing operation. The hole quality on sheet metal parts is directly dependent on the die design and process parameters. In piercing process, the shear edge of pierced hole is made of different zones based on the method of material deformation that has occurred. The secondary operations such as shaving, reaming and grinding are needed for manufacturing the precise-dimensioned holed parts without any cracks, resulting in the increase of both production time and costs. From the previous studies, it can be noted that, very few researchers worked on manufacturing process of roller chain. Most of the work based on metallurgical investigation, improvement of efficiency and performance of chain. Very little work on improving life of the chain and minimization of its failure by manufacturing process. From the chain failure case studies it can be noted that the root cause of failure was faulty manufacturing process, heat treatment and improper material selection.

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 to pin and bush wear, which decrease the breaking load and life of chain. The surface made during piercing operation is not smooth throughout so the real area come in contact with pin is less than the area we consider during the calculation. Hence the breaking load capacity of roller chain reduced, and to make hole surface smooth secondary operations like reaming, shaving and trimming have to be perform additionally. Which increases overall manufacturing cost. So the aim is to make hole surface smooth by modifying die design.

II. LITERATURE REVIEW

Pusit Mitsomwang et.al conclude that, an overlapping (negative) punch/die clearance was not suitable for burrless cutting of the worksheet. When using a positive 2–20% clearance, two primary cracks were initiated in the vicinity of the cutting tool corners, where only one of the two cracks was largely propagated into the bulk of the worksheet. This deviated propagation strongly deteriorated the quality of the sheared profile of the polycarbonate worksheet. The deviated propagation of the crack seemed to be affected by an in-plane/lateral unbalanced stress state in the worksheet. As the shearing velocity varied ranging from 0.05 to 1.0 mm s^{-1}, the characteristics of the cutting load resistance were slightly variant, while the velocity seemed to have almost no effect on the pattern of crack initiation and its propagation. They describes that punch/die shearing is one of the most attractive mechanical methods for cutting off the Polycarbonate worksheet [1]. Rakesh Kumar Pathak et.al studied punching of multiple holes of intricate shapes in metals. He found out the equations for optimum clearance between punch and die. And developed equation for length of penetration [2]. Wang Hong et.al calculated fine blanking force and die clearance. Then designed fine blanking compound die. He concluded that quality of the banking part is directly related to quality of the mold design [3]. Masao Murakawa et.al improved the surface quality of sheared products by means of a combined process of finish blanking and press shaving applied to materials having very high strength. They found out smallest possible clearance between Punch and Die [4]. V Bram Armunanto et.al examines the relationship between clearance, punch and dies circularity and circularity of the product of the punching process. He found that increasingly tight or small clearance between the punch dies does not guarantee the product circularity punching the smaller or stable [5]. Suthep Yiemchaiyaphum et.al mentioned that the hole quality on sheet metal parts is directly dependent on the die design and process parameters [6]. Sutasn Thipprakmas discussed the requirements for the fine blanking (FB) technology that the precision blanked products could be obtained are more demanding [7].

III. DIE MODIFICATION

A. Optimum Clearance

The clearance between die and punch plays important role in shearing mechanism of workpiece. So there is necessary that clearance would be optimum. Rakesh Kumar Pathak derived the equation to found out optimum clearance.

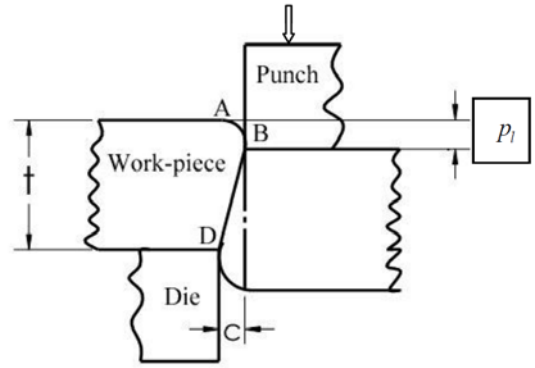

Fig. 1. Deformation of work-piece during punching

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. 1. For simple analysis it is assumed that the cracks initiate at the point B and D it starts to grow as shown in Fig. 1 Consider a punch and die with the work-piece shown in Fig.1. 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 e_f, the fiber ruptures at this point. [2]

$$\frac{t}{c_0} = 1.36e^{\varepsilon_f}\left[\frac{2.3e^{\varepsilon_f}-1}{2e^{\varepsilon_f}-1}\right] \quad (1)$$

Where, t = Thickness of plate

ε_f = Strain at failure

e_f = Engineering Strain

c_o = Clearance in Die and Punch

Thickness of link plate is 7mm.

Yield Strength = 450MPa

Young's Modulus = 210 MPa

Engineering strain, e_f = Yield stress/Young's Modulus

$e_f = \sigma / E = 450/ 210 = 2.1428$

$\varepsilon_f = \ln(1 + e_f) = \ln(1 + 2.1428)$

$\varepsilon_f = 1.1451$

From equation 1,

$C_0 = 1.389$ mm

So the optimum clearance obtained by R.K. Pathaks relation is 1.389 mm.

Pusit Mitsomwang et.al studied the effect of various parameters on cutting characteristic of sheet.

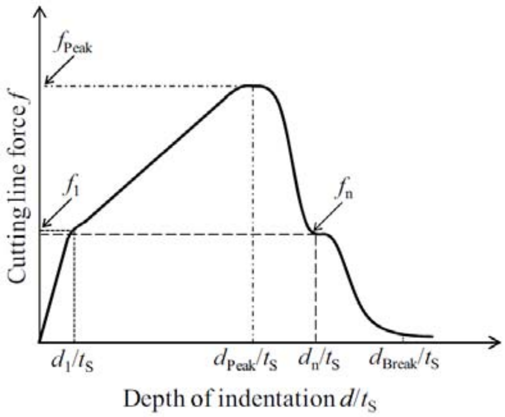

Fig. 2. Line force response model

Fig. 2 illustrates an abstracted line force model which has been drawn based on the experimental response of f-d/t_S. In this figure, $f_1$and d_1/t_S denote the 1st inflection point of f and its position of indentation depth, while the maximum peak point of f and its peak position are indicated by f_{Peak} and d_{Peak}/t_s, respectively. The line force f_n and position d_n/t_S represent the 2nd inflection point off and its position of indentation depth. And, the breaking position of indentation depth for the worksheet is presented by d_{Break}/t_S. [1]

f_1 = Force when small crack begins in work sheet.

d_1/t_s = Ratio of Depth of punch to total thickness of work sheet at f_1 cutting force.

F_{Peak} = Peak force to create plastic deformation in work sheet.

d_{Peak}/t_s = Ratio of Depth of punch to total thickness of work sheet at f_{Peak} cutting force.

f_n = Force when total cutting take place of work sheet.

d_n/t_s = Ratio of Depth of punch to total thickness of work sheet at f_n cutting force.

d_{Break}/t_s = Ratio of Depth of punch to total thickness of work sheet when two work sheet get separated.

B. Effect of Punch/Die Clearance on Cutting Characteristic

In this experiment feed velocity is basically fixed. The values of clearance is changed from 0.2 to 2 in steps.

Calculation for 0.2 mm clearance,

Max. Principal Stress near the punch corner, σ_1

$\sigma_1 = -417.1\ (c/t_s) + 425.9 = 413.983$ MPa

Max. Principal Stress near the die corner, σ_1

$\sigma_1 = -359.1\ (c/t_s) + 414.7 = 404.44$ MPa

Min. Principal Stress near the punch corner, σ_2

$\sigma_2 = 82.97\ (c/t_s) – 84.11 = -81.7395$ MPa

Min. Principal Stress near the die corner, σ_2

$\sigma_2 = 94.38\ (c/t_s) - 88.21 = -85.5134$ MPa3

Shear Stress near the punch corner,

$\tau = (\sigma_1 - \sigma_2) / 2 = 247.861$ MPa

Shear Stress near the die corner,

$\tau = (\sigma_1 - \sigma_2) / 2 = 244.975$ MPa

Similarly values are calculated for c = 0.4, 0.6… 2. And the table is generated containing this values.

TABLE I
PRINCIPAL STRESSES

C mm	Max. Principal Stress (σ_1) near the punch corner	Max. Principal Stress (σ_1) near the die corner	Min. Principal Stress (σ_2) near the punch corner	Min. Principal Stress (σ_2) near the die corner
0.2	413.983	404.44	-81.739	-85.513
0.4	402.065	394.18	-79.368	-82.816
0.6	390.148	383.92	-77.998	-80.120
0.8	378.231	373.66	-74.627	-77.423
1	366.314	363.4	-72.257	-74.727
1.2	354.397	353.14	-69.886	-72.030
1.4	342.48	342.88	-67.516	-69.333
1.6	330.563	332.62	-65.145	-66.637
1.8	318.645	322.36	-62.774	-63.940
2	306.728	312.1	-60.404	-61.244

TABLE II
SHEAR STRESSES

Clearance	Shear Stress near Punch Corner	Shear Stress near Die Corner
0.2	247.8612	244.9767
0.4	240.7173	238.4984
0.6	233.5734	232.0201
0.8	226.4295	225.5418
1	219.2857	219.0635
1.2	212.1418	212.5824
1.4	204.998	206.107
1.6	197.8541	199.6287
1.8	190.7102	193.1504
2	183.5664	186.6721

Graph is plotted for Shear Stresses near punch and die corner against clearance value in mm.

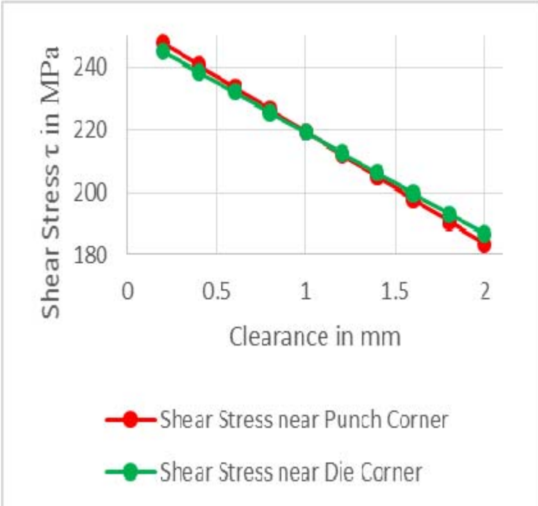

Fig. 3 Shear Stress vs Clearance

From Graph it is clear that optimum clearance is in between 0.9 to 1.4 mm. and it is already calculated as 1.389 mm. This satisfies both the conditions.

C. *Effect of Feed Velocity*

A few researchers worked on effect of feed velocity. Nagasawa et al. studied the wedge indentation cutting of a sheet. He found that the indentation velocity of cutting blade affected the cutting peak load resistance and the sheared profile. In order to investigate the effects of the feed velocity on cutting characteristics such as the sheared edge profile, the feed velocity of the main punch V was chosen as 40,45,50,55 and 60 mm/s.

Normalized Depth (d_l/ts)

$d_l/ts = 0.04 \times V + 0.84 = 0.04 \times 40 + 0.84 = 2.44$

Normalized Depth (d_{peak}/ts)

$d_{Peak}/ts = 0.07 \times (c/ts) + 1.06 = 0.07 \times 40 + 1.06 = 3.86$

Cutting force f_l

$f_l = 2.14V + 21.34 = 2.14 \times 40 + 21.34 = 106.94$ KN

Cutting line force f_{Peak}

$f_{Peak} = 2.72V + 48.59 = 2.72 \times 40 + 48.59 = 157.39$ KN

Cutting line force f_n

$f_n = 2.26V + 18.51 = 2.26 \times 40 + 18.51 = 108.91$ KN

TABLE III
NORMALIZED DEPTH

Cutting Velocity in mm/s	Normalized Depth (d_l/ts)	Normalized Depth (d_{Peak}/ts)	Cutting line force f_l in KN	Cutting line force f_{Peak} in KN	Cutting line force f_n in KN
40	2.44	3.86	106.94	157.39	108.91
45	2.64	4.21	117.64	170.99	120.21
50	2.84	4.56	128.34	184.59	131.51
55	3.04	4.91	139.04	198.19	142.81
60	3.24	5.26	149.74	211.79	154.11

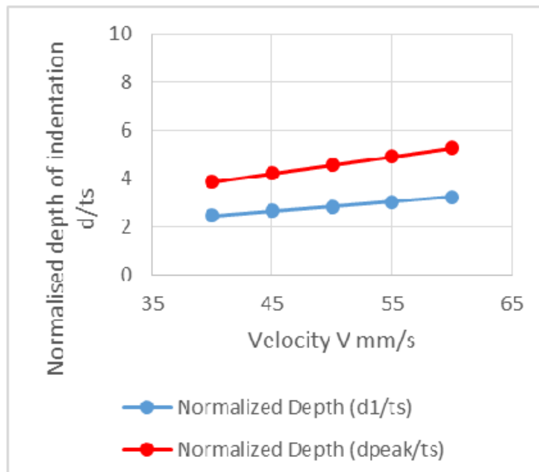

Fig.4 Effect of Velocity V on depth of indentation

The values of d_l/ts and d_{Peak}/ts were almost not affected by Velocity V. when increasing V both f_l and f_{Peak} increased. The feed velocity V had almost no effect on gradient $\partial f / \partial (d/ts)$.

D. *Effect of Cutting Force*

TABLE IV
CUTTING LINE FORCE

C mm	Cutting line force f_l in kN	Cutting line force f_{Peak} in KN	Cutting line force f_n in KN
0.2	413.983	404.44	-81.739
0.4	402.065	394.18	-79.368
0.6	390.148	383.92	-77.998
0.8	378.231	373.66	-74.627
1	366.314	363.4	-72.257
1.2	354.397	353.14	-69.886
1.4	342.48	342.88	-67.516
1.6	330.563	332.62	-65.145
1.8	318.645	322.36	-62.774
2	306.728	312.1	-60.404

Cutting force f_l

f_l = -6.92 × (c/ts) + 21.13= -6.92 × (0.2/7) +21.13 = 20.9323 KN

Cutting force f_{Peak}

F_{Peak} = -27.11 × (c/ts) + 50.24 = -27.11 × (0.2/7) +50.24 = 49.4654 KN

Cutting force f_n

f_n = -58.16 × (c/ts) + 21.24 = -58.11 × (0.2/7) + 21.24 = 19.5783 KN

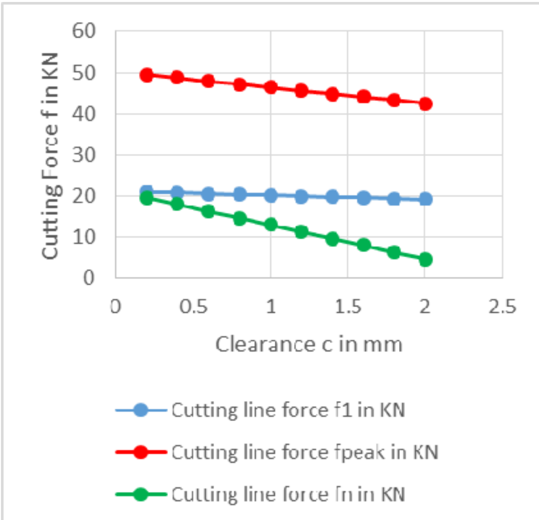

Fig. 5 Relationship between the referenced cutting line forces and the clearance c/ts

Fig. 5 shows the characteristics of the cutting line force f_l/ts, f_{Peak} and f_n/ts with respect to the clearance c/ts. As shown in this figure, the referenced cutting line forces tended to decrease with c/ts.

IV. CONCLUSION

The punching characteristic of a 7 mm thickness worksheet subjected to straight punch and die shearing were investigated with respect to variation in cutting parameters. The negative (overlapping) punch/die clearance was not suitable for cutting off the worksheet with a fine surface finish. The optimum clearance comes out to be 1.389 mm. And this is verified by the other method used in study. The shearing parameters like feed velocity, cutting line force has not much great effect on sheared profile surface finish. It becomes unfeasible to make changes in parameters like feed velocity and cutting line force as the cost required to make modification in press machine is moderate.

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