Piercing Tool Design

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Abstract— This project describes the development of design of a very precise piercing tool for front cover of clutch plate. The approach to system is based on knowledge base rule. The term piercing tool usually refers to one station die, design around a common vertical centre line, in which two or more operation are completed during a single press stoke. This project is about front clutch cover plate which is manufactured in multiple stages on different press machine. Due to this cost of component, time for manufacturing the product and man power required is more. To overcome these disadvantages we are trying to develop die and punch which combine all this operation on single press machine.
Key words: Press Tool, Piercing Die, Punch-Die Assembly

I. Introduction

Sheet metal forming processes are technically among the most important metalworking processes. Products made by forming process include a very vast variety of shapes and sizes, ranging from simple bends to double curvatures with shallow or deep recesses and even very mosaic shapes. Typical examples are automobile bodies, aircraft panels, appliance bodies and Kitchen. Sheet-metal forming processes are widely used in the manufacturing industry. It is usually involved in developing the tools namely die and punch. Usually, tools are costly and the cycle time for building them is long. though, once die and punch are built, the tools can be used to produce a large amount of products. Therefore, sheet-metal forming is a simple and handy manufacturing process. Great productivity and low production cost can be expected for commercial scale production utensils and beverage cans.

A press is a sheet metal working tool with a stationary bed and powered ram can be driven towards the bed or away from the bed to apply force or required pressure for various metal forming operations. A line fig of a typical press is explained in the hydraulic system. The relative area of bed and ram in the press are assured by the structure of its frame. The punch is generally takes into the punch holder and punch holder is attached to ram. A bolster steel plate is attached to the bed of the press and die is mounted on the bolster steel plate.

II. Problem Statement

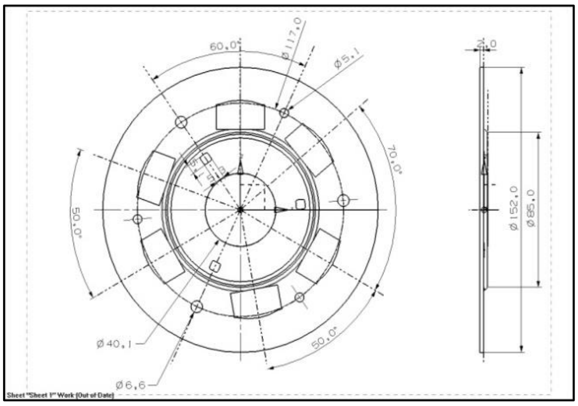

Fig. 1: Component Drawing

These are circular front cover plate of the clutch on which number of holes to be pierced. These holes are located on different PCD. 2D figure of the cover plate is shown as bellow:

Total number of operation required on the cover plate with its location on different PCD is listed in table as follow:

Sr. No.	Operation	Dimension	Location
1	Hole enlargement	Ø 40mm	Centre
2	Square	5.1 × 5.3	68.4PCD
3	Circular hole	Ø 5.1	117PCD
4	Circular hole	Ø 6.6	117PCD

Table 1: No. of operation

Previously these holes are pierced on three different press tools. This process is time consuming process as it consists of stages and material handling between those stages. On these three stages, they required three labours for performing the operations. Hence production cost is more as three press tools as well as three operators are required for doing whole operations. In this process the production rate also low. Production accuracy is reduced as number of stages increased.

III. Objective

To pierce all holes simultaneously by using suitable alternatives within a short time in order to increase productivity, if we use some alternatives for making hole simultaneously, then production rate is increase by reducing cycle time. The objectives of this project are as follows:

1) To minimize the cycle time of manufacturing.
2) To minimize rejection.
3) To reduce the labour cost.
4) To reduce human effort for rework.
5) To decrease production cost & hence increases in profit.
6) To increase the process efficiency.
7) An ultimate objective of project is nothing but improvement in the productivity, and which will automatically result into higher profit

IV. Design Methodology

Our objective is to increase the production rate and the production rate is increased either by increasing the speed of operation or minimizing the stages to single stage by combining the operation. But as we increased the speed of operation, the accuracy goes decreasing. Hence for increasing the production rate, we select the methodology which reduced the stages to minimum.

The probable solution is as follows

1) Gang Drilling Machine
2) Press Tool.

By comparing above two solutions we select press tool machine because cycle time & number of stages are less than gang drill machine.

V. PRESS TOOL DESIGN

A. Cutting Force

The force required to penetrate the stock material with punch is the cutting force. If the die contains more than one punch that penetrates the stock material simultaneously, the cutting force is sum of the force for each punch the knowledge of cutting force is important in order to prevent overloading the press or failure to use if to the capacity and hence it is calculated in preliminary analysis of the stock material the press or failure to use if to the capacity and hence it is calculated in preliminary analysis of the stock material the perimeter of the cutting edge and the shear strength of the stock material. The shear strength of the stock material is the force necessary to serve one square inch of the material by direct shearing action. The distance, which the punch enters into the work material to cause rupture to tap lace is called penetration and is usually given as penetration of stock thickness. [3]

The percentage penetration depends on the material being cut and also on the stock thickness. When a hard and strong material is being cut, very little penetration of them punches is necessary to cause fracture. With soft material, the penetration will be greater. The percentage penetration also depends upon the thickness, being smaller for thicker sheets and greater for thinner sheets, as shown in table:

Stock thickness T (mm)	25	20	13	12.5	10	8	6	5	3	2.5	1.6	Below 1.6
Penetration % of T	25	31	34	37	44	47	50	56	62	67	70	80

Table 2: Percent penetration [3]

The cutting force formula is as follows:

$F_{max}= p \times t \times \tau_s$

F= Cutting force in N

P =perimeter of component in mm

t = stock thickness in mm

τ_s= shear strength of the stock material, in N/mm^2

Initially we calculate perimeter of the pierced part

1) *For Square Hole*

$$\text{Perimeter}= P = 2(5.1) + 2(5.3) + 2(2\pi \times 1)$$
$$= 19.083 \text{ mm}$$

2) *∅ 6.6 mm hole*

$$P = \pi \times d$$
$$= 6.6\pi = 20.73 \text{ mm}$$

3) *∅ 5.1 mm hole*

$$P = \pi \times d$$
$$= 5.1\pi = 16.022 \text{ mm}$$

4) *∅ 40 mm hole*

$$P = \pi \times d$$
$$= 40\,\pi = 125.66 \text{ mm}$$

Force required for individual punch:

a) For square hole

$$F = p \times t \times \tau_s$$
$$= 19.083 \times 2 \times 440$$
$$= 16793.04 \text{ N}$$

b) For three holes

$$F_1 = 3\times 16793.04$$
$$= 50379.12 \text{ N}$$

c) For hole having ∅ 6.6 mm

$$F = p \times t \times \tau_s$$
$$= 20.73 \times 2 \times 440$$
$$= 18242.4 \text{ N}$$

d) For three hole

$$F_2 = 3 \times 18242.4$$
$$= 54727.2 \text{ N}$$

e) For hole having ∅ 5.1 mm

$$F = p \times t \times \tau_s$$
$$= 16.022 \times 2 \times 440$$
$$= 14099.36 \text{ N}$$

f) For three hole

$$F_3 = 3 \times 14099.36$$
$$= 42298.08 \text{ N}$$

g) For central hole having ∅ 40 mm

$$F_4 = p \times t \times \tau_s$$
$$= 125.66 \times 2 \times 440$$
$$= 110580.8 \text{ N}$$

Total force required for piercing,

$$F = F_1 + F_2 + F_3 + F_4$$
$$= 50379.12 + 54727.2 + 42298.08 + 110580.8$$
$$= 257980 \text{ N}$$

Considering over load 25% of the cutting force

Net cutting force = 1.25×257980.12

$$= 330214.55 \text{ N}$$
$$= 330.21 \text{ KN}$$

PRESS TONNAGE:

$$P.T. = (F/9.81)$$
$$= (330.21/9.81)$$
$$= 33.66 \text{ Tons}$$

B. Elastic Recovery Allowance

We know that in metal working processes, the total deformation imparted to the workpiece will be sum of elastic deformation and the plastic deformation. We also know that elastic deformation is recoverable whereas plastic deformation is permanent. So, at the end of metal a working operation, when the pressure on metal is released, there is an elastic recovery by the material and the total deformation will get reduced little this phenomenon is called as "spring back". This phenomenon is of more importance in cold working operation, especially in forming operation such as bending etc. spring back depends upon the yield point strength of metal, the higher the yield point strength of a metal greater the spring back. The amount of spring back for forming operation is difficult to predict and cut and trial method is more satisfactory to account for it. To compensate for spring back, the cold deformation must always be carried beyond the desired limit by an amount equal to the spring back.[3]

Stock thickness in mm	ERA(mm)
Up to 0.25mm	0.0125
0.25 to 0.75mm	0.0250
Over 0.75mm	0.0500

Table 3: ERA With Respect To Stock Thickness [3]

Here stock thickness is over the 0.75mm, hence elastic recovery allowance (ERA) is to be 0.0500mm

C. Die Opening

The sidewalls of the die block opening should be provided with sufficient relief or taper so that the blanks drop clear through. The taper can either starts from the top surface itself or after repeated regrinding. With fully tapered die cavity design the die opening size increased after each regrinding. The straight land should at least be equal to the stock thickness and not less than 3 mm. The relief angle or the taper angle is taken as 1 degree to 2 degrees. [3]

Clearance(C) = $0.00032 \times t \times \tau_s$

$= 0.00032 \times 2 \times 440$

= 0.29 mm

1) *For hole having Ø 40 mm*

– Punch size = hole size + 2 ERA
 = 40 + 2(0.05)
 = 40.1 mm

– Hole size = Punch size + C
 = 40.1 + (0.29)
 = 40.3 mm

2) *For Square Hole*

– Punch size = hole size + 2 ERA
 = 6.52 + 2(0.05)
 = 6.62 mm

– Hole size = Punch size + C
 = 6.62 + 0.29
 = 6.91 mm

3) *For hole having Ø 5.1 mm*

– Punch size = hole size + 2= 5.1 + 2(0.05)
 = 5.2 mm

– Hole size = Punch size + C
 = 5.2 + 0.29
 = 5.49 mm

4) *For hole having Ø 6.6 mm*

– Punch size = hole size + 2 ERA = 6.6 + 2(0.05)
 = 6.7 mm

– Hole size = Punch size + C
 = 6.7 + 0.29
 = 6.9 mm

D. Angular Clearance

During the metal cutting operation some of the grain structure is stressed to a point below the elastic limit. When the cutting operation is completed a small amount of spring back occurs, causing the remaining hole in the stock material to reduce in diameter and gripped tightly. [3]

Strip thickness in mm	Angular clearance(in degrees)
0 to 2	¼
2 to 7.5	½
7.5 to 12	¾
Over 12	1

Table 4: Angular clearance [3]

Here stock thickness is below the 7.5 mm hence angular clearance is ½ degree on the die.

E. Die Button

The key point in die design is to make sure that no chaff gets clogged in the die hole. The reason for this is that the force for pushing down the chaff is quiet large and the force for punching the hole becomes considerably large. [4]

Design die buttons

1) *Ø 40 mm Die Button*

Die Button Thickness Perimeter = π × 40
 = 125.66 mm

Die Thickness = 25.4 + (125.66) × 0.015
 = 27.30 mm

2) *Ø 5.1 mm die button*

Perimeter = π × 5.1
 = 16.02 mm

Thickness = 25.4 + (16.02) × 0.015
 = 26.44 mm

3) *Ø 6.6 mm die button*

Perimeter = π × 6.6
 = 20.73 mm

Thickness = 25.4 + (20.73) × 0.015
 = 25.71 mm

4) *Square Hole Die Button*

Perimeter = $2(5.1) + 2(5.3) + 2(2\pi \times 1)$
 = 27.08 mm

Thickness = 25.4 + (27.08) × 0.015
 = 25.80 mm

F. Punch

The punch be a perfect mate to a die block opening the size of the working surface of the punch is obtained by subtracting the total clearance from the desires size of blank. The punch is usually provided with a wide flange or shoulder to facilitate mounting and prevent its deflection under load. The minimum length of punch should be such that it extends far enough into the die block opening to ensure complete shearing of blank. The punch length must also provide for the anticipated number of regrinds. The buckling tendency with decrease in the diameter.

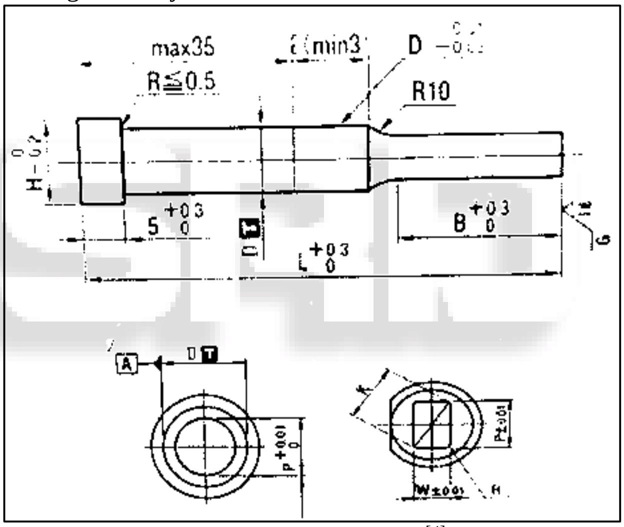

Fig. 2: Shape of punch [4]

1) *Top Piercing Punch Ø 40 mm*

We are taking standard punch from misumi India pvt. Ltd

Standard Dimension: Length of punch = 90 mm

S_{ut} = 370N/mm^2 (National / International Standards Specification & Material Thickness Chart)

Shear Stress = 0.6 × S_{ut}

= 0.6 × 370

= 220 N/mm^2

Shear force = π × d × t × τ

= π × 40 × 2 × 220

= 55.29 × 10^3 N

Buckling Force = $(\pi^2 \times E \times I) / (L_p)^2$

Where, E =Modulus of elasticity = 2.15 × 10^5 N/mm^2

I = moment of inertia

L_p= length of punch in mm

From this we had calculated length of punch

L_P = 2196.09 mm

Checking for buckling of force =F = $(\pi^2 \times E \times I) / (L_p)^2$

= 31.84 × 10^6 N

31.84 × 10^6N ≥ 55.29 × 10^3 N ……………. Design is safe

2) Top Piercing Punch Ø 5.1 mm

We are taking standard punch from misumi India pvt. Ltd
Standard Dimension: Length of punch = 90 mm
S_{ut} = 370N/mm^2 (National / International Standards Specification & Material Thickness Chart)

– Shear Stress = $0.6 \times S_{ut}$
$= 0.6 \times 370$
$= 220$ N/mm^2

– Shear force = $\pi \times d \times t \times \tau$
$= \pi \times 5.1 \times 2 \times 220$
$= 7.049 \times 10^3$ N

– Buckling Force = $(\pi^2 \times E \times I) / (L_p)^2$
Where, E =Modulus of elasticity = 2.15×10^5 N/mm^2
I = moment of inertia
L_p = length of punch in mm
From this we had calculated length of punch
L_p = 16290 mm

– Checking for buckling of force =F = $(\pi^2 \times E \times I) / (L_p)^2$
$= 8.69 \times 10^3$ N
10^3 N $\geq 7.049 \times 10^3$ N ……………. Design is safe

3) Top Piercing Punch Ø 6.6 mm

We are taking standard punch from misumiIndiaPvt. Ltd
Standard Dimension: Length of punch = 90 mm
S_{ut} = 370N/mm^2 (National / International Standards Specification & Material Thickness Chart)

– Shear Stress = $0.6 \times S_{ut}$
$= 0.6 \times 370$
$= 220$ N/mm^2

– Shear force = $\pi \times d \times t \times \tau$
$= \pi \times 6.6 \times 2 \times 220$
$= 9.123 \times 10^3$ N

– Buckling Force = $(\pi^2 \times E \times I) / (L_p)^2$
Where, E =Modulus of elasticity = 2.15×10^5 N/mm^2
I = moment of inertia
L_p = length of punch in mm
From this we had calculated length of punch
L_p = 147.18 mm
90 mm <147.18 mm

– Checking for buckling of force =F = $(\pi^2 \times E \times I) / (L_p)^2$
$= 24.40 \times 10^3$ N
10^3 N $\geq 9.123 \times 10^3$ N ……………. Design is safe

VI. SQUARE PUNCH

We are taking standard punch from misumiIndiaPvt. Ltd
Standard Dimension: Length of punch = 90 mm

– Square punch = 5.1×5.3

– Perimeter of fillet = $2 \times \pi \times R$
$= 2 \times \pi \times 1$
$= 6.28$ mm

Perimeter of remaining sides = $(5.1 - 2) \times 2 + (5.3 - 2) \times 2$
=12.8 mm
Total Perimeter = 19.08 mm

– Shear Force = $P \times t \times \tau$
$= 19.08 \times 2 \times 220$
$= 8395.2$ N

– Buckling force = $(\pi^2 \times E \times I) / (L_p)^2$
L_p = 121.68 mm
90mm < 121.68mm ………………..Design is safe

A. Design of Auxiliary Pillar

The Die structure is used very often in product formation applications that require relatively accurate shapes. In accurate formation, very often the formed shape becomes finely detailed, and since even the punch shape becomes weak, one would desire to strengthen the punch. In order to guide the tip of the punch, it is necessary that the stripper maintains horizontally and only carries out up and down movement; a stripper guide was placed between the stripper and the punch plate. [4]

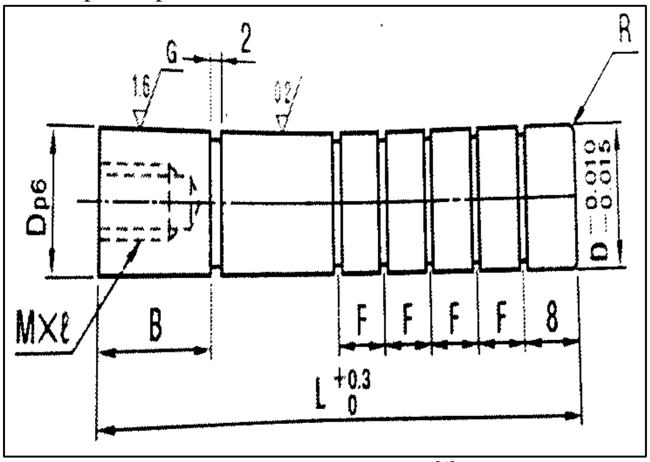

Fig. 3: Auxiliary pillar[4]

From standard data,

Parameter	Dimension(mm)
D	22.5
F	10
L	105.5
R	3
B	30

Table 5: Auxiliary pillar specification

VII. OBSERVATIONS AND RESULT

According to previous method of manufacturing of component, we get some results and these results are compared with new method established by us. This comparison is shown below:

SR NO	PARAMETER	BEFORE DIE DESIGN	AFTER DIE DESIGN
1	Labour required	4	1
2	Machine required	4	1
3	Machining time	5min (except M.H.)	1
4	Material handling time	4 min	0 min
5	Qty. produced/hr	Approx 100	Approx 100
6	Rejection	7-8/100	2-3/100

Table 5:

VIII. CONCLUSION

Previously, the component was machined with conventional piercing tool. The operation requires 4-5min. for piercing all the holes in the component. Various alternatives method such as gang drill, press working are evaluated in this work

in order to minimize process time with improvement in process characteristics and minimizing rejection. This machining time can be reduced with by piercing the holes with the press working with the help of mechanical press.
Thus, the project model is a concept that can be used in the press working for the benefits like:

- Cost saving
- Time saving
- Increasing rate of production
- Flexibility in production
- Making the work easier and aesthetic
- Easy forming and cutting.

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