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Tool and Die Design for a Piercing Operation of Strip

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ABSTRACT

The sheet-metal parts have already replaced many expensive cast, forged, and machined products in today's practical and cost-conscious world. The factor is obviously the relative cheapness of these methods, or otherwise mass-produced parts, as well as greater control of their technical and aesthetic parameters. Press working is generally defined as a chip less manufacturing process by which various components are made from sheet metal. To produce a particular component in large quantity press tools are used. Metals having thickness less than 6mm is generally considered as strip. Metals having thickness greater than 6mm is considered as plate. In this work, According to organization need that the required strip part should have semi circular ends at both the ends. So in this work an attempt is made on to design the die for the strip to meet the actual operations requirement, materials, and calculations involved in it. The theoretical calculations for die are done and the parts are drawn with the help of software. The analysis of these parts is done on Ansys software and the results are taken.

Keywords : Die, Force, Press, Punch, Stress

I. INTRODUCTION

Press working is generally defined as a chip less manufacturing process by which various components are made from sheet metal. For this the machine used for press working is called press. Punch/punches are equipped with suitable ram and a die block is attached to the bed. Stamping is produced by the downward stroke of the ram when the punch moves towards and into the die block. The punch and the die block assembly are specifically termed as die set and the operations are usually done at room temperature by press working. These press tools are used to produce a particular component with large quantity, out of sheet metals where particular component achieved depends upon press tool construction and its configuration. Metal forming is one of the manufacturing processes which are almost chip less. For carrying out these operations mainly presses and press tools are used. These operations include deformation of metal work pieces to the desired shape and size by applying force or pressure. Mass production work facilitates by presses and press tools.

II. PROBLEM STATEMENT

[A]According to the part design the strip should have semi circular ends at both the ends. So, the aim is to find the solution to do this operation.

[B] Objective:-

1. The operation should take the time in between 1/2 to 1 ½ minute.
2. To achieve the better quality of product after the operation
3. To increase the productivity

2.1Principle of metal cutting (mechanics of shearing)

Shearing process is that cutting of sheet metal with press work. The gap between the punch and die called as clearance but punch is same shape of the die opening. When punch apply pressure on metal strip then material enters into die cavity at that time material is subjected to both tensile and compressive stresses when it crosses elastic limit then after 1/3rd of material thickness then this material get fracture. This only possible by providing optimum clearance between punch and die. The importance of clearance as if there is no optimum clearance then instead of fracture material will get bend. Considering this there is need to provide optimum clearance between punch and die.

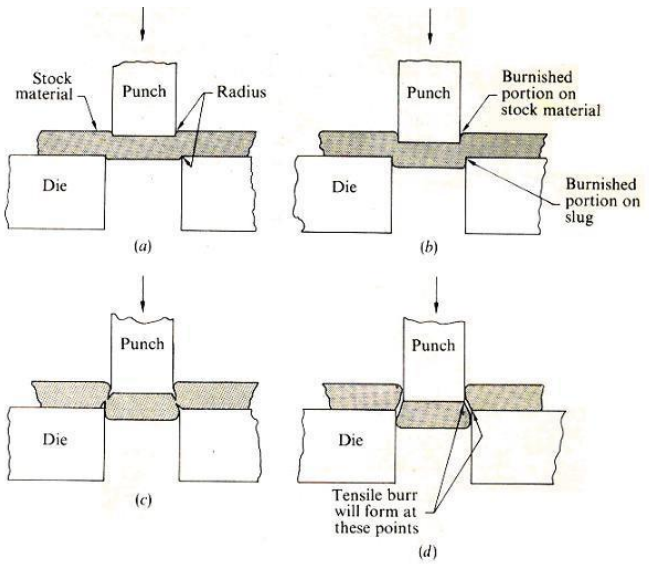

Fig. No.1:- Mechanics of Shearing

III. DESIGN OF DIE

The design of the die block depends on the workpiece size and the thickness, although the contour of the workpiece and type of die may be influential at times. While designing the force or press capacity should be considered. The design calculations are as given below:

As the size of the strip or workpiece is L=114mm, W= 20mm, T= 3mm, so considering this size one should design as

- Force Calculations:-

Cutting Force= Shear Area x Shear Strength x Thickness of material

= (35.867 x 30.22 x 3)

= 3251.703

=3.251 Tones

≅ 3.5 tones

Press capacity is increased by 20% hence press capacity is 1.2 x 3.5 = 4.2 tones

- Die Block Size:-

The die assembly including the stripper and all bottom elements are mounted on the bottom plate. The bottom plate gives cushioning effect to the die and provides enough space for the tool to be clamped to the press bed. There may be an opening in the base plate, which allows the blank, or slug to fall and clear off from the tool.

It is usually made from D2 tool steel material and is hardened to 60-62 HRC.

Die Area: It is the available surface area for mounting punch and die components (press tool) in the press. The die area on the die shoe should be at least 6 mm larger all around the die set.

In present the available die area is 7225 mm^2.

Die block thickness= $\sqrt[3]{cutting\ force}$

= $\sqrt[3]{3.5}$

= 1.518 cm

= 15.18 mm

≅18 mm

- Clearance :-

In piercing operation the clearance is kept on die.

Die Size= Punch Size + 2C

Where C is clearance should be 3 to 8% of material thickness

Clearance = 033x 3

= 0.495

≅ 0.5 mm i.e. 0.25 mm / side

- Die Size:-

For Piercing operation,

Punch size = Actual Size of area

= 35.867 mm^2

Die Size = Punch Size for pierce + 2x clearance

= 35.867 + 2x 0.25

Die Size = 36.367 mm^2

- Plate Thickness:-

i) Bottom plate Thickness= 1.75x die plate thickness

= 1.75 x 18

= 31.5 mm

ii) Top plate thickness = 1.25 x die plate thickness

= 1.25 x 18

= 22.5 mm

iii) Punch Holder Plate Thickness= 0.75 x die plate thickness

= 0.75 x 18

= 13.5 mm

iv) Stripper plate thickness= 5mm (as material thickness is 3mm)

- Screw Dimensions:-

As the force acts in vertical direction the force exerted is assumed to be 10% of the shear force applied

10% of shear force = 10% of 3500 kg

= 350 kg

Force= Stress x Area

350= 35(for high strength steel) x (3.14/4) x d_c^2

d_c= 3.56 mm ≅ 5 mm

Stripping Force = 3% of 3500 kgf= 105 kgf

- No. of bolts Required:-

$$\text{Stripping Force} = \frac{\pi}{4}\, d_c 2 \times n \times \textit{shear strength of bolt}$$

Where, n= no. of bolts

Shearing strength of bolt= 55 to 56 kg/mm^2(for mild steel)

105 x 100 = 0.78539 x 5^2x n x 56

= 7.54≅ 8

Bolts required are 8

- Total length of punch:-

$L_p = t_d + t_s + t_h + S + b$

Where, S= Sharping Allowance

b= min. distance between stripper & punch

L_p= 18 + 5 + 13.5 + 1.5 + 18

= 56 mm

OR

F= 0.7 t L (UTS)

3500 = 0.7 x 3 x L x 30

= 55.56 mm ≅ 56 mm

DEFLECTION AND STRESS CALCULATION

A. Die block

For doing the stress calculations assuming that the die block (die plate) is considered to be as fixed beam. The deflection is calculation using the strength of material formula for fixed supported beam.

∴Deflection, $\delta = \frac{FL^3}{192EI}$

Where F= 80% of cutting force

= 0.8× 34875

= 27900 N

L =78.50 mm, E = 2×10^5 N/mm^2

$I = \frac{bh^3}{12}$

$= \frac{78.50 \times 22.5^3}{12}$

= 7.451×10^4 mm^4

Where b = 78.50 mm, h = 18 mm

$\therefore \delta = \frac{27900\times78.50^3}{192\times2\times10^5\times7.451\times10^4}$

= 4.71701×10^{-3} mm

Stress, $\sigma = \frac{F}{A}$

$= \frac{27900}{78.50 \times 18}$

= 19.7452 MPa

B. Top plate

For doing the stress calculations assuming that the bottom plate is considered to be on parallels.

Deflection $\delta = \frac{FL^3}{48EI}$

Where F = 80% of cutting force

= 0.8× 34875

= 27900 N

L = 78.50 mm, E = 2.1×10^5 N/mm^2

$I = \frac{bh^3}{12}$

$= \frac{78.50 \times 18^3}{12}$

I = 3.8151×10^4 mm^4

Where b = 78.50 mm, h = 22.5 mm

$\therefore \delta = \frac{27900\times78.50^3}{48\times2.1\times10^5\times3.8151\times10^4}$

=$3.50951\text{x } 10^{-4}$ mm

Stress, $\sigma = \frac{F}{A}$

$= \frac{27900}{78.50\times22.5}$

= 15.7962 MPa

C. Bottom plate

For doing the stress calculations assuming that the bottom plate is considered to be on parallels.

Deflection $\delta = \frac{FL^3}{354EI}$

Where F= 80% of cutting force

= 0.8×34875 N

L= 78.50 mm, E= 2.1×10^5 N/mm^2

$I = \frac{bh^3}{12}$

$= \frac{78.50 \times 15^3}{12}$

I = 2.207812×10^4 mm^4

Where b = 78.50mm, h = 15mm

$\therefore \delta = \frac{27900\times78.50^3}{354\times2.1\times10^5\times2.207812\times10^4}$

=$8.2229 \text{ x } 10^{-3}$ mm

Stress, $\sigma = \frac{F}{A}$

$= \frac{27900}{78.50\times15}$

= 11.2829 MPa

D. Stripper plate

For doing the stress calculations assuming that the fixed stripper plate to be considered as a fixed beam support. Using the strength of material formula the fixed stripper plate deflection and stress is calculated.

Deflection $\delta = \frac{FL^3}{192EI}$

Where F=10% to 20% of cutting force

= 0.1×34875

= 3487.50 N

L = 78.50mm, E = 2.1×10^5 N/mm^2

$I = \frac{bh^3}{12}$

$= \frac{78.50 \times 5^3}{12}$

I = 0.8177×10^4 mm^4

Where b = 78.50mm, h = 5mm

$\therefore \delta = \frac{3487.50\times78.50^3}{192\times2.1\times10^5\times0.8177\times10^4}$

=$5.116 \text{ x } 10^{-3}$ mm

Stress, $\sigma = \frac{F}{A}$

$= \frac{3487.50}{78.50\times5}$

= 8.8851 MPa

E. Guide pillar

The diameter of guide pillar is

=1.1 to 1.3 × thickness of die plate

= 1.1×18

=20mm >15 mm.

∴Hence the guide pillars diameter is safe dimension. Assuming that the guide pillars as a cantilever beam vertical load. So guide pillar is as consider as a one side is fixed and other end is free column construction, From strength of materials for column construction of one end is fixed and other end is free type ,

Clipping load as, $P = \frac{\pi^2 EI}{4L^2}$

Where $E = 2.1\times10^5$ N/mm²

$I = \frac{\pi d^4}{64}$

=7853.98 mm⁴

d = 20mm, L=60mm

$P = \frac{\pi^2 \times 2.1\times10^5 \times 7853.98}{4\times60^2}$

=11304.36 Pa

Punch

Deflection $\delta = \frac{FL}{AE}$

$= \frac{27900\times52}{214.938\times2.1\times10^5}$

=0.03214 mm

Stress, $\sigma = \frac{F}{A}$

$= \frac{27900}{214.938}$

σ =129.8048 N/mm²

Punch material D2 is having the compressive strength as 2200 N/mm² and

∴ The stress induced which is less than the allowable strength.

DIE MODELLING:

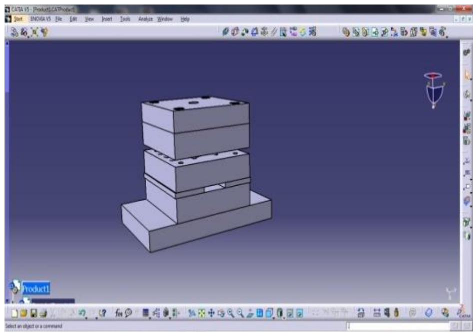

Fig.No.2: Die Assembly

II. FINITE ELEMENT ANALYSIS

The analysis of this die part is done in the ANSYS software. This gives the comparison between analytic and numerical value.

A. Modeling:-

The modeling of die parts is carried in CATIA Software. This model parts are imported to ANSYS software to do the analysis of these parts.

B. Material Properties:-

TABLE 1: MATERIAL PROPERTIES OF DIE PARTS

Sr. No.	Part Name	Modulus of elasticity [N/mm²]	Ultimate compressive strength [N/mm²]	Poisson's ratio	Density [Kg/mm³]
1	Die Block	$2.1\text{X } 10^5$	240	0.3	7800
2	Bottom Plate	$2.1\text{X } 10^5$	240	0.3	7800
3	Top Plate	$2.1\text{X } 10^5$	240	0.3	7800
4	Stripper Plate	$2.1\text{X } 10^5$	240	0.3	7800
5	Punch	$2.1\text{X } 10^5$	2200	0.394	7600

C. LOADS:-

The Load as 80% of cutting force as vertical for function elements like top plate, bottom plate and die plate are applied on z axis in positive direction of magnitude. And for punch like piercing punch the load is applied on z axis positive direction of magnitude as calculated cutting force of that operation as compressive load on surface.

D. ANALYSIS

The Load as 80% of cutting force as vertical for function elements like top plate, bottom plate and die plate are applied on z axis in positive direction of magnitude. And for punch like piercing punch the load is applied on z positive direction of magnitude as calculated cutting force of that operation as compressive load on surface.

Die Block (Die Plate):

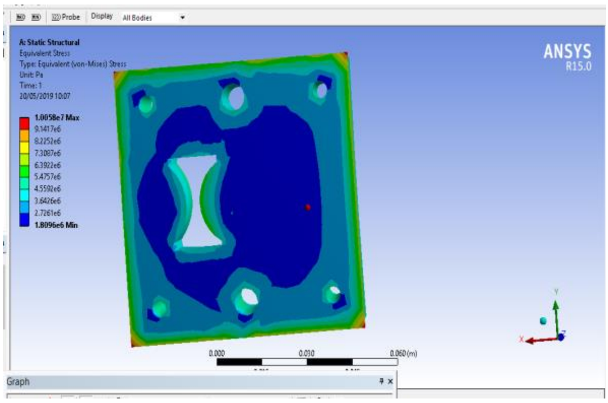

Fig. No.3: Equivalent Stresses in Die Block (Die Plate)

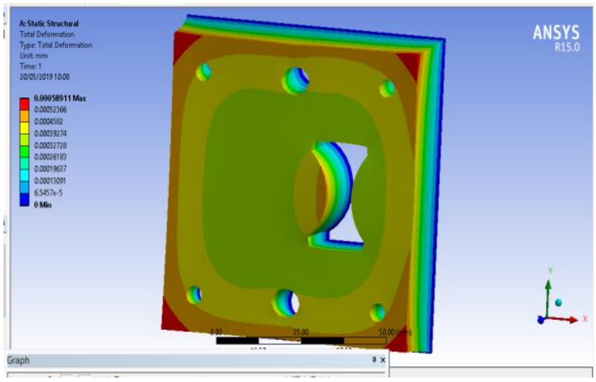

Fig.No.4: total deformation of Die block (Die Plate)

TOP PLATE:

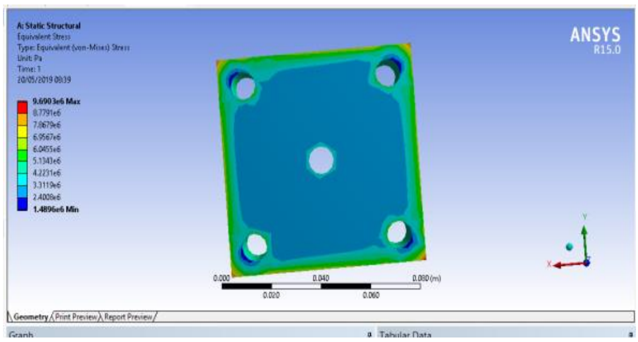

Fig.No.5: Equivalent Stresses in Top Plate

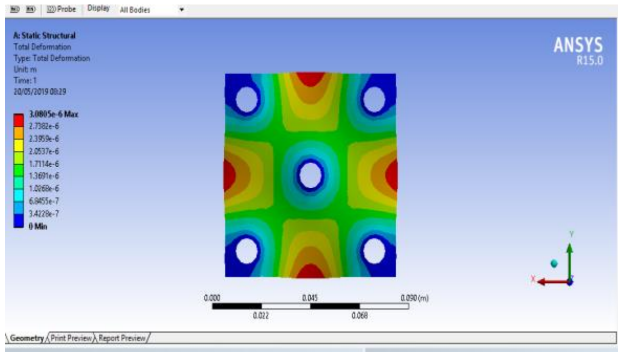

Fig.No.6: Total Deformation in Top Plate

BOTTOM PLATE:

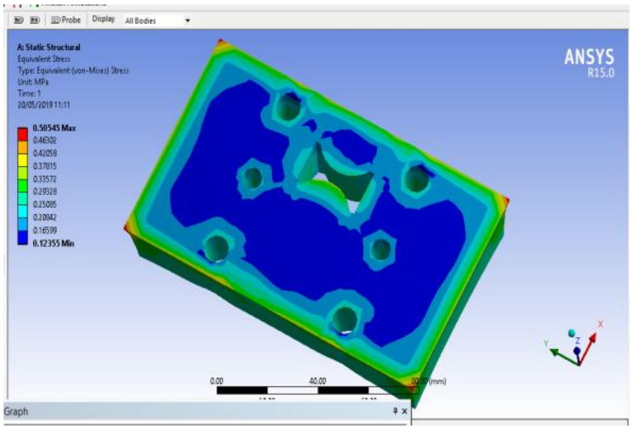

Fig.No.7: Equivalent Stresses in Bottom Plate

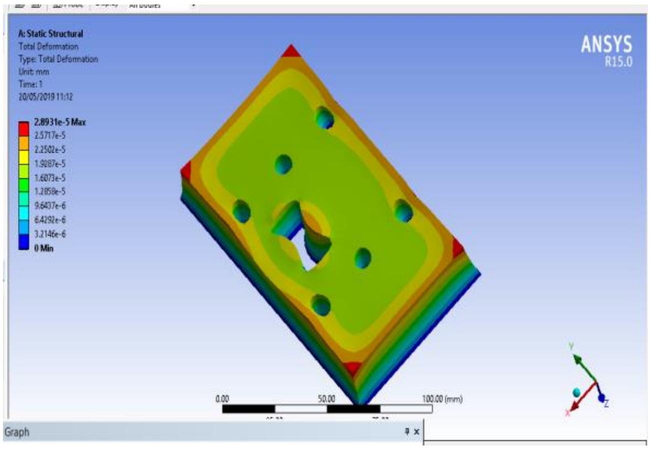

Fig.No.8: Total Deformation of Bottom Plate

STRIPPER PLATE:

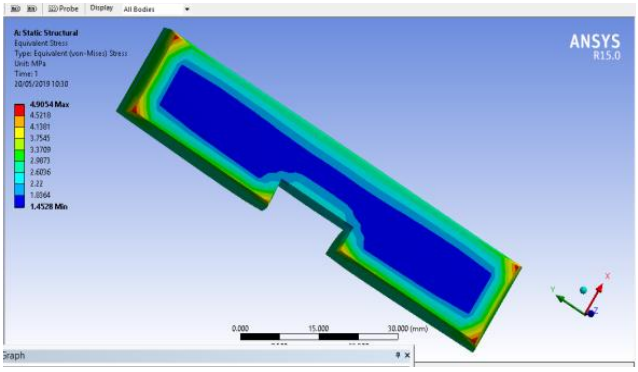

Fig.No.9: Equivalent Stresses in Stripper Plate

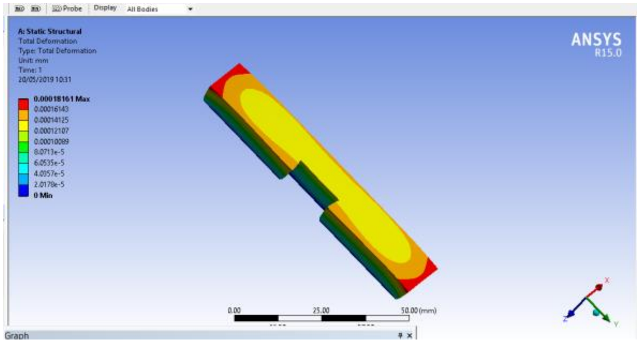

Fig.No.10: Total Deformation in Stripper Plate

PUNCH:

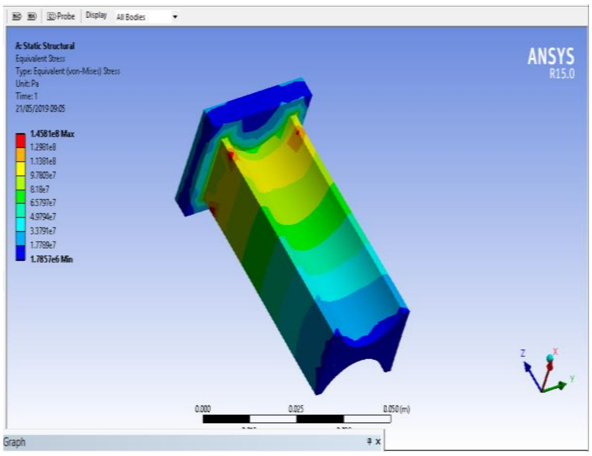

Fig.No.11: Equivalent Stresses in Punch

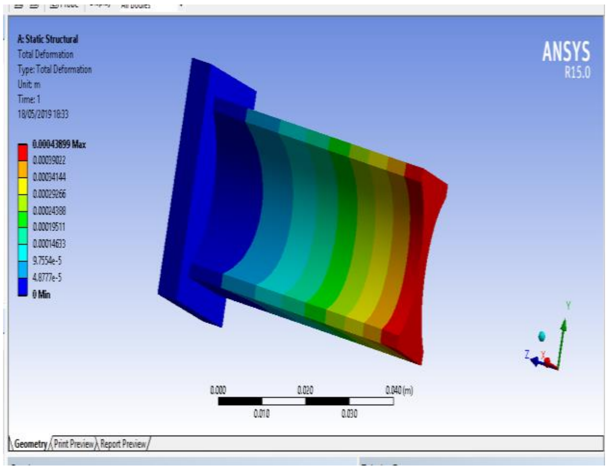

Fig.No.12: Total Deformation in Punch

III. RESULT AND ANALYSIS

TABLE 2: THEORETICAL AND ANALYTICAL RESULT

Sr. No.	Description	Calculated Result		Analysis Result	
		Deflection (mm)	Stress (MPa	Deflection (mm)	Stress (MPa
1	Die Block	0.00471	19.7452	0.004045	10.058
2	Bottom Plate	0.00822	11.2829	0.000289	5.0543
3	Top Plate	0.00350	15.7962	0.000308	9.6082
4	Stripper Plate	0.00511	8.8851	0.000781	4.4054
5	Punch	0.03214	129.8048	0.001859	145.81

TABLE 3: ACTUAL RESULTS

Sr. No.	Description	Outcome
1	Time Required To Do The Operation For 1 Workpiece	50 Sec.
2	Time Required For 100 Workpiece	110 Min.
3	Workpieces Completed In 1 Hr.	54
4	Die Setting Time	3 ½ Min.

IV. CONCLUSION

From this work, the design, materials and calculations for die are completed. Finite element method (FEM) analysis is done for piercing punch, bottom plate, top plate and die plate. The analytical and FEM result of these components of the die is is within the acceptable range. To check the appropriateness of the design of each component all the results of stress and displacement which were used as a parameter shows that it is within the allowable limit. The results obtained from ANSYS, the stress values for all parts are less than the respective yield stress value of the material. So, the designed die parts are safe under the given loading conditions. The deflections of all the parts during operation are kept below 0.025mm as per the recommendation of die manufacturer. The die setting for one time almost requires 3min. 30sec.The time required is achieved as about 50 seconds for one piece. The parts completed in 1hr are about 54 pieces.

V. ACKNOWLEDGMENT

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