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Design and Analysis of Progressive Die for an Industrial Part

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Abstract: ***Progressive die performs a series of operations in a single die at two or more workstations. There is given finish part at each stroke of press machine. Design and development of progressive die is one of the important phase in sheet metal manufacturing. The small error at any work station can induce heavy manufacturing losses through die failure, part geometry distortion and production risk. This research deals with designing a progressive die, simulating the blanking and piercing process. By using this die we can produce accurate component. In this work authors have designed a progressive die which have two work stations. The former operation is piercing and is followed by blanking. It is the material removing tool. This design tool is used in Mungi Engineers Pvt. Ltd. for manufacturing the part of differentiate gear box casing cover. There is the no of workstation gives the no of operation formed on the part. Required modeling is done with CATIA.***

Keywords: Progressive die design, differential gear box, blanking and piercing, Mungi Engineers.

1. Introduction

The die which performs two or more operation subsequently in a single stroke is known as a progressive die. This die is used for producing a finish part in a single stroke. Compound die is also use for this; but its construction more complicated than progressive die. In progressive die the strip is feed from one end and finish part take out from other end. There the strip pass over different workstations and the related operations are performed there over it.

In this paper the progressive die have two work stations. First workstation performs piercing operation and second one performs the blanking operation. At first station in piercing there two holes are pierced there. These holes are used for locating the strip at the blanking operation. For locating the strip there locating pins are used on die surface and pilot pins are used on punch surface.

Main objective of this paper is to design a progressive die, prepare a model of die and analyze the model using FEA technique.

2. Material for Die Components

The whole press tool is not required high strength material. Because all parts of press tool does not involve in operation. Here the more important members are die, punch, and hitting pad. These parts are required more strengthful material. The main principle while selecting the material for that part is given as;

i. The tool material have more wear, abrasive or adhesive resistance than the part material. Also its friction force is more than part material.
ii. The hardness of material is more than the part material.
iii. Fatigue, shear, compressive strength is more than part material strength and plastic or elastic deformation strength is less than the part material strength.

The material of part is mild steel. So here D2 type of steel is used for punch and die. It has more hardness and strength than the mild steel. Also OHNS, EN8, EN12 materials are used where the more wear and deformation occur; such as guide pillar, setting ring, stacking ring, backup plate and etc.

3. Design of Progressive Die

Top Plate, bottom plate and Guide pillars are the most basic part of die set and these two plates are guided by the guide pillars. This alignment is done here for improving accuracy, part quality, die life and reduce the set up time. The lower plate support the die, die housing, raisers, etc. And the top plate supports the punch, punch backup plate, Guide pillar bush, etc.

3.1 Die Clearance

Die clearance is depend on the part material property. If the material is ductile in nature then the clearance is small and for brittle material it is large clearance. If the clearance is given in reverse then there for ductile material it pass through die means here it draw from die instead of cutting. And in ductile material it damages the cutting edges of punch and die. The die clearance for mild steel is 2.5% or 5% of thickness per side.

C = 2.5 % of thickness
= (2.5/100) x 6 = 0.15 mm
Or C = 5% of thickness
= (5/100) x 6 = 0.3 mm

Large clearance increases the tool life. So here take 5% of thickness per side.

4.1 Force Analysis

- **Shear Force:-**

The shear stress can be given as;
Fs = L.S. x t x Ʈ
L.S.- Total Shear stress
t- Part Thickness
Ʈ- Shear strength of part material

At First workstation of progressive die there are two holes are pierced by piercing operation. So the shear force for piercing these holes is given by;

Fs = L.S. x t x Ʈ

Here; L.S. = 2 x Perimeter of hole
= 2 x π x dia. Of hole
= 2 x 3.1415 x 10 = 62.832 mm
t = 6 mm
Ʈ = 392.4 N/mm2
∴ Fs1 = 62.832 x 6 x 392.4
= 147.93 kN

At second workstation there is one blank is produced by blanking operation. So the shear force for blanking operation is given as;

Fs = L.S. x t x Ʈ

Here; L.S. = Perimeter of Blank
= 494.78 mm
t = 6 mm
Ʈ = 392.4 N/mm2
∴ Fs2 = 494.78 x 6 x 392.4
= 1165.43 kN

Total shear stress is given as;
T.S.F. = Fs1 + Fs2
= 147.93 + 1165.43 = 1313.36 kN

- **Stripping Force**

Stripping force is require to remove the strip from the punch after the cutting operation. It is given as 10% of Total shear force.

Stripping Force = 10% of total shear force
= 0.1 x 1313.36= 131.34 kN

- **Total Force:-**

Total force require for cutting is given as;
T.F. = T.S.F. + Stripping Force
= 1313.36 + 131.34
= 1444.70 kN

The factor of safety is consider to be 20% more.
∴ Requirement of press capacity is = 120% of Total Force
= 1.2 x 1444.7
= 1748.55 kN
= 176.72 Tone

But the existing suitable press machine capacity for the above requirement is 200 Tone.

4.2 Design Of Die Parts

- **Die Block:-**

The bottom assembly is the female part of the punch tool. The most important part of bottom assembly is die block. The cutting edge is given to the die block. The land is also provided on the die block. This land is provided for the proper cutting. The land for the die is given by the 1.5t.

For the first station here we select the two die buttons for the piercing operation. These are standard. It is taken from the MISUMI std. book. The selection is depend on the dimension and cost of it. From the requirement here MHD 20-35 P10.80 type of die buttons are used.

At second workstation for blanking operation there the thickness of die block is given by the formula;

$$Td = \sqrt[3]{shear\ force}$$

Where;
Td :- Thickness of die plate (in mm).
Shear force:- For blanking operation in kg.

At the blanking operation;
Shear Force = 1165.5 kN = 118.81 Tones.
∴ thickness of die block is;

$$Td = \sqrt[3]{118.81 \times 10^3}$$
$$= 49.16 \text{ mm} \approx 50 \text{ mm.}$$

∴ The stress in the die block is given as;

$$\sigma = \frac{force}{surface\ \ area} = \frac{1165.5 \times 10^3}{240 \times 200} = 24.30 \text{ N/} mm^2$$

The allowable strength of D2 material is 2000 N/ mm^2. And the calculated value is 24.30 N/ mm^2 is less than allowable strength. So the design of die block is safe.

- **Bottom plate**

The bottom plate is the base of lower assembly. There is die block, raiser, guide pillars are mounted on the bottom plate. This bottom plate is used to clamp the lower assembly of press tool over the bolster plate by using the clamping devices. The bottom plate is made from the mild steel material.

Thickness of bottom plate is given as;

T = 1.5 Td
= 1.5 x 50 = 75 mm.

The stress occur on the plate is given by;

$$\sigma = \frac{force}{surface\ \ area} = \frac{1444.7 \times 10^3}{600 \times 550} = 4.38 \text{ N/} mm^2$$

Allowable limit is 410N/ mm^2. So the design is safe here.

- **Punch**

Punch is made part of the press tool. The cutting operation is carried out here. So the material required for manufacturing the punch is harder than the part material. So d2 material is used for the punch manufacturing. The hardness of this material is 52-56 HRC.

The travel of punch is given by the following formula,
Travel = Entry in Stripper Plate + Entry in die + Part Thickness.
= 5 + 3 + 6 = 14 mm

Thickness of punch is depend on the punch alignment with stripper plate, compressed length of spring, and with punch

travel. So here we take 71 mm as punch thickness. The clearance is given on punch in blanking operation.
For the piercing punch there is its length is larger than its diameter. So the effect of length occurs on the performance on overall performance. The critical force acting on punch is given by Euler's formula such as;

$$\text{Fcri} = \frac{2\pi^2 EI}{l^2}$$

Where;
E – Modulus of Elasticity (For D2 material 2.1 x 10^5)
I – Minimum moment of inertia for punch.

$$I_{min} = \frac{\pi D^4}{64} = \frac{\pi \times 10^4}{64} = 490.87 \text{ mm}^4$$

The critical maximum length of punch is

$$l_{max} = \sqrt{\frac{2\pi^2 EImin}{P}}$$

Where;
P - load acting on a punch (73.97 kN)
∴ l_{max} = 165.85 mm
This is the maximum length which performs work safely.
Here I take the length of punch as l = 90 mm.
Area of punch is;

$$A = (\pi \times D^2/4) = 78.54\text{mm}^2$$
$$r_g = (I/A)^{0.5} = 2.5$$

Slenderness ratio (SA) = (L_e/r_g) = 72

Transition slenderness ratio (TSR) = $\sqrt{\frac{2\pi^2 E}{Syc}}$

S_{yc} = 2000 N/mm^2 (For D2 material.)

∴TSR = 45.52

There is buckling force is calculated by Euler's formula. Because S.R. is greater than T.S.R..

$$F_{cri} = \frac{\pi^2 EI}{L^2} = 171731.12 \text{ N} > 73965 \text{ N}$$

Applying load is less than critical load; so design is safe here.

- **Spring Selection:-**

The spring is used here for giving the stripping force and also for holding the blank. So this sprig selection is given by the stripping force.

The stripping force is 147.93 kN required here.

There for the spring is selected from the PAWAN Std. book. The PAWAN is the spring manufacturing company. They give their standards. By referring this here requirement is 147.93 kN force and 14 mm travel which is fulfill by PYE 64x50 type of spring. The specification of this spring is given as;

Load caring capacity of spring = 11.35 kN
Travel of this spring = 16 mm.
There for number of spring (N)

$$N = \frac{stripping\ \ load}{load\ \ carring\ \ capacity\ \ of\ \ spring} = \frac{147.93}{11.35}$$

= 14 Springs.

- **Top Plate:-**

The top plate is the base of upper assembly. There is punch, springs, guide pillars bush are mounted on the top plate. This top plate is used to clamp the upper assembly of press tool over the bolster plate by using the clamping devices. The top plate is made from the mild steel material.
Thickness of top plate is given as;

T = Td
= 50 mm.

The stress occur on the plate is given by;

$$\sigma = \frac{force}{surface\ \ area} = \frac{1444.7\times10^3}{600\times550} = 4.38 \text{ N}/mm^2$$

Allowable limit is 410N/mm^2. So the design is safe here.

- **Guide Pillar:-**

These are used here for the alignment of upper assembly with lower assembly. It guides the punch through the die. These also manufacture by harden material to resist the buckling effect.
There guide pillar diameter is given by;

D = 0.6 x Td
= 0.6 x 50
= 30mm ≈ 32 mm.

For the guide pillar there is its length is larger than its diameter. So the effect of length occurs on the performance on overall performance. For Guide pillar manufacturing St-42 material is used.

E – Modulus of Elasticity (For St-42 material 2.1 x 10^5)
I – Moment of inertia for pillar.

$$I = \frac{\pi D^4}{64} = \frac{\pi \times 38^4}{64} = 102353.87 \text{ mm}^4$$

Here take the length of pillar as l = 160 mm.
Area of punch is;

$$A = (\pi \times D^2/4) = 1134.11\text{mm}^2$$
$$r_g = (I/A)^{0.5} = 9.5 \text{ mm.}$$

Slenderness ratio (SA) = (L_e/r_g) = 33.68

Transition slenderness ratio (TSR) = $\sqrt{\frac{2\pi^2 E}{Syc}}$

S_{yc} = 860 N/mm^2
∴TSR = 112.08
There is buckling force is calculated by Johnson's formula. Because T.S.R. is greater than S.R..

$$F_{cri} = A\left(S_y - \frac{Sy^2 Le^2}{\pi^2 4Er_g^2}\right) = 946635.66 \text{ N} > 722350 \text{ N}$$

Applying load is less than critical load; so design is safe here.

4. Analysis and Results

The analysis is done for die by using the ANSYS software. This gives the comparison between analytic and numerical value. Part is drawn in CAD software and this part is call to ANSYS in (.igs) format. For CAD part there is CATIA software is used.

- **Analysis Result:-**

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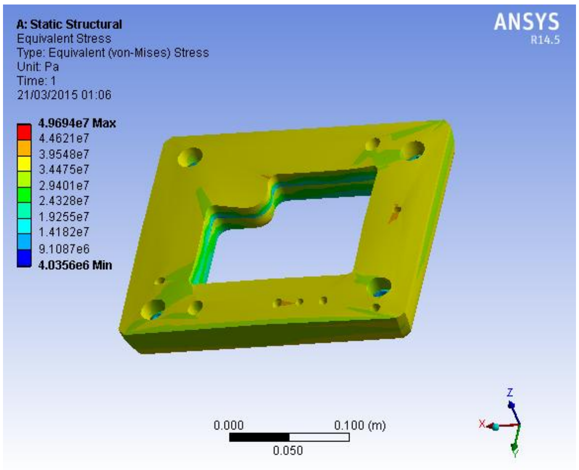

Figure 1: Stress Distribution for Die Block

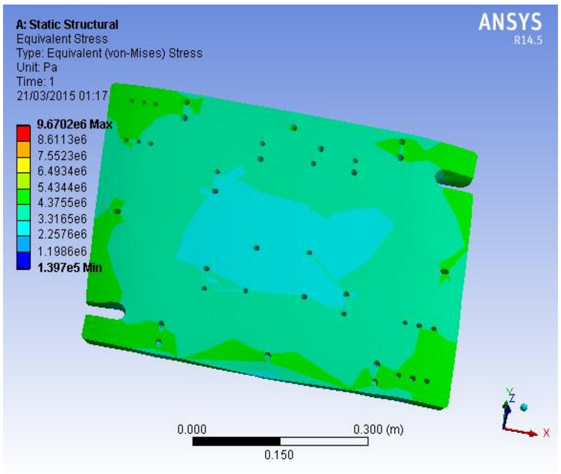

Figure 2: Stress Distribution for bottom plate

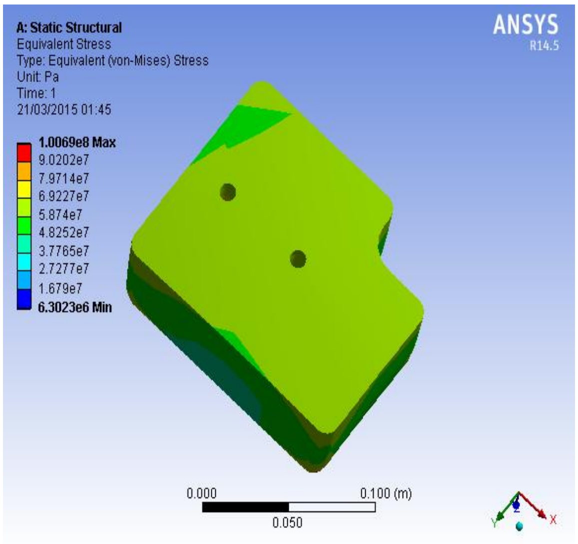

Figure 3: Stress Distribution for Punch Block

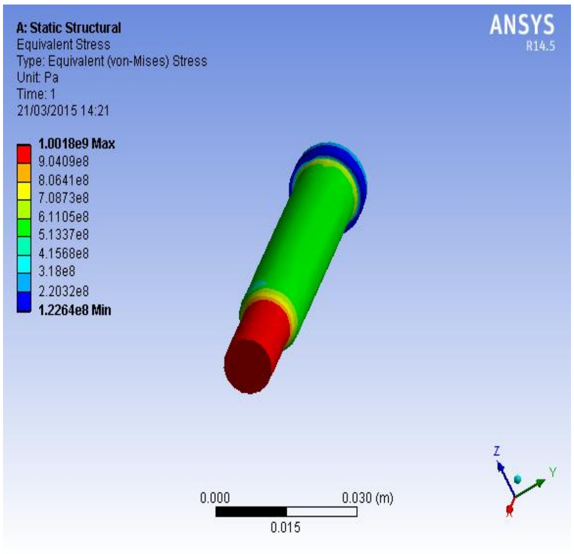

Figure 4: Stress distribution for Pierce Punch

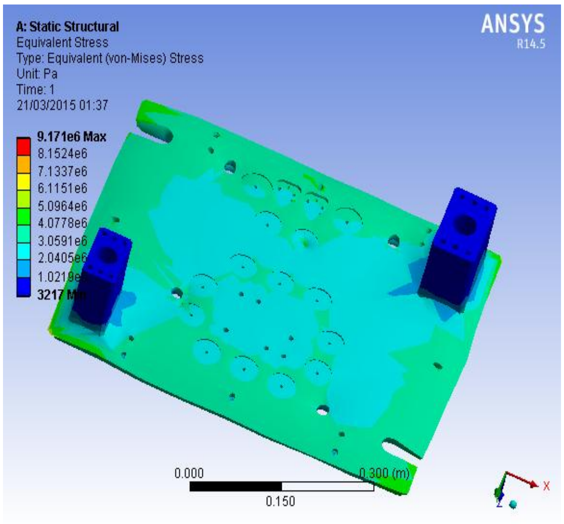

Figure 5: Stress Distribution for Top Plate

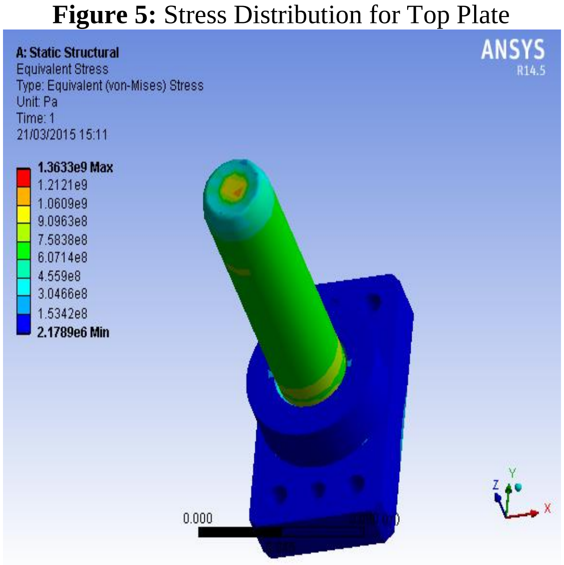

Figure 6: Stress distribution for Guide Pillar

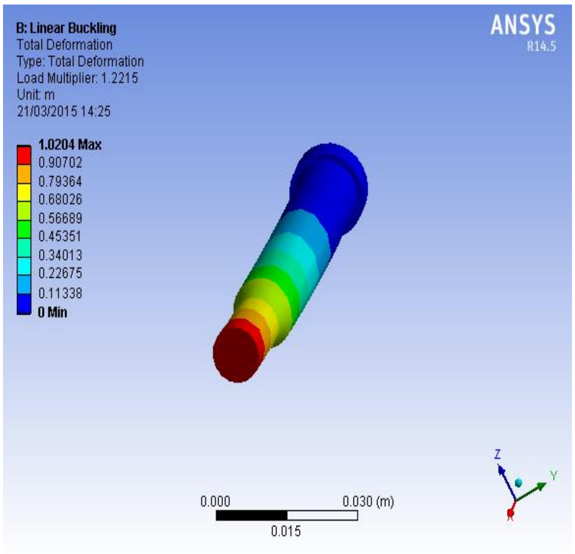

Figure 7: Linear Buckling for Top Plate

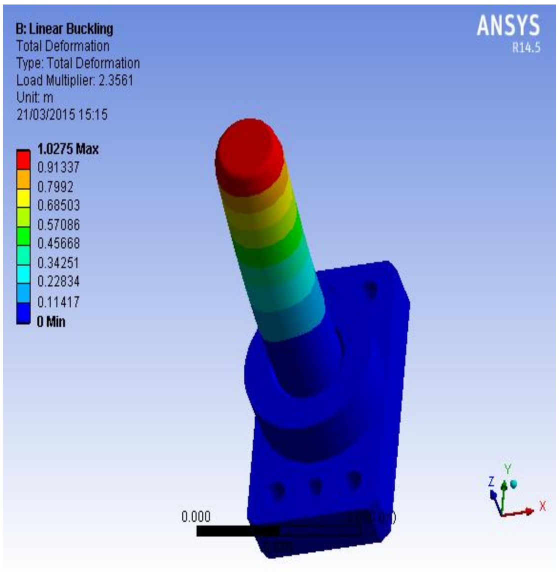

Figure 8: Linear Buckling for Guide Pillar

- Result Table:-

Sr. No.	*Part Name*	*Analytical Result (N/mm^2)*	*FEA Result (N/mm^2)*
1	Die Block	24.30	49.7
2	Top Plate	6.25	9.17
3	Bottom Plate	4.38	9.67
4	Punch	93.11	100.69

5. Conclusion

Progressive die is an economical way to form metal part with suitable of characteristic including strength, ductility, and wear resistance. This research deals with the two stage progressive die has been designed for the saddle plate manufacturing. Compound die is also used for manufacturing this plate but its design is more complicated and economically high expensive.
FEA analysis done for the guide pillar, die block, top and bottom plate, piercing punch. From this it is seen that the results are in acceptable range. The analytical and FEA result are nearly equal and both are in acceptable range.

The total tonnage required for saddle plate manufacturing is 178 Tones including 20% of the Factor of safety. There is for that range the press available in Mungi Engineers Pvt. Ltd. is 200 Tones. So this press is used for manufacturing saddle plate.

6. Future Scope

In the progressive die there should be some error of burr problem ob blank. So there is some problem in die clearance. Also there is problem in guiding the strip over the die surface.

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