

Research Article

Design of Punch and Die for Trimming Operation of Differential Bearing Cap

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Abstract

Versatility of the Manufacturing sector demands the production of Special Purpose Machines for increasing productivity, reducing machining time and human work force. Raw castings often contain irregularities caused by seams & imperfection in moulds, as well as access ports for pouring material into the moulds. A special purpose trimming machine can be used for removal of fins from castings rather than conventional manual grinding. This requires customized punch and dies according to the workpiece. This paper mainly deals with design of punch and die in a trimming machine for fettling of a differential bearing cap casting. Parameters are selected considering the geometry and material of the fin.

Keywords: Castings, trimming, fins, punch, die, fettling, differential bearing cap.

1. Introduction

A differential is located between the front and rear axles of an automobile. It is responsible for transmitting appropriate amount of power to the drive wheels during cornering. The differential is supported by a bearing system. Differential Bearing Caps serve as an attachment between the bearings, axle housing and the differential. These Differential bearing caps are mass produced by casting process. After the castings have been removed from the mould, the runners, & gates are removed. But even after shot blasting some extended projections or fins are observed on the finished product.



Fig.1 Differential Bearing Cap

Trimming is basically a process in which the unwanted, excess or irregular features are removed from a part. Usually trimming is the last operation carried on the part after which a finished part is formed. A trimming machine basically consists of a punch, punch holder, a die, die holder & a hydraulic system to provide the required force to the punch for trimming.

Die is a specialized component of a press, widely used in manufacturing industries to shape or cut the material. A die may be considered analogous to the female part in a complete tool assembly for producing work in a press. Similar to moulds, dies are also custom made according to the component they are used to create. Die block may be considered as a plate or block which encloses a die cavity. A Die set assembly consists of a lower and upper shoe, two or more guideposts and guideposts bushings. The bolster plate is used to support the lower shoe of a die set. The bolster plate is a thick plate mounted on the press bed, which is turn is used to locate and support the die assembly. The dimensions of the bolster plate are generally in the range of 5 to 12.5 cm thickness. The die block is supported by the lower shoe. Also the guide posts are mounted on it. The upper shoe is a part of the die set which contains the guideposts bushings. (Shrama, 2009).

A punch (moving component) is used to push a workpiece against the die (fixed component), in a pressing operation. This is the male component of the die assembly, which is directly or indirectly moved by and fastened to the press ram or slide. Clearance can be defined as the space or distance between the cutting

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tool, measured at the point where the cutting action takes place and perpendicular to the direction of tool movement. It has a significant effect on the finish of the cut (burr) as well as the machine's power consumption. This results in highly localized shear stresses on the material between the punch and die. Plastic deformation and fracture can be distinctively seen on the sheared material. Due to inhomogeneous nature of the material and the inconsistent clearance between the punch and die, the shearing action does not take place in a uniform manner. The rough edge is formed because of fracture which begins at the weakest point and progresses on to the next weakest point and so on until the entire workpiece has been sheared. The reduction in rough edge can be brought about by clamping it on the top with the aid of a die cushion. The fracture zone is completely eliminated after a certain pressure. However, the sheared edge of the workpiece will usually undergo work hardening and cracking. Excess clearance may lead to roll-over or heavy burring in a workpiece

2. Problem Description

Casting is the process of manufacturing metal or alloy parts. The parts of the desired shape are produced by pouring the molten metal into a prepared mould. Then metal is allowed to cool & solidify. The solidified metal piece is known as casting. Raw castings often contain irregularities caused by seams & imperfections in moulds, as well as access ports for pouring material into the moulds. Further, machining of the raw castings is required which involves cutting, grinding, shaving, or trimming away these unwanted bits this process is known as Fettling. The part i.e. Differential bearing cap is manufactured by casting process. After the castings, have been removed from the mould, the runners, & gates are removed. But even after shot blasting some unwanted thin fin of about 1.5 to 2.0mm thickness along its perimeter is observed. So, it is required to cut-off these extended fins from the component in the finishing process.



Fig.2 Actual Component

Generally, manual grinding of these fins is carried out in most of the industries but in order to reduce the

material handling time as well as to increase uniformity of the final product a trimming machine is employed. For this purpose, a punch & die of a trimming machine is to be designed in order to trim off the fins on the component.

3. Design

Following are the main components required to be designed for trimming of the differential bearing cap

- i. Working Components
 - a. Dies
 - b. Punches
- ii. Structural Components
 - a. Punch holder
 - b. Die holder
- iii. Guiding Components
 - a. Guide posts
 - b. Bushings

Table 1 Design Specifications

Parameter	Details
Capacity of Press	30 ton = 298.92 kN
Work piece Material Specifications (Spheroidal Graphite Cast Iron)	U.T.S. = 500 N/mm ² Elongation = 7% Hardness = 170 - 235 BHN Carbon % = 3.4 - 3.85 %
Tolerance on Job	± 0.8 mm
Fin Dimensions	Thickness = 1.5 - 2 mm Width = + 0.5 mm

3.1 Design Calculations

3.1.1 Perimeter & Centre of Pressure

The center of pressure is nothing but the center of gravity of the line perimeter of the part. The distance of center of pressure from each axis is determined by using following formula: (Shrama, 2009).

$$X = \frac{x_1 * L_1 + x_2 * L_2 + x_3 * L_3 + \dots}{L_1 + L_2 + L_3 + \dots}$$

$$Y = \frac{y_1 * L_1 + y_2 * L_2 + y_3 * L_3 + \dots}{L_1 + L_2 + L_3 + \dots}$$

$$(X, Y) = (70.00, 29.91)$$

Table 2 Calculation of center of pressure

No.	L (mm)	y(mm)	L*y
1	28	0	0
2	131.946	26.738	3527.972
3	28	0	0
4	45	22.5	1012.5
5	28.5	45	1282.5
6	6.94	48.47	336.3818

7	92.059	47.777	4398.303
8	6.94	48.47	336.3818
9	28.5	45	1282.5
10	45	22.5	1012.5
Total perimeter = 440.885 mm			13189.04

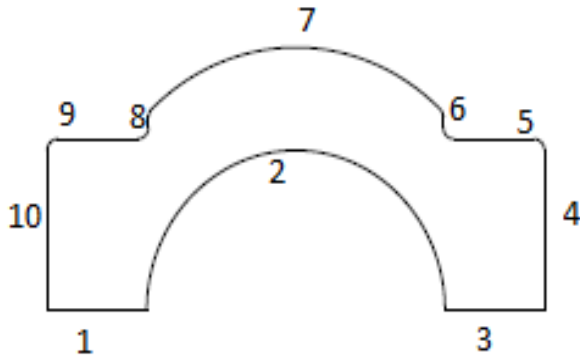


Fig.3 Numbering of line elements in calculation of center of pressure

3.1.2 Cutting forces

The maximum force required to cut a material (without shear on the punch) is given by (Vishwanath, 2013)

$$F_{max} = \text{Sheared area} \cdot \text{Shearing strength}$$

$$= A \cdot T_s = 881.77 \cdot 400$$

$$= 352708 \text{ N}$$

Shear Area = $2 \cdot 440.885 = 881.77 \text{ mm}$

Shear Strength = $0.8 \cdot \text{Ultimate tensile strength}$

$$= 0.8 \cdot 500$$

$$= 400 \text{ N/mm}^2$$

Work done to make a cut is given by,

$$E = F_{max} \cdot \text{Punch travel}$$

$$= F_{max} \cdot K \cdot t = 352708 \cdot 0.68 \cdot 2$$

$$= 479682.88 \text{ Nm}$$

The actual cutting force is less than maximum force, which is given by,

$$F = \frac{F_{max} \cdot K \cdot t}{(K \cdot t) + I}$$

Where, K = percentage of penetration = $68\% = 0.68$

F = Actual cutting force

I = Shear on the punch or die in cm

- For I = t; F = 307868.43 N
- I = 1.5t; F = 288965.59 N
- I = 2t; F = 272547.09 N
- I = 3t; F = 244736.16 N

1.1.1 Energy in Press work

$$E = F_{max} \cdot \text{Punch travel}$$

$$= 352708 \cdot K \cdot t$$

$$= 352708 \cdot 0.68 \cdot 2$$

$$E = 479682.88 \text{ N-m}$$

1.1.2 Power in Press work

$$\text{Power in press work} = \frac{E \cdot N_a}{60 \cdot N}$$

$$= 22842.04 \text{ W}$$

Where, $N_a = \text{actual number of strokes per min} = 2$
 $N = \text{Efficiency of press} (0.6 \text{ to } 0.85) = 0.7$

3.1.3 Die Holder thickness

Die shoe thickness = 50mm (for 100 to 300 kN)

$$= 63.5 \text{ mm (for 300 to 600 kN)}$$

3.1.4 Punch holder thickness

Punch holder thickness = $50 - 20 \text{ mm} = 30 \text{ mm}$
 (Punch holder thickness is preferably 20mm less than die shoe thickness)(Shrama, 2009)

3.1.5 Punch Length

The maximum punch length can be calculated using following empirical relation:

$$L = \frac{\pi \cdot d}{8} \times \sqrt{\frac{E \cdot d}{T_s \cdot t}}$$

(Shrama, 2009)

Where, L = Length of punch d = Diameter of part
 E = Modulus of elasticity
 T_s = Shear strength
 t = Thickness of material

Generally L = 60 to 85 mm, so L = 60mm (Shrama, 2009)

3.1.6 Die block thickness

The required minimum thickness of the die block depends upon the strength required to resist the cutting forces. It will depend upon the thickness & type of the material being cut.

Die block thickness is calculated using the following formula as;

$$T = \sqrt[3]{F}, \text{ cm CITATION Shr09 \l 16393 (Shrama, 2009)}$$

Where, F = Cutting force in ton

$$T = \sqrt[3]{(30)} = 3.107 \text{ cm}$$

$$T = 31.07 \text{ mm}$$

This is in conjunction with the ‘‘Rule of thumb’’ as the perimeter is greater than 250 mm.

3.1.7 Backup Plate

If, $P = (F/A) > 245 \text{ N/mm}^2$ only then a backup plate is used (Shrama, 2009)

Since, $P = 352708/5080 = 69.4 < 245 \text{ N/mm}^2$

Therefore; no need of Backup Plate.

3.1.8 Guideposts

For average range of die sets, the diameter of guide posts varies from 2.5cm to 7.5cm.

The diameter of guide posts selected here is 50mm.

4. Material Selection

Press tools are generally made using HCHCr, Steel alloys with high carbon. (K.Kishore, 2012) But before that based on many factors like cost, strength, hardness, strain and many parameters selection should be made. The materials used are generally selected are D2, EN31. Mild Steel is used as supporting plate. Apart from that materials like D3, high carbide materials, chromium steels and high speed steels are also used. (Subramanyamet al, 2016) The properties of the materials used in the experimentation are tabulated below:

4.1 En31

EN31 is alloy steel having the high carbon percentage which develops a high hardness with compressive strength and abrasion resistance which is suitable for automobile applications such as heavy duty gear, pinion, shaft, cam shafts, etc. For properties of En31 shown in Table 3, Table 4 & Table 5.

Table 3 Properties of En31

Carbon	0.18
Silicon	0.35
Manganese	1
phosphorous	0.05
sulphur	0.05

Table 4 Physical properties

Meltingpoint	Density
1421°C	7.7 x 1000 kg/m3

Table 5 Mechanical Properties and Thermal properties

Elastic modulus	190- 210 GPa.
Rockwell hardness	62
Izod impact	77.0 J
Thermal properties	Thermal expansion $10.4 \times 10^{-6}/^{\circ}\text{C}$

4.2 D2 STEEL

D2 steel is tool steel with cold work having high carbon & high chromium percentage. D2 is a deep hardening highly wear resistant alloy. (Subramanyamet al, 2016) This material hardens by air cooling so as to give minimum distortion after heat treatment.

This material is best suitable for tooling applications where wear resistance is important, such as blanking dies, threadrolling dies and forming dies. For properties of D2 steel as shown in Table 6 and Table 7

Table 6 Chemical composition in Percentage

Carbon	1.6
Silicon	0.6
Manganese	0.6
Chromium	13
Sulphur	0.03
Phosphorus	0.033
Vanadium	1.1
Molybdenum	1.2

Table 7 Physical properties and Mechanical properties

Density	7810 kg/m3
Rockwell hardness	65
Elastic modulus	215000N/ mm2
Yield stress	450N/ mm2
Tensile strength	750N/ mm2
Melting point	15400C

2. CAD Design

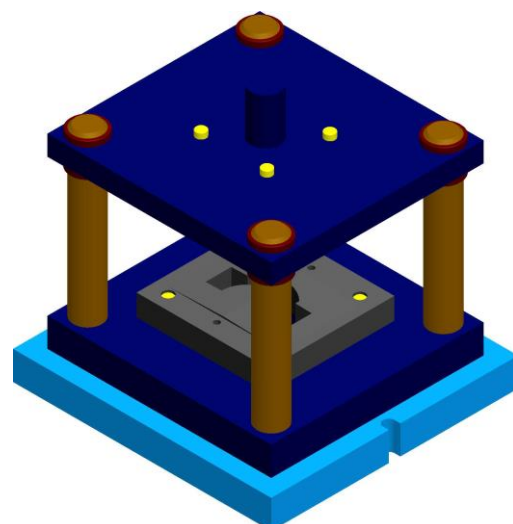


Fig.4 Solid model of punch and die assembly

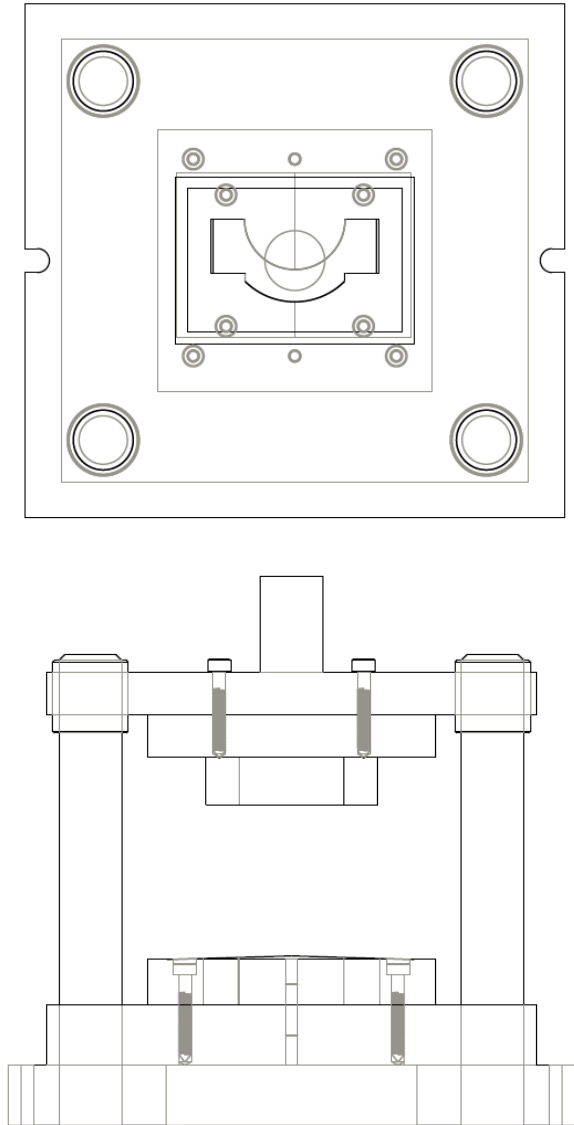


Fig.5 Orthographic drawings of assembly of punch and die system

Conclusions

Design of Press tool for trimming of Differential bearing cap is developed by following the fundamental die design principles. The output received is;

- Output product having perimeter 440.8 mm and the required cutting force is 29.4 tons. So it suits for above 30 ton press machines.
- It is seen from the calculations of actual cutting forces, that as the shear on the die increases the cutting force reduces.
- Shear of 1t, 1.5t, 2t and 3t were considered for the die. And by comparing the results a shear of 1.5t is suitable for the die as the cutting force lies within the range of available press tonnage capacity.
- More parts can be trimmed simultaneously if the shear on the die is maximized, as the cutting force required is less, but increasing shear also has some limitations.
- The tools generally made from steel alloys. Based on carbon composition they are classified in P type, D type, H type of all D type is having more carbon percentage which indirectly possess more strength. They are mainly used for making of tools

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