Compound Die Design: A Case Study

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Abstract: Various components/parts used in Mechanical industry are manufactured by sheet metal. They can be produced by different cold pressing processes. This paper presents a design of compound die by combining the blanking, piercing, drawing operation. Compound die design is applied to dies in which two or more cutting operations, typically piercing, blanking and drawing are performed in the same single station and completed during the single press cycle.

Keywords: Compound die design, Drawing operation, Punching, Blanking, Force.

1. Introduction

The evolution of products, dictated by the necessity to survive in the market, requires changing in manufacturing processes. This requires an integrated approach of constructive aspects, technological, organizational and management of the development stages in order to reduce as much as possible time and cost of the new products. Design activity has an important role in developing a new product. Design time being very often decisive in terms of the marketing time of the product. Compound die design is applied to dies in which two or more cutting operation, typically piercing, blanking and drawing are performed in the same single station and completed during the single press cycle. There are many ways to design a compound die, but since there is no place for the finished part to go during a compound die’s operation, the part must be pushed back into the scrap web such that it can then be carried out of the tool and extracted in one or another fashion later in the die cutting operation. This necessity for a separate parts extraction process is one downside of the compound die system. Advantages of a compound die system, first and foremost being the high and unsurpassed mechanical accuracy of a single step process. A second advantage of a compound die set up is its throughput. Because all internal and perimeter features of the part are created in one cycle. That means that if a strip is designed to create 10 parts, these 10 parts will be created in 10 press strokes.

2. Objective

Design of compound die for downlight housing by combining the blanking, piercing and drawing operation.

3. Case study - Die Design Calculations

The case study present here includes the design and development of the “down light housing assembly” that is used for popular LED Light mounting assembly. Three operations namely blanking, drawing and punching are required to produce the component. Detailed design procedure is given below. Figure 1 and 2 shows the view of downlight housing.

3.1 Design of die for blanking operation

Blanking is the operation of cutting a flat shape from the sheet metal. In the blanking operation required diameter are taken from the calculation of blank size in drawing operation. Blanking calculations are given below.

(i) Strip layout

Strip layout as shown in the fig 3. Economy Factor is depending upon the strip layout.
Figure 3: Housing 2D view

Economy factor = \( \frac{\text{area} \times \text{no. of rows} \times 100}{\text{width of strip} \times \text{pitch}} \) 

= 67.66%

(ii) Clearance = 10% x thickness = 0.08mm

(iii) Diameter of punch (dp1) = \( \text{Blank dia} + m = 191.05\text{mm} \)

(iv) Where, \( m = \text{Elastic recovery} \)

(v) Diameter of die = \( dp1 + \text{Clearance} = 191.13\text{mm} \)

(vi) Die Block Dimension

(vii) Perimeter (p1) = \( \pi \times \text{dia of die} = 600\text{mm} \)

\[ T_1 = 25.4 + (p_1 \times 0.015) = 26.49\text{mm} \]

\[ T = T_1 + \text{grinding allowance} = 27\text{mm} \]

\[ A = 1.5 \times T = 40.5\text{mm} \]

Where,

- \( P1 = \text{Perimeter} \)
- \( T = \text{Thickness of die block} \)
- \( h = \text{Land of die block} \)

Angular clearance \( \alpha = 2^\circ \) or \( 3^\circ \)

(viii) Blanking force = \( \pi \times D \times t \times \sigma_f = 19\text{ton} \)

Where, \( D = \text{blank diameter} = 191 \)

\( h = \text{cup height} = 23\text{mm} \)

\( d = \text{punch diameter} = 133\text{mm} \)

\( \sigma_f = \text{shearing force} = 400 \text{ N/mm}^2 \)

(ix) Thickness of Plates

- Die plate (TD) = \( \sqrt{\frac{F_c}{\sigma_c}} = 31.4 \text{ mm} \)
- Top plate = \( 1.5 \times \text{TD} = 46.5 \text{ mm} \)
- Bottom plate = \( 1.75 \times \text{TD} = 82\text{mm} \)
- Punch holder plate = \( 0.75 \times \text{TD} = 23.4 \text{ mm} \)
- Stripper plate = \( 0.5 \times \text{TD} = 15.5 \text{ mm} \)
- Thrust plate = 8.5 mm

3.2 Design of die for drawing operation

Drawing is a process of forming a flat work piece into a hollow shape by means of punch which causes the blank to flow into a die cavity.

(i) Blank Diameter (D) = \( \sqrt{d^2 + 4dh} = 191 \text{ mm} \)

(ii) Draw Force – Draw Force can be calculated by empirical relation,

\[ P = \pi d \times t \times ((D/d) - C) = 12\text{ ton} \]

Where, \( P = \text{Draw Force in Tons} \)

\( S = \text{Yield strength of Metal in } \text{ N/mm}^2 \)

\( C = \text{Constant (Take 0.65 to 0.7)} \)

(iii) Die clearance -

Die clearance = \( 1.1 \times t = 1.1 \times 2 = 2.2 \) (For single side clearance)

Punch diameter (dp) = \( d - 2 \times t = 131.4\text{mm} \)

Die diameter \( dp = dp + 2 \times (1.1 t) = 133.16\text{mm} \)

(iv) Draw Ratio – At this component, the Draw = \( H/d = 23/133 = 0.2 < 0.7 \) which indicates the draw is simple & may require only one stage for completion.

(iv) Draw & Punch radius – The Draw radius usually ranges from 4 to 10 times the Blank thickness, therefore, Radius of Draw Die = \( Rd = 4.5 \times 0.8 = 3.6\text{mm} \)

The Punch radius usually ranges from 3 to 4 times the Blank thickness, Therefore, Radius of Punch = \( Rp = 3 \times 0.8 = 2.4\text{ mm} \)

(v) Blank Holding Force = \( 1/3 \times \text{Drawing Force} = 4\text{ton} \)

(i) Punch design

Checking the punch for crushing,

\[ \frac{\pi}{4} X d^2 X \sigma_f = 133706.18 = \frac{\pi}{4} X 133^2 X \sigma_f \]

\( \sigma_c = 9.62\text{N/mm}^2 << 750 \text{ N/mm}^2 \)

Safe in crushing.

Maximum length in punch,

\[ L_{max} = \frac{\pi d}{Q} X (\frac{E \times d^2}{t \times \sigma_f})^{1/2} \]

\( L_{max} = 21.29\text{mm} \)

Where, \( E = 200 \times 10^3 \text{ N/m}^2 \)

Taking the length of punch, \( L > 25 \text{ mm} \)

3.3 Design of die for punching operation

3.3.1 Punching operation -A (105 mm)

Punching is a cutting operation by which 105mm hole are made in the sheet.

(i) Clearance = 10% x thickness = 0.08mm

(ii) Diameter of punch = 105.05mm

(iii) Diameter of die = 105.1 mm

(iv) Cutting force required

\( F_c = \pi x d \times t \times \sigma_f = 11\text{ton} \)
(v) Die Block Dimension

- **Perimeter** ($p_1$) = $\pi \times \text{dia of die} = 330\text{mm}$
- $T_1 = 25.4 + (p_1) = 26.49\text{mm}$
- $T = T_1 + \text{grinding allowance} = 27\text{mm}$
- $h = 10\% \times T = 2.7\text{mm}$
- $A = 1.5 \times T = 40.5\text{mm}$

Where,
- $P1$ = Perimeter
- $T$ = Thickness of die block
- $h$ = Land of die block

Angular clearance $\alpha = 2^\circ \text{ or } 3^\circ$

Material for Die block should be use HCHCr

Hardness − Die Block should be harden upto 60 to 62 HRC

(vi) Punch design

Checking the punch for crushing,

$$\text{Cutting force} = \frac{\pi}{4} X d^2 X \sigma_c$$

$10557.5 = \frac{\pi}{4} \times 105^2 \times \sigma_c$

$\sigma_c = 12.19 \text{ N/mm}^2 \leq 750 \text{ N/mm}^2$

Safe in crushing.

Maximum length in punch .

$$L_{max} = \frac{\pi d}{8} X \left(\frac{E X d}{t X t S}\right)^{1/2}$$

$L_{max} = 10.56\text{ mm}$

Taking the length of punch, $L=25\text{ mm}$

3.3.2 Punching operation – B (5mm)

It is cutting operation by which four hole of 5mm are made in the sheet.

(i) Diameter of punch = $5+0.05=5.05\text{ mm}$

(ii) Diameter of die = $5.1\text{ mm}$

(iii) Cutting force required

$F_{C2} = \pi \times \text{dia of punch} \times t \times \sigma_c = 0.5\text{ ton}$

Total cutting force for 4 holes $= 0.5 \times 4 = 2\text{ ton}$

(iv) Die Block Dimension

- **Perimeter** ($p_1$) = $\pi \times \text{dia of die} = 330\text{mm}$
- $T_1 = 25.4 + (p_1) = 26.49\text{mm}$
- $T = T_1 + \text{grinding allowance} = 27\text{mm}$
- $h = 10\% \times T = 2.7\text{mm}$
- $A = 1.5 \times T = 40.5\text{mm}$

(iv) Punch design

Checking the punch for crushing

$$\text{Cutting force} = \frac{\pi}{4} X d^2 X \sigma_c$$

$5026.55 = \frac{\pi}{4} \times 5^2 \times \sigma_c$

$\sigma_c = 256 \text{ N/mm}^2 \leq 750 \text{ N/mm}^2$

Safe in crushing

Maximum length in punch.

4. Conclusion

- Successfully Design a compound dies by combing blanking, drawing and punching operation.
- It is possible to get product in single die
- The developed cad design conforms the possibilities of compound die
- The simulation also confirms the die design

References


Author Profile

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