Design and Analysis of Progressive Tool for Photo Frame Hook

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Abstract

Design and development of progressive tools for the sheet metal component is one important phase in sheet metal manufacturing. Sheet metal press working process by progressive tools is a highly complex process that is vulnerable to various uncertainties such as variation in progressive tools geometry, stripe layout, die shear, material properties, component and press working equipment position error and process parameters related to its manufacturer. These uncertainties in combination can induce heavy manufacturing losses through premature die failure, final part geometric distortion and production risk. Identification of these uncertainties and quantifying them will facilitates a risk free manufacturing environment, which can be obtained by effective tool design.

This project aimed at designing and analyzing a progressive tool for photo frame hook with aid of computer aided design package. The design of the tool is intended both skilled and unskilled labour and mass production of the component, which is cost effective and consumes lesser time for production.

Keywords: Progressive tool, Strip layout, Press tonnage, Punching force, Analysis

1. Introduction

In sheet metal forming when dealing with complicated shapes the process sequence, die geometry, perform shape and process parameters at each stage are designed based on past experiences and trial and error. As a result die and process development may be time consuming and costly. Therefore a computer aided approach is highly desirable for designing robust process sequence to reduce expense.

2. Objective of the project work

The purpose of the present investigation is to study the manufacturing of sheet metals by use of a progressive tool. It is necessary to go through the various stages of designing and finding out the possible failures or errors that would happen at the time of manufacturing. In sheet metal forming when dealing with complicated shapes the process sequence, die geometry, perform shape and process parameters at each stage are designed based on past experiences and trial and error. As a result die and process development may be time consuming and costly. Therefore a computer aided approach is highly desirable for designing robust process sequence to reduce expense.

3. Tool Design for Photo Frame Hook

3.1 Component diagram

![Component Diagram]

Fig. 3.1 Component Diagram
3.2 Component Analysis

- **Material**: Mild Steel (S42)
- **Thickness**: 2 mm
- **Shear strength**: 35kg/mm²
- **Temper grade**: Hard
- **Supply condition**: Strips
- **Geometry tolerance**: IS2102

3.3 Strip layout

Fig. 3.2 Scrap Strip Layout

3.4 Design Calculations for the Tool

Component Material = MS
Thickness of the strip= 2mm
Component area = 1086.16 mm²

\[
\% \ of \ strip \ used = \frac{\text{Area of component}}{\text{length of strip} \times \text{width of strip}} = \frac{1086.16}{37.5 \times 44} = 0.6582
\]

\[
\% \ of \ strip \ used = 0.6582 \times 100 = 55.58 \%
\]

Shear force = \( K \times L \times t \times S_{sh} / 1000 \) tons

Where,
- \( K \) is a constant = 1.1 to 1.5 (based on clearance)
- \( L \) = length of cut in mm
- \( t \) = thickness of stock in mm
- \( S_{sh} \) = shear strength of material Kg/mm²

\[
\text{Shear force} = 1.5 \times 211.95 \times 2 \times 40 / 1000 = 25.43 \text{ tons}
\]

Stripping force = 10% of shear force

\[
\text{Stripping force} = 10 \times 25.43 / 100 = 2.54 \text{ tons}
\]

Total force = shear force + stripping force

\[
= 25.43 + 2.54 = 27.98 \text{ tons}
\]

Press tonnage = 1.2 x total force

\[
= 1.2 \times 27.98 = 33.57 \text{ tons.}
\]

Thickness of the die plate

\[
(td) = 3 \sqrt[3]{F_{sh}} \quad F_{sh} = \text{shear load in ton}
\]

\[
td = 3 \sqrt[3]{16.95} = 2.56 \text{ cm} = 25.6 \text{ mm}
\]

**Die thickness selected** = 30mm

**Thickness of top plate** = \( 1.25 \times td \)

\[
= 1.25 \times 30 = 37.5 \text{ mm}
\]

**Thickness of bottom plate** = \( 1.5 \times td \)

\[
= 1.5 \times 30 = 45 \text{ mm}
\]

**Thickness of punch holder** = \( 0.5 \times td \)

\[
= 0.5 \times 30 = 15 \text{ mm}
\]

**Thickness of stripper plate** = \( 0.5 \times td \)

\[
= 0.5 \times 30 = 15 \text{ mm}
\]

**Cutting clearance** = 4% of sheet thickness

\[
= 0.04 \times 2 = 0.08 \text{ mm/side}
\]

**Blanking Punch Size** = Blank Size – Total Clearance

**Piercing Punch Size** = Hole size – Total Clearance

3.5 Assembled View of Progressive Tool

Fig. 3.3. Assembled View Of Progressive Tool

3.6 Die Plate Design
Assuming that the die block (die plate) is considered to be as fixed beam. The shoe deflection is calculated using the strength of material formula for fixed supported beam,

\[ \delta = \frac{FL}{3\times192EI} \]

Where,

\[ F = 0.8 \text{ of cutting force} \]
\[ = 0.8 \times 25434 \text{ kgf} \]
\[ = 203472 \text{ N} \]
\[ L = 125 \text{ mm}, E = 2.1 \times 10^5 \text{ N/mm}^2 \]
\[ I = \frac{bh^3}{12} = 3.48 \times 10^7 \text{ mm}^4 \]

\[ \delta = \frac{(203472 \times 125^3)}{192 \times 2.1 \times 10^5 \times 3.48 \times 10^7} \]
\[ = 28.26 \mu\text{m} \]

Stress, \( p = \frac{F}{A} \)
\[ p = \frac{203472}{0.155 \times 0.085} \]
\[ = 5.98 \times 10^7 \text{ N/m}^2 \]

3.7 Bottom Plate Design

Assuming that the bottom plate is considered to be on parallels. The shoe deflection is calculated using the strength of material formula for parallels supported beam,

\[ \delta = \frac{FL^3}{354EI} \]

Where,

\[ F = 0.8 \text{ of cutting force} \]
\[ = 0.8 \times 25434 \text{ kgf} \]
\[ = 203472 \text{ N} \]
\[ L = 195 \text{ mm} \]
\[ E = 2.1 \times 10^5 \text{ N/mm}^2 \]
\[ I = \frac{bh^3}{12} = 2.5 \times 10^6 \text{ mm}^4 \]

\[ \delta = \frac{(203472 \times 195^3)}{354 \times 2.1 \times 10^5 \times 2.5 \times 10^6} \]
\[ = 3.4 \mu\text{m} \]

Stress, \( p = \frac{F}{A} \)
\[ p = \frac{203472}{0.24 \times 0.14} \]
\[ = 6.05 \times 10^6 \text{ N/m}^2 \]

3.8 Top Half Design

Top half includes as for calculation and analysis purpose as top plate, punch back plate and punch plate. Assuming that the Top plate is considered to be on parallels. The shoe deflection is calculated using the strength of material formula,

\[ \delta = \frac{FL^3}{48EI} \]

Where,

\[ F = 0.8 \text{ of cutting force} \]
\[ = 0.8 \times 254340 \]
\[ = 203472 \text{ N} \]
\[ L = 195 \text{ mm} \]
\[ E = 2.1 \times 10^5 \text{ N/mm}^2 \]
\[ I = \frac{bh^3}{12} = 2.5 \times 10^6 \text{ mm}^4 \]

\[ \delta = \frac{(203472 \times 195^3)}{48 \times 2.1 \times 10^5 \times 2.5 \times 10^6} \]
\[ = 3.4 \mu\text{m} \]

Stress, \( p = \frac{F}{A} \)
\[ p = \frac{203472}{0.24 \times 0.14} \]
\[ = 6.05 \times 10^6 \text{ N/m}^2 \]

3.9 Stripper Plate Design

Assuming fixed stripper to be considered as a fixed beam support. The fixed stripper plate deflection and stress is calculated using strength of material formulae for parallels supported beam,

\[ \delta = \frac{FL^3}{192EI} \]

Where, \( F = 10\% \text{ to } 20\% \text{ of cutting force} \)
\[ = 25434 \text{ N} \]

\[ \delta = \frac{203472}{0.24 \times 0.14} \]
\[ = 6.05 \times 10^6 \text{ N/m}^2 \]
\( L = 125 \text{ mm}, \)
\( E = 2.1 \times 10^5 \text{N/mm}^2 \)
\( I = \frac{bh^3}{12} = 4.35 \times 10^4 \text{mm}^4 \)

Where, \( b = 155 \text{ mm}, h = 15 \text{ mm} \)
\( \delta = 11.92 \mu \text{m} \)

\( \text{Stress, } p = \frac{F}{A} \)
\( p = \frac{52354.8}{(176 \times 20)} = 1.93 \times 10^6 \text{ N/m}^2 \)

### 3.10 Piercing Punches

![Fig. 3.8 Piercing Punches](image)

Assuming that the piercing punch as consider as one end is fixed and compressive force is acting on other end. Here for cutting operation (piercing operation) 80% of cutting force is acting on punch as compressive nature.

We know that the compressive force on the punch is equal to the shear force on sheet metal.

**Piercing Punch-1**

Deflection of piercing punch,
\( \delta_p = \frac{P_p L}{A_p E} \)

Where, \( P_p = \text{Compressive force for piercing operation} \)
\( = 37699.1 \text{ N} \)
\( L = 42 \text{ mm} \)
\( A_p = 19.63 \text{mm}^2 \)
\( ,E = 2.1 \times 10^5 \text{N/mm}^2 \)
\( \delta_p = 3.83 \mu \text{m} \)

\( \text{Stress, } p = \frac{F}{A} \)
\( p = 2.89 \times 10^6 \)

**Piercing Punch-2**

Deflection of piercing punch,
\( \delta_p = \frac{P_p L}{A_p E} \)

Where, \( P_p = \text{Compressive force for piercing operation} \)
\( = 30159.2 \text{ N} \)
\( L = 42 \text{ mm} \)
\( A_p = 50.26 \text{mm}^2 \)
\( ,E = 2.1 \times 10^5 \text{N/mm}^2 \)
\( \delta_p = 1.19 \mu \text{m} \)

\( \text{Stress, } p = \frac{F}{A} \)
\( p = 3.50 \times 10^6 \)

**Square Piercing Punch**

Deflection of piercing punch,
\( \delta_p = \frac{P_p L}{A_p E} \)

Where, \( P_p = \text{Compressive force for piercing operation} \)
\( = 27600 \text{ N} \)
\( L = 42 \text{ mm} \)
\( A_p = 30 \text{mm}^2 \)
\( ,E = 2.1 \times 10^5 \text{N/mm}^2 \)
\( \delta_p = 1.84 \mu \text{m} \)

\( \text{Stress, } p = \frac{F}{A} \)
\( p = 2.63 \times 10^6 \)

### 3.11 Blanking punch

![Fig. 3.9 Blanking Punch](image)

Assuming that the blanking punch as consider as one end is fixed and compressive force is acting on other end. Here for cutting operation (blanking operation) 80% of cutting force is acting on punch as compressive nature.

**Deflection of blanking punch,**
\( \delta_b = \frac{P_b L}{A_b E} \)

Where, \( P_b = \text{Compressive force for piercing operation} \)
\( = 16849.2 \text{ N} \)
\( A_b = 2102.13 \text{mm}^2 \)
\( ,E = 2.1 \times 10^5 \text{N/mm}^2 \)
\( L = 42 \text{mm} \)
\( \delta_b = 1.603 \mu \text{m} \)

\( \text{Stress, } p = \frac{F}{A} \)
\( p = 4.8 \times 10^6 \)
4. Result of Analysis

Table .1 Result of Analysis

<table>
<thead>
<tr>
<th>Sl.No</th>
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<th>Analysis result</th>
<th>Calculated value</th>
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<td></td>
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<td>Deflection μm</td>
<td>Stress N/m²</td>
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<tr>
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5. Conclusion

progressive tool were modelled in Pro-Engineer 4.0. Each individual file was imported to Ansys12.0 software through Initial Graphics Exchange Specification (IGES) format. The following conclusions were made.

1. The results obtained through analysis are approximately nearer to the theoretical values. This demonstrates that the analysis carried out was correct.

2. It is also observed that the design of progressive tool is safe as all the stress values were less than the allowable stress of the material.

3. Manufacturing of progressive tool by analysis result facilitates risk free manufacturing environment, which goes a long way to minimize the overall cost of production.

4. The analysed values reduce the uncertainties in combinations which may induce heavy manufacturing losses by prematic die failure.

References


David T. Reid, Fundamentals of Tool Design, 3rd edition, Society of Manufacturing Engineers (SME).