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Design and Analysis of a Press Tool for Retainer used in Lower Door Hinge of Automobile

Dharshan B G[1]*, Ananthapadmanabham K C[2] and Hareesha N G[3]
[1,2]Don Bosco Institute of Technology/Mechanical Department, Bengaluru, India
Email: dharshubg@gmail.com, kcananth2000@yahoo.co.in
[3]Dayananda Sagar College of Engineering/Aeronautical Engg Department, Bengaluru, India
Email: hareeshang@gmail.com

***Abstract*—The scope of the work is to design and analysis of a press tool for component retainer which should meet the production requirement of 100,000 components for an automobile. To achieve this press tool is designed for producing a component in a single stroke in two stages and to optimize production rate and manufacturing cost. Based on features in the component, compound die is designed which can perform blanking and piecing operation in first stage followed by bending operation in the second stage. The structural analysis was carried out for the forming die and punches which shows that both the deflections and the stresses are well within the limits.**

***Index Terms*— Retainer, press tool, die sets, blanking die, piercing punch, forming die and punch.**

I. INTRODUCTION

Press tools is most widely used for a component which is fabricated in sheet metal may vary from a tiny item in a wrist watch to a large aircraft part with complex shapes, manually it is very difficult to manufacture a sheet metal components which is having complex shapes and having dimensional importance in its applications.Now a day's practice is to produce most of the sheet parts of any shape by using specially designed press tools and other combination of operations. The design of press tools and its manufacturing procedure are highly specialized and knowledge intensive in nature stampings are parts cut and formed from sheet metal. This sheet metal stampings have now replaced many components which were earlier cast or machined. Material economy and the resultant reduction in weight and cost, high productivity, use of unskilled labour and high degree of possible precision have rendered press work indispensable for many mass produced goods, such examples can be found in automobiles, aircraft, house hold articles, electronic and electrical appliances and others.This work covers the design and analysis of a press tool die set for the manufacture of a hot rolled sheet component "retainer", aimed at high productivity. A new tool with mass productivity and precise component are the primary requirements. To accomplish this through careful examination of the sheet metal component sample (3D solid model), geometric profiles, material Specification was the first step. Design exercise involves analysis of product, materials, processes, resources-equipment, quality, productivity and costs to design the tooling and develop the plan for its fabrication.

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II. METHODOLOGY

A. Component Details

The component "retainer" under consideration is a rectangular component of uniform thickness 1.4mm and size 92mm x 60mm. The component requires blanking of rectangular piece of size 103mm x 60mm, two pierced hole of Φ9mm and forming of the sheet to a depth of 13mm throughout the width of the component. As per the customer requirement gang stage tool is designed. Isometric view of the component is shown in Figure 1.

Figure 1. Component drawing

B. Materials used in press tool

Steels play an important role in manufacturing press tools. Because tool life is governed by the steel used, development and economical operation of the press tool is based on choice of materials. Steels used must be of suitable compositions and produced under best possible mill conditions. Appropriate heat treatment is also an important factor in determining tool operation. Tool materials must satisfy the Structural soundness and uniformity, Good machinability, sufficient strength and hardness to resist deformation in service, sufficient toughness to resist cleavage and erecting, Wear resistance and resistance to softening effect of heat.

- Mild steel.
- Water hardened tool steel (case hardened steel)
- Oil hardened tool steel (OHNS)
- High carbon high chromium tool steel (HCHCR)

C. Die set and Die construction

The die set is one of the basic tools of the stamping industry. It consists of a lower shoe and an upper shoe, together with guide posts and bushings by means of which the shoes are aligned.The bottom bolster supports the bottom half of the press tool consisting die block, front guide plate, rear guide plate, stripper plate, finger stop etc., They are fastened to the bottom bolster by means of socket head screw and dowels ensures alignment.The top bolster accommodates punches, punch plate, punch back plate etc. They are fastened by socket head screw and aligned by dowels.The top half and bottom half of the press tool are again aligned by guide pillar and guide bush with a fit H7/h6. The guide bush OD is having interference fit with top bolster H7/ P6. The exploded view of die set is shown in Figure 2.

TABLE I. ELEMENTS OF A DIE SET

SN	Description	Material	Hardness
1	Bottom Bolster	Mild Steel	--
2	Top Bolster	Mild Steel	--
3	Guide pillar	OHNS	HRC 55-57
4	Guide Bush	OHNS	HRC 55-57

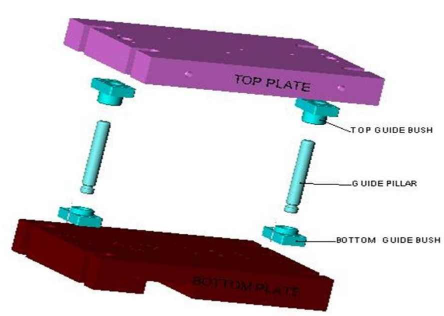


Figure 2. Exploded view of die set

D. Compound and Forming Dies

The term Compound die is applied to dies in which two or more cutting operations are performed, typically piercing and blanking are performed in the same single station and completed during the same single press cycle. The action of the piercing punch-die functions must be directionally opposed to the action of the blanking punch die functions. If the piercing punches do not act in the opposite direction with respect to the blanking punch, the die cannot be classified as a compound die.

Forming dies, often considered in the same class with bending dies, are classified as tools that form or bend the blank along a curved axis instead of a straight axis. There is very little stretching or compression of the material. The internal movement or the plastic flow of the material is localized and has little or no effect on the total area or thickness of the material. The operations classified as forming are bending, drawing, embossing, curling, beading, twisting, spinning and hole flanging. Compound and forming dies are shown Figure 3 and Press tool in closed condition shown in Figure 4.

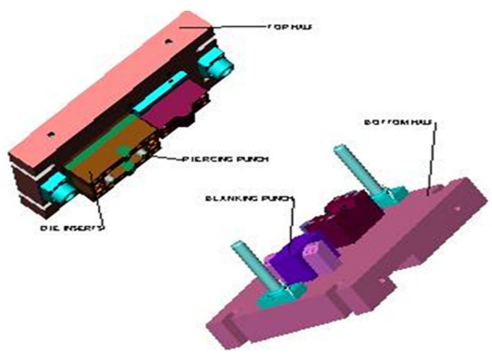


Figure 3. Compound and forming dies

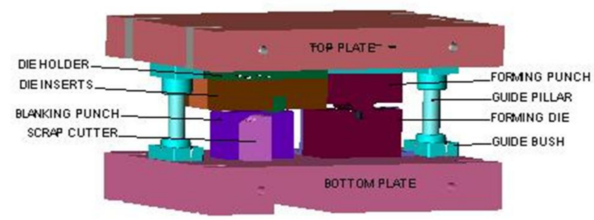


Figure 4. Press tool in closed condition

III. TOOL DESIGN

In this section step by step approach to the design of press tools based on experience, empiricism and expertise as applied to “Retainer” and various design calculations are given below:

A. Component details

Material	:	Hot rolled steel
Supply Condition	:	Soft
Thickness of strip	:	1.4mm
Type of feed	:	Manual

B. Strip layout and material utilization

This is forming tool the development length can be calculated using the formulae.

Development length (DL) = $L_1 + BA_1 + L_2 + BA_2 + L_3$

Bend Allowance (BA) = $\pi A/180\ (IR + KT)$

Where A = Angle between length (L_1) & length (L_2)

IR = Internal radius

K = Constant (1/3 for IR $\leq$ 2t)

T = thickness of strip

Development length=103mm

The strip layout is shown in fig (4.2). The percentage area of material utilization for the strip layout is computed from the following formula.

Width of strip = Width of component + 2 (thickness) x 2

= 60+2 (1.4) x 2

= 66 mm

Length of strip = Length of component + 2 (thickness) x 2

= 103 + 2 (1.4) x 2

= 109 mm

Percentage material utilization = Area of blank x number of rows x 100

$$= \frac{\text{Strip width x length}}{}$$

Strip width x length

= $\frac{6180 \times 1 \times 100}{66 \times 109}$

= 85.9

C. Clearance between punch and die

The clearance between punch and die for effective shearing is calculated by formulae

C = $0.005 \times t \times 3\sqrt{Fs}$

= $0.005 \times 1.4 \times 3\sqrt{30}$

= 0.04 mm/ side

D. Calculation of total Shear force

Shear Force = Shear Area x shear stress

F_S = (Length of cut x thickness) x Shear stress

F_S = $L \times t \times f_S \times n$

Where F_S = Shear force in Kgf

L = Length of cut in mm

t = Thickness of component in mm

f_S = Shear stress in Kg/mm^2

n = Number of holes

i) Force for piercing two holes (ϕ 9mm)

F_{Sh1} = $\pi dt \times f_S \times n$

= $\pi \times 9 \times 1.4 \times 30 \times 2$

= 2375.04 Kgf

ii) Force for blanking

F_{Sh2} = $L \times t \times f_S$

= $2\,(103 + 60) \times 1.4 \times 30$

= 13692 Kgf

iii) Force for forming

F_{Sh3} = $\frac{1.2\ SU \times w \times t2}{L}$

S_U = ultimate tensile strength in kg/mm2

w = width of forming in mm

t = thickness of component in mm

l = forming span

F_{Sh3} = $\frac{1.2 \times 40 \times 29 \times 1.4 \times 1.4}{13}$

= 209.8 Kgf

Total force = $F_{Sh1} + F_{Sh2} + F_{Sh3}$

= 2375.04 + 13692 + 209.8

= 16276.04 Kgf

E. Press Capacity Selection

The press should be capable of delivering approximately 30% greater than total shear force required by tool

∴ Press capacity required = $\frac{\text{Total shear force x 100}}{70}$

= $\frac{16276.04 \times 100}{70}$

= 23.2 tonnes

F. Design of die block

i) Thickness of die block

T_D = 3√Total shear force

= $3\sqrt{30}$

= 32 mm

Thickness of die block should be more to accommodate the shut height of the tool; hence thickness of the die block is taken as 45 mm

ii) Width of die block = Strip width + 2 (thickness of die block)
= 60 + 2 (35)
= 130 mm

iii) Length of die block = Strip length + 2 (thickness of die block)
= 103 + 2 (35)
= 173 mm

Die Block dimensions = 45 x 130 x 173 mm

Corresponding to the standard die block, Standard die set is selected from center pillar die set.

G. Design of piercing punch

Pierced hole is internal feature of component. Piercing punch controls the size and clearance is applied to die. Therefore,

a) Punch diameter = 9mm

b) Die aperture for ϕ 9m hole = 9 + 2C
= 9 + 2 x 0.04
= 9.08 mm

c) Punch Length = Shut height – Die thickness – Sum of die set -Bolster thickness – Punch plate thickness
= 262 – 70 – 130 – 6
= 56 mm

H. Design of Blanking Punch

In Blanking operation, die controls the size and clearance is applied to punch.

a) Length of the punch = Length of punch – 2C
= 103 – 2 x 0.04
= 102.92 mm

b) Width of the punch = Width of punch – 2C
= 60 – 2 x 0.04
= 59.92 mm

I. Design of Forming Punch and Forming Die

While designing forming punch and forming die the gap between punch and die is t + 10%t is taken. This 10% of t is provided to accommodate the variation in thickness of the component so that it does not damage the component.

i) Forming punch

Thickness of forming punch = Shut height – Die thickness – Sum of Die Set -Bolster thickness – Punch plate thickness
= 262 - 70 - 130 - 15
= 47 mm

Length of the forming punch = 123 mm

Width of the forming punch = 70 mm

ii) Forming die

Thickness of forming die = Shut height – punch thickness – sum of die set - Bolster thickness – forming punch thickness
= 262 – 47 – 130 – 15
= 70 mm

Length of forming die = 123 mm

Width of forming die = 70 mm

*J. Land and Draft*Land

After few thousand of operations the cutting edges of punch as well as the die block aperture becomes blunt , this results in burr on the component, hence die block surface are grinded by about 0.2 mm to get the sharp cutting edges.
A land of 3 to 5 mm is recommended for the die block.
Draft: The Sheared press components in die block apply horizontal force on the die block and do not fall freely. The amount of horizontal force applied per shear pieces that are stacked in die block is about 10% of the shear force. The slender punches like small piercing punches, notching punches and other delicate punches break causing tool lay down. Therefore, 1/4° to 1/2° draft is provided for the entire shearing aperture.

IV. RESULTS AND DISCUSSIONS

In the formation of nearly any engineering design project, some type of analysis is required. The analysis may involve stress-strain calculation or any dynamic behaviour of the system being designed. The computer can be used to aid in this analysis work. Probably the most powerful analysis feature of a CAD system is the finite element method. With this technique, the object is divided into a large number of finite elements which form an interconnecting network of concentrated nodes. By using a computer with significant computational capabilities, the entire object can be analysed for stress-strain and other characteristics by calculating the behaviour of each node. By determining the interrelating behaviour of all the nodes in the system, the behaviour of the entire object can be assured. The output of the finite element analysis is often best presented by the system for easy visualization by the user. For example, in stress - strain analysis of an object, the output may be shown in the form of a deflected shape superimposed over the unstressed object.
A typical analysis has three distinct steps.

- Build the model
- Apply loads and obtain the solutions
- Review the results.

A. Build the model

ANSYS uses pre-processor to define the element type to be used, the element real constants, the material property and to create the model geometry.CAD model and corresponding meshing of Forming die and punch are shown in Figure 5 through Figure 8.

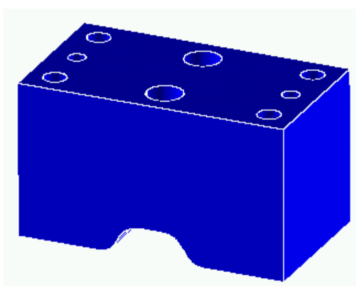


Figure 5. Forming Die

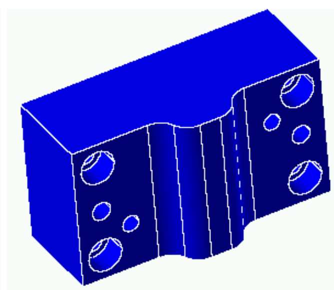
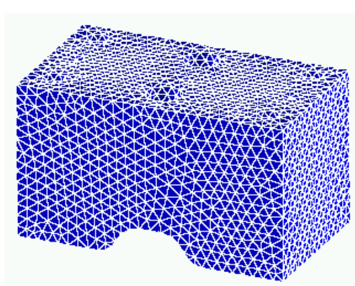


Figure 6. Forming Punch



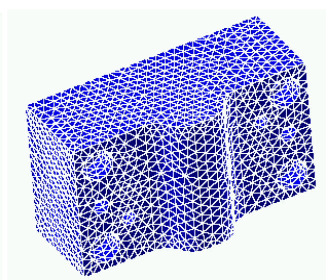


Figure 7. Meshed model of Forming Die Figure 8. Meshed model of Forming Punch

B. Loading and solution

The main goal of the finite element analysis is to examine how the structure response to the loading condition, specifying the proper loading condition, is therefore, key step to the analysis. The word load in ANSYS terminology includes the boundary condition and the externally or internally applied force functions.Loads are divided into six categories like DOF constraints, force loads, surface loads, Inertia loads, and coupled filed loads.In the solution phase of the analysis, the computer takes over and solves the simultaneous equations that the finite element method generates.The results of the solutions are:

1. Nodal degree of freedom values, which forms the primary solution.
2. The derived values, which forms the element solution. The element solution is usually calculated by elements integration points.

C. Review of results

Stress analysis is the most important step in finite element analysis. Two post processors are available to review the results. Post processor-1allows reviewing the results over the entire structure at any load step. Post processor-2 allows reviewing the variation of the particular result item at the specific point in the model with respect to the time, frequency or some other result item.Structural Analysis for forming die and forming punch are carried out for determining the deflections and stresses. Figure 9 and 10 shows the deformation in forming die and punch. Figure 11 and 12 shows the von misses stresses in forming die and punch. It was found that stresses were within the limits.

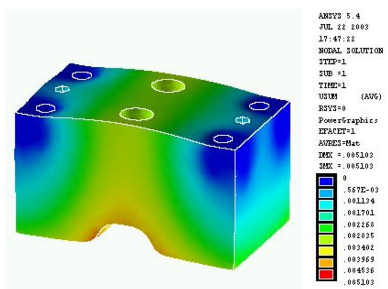


Figure 9. Deformation of Forming Die

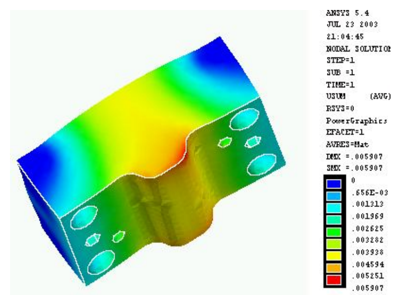


Figure 10. Deformation of Forming Punch

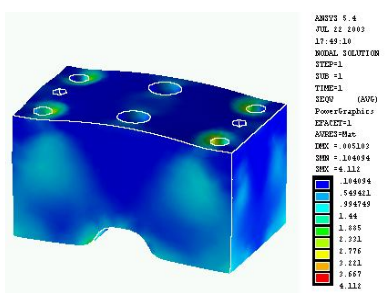


Figure 11. Von misses Stresses in Forming Die

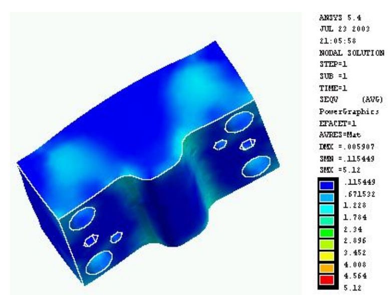


Figure 12. Von misses Stresses in Forming Punch

V. CONCLUSIONS

Design and analysis of press tool for hot rolled steel components of retainer has been accomplished. Several important aspects in the design of tooling for the manufacture of various elements of the press tools based upon critical examination of the geometry of the component. To optimize production rate and manufacturing costs compound tool is been designed. The structural analysis on form punch and dies gives deflection 0.005 mm and stresses 5.22 kg/ mm^2

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