FORGING DIE DESIGN & SIMULATION OF AUTOMOTIVE COMPONENT CLUTCH RELEASE FORK

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ABSTRACT **-** The main aim of this paper is to design a die for forging of clutch release fork and to simulate the forging process by using the software DEFORM-3 D to get defect free forging. This paper also gives a complete idea of conversion of component drawing into a forging drawing which includes addition of different allowances to actual component drawing. As an example, a real life design of clutch release fork has been taken and an attempt has been made to design Die set.

Key Words: Forging, Counter die lock, Simulation, Die Design, Clutch Release Fork.

I. INTRODUCTION

Forging is a metal forming process by which desired size and shape of the component is obtained by controlled plastic deformation. Advantages of forging process include high strength to weight ratio, directional properties, higher fatigue and impact strength compared to other metal forming and metal shaping processes[1]. Clutch release fork is an important component in clutch assembly which transfer motion from release mechanism to the release bearing and pressure plate. When the operator presses the clutch pedal, the clutch release mechanism pulls or pushes on the clutch release fork. The fork moves the release bearing into the centre of pressure.

Generally in industry Clutch release fork is made by closed die hot forging process with flash. Material is first heated upto forging temperature and then it is deformed in a set of dies(top and bottom die) which contains impressions in both top and bottom die block. The finisher or final die which contains all the details of forging is surrounded by flash land and gutter impression. This flash helps in filling the die cavity completely. Proper design of flash is important because the filling of die cavity is governed by flash land ratio which is the ratio of flash width and flash thickness. After forging the flash is removed by trimming operation. Dies are prepared by special steels like hot work tool steels and suitably heat treated to have proper hardness and toughness so that the dies have capable of pressing hot metal without any deformation in the die during forging.

In this paper, computer simulation of using DEFORM is carried out for the purpose of die filling and optimising other design parameters. DEFORM is a finite element based programme which is extensively used for the investigation of metal flow, die filling, defect analysis and prevention as well as prediction of forging properties[2].

II. MATERIAL USED:

The material used for manufacturing clutch release fork is medium carbon steel having mechanical properties shown in table 1. Dies are made of hot worked tool steel AISI-H-13.

TABLE 1: MATERIAL PROPERTIES OF CLUTCH RELEASE FORK

Material selected	AISI 1045
Young’s modulus	$2x10^5$ MPa
Poisson’s Ratio	0.3
Tensile Ultimate Strength	460MPa
Tensile Yield Strength	250MPa
Density	7850 kg/m^3

III DESIGN OF CLUTCH RELEASE FORK

Solid model of clutch release fork was made in CATIA as shown in figure 1.The machine drawing was first converted into forging drawing fig 2. First of all parting line was selected. Then finish allowances were added. After that draft and fillet and corner radii were added. Based on plan area and weight of the forging, flash thickness and width were found. Figure 3 and fig 4 show the CATIA model of forging. Figure 5 and Figure 6 show the die dimension and forging die set (top and bottom die) respectively.

A. Solid Model of Clutch Release Fork

Figure 1: The model of Clutch Release Fork was generated in CATIA V5R19

B. Forging Drawing

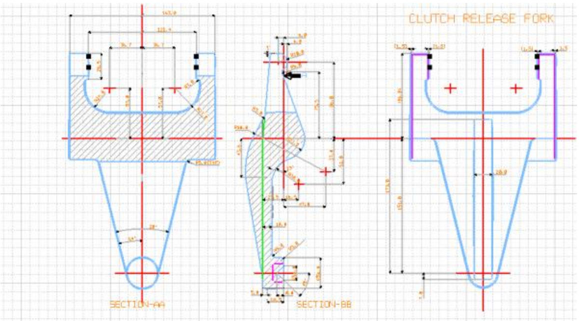

Figure 2 : Forging drawing of clutch release fork

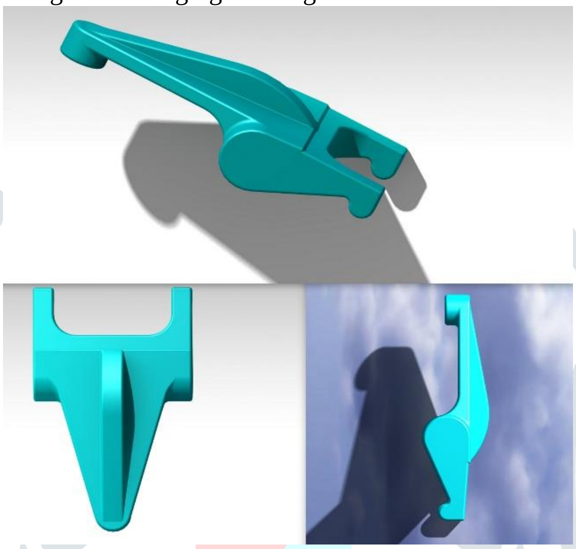

Figure 3: CATIA Model of Forging Drawing

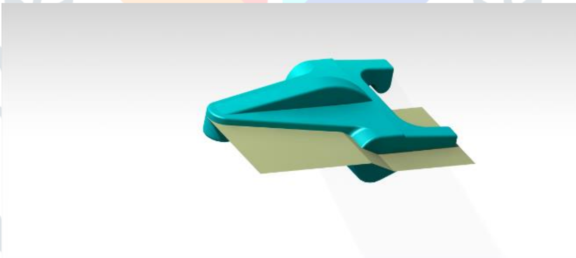

Figure 4: CATIA Model showing Parting Line

C. Selection of Parting Line [5]

The selection and shape of the parting line is one of the most important tasks of forging design. Some of the basic considerations involved in selection of parting line are

1. Avoidance of deep impressions
2. Avoidance of side thrust
3. Favorable grain flow

In design we select the inclined parting line in such a way that inclination does not exceed 70 degree. This is because more inclined flashes may create problems in trimming and machining.

D. Finishing Allowances [6]

Finish allowance refers to the amount of material that is to be machined from the forging to obtain the finished part. Forging dimensions are commonly analysed independently, with consideration given to all applicable tolerances; in making certain that a minimum desired clean-up exists after the forging is completed. Table 2 gives finish allowances for drop and press forgings.

TABLE 2: FINISH ALLOWANCES FOR DROP AND PRESS FORGINGS[7]

Over (mm)	But Not Over (mm)	Minimum Allowance per surface (mm)
-	205	1.5
205	410	2.5
410	610	3.0
610	915	4.0
915	-	5.0

E. Draft Allowances[4]

Draft is given for easy ejection of forgings from the die. When draft angles are too small there is a tendency for forgings to stick in the die impression, thus retarding production. The die becomes over heated and prematurely soft and the rate of wear is unduly increased. Draft angle should increase with the increase of the perpendicular distance of the forging from the parting line.

Generally there are two types of drafts, namely –

1. Outside draft – draft given on the periphery of the forging
2. Inside draft – all drafts other than drafts given on the periphery of the forging

F. Fillet and Corner Radius[4]

Sharp edges and corners are difficult to maintain in forgings, since sharp impression in dies lead to premature failure of die due to stress cracks and erosion at high temperature. A rounding off of the edge and corner is essential, the more generous the radius the greater will be the beneficial effect on die life.

Convex arc which joins two intersecting sides at an external angle of more than 180° is called corner radii whereas fillet is a concave arc which joins two intersecting sides at an external angle of less than 180°.

IV DESIGN OF FLASH AND GUTTER

Flash is excess metal force outwards from the work piece while it is being forged under closed impression. Flash has following functions:

1. It acts as a cushion from impact blows
2. It acts as a pressure release valve for the almost incompressible work metal.
3. It acts as a restriction to the outward flow of the metal so that the remote corners and deep cavities can be filled up

A gutter follows the flash land and it is used to accommodate extra material when die cavity is completely filled up and still there is some extra material in the cavity. When top and bottom dies touch each other this extra material flows into gutter through flash land.

There are many formulae which can be used to find out flash dimension. Table 3 gives different empirical relations for finding flash dimensions.[5]Here flash is designed based on Neuberger & Mockel formula which gives flash thickness of 3.23 mm.

Flash width: $w/t = 3+1.2(e^{-1.09W}) = 9.7$ mm

TABLE 3: FLASH DESIGN

Author	Flash thickness	Result
Bruchanov & Rebelskii	$t = 0.015\sqrt{A}$	2.4 mm
Thomas	$t = 0.016D$	2.89 mm
Vieregge	$t = 0.017D + \frac{1}{\sqrt{D+5}}$	3.14 mm
Neuberger & Mockel	$t = 0.89\sqrt{W} - 0.017W + 1.13$	3.23 mm
Teterin & Tarnovski	$t = 2\sqrt[3]{W} - 0.001W - 0.009$	3.7 mm

Gutter design: Gutter is designed on the basis of flash dimensions. For finding gutter dimension ref [6] is used.

Gutter thickness = 8 mm.

Gutter width = 20 mm.

V DIE BLOCK SIZE SELECTION [7]

The length of the die block ≥ the maximum length of the component + (2 × 1.5 × 12.86)

≥ 292 + (2 × 1.5 × 12.86)

≥ 332.5 mm

The width of the die block ≥ the maximum width of the component + (2 × 1.5 × 12.86)

≥193+ (2×1.5×12.86)

≥ 233.5 mm

The height of the die block ≥ 3 × maximum depth of the impression

≥ 3 × 12.86

≥ 38.58 mm

The actual dimensions of the die blocks are higher than, calculated dimensions to overcome the overflow of the metal as a flash and gutter.

The die block dimensions are 500 mm × 300 mm × 165 mm

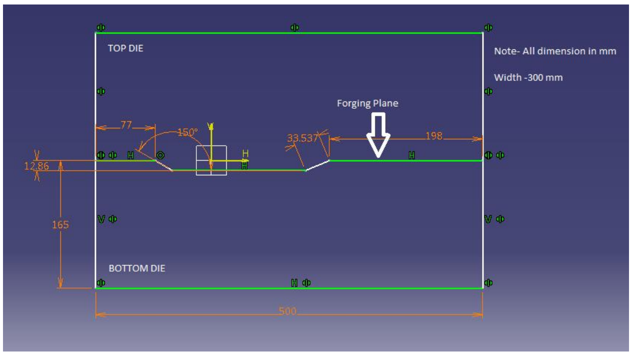

Figure 5: Showing Top and Bottom die dimension

VII DIE DESIGN

As shown in figure 4,the parting line selected is not lying in one plane. The two ends of parting lines are not meeting on same forging plane. If We select the parting line as shown in figure 4, there is much more tendency of side thrust development in dies. The consequence of such side thrust will be mismatched forging and at the same time it will have a tendency to damage the v runner of the hammer or column of press and also will damage the locking system of dies. To avoid such side thrust ,counter die locks are made which resist the side thrust and eliminate mismatch in forging. By using such counter die lock it is important to maintain the clearance between top and bottom dies during the production. If it is more then the specified value then dies should be taken out and welded and machined to get exact clearance. The side thrust can also be eliminated by placing two forgings facing each other (tandem position) in single die block but for this, die block size should be sufficiently large so that two forgings can be produced simultaneously. Since in our case die block size is small, counter die locks are used to avoid side thrust. Figure 6 shows dies with counter die locks. After designing die blocks , the dies are imported into DEFORM to simulate the process.

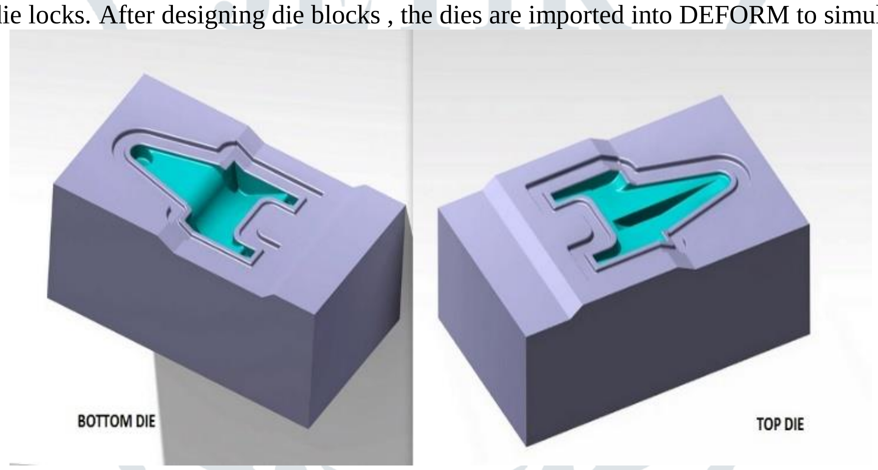

Figure 6: Die Set for Clutch release fork designed in CATIA

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VI SIMULATION

The simulation of forging process reduces the trial and error part on shop floor which is not only expensive but also time consuming. The optimum criteria may vary, depending on the product requirements, but establishing criterion requires thorough understanding of manufacturing processes. In metal forging technology, the design and control of the process require the determination of the deformation mechanics involved in the process. Without the knowledge of the influence of the process variables like friction conditions, work piece geometry and material properties on process mechanics, it would not be possible to design the dies and the equipment adequately, or to predict and prevent the occurrence of defects. In the forging sector, product and process development tasks regularly include the use of simulation software. This software not only makes it possible to solve the mechanical structural problems arising during the product development phase. They can also simulate the evolution and local distribution of thermo mechanical and elastic characteristics when a manufacturing process is being designed. The purpose of using the analysis in metal forming is to investigate the mechanics of plastic deformation processes, with the following major objectives

1. Establishing the kinematic relationships (shape, velocities, strains and strain rates) between the un deformed part and the deformed part i.e. predicting the metal flow during the forming operation
2. Establishing the limits of formability i.e. determining whether it is possible to perform the forming operation without causing any surface or internal defects in deforming material.
3. Predicting the stresses, the force and the energy necessary to carry out the forming operation. This information is necessary for die design and for selecting the appropriate equipment, with adequate force and energy capabilities to perform the forging operation.

The dies which are designed in CATIA are imported into DEFORM. Then the simulation is run for getting results. The simulation result is shown in Fig. 7.

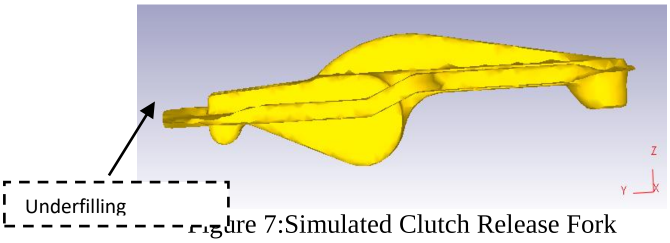

Figure 7:Simulated Clutch Release Fork

As we can see that there is under filling at the smaller end so design modification has been done. The fillet radius has been increased and peg height is decreased to 10 mm instead of 12mm.

After the design modifications there is no under filling at the smaller end. The simulated results are shown in the following figures.

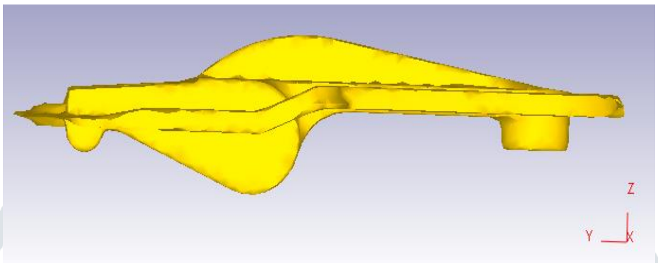

Figure 8: Simulated Clutch Release Fork after modification

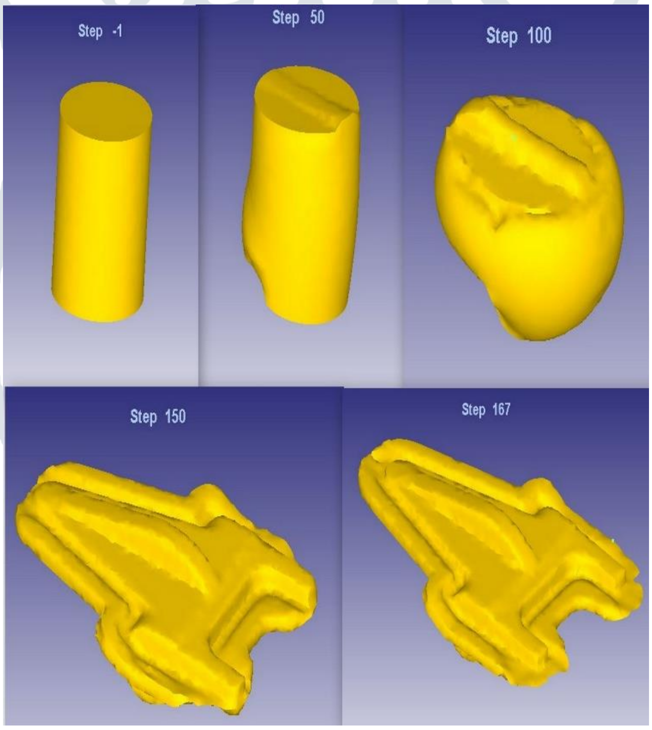

Figure 9: Stepwise simulation graphics

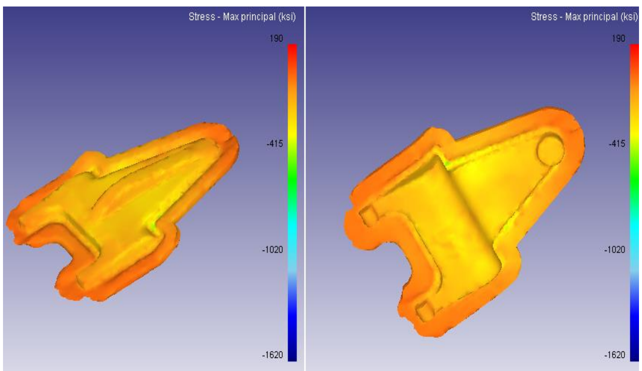

Figure 10: Max Principal stress

blank.

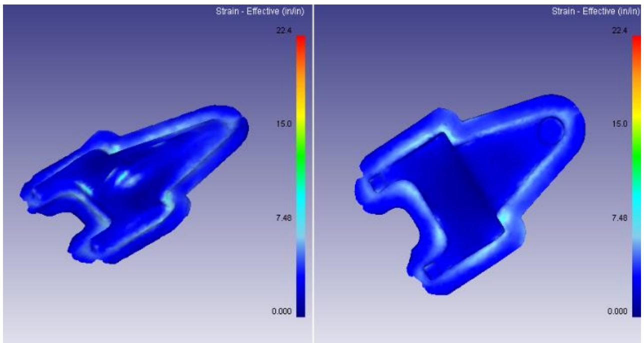

Figure 11:Effective Strain distribution

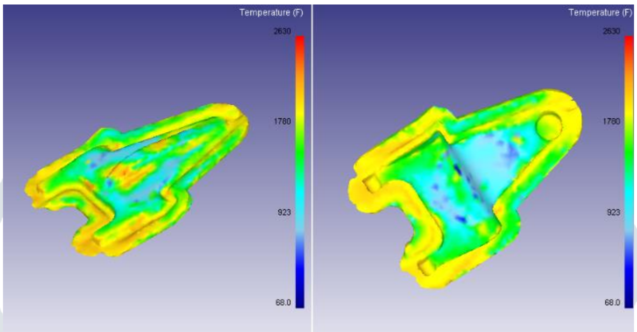

Figure 12: Temperature Distribution

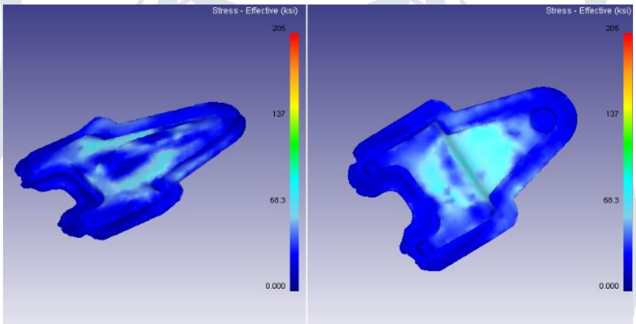

Figure 13:Effective Stress Distribution

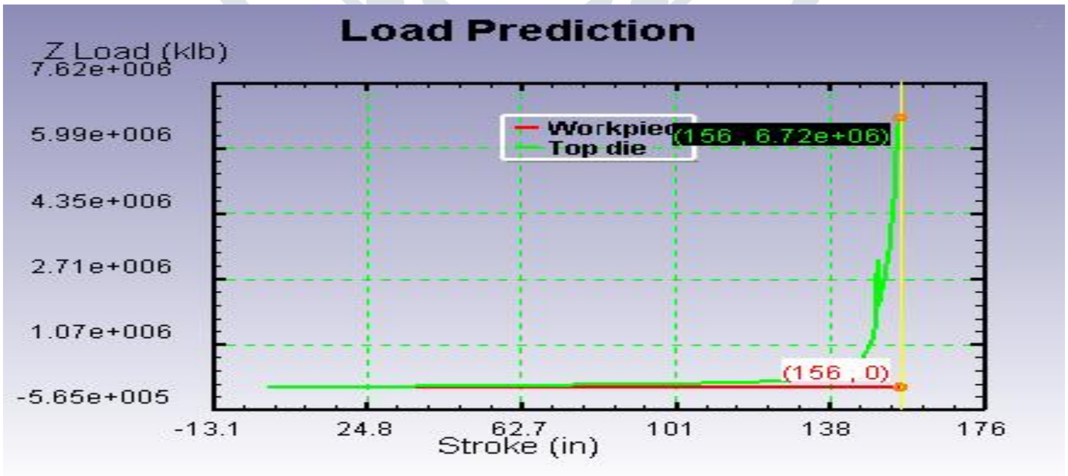

Figure 14:Load vs Stroke Curve

Given table shows the load induced in the Top die during different Flash land ratio and different percentage of reduction in blank.

II. CONCLUSIONS

1. This paper presents a method for performing forging simulations using DEFORM. Based on suitable parameters the forging process for clutch release fork was simulated. Compared with actual forging simulation saves cost and improves efficiency.
2. Counter die lock sets for clutch release fork has been tried just to eliminate the side thrust and forging simulation process is analyzed.
3. The first die set resulted in under filling at the smaller end.
4. Under filling effect has been eliminated by increasing the radius and decreasing the peg height.
5. So simulation before practical forging is useful which not only control defects but also provide some reference value for improvement of the process.

III. REFERENCES

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