DESIGN AND SIMULATION OF AXLE TUBE NUT FORGING

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***Abstract**:* In this paper component drawing of Axle tube Nut has been converted into forging drawing and based on forging drawing die design has been performed. For filling the die cavity importance of flash thickness and fillet radius has been shown with the help of finite element based software DEFORM 3D.

Key words: **Closed Die Forging, Flash Land Ratio, DEFORM 3D, Effective Stress and Effective Strain.**

1. INTRODUCTION:

Forging is a plastic deformation process which can be performed at room temperature or at high temperature. Due to controlled plastic deformation which is normally conducted with the help of hammer or press, there is improvement in mechanical properties. It provides directional strength, structural integrity, impact strength, uniformity, high strength to weight ratio[1]. There are many applications of forged components like in aerospace, automotive, off highway equipments, farm machinery, plumbing, ordinance, rail etc.

Main disadvantages of forging is its high cost and high lead time for producing dies and designing dies. Now a days CAD, CAM and CAE techniques are used to reduce shop floor trial and error and also to improve the quality of forgings. Usually 3D modelling of forging dies are made with the help of CAD software like CATIA, PRO-E etc. If any change is required during simulation these can be very easily done in these software.

AXLE NUT is an automotive part (fastener) which is connected with a rod or spindle (either fixed or rotating) passing through the centre of a wheel or group of wheels which is known as axle and it allows or causes it to turn ,especially one connecting two wheels of a vehicle. The function of fastener is to support or transmit some form of externally applied load. The mechanical property required is tensile strength. Tensile strength is the maximum tension-applied load the fastener can support prior to or coinciding with its fracture. Normally medium carbon steel En 8 is used for these purpose.

In this paper part drawing has been made with the help of CATIA software and simulation has been conducted with the help of DEFORM 3D simulation software which is a finite element based software. This software helps in getting load requirement during forging, pressure in die and tool, stresses, strains and strain rate distribution in the material during processing, residual stresses in final product, defects if any present, geometric accuracy, surface integrity, microstructure.

Deform 3D[7] is a powerful process simulation system which is suitable to analyse the three dimensional (3D) flow of complex metal forming processes. DEFORM-3D is a practical and efficient tool to predict the material flow in industrial forming operations without the cost and delay of shop trials. Based on the finite element method, DEFORM has high accuracy and robust in industrial application. The simulation engine is capable of predicting large deformation material flow and thermal behaviour with astonishing precision.

Finite element simulations like DEFORM 3D, can be very suitable for optimisation of existing process and reengineering of process when it is applied with suitable and proper plant parameters.[2]. Optimization can be achieved quickly and efficiently through the use of simulation software modelling provides more information about the process i.e. load requirement and metal flow and defect formation at different stage of the process.[3]**.** H Grass et al[4] have studied FEM software and found that it was capable to study the material flow by monitoring the position of selected material points, which can be used to optimize die design and material flow (die filling) of hot forming processes for production of a connecting rod.

2. METHODOLOGY;

The preparation of CAD or 3D modeling of Axle Tube Nut was done by using CATIA V5R19 software. Then this component drawing was converted into forging drawing. For this first of all suitable parting line was selected. Selection of parting line is very important as it will affect die filling, ease of trimming, formation of defects, extent of mismatch, amount of draft etc during forging operation. The selection of parting line is done by keeping in view that there should not be deep impression, there should not be side thrust and as per strength requirement, the grain flow should be aligned in the direction or parallel to the direction of maximum load requirement. After this different types of allowances like machining allowances, draft allowances are added to component drawing. Then suitable fillet and corner radii are selected. Optimum values of all these for example fillet and corner radii ,draft angles are required. Once forging drawing is ready then from this forging drawing finisher die is designed. Finished die is surrounded by one shallow impression which is known as flash land and after this flash land one more deeper impression is made which is known as gutter. For conventional forging the function of flash land is to help in filling the die cavity completely and function of gutter is to accommodate extra material which is left after filling the die cavity. It is very important to design flash geometry correctly because the length and thickness of this flash land govern the die filling and load requirement. Once this is done next is determination of die block material and size. Selection of forging equipment is done based on availability of equipment, production rate requirement, size of the component, section thickness of the forging etc. Depending upon the complexity of the component intermediate die or preforming dies are designed.

3. EXPERIMENTAL DETAILS:

The model of AXLE TUBE NUT was generated in CATIA V5R19 and it is shown in Fig.1

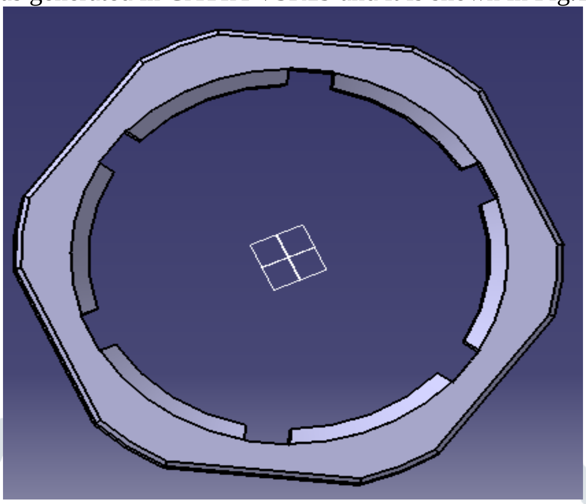


Fig 1:CATIA Model of Component Drawing

3.1 Design of Flash:

Flash thickness is important design parameters, the levels of flash thickness has been considered by the calculation of the conventional method of the forging process. This is given in Table 1[5].

Table 1: Design of flash thickness[5]

Author	Flash thickness
Bruchanov & Rebelskii	$t = 0.015\sqrt{A}$
Thomas	t= 0.016D
Vieregge	$t = 0.017D + 1/\sqrt{(D+5)}$
Neuberger &Mockel	$t = 0.89\sqrt{W} - 0.017W + 1.13$
Teterin &Tarnovski	$t = 2\sqrt[3]{W} - 0.001W - 0.009$

Flash thickness is designed based on Neuberger & Mockel formula which gives flash thickness as:
t=1.75 ≈2mm , Wt of the component is found to be 0.5 Kg.
Assuming w/t=3, the width of flash land' w' was 6mm. The gutter was designed as per reference [6]
CATIA model of forging drawing is shown in Fig 2.

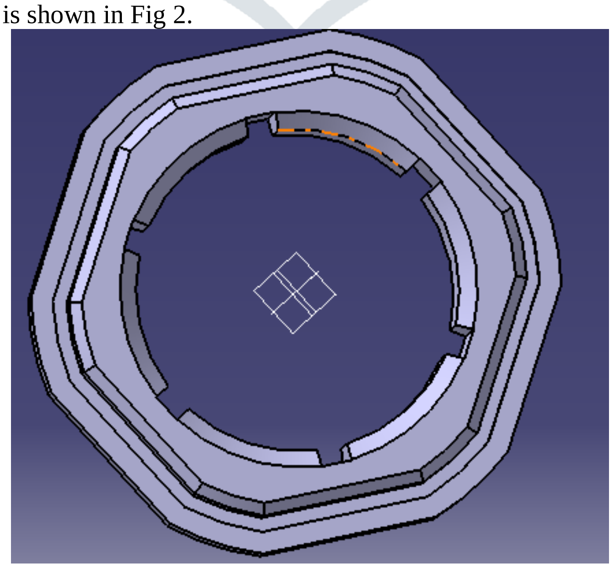


Fig 2: CATIA model of forging drawing

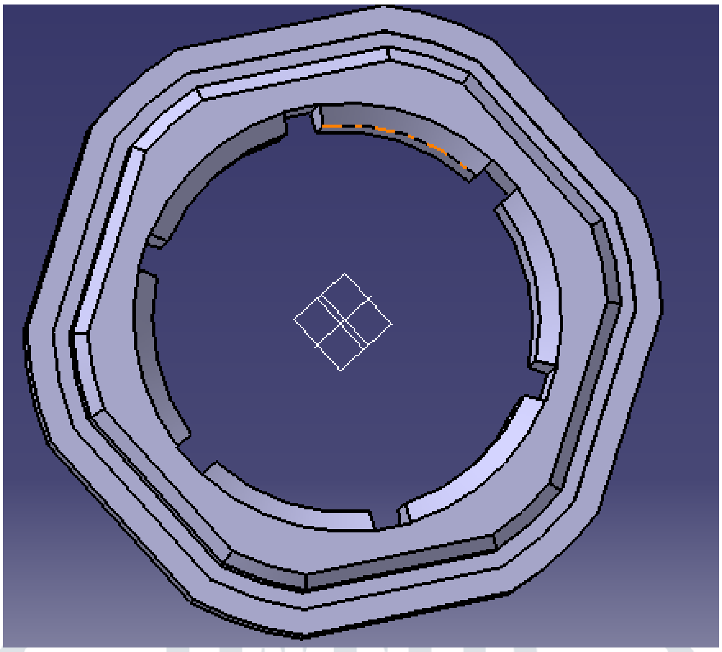


Fig.3: CATIA Model of Forging Drawing with Flash and Gutter

3.2 Calculation and Determination of Die Block Size;

As per theory, in calculation the surface area of the die block, it should be ensured that the distance between the outer periphery of the impression and die edge should be more than 1.5 times the maximum depth of the impression.

The dimensions of the die are calculating by using the empirical formula

$$W \geq 1.5h + x + 1.5h$$

Where w = width of the die (mm), h = maximum height of the component in the die (mm)

x = width of the component in the die (mm)

Width of die block (W): $W \geq 1.5h + x + 1.5h$

≥ 170mm

Length of die block (L): $L \geq 1.5h + x + 1.5h$

≥ 170mm

Calculation of height (H): H ≥ atleast 3 times of maximum depth of impression

≥ 75

After designing die block, Boolean operation is performed on the die block to get the die cavity. Then the preform and dies are imported into DEFORM to simulate the results.

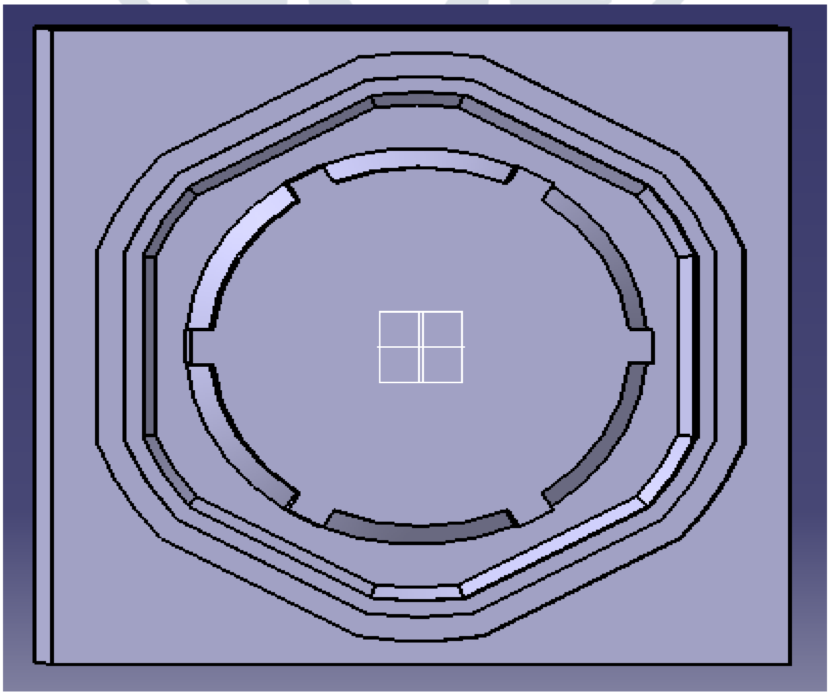


FIG.4 CATIA design of Top/Bottom dies

4. SIMULATION:

4.1 Simulation Parameters: Following parameters(Table 2) were used for the simulation of the forging process.

Table 2: Input data for simulation

Material of Billet	En8
Material of Die	H-13
Billet Temperature	1200ºC
Die Temperature	150°C
Velocity of top die	3mm/sec
Coefficient of friction	0.5
Number of meshes in dies	25000
Equipment	Mechanical Press

4.2 Simulation Results and Discussion:

Case1: By directy placing the billet in the impression(Without any upsetting)

Fig 5 shows that billet is directly placed on the single die cavity without any preform.

Different steps are shown in Fig 6. From simulation it is clear that even after 100 steps there is under filling in the teeth and inner part of the component.

Case2 :Now the flash thickness was reduced to 1.5 mm , flash width was kept to 6.0 mm and inside radius was increased. And again the forging simulation was performed. Modified dies are shown in Fig 7 and different stages are shown in Fig 8. From Fig 8 it is clear that now there is no under filling and dies are completely filled up.

In case 1 when there is more flash thickness and width of the flash land was same, most of the material escaped through the gap and also there was shortage of material to fill the die cavity. In this case load requirement was also less due to less restriction. In case 2 when flash thickness was reduced there was more restriction for metal to flow out of the die cavity and as a result material was forced to fill the intricate pockets and inner parts and teeth were completely filled up. Although the load requirement in this case increased slightly. Fig 9 shows the load vs stroke curve for case2. This curve also shows that in the beginning when stroke length was less the load requirement was less. As soon as forging process completed the load requirement was very high.

Fig10,Fig11,Fig12 show effective stress, effective strain and temperature distribution.

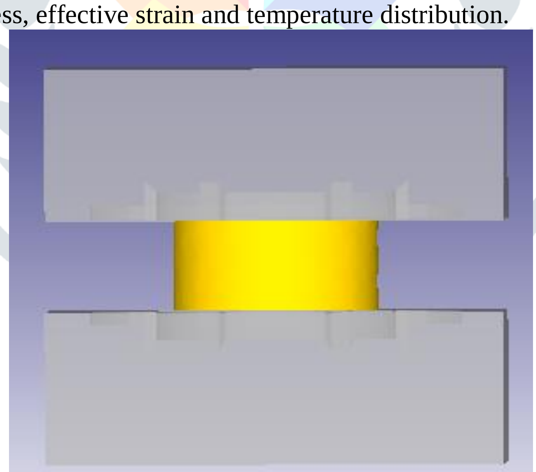
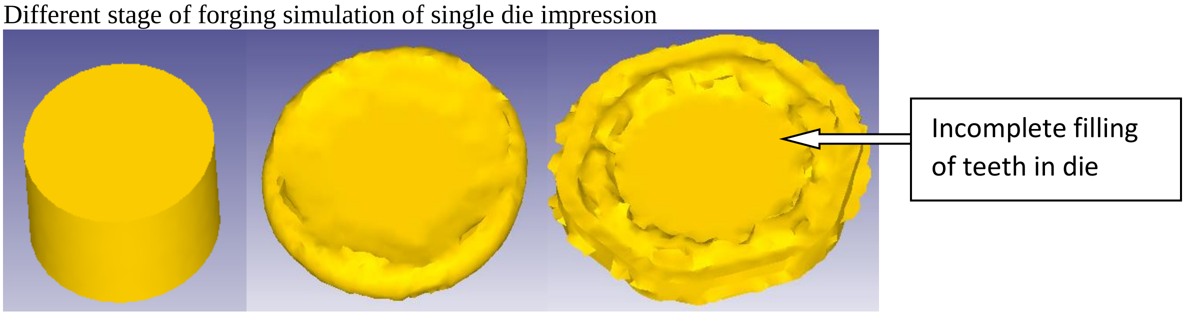


Fig 5 work piece in die without preform

Different stage of forging simulation of single die impression



(a) (b) (c)

Fig 6 Work piece geometry in process simulation without pre forming

(a) raw material, (b) after 40 steps change in the work piece,(c) after 100 steps change in the work piece.

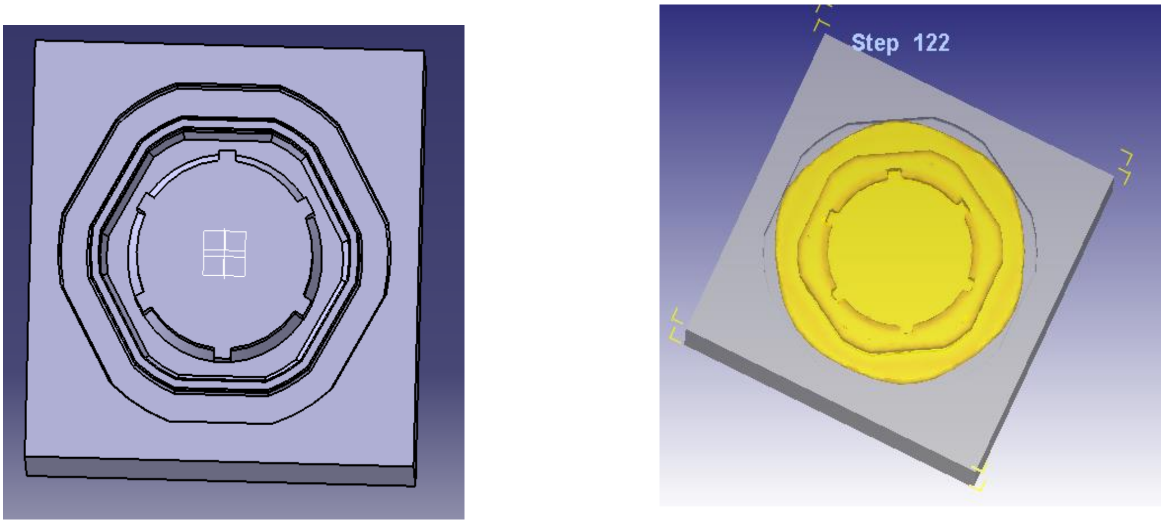
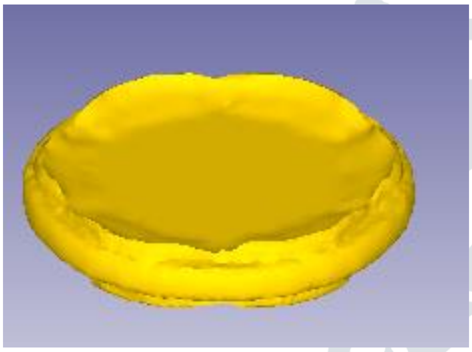
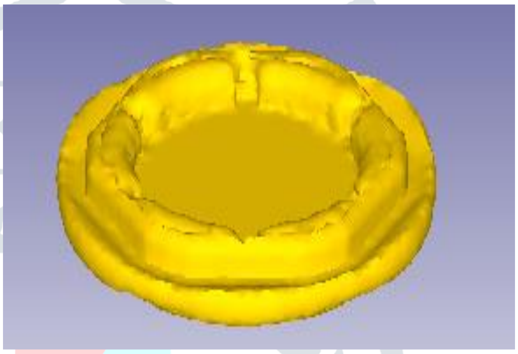


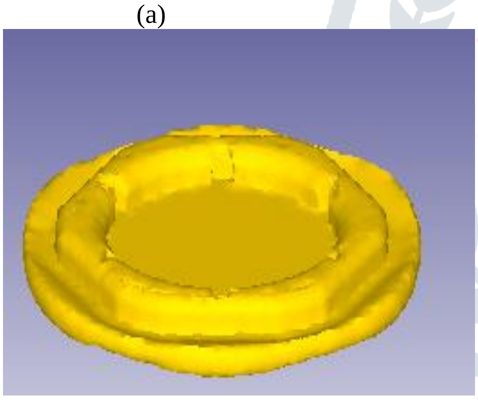
Fig 7 Modified dies and dies filled with metal



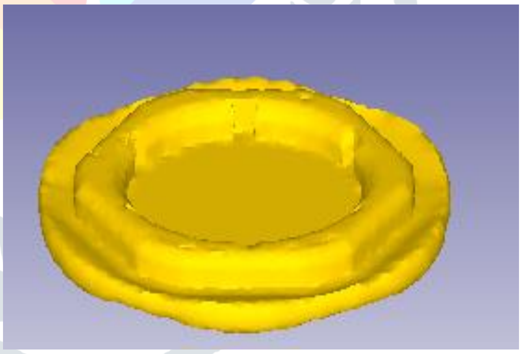
(a)



(b)

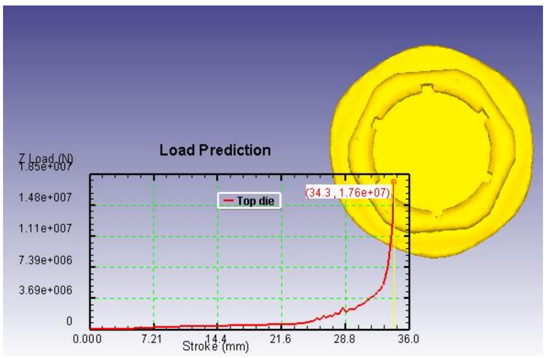


(c)



(d)

Fig 8 Different stages of simulation of modified die impression



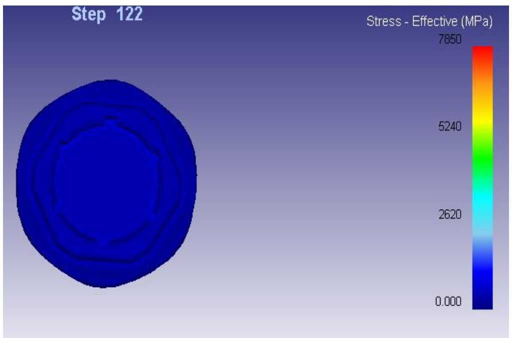


Fig 9 Load vs stroke curve.

Fig 10 Effective Stress Distribution

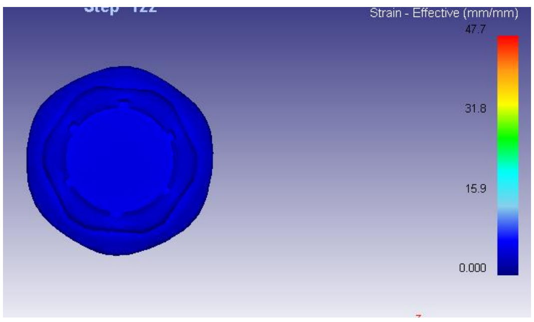


Fig 11 Effective Strain Distribution

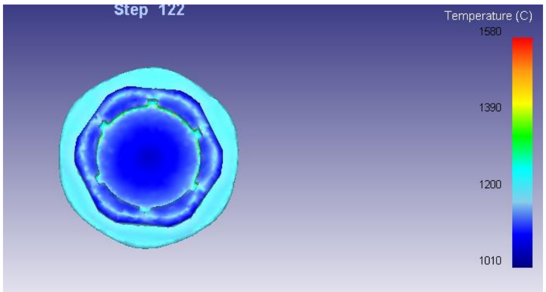


Fig 12 Temperature distribution

5. CONCLUSIONS:

1. Finite Element based simulation software is very effective for simulating forging process.
2. One of the most common occurring forging defects under filling can be controlled by correct die design. It is very important to control the flash land geometry to control the filling of die cavity.
3. By using simulation software, shop floor trial and error can be eliminated or reduced. This helps in controlling forging rejection on shop floor and finally reducing the cost of the forging.

6. REFERENCES

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