DESIGN AND ANALYSIS OF FORGING DIE TOWARDS IMPROVING LIFE OF CLOSED DIE BY USING FINITE ELEMENT ANALYSIS

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ABSTRACT

Forging process is one of the most adopted methods for forming complex shaped component with geometrical accuracy. More than fifty percent of the forgings are processed through this way. Forged components required in many engineering sectors, most of them in the automotive sector. The majority of the safety critical component and load bearing structural components are process through it. The benefit of forging is faster productions of complex shapes with less wastage of material.
For the complex shape component, metal flow analysis of the process is very difficult because a number of experimental testing and production trials are being done in the industry in order to develop a strongly formed manufacturing process. Such practices involve huge investment in tools and raw materials as well as valuable time and efforts .To take the virtual trials and simulation based design finite element method is best suitabletool.This would lead to an improvement in overall efficiency of the process at a lower cost.
As a sample case, a real life automotive driveline component like yoke, is taken for investigation. A simulation approach using a (SIMUFACT), based on finite element method. Trials were conducted using an industrial forging press machine a generated were validated against those predicted in simufact software. The relation between them was found to be similar and satisfactory.A typical yoke, used in the propeller shaft of heavy commercial vehicles may be considered as a sample component.
The research involved analysing the initial effects of (1)friction, (2) workpiece temperature, (3) die temperature, and (4) Flash Thickness were examined. To obtain the results the forging process was design in PTC creo 3.0 , simulated in Simufact Software and experimental setup and examined using two-level full factorial design of experiments (Analyzed with Minitab &MS. Excel).Theproduct reviewed was at the VARSHA FORGING Waluj, Aurangabad.

Keyword : *Die Life Improvement , Simufact, Annova, Taguchi, Modeling.*

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1 Introduction

All manufacturing processes, forging can be considered as one has been constantly revolutionizing and evolving along with man since the conception of fire. Throughout its history, metal forming has been an inadvertent sign of wealth, technology, and power. Today's outputs of automotive, aerospace, and industrial products are controlled by the countries that are producing the majority of accurate metal parts using the most cost efficient process control.metal forging is still one of the most tell tale signs of a countries growth and power.

1.1 Forging Processes

Forging is performed by applying compressive forces, through two dies, to a metal (work-piece) above the yield strength resulting in plastic deformation of the billet.This process refines the grain structure of the metal, removes any gas pockets or voids, improves chemical

segregation, mechanical and physical properties, and therefore increases reliability and consistency. By manipulating the process and output properties,parts are held to exceptionally tight tolerances. These parts require only a few processes to produce a finished
product. With these exceptional controllable properties and versatility, it is easy to see the importance of forged parts to almost every facet of industry.

1.2 Forging Future

As the technological trend of producing smaller, less expensive and more reliable products continues, the forging industry, which produces the components, will continue to
grow. Since forging is a highly reliable, repetitious and environmentally friendly process there is no doubt it is a staple for future manufacturing. The future of forging is an energy efficient, automated process with little scrap, and a much higher turnover rate. It will be safe, clean, and environmentally friendly. To achieve this, research in improving the empirically driven processes used today must be preformed
of the most adopted metal forming process. The properties generated in the product by the process, such as acceptable dimensional accuracy, higher strength to weight ratio, superior micro structure make the forging process attractive. Other attributes such as faster processing and low material wastage, push down the cost of production of complex shaped parts.Metal forming is a process that

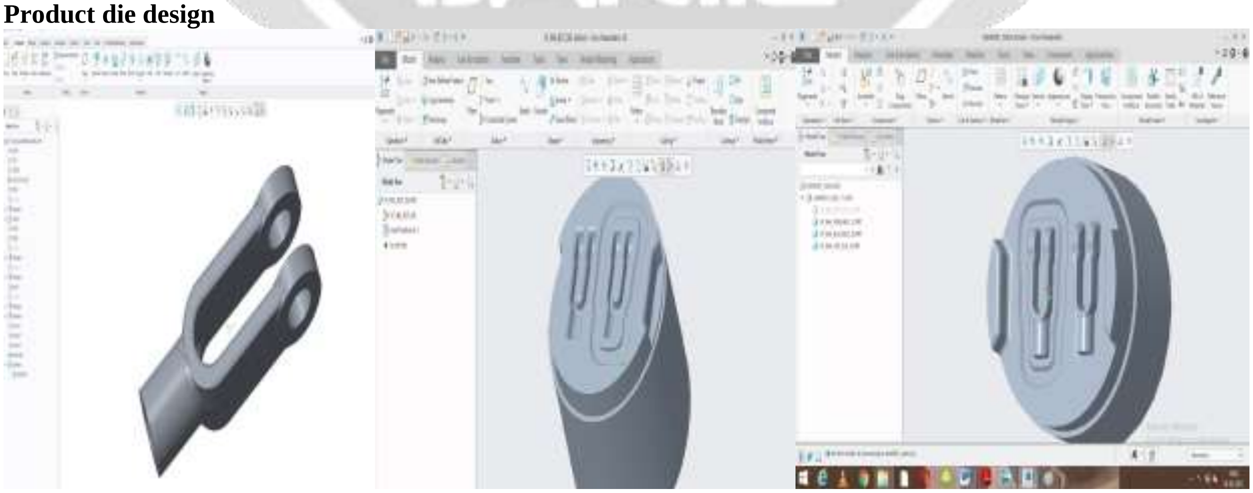
2. Problem Statement

Die failure contributes to increase in production costs. Due to micro cracks generated in forging die it will reduce the life of forging die. The defects occur in part was major problem in industry due to die life reduced.The ability to predict failure of forging dies is important to any industry that which forges parts, or incorporates forgings into part design.
By predicting die failure, redesign of work piece geometry and material, die material and surface treatment, lubrication, processing temperature, and forging velocity, can be optimized to obtain the most efficient and cost effective manufacturing process possible. It will also allow for the evaluation, with respect to quality, performance, and cost of alternate materials, processes, and process parameters for the affordable manufacturing of reliable components.

3.Methodology:

1)Study of different pre forming process parameters of forging die.
2) Die 3D modeling for various values of parameters using creo3.0 software.
3) Simulate the model to study the metal flow. then verified by comparing the predictions with the experimental results
4) Use a multi-factor three level design of experiments to determine the effects and interactions of varying parameters on process outputs and accurately determine die life

Product die design



a)3D model of final machined component ***b)*** **Die Design Stage**

4 Expermental Result

This chapter includes the experimental work done on the chosen component, data generation from simulation driven process.

4.1: Determination of Billet Size for the Experiment

The machine drawing of the component was studied and model for the same was generated using the PTC Creo solid modelling software. It is then converted to into the forging model by introducing simplification of features and adding up allowances. The next step is to decide the input billet size for the processing. Referring to the data generated from model, we can find the followings:

1. Net weight of the finished component = volume of the finished component (from model) x density (steel)

Volume of forging =20962.1 mm3

Density of material = 7.85×10-6 kg/mm3

Therefore, the net weight of the component is 0.165 kg

2. Net weight of the forging component = volume of the forged component (from model) x density (steel)

Volume of forging = 29949.3 mm3

So the net weight of the component is 0.235 kg

3. Estimated flash loss = (15 to 20) % of the net forging weight based on complexity of geometry

= 0.65kg (considering the upper limit)

4. Required input billet weight = Net weight of the forging + Flash loss

=0.305 kg

5. Approximate yield of production = (Net weight of the forging/ Billet input weight) x 100

= 83.4 %

In general, square, rectangular shaped billets are preferred over round; for forging such complex shapes. The flat side of such billets ensures proper seating in the cavity, and less attention on operating required.

Considering round billet with rounded dimension:

Diameter 25 mm ,length 73 mm weight 0.305 kg

the derived input billet dimensions are Dia 25mm ,L 73 mm.

4.2: Actual Experimental Setup:

The actual trial was taken at the forging division of Varsha forging located at B7 MIDC Waluj, Aurangabad. The following facilities of the plant were used for the experimental work:

I. Mechanical cranked press of capacity 800T was used for the forging operation. In Image of the setup is shown in Fig. The inline induction heating arrangement was used for heating the billet to required temperature.

II.VMC Vertical Milling machine was used for manufacturing of dies.

Fig Mechanical screw press with automated induction heating arrangement

4.3: Validation and Verification of Experimental Procedure:

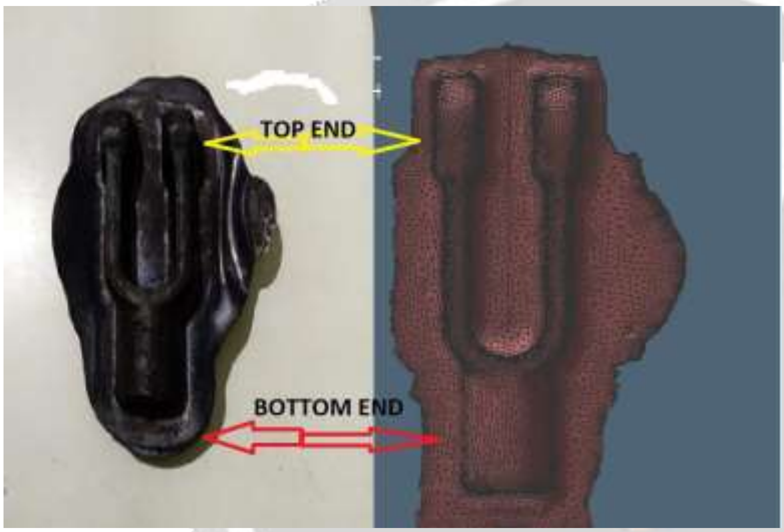
The selected method for metal forming analysis is simulation driven. A simulation predicts the desired behaviour, based on mathematical and computational models. In this particular experimental model extensive finite element formulations are used.

Verification in general terms, refers to checking the correctness of the formulated model. Whereas validation refers to checking the exactness of the model to predict the real life situation. So, the validation of the initial set results is found essential to:
- Ensure that the input values and assumptions made are correct or justified.
The model is adequate to predict actual behaviour.
- Correlation between the predicted value and the actual findings

To validate the adequacy of the model, an actual trial was conducted on the machine. The input parameters were measured during the process. These input values were fed to the simulation model, along with some suitable assumptions.

The validation criteria were set as:
- Mapping the generated flash pattern and its dimensions at the last forging stage. (i.e. finisher stage)

In the actual trail the billet material is processed through all the three stages of forging. (i.e.upsetting, blocker and finisher stage). Similarly a three stage trial is performed using SIMUFACT software. The generated flash pattern in both the actual and the simulation result was found identical. The metal flow pattern is also found similar. The comparison between actual and predicted flash pattern . The comparison of the metal flow pattern at central cross section



Comparison between Actual Vs. Predicted Flash Pattern; Different Views
(Actual Component; Simulation Prediction)

4.4 Dimensional validation table for flash width/pattern (Actual/Predicted)

Sr No.	Region of Observation	Actual trial findings		Predicted by simulation		Variation in % w.r.t actual trail findings
		Observed values (mm)	Mean	Observed values (mm)	Mean	
1	TOP END(Flash generated)	7.2 7.5 7.3 8.1 8.5	7.7	6.954 7.854 7.12 7.52 7.56	7.4	4.14%
2	BOTTOM END(Flash generated)	7.5 7.1 7.7 8.2 8.5	7.8	6.887 6.995 7.216 7.92 8.12	7.42	4.87%

It can be observed from the the table that, there exists a variation of 4.5% between the actual findings and predicted value. Considering the complexity of the geometry, multistage forging and the amount of metal flow involved, this correction can be considered good enough to proceed further experimentation

Sr.No	Weights (Kg)	Predicted model weight(kg)	Actual finding weight(kg)
1	Cut wt.	0.280	0.300
2	Forging wt.	0.218	0.240
3	Machining wt.	0.141	0.151
4	Flash wt.	0.054	0.05

From the above table its observed that predicted weights of model and actual weight is similar.

5. Simulation Result

5.1 Design by Simulation

Simulation is the process of conducting virtual computer based experiments, founded on mathematical and logical modelling techniques. The finite element based modelling is the most adopted simulation technique for engineering analysis. Design by simulation is a systematic approach where the objective is to perform virtual iterative trials to understand the effect of parameters on the output and the overall behaviour of the system as a whole. In case of a bulk forming process such as forging, the simulation technique can be used both for process analysis and die design.

5.2 Purposes of Design by Simulation:

The purpose of process modelling through simulation aims at the followings: To gain a comprehensive insight into the process to understand different mechanism and phenomena involved. - The study can be performed in isolation, so that actual setup is not disturbed. - Reduces effort on expensive trials, thus reduce overall development time. - Testing the effectiveness of new concepts before actual implementation. - Reduced effort on analytic requirements. - To find out the results in easily demonstrable models, which can be further scaled to advanced analysis, such as die wear, die life estimation etc.

5.3 Stage-wise Simulation Results:

The simulation results are interpreted by using post-processor. The output parameters can be customised to suit the problem definition and to improve the overall understanding of the process. The stage wise deformation and the resulting metal flow behaviour are shown in Fig.5.4-5.6. It captures the transformation of simple billet geometry; into the complex shaped component along with the effective stress distribution during the process.

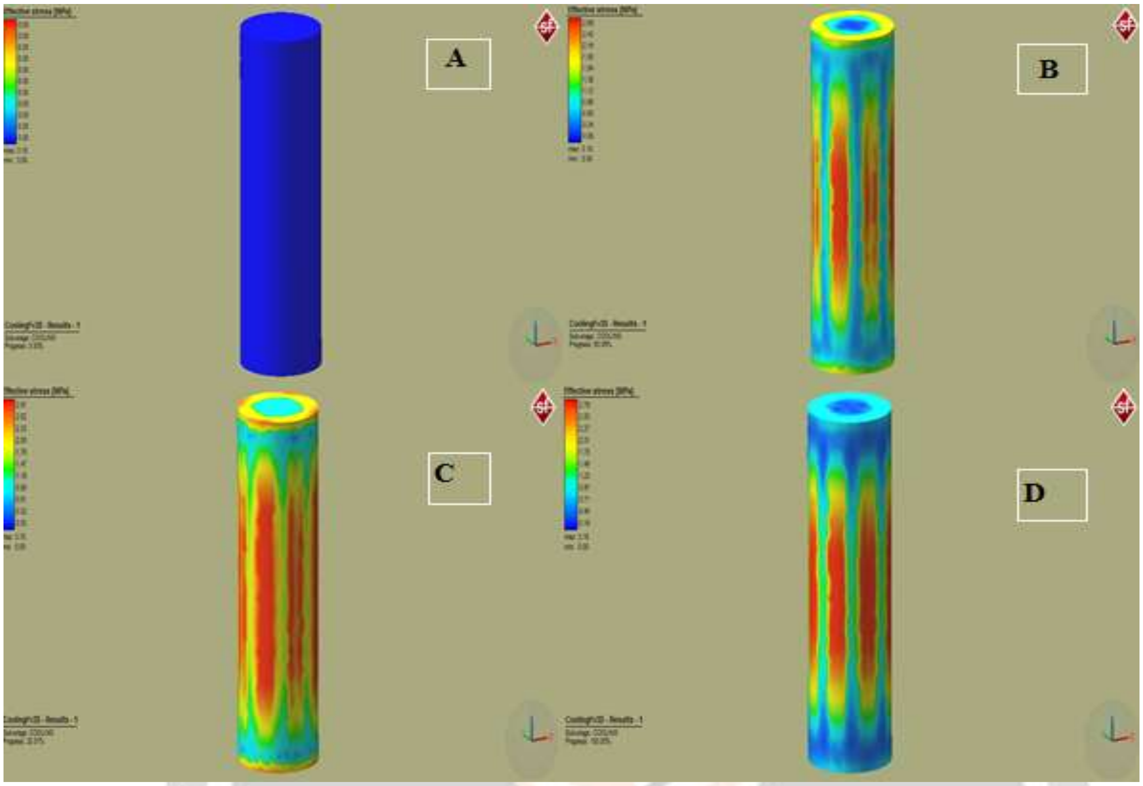
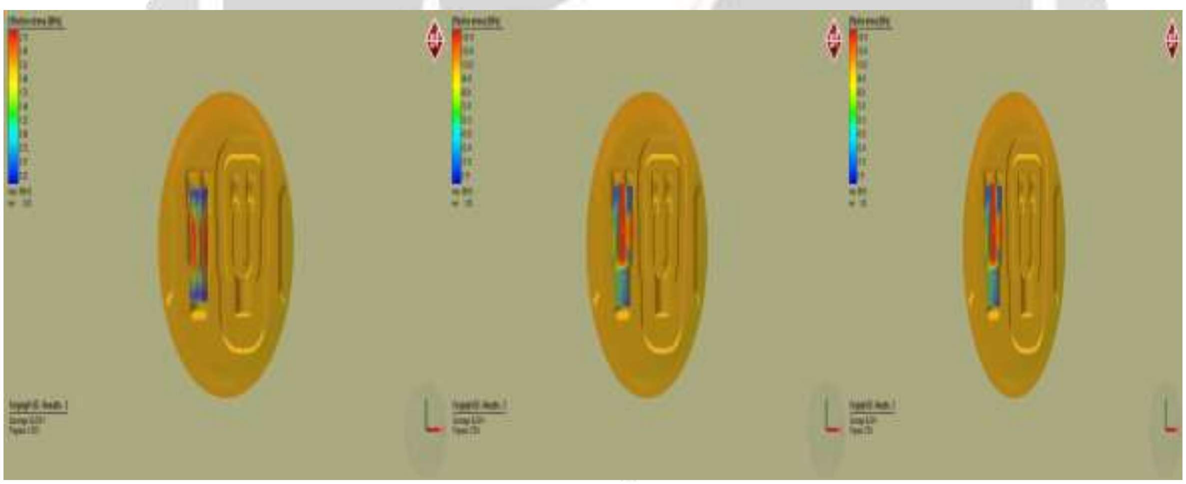


Fig (a-d) Step- wise simulation result of workpiece; Effective stress plot



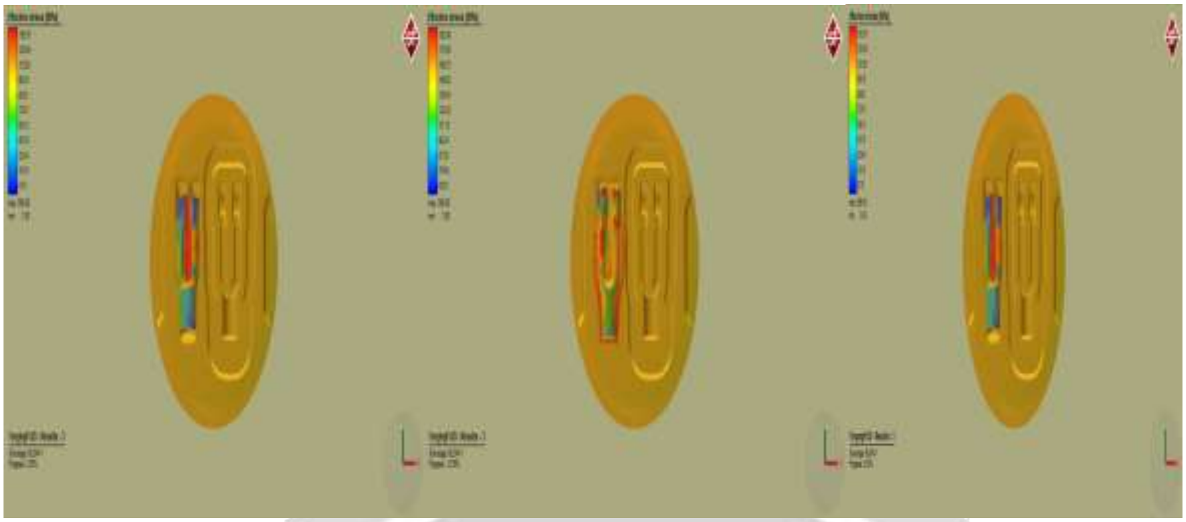
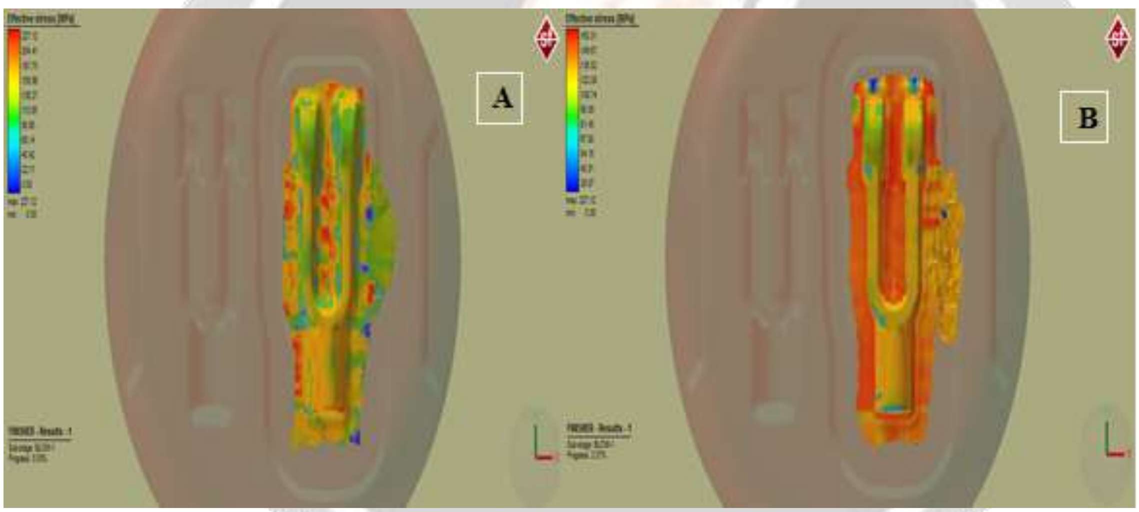


Fig Step- wise simulation result of blocker; Effective stress plot



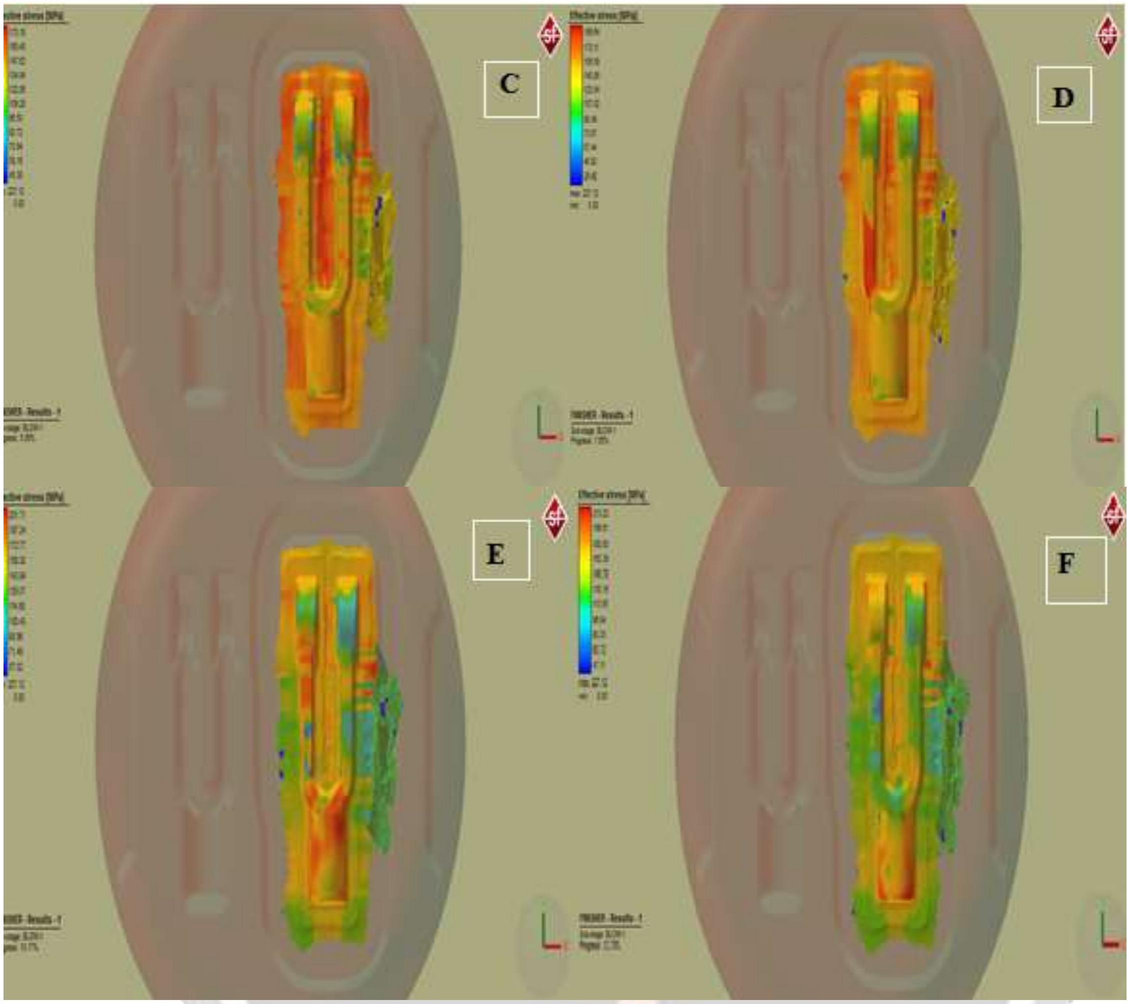


Fig (A-F) Step- wise simulation result of finisher; Effective stress plot

The result shows that, the metal flow at the finisher stage is limited; whereas it is maximum at the blocker stage. This is desirable and in line with the criteria for die design adopted.

The predicted load stroke curve and temperature distribution for the blocker stage is shown as a sample An upsurge in temperature (to 1150 oC) is observed, at the end of deformation process from initial input value (to 1000 oC). This can be attributed to the conversion of mechanical work into heat energy, during the process of deformation

Actual set up showing billet and die used for experimental trial
a) Input billet material, b) Blocker and Finisher bottom die, c) actual component without flash

Experimental Details Aiming Design of Experiments: A set of experiments with varying level of these parameters were planned via simulation to capture the effect on forging load and effective stress. The selected levels are as shown in Table

Parameters	Level		
Workpiece temp (° C)	1000	1150	1200
Die Temp(° C)	200	200	250
Friction	0.6	0.8	0.7
Flash thickness(mm)	1.5	2	3

6.Experimental Results

Experimental finding of the forging load at different levels of input parameter

RUN	Work piece Temp (°C)	Die Temp	Friction Factor	Flash Thickness	Blocker		Finisher	
					Forging Load (kN)	Effective Stress (MPa)	Forging Load (kN)	Effective Stress (MPa)
1	1000	200	0.6	1.5	13906.2	239.858	749.05	239.842
2	1000	200	0.8	2.0	12500.7	351.52	842.30	335.5
3	1000	250	0.7	3.0	1433.2	299.6	801.20	278.2
4	1150	200	0.8	3.0	1460.6	396.932	507.02	227.121
5	1150	200	0.7	1.5	1389.2	125.23	503.50	271.5

6	1150	250	0.6	2.0	15299.3	130.51	643.20	321.2
7	1200	200	0.7	2.0	1524.2	345.2	841.20	325.4
8	1200	200	0.6	3.0	1945.5	399.2	696.50	348.2
9	1200	250	0.8	1.5	20309.6	239.637	1023.50	237.92

7. Conclusions

In this work, an automotive driveline component (Yoke) is taken as a reference sample, to study the metal forming behaviour during closed die forging. The effect of selected input (forging) parameters on forging load and effective stress is determined. The Taguchi method is used to find out the best possible combination for the desired response

1) The billet temperature, die temp,flash thickness and friction are found to have a significant effect on the forging load. Among the four, the temperature of the input billet is found to be the most significant parameter followed by flash thickness and friction factor, in that order.

2)Just as the forging die life prediction equation itself will be a valuable tool in the cost reduction, design and optimization of forging dies for the forging industry, the research preformed for this thesis will be a valuable primary step in developing the die life equation.

8. References

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