Design and Analysis of a Die for an Automotive Component

Nikhil S. Godse, Pradeep J. Awasare

***Abstract*— New product development require a lot of process knowledge and experience. Design of die depends on the processing steps, nature of work piece material, its flow stress, temperature of working, frictional condition at interface, etc. Even lot of trial and error needs to be done to arrive at a optimum process. But now with use of reliable computer simulation tools it is possible to produce components without a single forging trial. Rapid prototyping technology increases the speed of production and adds flexibility for end users. This saves a lot of energy, time and money. Additionally use of simulation tools gives much more insight about process and possible forging defects. In this paper a Forging Die is designed for an automotive component. With the help of computer simulation, the complete forging process is simulated and changes are carried out to develop the required component. Forging defects are removed which were observed during simulation of Forging process.**

***Index terms*- Forging, Meshing, Metal Flow Simulation**

I. INTRODUCTION

Forging is an ancient form of manufacturing process which involves shaping of metal. Among all the manufacturing process forging process holds a great importance because of its ability to manufacture components accurately, with minimum scrap. In forging the initial material is a relatively simple geometry and as the end component is the required product with intricate shape. Forging is an experience oriented technology. Throughout the years a great experience has been accumulated.

In the past forging die design procedure was based on the experience and knowledge of die designer and some empirical guidelines and thumb rules. The need for a different variety of forgings and faster design procedures relatively with increasing costs led to use of Computer Aided Design (CAD) techniques as a feasible alternative in forging die design. The ever increasing costs of material, energy, and manpower require that forging processes and tooling be designed and developed with minimum amount of trial and error with shortest possible lead times.

Traditional engineering design approach is the process of identifying the right combination product parameters which is often manual, time consuming and involves a step by step approach to identify the right combination of product and associated process parameters for the best solution. Therefore, to remain competitive, the cost effective application of computer-aided techniques, i.e. CAD, CAM, CAE, and finite element analysis (FEA) based computer simulation is an necessity. The use of simulation tools helps to understand the forging process and thereby predicting the effects that would take place and hence make changes so as to avoid the defects.

II. LITERATURE REVIEW

Shamasundar [1] has studied the forging of the crankshaft component which is the most critically loaded part in auto assembly. In his paper of prediction of defects with the analysis of grain flow in the forging process by process modeling he has studied cases such as grain flow evolution, analysis of defects such underfill, folds. Caporalli, Gileno, et al [2] in his paper Expert system for forging has found that designing of a forging process is quite expensive because it involve a lot of iterative actions to be taken so he proposed a system where the whole process can be easily controlled merely by making use of new tools available. Bramley and Mynors [3] in his paper Study of simulation tools has focused on the inherit capacity of the simulation tools which can be used for forging process. Hartley, Rowe and Sturgess [4] in his paper Numerical simulation of forging system has studied the recent research taking place in the forging process. hartley and Pillinger [5] in his paper of Numerical simulation of forging has made use of simulation tool for the forging process. Oh, Wu, Tang, et al [6] in his paper related to the capabilities and application of FEM code has studied that the use of simulation tools helps in optimization process. Tomov, Gagov and Radev [7] in his paper of Numerical simulation of hot die forging process has made use of finite element method for the designing of hot die forging process. Jolgaf, Hamouda, et al [8] in his paper related to the use of CAD/ CAM system for forging process has shown that use of such tools helps in the designing process of forging.

III. PROBLEM DEFINITION

The aim is to develop an three cylinder crankshaft approximately weighting 22kg. Closed Die Forging process will be used and the component will be forged in blocker and finisher die. The computer simulation tool will be used so as to predict the defects such as underfill, folds and actions will be taken to reduce the defects and produce a defect free component.

IV. FORGING SIMULATION METHODOLOGY

In forging simulation methodology the actual forging process is being simulated in Forge simulation software. This helps to get an insight of how the forging will take place

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without taking any shop trials. With the rapid development in the forging field and to maintain the competitiveness the use of such tools has been an advantage to the industry. With the help of such the design engineer can easily check the forging process for any defects and thus it will help to save time, money and help to improve productivity.

The simulation tool help in the process modeling of Forging to achieve the required goal. With the help of process modeling changes can be made in the product design in the early stages of product development. Firstly an Computer Aided Design (CAD) model of the Blocker and Finisher Dies are developed as per the requirement of the crankshaft. The Blocker die gives an primary shape, whereas the Finisher Die consists the main impression of the required crankshaft.

V. MESHING OF DIE

After the development of the CAD models of the Blocker and Finisher die, the dies are meshed in meshing software called as Hypermesh. Before meshing the cleaning of the dies is required. The geometry consists of free edges, three or more surfaces having an common edge which needs to be cleaned before meshing. The free edges are deleted and some of the edges which cannot be deleted are joined to form a smooth surface.

The cleaning is important because the geometry surface needs to be continuous. The meshing of the dies is the next step. The impression sinking region is meshed with small sized elements with a very fine mesh, the next striking faces and the gutter region are meshed with a little more coarse mesh size and finally the outside surfaces like the side walls are meshed with more coarse mesh size. The number of elements generating during meshing needs to be controlled or to be precise needs to be maintained as it affects the computation time. This is done to reduce the computation time in the simulation process. The mesh sizes for the impression sinking region is 1 to 2, for striking faces is 2 to 8, and for side walls it is 8 to 16. The figure 1 shows the meshed Blocker Die and figure 2 show meshed finisher Die with the striking face, impression sinking region and the side walls.

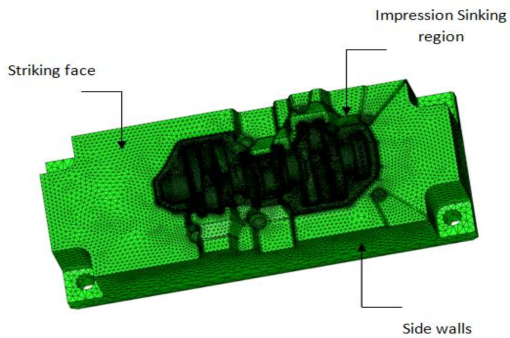

Figure 1. Meshed Blocker Die

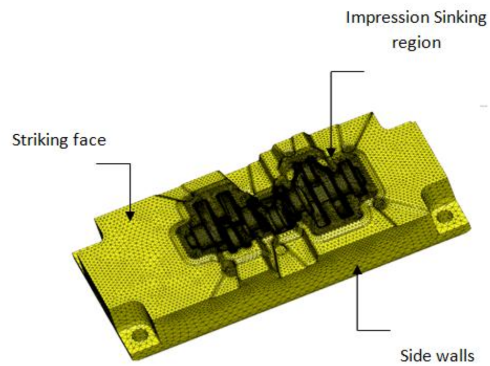

Figure 2. Meshed Finisher Die

VI. SIMULATION PROCESS

Simulation of the process is done on the software called as Forge where the virtual manufacturing of the forging is done to analyse parameters like underfill if taking place, folds. Working of the software takes place in three stages which are preprocessor, computation and the postprocessor. The various input required for computer simulation were initial preform geometry, material details, die geometry, forging equipment details, etc.

One of the important feature available is the ability to observe the metal flow simulation. The metal flow pattern helps to understand how the metal flow takes place, which helps in finding out whether there is any folds taking place.

The figure 3 shows the underfill occuring in a blocker die and is taking place at three place. The underfill is an undesirable defect which should be given an prior importance and measures should be taken so as to get a fill up.

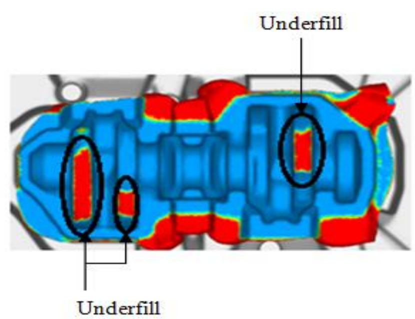

Figure 3. Underfill taking place in Blocker Die

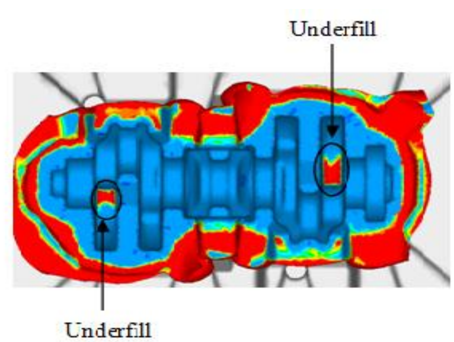

Figure 4. Underfill taking place in finisher Die

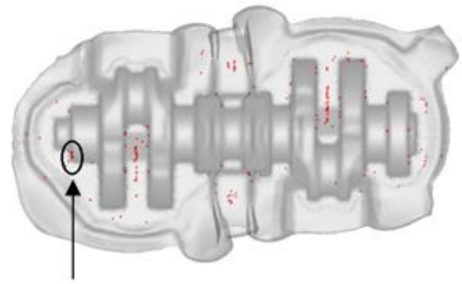

Figure 5. Fold taking place in finisher Die

The Figure 4 shows the underfill occuring in an finisher die. It is necessary to get an fillup in the finisher die as it resembles the main product. The figure 5 shows the fold analysis which can be used for prediction of folds. The figure shows the formation of folds in the highlighted portion. As stated earlier the underfill and fold formation is an defect. To overcome the problem of underfill and folds number of iterations were performed and the change in stock size and in die geometry helped to achieve fillup. Some modifications were made in the finisher die to prevent the formation of the folds.

Figure 6 and 7 shows material filling in the die cavity of the blocker die and finisher die respectively. Figure 8 show no fold formation in the finisher die.

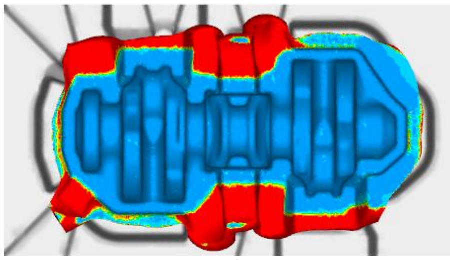

Figure 6. No underfill in Blocker Die

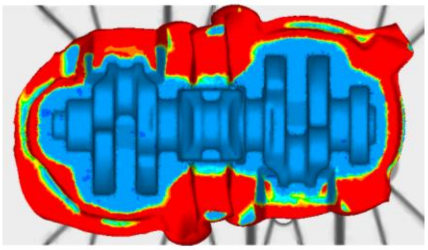

Figure 7. No underfill in Finisher Die

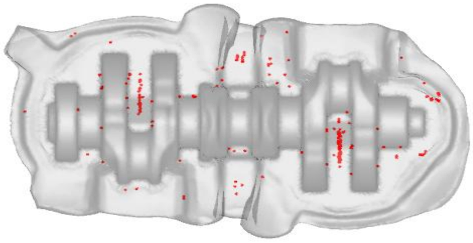

Figure 8. No Fold formation in finisher Die

The red dots in the other area shows up due to the distortion of the mesh taking place during forging process. It was been observed that the simulation process helps in analysing the results and thus making changes so as to develop product as per the requirement.

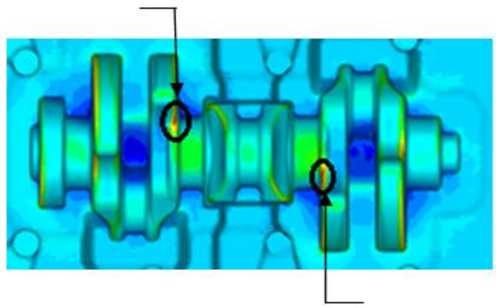

Figure 9. Finisher Die Stress results

The simulation software is also used for the Die stress analysis. The finisher dies which show fillup and has no folds i.e. die with no defect is used for die stress analysis. The Figure 9 show die stress results of the finisher die. The die stress analysis is used to determine high stress zones which would help them making some changes in the die geometry for further products so as to reduce the stresses in die.

VII. RESULTS AND DISCUSSION

Dies being developed for an three cylinder crankshaft and simulation was carried out for prediction of defects. Underfill, folds were being observed in the dies and iterations were carried out to remove these defects. Stress analysis was being done and it was found that the stress where within the stress limits.

VIII. CONCLUSION

With help of the simulation tool it is quite easy to make changes in the product development stage and reducing the costs associated with trails. The simulation tools give an insight into the forging process and helps in developing an process model. The computer simulation helps to capture the defects occurring during the forging process and thus helps in making changes. The entire process helps to arrive at an design with no defects, reducing the costs and thus improving the productivity.

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