Conference Article

The Effect of Pre-Forming on The Forged Part in the Hot Forging Process

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Abstract

Analysis programs based on finite elements have great importance in verifying the design and production processes. In the automotive industry, many parts are produced by hot forging process. The die designs of the parts to be produced by hot forging process are verified by finite element analysis programs. In this study, the importance of pre-forming in hot forging process is investigated by using finite element method and the necessity of pre-forming is indicated by the analysis. In the analysis phase of the study, hot forging finite element analysis was performed for 4 different cases of the torque rod housing that one of the suspension parts of heavy commercial vehicles part using FORGE NxT program. In addition, experimental studies were carried out for these cases and the results obtained were compared with the analysis results. The results obtained as a result of the analysis and experimental study were found to be consistent with each other. It has been observed that pre-forming is very important and necessary in the hot forging process in order to increase die life and to reduce die runaway, crease and non-filling problems.

Keywords: Hot forging, preforming, finite element method, FORGE NxT, Die

1. Introduction

Among manufacturing processes, forging technology has an important place as it helps to produce parts with superior mechanical properties with minimal material waste [1]. Forged parts are used in high performance, high strength and high reliability applications where human safety is important. They are also used in a wide range of harsh environments, including highly corrosive, extreme temperatures and pressures [2]. In the forging industry, the design of process sequences for specific parts relies heavily on experimentation, accumulated experience and the skill of process designers. In multi-stage forging processes, pre-die design is critical to ensure the production of defect-free parts [3]. The design of the pre-form includes factors such as changing the billet shape, varying the flange thickness and width, increasing the corner and corner radii to reduce forging loads, as well as ensuring that the die impression is fully filled. A good pre-die design ensures proper distribution of metal in the die cavity [4]. The most important engineering work in the hot forging process is to determine the sequence and number of forging stages of the part to be produced and the die designs to ensure error-free production. At this stage, within the framework of general forging rules in the industry, designers use their own experience and experience in die designs and design by trial and error method. Therefore, cost and time loss is inevitable [5]. The defects encountered in hot forging are non-filling of the material, formation of layers in the part, misalignment of the part and premature wear of the die. The factors that cause these defects are insufficient material, low annealing temperature, faulty or inadequate pre-forging design, incorrect die material selection, incorrect burr formation, etc [6]. For forging simple cylindrical and axisymmetric shapes, billets can usually be forged in a single operation. However, for complex shapes, often die filling can only be satisfactorily achieved through the use of a pre-forming process. Properly designed pre-forms can result in reduced forging loads, eliminate flow errors and allow hollow parts to be made from solid bar [7]. The amount of residual material formed on the die opening line and between the die halves of the forged part is called burr. In forging in closed dies, the residual material flows into the burr cavity [8].

2. Materials and Methods

2.1 Material

The chemical composition of the forged housing raw material used in the study are given in Table 1. The diameter of the raw material used for housing production was determined as 60 mm, length as 165 mm, raw material temperature as 1150 C° and these values were kept constant in the analysis.

Table 1: C45 Material Chemical Compositions (weight %) [9]

Content	C	Si (max)	Mn	P (max)	S (max)	Cr (max)	Ni (max)
%	0.42-0.50	0.40	0.50-0.80	0.045	0.045	0.040	0.040

2.2 Method

The following steps can be followed to determine the pre-forming form during hot forging die design;

- Cad model of the part is created.
- The burr line is drawn 6 mm around the part.
- Transverse and longitudinal planes are created on the model at 1 mm intervals.
- The cross-sectional area of the part at each 1 mm is calculated and the volume distribution graph of the part is obtained.
- With the help of the curve obtained in this graph, the geometry of the pre-forming form is obtained.

Figure 1 shows the part cad data with planes created.

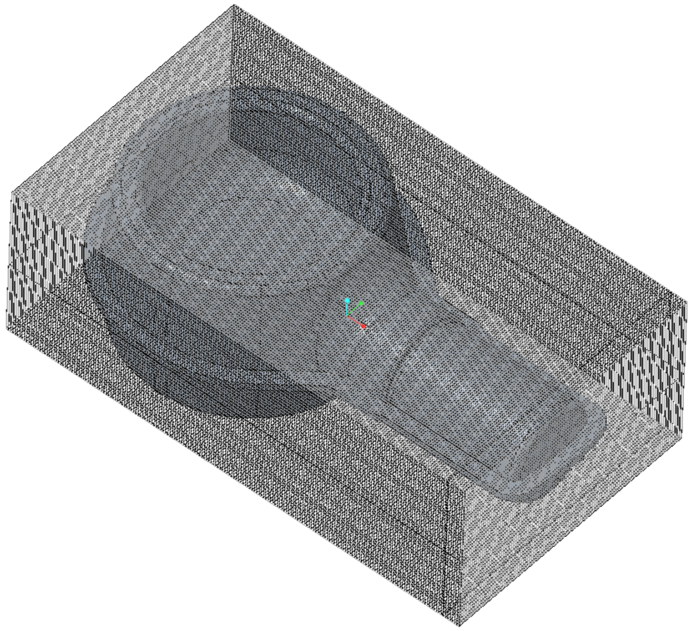

Figure 1: Planes on part cad data

Figure 2 shows the volumetric distribution graph based on the cross-sectional area values taken from the housing model.

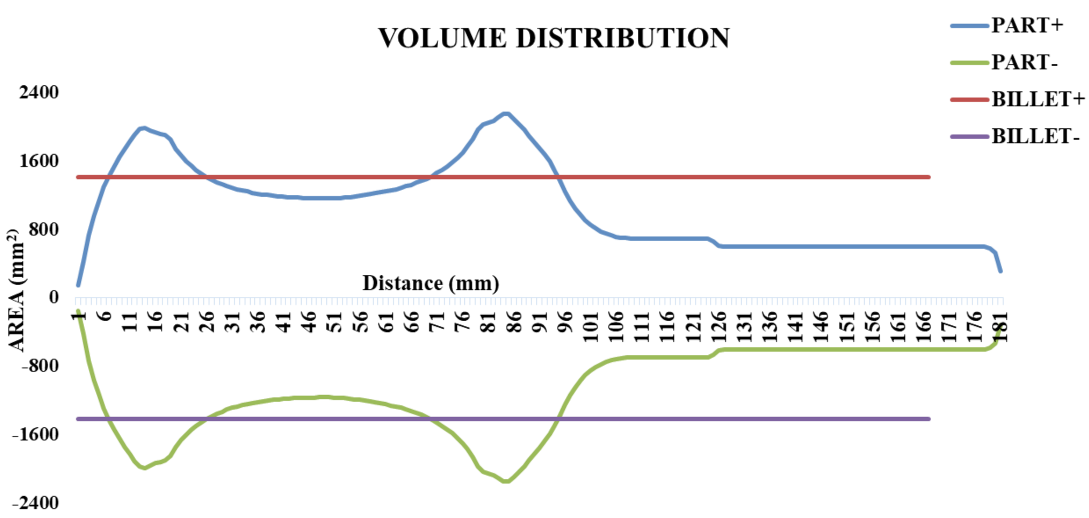

Figure 2: Volumetric distribution graph for determination of pre-forming

According to the obtained volumetric pre-forming graph, the forging stages are given in Table 2.

Table 2: Prescribed forging stages and objectives

Forging Steps	Objective
Upsetting	It is aimed to increase the diameter by bulging the billet to cover the largest area in the volumetric distribution graph.
Shaft Crush	It is aimed to collect the volume in the head part and fill the shaft length by preventing excess burrs that will form in the shaft part of the part.
Rough Forging (Pre-forging)	It is aimed to minimize the die deformation that will occur in the final forging, to facilitate the material flow in the final forging, to store the volume to fill the final forging, to facilitate the positioning of the part in the final forging die.

3. Results

3.1 Finite Element Analysis

In this study, finite element forging analysis was performed for the following 4 different cases.

1- Only the final forging.
2- Pre-forging and final forging process.
3- Upsetting, pre-forging and final forging process.
4- Upsetting, shaft crushing, pre-forging and final forging process.

3.1.1 Only Final Forging

In this analysis, the forging process analysis was carried out in the final forging die without any pre-forming on the billet and the filling condition of the part and the stresses occurring on the die were examined. The filling state of the part is shown in Figure 3.

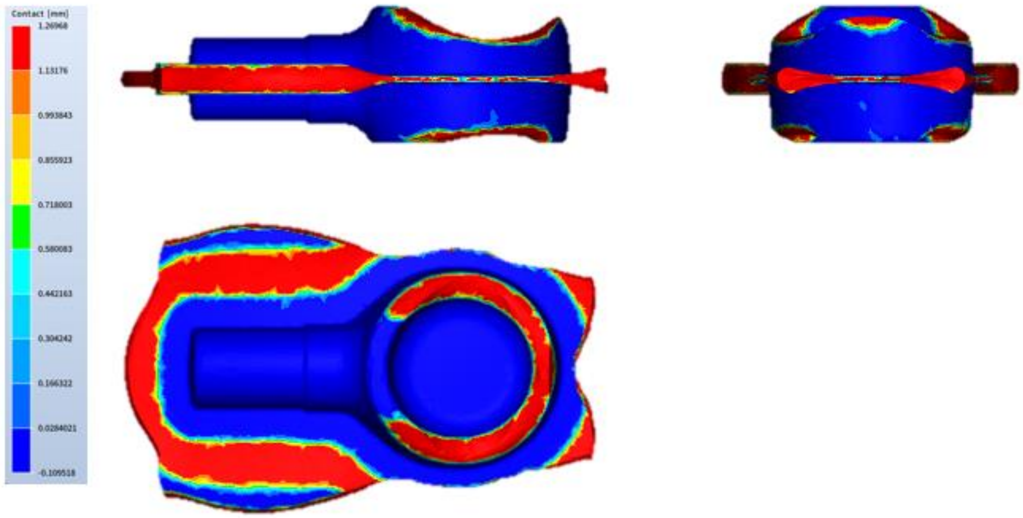

Figure 3: Filling state of the part only in case of final forging

As a result of the analysis, the design made without pre-forming showed a large amount of non-filling in the part. It is understood that forging in a single stage is not suitable. A maximum stress of 7998 [mm.MPa] was observed on the die.

3.1.2 Pre-forging and final forging process

In this analysis phase, the rough pre-forging process, which was created by using the volume distribution graph, was included in the process and the condition of the part after rough pre-forging and final forging was examined. The filling state of the part is shown in Figure 4.

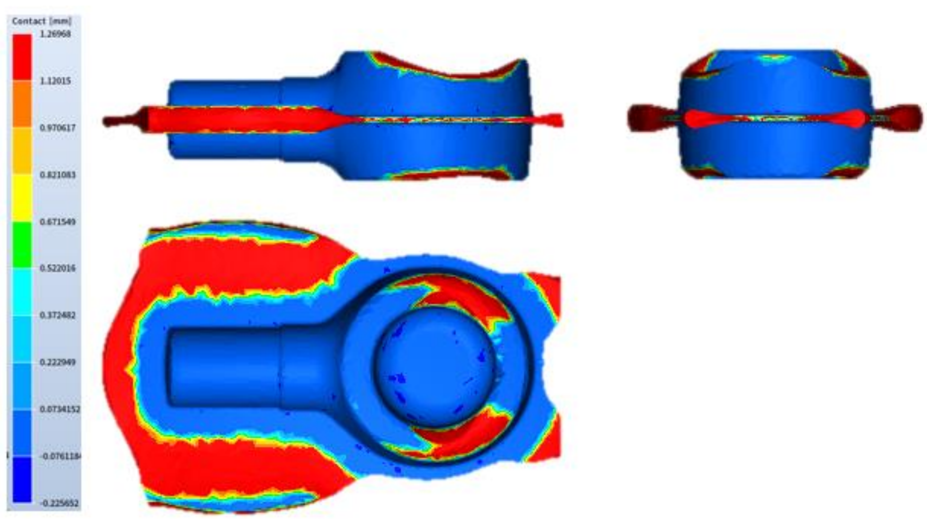

Figure 4: Filling state of the part after pre-forging and final forging process

As a result of the analysis, there was an improvement in the filling of the part after the addition of the preforging stage, but not enough to fill the head of the part. The maximum stress on the die was observed at 4138 [mm.MPa].

3.1.3 Upsetting, pre-forging and final forging process

The diameter corresponding to the largest cross-sectional area of 4295 mm^2 calculated during the obtaining of the volumetric distribution graph was 74 mm. In the first stage, the billet with a diameter of 60 mm and a length of 165 mm was bulged at forging temperature to a diameter of 75 mm and a length of 115 mm.

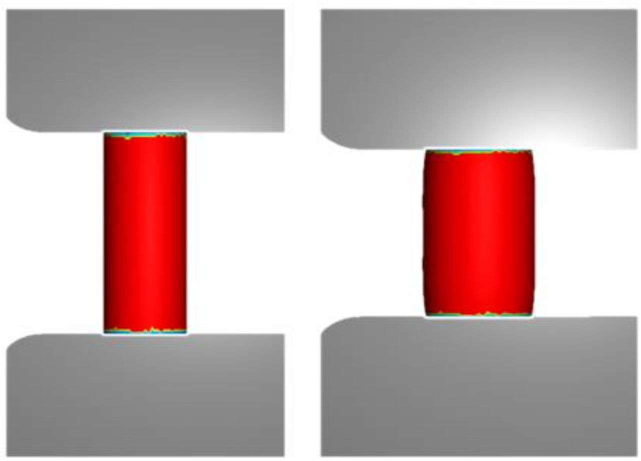

Figure 5: Billet view before and after upsetting process

As a result of the analysis, it was seen that a sufficient volume of material was collected in the head part of the part after the upsetting operation was added. However, a non-filling situation was observed in the shaft part of the part. A maximum stress of 4090 [mm.MPa]. was observed on the die. The part filling condition after the final forging is shown in Figure 6.

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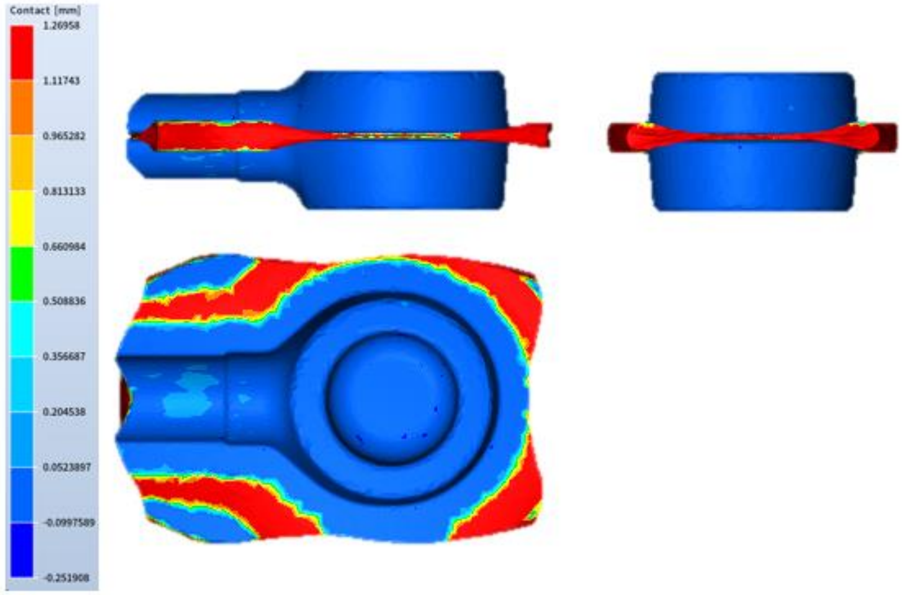

Figure 6: Filling state of the part after upsetting, pre-forging and final forging process

3.1.4 Upsetting, shaft crushing, pre-forging and final forging process

In this analysis phase, the shaft crushing operation was added due to excessive burrs from the shaft part of the part and not filling its length. Shaft crushing length was determined as 55 mm and height as 40 mm.

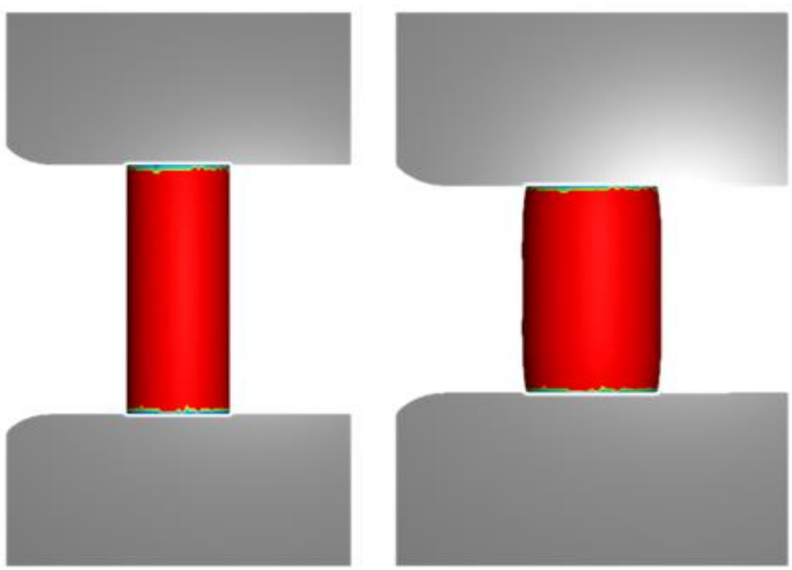

Figure 7: Billet view before and after upsetting process

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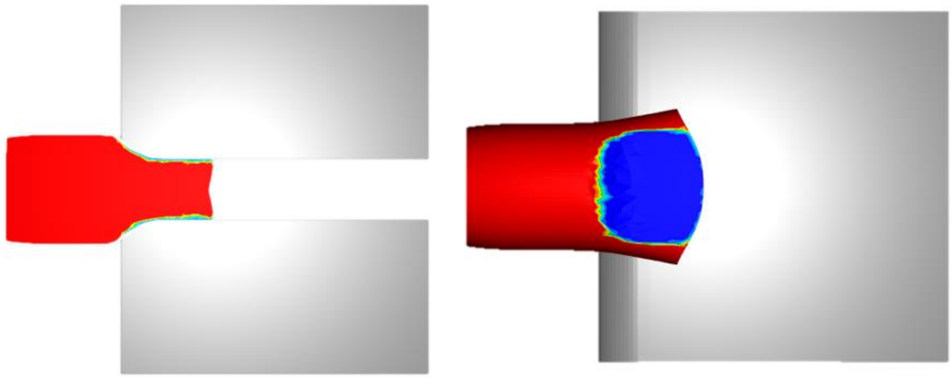

Figure 8: Billet view after shaft crushing process

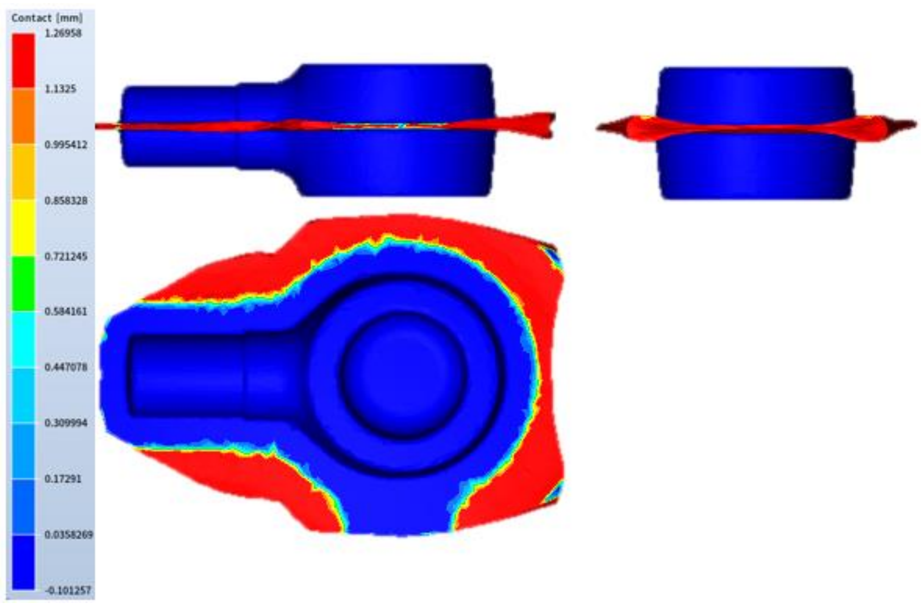

Figure 9: Filling state of the part after upsetting, shaft crushing, pre-forging and final forging process

As a result of the analysis, it was seen that the part was completely filled after the shaft crushing operation was added. The maximum stress on the die was 5172 [mm.MPa].

3.2 Experimental Studies

In addition to the analyses made for 4 different cases for the hot forging process of the torque rod housing, forging process was carried out for these 4 different cases. In the experiments performed without pre-forming, non-filling problem was observed in the head and shaft parts of the part as seen in the analysis.

In the experiments carried out with upsetting, shaft crushing operation and rough forging, it was seen that the part was well filled.


(a) (b)

Figure 10: (a) Part forged without pre-forming (b) Pre-formed and final view of part

4. Conclusion

- The results obtained as a result of the analysis and experimental studies were found to be consistent with each other. It is understood that finite element analysis has an important place in die designs for hot forging process.
- With the addition of pre-forming stages, it was observed that the stresses occurring on the die were highly reduced. Thus, the pre-forming process is of great importance in terms of die life.
- Forging defects, non-filling and excessive raw material consumption can be minimized by correctly determining the pre-forming stages.

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