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DESIGN OF HOT FORGING PROCESS OF PARTS WITH COMPLEX GEOMETRY IN DIGITAL ENVIRONMENT

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ABSTRACT
Hot forging of complex part is usually performed as multi-stage process. Therefore, forming sequence design together with preform shapes is a very challenging engineering problem with numerous possible solutions. In past, the conventional approach to the forming sequence design has been empirical and mainly based on trial and error procedure that is time and money consuming. Nowadays, with development of CAE technique and software packages it is possible to design entire forging process in digital environment, more effectively and more reliably.
In this paper hot forging process of part with complex geometry such is pneumatic clamp (yoke like element), is considered. The shape of the pneumatic clamp is very unfavorable for forging technology and therefore defects and part inaccuracy as well short lifetime of forging tools are common. In order to overcome the existing problems Finite Volume (FV) analysis of forging process has been conducted by using Simufact.Forming 9.0 program package and an optimization procedure of forging steps and tool geometry carried out.
Keywords: FV simulation, hot forging, yoke-like part

1. INTRODUCTION
Hot forging as one of the oldest ways for processing metals, still has a key role in the production of components built-in applications where reliability, demanding environments, human safety etc. are critical consideration. In the past, tradition and unique position among manufacturing processes have made this technology very rigid in terms of process improvements. But permanent rise in the cost of energy and raw materials, demands for increasing accuracy of forged components, higher ecological requirements etc. forced many forgers to make a review of their manufacturing procedures so they can be cost and quality competitive on market [1, 2].
Hot forging is usually performed as multi-stage process and therefore optimization of forming sequence and preform shapes is crucial for obtaining high-quality forgings with minimum cost. Forming sequence design of hot forging process is time and money consuming procedure [3]. For a long time set-up of forging process has been based upon activities strongly dependent on human experience [2, 4] and performed by experimental trial-and-error approach. However in many cases, this procedure is neither optimal nor cost effective in terms of achieving desired properties of final product. Opposed to such approach, recent development of computer-aided simulation techniques, offers the possibility to design forging process in more efficient and qualitative way. Moreover, process optimization which is realized in digital environment enables concurrent analysis of large number of process variables and perform solutions before actual try out [5,6].

In this paper hot forging of part with complex geometry such is pneumatic clamp (yoke like element), is considered. In order to overcome the most common problems which occurs in practice during forging of this type of element, Finite Volume (FV) analysis of the existing forging process has been conducted by using Simufact.Forming 9.0 program package. According results, in next step an optimization procedure of forging operations and tool geometry is carried out.

2. PROCESS DESCRIPTION AND FV-MODELING

Pneumatic clamp, which one model is given in Fig.1, is used as cable carrier and stretching element of high voltage transmission lines. In exploitation the pneumatic clamp is exposed to heavy thermo-mechanical loads and therefore this yoke-like part is traditionally manufactured by hot forging. However, its irregular geometry (combination of long body and yoke-like head) is very unfavorable for forging technology. The result is frequent occurrence of defects on the forgings. (Fig2.).

Figure 1. Finil shape of pneumatic clamp (after machining)

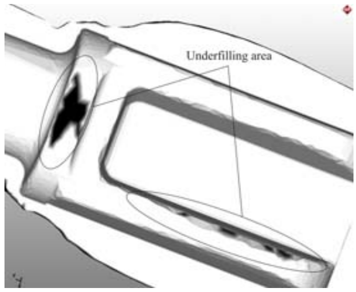


Figure 2. Underfilling areas at head section of pneumatic clamp

The conventional process of hot forging of the pneumatic clamp comprises following operations: preforming, final forging, flash trimming and plate punching. Here analyzed hot forging process of the pneumatic clamp is applied at “Proleter”-Arilje, (Serbia) forging plant. This forging process is designed upon trial and error method and upon experience. Preforming operations are realized by flat dies (open die forging) as finial forging is obtained by blocker die with one impression. The existing forging variant is unsatisfactory in terms of forging component quality (insufficient die filling-Fig.2) and accuracy as well short lifetime of the forging tools [7].

In simulations, the following assumptions of the process variables are implied: the dies are considered as rigid bodies, fixed bottom die and movable upper die, strain rate $\dot{\varphi}$=6.5 [s^{-1}]. As for boundary conditions the initial forging temperature is 1150°C, preheated dies temperature 400°C, constant friction model is applied and friction factor is assumed to be m=0.3 [15]. The capacity of pneumatic hammer which is used in simulations is limited to 80kJ in respect of the actual hammer capacity in industry.

3. ANALYSES of EXISTING FORGING PROCESS

Intermediate steps in preforming with open dies are schematically illustrated in Fig.3. Dimensions of the billet made from steel C45 (DIN) were 55x55x113mm. It requires 6 blows while rotating the workpiece between upper and bottom die to obtain preform which is then forged into the final shape. For complete cavity filling of the finishing dies, 3 blows are required when use 80kJ hammer. Fig.4 displays distribution of contact stresses at the end of forging. Predicted values of the contact stresses are pretty high 1800MPa in average and with maximum values of 3000 MPa. It means that finishing dies are overloaded in some sections which may reduce their service life significantly.

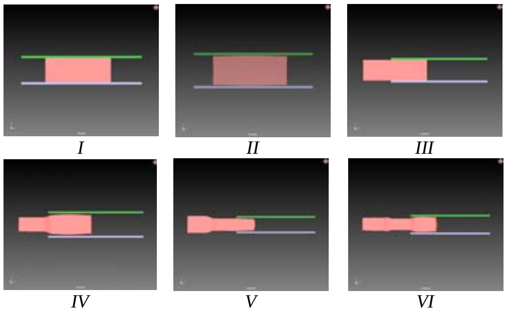


Fig.3 Preforming stages realized with open dies

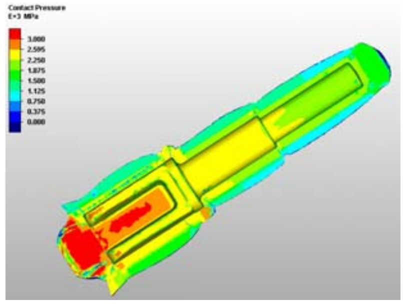


Fig.4 Contact stresses in the operation of final forging (open-die preform)

Exploring the problems of cavity underfilling and poor geometry occurrence at head section of the pneumatic clamp (Fig.2) following factors were identified as possible causes of these problems: incorrect positioning of the preform in the finishing impression, cooling of the workpiece and unallowable drop of the temperature as a consequence of long preforming time, and inappropriate preform shape.

4. OPTIMISATION of HOT FORGING PROCESS OF PNEUMATIC CLAMP

The main objectives in developing of new forming-sequence design were:

- reduction of the number of operations from classical forging process sequences
- improvement of material flow and die cavity filling process in operation of final forging
- material saving through flesh reduction

In new forging process one preparation step and two performing operations are planned before final step is performed. Preparation step (flat upsetting at small high reduction) is scheduled in order to remove the scale from the billet surface and to improve metal flow in further forging operations. Blocker die with three impressions is used for preforming and final forging. The first preforming impression is intended for rough shaping (mass distribution) as the second one is employed for preliminary shaping of workpiece. Operation for preliminary shaping is commonly applied when forging part with complex geometry to ensure complete die cavity filling as well to reduce contact pressures and die load in operation of final forging. Based on the results of previous simulation both preforming impressions are designed elliptical in order to increase the portion of horizontal forces crucial for proper material flow.

In this case, bulk 50x50x134mm is used as the billet which is about 2% less then in exiting process. Preforming for mass distribution is realized with 2 blows of the hummer and 90° rotation of the workpiece around longitudinal axis after first blow. Intermediate shapes and effective stresses within workpiece during operation of mass distribution and after preliminary forging are displayed in Fig.5 and Fig.6.

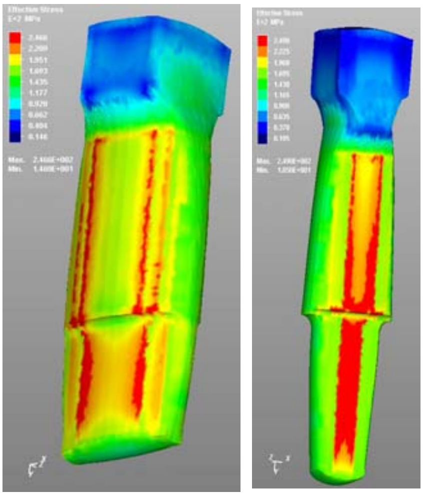
Final forging requires 2 blows of 80MJ hammer for complete filling of the die cavity. Simulation shown that in this case defect free part could be obtained (Fig.7.a), as the amount of material into the flash was reduced for about 5%. Also, contact pressures are significantly lower with maximal predicted value of 850MPa (Fig.7.b).

5. CONCLUSION

In this paper an existing process of hot forging of the pneumatic clamp is analyzed by FVM simulation with goal to reduce contact pressures in the operation of final forging and to improve geometrical accuracy of the forged part. In that purpose a new performing sequence is designed. From obtained results following can be concluded:

- Preform stages and intermediate shape influences very much both: accuracy of final part and die load
- Preforming stages realized with open dies are very time and energy consuming
- Part accuracy is very sensitive to the positioning and centering of the preform in the finishing impression.

- Contact pressures in the operation of final forging are very height in case when use the preform obtained by flat upsetting
- Preforming with impressions for mass distribution and preliminary shaping ensure defect-free, complete die fill and small metal loses into flash



I blow II Blow

Figure 5. Preforming steps in operation for mass distribution

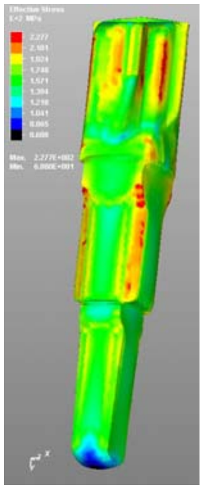
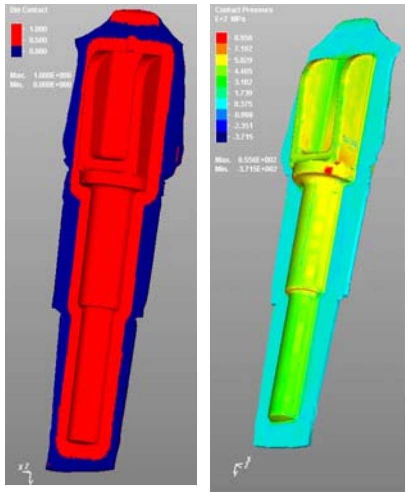


Figure 6. Final shape of preform



a) b)

Figure 7. Die-material contact (a) and contact stresses (b) after final forging

6. ACKNOWLEDGEMENT

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