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FINITE ELEMENT SIMULATION (FES) OF THE FULLERING IN DEVICE WITH MOVABLE ELEMENTS

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In the paper there is studied stressed-and-strained state formed in a billet by fullering in a tool with movable elements. It is determined that compressing stresses prevail in the studied tool; they improve the quality of the processed billets. Even maximum main normal stresses have compressing characteristics at slight tensile stresses. Stressed-and-strained state was studied by using the computer simulation method which was performed in the DEFORM 3D software. The obtained results confirm the efficiency of the new tool in processing cylindrical billets.

*Key words: f*errous materials, tool, stress, strain, FES

INTRODUCTION

Developing resource-saving ways of obtaining materials with properties combining simultaneously high durability and plasticity in the conditions of using rather simple and inexpensive devices permitting to spend a minimum possible amount of time when processing products is very topical. A high share of products made if ferrous metals consists of cylindrical billets. However specifics of processing cylindrical billets consist in emergence of tensile stresses in the central layers of a billet directly when carrying out technological operations.

Stressed-and-strained state and the character of the metal current when forging are defined by the combination of the form factor, the temperature and kinematic factors. Besides, the size and the shape of the final billet in the processes of opened and closed forging depend first of all on the parameters of the working dies speed, the temperature of the dies and the billet, the deformation speed, etc. [1, 2]. Realization of the process of forging promotes increasing the indicators of durability at the sufficient level of plasticity. At this there takes place the effective crushing of grain and eutectic phases [3]. There is widely used forging with compacting the powder materials [4]. However in open forging there is observed heterogeneity of the stressed-and-strained state. The most severe conditions are characteristic of the extreme areas of the billet.

The main drawback of traditional processes of forging, rolling and pressing is considerable unevenness of stresses and strains distribution, as well as a high level of using the resource of the material plasticity directly when processing [5]. When selecting the scheme of deformation there are emphasized the schemes realizing shear strains [6, 7].

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When realizing the comprehensive closed forging the structure uniformity is achieved by carrying out a large number of cycles of deforming [8]. At this increasing the cycles of deforming promotes the growth of the limit of fluidity, strength and relative lengthening.

In work [9] the authors also note the existence of inhomogeneity of the grains distribution after multiaxial forging. The authors of work [10] revealed that within hot gorging there is needed the temperature 0,8 $T_{пл}$ and the true deformation 0,92 for destructing the oxide layer of the powder billet. The results were obtained when studying the impact of deformation at various forging temperatures on the morphology of particles, intergranular porosity, the oxide layer and hardness. The authors revealed anisotropy of mechanical properties of the studied billets.

In work [11] there is considered the problem of forming superficial cracks in hot forging of a cylindrical bar. It was revealed that the most dangerous is the forging temperature below 650 °C. By means of modeling in the FORGE program there was assessed the criterion of destruction and shown the impact of the deformation speed, the temperature and the parameters of destruction on the process of superficial cracks emergence when forging.

The authors of work [12] considered the multi-purpose optimization of the forging tool geometry when forging cylindrical billets. At this the authors emphasize that for producing large cylindrical forgings there are used as initial billets the cast ingots containing a large number of defects, such as porosity due to the wrong pouring or gas generation, rough structural components as a result of long cooling. These defects reduce the quality of billets obtained as a result of carrying out forging. According to the authors, there was most widely used forging in the combined dies when the die is flat and the bottom one has a V-shaped cut. At this, despite the statement of the authors that using the combined dies with V-shaped cuts with the angler 90° of the bottom die is optimum, the strain intensity distribution for all the cases considered by the authors was not homogeneous. Besides, there is observed the strains concentration either in the center of the billet or with some shift from the center.

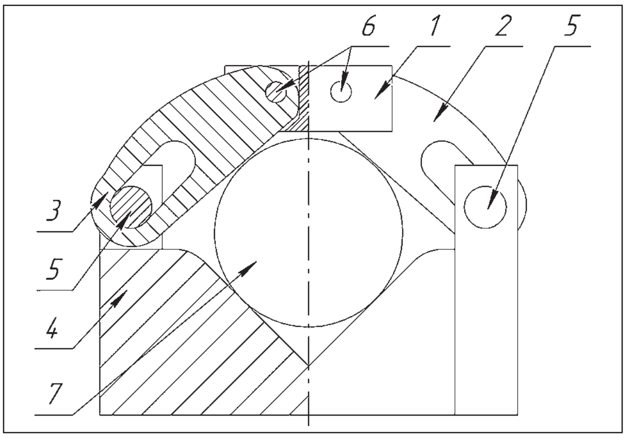
When realizing the fullering the largest bottleneck remains cylindrical billets forging. A specific feature of forging cylindrical billets is the stressed-and-strained state in the course of deforming. When forging cylindrical billets intensification of stresses in the central part of the billet is very dangerous. As a rule, the lines of the maximum punching stresses are located cross-shaped at the angle 90 ° to each other and 45 ° to an axis of the loading applying. The emergence of the forging cross can cause loosening and cracking of the billet in the central part. In addition, in the fullering of cylindrical billets in the cross section there emerges a big gradient of stresses and strains.

MATERIAL AND METHODS OF STUDYING

Studying fullering of cylindrical billets was carried out by the finite elements method in the environment of the DEFORM 3D software complex. The deformable body in the model was determined by the grid of tetragonal finite elements distributed in the billet volume. The total number of finite elements was selected equal to 30 000. For equipping there was used instrumental steel. As the model material there was used constructional steel of grade 35. Modeling was carried out taking into account heat exchange (heat transfer) between a billet, the equipment and the environment under normal conditions (the ambient temperature was taken equal to 20 °C). For the tool there was selected the room temperature. The temperature of the billet was set according to the forging interval and was selected equal to 900 °C. When modeling there was considered the stressed-and-strained state at friction coefficient equal to 0,1; 0,3 and 0,5. When studying there was assumed that the billet length was equal to the dies width, the rigid ends were not considered. There was considered a single course of the tool, the dimensions of the billet were Æ 50 x 60 mm. Studying was carried out when drafting by 10, 15 and 20 %.

RESULTS AND DISCUSSION

Realization of forging in flat dies results in essential heterogeneity on the billet section both of stressed and strained state. The simulation showed inhomogeneity of all the indicators of stressed state on the billet section (when drafting by 15 %); there was observed the maximum stress concentration in the field of the forging cross, the gradient of strain intensity between the central and peripheral layers reaches 0,5. Using the combined dies: the flat top one and the bottom with a cut at the 90 ° angle displaces the forging cross to the flat die, at this the gradient of strain intensity reaches 0,68.



1 – top die; 2, 3 – movable working elements; 4 – bottom die; 5 – bottom die hinges; 6 – top die hinges; 7 – billet
Figure 1 A device for fullering

For the purpose of ensuring homogeneity of stressed state there was developed a new modification of the tool for the fullering of cylindrical billets. The tool geometry is presented by two dies: a bottom die with a cut at the 90° angle and a top die of a new design with movable components. At this the new movable die is executed in such a way that in an initial moment the angle of the components disorder is equal to the angle of the cut die, in the process of the dies moving to each other the angle of the compound die increases smoothly and to the end of the movement it becomes equal to 180 °, i.e. its shape becomes similar to the shape of the flat die (Figure 1).

The existence of movable elements excludes the formation of punching stresses in the central zone of the billet. In deforming there is mainly observed homogeneous distribution of stresses and strains both when drafting by 10 and by 15 %. In the process the growth of stresses happens from contact sites, then the values of stresses are leveled on the entire section of the billet, and the process repeats. The continuous movement of the movable elements excludes the emergence and accumulation of the maximum stresses in the zone of the forging cross, promoting a uniform machining of its entire section. The variation of the friction coefficient does not render an essential impact on the character of stressed-and-strained state, but it effects numerical indicators. At the friction coefficient equal to 0,1 there is observed a weak contact of the billet with the tool, the billet slips on the tool. The friction coefficient equal to 0,5 develops an essential resistance to the shear of the contact layers along the working surface of the tool causing the warming up of the billet peripheral parts. The most bright effect of the friction coefficient is shown in assessing the tendency to destruction. In the central layers the tendency to destruction for all the considered cases does not exceed 0,01. It was revealed that the minimum tendency to destruction in the peripheral free layers is observed in deforming with the friction coefficient equal to 0,3 that was taken as optimum. In deforming in the new tool the maximum tendency to destruction was 0,2 that would provide the forming of a high-quality billet.

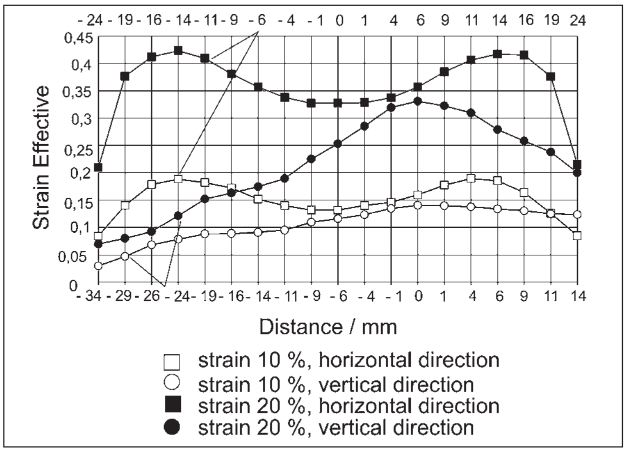


Figure 2 Distribution of strains intensity on the billet section in deforming by 10 and 20 %, respectively

It was revealed that the greatest values of stress intensity were in the zones that are in contact with the tool. In these zones stress intensity in deforming with the friction coefficient equal to 0,3 reaches 160, 190 and 210 MPa for the strain extents 10, 15 and 20 %, respectively. At this at free sites stress intensity dis not exceed 100 MPa for all the considered strain extents. In the axial zone stress area intensity makes 80, 110 and 140 MPa, respectively. In Figure 2 there is shown the distribution of strain intensity on the billet section in the vertical and horizontal directions when deforming by 10 and 20 %, respectively. For the vertical section of the billet it is asymmetrical in connection with the existence of a cut in the bottom die. As in case of stress distribution, the strain extent exerts an impact on the value of strains intensity, but not on the nature of their distribution.

In the horizontal direction strain intensity is distributed symmetrically relative to the sample center. In the central zone the values of strains intensity in deforming by 10 % make 0,14. The maximum strains (0,18) are in the layers located at the distance of 14 to 16 mm from the center. In peripheral layers there is observed decreasing strains intensity to 0,08.

Increasing the strain extent up to 20 % causes the growth of strain intensity of the central layers to 0,33. The maximum strains (0,43) are also in the layers located at the distance of 14 to 16 mm from the center. In peripheral layers the values of strains intensity are 0,22.

The values of strain intensity in the vertical section in the central zone and the top new die with movable elements make 0,1 to 0,14 at the 10 % strain extent. Increasing the strain extent up to 20 % promotes the growth of strains intensity to 0,2 near the top movable die and 0,32 for the central layers. In the zone close to the cut die the values of strains intensity decrease to 0,05 and 0,2, respectively for strains extents equal to 10 and 20 %.

CONCLUSIONS

There was performed the finite element simulation of the process of fullering in a new tool with movable elements. There was carried out the comparative analysis with fullering under a flat and combined dies with a bottom cut die. It was revealed that the new device provided homogeneity of stressed-and-strained state of the billet within a single drafting, while in fullering in traditional dies there is observed essential heterogeneity of stressed-and-strained state. Using the new tool permitted to exclude completely the emergence of tensile stresses in billets deforming.

The extent of the billet strain is corrected by the angle of the movable working dies. Increasing the extent of strain for a single drafting promotes the growth of the values of stressed-and-strained states indicators. The nature of distribution with increasing the extent of the billet strain does not change.

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Note: Translator into English N. Drak, Karaganda, Kazakhstan