Volume 62 • Issue 2 • February 2014

Journal of Achievements in Materials and Manufacturing Engineering

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Simulation of the new technology of forging of blanks such as slabs and plates made of ferrous metals and alloys

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Received 18.12.2013; published in revised form 01.02.2014

ABSTRACT

Purpose: This article is devoted to the development and mathematical modeling of the new technology of forging of blanks such as slabs and plates from ferrous and non-ferrous metals and alloys in a step dies with a wedge bumps and hollows, allowing for minor energy consumption to intensify shear deformation in both longitudinal and transverse directions. **Design/methodology/approach:** The combination of two designs of dies will allow with minor inputs to intensify the shear deformation, in both longitudinal and transverse directions.

Findings: When its use the optimal and uniform distribution of the stress state is realizing, adequately implemented deforming, especially in the axial zone, as well as significantly less deformation load compared to the flat step dies. The use of a step-wedge dies during deformation will produce blanks with the qualitative deforming of the structure throughout the cross-section with little energy consumption.

Researches limitations/implications: During the simulations were studied energy-power parameters and stress-strain state of workpiece under its deformation in dies of new design in comparison with forging of similar workpieces in a normal step dies and ordinary wedge dies.

Originality/value: Wide development must receive an engineering service, as a basis for a knowledge-based economy. One of the main directions of implementation of this strategy is the construction of new and modernization of old enterprises for processing of ferrous and non-ferrous metals and alloys by pressure treatment that will produce competitive products not only on the domestic market, but also on international.

Keywords: Computer modeling; Slabs and plates; Forging

Reference to this paper should be given in the following way:

A. Naizabekov, S. Lezhnev, O. Krivtsova, A. Tolkushkin, E. Panin, Simulation of the new technology of forging of blanks such as slabs and plates made of ferrous metals and alloys, Journal of Achievements in Materials and Manufacturing Engineering 62/2 (2014) 75-80.

ANALYSIS AND MODELLING

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1. Introduction

At the moment in the world there are many energy -saving technologies, allowing to receive high-quality metal by rolling, forging, pressing and other methods of pressure treatment. During forge process this problem is successfully solved by deformation of metals in the special tools that implement shear and alternating deformation in the whole volume of deformable metal. Because the implementation of intensive shear deformation in the process of forging leads to a significant change in the microstructure source and the improvement of mechanical properties of deformed metal.

Tools that allow implementing deformation of metal by shear are step dies (Fig. 1a) [1] and dies which have a cross-sectional profile in the form of a wedge (Fig. 1b) [2,3]. These designs of dies allow implementing severe shear deformation throughout the volume of the deformable metal during the drawing process of the workpieces to produce forgings type of plates made of ferrous metals and alloys. Intensification of shear deformation during forging in step dies is largely in an longitudinal direction, and when using wedge dies on the contrary in the transverse direction.

At the Department "Processing of metals by pressure" of Karaganda State Industrial University was proposed to combine two designs of dies: step and wedge dies (Fig. 2). The combination of these two designs of dies will allow with minor inputs to intensify the shear deformation, in both longitudinal and transverse directions.

2. Preparation of model

During the development of technological process of forging of blanks on new dies and selecting the appropriate equipment is very important to value the load and the stress-strain state caused by the deformation. Analysis of the strain state allows to study the distribution of the accumulated deformation in the entire volume of the workpiece during deformation, to identify those areas that are more susceptible to deformation, and on this basis to define rational as geometrical and technological parameters of deformation. The study of the stress state is also an important stage in the development of a new technological process. Because the study of stress distribution in the workpiece during deformation allows to identify areas prone to the formation of defects due to the occurrence in them of large tensile stresses. This gives the opportunity to make the necessary adjustments to reduce the intensity of tensile stress and thereby prevent the formation of defects. To determine these values there are different methods. One such method is a method of computer simulation.

Simulation of various deformation processes in metal forming is an important task, because it allows the researcher to look "inside" of the process, to evaluate the resulting stress and strain, to predict the occurrence of defects. Simulation allows to identify the rational parameters of the tool and workpiece for better process behaviour. Modern modelling software systems provide tremendous opportunities for work. They allow to simulate almost any process, avoiding costly experiments.

To conduct the study were built 3 models of dies: wedge with angle of the wedge 170°. This value of the angle of the wedge was chosen as in the paper [2] it was proved that the optimal allocation of strain stress state occurs at large angles of the wedge (from 160 to 180). Step-wedge and flat step dies were also built. As the material for the workpiece was selected steel 15.

After simulation of the drawing process through jaunty, were compared on the following parameters: fracture criterion, equivalent strain, equivalent stress, hydrostatic pressure and force forging. These parameters were considered in the following areas: in wedge dies were considered cross-section of the workpiece (Fig. 3a); in step-wedge and flat step dies these parameters were considered on a slope, in a section perpendicular to the inclined faces (Fig. 3b, 3c), because on this area realized the shear deformation at step dies. Figs. 4-8 shows the simulation results.

a) b) c)

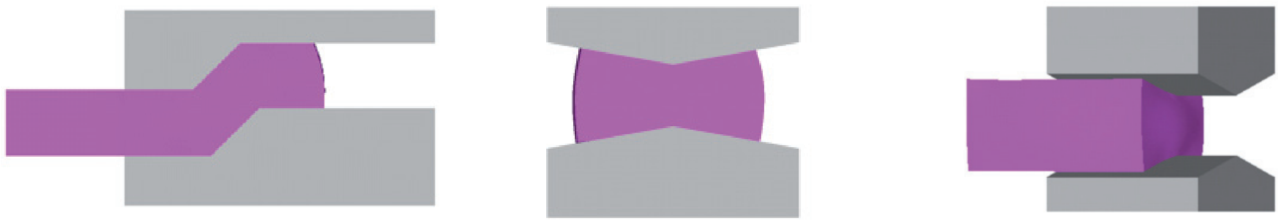


Fig. 1. Known construction of dies, a) step; b), c) wedge

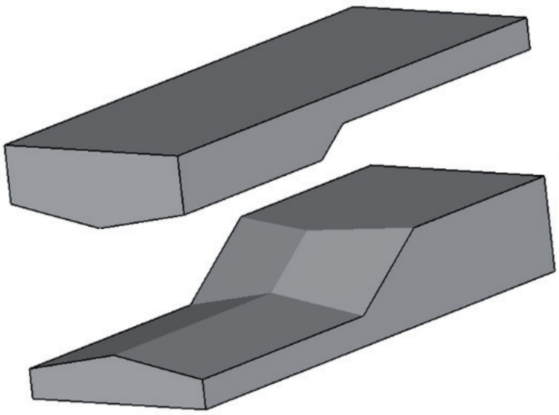


Fig. 2. New design of step-wedge dies

3. Results and discussion

Figure 4 shows the values of the damage for the three investigated samples. Damage indicates the degree of action of tensile stresses, which adversely affect the mechanical properties of metals and lead to the formation of defects. Comparison of the three models shows that the greater the value of damage has billet, deformed in flat step dies. At the same time billets, deformed at wedge and step-wedge dies have significantly smaller value of damage. High value of damage on the end surface of billet, deformed at flat dies, occurs because of barrelling during forging. On the other hand wedge, beside intensification of compressive stresses in the axial portion of the workpiece, reduces the intensity of the tensile stresses, almost preventing the formation of barrels in the workpiece.

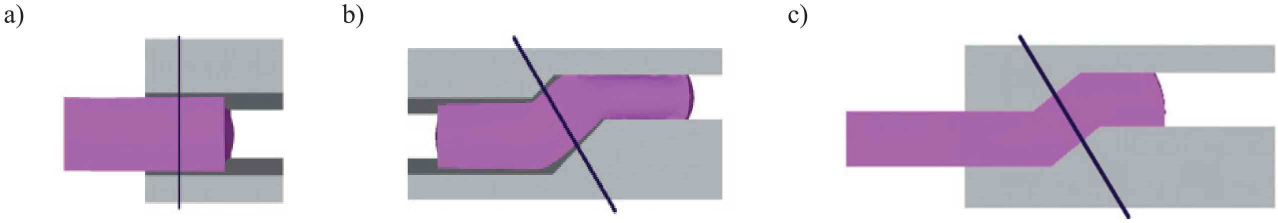


Fig. 3. Layout of the cross sections for the location of strain-stress state, a)wedge dies; b) step-wedge dies; c) flat step dies

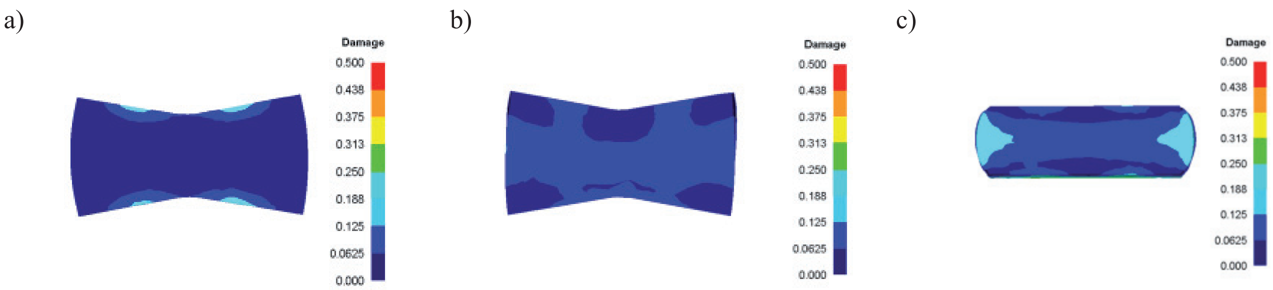


Fig. 4. Damage, a) wedge dies; b) step-wedge dies; c) flat step dies

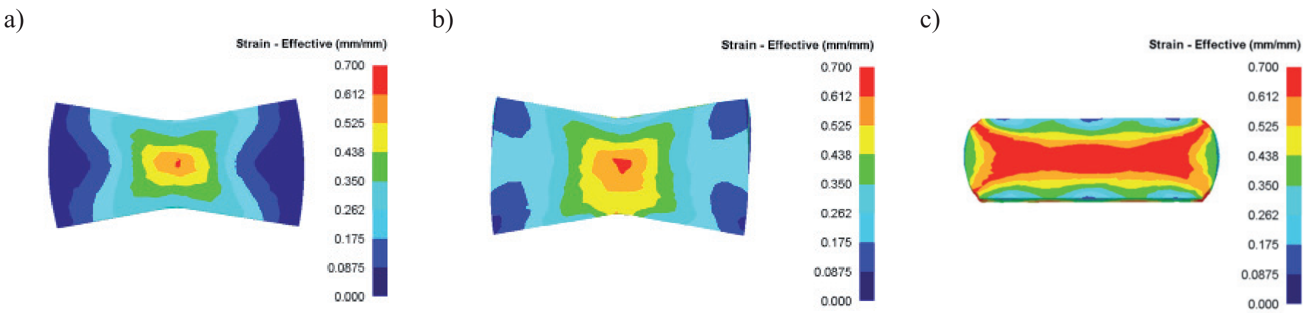


Fig. 5. Strain effective, a) wedge dies; b) step-wedge dies; c) flat step dies

Strain effective shows the intensity of deforming of workpiece throughout its cross-section. Fig. 5 shows that the highest level of equivalent strain is realized in flat step dies, since the distribution of the contact surface on the width of the workpiece is uniform. In dies with wedge, the highest value of strain effective is realized in the zone of influence of the wedge – axial. As the distance from the axial zone level of strain effective is reduced.

Stress effective is a generalized result of three principal stresses. As a radical expression always takes a positive value and allows to evaluate the overall level of stress at a given point. When considering all three models (Fig. 6) it was found that the optimal pattern of distribution of the stress effective is implemented in a step-wedge dies, because during the deformation in them stress effective is the most uniform distribution over the entire cross-section, which is a combined effect of the inclined stepped channel and transverse wedge. In contrast to this model in the wedge dies the distribution of stress effective is less uniform, due to the lack of step zone intensification of stresses is much less, the main focus in the axial zone; on the side parts the effect of stress is slightly. In the flat step dies, due to the extensive contact surface intensification of the stress effective reaches its maximum, in cross section there are no areas without stress. However, there is an extremely uneven distribution of stresses – in the contact areas, the stress value exceeds the value of the axial more than 2 times, which can lead to anisotropy of mechanical properties over the cross section of the workpiece.

Unlike the stress effective, stress mean shows the intensity of the compressive and tensile stresses in the cross section of the workpiece, i.e. the magnitude of the stress can take both positive and negative value (Fig. 7). Analysing this option, it's possible to identify those areas that are exposed to tensile stresses, i.e. they are the most dangerous from the point of view of occurrence of defects. As with the consideration of stress effective in the study of stress mean determined that the best option is step-wedge dies that are experiencing the most uniform distribution of this parameter. Along with this, the maximum tensile stresses up to 6 MPa, which is relatively small. In wedge dies distribution of stress mean similar to the step-wedge dies, however, there is intensification of tensile stresses due to the single action of the wedge without the participation of the inclined stepped zone. The maximum value of tensile stress reaches 32 MPa. In the flat dies distribution of stress mean is the most uneven. In the central part of the billet is dominated by compressive stresses reach values of – 300 MPa, however, in the lateral parts in the surface layers occurs significant tensile stresses, which can lead to cracking. The maximum value of tensile stress is 50 MPa.

a) b) c)

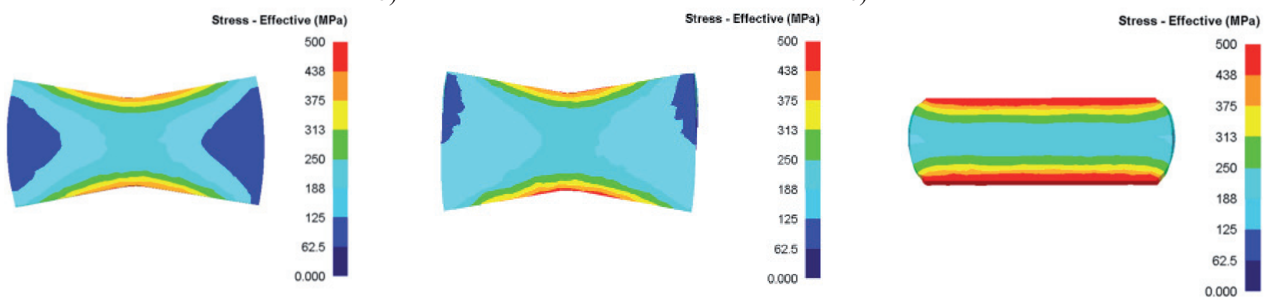
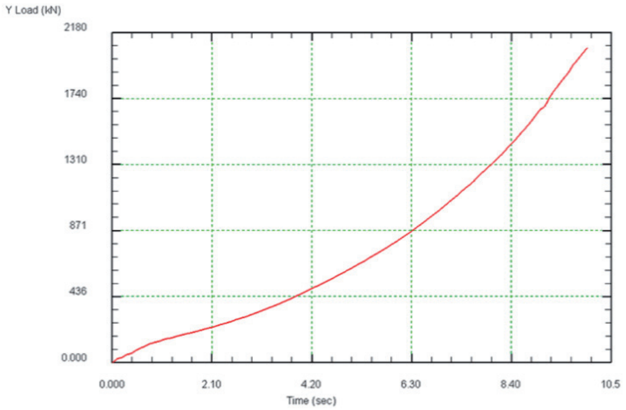


Fig. 6. Stress effective a) wedge dies; b) step-wedge dies; c) flat step dies

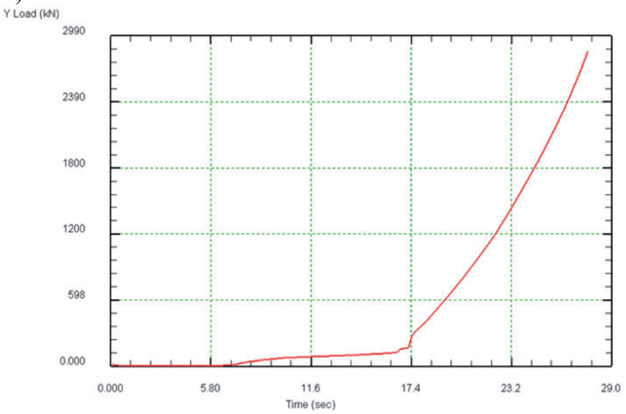
a) b) c)

Fig. 7. Stress mean, a) wedge dies; b) step-wedge dies; c) flat step dies

a)



b)



c)

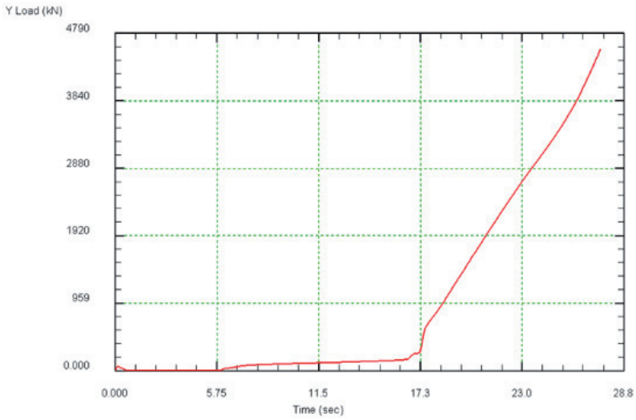


Fig. 8. Deformation load, a) wedge dies; b) step-wedge dies; c) flat step dies

The deformation load graphs (Fig. 8) shows that the greater load required for deformation of the workpiece in a flat step strikers (~4800 kN). At the same time the value of load on the deformation of the workpiece in the wedge and step-wedge dies significantly less. It's because the area of contact surface of the workpiece with the tool in a step dies significantly higher than in the wedge dies. Least load is spent on drawing of the workpiece in a simple wedge dies (~2200 kN), because there are only the forge operation, and in step-wedge dies besides forging operation the workpiece is subjected to shear deformations on the second plot (~3000 kN). Also in step-wedge dies was made two longitudinal sections: at a distance of 25 and 50 on the width of the workpiece (Fig. 9).

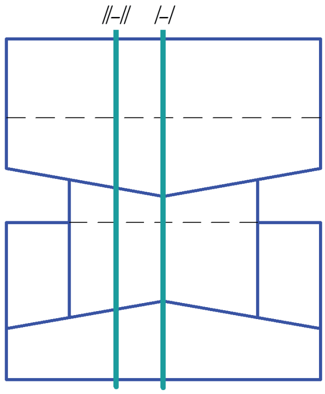


Fig. 9. Layout of the cross-sections for the location of strain-stress state

This was done in order to study the main parameters of the strain stress state (strain and stress effective) in the longitudinal direction, since at each of the three sections of the step-wedge dies implemented various deformation schemes.

Analysing the received picture of the distribution of strain stress state (Figs. 10,11), clearly, that on the third (output) plot both parameters are distributed evenly across the width of the workpiece in both sections, that is a consequence of the deformation of the workpiece by flat areas of dies. On the first (input) plot the distribution of the parameters similar to the distribution in the wedge dies. On the Central (inclined) plot the stress is concentrated in the axial zone of the workpiece, at a distance of 25% of its width is reduced by half. The distribution of the strain effective is similar to stress – maximum values occur in the axial zone, as the distance from the centre, their intensity decreases. Also in the axial zone clearly shows the increase of the deformation rate when moving from the input plot on a slope, due to the additional influence of an inclined step along with wedge.

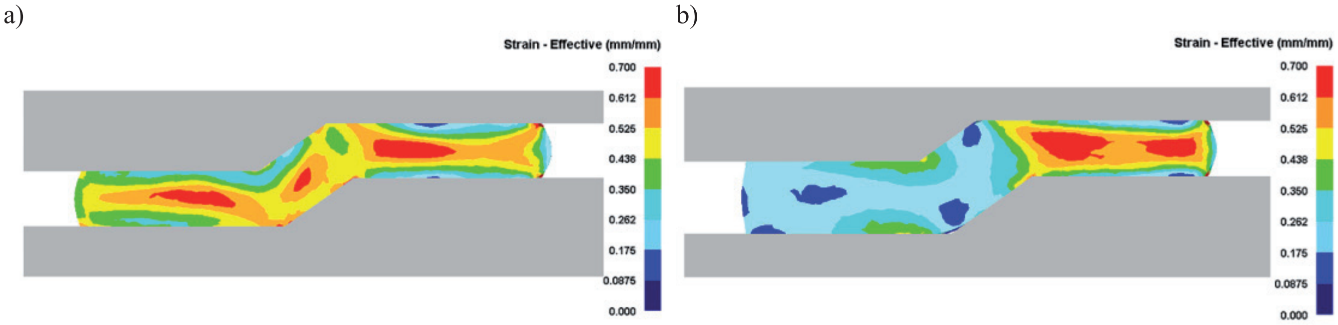


Fig. 10. Deformation parameters in the longitudinal direction, a) 50% of the width; b) 25% of the width

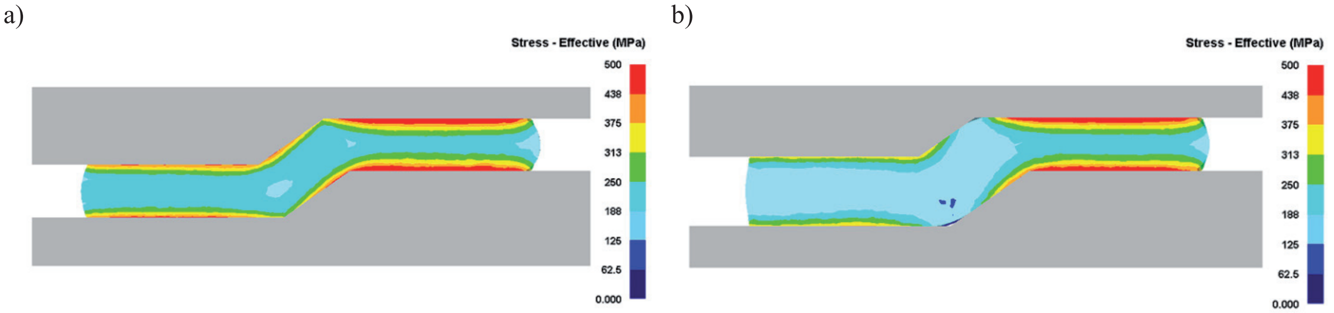


Fig. 11. Parameters of stress in the longitudinal direction, a) 50% of the width; b) 25% of the width

4. Conclusions

Computer simulation of the deformation of the workpiece in the new design of forging dies, combining elements of the known wedge and step dies were conducted. A comparative analysis of the stress-strain state and emerging load showed that the new design of step-wedge dies is the best option for the implementation of the drawing process is rectangular blanks. When its use the optimal and uniform distribution of the stress state is realizing, adequately implemented deforming, especially in the axial zone, as well as significantly less deformation load compared to the flat step dies. Thus the use of a step-wedge dies during deformation will produce blanks with the qualitative deforming of the structure throughout the cross-section with little energy consumption.

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