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# DEVELOPMENT AND COMPUTER MODELING OF A NEW FORGING TECHNOLOGY OF FORGINGS SUCH AS SLABS AND PLATES

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## ABSTRACT

*This article is devoted to the development and computer modeling of a new technology of forging of workpieces such as slabs and plates in a step-wedge dies, allowing with minor energy consumption intensifying shear deformation in both longitudinal and transverse directions. During modeling the stress-strain distribution and closure of defects of workpiece were studied after its deformation in a new designed dies in comparison with forging in a normal step and ordinary wedge dies.*

*Keywords: forging, computer modeling, strain-stress distribution, closure of defects.*

## INTRODUCTION

In last few years significant attention of specialists throughout the world in the field of plastic deformation is focused on the unordinary effects which appears in the process of deformation implemented by the application to the workpiece of shear or alternating deformations [1 - 2]. Simultaneously, the researchers are interested in the processes of plastic deformation in which one part of the workpiece is subjected to shear relative to another part, i.e. shear deformation. In Descartes system there are three main planes of application of shear (Fig. 1). It is possible in each plane and axis cycling shears with the change of the sign of displacement, thereby creating alternating shears. Also, each plane has two directions of shear for each of the main axes or rotation in the plane of shear of one part relative to another around a perpendicular to this plane axis.

Implementation of intensive shear deformation under the scheme of deformation by flat dies with the imposition of additional single-threaded shear strains allows a forging tool with flat working surfaces, as proposed by the authors [3]. The difference from the previously existing similar tools is that the tool has no complex assemblies which simplifies the installation, setup and use.

The works [4, 5] proved that it is possible to develop a substantial alternating deformation in the whole volume of deformable workpiece during forging in the dies with elastic elements. The use of the dies with elastic elements allows better processing of the cast structure of the metal and obtaining fine equiaxed grains throughout the volume of the deformed workpiece without significant change of its original size and to obtain forgings with the best mechanical properties as compared with forgings, forged according to the current technology in flat dies.

It is also known a design of another tool for implementation of the drawing operations which comprise of upper and lower dies with shape of lock [6]. The main difference is that for improving the quality of metal forgings, the tool has the shape of lock, thus providing a high localization of shear deformation in the whole volume of the deformable workpiece with a little change of the sizes of the source material [7].

During the forging process of the forgings such as slabs and plates, the problem of quality improvement

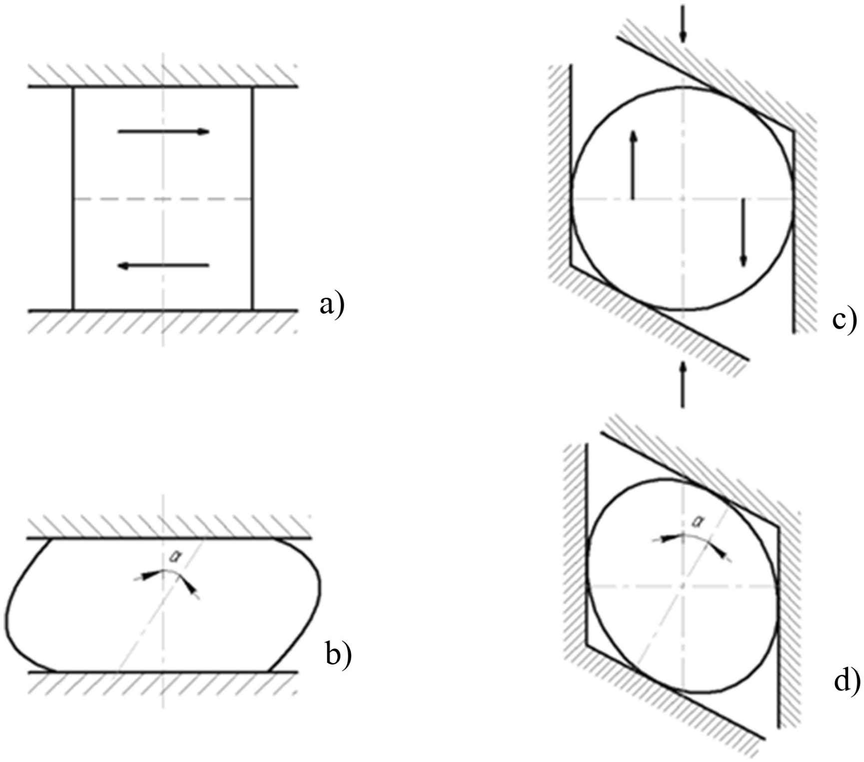


Fig. 1. Deformation schemes of workpieces with overlap of the shifts in horizontal transverse (a, b) and longitudinal vertical (c, d) planes of the deformation.

of the metal forgings with minimum reduction can be solved by using trapezoidal dies [8], which allows the development of sign-variable deformation in the whole volume of the deformable workpiece. The workpiece during drawing in these dies is subjected to a simple shear on inclined sections of the tool.

Tools also allowing implementation of shear deformation of metal are step dies (Fig. 2a) [9]. During forging in step dies the workpiece on flat sections is subjected to upsetting process, while on the sloping section occurs shear deformation. During the upsetting process occurs a barrel distortion, which has a negative effect on the uniformity of processing of the cast structure of metal. On lateral sides, there are significant tensile stresses. In works [10, 11] research of new design of dies with a cross-sectional profile in the shape of a wedge is conducted (Fig. 2b, 2c). In particular, it was studied the influence of the wedge angle on the strain-stress distribution of the workpiece and power parameters, also the dependence of the influence of the wedge angle on the closure of axial defects. It was found that, the larger the wedge angle, the more intensive was the processing of the axial part of the workpiece, but at the same time with increasing angle increases the unevenness of distribution of strain over the cross section of the workpiece.

At the Department «Processing of Metals by Pressure» of Karaganda State Industrial University the idea to combine two designs of dies: step and wedge dies is

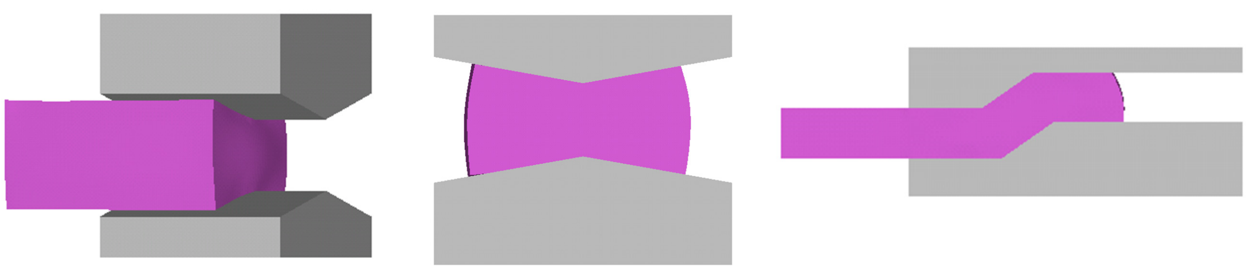

Fig. 2. Known construction of dies (a - step; b, c – wedge).

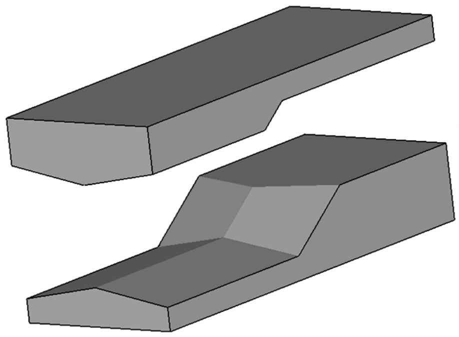

Fig. 3. New design of step-wedge dies.

proposed (Fig. 3). The combination of these two designs of dies will allow intensification with minor inputs the shear deformation, in both longitudinal and transverse directions [12].

During the development of the 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. The 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 the rational 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. The study of stress distribution in the workpiece during deformation allows identifying areas prone to the formation of defects due to the large tensile stresses in them. This gives an opportunity to make the necessary adjustments to reduce the intensity of tensile stress and thereby to prevent the formation of defects. There are different methods to determine these values. One of them is the method of computer modeling.

Modeling 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. The modeling allows to identify the rational parameters of the tool and workpiece for better process behavior. The modern modeling software systems provide tremendous opportunities for work. They allow modeling of almost any process, avoiding costly experiments.

**Research methodology**

To conduct the study three models of dies were built: wedge with angle of the wedge 170°. This value of the angle of the wedge was chosen as in the paper [10] since 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 a material for the workpiece was selected steel 15.

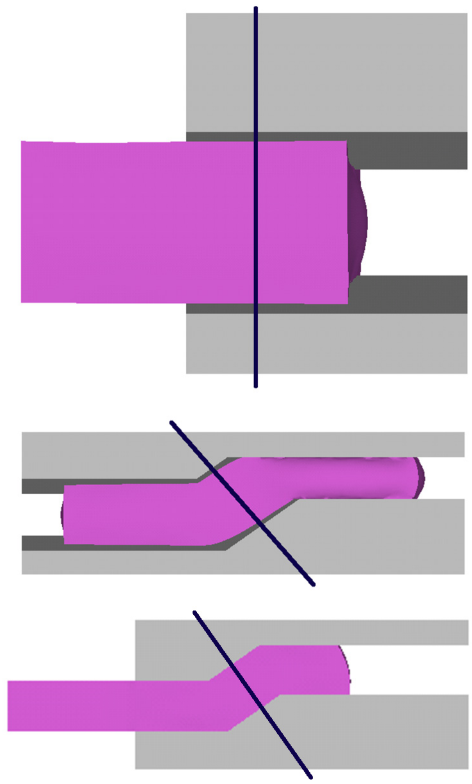

Fig. 4. Layout of cross sections for location of strain-stress distribution (a - wedge dies; b - step-wedge dies; c - flat step dies).

After modeling of the drawing process through jaunty, the following parameters were compared: 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. 4a); in step-wedge and flat step dies these parameters were considered on a slope, in a section perpendicular to the inclined faces (Figs. 4b, 4c), because on this area the shear deformation at step dies is realized.

## RESULTS AND DISCUSSION

Figs. 5 - 9 show the results of modeling.

Fig. 5 shows the values of the damage for three investigated samples. The damage indicates the degree of action of tensile stresses, which adversely affect the

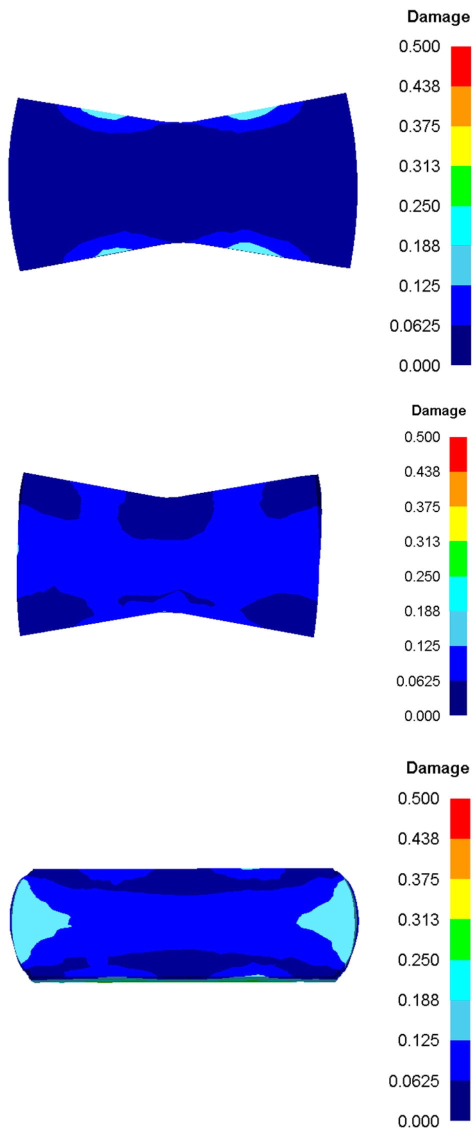


Fig. 5. Damage (a - wedge dies; b - step-wedge dies; c - flat step dies).

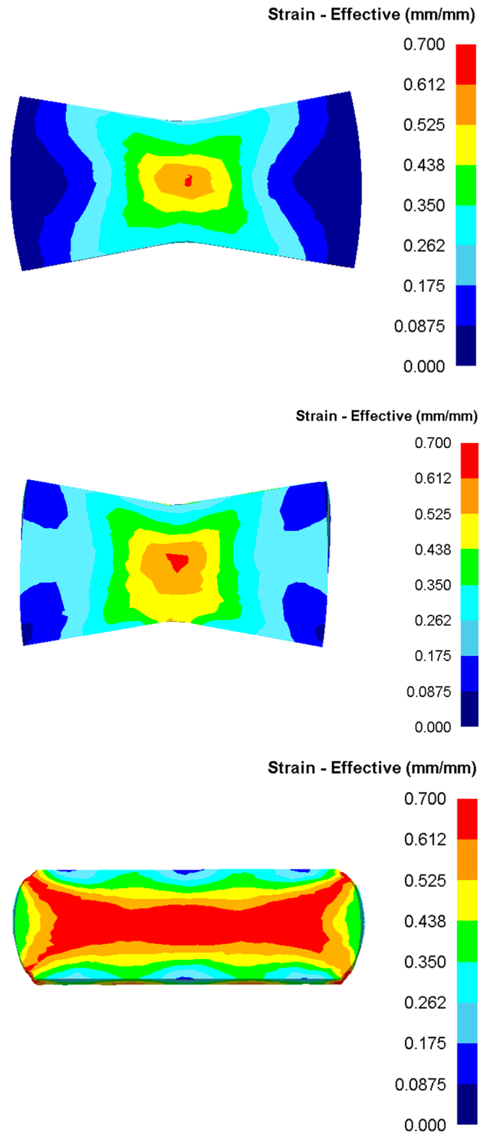


Fig. 6. Strain effective (a - wedge dies; b - step-wedge dies; c - flat step dies).

mechanical properties of metals and lead to formation of defects. The comparison of the three models shows that the billet, deformed in flat step dies, has greater value of damage. 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 barreling 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.

The 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, the level of strain effective is reduced.

The stress effective is a generalized result of three principal stresses. As the radical expression always takes a positive value and allows evaluating the overall level of stress at a given point. When considering all three models it was found that the optimal pattern of distribution of

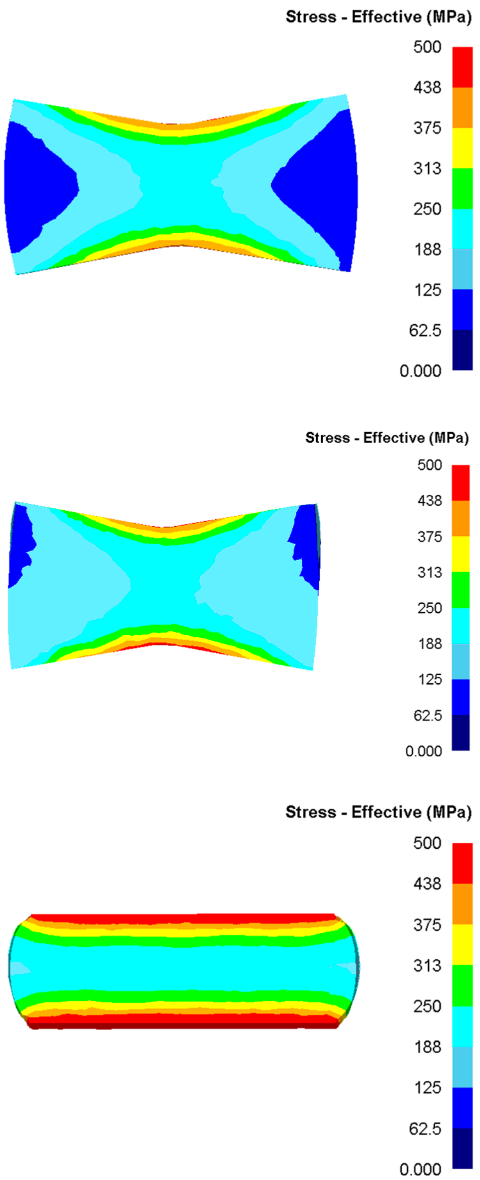


Fig. 7. Stress effective (a - wedge dies; b - step-wedge dies; c - flat step dies).

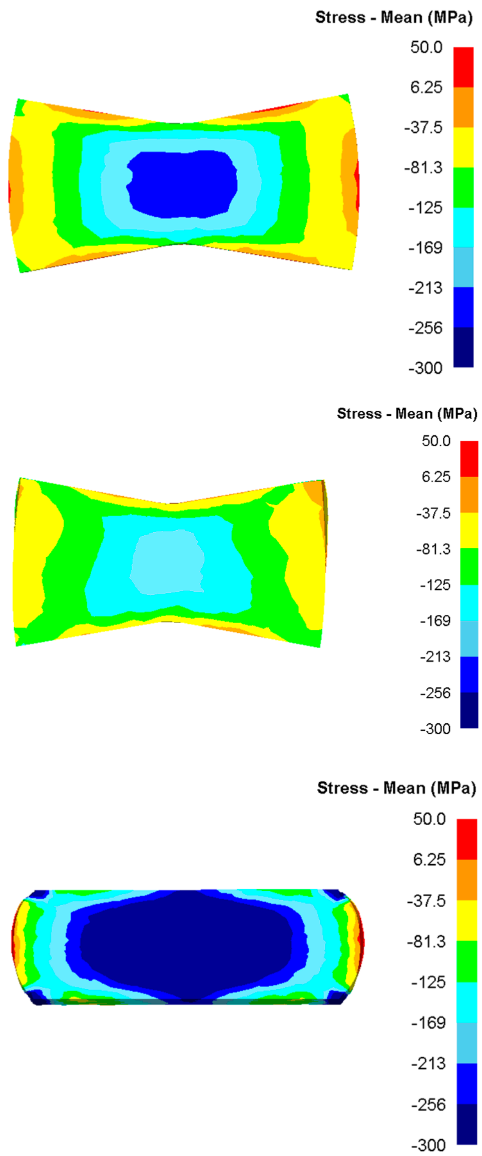


Fig. 8. Stress mean (a - wedge dies; b - step-wedge dies; c - flat step dies).

the stress effective is implemented in a step-wedge dies, because during the deformation in them the stress effective is with 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, the intensification of the stress effective reaches its maximum, in the 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. Analyzing this option, it is 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

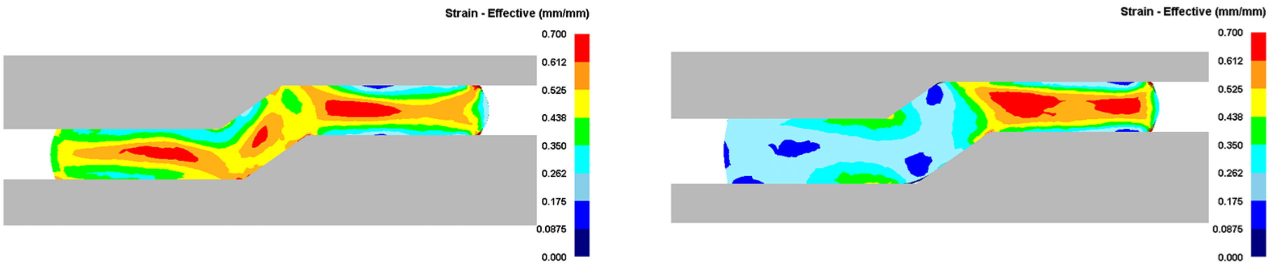


Fig. 9. Deformation parameters in the longitudinal direction (a - 50 % of the width; b - 25 % of the width).

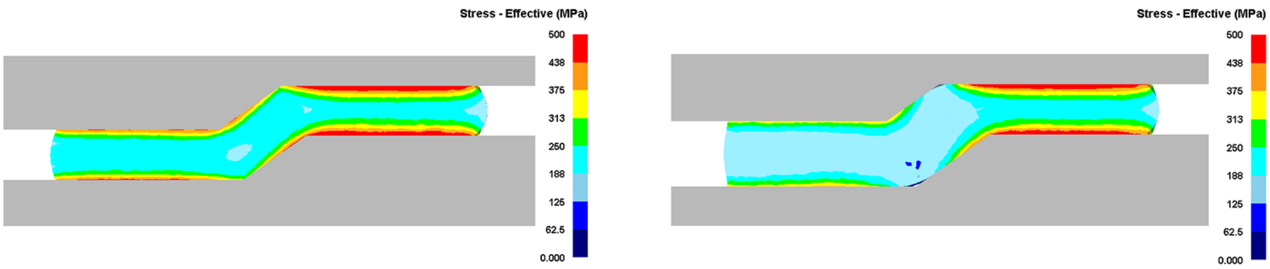


Fig. 10. Deformation parameters in the longitudinal direction (a - 50 % of the width; b - 25 % of the width).

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 stress is up to 6 MPa, which is relatively small. In the wedge dies the distribution of stress mean is similar to the step-wedge dies, however, there is intensification of tensile stresses due to the single action of the wedge without 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. The central part of the billet is dominated by compressive stresses which 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.

On the second step of modeling the strain-stress distribution in longitudinal direction of workpiece, deformed in a step-wedge dies was studied. To do this, two longitudinal sections were made: at a distance of 25 % and 50 % (center) from the width of the workpiece.

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

Analyzing the picture of distribution of strain stress state (Figs. 9, 10), is clear, 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 both parameters are 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 reduced by half. The distribution of the strain effective is similar to stress - the maximum values occur in the axial zone, as the distance from the center, their intensity decreases. 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.

On the third step of modeling the effect of the new scheme of deformation on the closure of internal defects was studied. For this modeling in the software package KOMPAS were built rectangular workpieces with sizes 30x60x200 mm and 3 mm diameter holes through the entire cross section of the workpiece, which simulated internal defects of workpice (voids, pores, etc.).

A study of the closure process is carried out in three sections and three reduction values: 10 %, 15 % and 20 %. The modeling results are presented in Fig. 11.

The analysis of results of closure of internal defects distributed through the cross section of workpieces showed that during deformation in the step-wedge dies

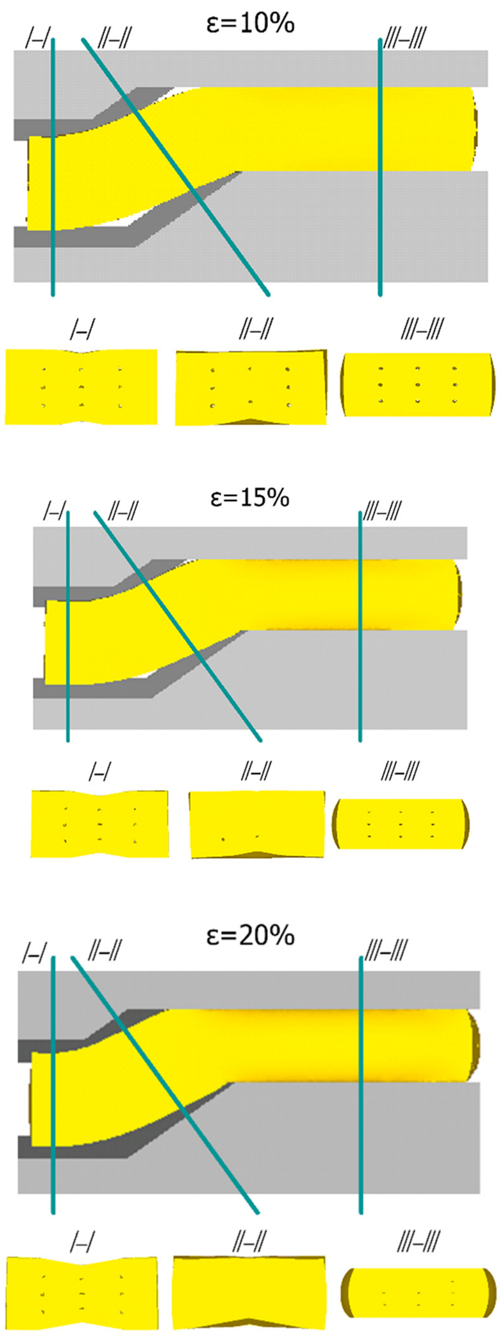


Fig. 11. The results of modeling of closure of the internal defects.

at the reduction value 15 % on a sloping section with a wedge the defects are almost closed. Complete closure of internal defects in this area occurred at the reduction value of 20 %. The closure of internal defects is less intense on the first section (a flat section with a wedge), in this case, there is a more intense closure of defects in the middle section. On a flat section of dies, made without a wedge (section 3) the closure of the defect occurs mostly by forging cross. However, even with a reduction value 20 %, closure of defects in the section 1 and 3 is not observed.

Due to the fact that the forging process in step-wedge dies means not only upsetting process but also the process of drawing, so during drafting the entire volume of the workpiece passes through all three sections of dies, which will contribute to a more intensive closure of internal defects, since these sections assume different scheme of closure of internal defects.

## CONCLUSIONS

Computer modeling of the deformation of the workpieces 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 implementation of the drawing process is rectangular workpieces. When the optimal and uniform distribution of the stress state is realizing, adequately is implemented deforming, especially in the axial zone. It was conducted also a study of the process of closure of internal defects, and it was found that the most favorable pattern of closure of internal defects occurs on a sloping plot of step-wedge dies. Thus, the use of step-wedge dies during deformation will produce blanks with qualitative deforming of the structure throughout the cross-section with little energy consumption.

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