RESEARCH OF THE DEFORMATION PROCESS OF BLANKS IN THE DIES WITH ELASTIC ELEMENTS

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ABSTRACT

This article is devoted to research of the deformation process of blanks in the new tool, that consists of two dies. Key feature of these dies is elastic elements in the view of springs. It was proved the feasibility of using a new design - dies with elastic elements instead of the currently used flat dies, since the proposed technology allows to obtain a billet of high quality with uniform equal-axes fine-grained structure with less forging reduction.

Keywords: forge, elastic elements, shear deformation, mechanical properties.

INTRODUCTION

Currently used technologies and equipment by large metallurgical and machine-building manufacturers, in particular press-forging production, can be considered long outdated and ineffective. A common problem for all is the high energy intensity of production, low productivity and not very high product quality. The traditional technologies of processing of cast metal are characterized by a significant consumption of time and energy to obtaining good metal, as the workpiece undergoes multiple changes in its shape and size for removal of all internal defects and development of cast structure throughout its volume.

Recently in the field of processing of metals by pressure, was developed a number of methods, based on the development of alternating and additional shear deformation in the volume of a deformable metal, due to the influence of a tool design. Such methods include upsetting with torsion [1], deformation with asymmetric load application [2, 3], upsetting and cogging of the workpiece in the tool with a complex movement of the dies [4, 5], cogging process in step [6], wedge [7], trapezoidal [6], and a stepped-wedge dies [8]. However, these methods of deformation are inefficient and time consuming, and in some cases, impossible for use in an industrial environment, as in some cases, shear deformation is accompanied by large single compressions or great deformation efforts.

In this regard, the development and creation of qualitatively new technologies and tools that significantly improve the quality of the finished product and stabilize its properties, with minor changes of dimensions of the initial billet is an urgent task.

Description of new tool

One of these tools are dies with elastic elements (Fig. 1) [9], the design of which, due to the development of a substantial alternating deformation, allows to deform the cast structure with obtaining a small equal-axis grains throughout the volume of the deformed metal without appreciably changing the initial dimensions of the workpiece.

The tool for deforming billet, as shown in Fig. 1, includes top and bottom dies, equipped with working panels in the form of a triangular right prism, related to

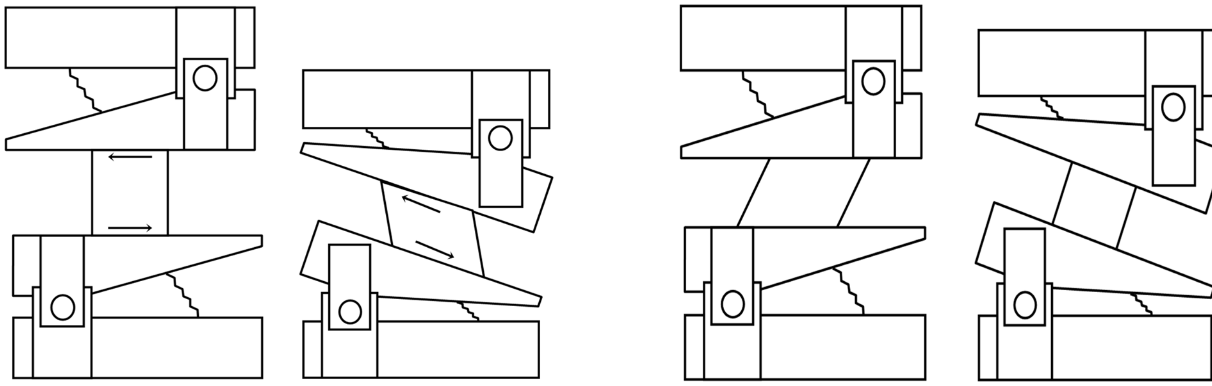

Fig. 1. Scheme of deformation of blanks in the dies with elastic elements: a - the first passage; b - the second passage.

the upper and lower flat portions of the dies on one side by the hinge, and on the other side by the elastic element. The tool works in the following way. When the slider moves down, the upper anvil presses on the workpiece, as in the early time of compression the deformation force is equal to the stiffness of the elastic elements, the first is the normal upsetting of the workpiece. With the gradual increase of the cross sectional area of the billet, the deformation force begins to grow and as a result of opposition from the workpiece elastic elements in the dies are compressed, and working panels are moved in the inclined direction of the upper and lower flat parts of the dies, respectively. Because of this, there is a shift of one part relative to another workpiece. After reaching a required value of compression, the upper anvil is raised together with the press slider, and the elastic elements return working panels to its original position. Then the feed of the workpiece occurs and its compression in the same way. After deformation of entire workpiece, it is rotated around its axis by 180° and rectified in the same dies.

As the elastic elements in this design of the dies can be rubber or polyurethane, hydraulic and pneumatic devices, coil springs of various designs. On the basis of economic and design factor, the most effective is used as the elastic elements of the springs, manufactured from wire of various cross sections: round, square, rectangular, etc. To achieve the universality of the process of deformation of billets (i.e., the increase in the range of the original workpieces of different sizes and from different grades of steel) in the dies with elastic elements, which act as springs in compression, you can apply double or triple helical cylindrical springs. The required spring stiffness for deformation of workpieces of any size in the dies with elastic elements can be calculated with the diagram shown in Fig. 2 according to the eq. (1), [10]:

$$k = \frac{1}{\lambda n(a+c)\cos\varphi}[m_2 g(\tfrac{1}{3}l - e) + (P_{DEF} + m_1 g)a] \quad (1)$$

where:

m_1g - the force of gravity of the workpiece;

m_2g - the force of gravity of the triangular panels;

PDEF - the force of deformation at the initial time of compression;

j - angle of inclination of the striker;

l - spring travel in the end position of working panel;

n - occurs number of elastic elements.

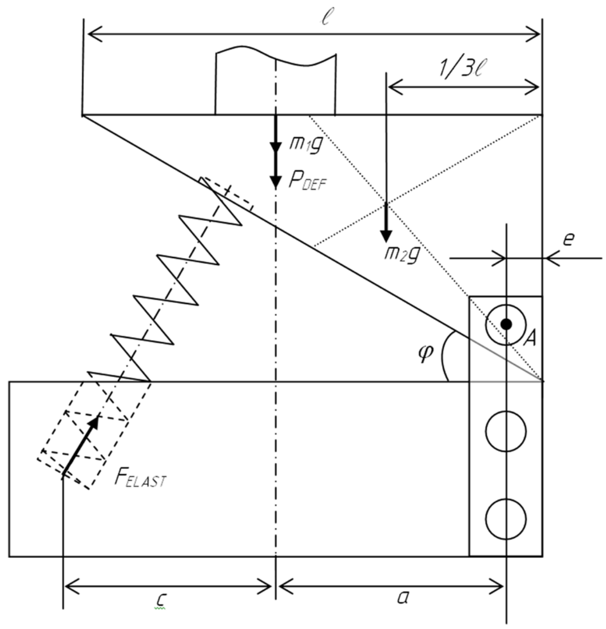

Fig. 2. Calculation scheme to determine the stiffness of the spring.

EXPERIMENTAL

To confirm that the use of the dies with elastic elements allows to be increased the quality of the blanks, laboratory experiments on deformation of aluminum, tin, and plasticine samples in the proposed dies were carried out. The main objective of the experiment was the observation of closure of internal defects and changes of microstructure occurring in the metal under the influence of the deforming tool.

The experiment was conducted in two stages. At the first stage the influence of tool design on the closure of internal defects was studied. For this reason, plasticine samples of size 35×35×50 mm, in which were performed nine holes with diameter of 1.5 mm were made. Percentage of defects in the volume amounted to 1.3 %.

Plasticine samples were deformed in the proposed dies with the angles α = 30 and 40 and in flat dies. The angle of inclination of the working panel was chosen based on the ability of the tool to realize a significant shear deformation in the whole volume of the deformable metal [6], as well as of the geometric parameters of the tool. The deformation of the samples in the dies with elastic elements was performed as follows: the sample was set in the dies of new design, then was done its transverse shear (displacement of one side of sample relative to another). Then the straightening of deformed sample in the same dies was done. For this, the samples were rotated around its axis by 180° and the shift of one part relative to another was carried out (Fig. 1b). In this case, the material undergoes alternating deformation. To obtain comparative data of clay samples with the same size and deformed in a flat strikers with forging reduction appropriate of specimen deformation in the dies with elastic elements.

The closing holes during the deformation of samples in the flat dies and in the dies with elastic elements were fixed to the termination of the movement of kerosene through the holes.

The analysis of experimental data on the investigation of closure of internal defects showed that during the deformation of samples in the dies with elastic elements with angle of inclination a = 30° all artificial defects were closed completely, except for those that were located on the major diagonal. After rectification of the samples there was a complete closure of all defects. The sample sizes in the end were: h×b = 27×39 mm at forging reduction U = 1,16. In the process of deformation of samples in dies with angle a = 40° artificial defects were closed completely when forging reduction U = 1,15, the dimensions of the samples after the rectification were h×b = 28×38 mm. After deformation of material in the flat dies with forging reduction U = 1.16 only a partial closure of the artificial defects located at the forge cross occurs. In the zone of difficult deformation the closure of holes was not observed. Complete closure of the artificial defects in the existing technology has occurred only when forging reduction U = 1,31. The final dimensions of sample were: h×b = 26,5×35 mm.

In the second phase it was conducted research, the main task of which was the observation of the microstructure changes occurring in the metal during the deformation of samples in the flat dies and tool with elastic elements.

Before deformation we investigated the microstructure of the initial samples, made of aluminum alloy AK6 and tin alloy T4 with dimensions 30×30×50 mm using a scanning electron microscope JOEL.

Then the aluminum samples were heated to a temperature of 470 ± 5°C; tin samples were deformed at room temperature of 20 ± 2°C. The first batch was subjected to alternating deformation in the dies with elastic elements, according to the above-proposed technology (one cycle). The second batch of samples were deformed similarly to the first game, then after straightening they were deformed in the same tool without tilting (two cycles). The average sample sizes after the first cycle of deformation were 28×31×51,8 mm, and after the second cycle were 28×29×55,4 mm.

RESULTS AND DISCUSSION

To conduct a comparative analysis, metal samples of the same size were deformed in a flat dies with compression and canting scheme corresponding to the compression and canting in the dies with elastic elements.

From all deformed metal samples were made templates to study the microstructure. The results of metallographic analysis are shown in Table 1.

The results of metallographic studies have shown, that the processing of initial aluminum and tin structure during deformation in flat dies with the specified forging reduction occurs only in the area “forging cross”. In the zone of difficult deformation the structure is coarse,

Table 1. The results of metallographic analysis.

№	Parameter	Material	New dies		Flat dies	
			Surface	Center	Forge cross	Zone of difficult deformation
1	Initial grain size, μm	aluminium	75.0			
		tin	44.2			
2	The grain size after the 1st cycle of deformation, μm	aluminium	44.8	44.3	68.0	72.7
		tin	21.6	19.5	38.8	41.3
3	The grain size after the 2nd cycle of deformation, μm	aluminium	11.2	10.8	46.2	68.1
		tin	2.9	2.8	30.7	35.1

which leads to the uneven structure of the volume of the metal. The grain structure of the metal, that is deformed in the dies with elastic elements, is more intense and simultaneously throughout the volume of the sample.

To verify the efficiency of the proposed forging instrument and confirmation of theoretical and experimental researches in laboratory conditions it was carried out forging of billets of steel 20 with dimensions b×h×l = 200×200×300 mm in the Forging plant of JSC "Arcelor Mittal Temirtau" on a hydraulic press with a force of 12,5 MN. The forging was produced by the proposed technology in the dies with elastic elements (Fig. 3) and the existing technology in flat dies. The main purpose of the study was to determine the influence of forging process on microstructure and mechanical properties of steel. The workpiece before deformation is heated in a methodical furnace to a temperature 1200 ± 10°C.

Deforming of the first sample is performed in the dies with elastic elements in the following way. Hot workpiece is served in the dies with elastic elements, which was pre-heated to a temperature equal to 300°C to reduce heat transfer from the heated workpiece to the tool. It was made compression with relative deformation εh = 8.5 %. Then the billet was rotated around its axis by 180° and implemented the alternating deformation to give its cross section a rectangular shape. Thus, the workpiece with sizes 200×200×300 mm was forged in the dies with elastic elements for size b×h×l = 175×207×331 mm, the degree of height deformation was 12,5 %. The second sample is deformed in a similar way, but with the degree of height deformation equal to 20 %, in this case, the dimensions of the workpiece after deformation and rectification were b×h×l = 160×222×338 mm. The third workpiece is deformed in the dies with elastic elements with a relative reduction of 35 % allowing to obtain the dimensions of the forging equal to 130×251×368 mm. The forging reduction at different degrees of deformation of workpieces was: 1,14; 1,25; 1,54.

From the second batch of blanks with sizes b×h×l = 200×200×300 mm in flat tool were forged three forgings so that their sizes match the size of the forgings obtained in the dies with elastic elements. The deformation of the billets, heated to a forging start temperature 1200°C, was produced in a flat die in a similar way and with the same degree of height deformation that when forging in the dies with elastic elements.

The forging cycle for 3 forgings, as in the dies with elastic elements, as in flat dies was 20 minutes. The consumption of gas and electricity for the manufacture of three forgings in both cases was 385 m3 of gas and 400 kW of electricity. But during the deformation of

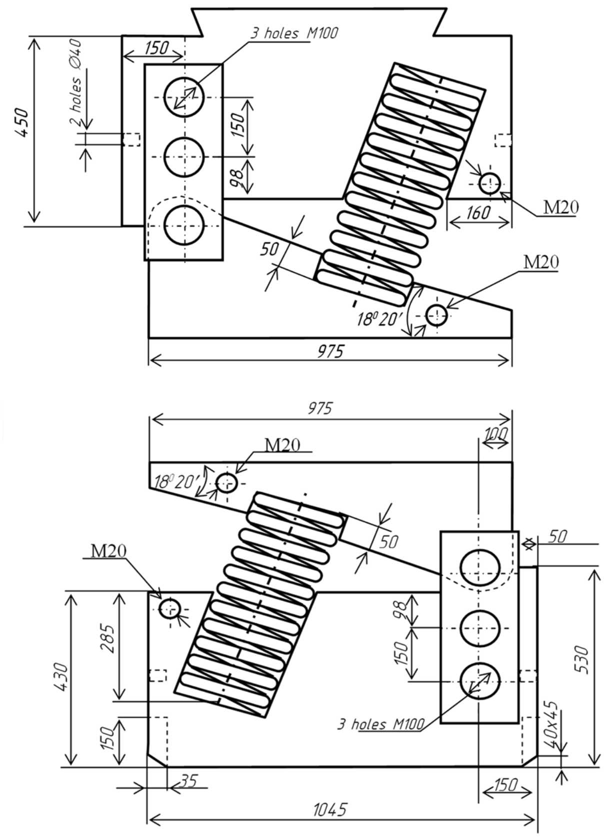

Fig. 3. Dies with elastic elements for industrial testing.

flat workpieces in the flat dies the high mechanical and performance properties are achieved typically when forging reduction equal to U ≥ 2.5 [11], that is much larger than the deformation of the workpieces in the dies with elastic elements, the design of which allows to realize a significant shear deformation in the whole volume of the metal and correspondingly to high quality metal with a smaller forging reduction. Based on this we can conclude that when using flat dies for deformation of forgings of rectangular cross-section, high mechanical and operational properties of the metal will be achieved with a larger consumption of gas and electricity.

All six forgings were labeled. Then they were cut into templates in the longitudinal and transverse directions to manufacture samples for mechanical testing, microstructure analysis and hardness test.

After that standard samples for the tensile and impact toughness tests were made. The shape and size of the data samples were assigned according to GOST 1497-84 and GOST 9454-60. From the rest of the templates were made thin sections for microstructural analysis and hardness test. The test specimens tensile test conducted on the stand MI40KU. The impact test was carried out using the pendulum.

According to the statistically processed results of the mechanical tests the average values of properties were determined and the plots of strength, plastic properties and impact toughness of strain are made (Fig. 4). The microhardness was measured on the optical microscope Leica.

The results of mechanical testing and hardness measurement show that the strength properties of steel 20, forged on the proposed technology are 5 - 7 % higher than the same indicators of the workpiece, deformed in a flat dies, but the plastic characteristics (elongation and contraction) of forgings, forged in the dies with elastic elements, are average 15 - 20 % higher than the same, obtained during forging on the current technology. In the process of studying the toughness of the metal, it was revealed that the tendency to brittle fracture of metals, forged in the dies with elastic elements is reduced by 25 - 30 % compared to the blanks obtained in flat dies. In addition, it was found that the microhardness of the volume, obtained by the proposed technology, is distributed more evenly than in billets, deformed in flat dies (Table 2).

The evaluation of anisotropy of mechanical properties, as the ratio of the maximum mechanical property to the minimum value of this characteristic [12], showed that the implementation of the alternating deformation

Table 2. The microhardness of samples of steel 20, with the compression strain of 35 %.

Dies	Cutting direction	Surface zone, HV	Axial zone, HV
flat	transverse	204,3	185,7
		205,6	172,3
		200,6	187,5
	longitudinal	233,4	227,9
		240,1	221,5
		236,8	220,7
with elastic elements	transverse	224,3	210,8
		220,5	211,0
		226,0	215,7
	longitudinal	252,2	250,8
		260,0	258,4
		255,5	250,1

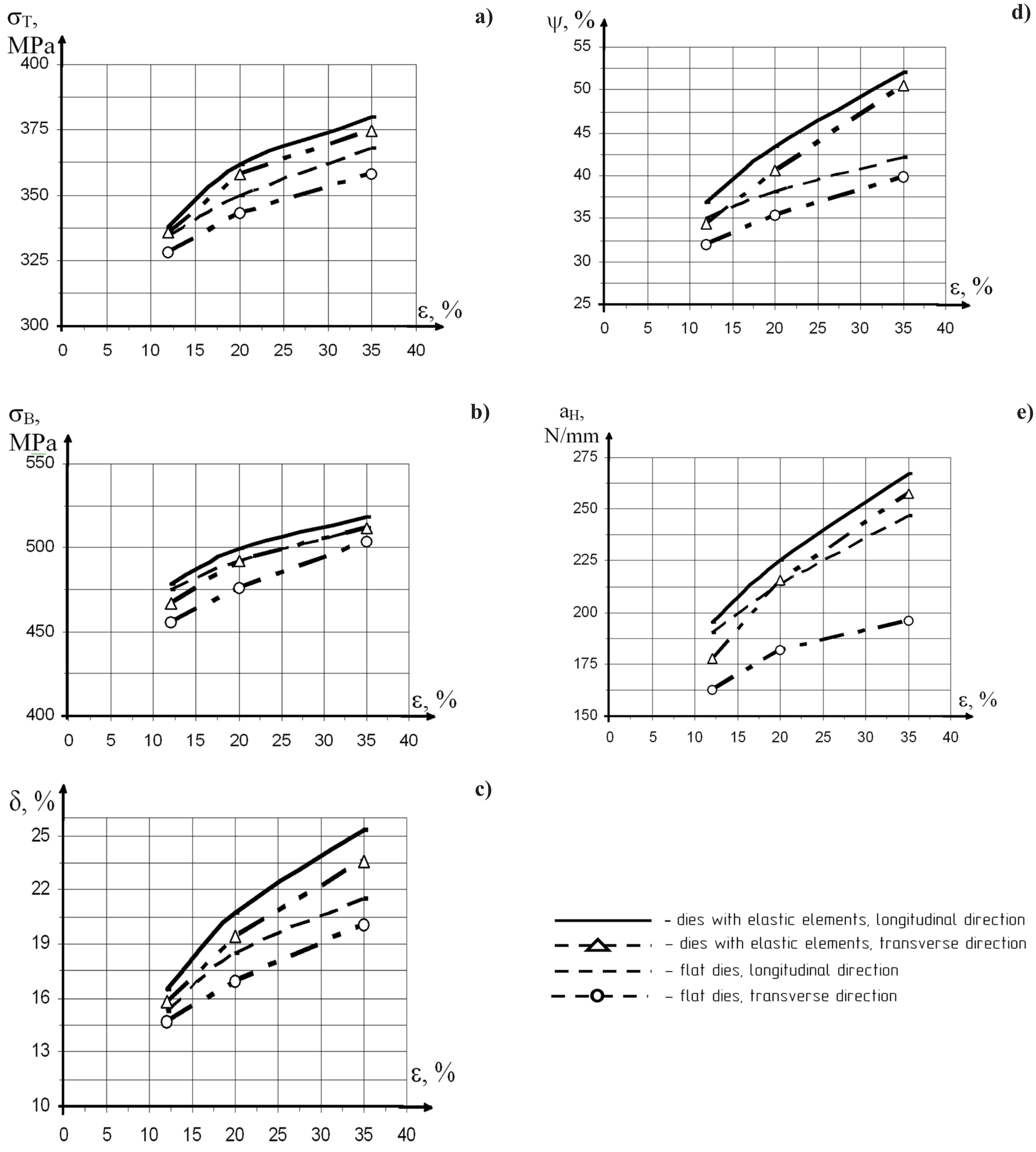

Fig. 4. Plots of strength and plastic properties from compression: a - yield strength; b - tensile strength; c - relative elongation; d - relative narrowing; e - toughness.

in the whole volume of the workpiece during forging in the dies with elastic elements, allows to reduce the anisotropy of strength and plastic properties compared to the forging of workpieces according to the existing technology in flat dies.

This advantage of uniform distribution of mechanical properties by volume of forgings due to the fact that when using the dies with elastic elements provided by the non-monotonicity of plastic flow and more uniform distribution of deformations throughout the volume

Table 3. The results of the grain score determination of the forgings steel 20, with the compression strain of 35 %.

Tool	Study direction	Axial zone	Surface zone
Dies with elastic elements	transverse	8-9	8-9
	longitudinal	9	8-9
Flat dies	transverse	6-7	7-8
	longitudinal	7-8	7-8

of a deformable workpiece, that is the most important technical factors for obtaining forgings with isotropic structure [6].

The grain size of forgings, forged by the proposed and the existing technologies, was determined according to GOST 5639-82 "Methods for detection and determination of grain size". For determining the grain score was used optical microscope Leica. The data obtained in the study of the microstructure of steel 20, are shown in Table 3.

The study of the changing of grain score of steel 20, showed that the grinding grain structure of the metal at the deformation in the dies with elastic elements occurs more intensively and uniformly in comparison with flat die.

That can be explained by the development of intense shear deformation throughout the volume of the deformable metal in the case of using dies with elastic elements and the appearance of zones of difficult deformation when using flat dies.

CONCLUSIONS

This article is devoted to research of deformation process of blanks in the new tool, that consists of two dies. Key feature of these dies is the elastic elements in the view of springs. It was proved the feasibility of using a new design - dies with elastic elements instead of the currently used flat dies, since the proposed technology allows to obtain a billet of high quality with uniform equal-axes fine-grained structure with less forging reduction.

REFERENCES

1. Patent USSR № SU 1044405A, Tool for precipitation with torsion, V.A. Talmazan, V.B. Tyagunov, 1983, Bull. 36, (in Russian).
2. A.B. Naizabekov, S.N. Lezhnev, A.Zh. Bulebaeva, Investigation the process of billet deforming in special tool without significant variation of initial sizes, Izvestiya VUZ. Chernaya Metallurgiya, 6, 2001, 23-25, (in Russian).
3. I. Aliev, I. Zhbankov, L. Tahan, Simulation of forging and pulling in combined dies asymmetric shape, Bulletin of NTUU "KPI", Series "Mechanical Engineering", 3, 69, 2013, 77-83, (in Russian).
4. V.A. Tyurin, Innovative technology of forging, Forging and stamping production, 5, 2006, 27-29, (in Russian).
5. V.A. Tyurin, Innovative technology of forging with application of macroshear, Forging and Stamping Production, 11, 2007, 15-20, (in Russian).
6. A.B. Naizabekov, Scientific and technological bases of increasing the efficiency of the forging process with alternating deformations, Almaty, 2000, (in Russian).
7. O.E. Markov, Research of a technological forging process of large forgings by wedge dies, Izvestiya VUZ. Chernaya Metallurgiya, 12, 2012, 24-27, (in Russian).
8. A. Tolkushkin, E. Panin, V. Talmazan, Development and computer modeling of a new forging technology of forgings such as slabs and plates, J. Chem. Technol. Metall., 51, 4, 2016, 443-450.
9. A.B. Naizabekov, S.Y. Golumbovskaya, Forming

blanks in the dies with elastic elements, Proceedings of the international scientific conference "Science and education - leading factor of strategy "Kazakhstan-2030", Karaganda, Kazakhstan, 2003, 132-134, (in Russian).
10. A.B. Naizabekov, S.N. Lezhnev, S.Y. Golumbovskaya, M.I. Ormysheva, Determination of the parameters of the forging tool that implements the alternating deformation, Technology of production of metals and recycled materials, 1, 23, 2003, 74-77, (in Russian).
11. Y.M Okhrimenko, Technology of forging and stamping production, Moskow, Mechanical Engineering, 1976, (in Russian).
12. P.G. Mikljaev, Y.B. Fridman, Anisotropy of mechanical properties of materials, Moskow, Metallurgy, 1969, (in Russian).