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Development And Research Of Pressing Technology Of Billets In New Design Of Equal Channel Step Matrix

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Abstract. Performed a simulation of pressing process of the billet in new designed equal channel step matrix. Made a comparison of the deformation loads and distribution of accumulated strain in the billets, deformed in the proposed and previously known tools. Also investigated forming of the front end of the billets to determine the degree of sharpening of the end sections. Studied the influence of multi-cycle deformation process of billets in equal channel step matrix of a new design on the microstructure and mechanical properties.

Introduction

In the last two decades in any branch of science and industry competitive innovative solutions directly or indirectly associated with nanotechnology. Therefore, in all developed countries, including Kazakhstan, national programs with intensive development of nanotechnology research adopted.

One of the promising directions in nanotechnology is the development of technologies to get bulk nanostructured materials by severe plastic deformation.

In Kazakhstan, the development of technologies and tools for their implementation, allowing to obtain bulk nanostructured materials, intensively engaged only scientists of Karaganda state industrial University. Over the past 10 years at the University was developed a number of technologies to get ferrous and nonferrous metals and alloys with sub-ultrafine grain structure by equal channel angular pressing. In particular, these technologies include: the technology of pressing in the angular matrix with step [1], the technology of equal-channel angular pressing in the matrix with rollers [2], pressing technology in the equal channel step matrix with a narrowing channels [3], with different roughness of the matrix channels [4] and the technology of pressing in the angular matrices with quasi-ultra-small angles of joint channels [5].

Also, our research focused on the improvement of previously known technologies equal-channel angular pressing and tools for their implementation. Well known device for processing metals by pressure, comprising a punch and matrix, which has three channels of the same cross-section, two of which (input and output) are parallel to each other, and the average channel extends at an angle to the input and output channels [6] (Fig. 1).

During pressing in this tool it is possible to obtain sub-ultrafine grain metal structure with fewer cycles compared to pressing in the angular matrix and at less energy consumption, by implementing an alternating shear strain on two channel matrix joints. But all the same disadvantage of this device is a low degree of hardening in a single cycle of deformation. Yet another significant drawback of this device is impossibility of obtaining in this device billets with square ends. During deformation nature of the flow is so, that the billet has sharpened ends at angle about 30°. To obtain a rectangular ends machining is necessary to remove a large portion of the metal, which significantly reduces the coefficient of metal use (CMU). During multi-cycle treatment CMU reduces even more, because operation to trim of the ends before each cycle of deformation is required. Otherwise due to lack of the sustainability of the sharpened area of the billet during its deformation occurs defects type of clamp, which also must be removed by machining.

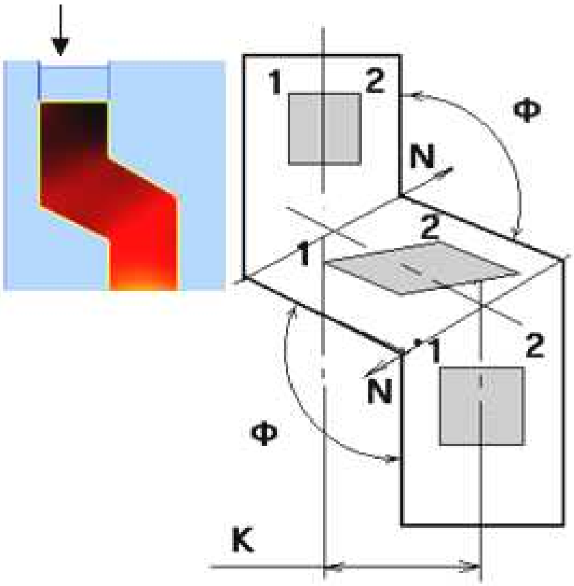
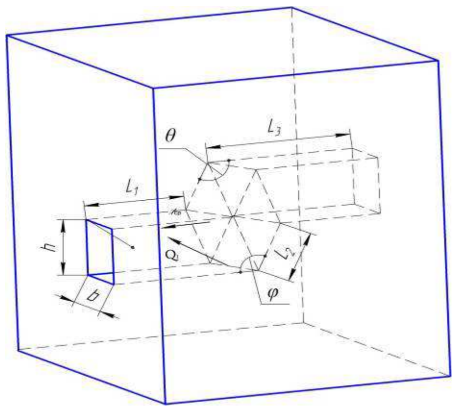


Fig. 1. Equal channel step matrix for pressing

Research methodology

To improve performance of the pressing process of billets in equal channel step matrix, namely, to improve the efficiency of hardening during severe plastic deformation, increase the coefficient of metal use and reducing the complexity a new design of equal channel step matrix was proposed [7].

The difference of the proposed matrix for pressing from previously known matrix [6] is that in the proposed matrix for pressing the intermediate channel is at an angle to the input and output channels, not in two but in three dimensions (Fig. 2).



1- input matrix channel;
2 - intermediate (deforming) matrix channel;
3 - output matrix channel.

Fig. 2. New design of equal channel step matrix

The presence in the matrix of intermediate channel disposed at an angle to the input and output channels in three dimensions, allows to develop significant shear strain in the whole volume of the billet with a slight change of its initial dimensions. At the same time realizes the two acts of severe plastic deformation: during the first severe plastic deformation occurs advance of the side and bottom layers of the billet faces, and at the second severe plastic deformation – layers advance of the second side and top faces. Thus the distortion of the end portions is minimized.

Pressing in this tool is carried out similarly to the pressing in previously known tool, i.e. as follows. Preheated to the temperature of the beginning of deformation billet is set in the receiving channel of the matrix, which by means of the punch is pushed sequentially into an inclined intermediate and then to the output channel. After complete extrusion of the billet into receiving channel, in the matrix set in the next billet, which pushes by the front end the previous billet out of matrix.

To test the effectiveness of deformation of the billet in the proposed device, a simulation of the pressing process was performed. The simulation results were compared with simulation results of pressing in the previously known pressing tool. The simulation was performed in the software package DEFORM-3D. In both cases simulated the deformation of the billet with sizes 15 x 20 x 150 mm, and the material randomly selected from the DEFORM-3D database was steel AISI 1015 heated to a temperature of 1100°C.

To study the impact of multi-cycle deformation of billet made of aluminum alloy AlMg5 in equal channel step matrix of the new design on the microstructure and mechanical properties of this alloy a laboratory experiment was carried out.

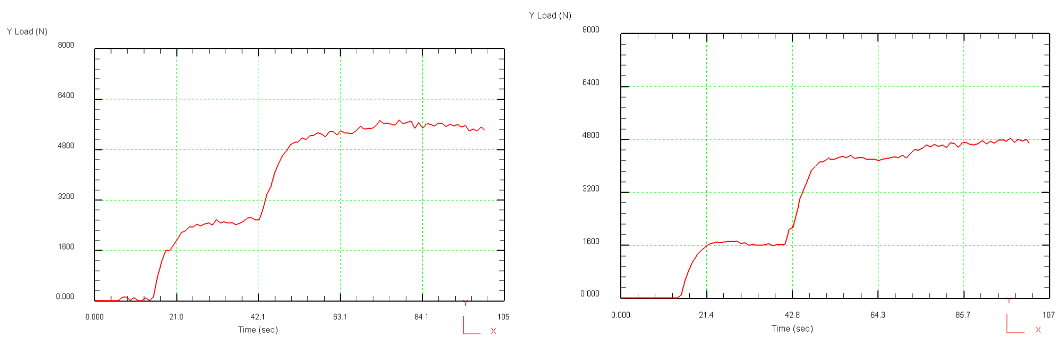
Deformation of aluminum billet carried on a hydraulic press in equal channel step matrix with the angle between the channels 135° and the offset in the third plane is equal to 25°, and the length of the intermediate channel 30 mm. Joints channels were performed without rounding. As the lubricant used graphite mixed with machine oil.

Pressing of the billets were carried out at room temperature of 20°C, which also contributed to obtaining sub-ultrafine grain structure.

To determine how many cycles the billet will withstand, it was decided to deform them to destruction.

Results and discussion

For the beginning graphics of emerging pressing force were constructed and analyzed (Fig. 3). When comparing the graphs of pressing forces in the proposed and previously known tools it can be seen that the values of load in these graphs differ slightly. This is because in previously known tool lays scheme of the direction twice changing of flow of the metal, and in the proposed tool lays scheme of triple change in direction of metal flow.

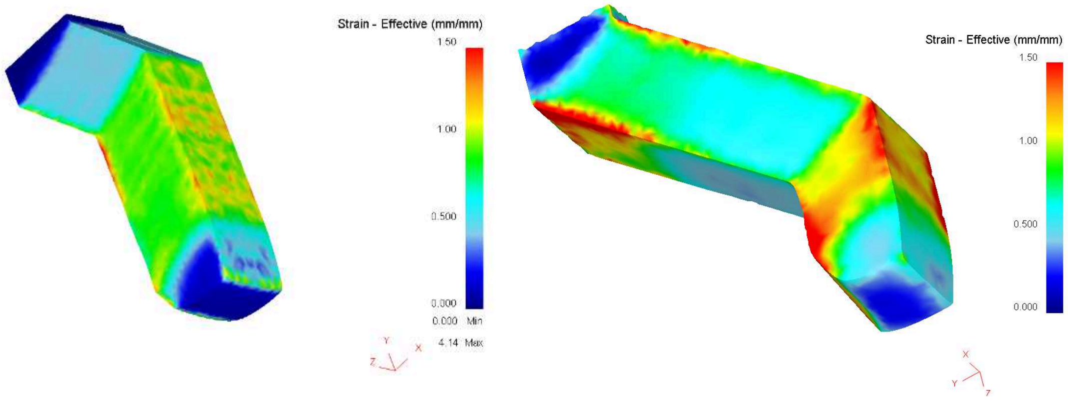


a) b)

a – known tool; b - proposed tool

Fig. 3. Graphics of pressing load distribution

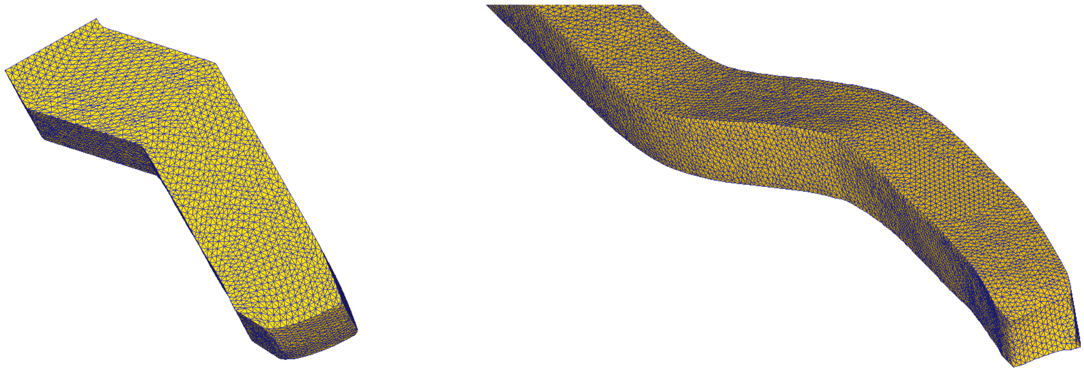
To show the effectiveness of the implementation of the pressing in the proposed tool, compared the distribution of accumulated strain in the billets, deformed in the proposed and previously known tools (Fig. 4). Forming of the front end of the billet to determine the degree of sharpening of the end sections was also investigated (Fig. 5).



a) b)

a – known tool; b - proposed tool

Fig. 4. Distribution of accumulated strain



a) b)

a – known tool; b - proposed tool

Fig. 5. Forming of the front end of the billet

As can be seen from the results of studies of the deformation of the billet in the above considered instruments, during the pressing of the billet in the known tool the front end of the billet strongly sharpens, that reflects negatively on CMU. During pressing of billets in the proposed tool, the front end of the billet is practically not sharpened and retains the shape of the rectangular faces. This can be explained by the fact that the design of the channels in the matrix implies advancing of layers on the faces in pairs in three planes, not two. Thus, there remains the original cross-sectional geometry at the front end of the billet.Analyzing the distribution of accumulated deformation shows that the most optimal scheme of deformation is implemented in the proposed tool. The implementation of severe plastic deformation in three dimensions leads to a significant refinement of the metal structure, which has a positive effect on its mechanical properties. And the presence of a scheme of triple direction changing of metal flow is, in fact, a scheme of alternating deformation, leading to a more uniform distribution of accumulated strain across the section of the billet, which allows to obtain the metal with sub-ultrafine grain structure at smaller quantities of cycles.

For the determination of grain size of the billets, deformed in equal channel step matrix of a new design GOST 5639-82 "Methods for detection and determination of grain size " was used. The data obtained in the study of the microstructure of aluminum is shown in Table 1.

Table 1. Results of determination of grain size

Cycle number	Initial	1	2	3	4	5	6	7
Grain size, microns	125-88	62-31	31-22	15-12	11-9,8	9,5-7,9	6,7-4,5	3,6-2

According to the results of metallographic investigations is seen that with the passage of each subsequent pressing cycle in equal channel step matrix of a new design there is a significant grain refinement of the material.

Experimental data shows, that only one billet made of alloy AlMg5 withstand 9 cycles then its further deformation is not possible, and all other billets were already destroyed after the 8th cycle.

In connection with these results it is possible to speak of a stable deformation without fracture of aluminum alloys AlMg5 up to 7 passes in equal channel step matrix of a new design.

But at the same time, in the course of the experiment, after the passage of the billet 7 cycles of deformation, it cannot achieve the grain size of 100 nm. Therefore, to obtain the structure of an aluminum alloy with a grain less than 100 nm further studies are necessary to determine the optimal conditions of heat treatment of the alloy before compression.

Summary

The analysis of the mechanical properties and microhardness of the deformed aluminum billets showed that the strength properties of the aluminum alloy grow significantly only up to 4 cycles, then their intensity decreases. Plastic properties conversely reduced with a greater degree up to 4 cycles, then their decline is becoming weaker. By judging about microhardness, it can be said that, as expected, it gradually increases with increasing pressing cycles in equal channel step matrix of a new design.

The analysis of anisotropy of mechanical properties, measured as the ratio of the maximum values of the mechanical characteristics to the minimum value of the same characteristics showed high uniformity of properties throughout the cross section of the billet by pressing it into equal channel step matrix of a new design.

References

[1] Innovation patent of Republic of Kazakhstan № 20970. Device for angular pressing. Naizabekov A.B., Andreyaschenko V.A., Lezhnev S.N. Bul. 3, 2009.

[2] Naizabekov A.B., Leznev S.N. Study of the deformation process of billets in a step tool with rolls. Technology and equipment for metal forming, Chelyabinsk, 2006. - p. 24-27.

[3] Lezhnev S.N., Shlychkov A.S., Efremov K.S. Theoretical study of the deformation process of the metal in equal channel step matrix with additional backpressure. 3rd International Kazakhstan metallurgy conference "50 years of Kazakhstan Magnitka ", (Collection of proceedings), Temirtau, 2010. – p. 173-178.

[4] Lezhnev S.N. Modeling and study of the process of billets pressing of round cross section at equal channel step matrix with different roughness of the channel matrix. Republican scientific journal. Technology of production of metals and recycled materials. Temirtau, 2010, №2. – p.168-173.

[5] O. Krivtsova, V. Talmazan, A. Arbuz, G. Sivyakova, Study the process of equal-channel angular pressing with quasi-ultra-small angles of joint channels using computer modeling in program complex DEFORM, 2014, Advanced Materials Research, 1030-1032, 1337.

[6] Patent of RF № 2181314. Device for metal forming. Raab G.I., Kulyasov G.V., Polozovsky V.A., Valiev R.Z., 2002.

[7] Patent of Republic of Kazakhstan №25864. Device for metal pressing. Naizabekov A.B., Lezhnev S.N., Panin E.A. Bul. 6, 2013.