Improvement of the Device for Continuous Pressing of Non-Ferrous Metals and Alloys and Computer Simulation of the Deformation Process in This Device

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Abstract. A new design of the device for continuous pressing is proposed, which combines the principles of the ECAP and Linex processes. To assess the possibility of the process and the efficiency of metal processing, computer modeling was performed. It is found that the greatest load is received by the mobile segments that ensure the movement of metal through the matrix. The distribution of stress-strain state parameters in the longitudinal section of the workpiece is extremely uneven, which is due to the transverse action of the pulling force. In the first two channels, due to a backpressure the compressive stresses occur. In the output channel, the metal experiences tensile stresses.

1. Introduction

The development of the modern world has been going on at an ever-increasing pace for a long time. The reality around us is constantly being modernized and supplemented with new elements, and first of all, various modern and in many cases innovative technology. At the same time, the constantly occurring development of technology simultaneously imposes higher requirements for the quality of non-ferrous metals and semi-finished products used for its production. Non-ferrous metals and alloys have been of great importance for more than a decade. They are used in almost all industries, including aircraft construction, chemical industry, mechanical engineering, and others. And in the manufacture of many parts for household appliances, cars and aircraft, etc. non-ferrous metals and alloys have no competitors at all.

The increased requirements for the quality and properties of non-ferrous metals and alloys dictate the conditions for the development of new innovative technologies for processing non-ferrous metals and alloys by pressure or improving existing technologies, but in any case aimed at obtaining after pressure treatment of non-ferrous metals and alloys with an ultrafine-grained (UFG) structure. This structure is characterized by an average grain size from 0.1 to 1 microns [1], and the increased interest in UFG materials is due to their improved physical and mechanical properties [2].

One of the most promising and economically justified methods for obtaining an ultrafine-grained structure, both in ferrous and non-ferrous metals and alloys, is the severe plastic deformation (SPD) method [3]. In many works of scientists from different countries of the world [4–10], it has been proved more than once that the processing of various metals and alloys by the SPD method makes
it possible to significantly reduce the initial structure of the metal without significantly changing the initial size of the workpiece.

Currently, numerous schemes have been developed not only for the implementation of severe plastic deformation: high-pressure torsion (HPT) [11]; equal-channel angular pressing (ECAP) [12]; comprehensive forging [13]; multi-axis deformation [14] and others, but also tools for their implementation. For example, numerous matrix designs for equal-channel angular pressing have been developed [15–20].

Further development of the scientific direction related to severe plastic deformation is associated with the development of new innovative methods for producing long-length products from ferrous and non-ferrous metals with an ultra-fine-grained structure. These methods include: the method of deforming the Conform [21]; equal-channel angular drawing [22]; combined processes “ECAP – drawing” [23], “rolling – ECAP” [24] and many others. A method of continuous pressing of non-ferrous metals and alloys called “Linex” is also known [25]. This method of deformation, although it allows you to obtain long products from non-ferrous metals and alloys, but most often from soft, but has one significant drawback: it provides an increase in the quality of metal products only when the size of the source material is repeatedly reduced, which leads to significant energy and labor costs.

2. Concept of new device for pressing

Based on this method of deformation and the tool for its implementation, it is proposed to create a new device for continuous pressing of non-ferrous metals and alloys without significantly changing the initial dimensions of the workpiece. This will be achieved by the fact that the device for continuous pressing of non-ferrous metals and alloys will include a movable part made in the form of two tape gripping blocks with rigid inserts, as well as a fixed part in the form of an equal-channel step matrix made without side walls (Figure 1).

![Figure 1. Device for continuous pressing of non-ferrous metals and alloys: 1 - movable belt blocks, 2 - fixed matrix with three channels of the same cross-section, two of which are parallel to each other, and the middle channel is located at an angle to the input and output channels, 3 - blank, 4 - idler pulleys, 5 - drive pulleys, 6 - fixed locking blocks.](image-url)

Pressing in this device is performed as follows. The workpiece is fed to the device, where movable tape blocks capture the workpiece and push it through the channels of the fixed matrix. Each belt gripper block is clad on two pulleys, one of which is idle, and the other is driven by an electric motor. This is why the tape gripping blocks are set in motion. The horizontal forming of tape gripping blocks is created by their movement along the workpiece and fixed locking blocks that perform a clamping role. To reduce the deformation force, grease is applied to the walls of the
fixed matrix, while there is no grease supply to the moving parts in order to increase the gripping capacity.

To assess the possibility of implementing the continuous pressing process in the proposed device and study it, a computer simulation of this process was carried out in the Deform software package. The initial dimensions of the workpiece were 10x15x100 mm. The material of the billet is AL-1100 alloy. The deformation was performed at room temperature. The angle of the channel junction in the matrix is 145°, to reduce the back pressure at the channel junctions, rounding with a radius of 5 mm was made, and the coefficient of friction with fixed side segments was assumed to be 0.1. For a stable process, it is necessary to ensure a high level of adhesion of the workpiece with the moving segments, so the coefficient of friction was set to 0.8.

3. Results and discussion

The simulation results were used to study the load force on all segments of the device, as well as the stress-strain state in the workpiece (figure 2).

![Figure 2. Load force on fixed (a) and movable (b) segments.](image)

On fixed segments, the amount of force varies, as in the case of a conventional ECAP – on a large segment, where there is a large backpressure, the force reaches 85 kN, on a small segment, the force is much lower, about 35 kN. On movable segments, the force value is the same, about 107 kN.

Due to the fact that the main force that causes the movement of metal through the channels of the matrix acts not in the longitudinal but in the transverse direction, the distribution of equivalent strain over the width of the workpiece is extremely uneven. This, in turn, is due to the nature of filling the matrix channels with deformable metal. Figure 3a clearly shows that due to the transverse action of the force, the second joint in the matrix is not filled, since the metal, after passing the inclined channel, moves in the direction of movement of the moving segments. As a result, the width of the workpiece metal gets a deformation from 0.4 to 6.2.

The reason for this phenomenon can be easily understood if we consider the stress state in the plane of the longitudinal section of the workpiece (figure 3b). When deforming in this device, all the metal gets a movement in the longitudinal direction. However, due to the construction of the matrix, when moving in the first channel, the metal experiences a backpressure from the joint angle, and when moving in the second channel, it experiences a backpressure from the inclined face of a large segment. Therefore, in these zones, compressive stresses of up to -20 MPa prevail in the metal. Everything changes after the metal passes the inclined channel. Here, there are no more obstacles.
in its path, and there is no backpressure. Therefore, in the output channel, the metal experiences tensile stresses up to +60 MPa.

Figure 3. Equivalent strain (a) and stress in the plane of the longitudinal section of the workpiece (b).

4. Conclusion
A new design of the device for continuous pressing is proposed, which combines the principles of the ECAP and Linex processes. To assess the possibility of the process and the efficiency of metal processing, computer modeling was performed. It is found that the greatest load is received by the mobile segments that ensure the movement of metal through the matrix. The distribution of stress-strain state parameters in the longitudinal section of the workpiece is extremely uneven, which is due to the transverse action of the pulling force. Therefore, to align the stress-strain state parameters on the section of the workpiece, it is recommended to perform an even number of deformation cycles with the workpiece turning 180 degrees after each cycle.

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