FEATURES OF STRUCTURE FORMATION AND MECHANICAL BEHAVIOR OF METALLIC MATERIALS UNDER CONDITIONS OF APPLICATION OF GRADIENT DEFORMATIONS

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Abstract. *The study of technological methods of plastic structure formation is an urgent task. Taking into account that structure formation depends on many factors and, first of all, on the deformed state, studies of the deformed state and structural studies involving TEM were carried out in the work. It is known that reliable data of the structural state allows predicting the mechanical and operational properties of the obtained semi-finished products and products. In this regard, the analysis of the effect of the processing route (C, Bc) on the structural changes after high-cycle active bending was carried out. A numerical simulation of the active bending process was also carried out, and the accumulated strain values were determined for 8 processing cycles. Established patterns of structure formation, depending on the level of accumulated deformation and processing route.*

KEYWORDS*: PLASTIC STRUCTURE FORMATION, ACTIVE BENDING, MODELING.*

1.Introduction

In the context of expanding industrial production, the need for new materials and for improving the physico-mechanical properties of known materials increases. Researches in this direction are conducted by many scientific centers all over the world. Great efforts are aimed at studying the features of the structural states of materials and their connection with the stress-strain state and other factors [1,2]. In this regard, there is an increasing need for the creation of promising industrial methods that allow to achieve improved properties of materials [3-5].

One of them is the method of active bending, which makes it possible to act on the initial structure under conditions of a continuous gradient under conditions of a strain gradient. In this regard, the aim of the work was to study the effect of the deformed state with two copper processing routes on the type of structure being formed.

2.Concept of process

A schematic diagram of the active bending used in research is presented in Figure 1. The proposed development is based on the well-known ECAP- “Conform” scheme, while in the deformation process, the workpiece 3 is pushed into the stationary bending matrix consisting of two elements of the matrix 1 and 2.

The method allows to combine the high-performance process “Conform” with bending deformation, which leads to a significant intensification of the hardening process of the deformable material due to the formation of a gradient structure. Active friction forces ensure process continuity

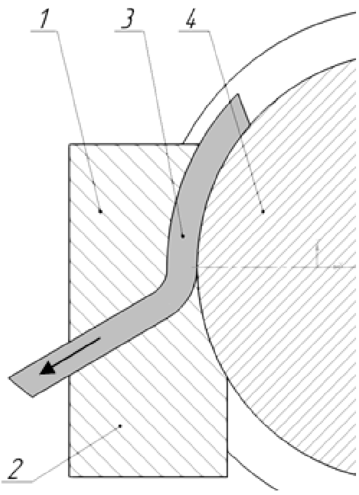

Figure. 1. *A schematic diagram of the bending of samples due to active friction forces according to the “Conform” scheme in a stationary bending matrix: 1, 2 - two matrix elements for bending; 3 – sample; 4 - drive roller with engraving*

For the simulation, the Deform 3D program was used to analyze the three-dimensional (3D) behavior of the metal during pressure treatment. This made it possible to obtain important information about the nature of the material flow in the forming tool, as well as about the stress-strain state and the temperature distribution during the deformation process.

When modeling the bend according to the “Conform” scheme at an angle of 90°, a square section sample with a size of 10x10 mm and a length of more than 150 mm was used for the first deformation cycle, a bend radius of 10 mm. For the subsequent cycles, a sample obtained by modeling on the previous cycle was used in order to obtain generalized data after passing through four sample processing cycles.

3. Results and discussion

Description of the structure of copper (M1) after bending on a horizontal installation ECAP-Conform

After 8 passes of active bending along the Bc route, a fragmented, close to equiaxed microstructure with misoriented fragments with sizes of ~ 0.3-0.5 μm was formed in the alloy. In the body and the boundaries of a significant part of the fragments, dislocation clusters with a scalar dislocation density ρ_d are observed, reaching values ρ_d in individual fragments of ~ 10^{11} cm^{-2}. With a further increase in the number of passes (degree of deformation), the dislocation density practically does not increase, i. e., it reaches saturation after 8 passes.

The estimate of the dislocation density, determined from the results of X-ray structural analysis, corresponds to the maximum value of ρd obtained by electron microscopic studies of thin foils.

Analysis of microdiffraction patterns obtained on thin foils from deformed flexible materials, as well as EBSD analysis, indicates a significant disorientation of the fragments after four passes. In general, these studies showed that in the process of bending along the V-route, medium- (5–15 °) and high-angle (~ 15 °) boundaries of deformation type are formed in copper.

At the same time, eight passes, which are flexible along route C, lead to the formation of a microstructure with lengths stretching in the direction of ~ 35–45 ° to the rod axis with sizes of ~ 1–3 μm in length and 0.2–0.6 μm in thickness. In many elongated fragments and boundaries between them there are clusters of dislocations with a scalar density ρd exceeding 10^{11} cm^{-2}. EBSD analysis showed the presence of a whole ensemble of fragment boundaries with different misorientations, among which medium- and high-angle deformation boundaries predominate.

The definition of microhardness in cross section of samples after bending is shown in Fig. 2 and 4. The magnitude of microhardness in the cross section varies in accordance with the character of the formed gradient structure, the features of which are higher HV values in the central rod area and a decrease in the HV value in near-surface areas for both bending paths (Fig. 2 and 4).

Obviously, such a dependence of the microhardness variation is due to the heating of the rods in the process of bending and the possible redistribution of dislocations and a decrease in their density in the near-surface region of the rods.

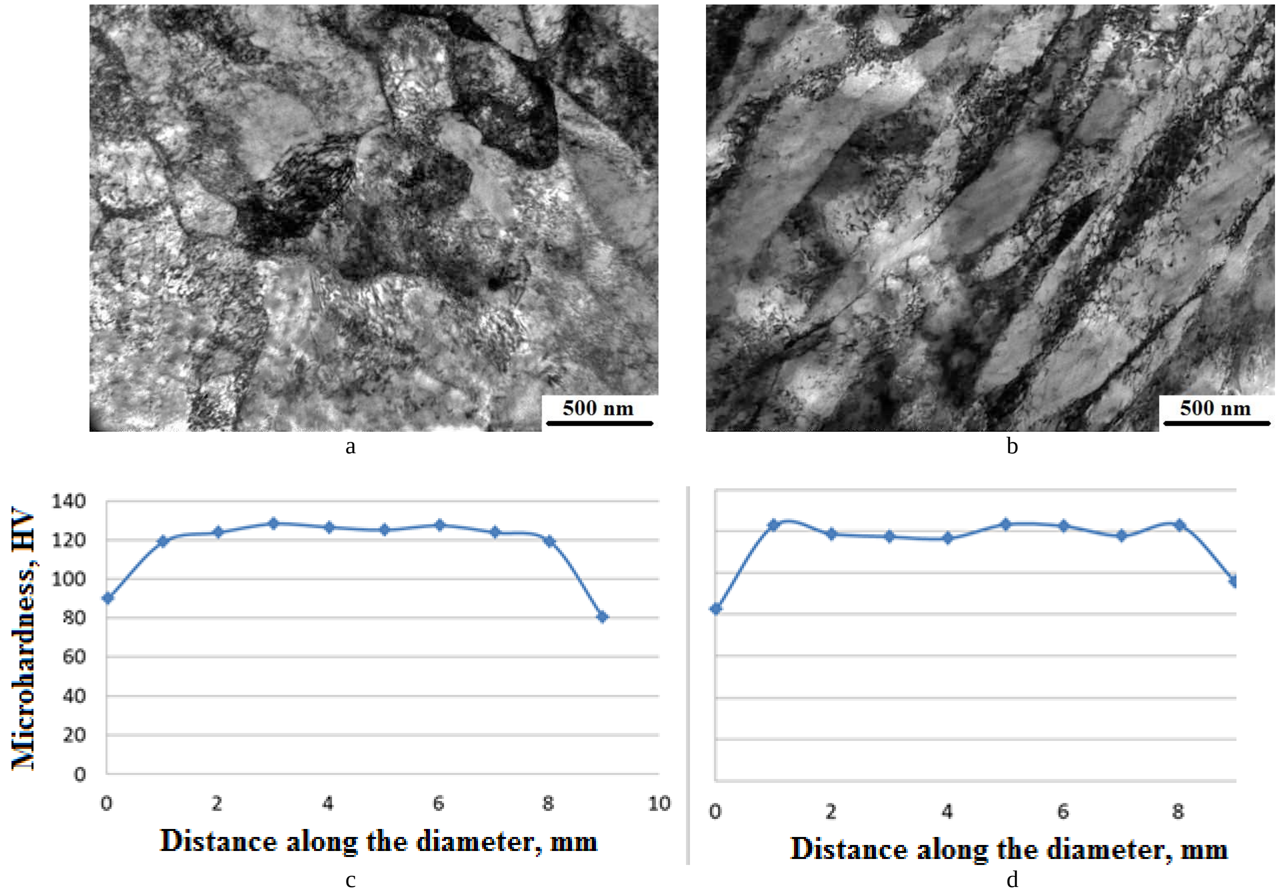

Figure 2. *8 passes are flexible: a - route Bc; b - route C; c, d – the dependence of the microhardness HV on the distance along the diameter of the rod, respectively, for routes Bc and C*

4. Conclusion

1. Using numerical simulation, it is established that active bending provides, after 8 processing cycles, the level of accumulated deformation e = 4.2 in the middle region and e = 5.0 in the near-surface cross-sectional area of the workpiece.

2. It has been established that when using the method of active bending along the Bc route, a grain-subgrain equiaxial structure with an average grain size of ~ 0.3-0.5 µm is formed in a deformed copper sample; a cross section of ~ 0.2–0.6 µm and a length of ~ 1–3 µm. UMP range.

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5. References

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