GRADIENT STRUCTURE AND METHODS FOR THEIR PREPARATION

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Abstract. *The development of new technological methods of SPD for the production of mass production with improved properties due to the deep grinding of the original structure is an important task. The purpose of this work was to study the active bending to grind the structure and create promising, for operational use, gradient structural states in long rods of copper grade M1. Active bending was performed using an extruder according to the "Conform" scheme. The results of the analysis stress-strain state is using computer simulation and structures using optical microscopy. It is established that the active bending method provides over four processing cycles high strain accumulation (e = 3-4) and formation subgrained- structure UFG type.*

KEYWORDS: *METAL PROCESSING BY PRESSURE, SEVERE PLASTIC DEFORMATION, FINITE ELEMENT METHOD.*

1.Introduction

In the modern world, the need for new materials is increasing, as well as for the improvement of their physical and mechanical properties. In this regard, there is an increasing need for the creation of promising industrial methods allowing to achieve improved properties in the material. The most effective methods are SPD [1,2]. However, their development is hampered by low manufacturability of the proposed technical solutions, especially for the production of mass products. In this regard, the paper considers the method of active bending, based on the use and advantages of the "Conform" scheme [3-5]. Its main advantage is the improvement of the tribological situation in the process of the formation of ultrafine-grained (UFG) gradient structures providing products with increased wear resistance and ductility at high strength indices [??]. The object of the study was a long rod of technically pure copper.

2.Concept of process

Principal diagram of 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 1,2 due to active friction forces of the drive roll with engraving 4. The method makes it possible to combine the high-performance "Conform" process with bending deformation, which leads to a considerable intensification of the hardening process of especially the near-surface layers of the deformable material due to the formation of the structure. Active friction forces ensure continuity of the process.

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

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

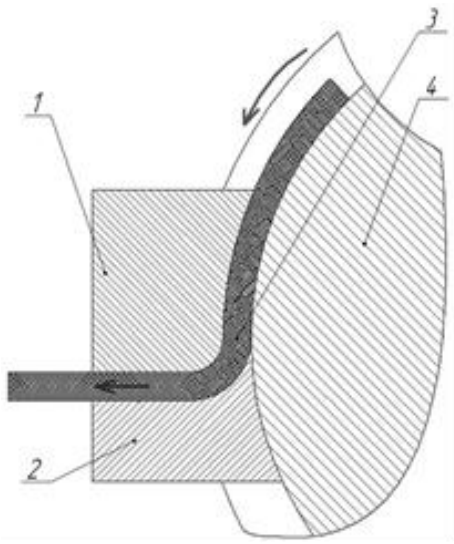


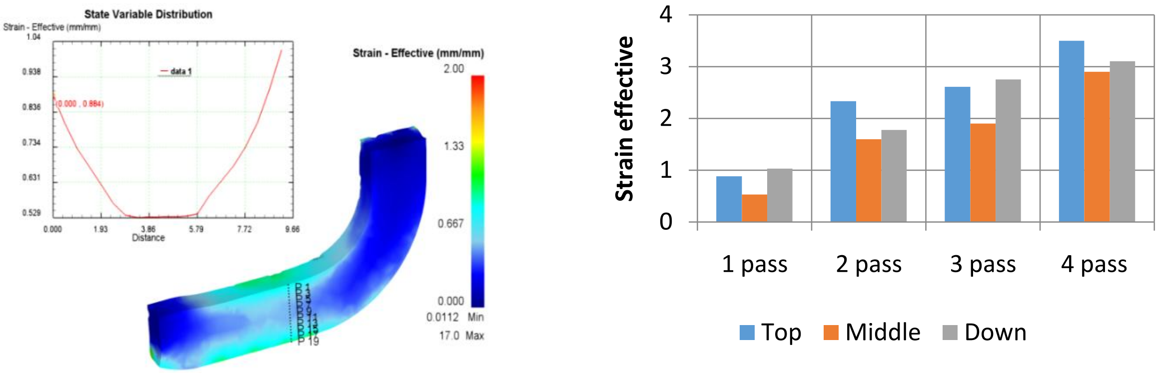
Figure. 1. *Principial schem of bending of samples due to active friction forces according to the "conform" scheme in a stationary bending matrix: 1, 2 - two matrix elements for bending; 3 - sample; 4 - drive roller with engraving.*

Process simulation parameters

- Initial sample plastic body, with a number of finite elements 70000 pcs.
- Tool - absolutely rigid body.
- Tool without a finite element mesh.
- The rotational speed of the drive roller is selected constant - 1 rad / sec.
- The temperature at the first treatment cycle was taken at room temperature and was 20 ° C.
- Simulation is performed taking into account the increase in the temperature of the workpiece from the heat effect during plastic deformation (deformation heating).
- The temperature of the rollers is constant, corresponds to - 20 ° C.
- Use Siebel coefficient of friction f = 0,2.
- The impermeability condition is set on the contact surfaces of the equipment.
- Number of modeling steps more than 1000 for all four cycles of the bending process.

3. Results and discussion

The conducted virtual experiment and its analysis showed that in the process of processing on the surface of the workpiece during bending at angle of 90 degrees, maximum values of the strain intensity are observed. So after one cycle in the upper part of the workpiece, the accumulated strain intensity reached e = 1.04, and in the lower e = 0.88 and increased proportionally with the number of sample passes through the deforming channel (see Fig. 4).

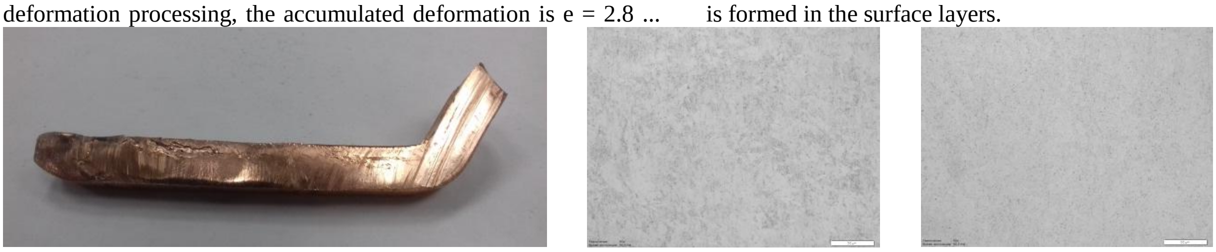


a b

Fig. 3. *Picture of the deformed state of the sample after the first bending cycle at 90° (a) and the diagram of the strain intensity accumulated over the cross section of the workpiece after four passes (b)*

Plastic deformation by the proposed method leads to formulations that allow one to obtain a gradient of properties in a deformable material. So, with a subsequent analysis of the accumulated strain in the process of bending an angle of 90°, it can be seen that with an increase in the number of bends, the accumulated strain also increases. So after four cycles of deformation processing, the accumulated deformation is e = 2.8 ... 3.5 for an angle of 90 °, with the maximum value of accumulated deformation observed in the near-surface region of the deformable sample, and lower values in the middle area.

The results of laboratory studies for obtaining experimental samples and structural studies are presented in Figure 5. It has been established that a finer grain-subgrain-type structure is formed in the surface layers.



a *b* *c*

Figure 5. a *- general view of the sample in the process of active bending, b - the structure of the middle zone of the cross section of the sample (OM), c - the structure of the surface area of the cross section of the workpiece (OM)*

4. Conclusion

It is established that when using the method of active bending in a deformable copper sample, a gradient of a grain-subgrain structure of the UFG range is formed. Using virtual simulation, it is shown that the method of bending according to the “Conform” scheme provides, after 4 processing cycles, the level of accumulated deformation e = 2.8 in the middle region and e = 3.5 in the near-surface region of the cross section of the sample.

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