Stress-strain state of workpiece from Cu-Cr alloy processed by severe plastic deformation by ECAP

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1. Introduction

The aim of this work is to study the stress-strain state and thermal effect in a workpiece from low-alloyed Cu-0.6Cr bronze under conditions of intense plastic deformation by equal-channel angular pressing (ECAP). To do this, physical modeling of the sedimentation of the samples was carried out on a Gleeble 3500 installation at temperatures of 20, 400, and 800 ° C and strain rates of 3, 30, and 300 mm / s. Based on the data obtained, a computer simulation of the process of ECAP was carried out in the Deform 3D software package. As a result, the fields of stress distribution, deformation, temperature (deformation heating) and power characteristics of the ECAP process are obtained, depending on various initial temperature and speed conditions.

2. Objective and research methodologies

The work used an industrial conductive alloy Cu-0.6Cr. The initial state was obtained in the process of high-temperature treatment at 1000 ° C for 1 hour and subsequent quenching in water. Alloy samples 10 mm in diameter and 14 mm in height were upset on a Gleeble-3500 physical modeling complex at a strain rate of 3, 30, and 300 mm / s. The temperature of the experiment was 20, 400, and 800 ° C. Further, based on the data obtained by physical modeling, a database was prepared for finite element computer modeling in the Deform 3D software package. After preparation, modeling and analysis of the results were carried out.

3. Results

Under conditions of severe plastic deformation by the ECAP method, intense deformation heating occurs (Figures 1,2). The deformation rate has the most significant effect on heating, so at an initial temperature of 400 ° C, with an increase in the deformation rate from 3 to 300 mm / s, deformation heating increases from 30 to 220 ° C.

With an increase in the initial temperature, the degree of heating decreases. So, at an initial temperature of 20 ° C and a deformation rate of 30 mm / s, the heating is 100 ° C, and at an initial temperature of 800 ° C, the heating is 30 ° C.

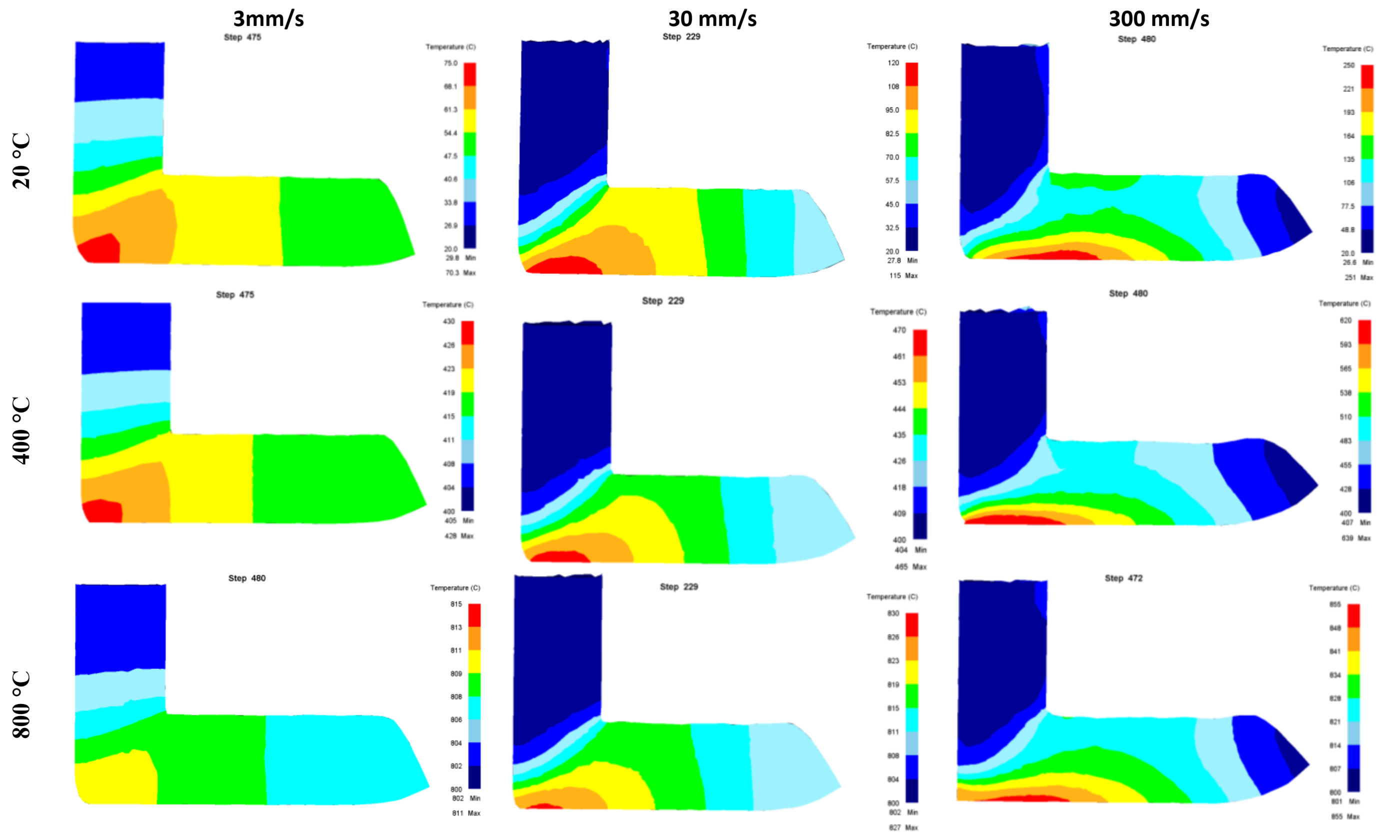

Fig. 1. *Temperature fields at different temperature-speed conditions*

With an increase in the initial temperature, the required pressing force (Figure 2) decreases, for example, from 208 kN at 20 ° C and a deformation rate of 3 mm / s to 46.3 kN at 800 ° C. An increase in the rate of deformation leads to an increase in the required force. For example, for 400 ° C, an increase in the deformation rate from 3 to 300 mm / s leads to an increase in the force from 113 to 244 kN. Thus, in the selected range of conditions, the most favorable is the mode including processing at an initial temperature of 400 ° C and a strain rate of 30 mm / s, providing a temperature increase of no more than 70 ° C and a low pressing force. The distribution of accumulated deformation (figure 3) is non-uniform. The maximum values are observed in the lower peripheral region and are e ~ 2.5, which can have a positive effect on the strength and wear resistance characteristics of the finished product. The minimum values in the central region are of the order of e ~ 1.5.

The simulation results show that in the deformation zone in the shear region, compression stresses prevail, reaching values of the order of 230 MPa. (Figure 4). In general, effective stresses in the deformation zone have a uniform distribution (~ 300 MPa) with local maxima in the peripheral zones of intersection of channels (more than 350 MPa). (Figure 5).

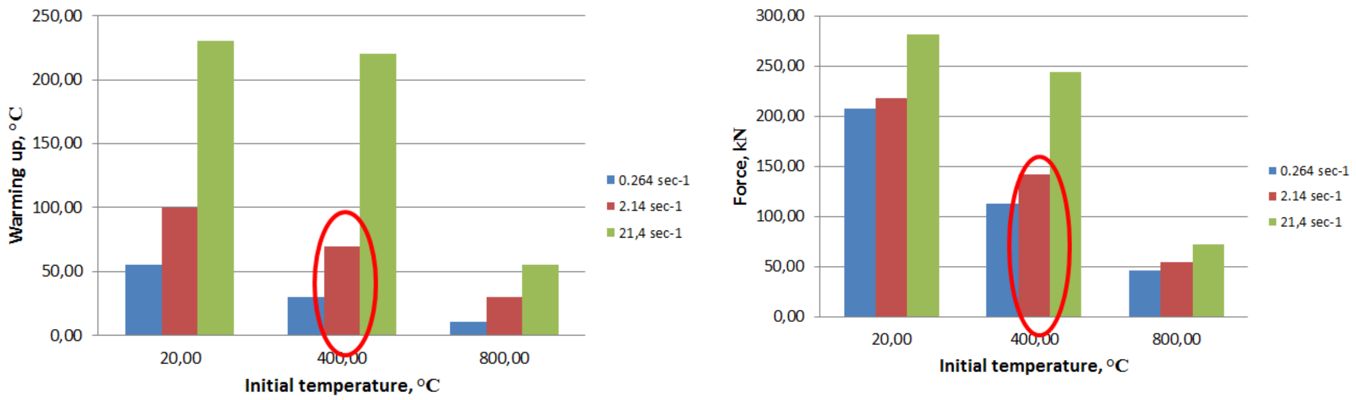

Fig. 2. *Variation of warming up during deformation and pressing force depending on the initial temperature and velocity*

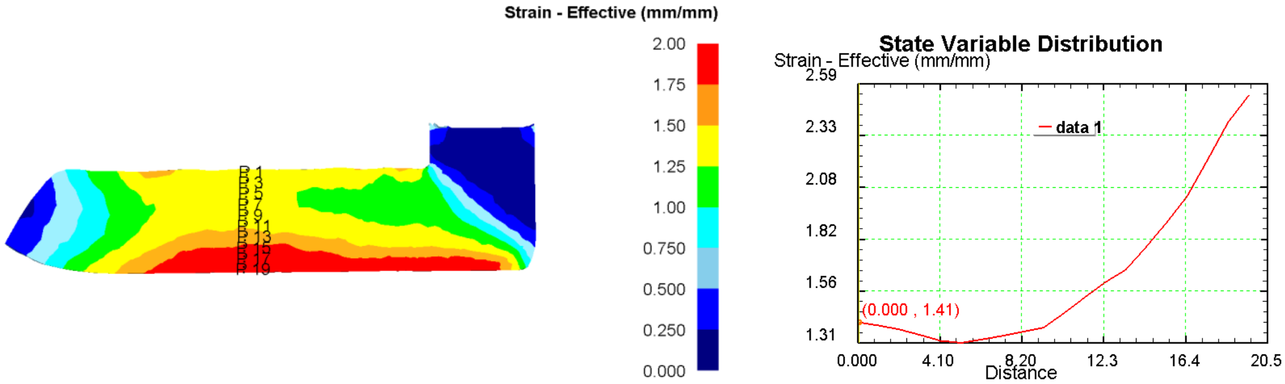

Fig. 3. *Accumulated deformation distribution (The rational technological mode)*

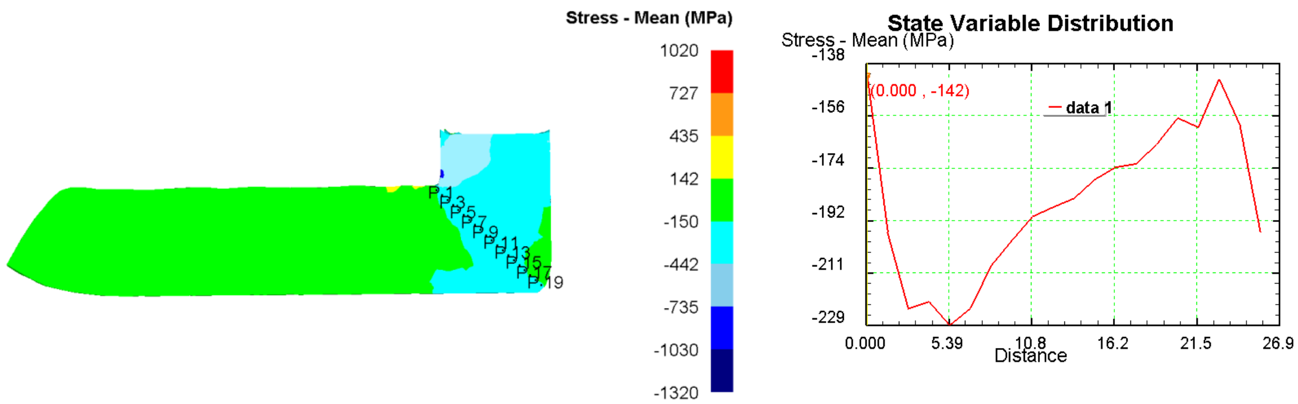

Fig. 4*. Stress mean distribution (The rational technological mode)*

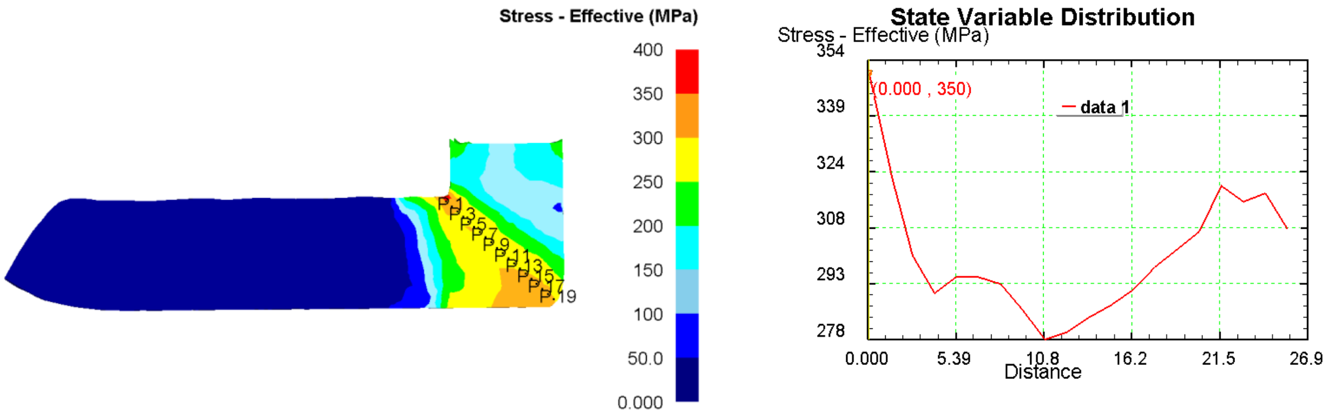

Fig. 5. Stress effective distribution (The rational technological mode)

3. Conclusion

Thus, in the course of computer modeling, a comprehensive analysis of the stress-strain state of workpieces was carried out during processing by the ECAP method and ECAP with extrusion, an assessment of the energy-force models of the process, shown on the tool, was carried out, depending on the temperature and speed parameters of processing.

In conditions of intense plastic deformation by the ECAP method, intense warming up during deformation. The most significant effect on heating is exerted by the deformation rate, so at an initial temperature of 400 °C, an increase in the rate of deformation from 0.264 to 21.4 sec-1, deformation heating increases from 120 to 250 °C;

With an increase in the initial temperature, the degree of warming up decreases. So, at an initial temperature of 20 °C and a strain rate of 2.14 sec-1, the heating is 100 °C, and at an initial temperature of 800 °C, the heating is 30 °C;

With an increase in the initial temperature, the required pressing force substantially decreases, for example, from 208 kN at 20 °C and a strain rate of 0.264 sec-1 to 46.3 kN at 800 °C. An increase in the strain rate leads to an increase in the required force. For example, at 400 ° C, an increase in the strain rate from 0.264 to 21.4 sec-1 leads to an increase in force from 113 to 244 kN.

The optimal technological mode for the formation UFG structures is an initial temperature of 400 degrees and a strain rate of 2.14 sec-1 (equipment rate of 30 mm/sec) and true strain e~1.

Acknowledgments

The study was supported by the Russian Science Foundation (project №19-19-00432).