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STUDY OF THE KINEMATICS OF THE MOVEMENT OF SOLID INCLUSION IN PLASTIC FLOW

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ABSTRACT

The conditions of interaction of a solid-reinforcing inclusion with a metal matrix of a dispersed-reinforced composite material in the focus of deformations during isothermal pressing are considered. As a result of numerical modeling, the mechanism of reorientation in the direction of metal flow of solid reinforcing inclusions is substantiated. It is shown that the mechanism of rotation of the inclusion in the direction of flow of the metal depends on the gradient of the velocities of the material particles of the matrix. It is shown that the use of back pressure improves the interaction conditions at the boundary surface of the inclusion and the matrix, reduces the likelihood of microcracks, and the process in hot plastic deformation creates conditions for "healing" of existing microdamages..

INTRODUCTION

One of the most important factors in increasing the operational reliability and resource of modern products of science-intensive mechanical engineering is the use of structural materials with a high level of mechanical properties. [1]. Among such materials, a special place is occupied by composite materials, in particular, dispersion-hardened materials [2].

In [3], the technological features of manufacturing a billet of a gas turbine engine compressor blade from a quasi-composite material based on BT8 titanium alloy dispersion-hardened with TiB_n eutectic are presented. As a result, it was shown that the technological modes that affect the quality of the finished product differ from isothermal pressing of the blade blank made of an unreinforced titanium alloy, for example, described in [4, 5]. It is shown that these features are associated with the presence of solid dispersed inclusions that interact with the base metal (matrix) during plastic deformation, as noted in [6, 7]. During their interaction, there is some fragmentation and reversal of dispersed inclusions of the strengthening component in the direction of flow of the matrix metal at large deformations. An essential issue in the implementation of such processes is to ensure the continuity of the composite material for the full realization of its strength properties in products.

The goal of this work was to study the conditions for the interaction of a dispersed inclusion (DI) with a metal matrix in the deformation zone during isothermal pressing.

EXPOSITION

The modeling of the process of direct pressing of the workpiece with rigid inclusions was carried out by the method of endseven elements. In the decision the scheme of flat deformation and volume stress state was accepted.

As the main material of the workpiece - the matrix was adopted titanium alloy BT8. Direct pressing was carried out with a punch, which was given a certain movement U_y. When modeling direct pressing with back pressure on the lower end there is a counter-punch, to which a distributed force was applied q.

The simulation was performed under the condition of material hardening and friction on the contact surfaces. Properties of the base material of the workpiece of titanium alloy BT8 in the initial state: Young's module $E = 1,2 \cdot 10^5 MPa$ Poisson's ratio $\mu = 0,3$, conditional yield strength $\sigma_{0,2} = 300MPa$, $\sigma_B = 700MPa$ [8-9].

The inclusion was considered absolutely rigid in comparison with the main material of the workpiece, as the Young's modulus of rigid inclusion is 3 orders of magnitude higher than the Young's modulus of the basic material of the workpiece and is $E = 2 \cdot 10^8 MPa$. The coefficient of friction in contact between the workpiece, the punch, the counter-punch and the matrix was taken $f = 0,08$.

Simulation of the direct pressing process was performed in a quasi-dynamic setting, instead of the speed of movement of the punch was set a certain stepwise movement. Solving a quasi-dynamic problem significantly reduces the calculation time, without losing the accuracy of the calculation.

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In the process of isothermal pressing, the kinematics of the DI motion in the deformation zone is shown in Fig. 1.

When the metal moves in the direction of compression of the DI depending on the stage of movement in the deformation zone changes its position depending on the direction of deformation. This is due to the change in the velocity of the metal V1 in the deformation zone, as well as the acting stresses on the boundary surface of the "base metal-inclusion".

In fig. 2 - 5 shows the distribution of the main components of the stress tensor in the microvolume on the boundary surfaces S1 and S2 of the inclusion at the intermediate stage - 4. The components of the stresses σ_x and σ_y are compressive. Their distribution on surfaces S1 and S2 is uneven (see Fig. 6). Equivalent resulting forces from the action of stresses $F_i = \int\limits_{s_1} \sigma_i ds$ applied to the surfaces S1 and S2 at some distance ℓ_m create a moment (Fig. 6), the result of which is the return of DI.

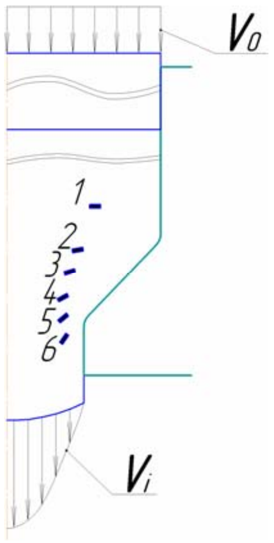
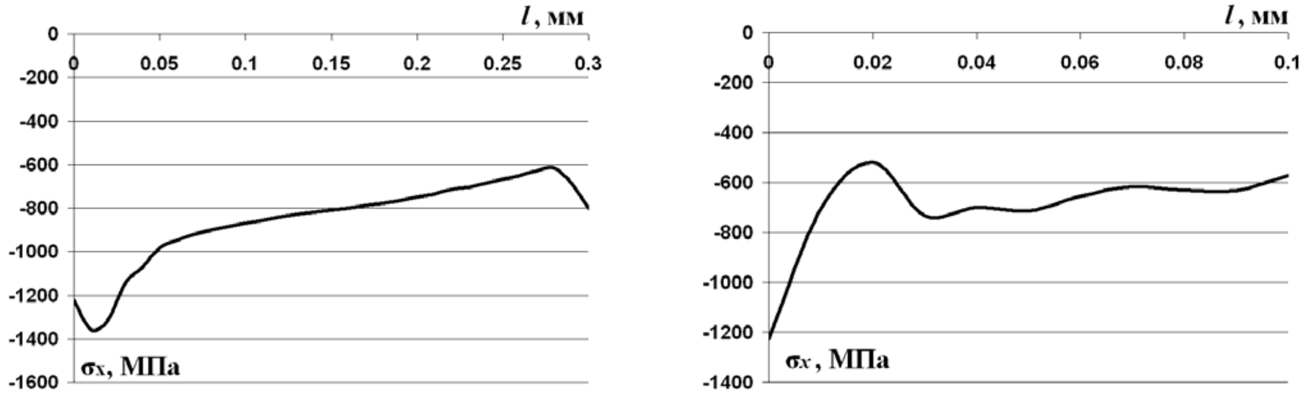
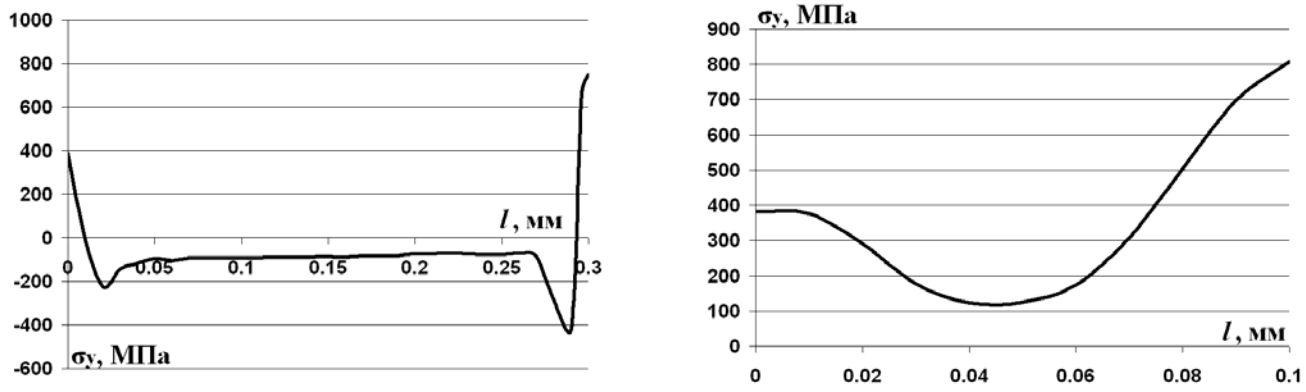


Fig. 1. Kinematics of movement of dispersed inclusion at pressing: 1, 2, 3, 4, 5, 6 - stages of movement of DI in the direction of pressing



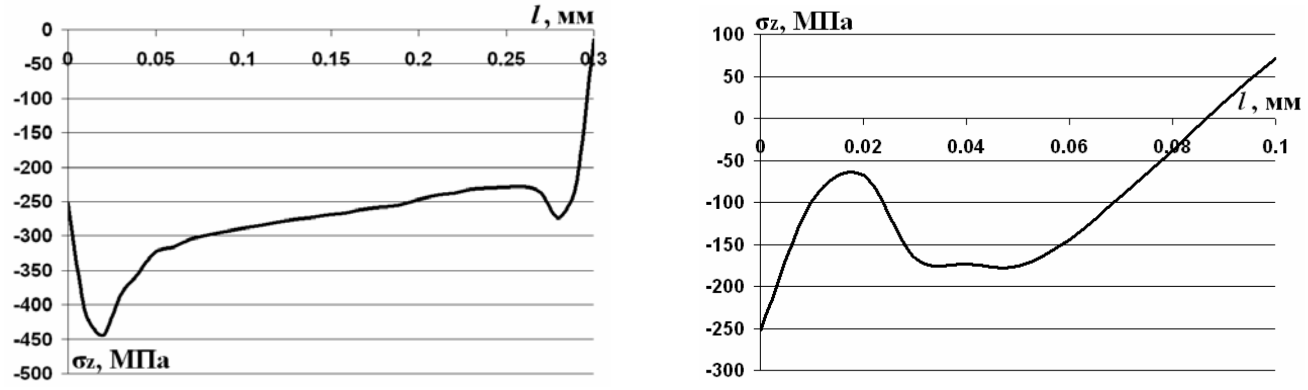
a *b*

Fig. 2. Stress distribution σx at the boundaries S1 (a) and S3 (b)



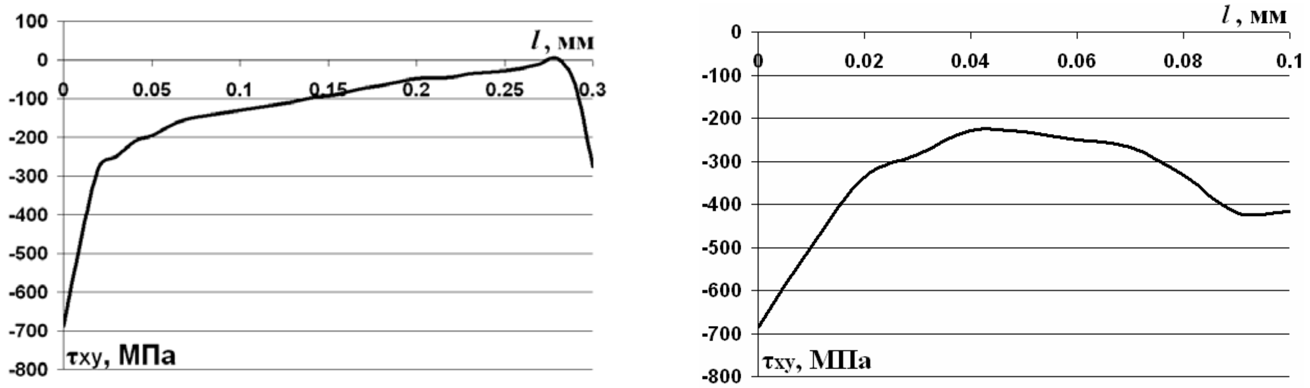
a *b*

Fig. 3. Stress distribution σy at the boundaries S1 (a) and S3 (b)



a *b*

Fig. 4. Stress distribution σz at the boundaries S1 (a) and S3 (b)



a *b*

Fig. 5. Stress distribution τxy at the boundaries S1 (a) and S3 (b)

The rotation of the inclusion occurs if the metal flow has a gradient of velocities of material particles in the cross section of the deformation cell, which is created by a stress gradient in the cross section in the macro volume of the deformation zone.

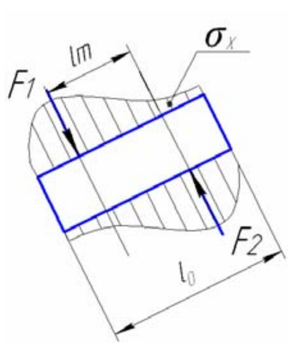


Fig. 6. To calculate the moment of forces acting on the dispersed inclusion in the medium of the moving matrix

The compressive mean stresses and the compressive components of the stress tensor also act on the boundary end surfaces S3 and S4. back pressure, as shown in Fig. 7. This indicates the resistance to deformation of the matrix metal on these boundary surfaces.

In real conditions at formation of eutectically strengthened titanium alloys at big plastic deformations there is a destruction (grinding) of eutectic - borides of titanium (TiB_n). Thus on the crushed inclusion (TiB_n) free surfaces appear [3]. In the process of hot plastic deformation, compressive stresses on the surface of dispersed inclusions contribute to the "healing" of the microcracks that have formed.

The increase of average compressive stresses is promoted by use of a back pressure of Fig. 8.

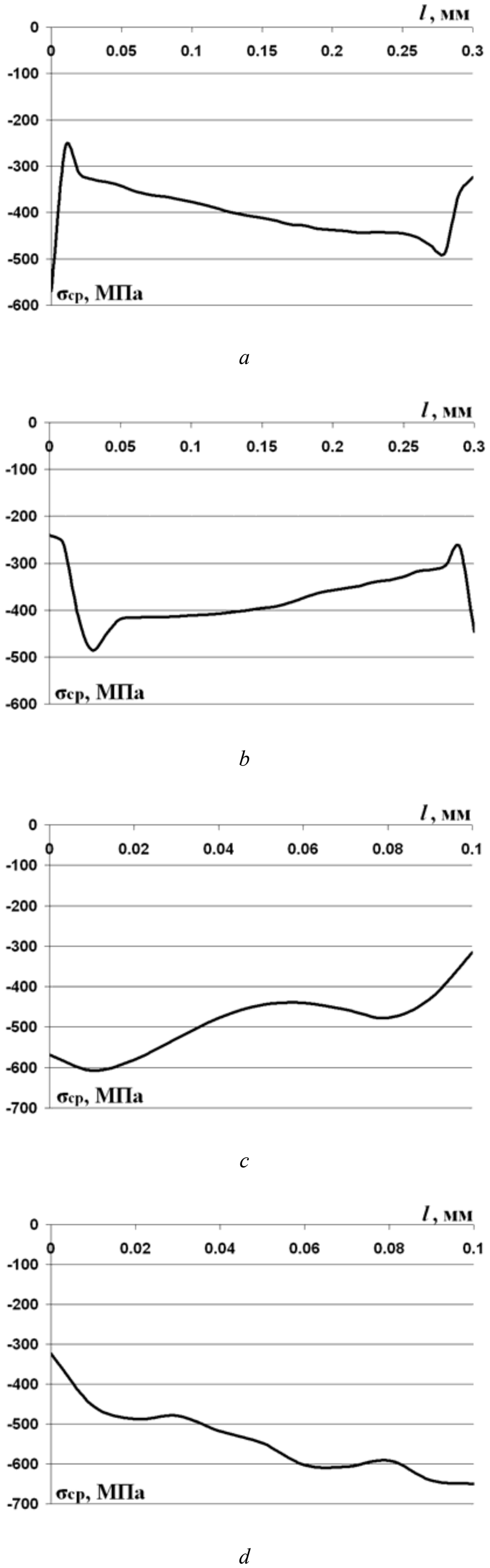
When creating a back pressure of 600 MPa, the value of the average stress on the surfaces S1 and S2 increases approximately 2 times and is equalized by the cross section of the inclusion.

The average pressure at the ends of the inclusion (surfaces S3 and S4) increases more intensely - 2.2-2.3 times.

Along with the average stress, the degree of compression increases and for individual components of the stress tensor on the surfaces of the inclusion in the process of deformation with back pressure. At the same time on surfaces of inclusion, practically, there are no zones of tensile stresses.

As a result of numerical modeling, the mechanism of reorientation in the direction of metal flow of solid reinforcing inclusions, which are characteristic of quasi-compositional eutectic reinforced materials, is substantiated.

Preliminary analysis of the stress state during the interaction of the matrix metal with the inclusion, shows that the use of back pressure improves the interaction conditions at the boundary surface of the inclusion and the matrix. the probability of development of microcracks decreases. Carrying out of process in the conditions of hot plastic deformation creates conditions for "healing" of already available microcracks.



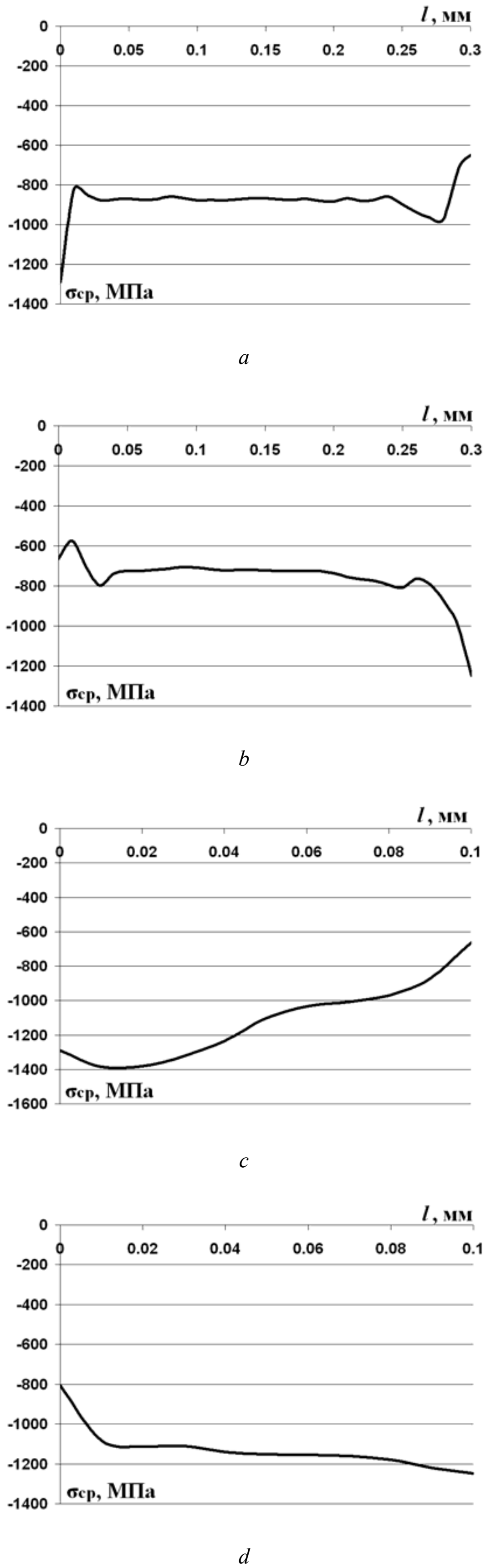
a

b

c

d

Fig. 7. Distribution of the value of the average stress in the matrix material on the surfaces: S1 - a), S2 - b), S3 - c), S4 - d)



a

b

c

d

Fig. 8. Distribution of the value of the average stress in the matrix material on the surfaces: S1 - a), S2 - b), S3 - c), S4 - d)

CONCLUSION

The conditions for the interaction of a dispersed inclusion with a metal matrix in the deformation zone during isothermal pressing are considered, the control of which makes it possible to ensure the continuity of the composite material for the full realization of its strength properties in products

The mechanism of turning the inclusion in the direction of the metal flow is substantiated depending on the velocity gradient of the material particles of the matrix, which is created by the stress gradient in the cross section. The results obtained are in good agreement with experimental data.

It is shown that on the boundary of the "inclusion - matrix" surface, average compressive stresses act, which prevent the destruction of the metal. The magnitude of the average stresses increases with the use of back pressure. Carrying out shaping under isothermal conditions contributes to the "healing" of microdefects that can form during crushing of the reinforcing components.

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