ROLE OF PACKING-DEFECT ENERGY IN THE LOCALIZATION OF PLASTIC STRAIN DURING SHOCK-WAVE LOADING OF COPPER-BASED SOLID SOLUTIONS

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The formation of deformation structure accompanying a change in the packing-defect energy (PDE) and the conditions of deformation of copper-based solid solutions under shock-wave loading were investigated by the method of optical microscopy. It is shown that in the case of solid solutions with high PDE plastic strain is localized. This localization increases with the amplitude and duration of the shock pulse, and this in turn gives rise to the generation and growth of microcracks.

Investigations of high strain-rate processes have established that such processes proceed inhomogeneously and are concentrated in narrow discrete zones (up to several tens of microns wide) located between regions of relatively uniform strain [1].

Such localized sections of intense shear strain are known as adiabatic shear bands. The localization of plastic strain during rapid deformation is caused by both the fact that the stress depends on the rate and degree of strain and by the significant increase of the temperature accompanying strain, which under conditions of limited removal of heat can result in thermal local disordering and, ultimately, failure [2-4].

It should be noted, however, that the disordering occurring under such loading must be regarded not only as resulting from the thermal effect, owing to adiabatic heating, but also as a consequence of dynamic recovery.

Local annihilation of screw dislocations, especially annihilation stimulated by external stress, makes the greatest contribution to the dynamic recovery of fcc metals [5]. Decreasing the resistance to motion of dislocations, it creates the prerequisites for localization of plastic strain. It is well known [6] that the appearance of dynamical shear strain in the glide plane is associated with the quantity $P\Delta t$, where $P$ is the amplitude of the shock pulse, whose effect consists of generating defects during the passage of the shock front, and $\Delta t$ — the duration of the shock pulse — is responsible for the motion, interaction, and redistribution of these defects.

In copper and copper-based solid solutions, deformed under high pressure, the formation of defect structure is limited primarily by the rate of generation of dislocations. Although in such materials this rate reaches $10^{18}$ cm$^{-2}$·sec$^{-1}$, this is insufficient for a high degree of ordering. However, for pulses with a duration of several microseconds relaxation processes are so intense that dynamic recovery can occur [7].

This indicates that the character of the structure formed under shock loading is determined largely by the duration of the shock pulse.

On the other hand, the microstructure formed in fcc metals and alloys depends, to a significant degree, on the PDE, since the capability for age-hardening is associated with this factor [6]. It is well known [8, 9] that materials with high PDE are characterized by a low exponent of age-hardening, in contrast to the exponent for a material with a lower PDE. Taking this into account, as well as the expression for the critical strain $\gamma_c$ for the onset of flow localization under loading by an explosion [10], where

$$\gamma_c = C_0 \pi \frac{\partial \sigma}{\partial T},$$

where $C_v$ is the specific heat capacity, $n$ is the exponent of the age-hardening, and $\frac{\partial \tau}{\partial T}$ is the slope of the temperature dependence of the shear stress, it can be expected that under conditions of dynamical loading an increase in the PDE will give rise to the appearance of localized shear bands.

On the basis of what was said above, we investigated the development of deformation structure and appearance of localization of plastic flow for different values of PDE of a material as a function of the applied pressure and the duration of the shock pulse.

Age-hardening alloys of the system CuAlCo with different percentage content of aluminum, which makes it possible to set the value of the PDE, varying it over a wide interval, and thereby to change deliberately and significantly the mechanism by which the alloy is deformed, were investigated. Samples of the alloys Cu-8 at. % Al-2 at. % Co and Cu-15 at. % Al-2 at. % Co in a state of supersaturated solid solution, prepared by quenching in water from temperatures of 900-950°C, were employed.

A high-velocity collision of samples in the form of a small cube with an edge length of 10 mm and a duraluminum barrier of different thickness, which made it possible to vary the duration of the shock pulse, were conducted on a projecting setup with velocities of