ON THE DIRECT RELATIONSHIP BETWEEN MACROSCOPIC PHENOMENA OF PLASTIC FLOW LOCALIZATION AND SOLIDS MICROCHARACTERISTICS[1]

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It is known that plastic flow tends to localize from yield point to ductile failure [1]. Interpretation of experimental data on flow macrolocalization is a complicated task that still remains to be solved. To date the phenomenology of the localization effect has been elucidated and the space-time regularities, which are characteristic for localization development, have been established. Localization might be regarded as a typical example of self-organization if the term “self-organization” is used in the meaning proposed by Haken, i.e. acquisition by a system of a spatial, a temporal or a functional structure in the absence of any specific action from without [2]. Plastic flow localization has all the characteristic features of autowave processes [1]. Thus at the stage of linear work hardening, the localization of plastic flow occurs in the form of phase autowaves having length $5 \le \lambda \le 15$ mm and propagation velocity $10^{-5} \le V_{aw} \le 10^{-4}$ m/s. A special technique of double-exposure speckle photography intended for visualization of localized plasticity patterns has been developed [1]. This enabled one to obtain a vast array of data on the above quantities for a range of materials.

The present paper contains an attempt to reveal relationships between the above waves and the microscopic characteristics of the deforming medium. The wavelength, λ, and the propagation velocity, V_{aw}, were measured at the linear work hardening stage for the tested specimens of Cu, Ni, Al, Sn, Fe, V and Zr. The speckle-interferometry technique developed specially for similar investigations was used.

On the base of experimental data a close correlation has been established between the product of auto-wave macroscopic parameters, $\lambda \cdot V_{aw}$, and that of material microscopic parameters, $d \cdot V_{\perp}$ (here d is the spacing between close-packed planes of the lattice and $V_{\perp}$ is the rate of transverse elastic waves).

In each instance, the following equality apparently holds good within an acceptable range of accuracy, i.e.,

$$\lambda \cdot V_{aw} \approx 1/2 d \cdot V_{\perp} \tag{1}$$

where, the terms have the units of the diffusion coefficient $L^2 \cdot T^{-1}$. To verify relation (1), we used borrowed values of d and $V_{\perp}$ [3, 4]. Relation (1) was averaged for linear work hardening stages as $\langle 2\lambda \cdot V_{aw} / d \cdot V_{\perp} \rangle \approx (1.04 \pm 0.14) \approx 1$. Eq. (1) relates the micro-scale characteristics d and $V_{\perp}$, which are observed for elastic waves propagating in crystals, to the macro-scale parameters λ and V_{aw}, which are observed for elastic waves propagating in crystals, to the macro-scale parameters λ and V_{aw}, which are obtained for localized plastic flow auto-waves generated in the same crystals. The products of these values, $d \cdot V_{\perp}$ and $\lambda \cdot V_{aw}$, are invariants for elastic and plastic deformation processes, respectively ($\varepsilon \ll 1$ and $\varepsilon \approx 1$, respectively). The above regularity stems from the fact that the processes of elastic and plastic deformation are closely related. In the course of deformation the redistribution of elastic stresses occurs via micro-scale processes at the rate $V_{\perp}$, while the rearrangement of localized plastic flow nuclei involves macro-scale processes occurring at the rate V_{aw}, with the processes of both types being related by Eq. (1). Thus, the macro-localization phenomena must be regarded as an attribute of plastic deformation rather than a random disturbance of plastic flow homogeneity.

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