NUMERICAL SIMULATION OF THE ENERGY STORAGE RATE IN METALS UNDER QUASISTATIC LOADING

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During the deformation process of metals the mechanical energy expended on the shape change of the specimen is converted into thermal energy generated by the defects motion and annihilation and the stored energy of a plastic deformation accumulated in the elastic defect fields.

The experimental and theoretical study of the energy balance during deformation has a long history. The importance of this problem was originally shown by J. H. Lambert in 1779 in his work concerning the energy similarity of mechanical and thermal failure processes of solids. A substantial contribution to this matter was made by V.S. Ivanova, who proposed the structure-energy theory of metal fracture. A detailed analysis of thermodynamic effects produced by cyclic deformation and failure in metals was carried out by V.T. Troshchenko and V.V. Fedorov. In 1937 Taylor and Quinney made a first attempt to measure experimentally the value of the stored energy. They assumed that the rate of plastic work converted into heating is a constant, but further development showed its dependence upon strain and strain rate.

The existing theories analyses of the energy balance description in the material during plastic deformation lets us to assume that a stored energy arises in the material due to the defects evolution on the different structural levels and its adequate description requires the constitutive equations of the structural defects evolution.

In this work the storage energy process is described with the use of the statistical model developed in the Institute of Continuous Media Mechanics UB RAS. The defects ensemble evolution in the material is modeled using the internal field variable representing a defect density and coinciding with the additional deformation due to the defects emergence and growth. The model takes into account the evolution of all tensor components, which describe the volume concentration and defect orientation and lets us to model the energy balance in the material under its plastic deformation.

Numerical simulation was carried out in the finite element package Simulia Abaqus 6.13. The above mentioned model for the determination of the stored energy rate was implemented in the package using the procedure UMAT. There were considered numerical experiments on the quasistatic tensile of the steel and Armco iron specimens. The obtaining results showed that the model allowed us to describe adequately not only stress-strain state of the material using standard finite element package as well as to calculate the values of the homogeneous stored energy and dissipated energy. A good agreement between simulated results and original experimental data was shown.