A NUMERICAL SOLUTION OF LONGITUDINAL WAVE PROPAGATION IN A MINIATURIZED SPECIMENS OF TANTALUM AT DIRECT IMPACT COMPRESSION TEST

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Abstract

The results of experimental and numerical investigations concerning an influence of strain rate on mechanical properties of pure tantalum are presented. Experiments were carried out using Direct Impact Compression Test (DICT) technique, [1]. The miniaturization concept of the experimental setup for the dimensions of specimen (diameter d_S = 1.5 mm and thickness l_S = 0.50 mm), Hopkinson transmitter bar diameter (d_H = 3.0 mm) and the striker (diameter d_I = 11.5 mm and the length l_I =12 mm), together with application of a novel optical arrangement for measurement of striker velocity, enabled compression tests to be executed at strain rates from 1.0 x10^3 s^{-1} to 0.5 x10^6 s^{-1}. The Perzyna elasto-viscoplasticity theory [2] is applied to predict the dynamic compression yield strength of the tested material at different strain rates. In the course of specimens deformation by means of the DICT technique, it was observed that the peak force obtained from the strain gauge mounted on the transmitter Hopkinson bar was lower than the peak force obtained within the framework of the uniaxial stress wave analysis. An explanation of this discrepancy is provided due to the analysis of the localization of deformation in the tested specimens considered as three-dimensional body subjected to high strain rate loading and the resulting stress wave attenuation as it propagates within the specimen.

The Perzyna constitutive relation, which accomplish in one formula the description of behaviour of the material for the entire range of strain rates is applied, cf [2]:

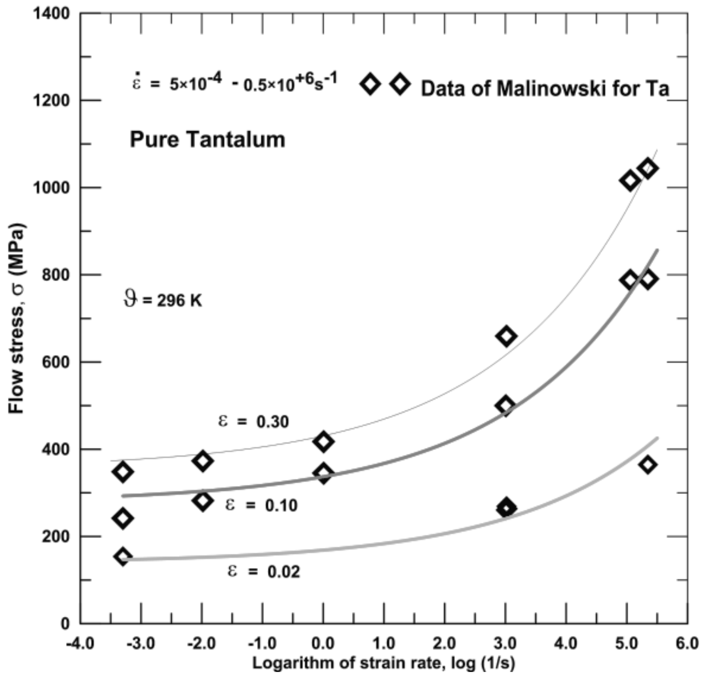
$$\dot{\bar{\varepsilon}}^p = \frac{1}{T_{rel}\left(\dot{\bar{\varepsilon}}^p\right)} \left\langle \Phi\left[\frac{\sigma_{eq}}{\sigma_y\left(\bar{\varepsilon}^p, T\right)} - 1 \right] \right\rangle, \tag{1}$$

where T_{rel} is the relaxation time for mechanical disturbances, $\langle \bullet \rangle$ denotes the Macauley bracket and $\sigma_y\left(\bar{\varepsilon}^p, T\right)$ is the static yield stress function. The static yield stress function depends on the plastic strain $\bar{\varepsilon}^p$ and on temperature T. The empirical overstress function Φ is determined basing on available experimental results.

The isotropic work-hardening-softening function $\sigma_y\left(\bar{\varepsilon}^p, T\right)$ is postulated:

$$\sigma_y\left(\bar{\varepsilon}^p, T\right) = \left(\mathrm{A} + \mathrm{B}\,(1 - \exp(-\mathrm{C}\varepsilon))\right)\left(1 - \Theta^{\mathrm{m}}\right). \qquad (2)$$

The overstress function Φ is assumed in the form of power law with the power parameter D. It is presumed that the strain rate is additively decomposed into the elastic part obeying the isotropic Hooke's law and the plastic part governed by the associated flow rule. The numerical model based on ABAQUS/Explicit programme contains three main parts: striker, specimen and transmitted bar. In computations the mesh of the specimen contains 1500 elements, 21000 elements for striker, 6800 elements for transmitted bar. All elements are of the type C3D8R (ABAQUS).



The figure above shows comparison of the Perzyna model (solid lines) with the experimental flow stress data (symbols ◊) of pure tantalum with respect to logarithmic strain rate at 296 K and varying strains ε = 0.02, 0.1 and 0.3. The hardening law Eq. (2) is specified for: A = 29.8 MPa, B = 314.8 MPa, C = 6.90, D = 0.0124, m = 0.25. There is an increase in dynamic yield strength of tantalum at high strain rate loading comparing with that one corresponding to the quasi-static test. In the range of the strain rates considered, the strength magnification factor is up to 3.0 for pure tantalum. A good correlation between the experimental data and the Perzyna overstress model predictions for strain rates up to $0.5x10^6$ 1/s can by clearly observed.

References

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