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INFLUENCE OF THE TYPE OF STRESS–STRAIN STATE ON THE TRUE STRESS–STRAIN CURVE FOR THE ELASTOPLASTIC MATERIALS

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Abstract. We present a description of the current status of research on deformation properties of elastoplastic materials under quasi-static loading. Based both on experimental and theoretical approach and on the developed method, true stress-strain curves were produced in the case of stretching of a cylindrical shell and a solid rod until fracture. The difference between produced curves for these types of specimen is shown for the first time for heterogeneous and non-uniaxial stress-strain state after beginning of the localization process of deformation. We show that the difference between the curves is inversely proportional to the volume rate of stress-strain state at the neck of a specimen.

1. Introduction

Plasticity theories based on the hypothesis of single curve are being used for simulation of deformation and fracture of structural elements. In the framework of the hypothesis, material properties are formulated as a scalar dependence of stress intensity on the deformation intensity (the Odqvist parameter). It is assumed that the curve does not depend on the type of stress-strain state. Apparently, the hypothesis of single curve was first proposed by P. Ludwik [1]. The hypothesis has been checked in papers of many famous experimenters, but only for deformations smaller than 10-20 %. There are some research results [2-4] illustrating the influence of the type of stress–strain state on the stress–strain curve, but experiments show that the hypothesis is violated for initially anisotropic material only.

The true stress–strain curves of materials defined up to fracture are required for the study of large deformations and limit states of structural elements. It is stated in [5] that the problem of getting the elastoplastic stress-strain curve up to fracture has not been resolved yet. The main issue lies in the explanation and description of the drop-down part of the curve, which corresponds to so-called phase of unstable (supercritical) deformation [6, 7]. Obtaining these data using available tools and direct measurement is rather difficult because heterogeneous and non-uniaxial stress-strain state arising in laboratory specimens as well as the influence of stress concentrators, boundary effects etc. Traditionally, the deformation and strength properties of the material are identified based on experimental and analytical approaches using experimental data and simplifying hypotheses, which impose restriction on the specimen's shape and the type of loading. These methods allow obtaining the characteristics of elastoplastic materials using a homogeneous uniaxial stress-strain state only, which is not observed in real experimental conditions for large deformations. So, at the moment there are no effective methods of obtaining the strength and limit properties of materials for large deformations and heterogeneous stress-strain state with acceptable

- The true stress-strain curves match up to beginning of deformation localization;
- The value of strain intensity on true stress-strain curve for beginning of deformation localization for shell (47 %) is higher than value for solid rod (37 %). Results of the analysis of physical and computational experiments show that this occurs because of the initial hardening and deformation anisotropy resulted from manufacture of the shell is greater that the rod;
- After the beginning of localization the true stress-strain curves differ significantly and the hardening increment for the shell almost corresponds to the value before stability loss; hardening of the solid rod decreases and the stress-strain curve tends to perfect plasticity (see Fig. 1);
- The variation of spherical component of stress tensor after stability loss depends on the type of specimen. Increment of spherical component for a solid rod is significantly greater than that for a shell (see Fig. 2);

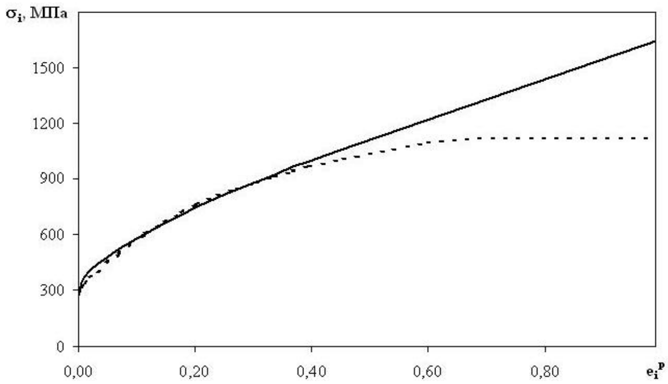

Fig. 1. Dependency of stress intensity σ_i from plastic strain intensity e_i^p for 12X18H10T steel defined up to fracture under tension of shell (solid line) and solid rod (dot line).

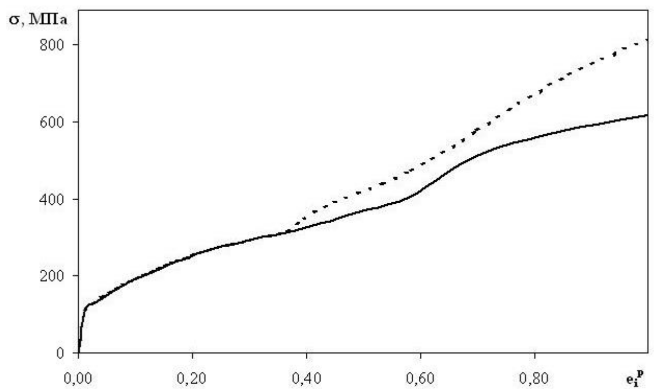

Fig. 2. Relation between spherical component of stress tensor σ and plastic strain intensity e_i^p in the middle of neck of shell (solid line) and solid rod (dot line) for steel 12X18H10T.

We can conclude that the true stress-strain curves constructed for a cylindrical shell and a solid rod with heterogeneous and non-uniaxial stress-strain state after the beginning of localization are different. The deviation between curves is inversely proportional to the volume rate of the stress-strain state in the middle of the neck.

4. Conclusion

It is necessary to use methods based on experimental and computational approach to investigate the deformation and strength properties of elastoplastic materials. This approach allows providing complex analysis of the material properties and studying the behavior of deformation and fracture processes taking into account all required factors. In particular, the method developed previously allows determination of the influence of the type of stress-strain state on the form of true stress-strain curve up to the fracture for a cylindrical shell and a solid rod made from 12X18H10T steel. These results should be considered in the further analysis of experimental and analytical data. Investigations in this area need to be developed and improved as they form the basis for the simulation of deformation and fracture processes of materials.

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