Equation (24) is similar to the approximate equation derived in [5] for \( f \) in the Euler problem. These calculations by expressions (23) and (24) are shown in Figs. 2 and 3 by broken lines.

LITERATURE CITED


CRITERION OF GEOMETRIC INSTABILITY FOR THE PROCESS OF TENSILE DEFORMATION OF THIN SPECIMENS

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Deformation of a long thin rod of uniform cross section is investigated. The problem of geometric loss of strength is considered more rigorously: a deformation equation is derived which describes tension at a constant rate for long and thin specimens in which a possible dependence of cross section on time and coordinates along the specimen axis is taken into account. An instability criterion is established for solving this problem in relation to local variation of the cross section. This criterion of geometric instability is compared with experimental data obtained in studying low-temperature spasmodic deformation.

With active deformation (tension or compression) of a metal specimen the process of plastic flow very often acquires an unstable character, i.e. more or less regular alternation of falls and rises in deforming load providing a constant strain rate is observed. This phenomenon, which has received the name 'spasmodic deformation,' at room and elevated temperatures is mainly for alloys (the Portevin-Le Chatelier effect) and it is explained by the specific nature of dislocation-diffusion processes in them [1]. However, in the low temperature region the tendency towards spasmodic deformation develops not only in alloys but also in many single-crystal and polycrystalline metals, and therefore spasmodic deformation is assumed to be one of the most important features of low-temperature ductility [1-13].

The tendency of specimens towards spasmodic deformation and its nature may be controlled by changing their shape, surface dimensions and condition, and also experimental conditions (strain rate, stiffness of the deforming machine, temperature and heat removal conditions), the internal condition (variation of the defect structure or transfer of metal specimens from a normal to superconducting condition), and a number of other factors.

The variety of forms of this effect and conditions for observing it do not provide a basis for relating spasmodic deformation to the action of a single physical mechanism. Currently several mechanisms of this phenomenon are known and actively discussed: periodic formation and outbreaks of dislocation accumulations; deterioration of volumetric and surface dislocation sources which exhibit a spectrum of starting stresses; occurrence of nonlinear dislocation density waves in quite dense dislocation assemblies; heating of the whole specimen or individual parts of it and disruption of thermal stability for the deformation process; geometric weakening connected with increasing reduction of the specimen cross section over its whole length or in individual areas.

Theoretical description of spasmodic deformation infers solution of two main problems. The first is derivation of criterion for loss of stability, a specific inequality connecting

Fig. 1. Development of geometric instability with low-temperature deformation for titanium alloy VT1-0 with different profiles for specimen cross section.

specimen characteristics, and experimental conditions with fulfillment of which the deformation process deviates markedly from a stable regime. The second problem is more complicated, i.e., establishing mechanisms which stabilize deformation after loss of stability and describe the time evolution of the process within the limits of an individual cycle (a jump). It is noted that currently the most developed hypothesis is that of thermal instability for which in a number of cases both these problems have been formulated and resolved [3-5, 9]. Analysis of the rest of the instability mechanisms listed above has been mainly limited to formulation of some qualitative considerations of the loss of stability criterion and as a rule mathematical formulation of it was either generally absent or it related to a very simple model of the process.

Among all of the possible factors which cause occurrence of deformation instability in our opinion a very important role is played by the geometric weakening mentioned above [10]. It has been detected by experiment that very often deformation of round specimens is accompanied by necking (Fig. 1a), for flat specimens by a shear band (Fig. 1b) and faults, and for cylindrical specimens by spiral shear bands (Fig. 1c). The number of these local specimen reductions of specimen cross sectional area correlate with the number of jumps in deforming load in the deformation diagram, and the depth of individual jumps in load \( \Delta P \sim P \frac{\Delta S}{S_0} \), where \( P \) is load, \( S_0 \) is initial specimen cross section, \( \Delta S \) is local change in cross section. It is apparent that even with a stable nature for the plastic deformation process within the volume of a specimen the reason for instability may be unsteadiness in relation to a change in its cross section.

On the basis of simple phenomenological considerations an adequate condition has been formulated [14] for geometric weakening: observation in some specimen cross section of the inequality

\[ \sigma > \frac{d\varepsilon}{d\varepsilon}, \]

where \( \varepsilon \) and \( \sigma \) are average values of strain and deforming stress through the cross section.

In the present work the problem of geometric weakening is considered more rigorously: a deformation equation is obtained describing tension at a constant rate for long and thin