Energy estimates of the onset of instability in tension test for orthotropic materials(*)

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THE ENERGY criterion of instability of quasi-static plastic deformation processes, proposed recently by the author, is used to derive estimates of the onset of instability in tension of orthotropic materials. A homogeneous, three-dimensional, prismatic specimen of arbitrary cross-section subject to uniaxial tension is considered. Shear-free end conditions are assumed, and flexibility of the testing device is modelled by a spring carrying the axial load. The material is taken to be time-independent and orthotropic but is otherwise arbitrary, with the restriction that the generally nonlinear constitutive rate equations admit a potential. For instance, the material may be elastic-plastic obeying the normality flow rule, with or without the yield vertex effect.

Roughly speaking, it is postulated that a quasi-static deformation process becomes unstable if there exists another kinematically admissible deformation mode which requires less energy to be supplied in a vanishingly small time interval to the system consisting of the deformed body and the loading device. This general criterion is specified for the tension problem considered.

It is demonstrated that several different forms of instability in tension test are posible, and that their appearance can be estimated in a consistent way by using the single energy criterion.

A simple criterion is obtained for the dynamic type instability when the control of the process is lost; it reduces to the classical maximum load criterion for "soft" loading devices. The criterion for the necking type instability involves the specimen geometry, while, most of the material parameters have been eliminated by using the assumption of orthotropy. A closed-form formula is obtained which provides an upper bound to the true stress at the onset of necking. The formula is valid for arbitrary cross-sections and for a wide class of orthotropic materials, and coincides with the Considere criterion for infinitely slender specimens. Comparison with previous bifurcation analyses done for simple cross-sections and particular materials shows a good agreement of results when the specimen is not too short.

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Finally, the energy criteria for certain other forms of instability are discussed, in particular, for the shear band formation. These criteria are generally very sensitive to details of the constitutive description.

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