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Criteria of yielding for ductile materials under static loading

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CRITERIA OF YIELDING FOR DUCTILE MATERIALS UNDER STATIC LOADING

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CRITERIA OF YIELDING FOR DUCTILE MATERIALS UNDER STATIC LOADING

1. NOTATION

f_e	equivalent uniaxial tensile stress	N/m^2	lbf/in^2
f_y	uniaxial tensile yield stress	N/m^2	lbf/in^2
f_1, f_2, f_3	principal stresses $(f_1 > f_2 > f_3)$	N/m^2	lbf/in^2
Convention:	Tensile stresses positive. Compressive stresses negative.		

Both SI and British units are quoted but any coherent system of units may be used.

2. NOTES

The strength of a homogeneous isotropic material is generally obtained from simple uniaxial tensile tests. In such tests a noticeable departure from the linear stress-strain relationship often occurs well before the tensile strength is reached. The stress at which this non-linearity reaches a prescribed value is termed the yield stress*. This stress is often used as a design criterion for components that have to maintain their form. However, the stresses to which engineering components are subjected are usually more complex than simple tension. It is therefore necessary to predict the point of yielding under multiaxial stresses from a knowledge of the material yield stress provided by the simple uniaxial tensile test. This is done by expressing any combination of the principal stresses acting at a point as an equivalent uniaxial tensile stress, f_e. Yielding occurs when this value of f_e reaches the uniaxial yield stress. Thus, f_e may be termed the yield criterion.

3. DUCTILE MATERIAL CRITERIA

Since yielding is in essence a shear phenomenon, it is appropriate that the criteria should be based on either the shear stresses or shear strains present in the material. Of the various yield criteria developed only two, termed the maximum shear stress criterion and the shear strain energy criterion, follow this principle and correspond closely to the material behaviour. Table 3.1 provides a synposis of these two criteria for systems of both two- and three-dimensional principal stresses. The merits of these criteria are discussed in the following section.

For two-dimensional stress systems Figure 1 provides the yield boundary represented by the two criteria in terms of the ratios of the principal stresses to the uniaxial yield stress, f_y. Provided that a point defined by these ratios lies within the bounds of a yield criterion curve, the material is below the state of yield according to that criterion. Also shown are the regions in which experimental results typically fall.

3.1 Maximum Shear Stress Criterion (Tresca)

The criterion, formulated by Tresca and Guest, states that yielding occurs when the maximum shear stress reaches the same value as in the case of uniaxial tension at yield, that is, half the tensile yield stress. Thiscriterion is widely used since f_e, which is simply given by the largest difference between the principal stresses, is usually conservative with respect to experimental results.

* The general behaviour of a material as it approaches and passes this stress is discussed in Section 4.

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