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PLASTICITY OF DAMAGED SOLIDS AND SHEAR BAND LOCALIZATION

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The main objective of the paper is the investigation of shear band localization conditions for finite elastic-plastic rate independent deformations of damaged solids.

A combination of isotropic work-hardening and kinematic hardening effects of a porous solid is considered.

The first part of the paper is devoted to the formulation of the constitutive relations for elastic-plastic solids when isotropic and kinematic hardening effects and micro-damage process are taken into considerations.

The yield criterion is assumed to depend on the first J_1 and the second J_2 invariants of the deviator of the stress difference between the loading point and the center of the yield surface as well as on the porosity parameter ξ .

The isotropic work-hardening effect is incorporated in the theory directly by defining the work-hardening-softening material function.

The kinematic work-hardening effect is generated by finite plastic deformations whereas the micro-damage process is described as a sequence of nucleation, growth and coalescence of microvoids. Both effects are described by means of internal state variable method. To describe the kinematic hardening effect the tensorial internal state variable, interpreted as the residual stress tensor, is introduced. To determine the micro-damage process the scalar internal state variable, interpreted as the porosity parameter is chosen.

The finite deformation, rate independent plasticity theory for damaged solids with the framework of the rate type material structure with internal state variables is developed.

As a result of the postulates introduced the normality does not apply.

The localization of plastic deformations into a shear band is discussed as an instability of plastic flow process. Different effects on localization phenomenon are investigated. Particular attention is focused on kinematic hardening and micro-damage effects.

The critical hardening modulus $H_{cr.}$, when the shear band localization takes place, is given in the form

$$\frac{H_{cr.}}{G} = (1-QP) \left[\frac{(1+\nu)(A-B)^2}{3(1-\nu)} - \frac{1+\nu}{2} (T+A+B)^2 \right] \quad (1)$$

where

$$T = \frac{\tau'_{II}}{\sqrt{J_2}}, \quad \tau'_{II} \text{ is the mean value of principal stresses,}$$

$$A = n_1 + \xi n_2,$$

$$B = A + \left[n_2 J_1 + \frac{\kappa_0}{\xi^F} (1 + h_0 \epsilon^P) \right] \frac{l(J)}{(1-QP)},$$

$$P = \sqrt{J_2} + \{ A + [n_2 J_1 + \frac{\kappa_0}{\xi^F} (1 + h_0 \epsilon^P)] l(J_1) \} J_1,$$

ξ denotes the porosity parameter, $l(J_1)$ is the nucleation material function, $n_1, n_2, \kappa_0, \xi^F, h_0$ are the material constants. The function Q appears in the evolution equation for the kinematic hardening internal variable α and can depend on the current state of stress.

The solution of eq.(1) may be represented by the family of parabolas as is shown in the figure.

References

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