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PHYSICAL NATURE OF SHEAR BANDS FORMATION AND CONSTITUTIVE MODELLING
FOR PLASTIC INSTABILITY

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Studies of plastic deformation instability phenomena over the last decade reveal that the classical Prandtl-Reuss isotropic hardening model based on the Huber-Mises yield condition (i.e. J_2 flow theory) and the isotropic hardening models introducing the effect of porosity (e.g. the Gurson model) give an overly stiff response and predict unrealistically high strain or void volume fraction at which localization first occurs. This can be relaxed by introducing effects of path dependent material strain hardening. The kinematic hardening law, which may be used to approximately model a material that develops a rounded vertex on the yield surface, can introduce such a path dependence (cf. HUTCHINSON and TVERGAARD (1981)).

On the other hand, it has been recognized in the metallurgical literature that shear bands result from the changes in deformation path, which play primary role in the case when the effects of thermal softening and ensuing microfractures are negligible. This changes can occur as a result of the rotation of crystalline microvolumes. This sort of path dependent hardening property can be pivotal in the modelling for plastic deformation instability. The thorough study of this questions indicates the necessity of such a constitutive modelling which:

- (i) corresponds to the key physical mechanisms responsible for plastic flow in crystalline media preceding the onset of deformation instability
- (ii) takes into consideration the path dependent material hardening and the structure of anisotropic continuum.

One of the typical microscopic mechanisms responsible for the accommodation of large plastic strains is fragmentation of crystalline structure and development of fragmented subboundaries and microbands which produce large relative rotations of material microvolumes. According to the recent investigations (cf. KORBEL and MARTIN (1986)) localization begins by a structural instability in the accumulated dislocation substructure and later becomes organized into macroscopic bands. The macroscopic shear bands have precursors in microbands representing an avalanche glide in a crystallographic slip system which can be considered in terms of a very fast, highly athermal glide of groups of coplanar dislocations, producing very

high lattice rotations. The formation of the macroscopic shear bands result from propagation of microbands throughout several grains. The shear bands are noncrystallographic in nature and may result from a change in deformation path. The developed shear bands are observed as clusters of microbands and elongated subgrains with high misorientation of crystal lattice which changes randomly across the band.

It can be concluded that these phenomena lead to rotational modes of deformation and internal rotational instabilities. They disturb the deformation path and plastic spin on the macrolevel. This is associated with the development of macroscopic shear bands.

The aim of the paper is to present the model for large plastic strains and the development of deformation instability in polycrystalline solids. The effect of internal rotational instability is incorporated here with use of the concepts of Mandel's director vectors, perturbed plastic spin and an internal variable representing the scalar density of local intrinsic disturbances (cf. PEÇHERSKI (1986)). The simplified model of the material with combined isotropic-kinematic hardening and perturbed plastic spin is formulated and an example of macroscopic shear band formation is discussed. The possible applications of the theory derived are discussed.

REFERENCES

1. HUTCHINSON, J.W. and TVERGAARD, V. 1981, *Int. J. Solids and Structures*, **17**, 451-470.
2. KORBEL, A. and MARTIN, P. 1986, *Acta Metall.*, **10**, 1905 - 1911.
3. PEÇHERSKI, R.B. 1986, *Proc. of the 2nd International Conference on Numerical Methods in Industrial Forming Processes - NUMIFORM'86*, Gothenburg, 25-29 August 1986, K. Mattiasson, A. Samuelsson, R.D. Wood and O.C. Zienkiewicz (eds.), 145-150, Balkema, Rotterdam-Boston.