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A new look at viscoplasticity generated by shear banding

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Abstract

The recent studies reveal that two types of shear banding generating the inelastic deformation in materials can be observed.

- *The instantaneous formation of the multiscale shear banding systems* from micro-shear bands of the thickness of the order of 0.1 μm through mesoscale clusters of micro-shear bands producing the discontinuity of microscopic velocity field v_m to the macroscopic zone of shear strain localization spreading through the representative volume element (RVE) of a traditional commonly used polycrystalline metallic solid. Such a case is discussed in detail in Pęcherski [1997], [1998], where a new concept of the RVE with strong singularity was introduced and the instantaneous shear banding contribution function was defined.
- *The cumulative type of shear banding* based on the accumulation of the particular contribution of micro-shear bands forming clusters in certain parts of RVE (in certain volumes contained in RVE). The micro-shear bands are contributing in such a case gradually in the development and growth of micro-shear bands clusters and finally the clusters accumulate in the macroscopic localization zone spreading across the macroscopic volume of considered material. Such deformation mechanism is observed in inelastic deformation of gum metals, where the giant faults play the role of elementary micro-shear bands. Also in amorphous solids as glassy metals or polymers the role of micro-shear bands play the local shear transformation zones (STZ). The concept of cumulative shear banding contribution function is introduced in the phenomenological viscoplasticity model, cf. Nowak et al. [2007].

Often the both types of the abovementioned shear banding mechanism appear with variable contribution during the deformation processes. General structure of viscoplastic flow law produced by instantaneous and volumetric shear banding is as follows:

$$\dot{\gamma}(1-f_{SB})=\dot{\gamma}_S, \quad 0\le f_{SB}<1, \;\; f_{SB}=\frac{\dot{\gamma}_{SB}}{\dot{\gamma}}, \; f_{SB}^V=\frac{V_{SB}}{V}$$

$$\dot{\gamma}_s=\dot{\gamma}_o\langle\Phi\left(\frac{F(\sigma)}{k}-1\right)\rangle \quad \text{Perzyna model}$$

$$\dot{\gamma}=\frac{\dot{\gamma}_0}{(1-f_{SB})}\langle\Phi\left(\frac{F(\sigma)}{k_s(1-f_{SB})(1-f_{SB}^V)}-1\right)\rangle$$

$$k_s=K\left(\in^p,\dot{\in}^p,\vartheta\right), \;\; \in^p=\int_0^t\left(\frac{2}{3}D^p:D^p\right)^{\frac{1}{2}}dt,$$

$$F(\sigma)=\sigma_e,\sigma_e=\sqrt{\frac{3}{2}S_{ij}S_{ij}}$$

The shear banding contribution function, c.f. Fig.1.

$$f_{SB}=\frac{f_{SB}^{\infty}}{1+\exp(a-b\bar{\varepsilon}^p)}$$

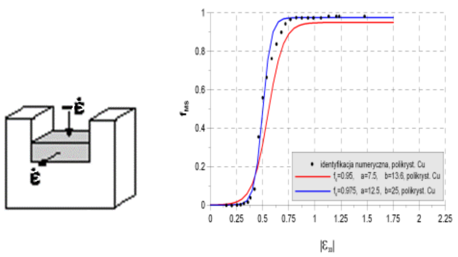

Fig. 1.The identified shear banding contribution function with use of the channel-die test.

Such a situation can appear in polycrystalline metallic solids which are subjected to the deformation with a distinct change of deformation or loading paths. Also materials revealing the hybrid structure characterising with amorphous, *ufg* and nanostructural phases are prone to the mixed type of shear banding responsible for inelastic deformation. Some recent results are discussed and confronted with earlier approach related with *the instantaneous shear banding contribution function.*

References

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