STRAIN LOCALIZATION ANALYSIS USING A LARGE STRAIN SELF-CONSISTENT APPROACH

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Abstract

The development of a relevant constitutive model adapted to sheet metal forming simulations requires an accurate description of the most important sources of anisotropy, i.e. the slip processes, the intragranular substructure changes and the texture development.

During plastic deformation of thin metallic sheets, strain-path changes often occur in the material resulting in macroscopic effects. These softening/hardening effects must be correctly predicted because they can significantly influence the strain distribution and may lead to flow localization, shear bands and even material failure. The main origin of these effects is related to the intragranular microstructure evolution. This implies that an accurate description of the dislocation patterning during monotonic or complex strain-paths is needed to lead to a reliable constitutive model.

First, the behaviour at the mesoscopic scale (which is the one of the grain or the single crystal) is modelled by a micromechanical law written within large strain framework [1]. Hardening is taking into account by a matrix whose internal variables are the mean dislocation densities on each slip system. This crystal plasticity based model is implemented into a large strain self-consistent scheme, leading to the multiscale model which achieves, for each grain, the calculation of plastic slip activity, with help of regularized formulation drawn form viscoplasticity [2].

An improvement of this model is suggested with the introduction of intragranular microstructure description. The substructure of a grain is described taking into account the experimental observations as stress-strain curves and TEM micrographs. Following Peeters' approach [3], three local dislocations densities, introduced as internal variables in the multiscale model, allow representing the spatially heterogeneous distributions of dislocations inside the grain (Figure 1). Rate equations, based on the consideration of associated creation, storage and annihilation, are used to describe the dislocation cells evolution. The coupling of the substructure to the critical shear stresses is performed thanks to the concepts of isotropic hardening, latent hardening and polarity.
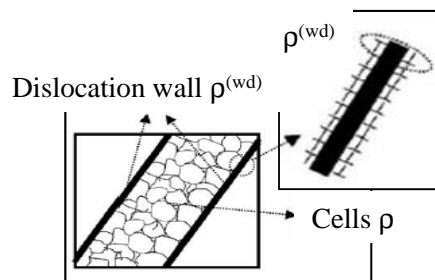
FIGURE 1. Schematic representation of the intragranular microstructure [3].

Moreover, a ductility loss criterion, first introduced by Rice [4], based on the ellipticity loss of the elastic-plastic tangent modulus, is used in these two models to plot Ellipticity Loss Diagrams (ELD). Qualitative comparisons are made with experimental Forming Limit Diagrams (FLD) for ferritic steel involving simple and complex loading paths. In particular, it is shown that numerical ELD have a shape close to experimental FLD and reproduce qualitatively the effects due to complex loading paths. Figure 2 gives an example of ELD plotted with the first model, without taking account of intragranular microstructure.

The impact of intragranular microstructure on strain localization is studied thanks to comparisons between ELD plotted with the two models.
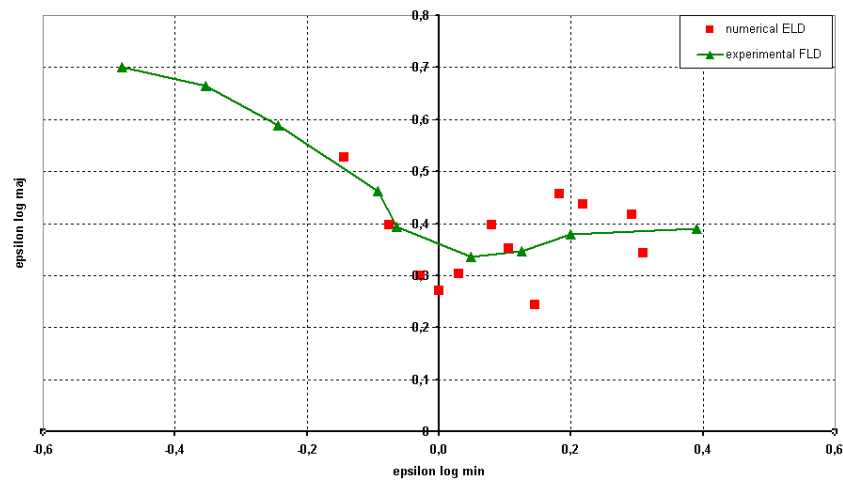

FIGURE 2. Comparison between direct, experimental FLD and numerical ELD for a ferritic steel.

Reference

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