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Strain path sensitivity in DC06 mild steel

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Introduction

Deepdrawing processes comprise complex material flow patterns leading to strain paths of complex shape, see Figure 1. DC06 mild steel shows strain path sensitivity, however classical material models do not account for these effects.

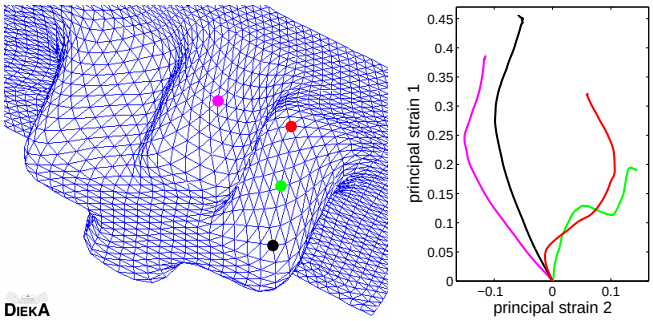

Figure 1: Simulation of a cross shaped can (left) and some strain paths of corresponding characteristic points (right).

Objective

Incorporate strain path effects in material models.

Material model

The dislocation structure that evolves during plastic deformation is responsible for the hardening behaviour of the material. A cellular structure develops, see Figure 2, and with increasing strain densed dislocation sheets, consisting of immobilised dislocations, develop. Their stiffness depends strongly on the deformation direction. Upon an orthogonal strain path change microbands are developed that penetrate the densed dislocation sheets. This requires high stresses, but once formed, microbands are easily deformed and stresses drop.

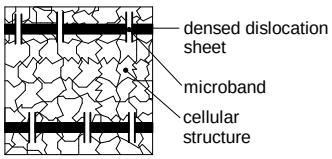

Figure 2: Schematic representation of the dislocation structure.

In the Teodosiu and Hu model [1] this is modelled in a combined isotropic/kinematic hardening model for elasto-plastic material behaviour. A fully implicit Return Mapping Algorithm (RMA) is developed that uses Voce-type evolutions to model the microstructural developments.

Experiments

To examine the mechanical response of the material a biaxial test facility is used. Samples are subjected to orthogonal tests, where the material is stretched with a plane strain condition followed by simple shear deformation. Four tests have been performed where the transition from stretching to shear deformation is varied from suddenly to fluently.

Results

In Figure 3 the results of the strain path changes are depicted. It is shown that a sudden strain path change (black lines) gives an overshoot in shear stress. The stress observed in the test with a gradual strain path change (blue lines) slowly converges to the monotonous simple shear test.

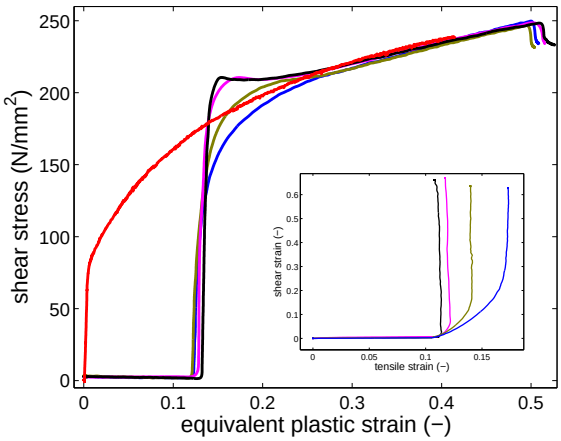

Figure 3: Results of the orthogonal tests. The inset shows the strain paths, respectively.

Future work

The material model has to be implemented and material parameters have to be determined to be used in industrial applications.

References

[1] H. Haddadi et al , International Journal of Plasticity (2006) Vol. 22, 2226–2271.

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