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A COMPOSITE CELL MODEL FOR BCC STRUCTURED METALS UNDER STRAIN PATH CHANGES

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ABSTRACT

During sheet metal forming processes, materials experience differently oriented strain paths resulting in transient hardening and softening effects due to the induced plastic anisotropy. The anisotropy in BCC metals originates from various sources active at different length scales. Slip asymmetry and intrinsic anisotropic effects caused by screw dislocation cores are the ones at the micro level, the development of dislocation sub-structures is relevant at meso level, and finally the texture development at the polycrystalline macro level plays a role. The observed anisotropy after a strain path change results from a combination of all these effects. It remains unclear which effect dominates the anisotropy observed during the change of the loading path for BCC metals. Recent works showed that the influence of the dislocation sub-structuring prevails at moderate strains for BCC crystals.

Plastic deformation starts with the movement of dislocations, and further deformation causes these dislocations to cluster and form regions of high dislocation density, enveloping regions with a low dislocation density. The structures accordingly obtained are called dislocation cells and a number of cells are surrounded by another structure, called dislocation block boundaries, to be recognized by polarized dislocations on each side. A change in the loading direction and consequently in the strain path leads to an altered evolution of these dislocation block structures resulting in a plastic anisotropy effect.

In the case of stress reversal dislocations glide in an opposite direction in their already active slip systems causing dissolution of dislocation cells. This results in a decrease of the yield stress of the material, which is commonly called the Bauschinger effect. When a cross test (tension and a subsequent shear) is applied, new slip systems are activated and dislocations are hindered by the dislocation block boundaries. The result is a transient increase of the yield stress and meanwhile the size of the dislocation cells increases.

Firstly, a crystal plasticity model [1] for BCC single crystals, taking into account the plastic anisotropy due to the non-planar spreading of screw dislocation cores and twining anti-twining asymmetry is implemented and the material parameters are identified by comparing the results for different orientations during monotonic loading. Then the morphology of the cell structure is incorporated in a composite

model [2] and embedded into the crystal plasticity framework. Dislocation activity and the microstructure evolution are included in the model by means of evolution equations formulated in terms of dislocation densities (of walls and cell interiors), the cell size and wall thickness respectively. Macroscopic effects of strain path changes are simulated and the evolution of the microstructure is compared with experiments.

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