Strain Path Sensitivity of Mild Steel in Experiment and Model

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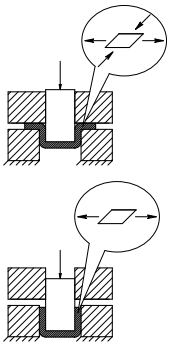
Material models

In finite element simulations the mechanical behaviour of a material is captured in a material model that is parameterized by some elementary uniaxial experiments. However, a deep drawing process (figure) shows that the deformation mode is not uniaxial and changes during the process. Sheet metal forming processes are strongly sensitive to the accuracy of the material models and therefor more complex tests and more extensive models are required.



Goal

The aim of this project is to investigate the mechanical behaviour of sheet metal under different strain paths and develop models that describe the observed phenomena.

Experimental observations

During plastic deformation of the material the dislocation structure changes (Figure 2) and causes hardening. After some deformation the dislocation structure is oriented according the deformation direction

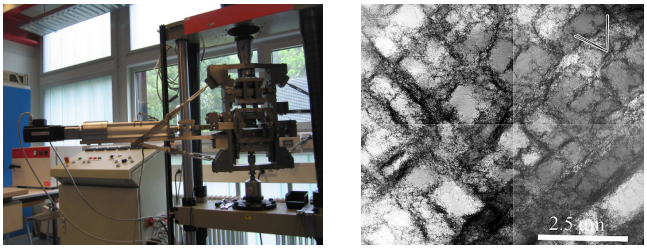


Figure 2: Left: Biaxial tester. Right: Dislocation structure (McCabe, Act.Mat. 52(705-714), 2004).

and acts as a barrier for deformations in other directions. Experiments with a biaxial tester have shown that a strain path change requires large stresses, hereby reorienting the dislocation structure with respect to the new deformation direction.

Modelling the mechanical behaviour

The Teodosiu and Hu model is used to describe the mechanical behaviour of the material. The model is physically based and calculates the stresses using the strength of the dislocation structure ($\mathbf{S}$):

$$\mathbf{S} \quad = \quad S_d \, \mathbf{N} \otimes \mathbf{N} \, + \, \mathbf{S}_L$$

Dependent on the direction of deformation ($\mathbf{N}$) a directional part (S_d) and a latent part ($\mathbf{S}_L$) contribute to the strength of the dislocation structure.

Results

Results of the experiments and the model are displayed in Figure 3. The characteristic overshoot in stress (σ_{xy}) can be qualitatively predicted with this model.

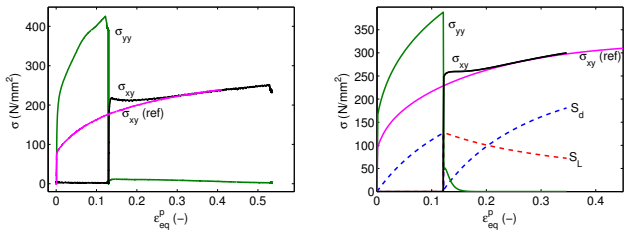


Figure 3: Experimental (left) and simulation (right) results.

Clearly, the evolution of the yield stress is strongly dependent on S_d, but after the strain path change, S_d is close to zero and the latent dislocation structure S_L initiates a overshoot in shear stress (σ_{xy}).

Future research

- Develop a strategy that determines the material parameters from experiments.
- Strain rate sensitivity needs to be implemented in the model, requiring experimental results.