Non-uniform straining and forming limits

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Introduction
Sequential stamping operations are often used for sheet metal forming. These operations produce non-uniform strain paths in a given element of a material. A change in strain path direction has a significant effect (fig. 1) on flow stress, strain hardening and formability of sheet metals [1]. Strong experimental evidence exists that classical material models, based on von Mises type theories, are incapable to predict these phenomena. Therefore, the method to be developed should be confronted with existing experimental data at an early stage.

![Figure 1: The deformation behavior of an aluminum sheet with different equibiaxial prestraining: uniaxial tension (left), FLD(right)](image)

Objective
The aim of this study is to arrive at a material model that is based on a crystal plasticity approach and enables the calculation of the effect of complex strain path histories in sheet metal forming processes.

Phenomena
Experimental investigations, e.g. [2], show that both structural and textural evolutions may be responsible for plastic behavior and instabilities during non-uniform deformation (fig. 2).

![Figure 2: The mechanisms involved in plastic deformation after a strain path change.](image)

Results
In the framework of crystal plasticity a hardening law should be defined taking into account the structure evolution influence on the macroscopic behavior. The crystal plasticity model with a Kocks-type hardening law

\[ h_{\alpha\beta} = h_0 \left(1 - \frac{s_{\alpha}}{s_{\infty}}\right)^\alpha q_{\alpha\beta} \]

has been applied to describe the strain hardening of a FCC polycrystal sheet during non-uniform straining. The results (fig. 3) demonstrate the necessity to enhance the model.

![Figure 3: The computational results for an aluminum sheet in uniaxial tension after different amounts of prestrain in equibiaxial stretching.](image)

Discussion and future plans
- The results obtained show that for an accurate description of the hardening behavior of sheet metals under complex strain paths the hardening law in the model has to be improved. Pursuing a physically based approach is desirable.
- To predict forming limit diagrams for plane stress configurations the finite element method in conjunction with an enhanced crystal plasticity model (to be developed) will be used. Deformation instability is supposed to occur as a natural result of strain field fluctuations caused by textural inhomogeneities.

References