

## Strain path dependency in metal plasticity

***Citation for published version (APA):***

Viatkina, E. M., Brekelmans, W. A. M., & Geers, M. G. D. (2002). *Strain path dependency in metal plasticity*. Poster session presented at Mate Poster Award 2002 : 7th Annual Poster Contest.

***Document status and date:***

Published: 01/01/2002

***Document Version:***

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

***Please check the document version of this publication:***

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

***General rights***

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

***Take down policy***

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

# Strain path dependency in metal plasticity

E.M. Viatkina, W.A.M. Brekelmans, M.G.D. Geers

Netherlands Institute for Metals Research, Eindhoven University of Technology, Department of Mechanical Engineering

## Introduction

Most of the industrial metal forming processes are characterized by a complex deformation history, which is composed of successive strain paths that may vary considerably in their orientation (Figure 1).

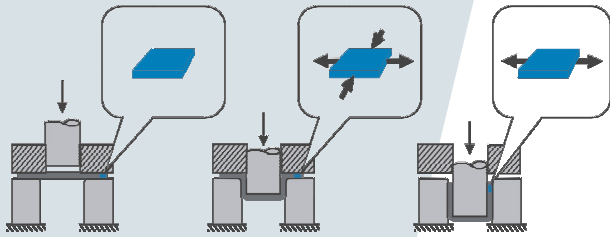
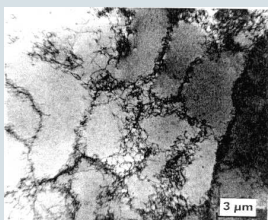


Figure 1 Strain path change during deep drawing.

Changes in strain path directions have a significant effect on the mechanical response of metals. Macroscopically the effect of a certain prestrain becomes manifest by an **increased reloading yield stress**, **transient hardening**, **hardening recovery** and **failure shift**. The effect is strongly **anisotropic** and depends on the amount of prestrain.

The aim of this project is to arrive at a material model that enables the numerical simulation of the effect of complex strain path histories in sheet metal forming processes, on the basis of evolving dislocation structures.

## Cell structure



Strain path change effects physically originate from a complex microstructure evolution. The present work deals with the contribution of the evolution of dislocation cell structures to these effects.

The evolution of a cell structure under deformation is schematized in figure 2.

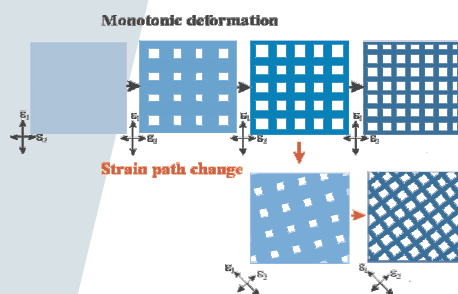


Figure 2 Scheme of the cell structure evolution.

## Methods

The material with embedded cells is modelled to behave like a composite consisting of a periodic array of two types of elements: the hard cell walls and the soft cell interiors, distinguishable by high and low dislocation densities correspondingly. The evolution of cells (Fig. 2) is taken into account by rate equations for the cell size, the wall thickness and the dislocation density inside the walls.

## Results

To validate the model sequences of two uniaxial tensile tests performed in different directions were considered. Figures 3 and 4 show stress-strain diagrams predicted by the model and experimentally obtained for prestrained copper. The curves are shown for different values of the prestrain  $\epsilon_{pre}$  and for different angles  $\xi$  between the subsequent tensile directions.

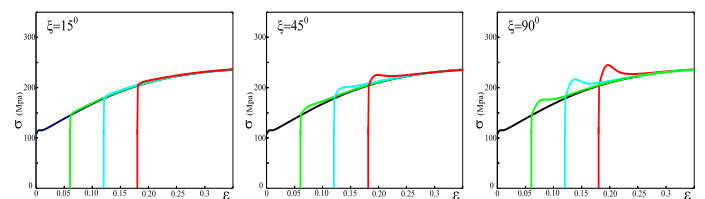


Figure 3 Theoretical prediction,  $\epsilon_{pre} = 0; 0.06; 0.12; 0.18$

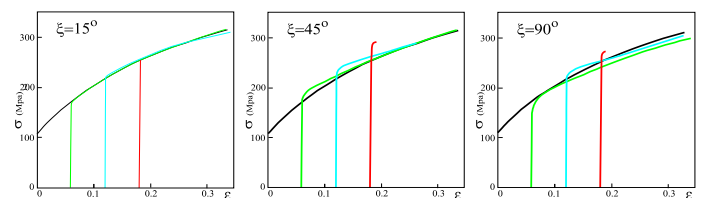


Figure 4 Experimental results (Mughrabi H., 1986),  $\epsilon_{pre} = 0; 0.06; 0.12; 0.18$

## Conclusions

The model predicts

- increased reloading yield stress
- transient hardening
- influence of the amount of prestrain
- influence of the amplitude of the strain change

The prediction is accurate for complex deformations with a strain path change up to 45°.

To improve the model for an adequate prediction of the deformation behavior after strong strain path changes, slip anisotropy should be taken into account.