Modeling martensitic transformation and its interaction with plasticity in metastable steels

Technische Universiteit Eindhoven University of Technology

Modeling martensitic transformation and its interaction with plasticity in metastable steels

A. Balmachnov, V.G. Kouznetsova, M.G.D. Geers

Introduction

Advanced high strength steels (AHSS), such as steels with transforming metastable phases, exhibit complex behavior: their engineering scale response to thermo-mechanical loading during processing and service is highly dependent on the microstructural features, whereas microstructural properties may evolve during the mechanical loading, e.g. due to martensitic transformation, Figure 1(b).

(a)

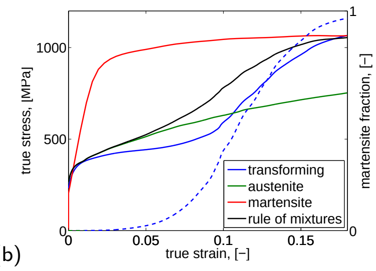

(b)


Figure 1: (a) Applications of AHSS (b) Behavior of Sandvik Nanoflex™ under uniaxial tension: stress-strain response and transformation evolution (dashed blue line)

This research aims to develop a model for prediction of metastable austenitic steels behavior, thus enabling optimization of the production processes.

Method and micromechanical model

The micro-level single grain transformation model is employed within the multi-scale computational framework (see Figure 2).

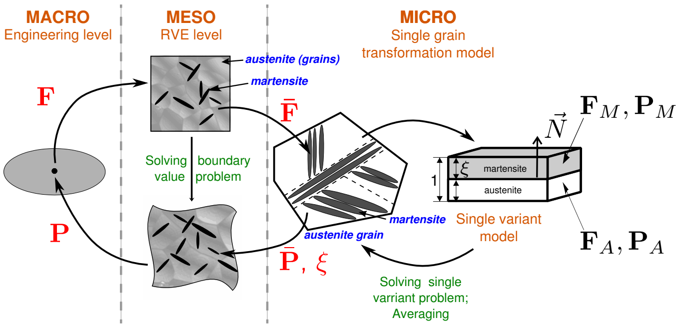


Figure 2: General multi-scale modeling framework for metastable austenitic steel

For each transformation system the model resolves in a coupled manner the evolution of martensitic volume fraction ξ and the mechanical stress-strain response for a given overall deformation $\bar{\mathbf{F}}$. Further on, volumetric averaging over all 24 possible martensitic transformation systems is performed to capture overall behavior of a transforming austenitic grain.

Interaction of plastic deformation and transformation is known to be twofold:

- I plastic deformation of austenite produces additional nucleation sites (promotes the transformation)
- II dislocation foresting in austenite around the interface might suppress the interface movement (retards the transformation)

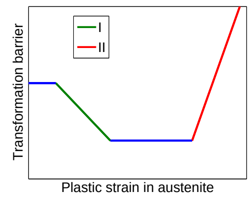


Figure 3: Proposed transformation barrier function

Based on these considerations phenomenological transformation barrier function introduced (Figure 3).

Results and future work

Modeling results are obtained for uniaxial tensile loading. Single crystal orientations have been selected according to the measured texture (Figure 4). The results show that various aspects of the transformation have been captured (Figure 5). Resulting shapes of material response curves are in qualitative agreement with experimental observations.

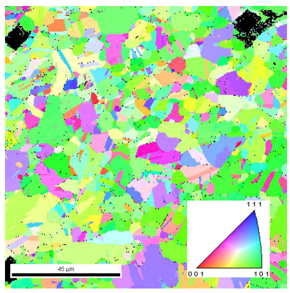
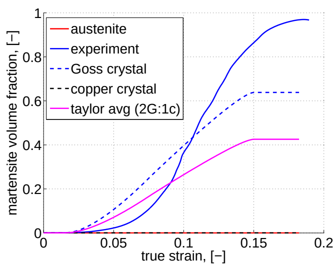


Figure 4: Texture, Goss:copper $\approx 2:1$



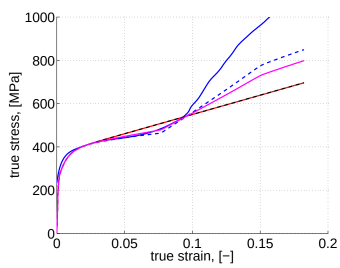


Figure 5: Simulations vs. experiment; martensite volume fraction evolution (left) and true stress (right) vs. true strain responses for crystals of major orientations and averaging

Future work includes further investigation of grains interaction and parameters identification to capture material response quantitatevely.