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A microscale model of martensitic transformation with incorporation of interaction between plasticity and transformation

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ABSTRACT

Introduction: Because of their superior properties advanced high strength steels (AHSS), such as steels with transforming metastable phases, are widely used in various applications in the range from automotive parts to medical equipment and domestic appliances. These materials exhibit complex behavior: their engineering scale response to thermo-mechanical loading during processing and service are highly dependent on the microstructural features, whereas microstructural properties may evolve during loading, e.g. due to martensitic transformation.

In this work we present a model aimed to predict the behavior of metastable austenitic steels at the meso- and microscales, with account for microstructural features relevant for accurate prediction of the material response, thus enabling optimization of the production processes and product designes for this type of materials.

Method and micromechanical model: In this work a micro-level single grain transformation model [1] is employed within a general multi-scale computational framework (Figure 1) adapted for metastable austenitic steels. Within the modeling framework, a lamella-type model is set up to represent the cumulative response of all transformation systems of the same orientation within the deforming austenite grain. 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, predicted by the phenomenological crystallographic theory of martensitic transformations [4], is performed to capture overall behavior of a transforming austenitic grain.

Martensitic transformation and plasticity: Based on experimental observations, the interaction between the martensitic phase transformation and the plastic deformation plays a crucial role in the behavior of this type of materials and can be described as two-fold [2], [3]:

- Plastic deformation of austenite produces additional nucleation sites for the transformation. This promotes the transformation in overall.

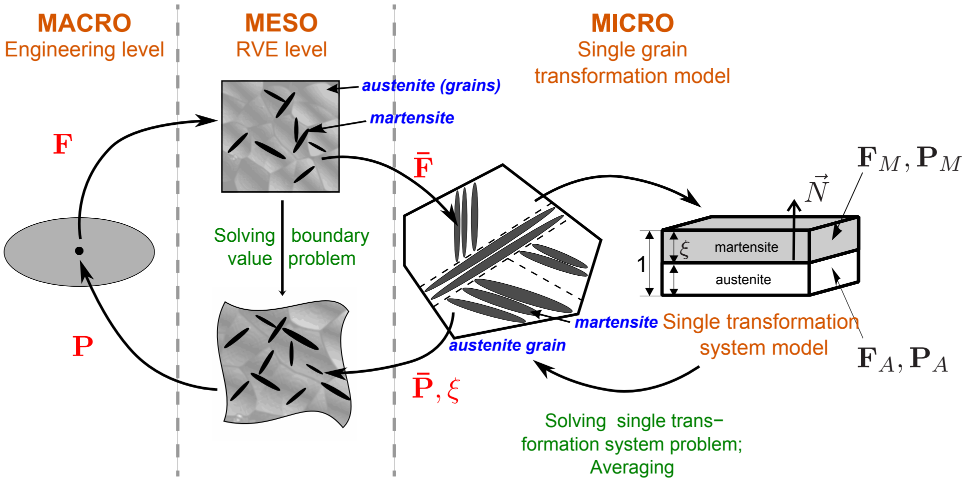

Figure 1: General multi-scale modeling framework for metastable austenitic steel

- Accumulation of plastic deformation causing dislocation foresting in the austenite around the interface might suppress the interface movement effectively increasing the transformation barrier and thus opposing the development of transformation.

In the model a history-dependent transformation barrier function is proposed to be used for phenomenological description of martensitic transformation and its interaction with plasticity in austenite at the grain level.

Results and conclusions: The model that takes into account the properties of the phases, the crystallographic features of martensitic transformation, the orientations of the transforming grains, and the deformation mode has been implemented into FE-framework.

In accordance with experiments the extent of the martensitic transformation and hence the overall response of the material predicted by the model are strongly dependent on the orientations of the grains and on the applied deformation modes.

Results of the numerical experiments representing uniaxial tension of the crystals of certain orientation show that the interaction between the phase transformation and plasticity can realistically be captured using the proposed transformation barrier function.

Further on, simulations of polycrystalline samples representing experimentally observed crystallographic texture are in good agreement with the results of experimental tests for a particular material, Sandvik Nanoflex^{TM}, under various loading conditions.

REFERENCES

[1] V.G. Kouznetsova and M.G.D. Geers. “Modeling the interaction between plasticity and the austenite-martensite transformation”. *International Journal for Multiscale Computational Engineering*, Vol. **5**, 129–140, 2007.

[2] Z. Nishiyama. “Martensitic Transformations”. Academic Press, 1971.

[3] G.B. Olson. “Transformation plasticity and the stability of plastic flow”, in *Deformation, Processing, and Structure*, ed. G. Krauss, ASM International, 391–424, 1984.

[4] M.S. Wechsler, D.S. Lieberman, and T.A. Read “On the theory of the formation of martensite”. *Trans. AIME Journal of Metals*, Vol. **197**, 1503–1515, 1953.