On the Prediction of Anisotropy Evolution in Polycrystalline Multiphase Materials

Erik Lindfeldt[†], **Magnus Ekh**[†]

[†] Division of Material and Computational Mechanics/Department of Applied Mechanics, Chalmers University of Technology, Hörsalsvägen 7B, SE-41296 Gothenburg, Sweden
erik.lindfeldt@chalmers.se

ABSTRACT

In this contribution a multiscale modeling (MSM) framework is used to model the behavior of a multi-phase polycrystalline material. The use of MSM is motivated by the interest in how mechanisms occuring at different length scales contribute to the macroscopic behavior. The modeling is conducted in the spirit of e.g. [1, 3].

Here, three different length scales are used to model the behavior of the material. The mesoscopic length scale is introduced to include the effects of interactions between grains. A mesoscopic Representative Volume Element (RVE) containing grains with (possibly) varying size and shape is used to predict the homogenized mesoscopic response i.e. the macroscopic response.

Interactions between the constituents (phases) of the material are studied within the microscale domain. A microscale RVE containing the phases with their typical shapes and volume fractions is used to model the homogenized microscopic response i.e. the mesoscopic response.

Since the constituents of the micromodel are assumed to be single crystal domains a crystal plasticity model in the spirit of e.g. [3] is chosen. The model, is based on a viscous formulation and a non-linear hardening model. A central issue in any crystal plasticity model is how to select which slip systems to include. For FCC crystals it is common practice to select the 12 systems of the $\{111\}\langle 110\rangle$ family (see e.g. [2]). However, in the present work examples related to a pearlitic steel, for which the ferritic phase comprises a BCC crystal structure, are presented. For such a crystal the choice of slip systems is less obvious. Up to 48 slip systems from three different families of slip systems could be active. In the present contribution the twelve slip systems from the $\{110\}\langle\bar{1}11\rangle$ family are chosen.

A framework such as this allows for a number of interesting phenomena to be studied. One example is to quantify the sources of anisotropy. The micro-RVE features two anisotropic mechanisms. To begin with, the response, in the plastic regime, is anisotropic due to the inherent directionality of the chosen slip systems. Furthermore, there exists a morphological anisotropy which is coupled to the chosen geometry of the micro-RVE. Consider for example a lamellar structure (such as the one found in a pearlitic steel where the cementite appears as layers embedded in a ferritic matrix). Clearly, given that the constituents are assigned different material parameters, changing the orientation of the micro-RVE will have an impact on the mesoscopic stress response.

Furthermore, by introducing a macroscopic yield condition it is possible to define a macroscopic yield surface. By doing that the effects of a previous loading history (e.g. from a forming operation) on the resulting yield surface can be studied. See e.g. [2, 4].

Acknowledgement: This work has been funded by the Swedish Research Council which is gratefully acknowledged.

References

[1] Frédéric Feyel and Jean-Louis Chaboche. Fe^2 multiscale approach for modelling the elastoviscoplastic behaviour of long fibre sic/ti composite materials. *Computer Methods in Applied Mechanics and Engineering*, 183(3-4):309 – 330, 2000.

[2] S.R. Kalidindi, C.A. Bronkhorst, and L. Anand. Crystallographic texture evolution in bulk deformation processing of fcc metals. *Journal of the Mechanics and Physics of Solids*, 40(3):537 – 569, 1992.

[3] Christian Miehe, Jörg Schröder, and Jan Schotte. Computational homogenization analysis in finite plasticity simulation of texture development in polycrystalline materials. *Computer Methods in Applied Mechanics and Engineering*, 171(3-4):387 – 418, 1999.

[4] I. Watanabe and K. Terada. A method of predicting macroscopic yield strength of polycrystalline metals subjected to plastic forming by micro–macro de-coupling scheme. *International Journal of Mechanical Sciences*, 52(2):343 – 355, 2010.