Numerically efficient multi scale material models for processes under thermal and chemical impact

Subproject M05/Scale transitions – Dr.-Ing. Johanna Waimann, Prof. Dr.-Ing. Stefanie Reese

Objective and approach

In subproject (SP) M05, methods for the generation of process signatures with application to processes with thermal, chemical and thermo-chemical main effects are developed. The overall objective is to explore the scale transition from the microstructure level to the polycrystal level in the context of process signatures based on an effective formulation of the material behavior in order to achieve a multi-scale description of the material modifications.

Current state of knowledge

SP M05 first investigated the homogenization approach according to Hashin and Shtrikman and applied it to the mechanical problem of solid rolling in cooperation with SPs M01 and M03 [1,2,3].

To model thermal boundary value problems, in particular dissipation and diffusion controlled phase transformations, SP M05 developed an efficient material model based on the principle of minimum dissipation potential [4,5]. The inclusion of thermo-mechanical coupling allows to take into account the stress evolution during thermal material loading (for example during induction hardening).

For processes with main chemical effects, SP M05 in cooperation with SPs M06 and F03 developed a homogenized dissolution model of the ECM process, which is based on effective material parameters and does not require computationally expensive remeshing steps [6]. After experimental validation by SP F03, the model was successfully used to simulate a PECM process (see Fig. 1) and to develop process signatures.

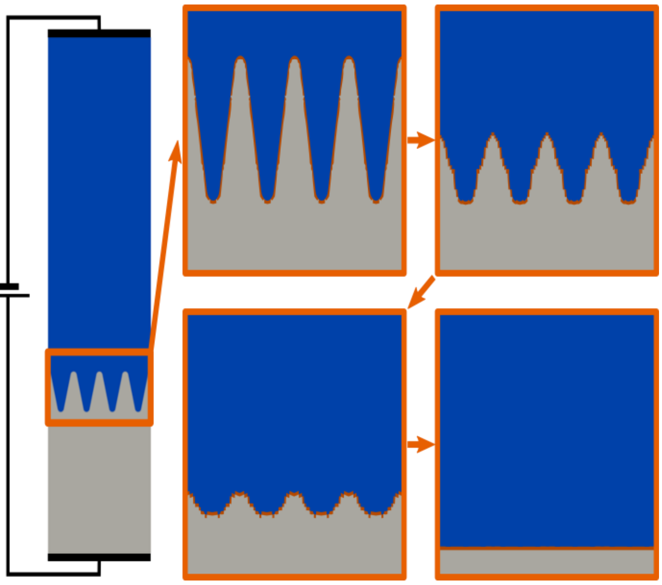

Figure 1: Simulation of the evolution of the surface roughness in a pulsed ECM-process [6].

Conclusion and further procedure

To perform complex process simulations, the CRC 136 requires efficient homogenization methods that simplify a high-resolution model but preserve its multi-scale character. This allows for high computational efficiency so that material modifications can be successfully represented in sophisticated simulations of process chains. Furthermore, SP M05 aims to extend the phase transformation model to include additional physical effects such as grain activities. In addition, the electrochemical resolution model is to be supplemented by fluid mechanical effects in the working gap as well as multiphase material behavior in cooperation with SPs M04, M06 and F03.

Publications

[1] Cavaliere, F.; Reese S.; Wulfinghoff, S., Computational Mechanics 65 (2020), 159-175, DOI: 10.1007/s00466-019-01758-4.

[2] Jaworek, D.; Gierden, C.; Kinner-Becker, T.; Waimann, J.; Reese, S., Procedia Manufacturing 47 (2020), 1442-1448, DOI: 10.1016/j.promfg.2020.04.314.

[3] Jaworek, D.; Gierden, C.; Waimann, J.; Wulfinghoff, S.; Reese, S., Technische Mechanik – European Journal of Engineering Mechanics 40(1) (2020), 46-52, DOI: 10.24352/UB.OVGU-2020-012.

[4] Jaworek, D.; Waimann, J.; Reese, S., Proceedings in Applied Mathematics and Mechanics 20(1) (2020), e202000319, DOI: 10.1002/pamm.202000319.

[5] Waimann, J.; Reese, S.; Junker, P., Technische Mechanik – European Journal of Engineering Mechanics 40(1) (2020), 87-96, DOI: 10.24352/UB.OVGU-2020-017.

[6] van der Velden, T.; Rommes, B.; Klink, A.; Reese, S.; Waimann, J., arXiv:2103.08426.