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A numerical approach to model high-temperature creep behaviour of Ni-base superalloys from microstructural morphology to grain size scales

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A constitutive model for the mechanical behaviour of single crystal Ni-base superalloys under high temperature conditions has been developed in the framework of a Cooretec project in cooperation with Siemens AG, MTU Aero Engines AG and University Bayreuth. In addition to the conventional material properties e.g. elastic constants, the model requires the parameters of the initial microstructure as an input. Thus, the γ'-precipitate size and the channel width of the γ-matrix were obtained from SEM micrographs. The model uses the slip system theory [1] and describes the movement, multiplication and annihilation of dislocations in the channels [2]. Furthermore, the cutting of precipitates [3] is another mechanism contributing to the plastic flow. The evolution of the morphology due to rafting and its effects on the deformation have been implemented according to [4]. The kinematic hardening is introduced as a stress tensor to realistically represent the strain hardening of arbitrary oriented single crystals.

The mechanical behaviour of single crystal specimens has been experimentally investigated in tension tests at different strain rates and in creep tests under various loads. The constitutive model has been calibrated based on the experimental data for temperatures of 950°C and 850°C and the [001] and [111] crystallographic orientations.

Finally, a micromechanical model was created to simulate the creep response of additive manufactured polycrystalline structures. An EBSD image is taken to obtain the grain geometry and their respective orientation. The grain boundaries are discretised using cohesive elements, whereas the single crystal model was applied to each grain in the representative volume. The polycrystal model is generated using Dream3D, NetGen and other software previously developed at the BAM [5].

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