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A crystal plasticity model incorporating the effects of precipitates in superalloys: Application to tensile, compressive, and cyclic deformation of Inconel 718

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Abstract

An elasto-plastic polycrystal plasticity model is developed and applied to an Inconel 718 (IN718) superalloy that was produced by additive manufacturing (AM). The model takes into account the contributions of solid solution, precipitates shearing, and grain size and shape effects into the initial slip resistance. Non-Schmid effects and backstress are also included in the crystal plasticity model for activating slip. The hardening law for the critical resolved shear stress is based on the evolution of dislocation density. Using the same set of material and physical parameters, the model is compared against a suite of compression, tension, and large-strain cyclic mechanical test data applied in different AM build directions. It is demonstrated that the model is capable of predicting the particularities of both monotonic and cyclic deformation to large strains of the alloy, including decreasing hardening rate during monotonic loading, the non-linear unloading upon the load reversal, the Bauschinger effect, the hardening rate change during loading in the reverse direction as well as plastic anisotropy and the concomitant microstructure evolution. It is anticipated that the general model developed here can be applied to other multiphase alloys containing precipitates.

Keywords: A. Microstructures; B. Polycrystalline material; B. Crystal plasticity; C. Numerical algorithms; Inconel 718

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