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A Crystal Plasticity Based Constitutive Model for the Temperature Dependent Anomalous Behaviors of Nickel-Based Single-Crystal Superalloy

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ABSTRACT

Ni-based single crystal superalloys have been favored in the high-temperature service zones of aeroengine and gas turbine due to its excellent mechanical properties at high temperature. It is very significant to construct a constitutive model that can accurately capture the mechanical response of Ni-based single crystals for simulation analysis. In this work, a forest dislocation density-based single crystal plasticity constitutive model was developed to capture the mechanical behavior of Ni-based single crystals, including the temperature dependent anomalous yield and tension/compression asymmetry. Firstly, thermally activated cross-slip mechanism was introduced into the hardening model to describe the anomalous yield response. Secondly, the transformation of dislocation motion mode from shearing to by-passing was described by an empirical function considering temperature effect. Thirdly, non-Schmid stress tensors were introduced into the constitutive model to capture the tension/compression asymmetric phenomenon. Multiple strengthening mechanisms were considered in the model, including solid solution, precipitates and base metal. Furthermore, the evolution of microstructural features (such as dislocation density, etc.) and contribution of each mechanism to mechanical response with increasing temperature were further analyzed. The model has been implemented via crystal plasticity framework and can accurately predict the temperature dependent mechanical response of Ni-based single crystal superalloy. This work provides a valuable guidance for accurately describing and predicting the mechanical response of Ni-based single crystals superalloy.

KEYWORDS

Crystal plasticity; temperature effect; single crystal superalloy; anomalous yield behavior; tension/compression asymmetry

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