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A combined CP theory and TCD for predicting fatigue lifetime in single-crystal superalloy plates with film cooling holes

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Abstract: Considering the effects of the numbers and diameters of film cooling holes, the Low Cycle Fatigue (LCF) performances of Ni-based single-crystal superalloy plate specimens were studied. The investigation found that the low cycle fatigue lifetimes of the single hole specimens were significantly longer than those of multi-holes specimens because of the multi-holes interference effect. Combined with the rate dependent Crystal Plasticity (CP) theory and the Theory of Critical Distances (TCD), the LCF lifetime prediction models of specimens with close packed film cooling holes were established. Instead of the SWT parameter, the models used the damage parameter of maximum resolved shear stress/strain, which can describe the multi-holes interference effect well. The damage model was defined based on the rate dependent CP framework. Combined with the Manson - Coffin formula, the concrete process of predicting LCF lifetimes of the specimen with close packed film cooling holes was given. Both the predicted and tested LCF lifetimes of the specimens were in the double error band.

Key words: LCF lifetime prediction; Ni-based single-crystal superalloys; Close packed film cooling holes; Crystal plasticity theory; the Theory of Critical Distances; Damage model

σ_a alternating stress

$\sigma_f^{'}$ fatigue strength coefficient

N_f the number of cycles to failure

F^e elastic deformation gradient

F^p plastic deformation gradient