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镍基单晶合金多轴非对称循环加载应力弱化损伤与低周疲劳研究

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Study on Stress-weakening Damage and Low Cycle Fatigue of Ni-based Single Crystal Superalloy Under Multiaxial Asymmetric Loading

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摘要

研究DD3镍基单晶合金在高温多轴非对称循环载荷下的低周疲劳特性，对比分析试样的应力应变响应和试验参数与疲劳寿命的关系，发现材料的循环硬化、软化特性与温度、加载相位角、应变加载路径有关；低周疲劳试验的轴向应变范围对疲劳破坏的贡献较大，切向应变范围的贡献较小；在轴向非对称循环载荷作用下，不同取向的试样均表现出应力松弛和非弹性应变累积现象，存在应力弱化损伤。引入与疲劳寿命呈指数函数关系的参量 F 表征材料在高温非对称循环载荷下产生的应力弱化损伤，结合von Mises等效应变范围、单晶应力三轴性因子和晶体取向函数构造循环塑性应变能作为疲劳损伤参量，建立疲劳寿命预测模型，利用低周疲劳试验数据进行多元线性回归分析，表明模型与试验寿命具有很好的相关性。

关键词： 单晶 合金 应力弱化损伤 应力比 低周疲劳 寿命预测

Abstract:

This paper presents a study of the tension/torsion low cycle fatigue characteristics under asymmetric cycle loading of nickel-based single crystal superalloy DD3. The stress strain response of specimens and the relationship between test parameters and fatigue life are analyzed. It is discovered that the cyclic hardening and softening characteristics of the material are related to the temperature, loading phase angle and strain loading path; tensile strain range has more contribution than shear strain range to low cycle fatigue failure; specimens all exhibit stress relaxation and gradual micro plastic deformation accumulation under asymmetric cyclic tensile loading; and there exists stress weakening damage. A parameter *F* which has an exponential function relationship with fatigue life is proposed by considering the stress-weakening damage produced in asymmetric cyclic loading. Combined with the stress-weakening damage *F*, von Mises stress range, the stress triaxiality factor and crystallographic orientation function, a formula of cyclic plasticity strain energy is put forward as a failure parameter, and a fatigue prediction model is built. Multiple linear regression analysis of low cycle fatigue test data shows that the model has good correlation with the failure cycle.

Keywords: single crystals superalloys stress-weakening damage stress ratio low cycle fatigue life prediction

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