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疲劳裂纹尖端残余应力场的深度-传感压痕测试与有限元分析

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Depth-sensing Indentation Measurement and Finite Element Analysis of Residual Stress Field near Fatigue Crack Tip

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摘要

飞机和发动机等重要装备承力结构在服役过程中通常承受变幅疲劳载荷作用。直接测量和分析由于过载塑性变形而导致的裂纹尖端附近残余应力场,对于较好地理解变幅加载下疲劳裂纹扩展行为,从而改善和发展疲劳寿命预测模型具有重要价值。本文基于微细尺度的深度-传感压痕(DSI)残余应力测量技术,研究了材料疲劳裂纹尖端附近残余应力场的实用测试技术,获得了铝合金中心裂纹拉伸试样在恒幅及单峰疲劳过载作用下裂纹尖端附近的残余应力场分布。同时,还采用弹塑性有限元方法模拟分析了相同疲劳载荷下裂纹尖端附近相应的残余应力场分布。相互验证表明:两种方法获得了基本吻合的结果。

关键词： 疲劳裂纹扩展 单峰过载 裂纹尖端残余应力 弹塑性有限元 深度-传感压痕技术

Abstract:

The aircraft, engine and other key load bearing structures are often subjected to variable-amplitude fatigue loading in the course of their services. Direct measurement and analysis of the residual stress field near a crack tip caused by plastic deformation due to overload is of great value for a better understanding of fatigue crack growth behavior under variable-amplitude loading, and thus for the improvement and development of a fatigue life prediction model. Based on the microscale depth-sensing indentation (DSI) residual stress measurement technique, this paper studies the practical testing of the residual stress field near a fatigue crack tip, obtaines the distribution of residual stress field near it in fatigue crack propagation process for a middle-crack tensile specimen of an aluminum alloy under constant amplitude and single peak overload. Also, it analyzes the residual stress distribution near the crack tip using the elastic-plastic finite element method under the same fatigue loads. Mutual authentication indicates that the results obtained by the two different ways agree well with each other.

Keywords: fatigue crack propagation single peak overload residual stress near crack tip elastic-plastic finite element depth-sensing indentation technique

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