表层强化材料中梯度微结构和残余应力对 I 型疲劳裂纹扩展的影响

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摘要：表面强化处理作为一种提高材料疲劳强度和寿命的方法，被广泛的应用于各类工程构件中。这种处理会在构件的亚表面形成硬化层并引入残余压应力，从而提高疲劳性能。由于表面硬化层具有梯度特征，疲劳裂纹在这种梯度强化层内的裂纹扩展行为难以定量预测。在梯度材料中，特别需要考虑残余应力的梯度分布和微结构的梯度变化对疲劳裂纹萌生和扩展的作用。

本工作选择表面强化的 S38C 钢和均匀微结构的 S38C 钢。表面强化的 S38C，具有梯度分布的微结构及残余压应力层。其中不同微结构的均质试样进行疲劳裂纹扩展实验，获得裂纹扩展门槛值和裂纹扩展速率的数据，分析微结构对疲劳裂纹扩展的影响。表面强化的试样进行三点弯曲疲劳实验，分析残余应力和微结构对裂纹扩展门槛值的联合影响，并描述残余压应力在周期加载过程中的变化和松弛规律，分析残余压应力对疲劳裂纹扩展的影响。

关键词：残余应力，疲劳裂纹扩展，显微结构，梯度强化材料，疲劳裂纹门槛值

Influence of gradient microstructure and residual stress on model I fatigue crack propagation in surface hardened materials

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Abstract：Surface hardening, as a method to improve fatigue strength and life, is widely used in engineering components. This will form a hardening layer in the sub-surface of components and cause compressive residual stress, so as to improve the fatigue strength and fatigue life. But due to the surface hardened layer with gradient feature, fatigue crack behavior in this gradient layer is difficult to quantitative predict. In gradient materials, we need to consider the effects of gradient distribution of residual stress and microstructure on the initiation and growth of fatigue cracks.

Two kinds of steel S38C specimens were used in this work. One is with gradient microstructure and the other is homogenous material. There is gradient distribution of compressive residual stress along the depth from surface for the gradient microstructure specimens. The homogenous specimens with different microstructures were subjected to fatigue crack growth experiment. From the tested data, we analyzed the influence of microstructure on fatigue crack rate and threshold. Gradient microstructure specimens were subjected to three-point-bending experiment to show the data of fatigue crack rate and threshold at different depths along gradient layer. The results revealed the effects of residual stress and microstructure on fatigue crack propagation.