疲劳裂纹尖端场位错分布的准静态 BCS 模型

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摘要：在载荷的往复加卸过程中，疲劳裂纹尖端场的塑性区形成并演化，其形成机制和演化规律大大影响材料的疲劳行为。晶体材料的宏观塑性行为是由微观位错行为所决定，在一定的空间尺度（如：细观）上，视位错分布为连续函数，引入位错密度函数表征材料的塑性行为。按照 Bilby、Cottrell 和 Swinden 的 BCS 模型，根据 Peierls-Nabarro 力的不同设置裂纹，假定位错滑移面与预制裂纹面重合，准静态求解了 III 型裂纹在循环剪切载荷下的位错密度函数演化的一维问题，给出了不同加卸载周次下对应的位错密度分布。位错密度函数的极值点和奇异点体现了位错塞积情况，而位错塞积与亚晶界和晶界的形成密切相关，因此这些点反映了晶体中亚晶界和晶界的状态。结果表明：在循环剪切载荷作用下，疲劳裂纹尖端场塑性区中的位错密度函数产生了若干极值点，代表着塑性区内位错塞积和亚晶界、晶界。

关键词：疲劳裂纹，循环载荷，位错密度，塑性行为，BCS 模型

QUASI STATIC BCS MODEL FOR DISLOCATION SPREAD FROM A FATIGUE CRACK TIP

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Abstract：The plastic zone of fatigue crack tip is formed and evolved, and its formation mechanism and evolution laws greatly affect the fatigue behaviour of materials under cyclic loading. Because of macro plastic behaviour of crystal materials depends on micro dislocation behaviour, we introduce dislocation density function to express materials plasticity in a proper spatial scale (such as mesoscale), in which dislocation distribution is regarded as a continuous function. According to Bilby-Cottrell-Swinden model, we set a planar crack using different back stresses based on Peierls-Nabarro concept, and suppose slip plane of dislocation coincides with crack plane. We quasi statically solve the one dimensional problem of dislocation density function evolution for mode-III crack stressed by cyclic shear, and present dislocation density spread from a fatigue crack tip in a sequential loading and unloading cycles. Extrema and singular points of dislocation density function imply dislocation piled up, which is closely relating with formation of subgrain and grain boundaries. The results show that several extrema of dislocation density function is produced in the plastic zone of fatigue crack tip, which represents dislocation piled-ups and subgrain and grain boundaries.

Key words：fatigue crack, cyclic loading, dislocation density, plastic behaviour, BCS model