A MICROSCOPIC MECHANICS MODEL OF CRACK GROWTH WITH FATIGUE-CREEP INTERACTION

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Summary An analytical micromechanics model is proposed to describe the influence and interaction of fatigue and creep. A recently proposed micromechanics model for fatigue crack growth is employed and further developed. The calculated dc/dN curves exhibit significant features of fatigue-creep interaction which is in general agreement with the experimental observation.

Many engineering components, such as steam turbine rotor systems, outer shell of nuclear reactors, or even solder connection in electronic packing, are prone to thermal fatigue under service condition. As their working temperatures are relative high, they may also endure creep damage. Up till now the most common way to treat the fatigue-creep problem is to make a simple linear superposition of the individual effects. However, the interaction between creep and fatigue is proved to be an important factor in engineering safety design[1]. It is also a very complex and difficult problem for researchers in the relative fields.

In the present work, an analytical micromechanics model is proposed to describe the influence and interaction of fatigue and creep. Here, a recently proposed fatigue crack growth model[2] is adopted which views the fatigue crack growth process as the intermissive elastic cleavage fracture of the dislocation free zone (DFZ). The effects of cyclic loading make the plastic zone hardening (or softening), thus raise the stress level in DFZ and bring it to fracture. The calculated dc/dN curves exhibit three different stages of fatigue crack growth which is in general agreement with the experimental observation.

In applying that model to thermal fatigue, we consider the following thermal loading condition (fig. 1). Here we suppose that, compared with the holding period at high temperature, the period of increasing and decreasing temperature is rather short, and the creep during that period may be neglected.

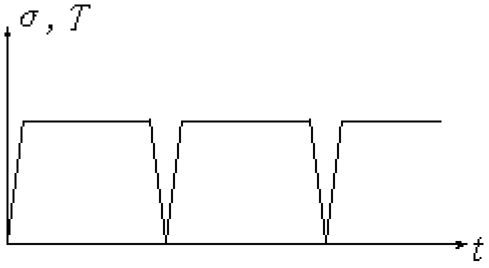


Figure 1 Schematic drawing of load spectrum

Thus at the period of increasing and decreasing temperature there is only the fatigue effect of thermal stress，while at the holding period there results the creep under the elevated stress caused by thermal loading.

The fatigue-creep interaction model is shown in Figure 2. Where the fatigue damage is represented by the climbing dislocations and the creep damage is represented by the micro void ahead

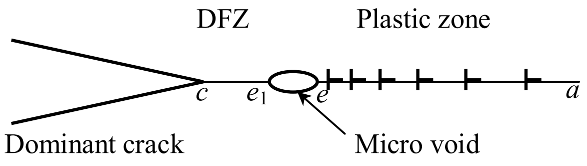
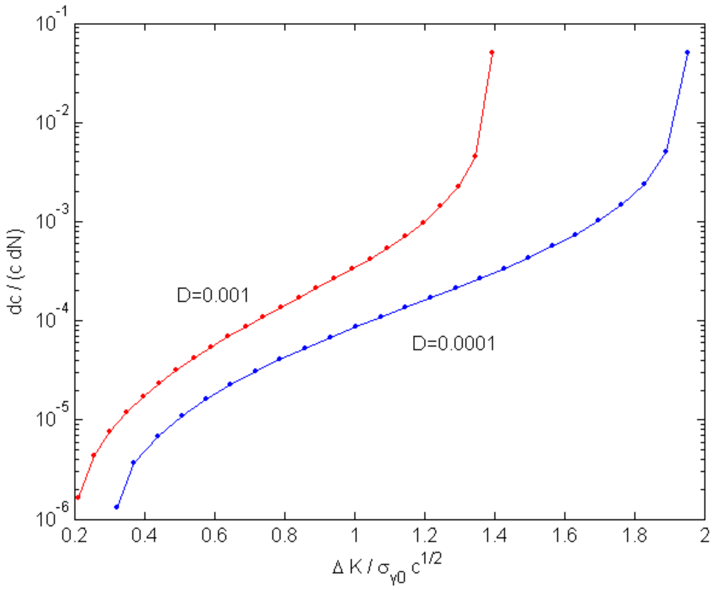


Figure .2 Schematic illustration of the coupling effect between fatigue and creep.

of the dislocation pile-up. The dislocation distribution function is determined by the integral equation of the equilibrium condition of dislocations [3]. For the tensile stress distribution in DFZ, we adopt the cohesive zone model. The bridging relation is taken of the form as nonlinear atomic action. When the bridging stress within DFZ increases up to the tensile strength, fracture takes place. If the cycle number is N, the DFZ size is Δ , then the fatigue crack growth rate becomes

$$\frac{da}{dN} = \frac{\Delta}{N}$$

Fig. 3 shows the effect of creep damage on fatigue crack growth behavior. From the figure we can see that the growth of the void enhances the stress concentration ahead of crack-tip, thus promote the growth rate of fatigue crack.



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