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Collective evolution of surface microcrack for compacted graphite iron under thermal fatigue with variable amplitude

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Abstract

With the growing demand of good performance and high reliability of the heated components, the cracking failure caused by the complex thermal loading of variable amplitude has become a crucial problem. The collective evolution of surface microcrack for compacted graphite iron under thermal fatigue with variable amplitude is studied in this paper, which is induced by pulsed laser. The thermal microcrack is analyzed with statistic method and fractal method systematically. The result shows that, the secondary microcrack is the primary crack pattern, and the number of main microcrack is the least. As the test goes on, the fractal dimension increases following the Hill's function. Furthermore, the effect of maximum temperature T_{max} and superimposed number N_{HCF} on the crack evolution is investigated. T_{max} in the heating stage mainly affects the number of main microcrack. With the increase of plastic strain amplitude, the fractal dimension increases exponentially, and gradually tends to be the critical fractal dimension D_0 of 1.395. The superimposed number N_{HCF} in the high-cycle stage mainly affects the number of secondary microcrack. The fractal dimension increases exponentially with the increase of N_{HCF}, and tends to be the critical fractal dimension D_0 of 1.404. The analysis of the collective behavior of surface microcrack is helpful for evaluating the damage degree and predicting the lifetime, which can be applied to other materials working under thermal loading of variable amplitude.

Keywords

Thermal fatigue, Variable amplitude, Surface microcrack, Collective evolution, Compacted graphite iron

1. Introduction

Cracking is a common failure for the component working under thermal fatigue[1, 2]. From the crack initiation to the final fracture, the material undergoes microcrack initiation, microcrack growth, macrocrack initiation and macrocrack propagation[3-5]. Although the initiation and propagation of microcrack happen in the initial stage, they are crucial for the further development of crack damage. Researches[6, 7] show that the process of fatigue damage is caused by all cracks, and the microcracks formed on the surface show collective behavior and random statiatical complexity[8]. Therefore, the usual fracture mechanics method, based on the situation of a single crack growth, is unsatisfactory for the analysis of microcrack network[9]. From the point of