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Effects of striated laser tracks on thermal fatigue resistance of cast iron samples with biomimetic non-smooth surface

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ABSTRACT

In order to enhance the thermal fatigue resistance of cast iron materials, the samples with biomimetic non-smooth surface were processed by Neodymium:Yttrium Aluminum Garnet (Nd:YAG) laser. With self-controlled thermal fatigue test method, the thermal fatigue resistance of smooth and non-smooth samples was investigated. The effects of striated laser tracks on thermal fatigue resistance were also studied. The results indicated that biomimetic non-smooth surface was benefit for improving thermal fatigue resistance of cast iron sample. The striated non-smooth units formed by laser tracks which were vertical with thermal cracks had the best propagation resistance. The mechanisms behind these influences were discussed, and some schematic drawings were introduced to describe them.

1. Introduction

Cast iron has long been a popular cast metal material, because of its low cost, good cast ability, convenient machining property and better wear resistance. It is widely applied in normal industrial productions such as brake drums, cylinders, steel moulds, hot rolls, and so on [1–3]. However, the thermal fatigue failure of above parts which was caused by alternate heating and cooling to their working surface had brought enormous economic losses every year [4–6]. Therefore, it is urgent and significative to enhance thermal fatigue resistance of cast iron.

Among most of the thermal fatigue situations of samples, the surface region suffers the maximum temperature and the biggest thermal stresses, and it is in a state of alternating plasticity [7]. Though a lot of methods have been used in the surface treatment of cast iron, they mainly aim to improve the wear and corrosion resistance of cast iron. Only a few has been reported on improving thermal fatigue resistance. In recent years, biomimetic surface embodied by many good examples such as the lotus effect, interference patterns of butterfly wings and the reduced dragging ability of shark skin has become increasingly interested [8]. As an important branch, biomimetic non-smooth theory is creatively developed by Ren et al. in Jilin University [9–11]. During past a few years, the author has studied on the thermal fatigue resistance of cast iron with non-smooth surface processed by a solid state Nd:YAG laser [12–14]. However, the interaction between distribution of laser tracks and propagation direction of thermal cracks has not been investigated. This factor plays an important role in changing the thermal fatigue resistance of samples. Therefore, the effects of striated laser tracks on thermal fatigue resistance of cast iron with biomimetic non-smooth surface were investigated in this paper. The purpose was to establish a foundation for the optimization of surface morphology and further for the application of biomimetic non-smooth surface technique in the future.

2. Experiment procedure

2.1. Materials

For this work, a gray cast iron named HT 200 with the compositions listed in Table 1 was applied as the starting material, and its microstructure (etched by 3% nital) was shown in Fig. 1. It can be seen that HT 200 is composed of pearlite (P) and flake graphite (G).

2.2. Sample preparation

Rectangular samples with dimensions of $40 \times 20 \times 6$ mm^3 were cut by an electric spark machine. A 3 mm diameter round hole was drilled at one side of every sample so that they could be fixed onto the plate of thermal fatigue experimental machine. Every sample was pre-cut 2 mm deep notch, aiming to forecast the propagate direction of thermal cracks. The vertical or parallel distance between the tip of notch and its closest non-smooth unit is 2 mm. Meanwhile, the samples were mechanically polished using progressively finer grades of silicon carbide impregnated emery paper

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