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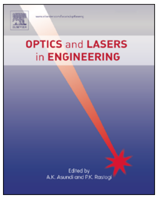

Thermal fatigue resistance of hot work die steel repaired by partial laser surface remelting and alloying process

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ABSTRACT

In this study, AISI H13 steel was processed using laser surface remelting and alloying with Co-based and iron-based powders for thermal fatigue resistance enhancement. The precracks were produced on the samples before laser treatment. The microstructures of laser treated zones were examined by scanning electron microscope. X-ray diffraction was used to describe the microstructure and identify the phases in molten/alloying zones. Microhardness was measured and the thermal fatigue resistance was investigated with self-controlled thermal fatigue test method. The results indicate that laser surface remelting and alloying can repair a large proportion of thermal cracks. Meanwhile, the strengthening network obtains ultrafine microstructure and super thermal fatigue resistance, which restrains the propagation of thermal cracks. Compared with samples treated with laser surface remelting and laser surface alloying with iron-base powder, samples treated with Co-based powder produce lower cracking susceptibility and higher thermal fatigue resistance.

1. Introduction

Die-casting process is technically easy and the most economical casting method to produce products with high precision, high surface quality and short lead time in the industry [1,2]. A distinguishing characteristic of the process is that the molten metal is injected into the internally cooled die cavity with high velocity within milliseconds. When casting solidifies, the die opens and ejects the casting. Consequently, the die may be externally cooled and lubricated by spraying [2,3]. In such alternatively heating and cooling conditions, one of the main reasons for the failure in die casting dies is surface heat checking which is caused by the thermal fatigue of die material [4]. Accordingly, the repair of damaged hot-work die steel is always a subject of major concern to engineering researchers [5].

Laser surface technology can produce a surface layer with strong metallurgical bonding to the substrate under the condition of rapid melting and solidification. Significant grain refinement and homogeneous microstructures with small dendrites in surface layer can be achieved [6]. Laser heating process can minimize microstructural changes in the heat affected zone which may lower the mechanical strength and chemical resistance [7]. Recently, laser cladding with powder has been conducted in several industrial applications for repair purpose [8–11]. Laser cladding of AISI A2 tool steel with two alloys of different protective properties was suitable for mould steel reparation [8]. Pulse laser cladding was feasible to repair titanium alloy aero engine [9] and develop tungsten carbide coating layer on X40CrMoV5-1 hot work tool steel using high power diode laser [10]. The cladding technique using a continuous wave Nd:YAG laser for manufacturing and repairing aeronautic components of Inconel 718 could satisfy the industrial requirements for aeronautic applications [11]. Functionally graded materials (FGM) produced by laser cladding could prolong the use of die casting tools subjected to thermal fatigue [12].

During past few years, major interests have been developed in the field of partial surface treatment with laser surface remelting (LSR) and laser surface alloying (LSA) for improving thermal fatigue resistance, wear behavior, tensile properties and adhesion resistance [13–17]. Thermal fatigue resistance of LSA AISI H13 steel using CrNi powder was improved where nucleation and propagation of thermal fatigue cracks were inhibited [13,14]. Wear resistance of LSR 3Cr2W8V steel was enhanced by producing strengthening points with high hardness on the surface [15]. Ultimate tensile strength and yield strength of LSR AISI H13 steel with strengthening stripes and grids were enhanced, while corresponding ductility increased even after thermal fatigue loaded [16]. LSR samples with striated non-smooth surface had lower susceptibility of adhesion to ejected polymer parts [17].

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Table 1
Chemical compositions of AISI H13 steel in wt%.

C	Si	Mn	Cr	Mo	V	Ni	P	S	Fe
0.41	0.97	0.38	4.82	1.19	0.92	0.07	0.007	0.002	Bal.

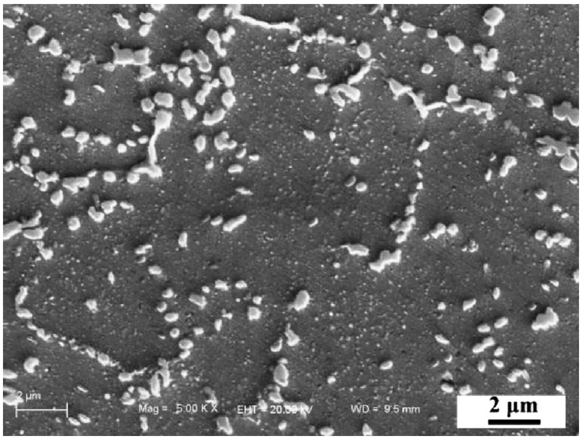

Fig. 1. Microstructure of annealed AISI H13 steel.

Table 2
Chemical compositions of alloying powders in weight %.

	C	Cr	Si	B	Mo	Ni	Fe	Co
Co-base	0.3–0.7	18–20	3.5–4.0	2.0–3.5	4.0–6.0	26–30	< 12	Bal.
Iron-base	0.5–0.7	12–14	2.0–3.0	1.2–2.0	4.0–6.0	32–39	Bal.	–

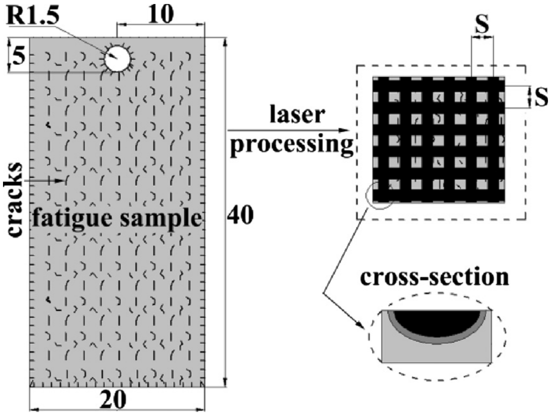

Fig. 2. Schematic diagram of laser surface treated zone and sample dimensions.

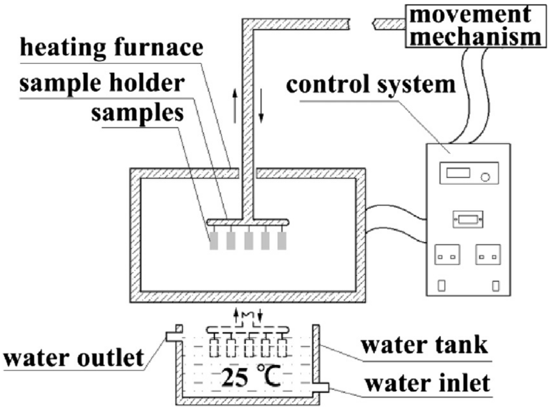

Fig. 3. Schematic diagram of thermal fatigue testing machine setup.

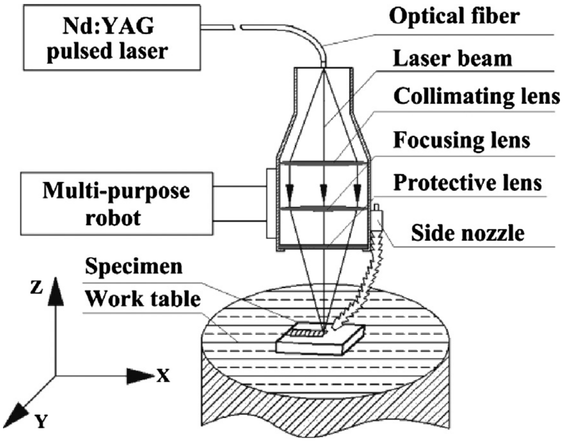

Fig. 4. Schematic diagram of laser processing setup.

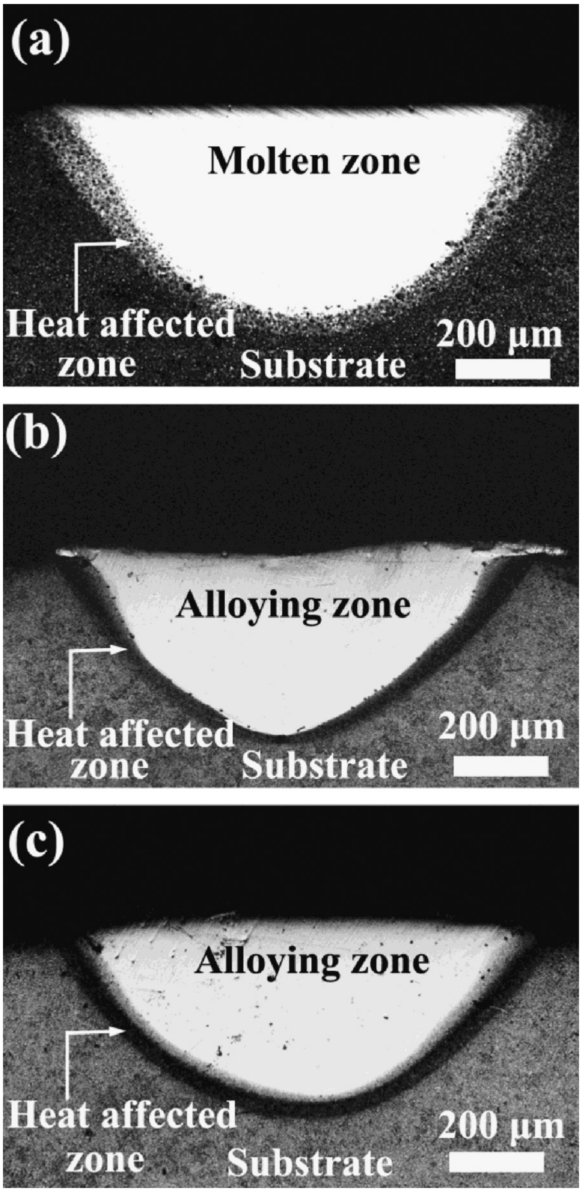

Fig. 5. Micrographs of cross-sectional surface of sample (a) LSR (b) LSA1 and (c) LSA2.