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Laser surface melting: A suitable technique to repair damaged surfaces made in 14 Ni (200 grade) maraging steel

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ABSTRACT

A high power solid Nd-YAG laser, operating in continuous mode, was used to re-melt the surface of a maraging steel, 14 Ni (200 grade), in different heat treatment conditions. Processing parameters were optimized for the employment of this technique as a repairing procedure of damaged surfaces to increase the useful life of tools made in maraging steels. Different zones can be found in laser-heated material. In addition, the absence of austenite reversion, consistent with the low nickel content of this steel, was found with the exception of a few very small pools of austenite found in a narrow layer in the heat-affected zone of samples corresponding to one of the studied heat treatment conditions of steel.

Laser surface melting (LSM) combined with aging heat treatment causes a significant rise in the hardness (from 325 to more than 520 $HV_{0.1}$) and in the wear resistance of the surface layer (with a decrease in the volume of lost material from 0.52 mm^3 in the steel in the laser surface melted condition to 0.28 mm^3 in the steel in laser surface melted and finally peak age hardening condition).

1. Introduction

Maraging steels are martensitic steels with low carbon content that offer an attractive combination of mechanical properties like high yield and tensile strength, high ductility, moderated fracture toughness and good weldability, achieved thanks to a fine precipitation of intermetallic compounds obtained after an aging heat treatment [1–4]. Their main disadvantage is their high price, caused mainly by the cost of the great amount of alloying elements involved (usually 17–19% Ni, 8–12.5% Co, 0.2–1.6% Ti) [2,4] and by the high purity required to ensure an elevated toughness which is habitually obtained by single or double-vacuum melting [2,5,6]. This could reduce their field of use to those applications where high material costs can be assumed: critical parts in the aeronautical, aerospace and military manufacturing [1,3,6]. However, nowadays maraging steels are also used in the manufacturing of die-casting tools since their properties make them become an adequate alternative to substitute high-speed hot-working tool steels such as AISI H11 and H13 [1,2].

The 14 Ni (200 grade) maraging steel is especially designed for use as die material in aluminum and magnesium alloy die-casting. Its lower nickel content (14%) increases resistance to reversion by heating from martensite to austenite during aging treatment [7], retards the austenite formation during die-casting [2,4], and also reduces the price of the steel. Due to their intense working requirements, these kinds of alloys are likely to suffer significant surface damage that would limit their service lives, and thus repair processes have been sought so as to amortize investments.

The use of laser technology in industrial applications has experienced a major boost in recent years [8]. Advantages such as high and uniform energy density, high heating and cooling rates, high productivity, low distortion, narrow heat affected zones and precise control of the treatable depth [9–11], make laser processing become a suitable technique to apply during local repair of dies, to re-melt surface cracks, to carry out local superficial heat treatments of welds and to repair components that have been overaged in service. Laser surface melting (LSM), surface quenching and surface alloying with cladding have been applied successfully on tool steel substrates to improve wear and corrosion resistance and, in general, to increase surface hardness [12,13]. Laser surface melting has been used to increase the surface hardness of tool [12,14–17], carbon [18] and low alloy steels [19] and gray and nodular irons [20], although sometimes the highest levels of hardness are achieved after a final heat treatment [21]. Usually the corrosion resistance of tool [21,22] and stainless steels [23,24] gets enhanced with this process and furthermore wear resistance is improved [25]. However, the improvement of each property depends to a great extent on the type and condition of the LSM treated alloy, some of them may even be impaired [26].

This paper studies the LSM effects on this low Ni maraging. A high power laser beam moves at high speed along the surface of the steel, melting metal without using a filler material. The fast solidification should lead to the formation of ultra-fine microstructures with high chemical homogeneity.

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Table 1
Chemical composition of 14 Ni (200 grade) maraging steel (wt. %).

Element	C	Ni	Mo	Co	Ti	Si	Cr	Mn	S	Fe
Composition according to the manufacturer	<0.008	14.00	4.50	10.50	0.20	<0.10	<0.30	<0.10	–	Bal.
Check analysis	<0.005	14.40	4.30	10.70	0.17	0.03	0.02	0.03	<0.0020	Bal.

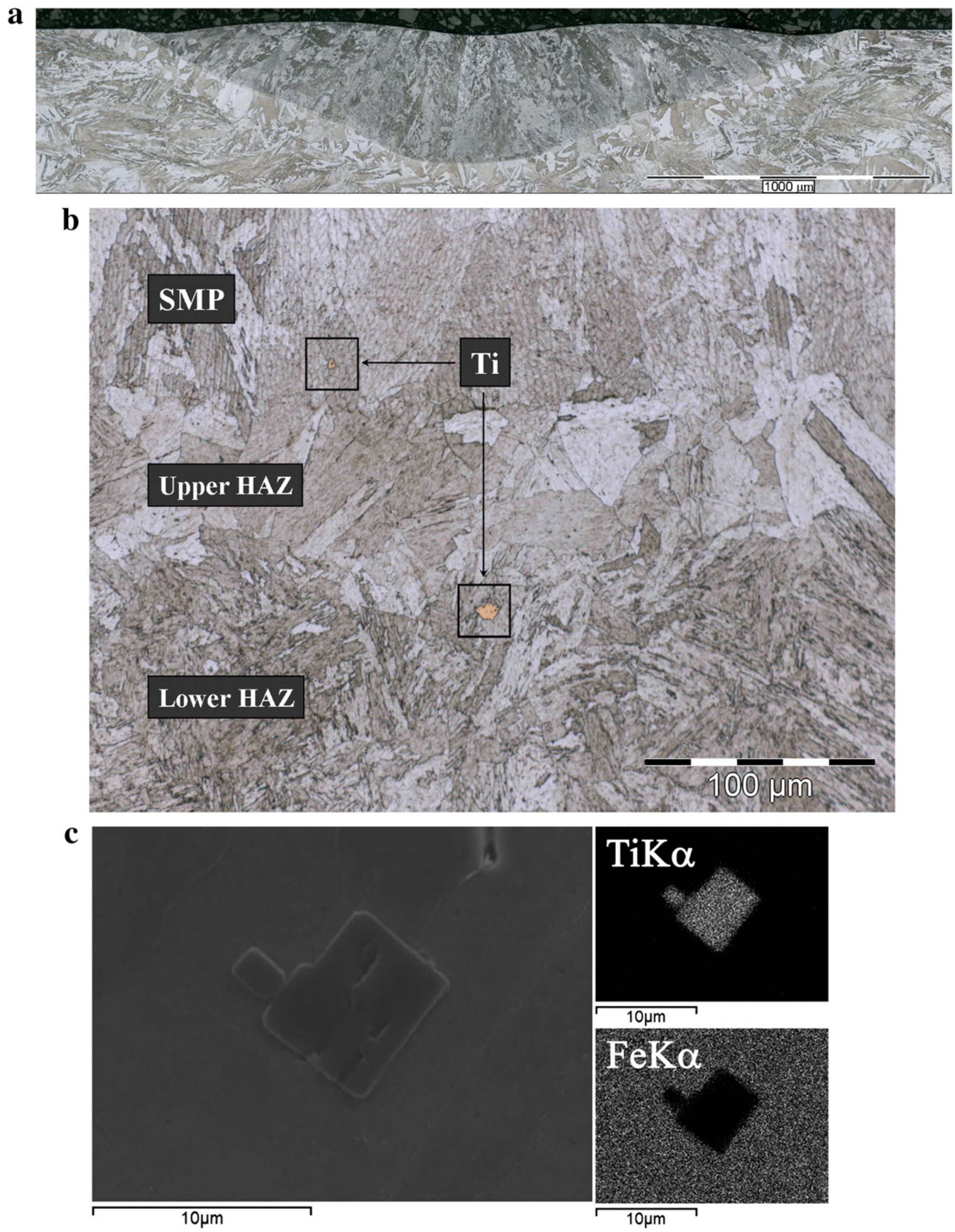

Fig. 1. Micrographs of the cross-sectional view of the single pass laser surface melted steel specimen in solutionised condition (condition A) processed at P = 2 kW with a surface energy density $E_d = 13.33\ J/mm^2$. (a) At low magnification. (b) Showing solidified melted pool (SMP), upper and lower heat affected zones of the parent metal (HAZ) and not dissolved titanium-rich particles. Etchants: Vilella and Nital. (c) Ti-rich particles detected in the initial solution annealed 14% maraging steel and which remain unaffected in the HAZ of the laser processed samples.