Microstructural evaluation of maraging 300 steel surface treated by Nd:YAG laser

Avaliação microestrutural do aço maraging 300 tratado superficialmente pelo laser Nd:YAG

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ABSTRACT
Maraging steels are Ni-Co-Mo-Ti alloys of ultra-high resistance and spread application, since defense and nuclear industry until aeronautic components, pressure vessels and sports industry. Maraging steels are composed by a metastable martensitic microstructure. This work aims to evaluate the microstructural behavior of a maraging 300 steel after superficial laser treatment to reduce the oxygen permeability in the structure, increasing

the mechanical resistance at elevated temperatures. Microstructural characterization was evaluated by scanning electron microscopy (SEM), X-ray diffraction and roughness by profilometry. The laser path typically of 500 µm wide was observed. Surface roughness results were R_a = 634 ± 160 nm; R_q = 789 ± 185 nm and R_t = 8,2 ± 3,2 nm. Laser treated sample exhibited, in addition of diffraction peaks due to the martensitic phase, additional peaks related to austenite phase and Fe_2N/Fe_3N. Therefore, laser surface nitriding can be used to change the surface properties.

Keywords: maraging 300, laser nitriding, microstructure.

RESUMO

Os aços maraging são ligas Ni-Co-Mo-Ti de ultra-alta resistência e ampla aplicação, desde a indústria de defesa e nuclear até componentes aeronáuticos, vasos de pressão e indústria esportiva. Os aços maraging são compostos por uma microestrutura martensítica metaestável. Este trabalho tem como objetivo avaliar o comportamento microestrutural de um aço maraging 300 após tratamento superficial a laser para reduzir a permeabilidade ao oxigênio na estrutura, aumentando a resistência mecânica a temperaturas elevadas. A caracterização microestrutural foi avaliada por microscopia eletrônica de varredura (MEV), difração de raios-X e rugosidade por perfilometria. O trajeto do laser tipicamente de 500 µm de largura foi observado. Os resultados da rugosidade da superfície foram R_a = 634 ± 160 nm; R_q = 789 ± 185 nm e R_t = 8,2 ± 3,2 nm. A amostra tratada com laser exibiu, além de picos de difração devido à fase martensítica, picos adicionais relacionados à fase de austenita e Fe_2N/Fe_3N. Portanto, a nitretação de superfície a laser pode ser usada para alterar as propriedades da superfície.

Palavras-chave: maraging 300, nitretação por laser, microestrutura.

1 INTRODUCTION

Maraging steels are Ni-Co-Mo-Ti alloys of ultra-high resistance and spread application, since defense and nuclear industry until aeronautic components, pressure vessels and sports industry. Maraging steels have been investigated by several steel producers, mainly for nuclear and aerospace applications, due to high mechanical resistance allied to an excellent tenacity, behavior that are required to reduce weight and increase safety (Sha and Guo, 2009; Reis et al., 2014a; Reis et al., 2017a; Reis et al., 2017b). These steels are part of the priority list of advanced materials to the Brazil's technological development and are proposed to replace the current 300M in some parts of Brazilian satellite launcher (Assunção, 2010; Santos, 2001). Maraging steels are composed by a metastable martensitic microstructure. Some research show that they revert to austenite when heated at intermediate temperatures, close to the aging temperature, becoming worst when increasing temperature and time of exposure (dos Reis et al., 2015; Gonçalves dos Reis et al., 2017; Reis et al., 2014b; Reis et al., 2015a;

Reis et al., 2015b). This work aims to evaluate the microstructural behavior of a maraging 300 steel after superficial laser treatment to reduce the oxygen permeability in the structure, increasing the mechanical resistance at elevated temperatures. Microstructural characterization will be done by scanning electron microscopy (SEM), X-ray diffraction and roughness by profilometry.

2 MATERIAL AND METHODS

The maraging steel used in this study was a 300-grade solution treated at 820 °C—1 h in a Brasimet Koe 40/25/65 furnace. Samples of 20 x 20 mm and 3 mm in thickness was grinded by using 200# and 600# SiC paper and then cleaned with acetone in a ultrasonic bath for 20 min. Laser surface treatment was carried out using a Rofin DY 033 Nd:YAG continuous laser, which was operated at a wavelength of 1064nm. The focus laser spot size had a diameter of 0.5 mm, and the treatment was performed under a nitrogen flow rate of 20 l/min. The energy and the sample speed were set at 675 W and 100 mm/s, respectively. The focal length of the lens used equaled 120 mm. Following laser surface treatment, the surface was characterized by scanning electron microscopy (SEM), X-ray diffraction and profilometry.

3 RESULTS AND DISCUSSION

Fig. 1 is a SEM micrograph showing the surface of the laser treated maraging 300 steel. We clearly see the laser path, each track typically 500 µm wide.

Figure 1. Micrograph maraging 300 steel surface treated with magnification of (a) 50x and (b) 150x.

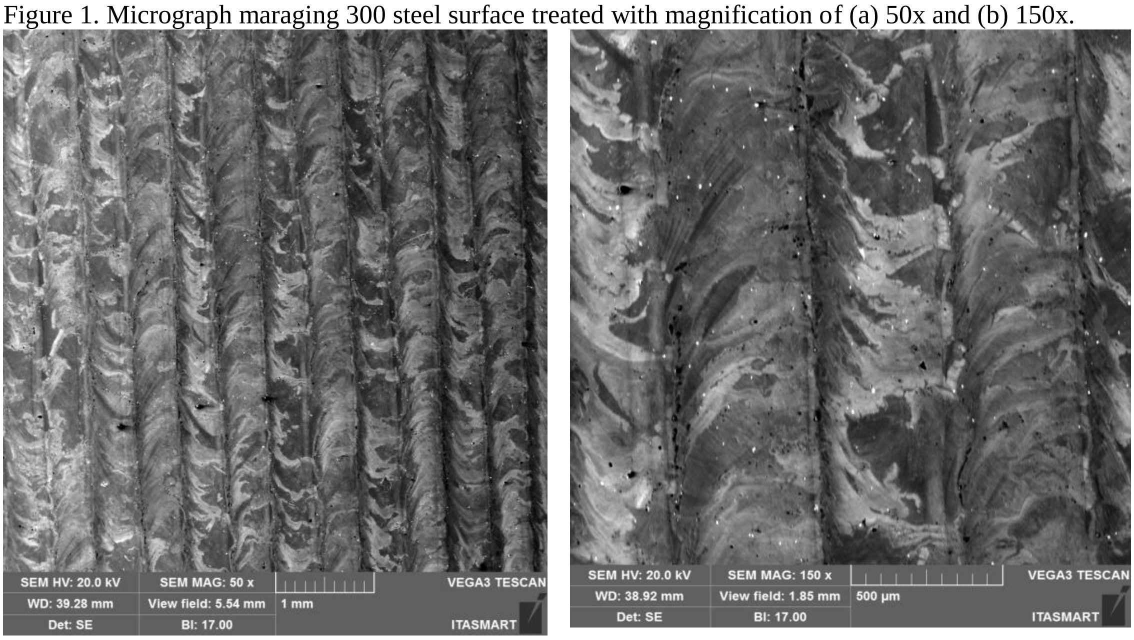
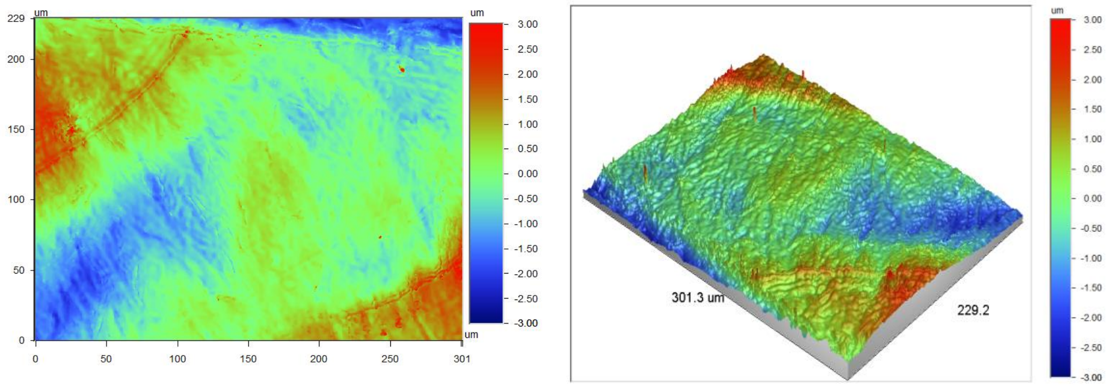


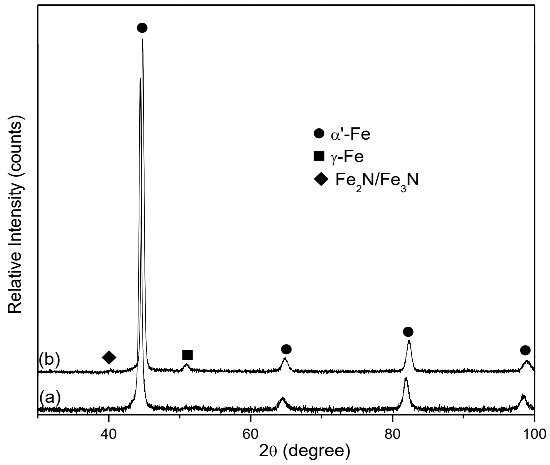
Fig. 2 is the 2D and 3D profilometry of the laser treated material. Surface roughness results: R_a = 634 ± 160 nm; R_q = 789 ± 185 nm and R_t = 8,2 ± 3,2 nm.

Figure 2. 2D (a) and 3D (b) optical profilometry images of maraging 300 steel laser treated.



The XRD pattern in the 2θ ranging from 30–100º of maraging 300 steel with and without laser treatment are shown in Figure 3. Both samples exhibit diffraction peaks due to the martensitic phase α'-Fe, but laser treated sample exhibit additional diffraction peaks related to austenite phase (γ-Fe) at 50.7° and related to Fe_2N/Fe_3N at 40.2°. Similar results are reported by Giacomelli et al. (2021) that have used CO_2 laser to treat maraging 300 steel. Austenite phase formation can be associated to the overaging caused by laser heating (Giacomelli et al., 2021; Reis et al., 2015a), and the iron nitrides are probably associated to the nitrogen gas added during the laser treatment (Giacomelli et al., 2021).

Figure 3. X-ray diffraction pattern of maraging 300 steel (a) without laser treatment and (b) laser treated.



4 CONCLUSIONS

Surface treatment with continuous Nd:YAG laser and nitrogen injection can be used to change the properties of maraging 300 steel, resulting in increased roughness and the formation of nitrides on the surface.

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