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Thermal laser oxidation based texturing as finishing treatment for improving surface properties of UNS R56400

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Abstract

Thermal treatments are commonly applied for modifying surfaces in order to improve their functional behavior through obtaining specific microstructures introducing external elements into alloys or developing coatings, which provide improvements in the surface integrity of the treated samples. Thermal laser treatments allow controlling features and thickness, without affecting the rest of material. In this contribution, the effect of scan speed on changes in the surface integrity of UNS R56400 (Ti6Al4V) laser oxidized samples has been evaluated from the variations of material hardness supplied by the oxide layer. The possibility of microcracks development, mainly derived from the oxides compactness has been taken into account. Taking as reference the tribological behavior of the modified alloy, the objective is to determine the relationship between laser texturing conditions and the improvement of mechanical strength under friction and slip situations.

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Keywords: Surface modification, Titanium alloy, Tribology, Crack growth, Thermal oxidation

1. Introduction

Surface modification treatments allow developing thin layers with specific features and properties over a wide range of materials, increasing the functional performance in harder conditions as currently industry demands [1-3].

Titanium alloys, particularly UNS R56400 (Ti6Al4V), are shown as strategic material set for the development of new technologies in a high diversity of work and research fields such as all the industrial sector, bioengineering or architecture. This peak is mainly due to the fact that this type of material shows very remarkable mechanical properties, high resistance to corrosive atmospheres, and excellent biocompatibility in organic environments [4-9].

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Although titanium alloys maintain a good behaviour at high temperatures, when thermal treatments are developed under non-protective atmosphere, the oxidation of the outer layers is very common. In most cases, oxidative processes on Ti6Al4V alloy result in the generation of an oxygen-enriched surface layer, showing higher concentrations of titanium dioxide (TiO_2) over other present species. Surface oxidation can provide improvements to mechanical properties, such as hardness increased, and play an important role in the modification of features of the affected layer as surface finish, colour tonality, or the resulting tribological behaviour [10-16]. However, aggressive or quick cooling processes may be the cause of instabilities in the development of the modified layer, resulting in a loss of the structural integrity of the alloy and favouring the appearance and growth of microcracks [11,17-23].

Texturing procedures by laser techniques are included within non-conventional finish manufacturing process, especially indicated for supply and/or removal of material. Such processes are among the most used processes for surface thermal oxidation treatments of Ti6Al4V alloy, mainly due to the ability to generate layers of modified material with controlled thickness without affecting highly the remainder thickness of alloy [24-30]. In this aspect, laser texturing parameters such as scan speed rate of the beam (Vs), or the environment (atmosphere under which the treatment takes place) are presented as relevant control variables in the growth of the layer affected by oxidation [31-35]. Also, this type of processes does not generate residues like lubricants or coolants, favouring the environmental sustainability.

Taking as starting point Ti6Al4V alloy samples subjected to different laser surface texturization conditions, the effects of thermal oxidation on the properties and tribological performance of the modified alloy have been evaluated. Variations of treatment intensity and its effects on surface integrity have been examined using scanning electron microscopy and optical techniques. In addition, a study has been carried out about the influence of the texturized effects on the hardness and tribological behavior of the samples.

2. Experimental procedure

2.1. Laser texturing

Thermal oxidation of UNS R56400 titanium alloy surface has been carried out by texturizing using an Ytterbium-fiber infrared pulsed laser system Rofin EasyMark F20. Surface texturizing was performed using bi-directional shading without overlap between displacements, setting the laser treatment parameters as shown in Table 1. This treatment results in the development of parallel straight microgrooves with a spacing of approximately 1.2 mm. By keeping constant the pulse rate and increasing the scan speed of the beam, it is possible to enhance the spacing between points where the energy is supplied, obtaining a different intensity range of treatments, Fig. 1.

Table I. Laser treatment parameters

λ [nm]	**Focal length** [mm]	**Ø Spot** [μm]	**P** [W]	**F** [kHz]
1062	185	60	10	20

Scan Speed (Vs) [mm/s]							
10	20	40	80	100	150	200	250

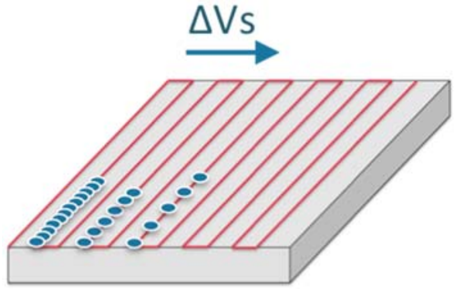

Fig. 1. Scheme of treatment process layout

The thermal oxidation of the alloy is produced when laser melts the outermost layer, being exposed to the introduction of the oxygen present in the air of the atmosphere under the modification treatment is carried out. Due to the reduced incidence depth of the textured technique, the cooling process takes place at following instants of the radiation by laser beam, at the treatment chamber temperature, which normally coincides with ambient temperature.