LASER DEPOSITION OF ALUMINA AND CARBON BLACK ON AISI 4340 STEEL

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ABSTRACT

In the present work, a laser beam was used to cover, with graphite (solid lubricant material) mixed with alpha alumina (α-Al_2O_3), surfaces samples of AISI 4340 steel. The proportion of each component used was 50%, mixed in a planetary ball mill for 2 hours. A CO_2 laser beam of 125 W and 0.2 mm beam diameter was used to irradiate the samples previously coated with the powders. The reduced friction of the mechanical part was confirmed by a tribo-tester in a reciprocal mode. Friction near to 0.15 was obtained with substrate steel hardened to 900 Hv with a ceramics top coating.

KEY WORDS: friction, alumina, graphite, lubricants.

1.- INTRODUCTION

Ceramic coatings are used to protect mechanical parts from thermal or corrosive degradation and could be applied from different methods: arc plasma spray, HVOF and by laser cladding. Laser treatments materials have been applied in a wide range of ceramic and metallic in an attempt to improve its properties [1]. The use of a CO_2, fiber or Nd-YAG laser beam can promote dense coatings metallurgically bonded to the steel substrate. Surface roughness, metallurgical bonding, increased densification, homogenization of alloying elements, fine distribution of precipitated phases are examples of properties modifications achieved by laser treatments, widely reported in the literature. [2-7].

2.- EXPERIMENTAL PROCEDURE

Samples of AISI 4340 steel with a thickness of 3 mm and 20 mm diameter, previously sanded (SIC paper 600), were used. A CO_2 laser with parameters of 125W and beam diameter of 0.2mm was used to irradiate the steel surface samples covered with a mixture of alumina, graphite plus carboxymethyl cellulose (as binder) mechanically mixed for 20 minutes in a plastic container with steel balls (52100) for the homogenization. Subsequently, the solution was sprayed with a pneumatic pistol on the surface of the steel samples, previously heated to 60℃. In the region of action beam on the sample surfaces, it was used a gas flow of nitrogen to prevent oxidation. To sintering the powders on the steel surface, the laser beam was focused on the steel surface.

3.- RESULTS AND DISCUSSION

3-The Figure 1a, presents a sample surface irradiated with 50mm/s and 1b with 150mm/s. With reduced beam energy no fusion of alumina occurs (Figure 1b), with a more smooth coating are produced.

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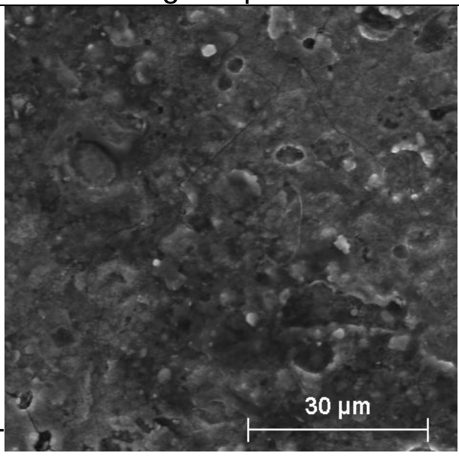

Figure 1a: Surface irradiated with 50mm/s.

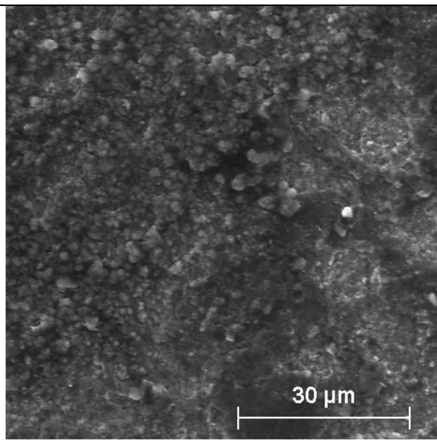

Figure 1b: Surface irradiated with 150mm/s.

The cross section of the sample irradiated with 150mm/s presents (Figure 2a) a regular and dense coating, with some porous near to the substrate surface. The SEM/EDS analyses were performed in the 2a sample (sample treated with 150mm/s). Each element was mapped with a different color, as indicated in the Figure 2b. It can be observed that the iron is present in the coating reaching the surface. The coating was applied only one time. Additional cladding steps minimize surface contamination by elements originating from the substrate [2].

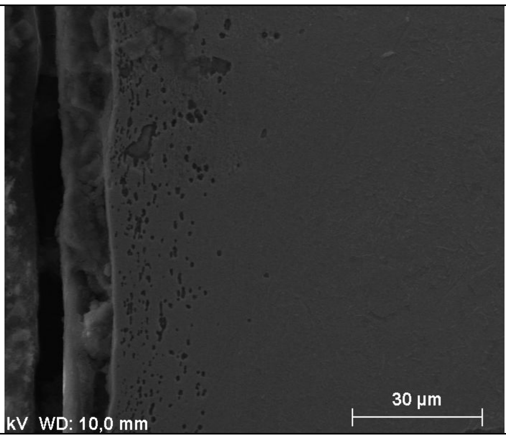

Figure 2a: Cross section by SEM of the coating.

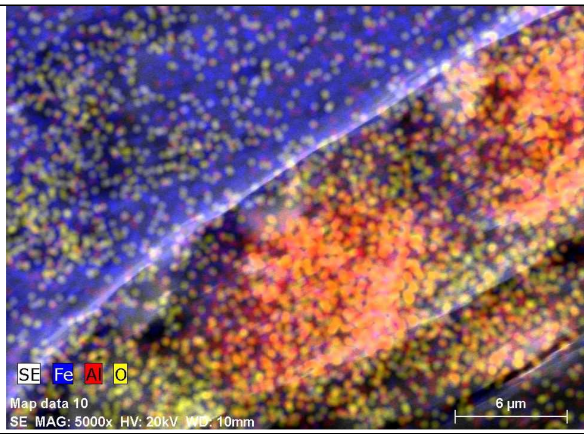

Figure 2b: EDS element mapping on the cross section coating.

To evaluate the phases transformations induced by the laser cladding process, X-ray diffraction of the sample are done and shown in the Figure 3. The substrate material presents ferrite grains (α), with a more pronounced pike near to 45º. The powder diffractogram presents: alumina and carbon pikes. After laser irradiations with 50mm/s, the iron oxidizes and towards to the surface. No carbons phases are noted in the coating surface. When the laser beam energy is reduced, the iron oxide phase is reduced and the carbon in the surface can be observed.

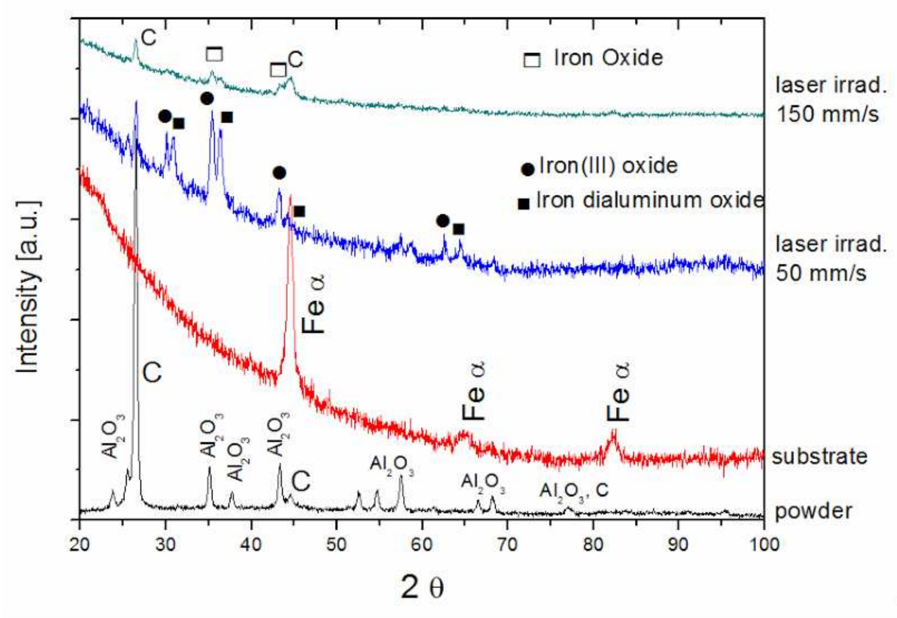

Figure 3: XRD diffractogram analyses for the powder and substrate material in as received and after laser cladding process.

The average microhardness of AISI 4340 steel without heat treatment is near to 300 $HV_{0,05}$. After the alumina-graphite coating cladding with CO_2 laser, we can observe that the hardness of the steel increased significantly, reaching an average of about 760 $HV_{0,05}$. Figure 4 shows the microhardness profile of the cross section of the heated affected zone (HAZ), (under the substrate). These results were obtained by means of microhardness Future-Tech / FM-700. According to the Figure 4, lower laser beam velocities promoted an extended hardened zone. This hardness increase was promoted by the heating and cooling of the sample.

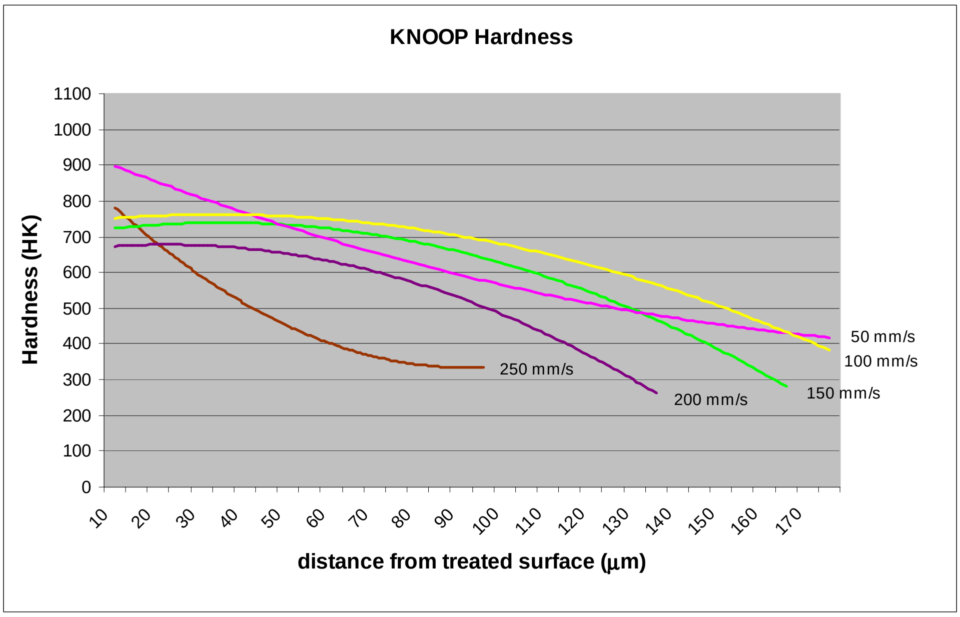

Figure 4: Knoop hardness profile on the cross section sample treated with a CO_2 laser beam in function of the beam velocity.

The irradiated samples were evaluated by pin-on-disc in the reciprocated mode with 5N applied on the alumina ball of 3mm of diameter. The results of the test are presented in the Figure 5a and 5b. A crater of 2micrometer depth and less than 0.15 of friction rate were obtained.

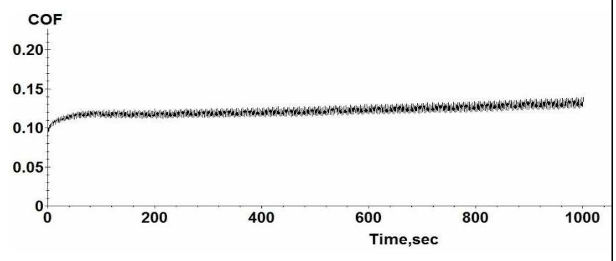

Figure 5a: Friction of sample treated with 50mm/s.

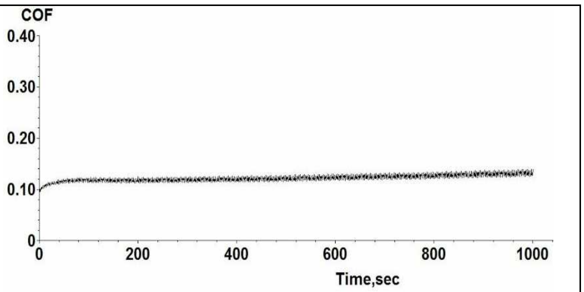

Figure 5b: Friction of sample treated with 50mm/s.

Lower beam velocity (lower energy) promoted reduced friction, which could be associated to the coating smoothness. In the test start there is a lower friction due to the lubrication promoted by weakly adhered graphite powder.

4 - CONCLUSIONS:

The extent of the treated layer, the homogeneity and the microstructure of the coating can be controlled by the laser parameters.

In the tribological test, it was observed that the sample treated with higher beam energy present higher coefficient of friction due the increase in the coating roughness.

Self lubricating coatings associated with the heat treatment hardness can be produced by the laser process.

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