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Covering with Carbon Black and Thermal Treatment by CO_2 Laser Surfaces of AISI 4340 Steel

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1. Introduction

The application of photo-absorbing coatings is a common practice, especially when lasers of low density power are used. These materials normally MoS_2, graphite and carbon black, futher the coupling of incident radiation, reducing the losses by reflection, common to the process, when CO_2 lasers are used as radiation source.

In a previous work, using graphite coatings, it was observed that part of the coating, after irradiation, remained on the metal surface. In pin on disc tests, it was observed a reduction in the coefficient of friction surface with this coating. REIS, J. L., (2009) improvement on the surface hardness, even using laser low of energy density power. This hardenning process was attributed to better coupling in the region of beam interaction with the metal surface. The laser hardening consists in heating and rapid cooling the steel surface. If the power density is enough, a layer on the steel surface will reach the austenitizing temperature (during heating) and then with rapid cooling, place the formation of martensites (Ganeev, R. A., 2002). The depth of the surface treated is determined by the law of thermal conductivity, where the propagation of heat occurs in a region of higher temperature to a region of lower temperature (Benedeck, J.; Shachrai, A.; Levin, L., 1980). The laser hardening allows the hardening of specific areas with controlled depth and with minimal surface deformation when compared to other methods. It also promotes, improves the mechanical properties and fatigue resistance, attraction, wear (reducing the friction factor) and increased resistance to corrosion (Dohotre, N. B., 1998; Machado, I. F., 2006). This work will evaluate the use of carbon black to replace the graphite used in the work of REIS, J. L. 2009, to eliminate the stage of solution preparation, grinding mills at high energy.

2. Methodology

The steel used in this work is AISI 4340. Its chemical composition was assessed by the optical spectrometer Thermo Scientific, Model ARL 3460 OES Metals Analyzer, presented in Table 1.

	Fe	*C*	*Mn*	*Si*	*Cr*	*Ni*	*Mo*	*P*	*S*
Steel 4340	95.79	0.361	0.638	0.261	0.794	1.702	0.221	0.024	0.008

Table 1. Chemical composition of steel AISI 4340 -% mass

Carbon black is formed by fine particles obtained by the process of pyrolysis or partial combustion of hydrocarbon gases or liquids. These nano-particulate structure, favors the coating with thin layers (Sector Report N 09, 1998). The shape of the particles was observed by scanning electron microscopy (SEM), Zeiss / EVO MA10, as shown in Figure 1.

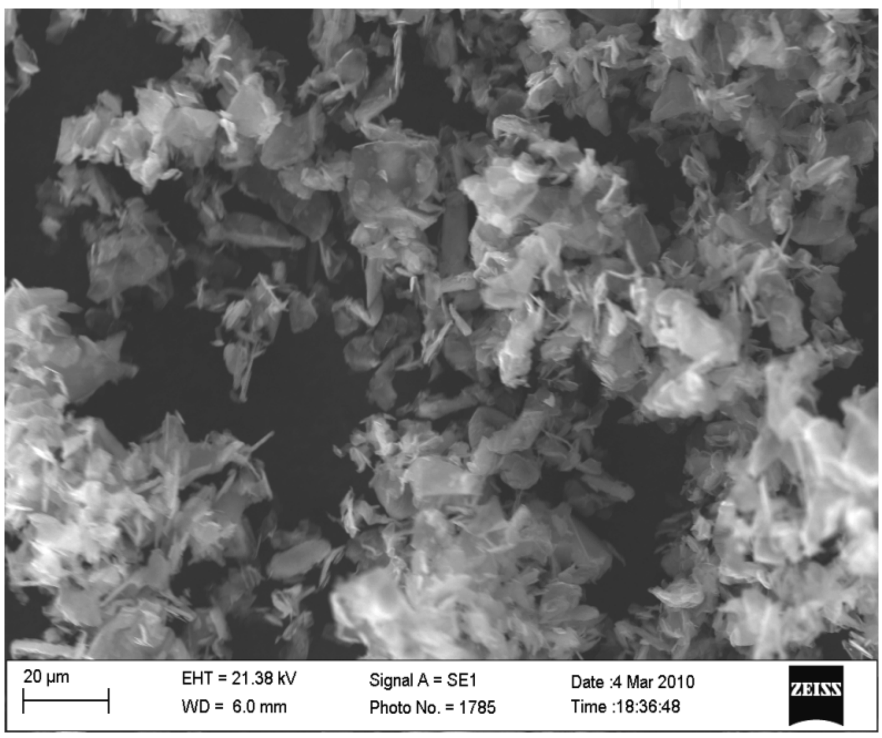

Fig. 1. SEM of particles of carbon black (1320X)

The particle size of the lubricant can influence the thickness of the coating deposited and after irradiation with the laser beam. In order to determine the size distribution of particles, carbon black was subjected to particle size analysis through testing by laser diffraction (CILAS 1064L, range from 0.04 to 500µm). The results of this analysis are presented in Figure 2.

Samples of AISI 4340 steel with a thickness of 3mm and 20mm diameter, previously sanded (SiC paper 600), were coated with a solution prepared with 10g of carbon black and 0.1g of carboxilmetilcelulose in 100ml of ethanol.

This solution was mechanically mixed for 20 minutes in a plastic container with metal balls to the homogenization of the solution. Subsequently, the solution was sprayed with a pneumatic pistol on the surface of steel samples previously heated to 60°C. Then the samples are irradiated with a beam of CO_2 laser (50W) and beam diameter of 300µm. In the region of action beam on the sample surfaces, we used a flow of nitrogen to prevent oxidation. Figure 3 shows the laser used and Figure 4, the diagram of the experimental set up of the treatment process.

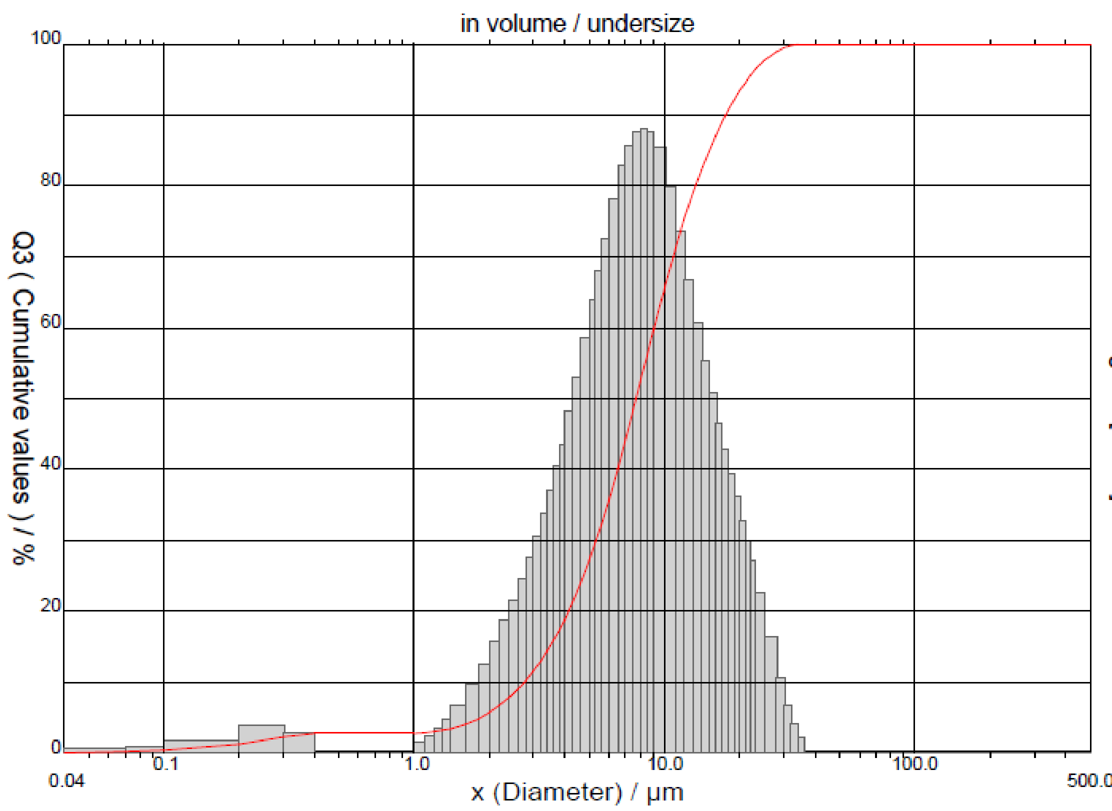

Fig. 2. Histogram of particle size distribution of carbon black.

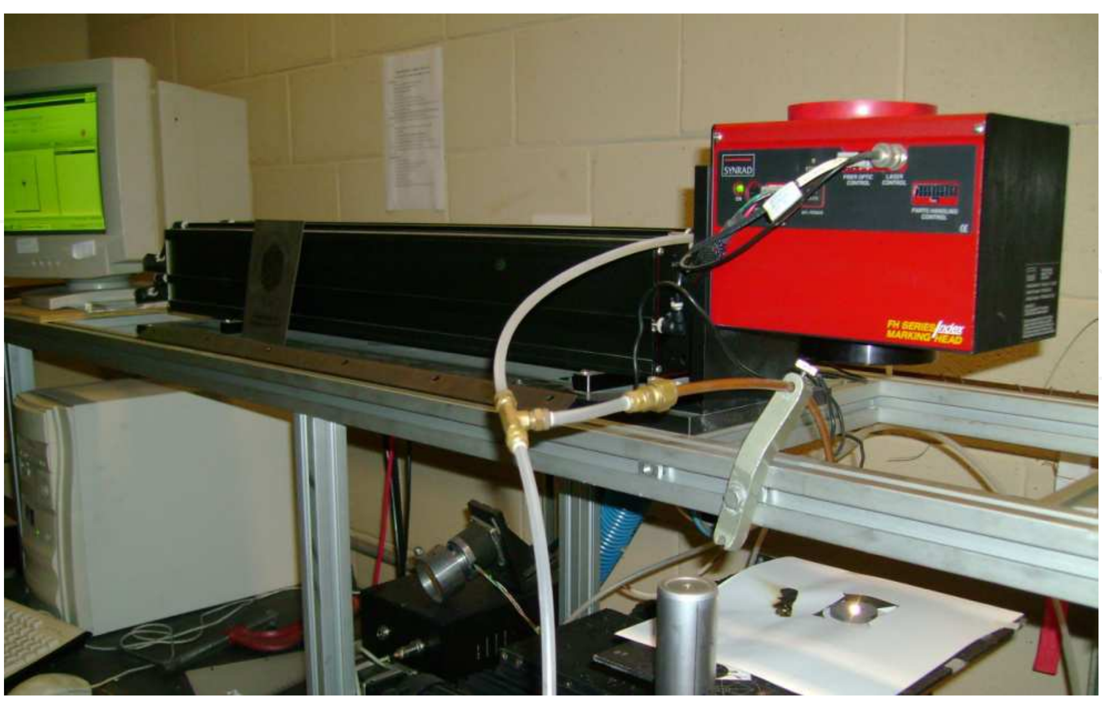

Fig. 3. Experimental set-up. CO_2 laser. Highlighted in red rectangular box, located galvanometric mirrors.

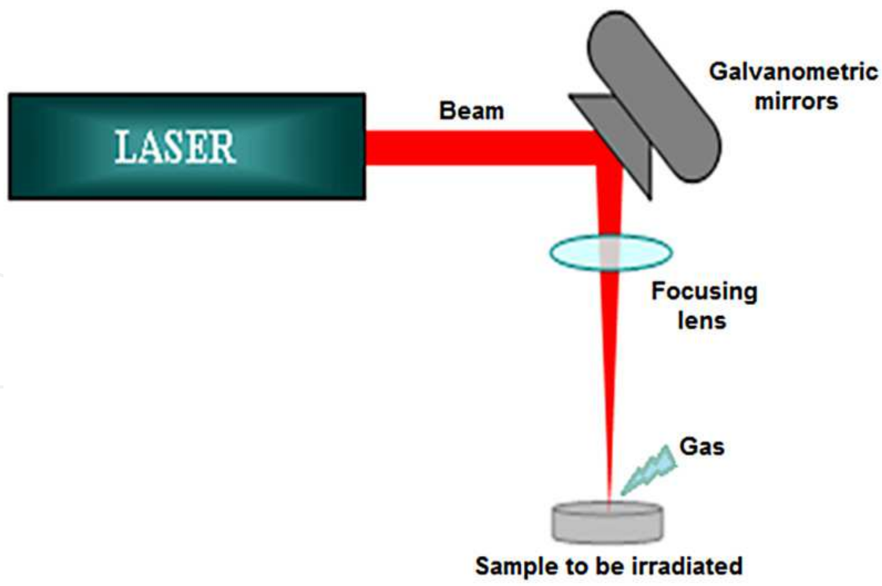

Fig. 4. Fitting of the experimental process. The laser beam is guided by a set of mirrors galvanometric controlled by software

The speed of scanning laser beam (mm/s), the resolution in pulses per inch (ppp) and number of heating cycles (NC) to be used in this experiment were selected from tests previously conducted (Chagas, D. C.; et al 2010). The Table 2 shows the parameters of the laser beam used in the treatment of the samples.

Samples	Speed (mm/s)	Resolution (ppp)	Number of cicles
P1	40	300	5
P2	60	300	5
P3	80	300	5

Table 2. Parameters of laser used for surface hardening of AISI 4340.

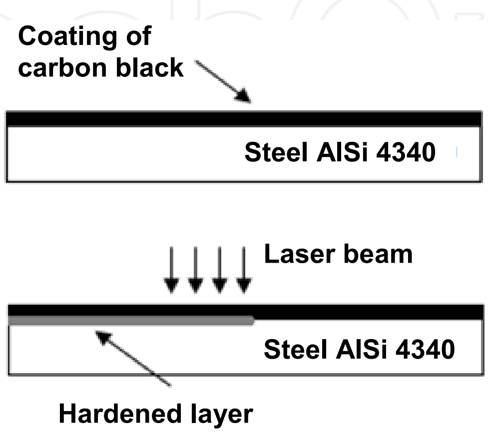

Fig. 5. Illustrates the layout of the treatment process, with laser beam, the samples previously coated with carbon black.

3. Results and discussions

The irradiated samples according to Table 2 were selected one that showed lower surface ablation and greater extension of the layer treated. These parameters were evaluated by measurements of roughness and optical microscopy (OM), respectively. Figure 6 shows a cross section of the treated region of the sample P2.

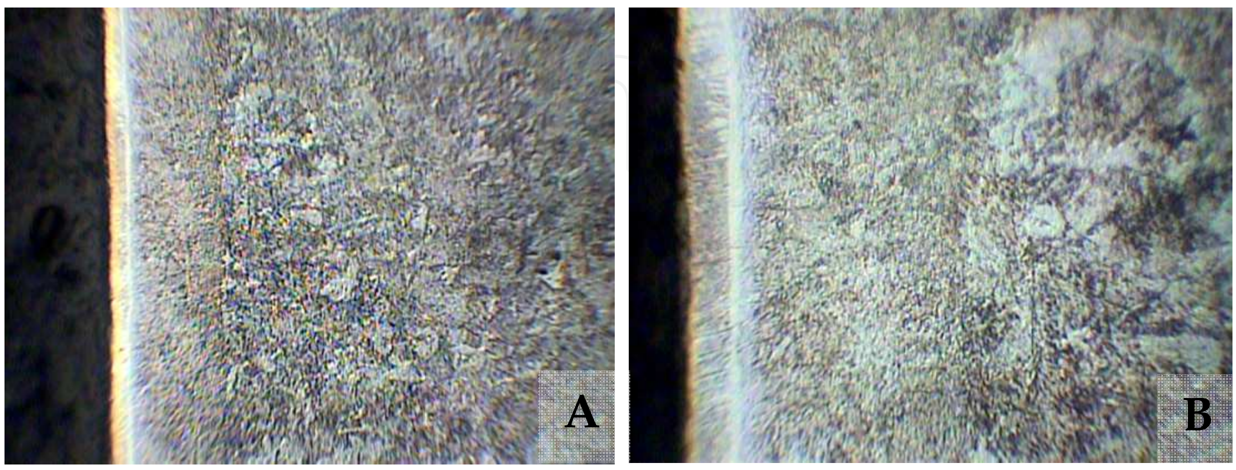

Fig. 6. Cross section of the irradiated surface of the sample P2. Optical microscopy a) OM-200X, b) OM-500X.

The average microhardness of AISI 4340 steel without heat treatment is 286 $HV_{0,05}$. After the thermal treatment with CO_2 laser, we can observe that the hardness of the material increased significantly, reaching an average of about 760 $HV_{0,05}$. Figure 7 shows the microhardness profile of the cross section of the treated region. These results were obtained by means of microhardness Future-Tech / FM-700.

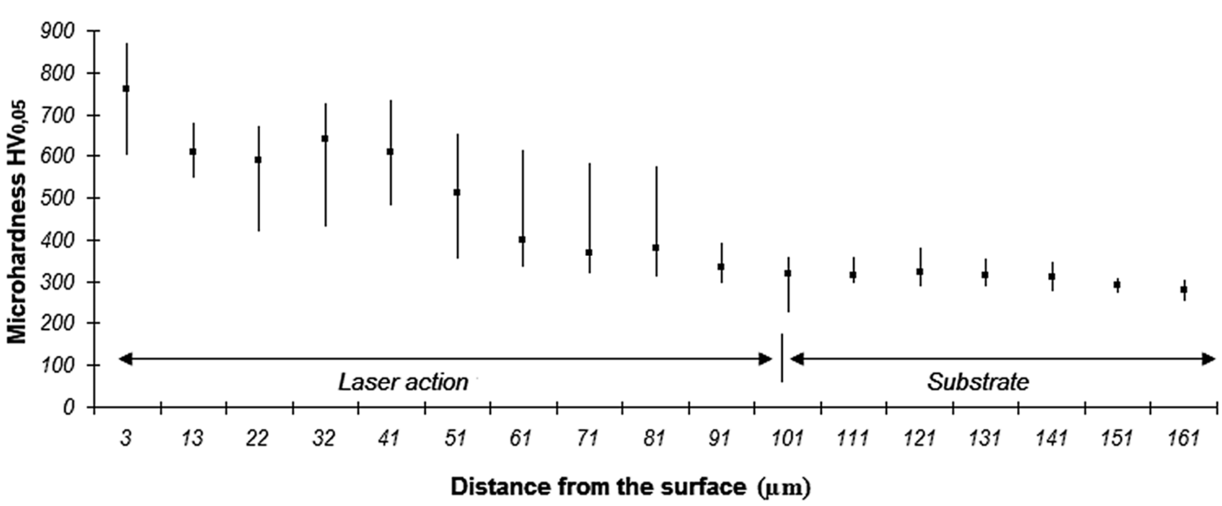

Fig. 7. Microhardness profile of cross section of the treated region after treatment via laser-coated carbon black.

According to Figure 7, there is increased hardness, occurred due to surface hardening process, resulting in heating and cooling of the sample.

The sample was subjected to tribological tests to evaluate the friction coefficient. The parameters used in the test were: linear velocity of 10cm/s, the track radius of 5mm, 52100 steel balls with 6mm diameter, number of rounds equal to 2000 and load of 5N. In this test, the sample is supported on a support rotation and pressed with a steel ball with known load, as shows the scheme of Figure 8.

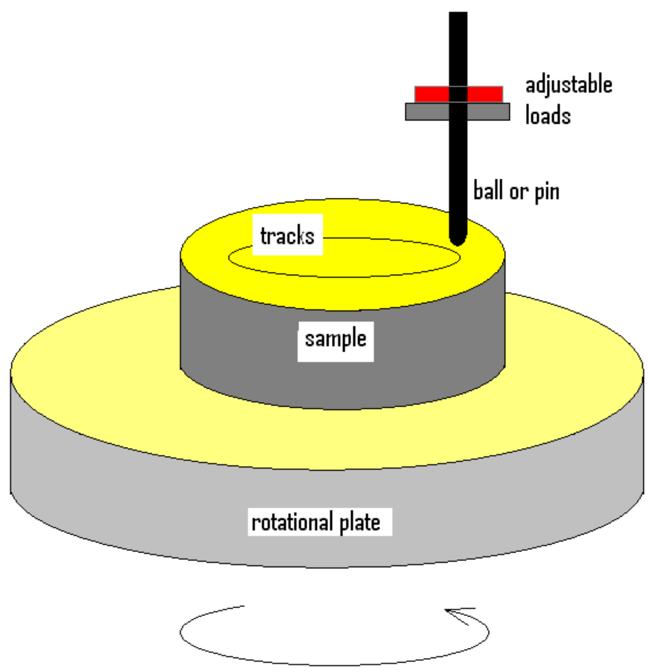

Fig. 8. Schematic drawing of the tribological tests

Then, the sample is rotated to evaluate the friction and the results obtained from the tribological tests, are presented in Figure 9.

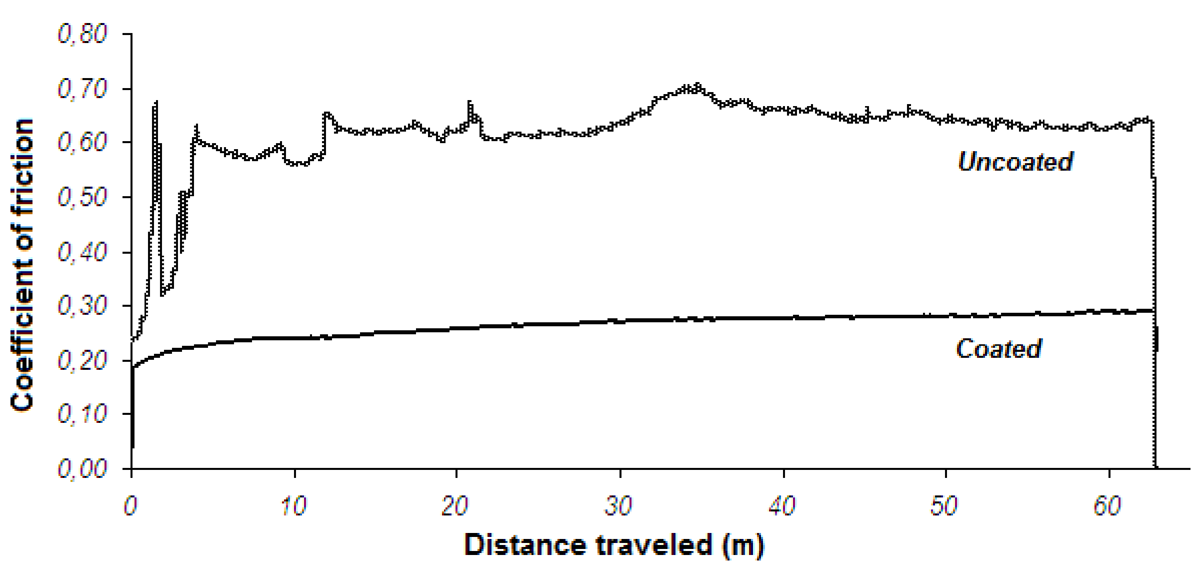

Fig. 9. Results of the friction coefficients of steel ball (52100) in 4340 and uncoated.

The tests of atomic force microscopy (AFM) were performed to evaluate the morphology and surface topography. The results obtained by AFM indicate a possible crystallization of carbon black, coalescence of grains and the appearance of new phases from the process of heating by laser, as shown in Figure 10.

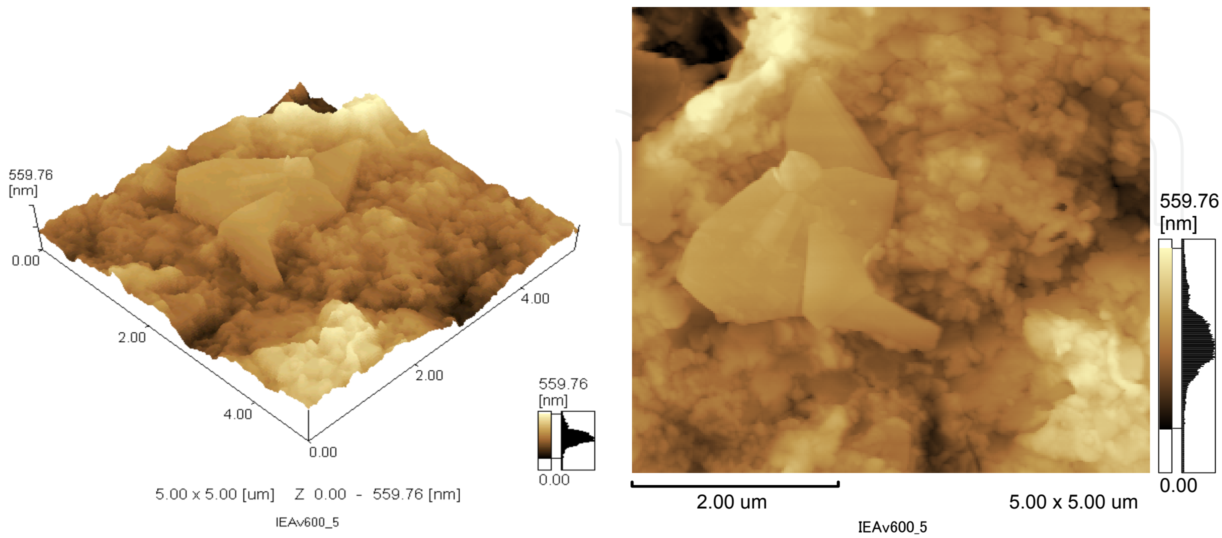

Fig. 10. AFM image obtained by the carbon black surface after irradiation with lasers. The bright spots in the figure correspond to higher regions and the darker the lower regions, according to the scale shown on the right side of the figure.

In roughness tests obtained by AFM, there is heterogeneous across regions with different surface roughness, where in the region obtained a RA= 87.999nm and region B was obtained RA= 124.115nm.

4. Conclusion

The experiments conducted indicate that the use of carbon black is feasible, presenting results of microhardness, friction coefficient, tempera and extent of the treated layer, similar to results reported by REIS (2009), and also eliminates the grinding step, which is required when using graphite.

The use of nanoparticles of carbon black aids in the absorption of radiation incident on steel, influences the alteration of microstructure and promotes surface temperature of the surface and still attached to the steel surface acting as a lubricant.

With the different laser parameters presented, it appears that high rates of speed in the beam of laser irradiation, the steel AISI 4340, showed no significant change in hardness, where the increase in hardness was 268 $HV_{0.05}$ to 405 $HV_{0.05}$. Unlike the lowest parameters that showed a homogeneous microstructure and with greater depths of layers treated, increasing by up to three times the surface hardness of steel, where the increase in hardness was 268 $HV_{0.05}$ to 760 $HV_{0.05}$. The extent of the treated layer, the homogeneity of the steel and its microstructure can be controlled by varying the parameters of the laser.

In tribological test, it was observed that the uncoated sample has a higher coefficient of friction of 0.70 and the samples coated with carbon black and further treated with lasers, have coefficient of friction of the order of 0.20, favoring better properties mechanical equipment and increase the service life.

In the trial by AFM showed that the coating presents heterogeneity throughout the area, with variations in surface roughness in different regions, possible crystallization of carbon black, coalescence of grains and the appearance of new phases resulting from via laser heating process.

5. Acknowledgement

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6. References

Benedeck, J.; Shachrai, A.; Levin, L., 1980, Case hardening of steel by a CO_2 laser beam, Optics and Laser Technology. October.

Chagas, D. C.; Dias, A. N.; Vasconcelos, G.; Antunes, E. F., 2010, Surface treatment and covering by carbon black AISI 4340 by CO_2 laser action, ISSN 1983-1544. Ativ.P&D IEAv, v.3, p.84.

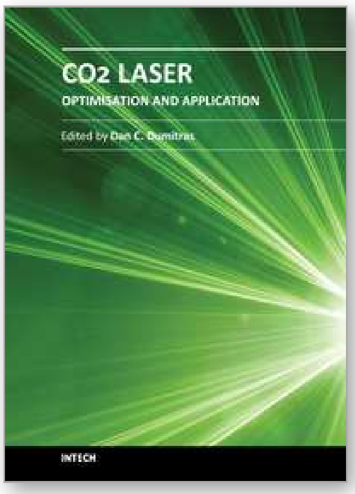
Dohotre, N. B., 1998, Lasers in Surface Engineering: Surface Engineering Series, Volume 1, ASM International – The Materials Information Society, Chapter 1 and 3.

Ganeev, R. A., 2002, Low-power laser hardening of steels, Journal of Materials Processing Tech., 121, 414-419.

Machado, I. F., 2006, Technological advances in steels heat treatment, Journal of Materials Processing Technology, 172, 160-173.

Reis, J. L., 2009, Thermal treatment of AISI M2 Steel by CO_2 Laser, 104f. Master Dissertation in Physics and Chemistry, Aeronautics Institute of Technology, São José dos Campos – SP.

Sector Report N 09, 1998, Chemical Complex, Carbon Black, BNDES.



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