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ASSESSMET OF PARAMETERS VARIATIONS FOR TREATMENT OF CO_2 LASER CARBURIZING OVER AISI 4340 STEEL

Renato Araujo Barros[1,2]
Jean Denape[2]
[1]FEG/UNESP – Faculdade de Engenharia de Guaratinguetá –SP - Brazil
[2]INPT-ENIT/LGP – Ecole Nationale d'Ingénieurs de Tarbes, Laboratoire Génie de Production, Tarbes – France
renatoaraujobarros@gmail.com, jean.denape@enit.fr

Karl Delbé
INPT-ENIT/LGP – Ecole Nationale d'Ingénieurs de Tarbes, Laboratoire Génie de Production, Tarbes – France
karl.delbe@enit.fr

Antônio Jorge Abdalla
IEAV/DCTA – Instituto de Estudos Avançados, Departamento de Ciência e Teconologia Aeroespacial, Divisão de Fotônica EFO-O – São José dos Campos - Brazil
abdalla@ieav.cta.br

Humberto Lopes Rodrigues
FATEC – Faculdade de Tecnologia e Ciências – Pindamonhangaba - Brazil
humberto@feg.unesp.br

Rennan Pereira Gama
FEG/UNESP – Faculdade de Engenharia de Guaratinguetá, SP, Brazil
renann.gama@hotmail.com

Abstract. *This study evaluated the best parameters for the carburizing treatment using a CO2 laser of low power over an AISI 4340 steel previously subjected to heat treatments of quenching and tempering. The coating process used is a liquid dispersion of carbon black in ethanol and carboxyl methylcellulose. The laser power was kept constant at 125 W and the resolution is 600 dots per inch. The variable parameter of CO2 laser was the speed. Two speeds were selected for the coating preparation: 1200 and 2000 m/s. After treatment, metallographic preparation and optical microscopy observation were performed in addition to the evaluation of parameter variations through hardness measurements and microscratch tests. Laser speed of 2000 m/s provided the best results reached, what is related to a better quality of coated zone, as a result of better carbon deposition on the surface.*

Keywords: *AISI 4340 steel; surface treatments; laser carburizing; microscratch tests.*

1. INTRODUCTION

The carburizing or coating with low-power CO_2 LASER improves the properties of steels wear and corrosion through changes in the surface layer by applying the coating obtained by heat treatment or located by depositing a layer of new materials to give the desired properties.

Improvements in mechanical strength and chemical resistance are very important to increase durability of this alloy , and so improve the quality of the products of companies that work with AISI 4340 steel (REIS, 2009; CHAGAS, 2010).

2. THE SURFACE LASER TREATMENT

The hardening via laser processing consists in heating the surface below the melting temperature to produce a phase transformation in the solid state without changing the substrate. The energy absorbed by the material is transformed into heat in a short time and when the heat source is removed, a hard phase is formed in the area heated by self-quenching.

In LASER quenching the power source which promotes the heating of the part is a LASER radiation incident on the sample surface. In this case, when the LASER beam reaches the surface of the material part of the radiation is transmitted from this, a second part is absorbed and a third is reflected. The absorbed part is responsible for the heating of the surface as shown in figure 1 (CHAGAS et al, 2012).

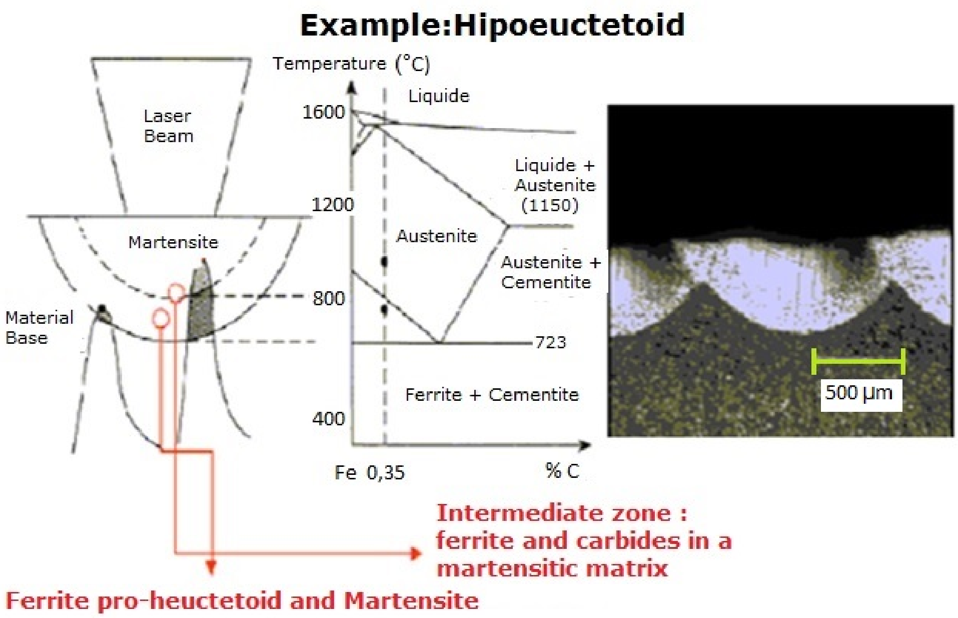


Figure 1. Diagram of a surface via LASER heating process. (CHAGAS et al, 2008)

When the LASER beam hits the sample its surface is heated and the heat starts to be transferred by conduction to the material. The heating is extremely fast to austenitizing temperatures, due to the concentration of energy in thin layers and cooling due to the surrounding cold layers. Because of this feature there is therefore the need to use a cooling fluid, causing a self- quenching.

The time of beam 's interaction with the surface should be sufficient to achieve temperatures above 727ºC , without however allowing the liquid phase of onset, and a period of time sufficient for the occurrence of the diffusion of carbon from cementite plates for the ferrite . After this period, there is a rapid cooling by transferring heat to the volume of the part not affected by the heat, causing the martensite and avoiding the precipitation of other phases such as bainite and pearlite.

The depth of the heat treated region is determined by the laws of heat conduction. The surface temperature increases at a rate proportional to the square root of the residence time and heat penetration distance into the workpiece is also proportional to the square root of the residence time. Therefore, the temperature and the incidence of the LASER dwell time on the surface affects the level of hardness. The depth of penetration can be precisely controlled by adjusting the parameters of the LASER beam (BENEDEK et al, 1980).

The effects that occur on the surface of the treated material is the basis for the development of numerous methods of surface treatment LASER materials, improving the performance of components and machines. All of these methods depend on both the radiation used, such as the mechanism by which radiation interacts with the material.

The interaction LASER / surface material depends on the ability to absorb the energy corresponding to the wave length and the interaction time between the LASER and the substrate.

All steel castings and irons that are curable by conventional methods also are by LASER. Although the transmission time for carbon is extremely short, steel and cast iron with a fine and homogeneous distribution of carbon are more suitable for LASER treatment.

3. CO_2 LASER

The CO_2 LASER is efficient (10-15 %) and strong, and can be operated in continuous or pulsed, depending on the device (DESTRO, 2009).

Its applications vary as the power levels of up to 15 kW. When the gas mixture contains parts of N_2 and He, a higher power output beam can be achieved as compared with the free equipment such addition (ASSUMPÇÃO, 2001).

Carbon dioxide LASER (CO_2) is the most important of gas LASERs and provides continuous power ranging fraction of a watt to tens of kilowatts for applications in materials processing in a large number of wave lengths contained in the track 9,6 to 10.6 microns due to transitions between rotational - vibrational levels of the CO_2 molecule.

4. MAIN PARAMETERS OF LASER

Because of the wide variety of LASER machines, with each having its own constructive characteristics, it becomes extremely complex define a general configuration of operating parameters that can be applied broadly. Therefore, this study focus to determine the best LASER parameters for the continuous formation of carburized layers. In this case, the main variables of the process LASER are (SOARES, 2005):

4.1. LASER power

The power is related to the behavior of the LASER beam that can be continuous or pulsed and whose influence on power is described below:

Effects of continuous power - In a continuous LASER power it is possible to control the output power. From the moment it walks in operation, the LASER power rises linearly to a power setpoint P. There are two main problems in this type of LASER: a deep penetration or lack of penetration. The maximum processing speed for a given thickness increases with the increase of power. The depth of treatment is inversely proportional to speed for a given mode , focus diameter size , and power.

Effects of pulsed power - for a LASER type pulsed the average power is lower than that of a continuous LASER power because power depends on the pulse duration and interval between pulses. The use of pulsed power allows for two variables: pulse repetition frequency (PRF) and percentage of coverage, which are factors that should be considered. The treatment rate vs. power is determined by the relationship between the size of the focal point, the PRF and the percentage of coverage. In this case, the speed is independent of the power. In the other hand the depth is power function. However, a much higher power will cause evaporation and ejection material and even perforation, if the sheet is thin. Regardless of the type of LASER, the average output can be controlled electronically and be conditioned by the type of LASER operation if so required.

4.2. Beam Scanning Speed

The effects of the LASER beam on the scanning speed processing are described primarily by the overall heat balance equation. But beyond these main effects there is a few others. First there is the beam velocity effect on the track at high speeds of which there is low penetration and low, evaporation material , and secondly there is the problem of shielding gas on the track at high speeds, because from a certain speed value protection may start to lose their efficiency by not follow the displacement of the beam .

4.3. Resolution (number of LASER pulses per unit area)

Another parameter that influence the LASER heat treatment is the resolution of the scanning beam. Resolution is given in numbers of LASER pulses per inch (ppi).

5. EXPERIMENTAL PROCEDURE

In this work, the following steps were taken to arrive at the final result: cutting the starting materials, sample preparation by sandpaper with a particle size of 600 mesh, CO_2 LASER treatment and characterization of the samples after 2% Nital etching.

The graphite solution was prepared with 10 g of graphite and 0.1 g of carboxymethylcellulose (CMC) in 100 ml of ethanol. The addition of CMC aimed to increase the green strength of the deposited layer. The solution was stirred for 30 minutes in a planetary ball mill with steel balls for homogenisation of the solution.

To make the surface of the steel coating it was used a spray gun of compressed air seeking the homogeneity of the mixture for the layer to be deposited. For better adhesion of the carbon black on the surface of the previously sanded samples was necessary to heat them to a temperature of about 60 °C. Soon after, with the aid of the spray gun made to spray graphite solution on the steel surface. The layer to be deposited must be homogeneous and not very thick, the metal surface must not be visible. The alcohol evaporates and leaves the graphite in the presence of CMC, forming a thin film to LASER irradiation. For a homogeneous layer it is necessary to be careful when handling compressed air gun, triggering with the same intensity and going at the same speed on the samples.

5.1 CO_2 LASER irradiation

The LASER used for the irradiation of the surfaces of the samples is a CO_2 LASER with an output power of 125W, diameter of the beam of 300μm and nitrogen flow to act as a protective layer on the irradiated layer, preventing oxidation (GANEEV, 2002 and LAVRAS, 2006).

The irradiation of the samples were performed by varying parameters in search of better parameter for the formation of the coating. The main variables to be studied in search of the best parameters are:

• Speed: it is the speed at which the LASER move over the surface. For this study, the speeds used were 1200 and 2000 mm/s.

• Resolution: determines the quality. The resolution is expressed in dots per inch (dpi). The higher the number of points corresponds to higher resolution. It was used 600 dpi.
• LASER Beam Diameter - 0.2 mm.

The LASER power was varied from 20 % to 100 % (250 W) due to preliminary studies wich showed that 50 W is the ideal power for heating the steel to the austenitizing temperature (REIS, 2009).

During irradiation the LASER beam moves over the surface of the sample, controlled by galvanometric mirrors, generating wide tracks and controlled thickness by a computer program.

The steel samples of AISI 4340 were irradiated with different values of the LASER beam scanning speed.

At last, in order to compare different conditions of coating, observations of the coated areas were performed through optical microscopy, scratch tests and their assessment by binocular microscopy.

6. RESULTS AND CONCLUSION

Observations of polished cross sections show that treatment produce a multiphase region successively composed of a superficial coated zone (CZ) with a high content of carbon and iron (carburized layer), a zone of interaction (ZI) affected by carbon diffusion and a heat-affected zone (HAZ). The laser treatment performed at a speed of 1200 m/s provided a greater inhomogeneity for the CZ (Fig. 2a) than the treatment carried out at a speed of 2000 m/s (Fig. 2b). The carburized layer presents Vickers hardness values in the order of 800 HV, much higher than the metal base (MB), 300 HV and the HAZ, 500 HV.

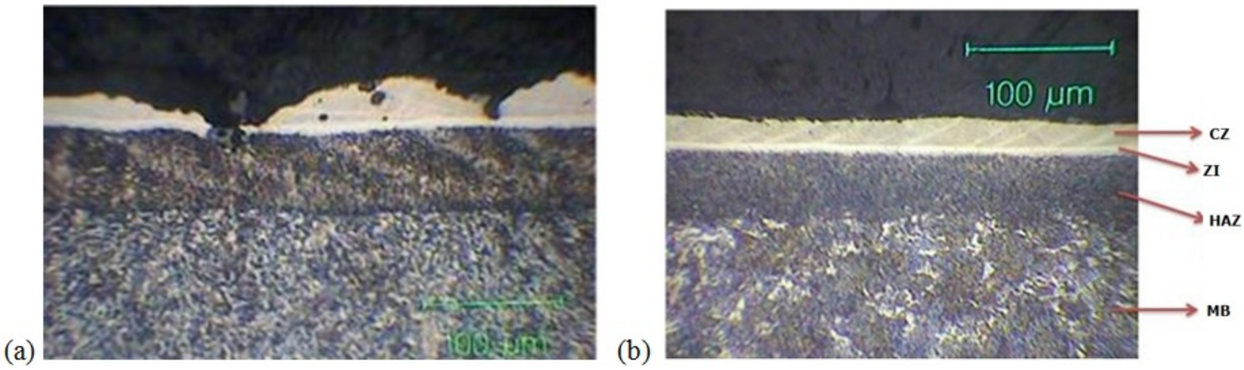


Figure 2: Polished cross section of AISI 4340 steel substrate with a carburizing treatment using a CO2 laser treated at 1200 m/s (a) and 2000 m/s (b), showing different layers of treated surface: Coated Zone (CZ), Zone of Interaction (ZI), Heat Affected Zone (HAZ) and Metal Base (MB).

The scratch tests were realized using a Vickers slider over a distance of 5 mm at a constant sliding speed of 30 mm/min. Three progressive loading conditions were carried out: from 0 to 5 N, from 0 to 10 N and finally, from 0 to 20 N.

Low friction coefficients close to 0.1 are recorded, independently of load, but treatments performed at higher laser speeds show a greater stability (Fig. 3). The groove width and depth as a function of load was measured with optical profilometry along the sliding distance, in order to detect the appearance of the substrate on the groove base.

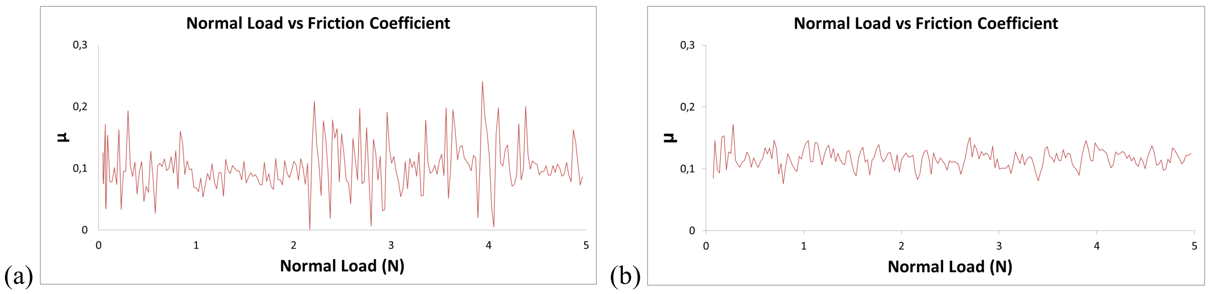
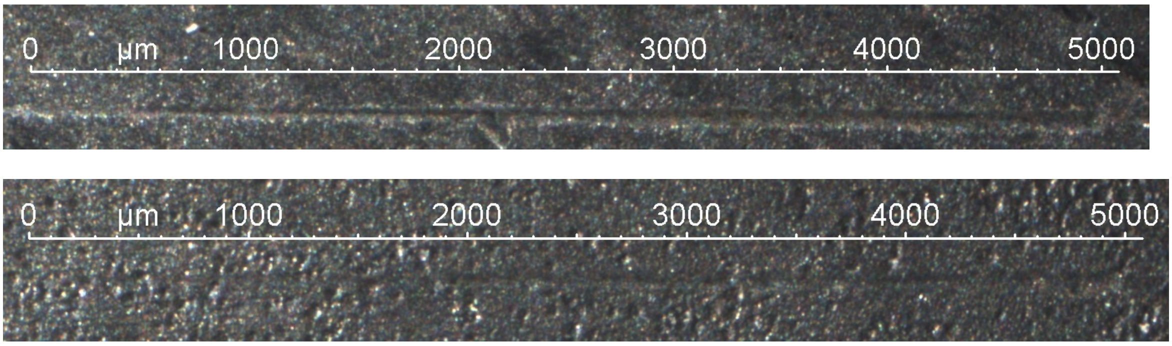


Figure 3: Friction coeficient as a function of normal load for samples treated with a laser speed of 1200 m/s (a) and 2000 m/s (b)

Finally, optical observations of the tracks reveal the damage changes during the sliding. For similar tests, with the same progressive normal load, the dimensions of the wear track look bigger for a coating prepared at a speed of 1200 m/s than at 2000 m/s. Deformation of the coating is the main accommodation mechanism, whatever the loading level, indicating a lack of the coating adhesion (fig. 4).



(a)

(b)

Figure 4: Comparison in detail between scratch morphologies after microscratch tests of the surfaces treated at speed of 1200 m/s (a) and 2000 m/s (b). Normal load is progressivly increase from left to right.

Indeed, the laser speed of 2000 m/s provided the best results reached. This may be related to a better quality of coated zone, as a result of better carbon deposition on the surface.

7. ACKNOWLEDGEMENTS

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