The Effect of Laser Surface Melting on the Microstructure and Mechanical Properties of Low Carbon Steel

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***Abstract*—**The paper presents the results of microhardness and microstructure of low carbon steel surface melted using carbon dioxide laser with a wavelength of 10.6μm and a maximum output power of 2000W. The processing parameters such as the laser power, and the scanning rate were investigated in this study. After surface melting two distinct regions formed corresponding to the melted zone MZ, and the heat affected zone HAZ. The laser melted region displayed a cellular fine structures while the HAZ displayed martensite or bainite structure. At different processing parameters, the original microstructure of this steel (Ferrite+Pearlite) has been transformed to new phases of martensitic and bainitic structures. The fine structure and the high microhardness are evidence of the high cooling rates which follow the laser melting. The melting pool and the transformed microstructure in the laser surface melted region of carbon steel showed clear dependence on laser power and scanning rate.

***Keywords*—**Carbon steel, laser surface melting, microstructure, microhardness.

I. Introduction

CARBON dioxide lasers are increasingly being used in the steel industry for surface modification such as surface melting, alloying, and cladding [1-8].

Laser surface melting leads to alteration in the local microstructure as a result of the rapid solidification which follows the laser scan [1], [2]. These changes in the microstructure are accompanied by changes in the properties such as microhardness, and corrosion resistance. Under suitable conditions, laser surface melting can be used to improve significantly the chemical and mechanical surface properties, but maintains unchanged material bulk properties, including ductility and toughness [1-8].

Laser surface melting of steels to improve surface hardness using a high power continuous laser has been reported previously [1], [2]. The Laser scanned surface was shown to result three distinct regions: the melted zone (MZ) consists primarily of fine grained martensite, the heat effected zone (HAZ) composed of coarse martensite containing retained soft austonite, and substrate (ferrite and pearlite) [1], [4]. Microhardness tests revealed that a higher microhardness than that of the original matrix.

In the present work, the microstructure and microhardness of low carbon steel after surface melting with scanning continuous wave CO_2 laser have been studied. The parameters investigated were laser power and scanning rate velocity.

II. Experimental Setup

Several specimens of low carbon steel dimensions were (10mm × 20mm × 30mm) of composition (in wt %) 0.18% C, 0.25% Nb, 0.19% Si, 0.78% Mn, 0.04%, Mo, 0.008%W. The received carbon steel composed of ferrite and pearlite and its hardness was 160 HV. Laser surface melting of the prepared sample were carried out using a CW CO_2 laser having a maximum power of 9 kW. The laser diameter of 2mm was directed perpendicular to the surface of the specimen. The laser power was varied from 800W to 2600W and a linear velocity was varied from 80mm/min to 200mm/min. Argon used as a buffer gas with flow rate of 1500 lit/hr during laser surface melting. Standard procedures were used to prepare metallographic specimen. Microstructure in the transverse section of the processed material was analyzed using optical microscope. The microhardness was measured on Vickers scale, loading the sample for 10s with 300g.

III. Results and Discussions

The laser surface melting of carbon steel led to the formation of melted zone MZ and the heat affected zone HAZ. Microstructures of the two distinct regions are as shown in Fig. 1(a), 1(c).

From Fig. 1(b) it can be seen that the melted region displays fine cellular structure, the inner region being martensite. Therefore the high cooling and the solidification rates which characterize the laser melting are consisting with the fine cellular growth and the formation of martensite in this region.

Accompanying the melting and solidification was heating and quenching of the regions adjacent to the melted zone. Transformation that occurred in these regions took place in the solid state. The rapid heating and quenching of the melted zone and the original matrix led to the formation of HAZ [1], [2], [4]. Fig. 1(c) shows interface between HAZ marked by pearlite colonies below and martensite grains above the substrate. The formation of martensitic structure in HAZ was

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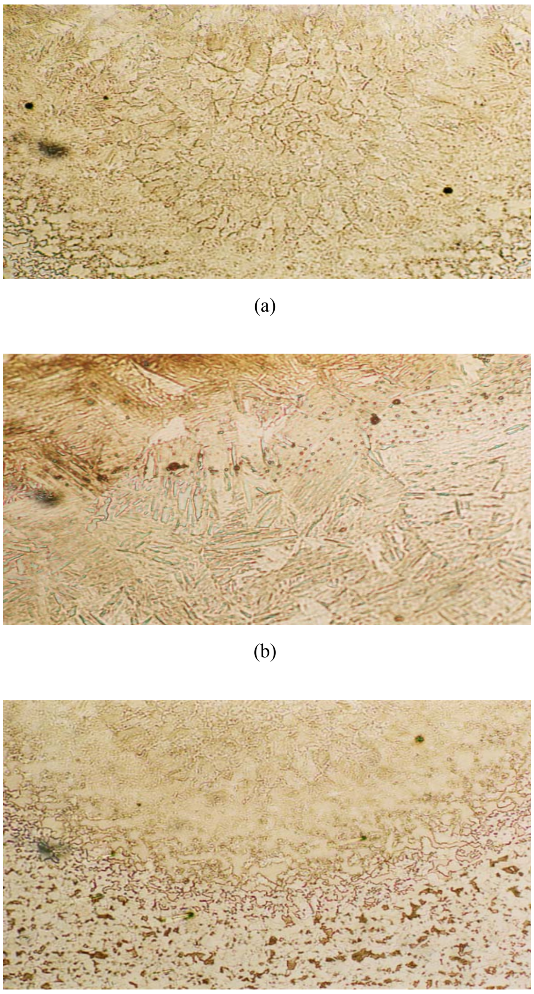
because of heated region during laser surface melting to the austenitic phase quenched thereafter [1], [2], [8].

The laser melting power and laser beam scanning rate have an observed affect on the microstructure and microhardness of steel. The depth of the melting pool increase with increasing power and with decreasing scanning rate. Increasing the scanning rate (decreasing the interaction time) at constant laser power produced finer microstructure in the melting zone, due to the increase in cooling rate as the laser beam passes the melted area. The microhardness Vs the depth plotted in Fig. 2 of laser surface melted carbon steel with different laser processing power but scanned at the same speed.



(a)

(b)

(c)

Fig. 1 Optical micrographs of laser surface melted carbon steel. The laser power in (a), (b) P=2000W and P=1000W in (c) The scanning speed v=200mm/min

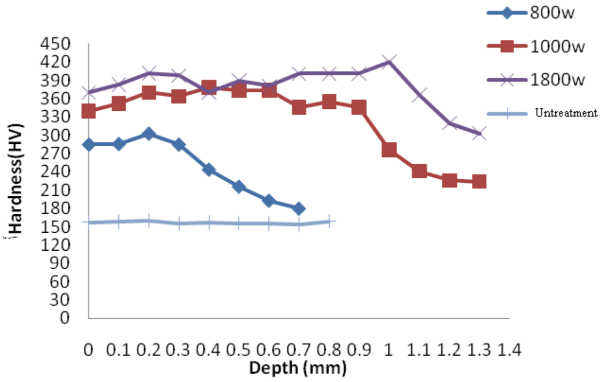


Fig. 2 Microhardness profile of the laser surface melted low carbon steel with different laser powers (v =200mm/min)

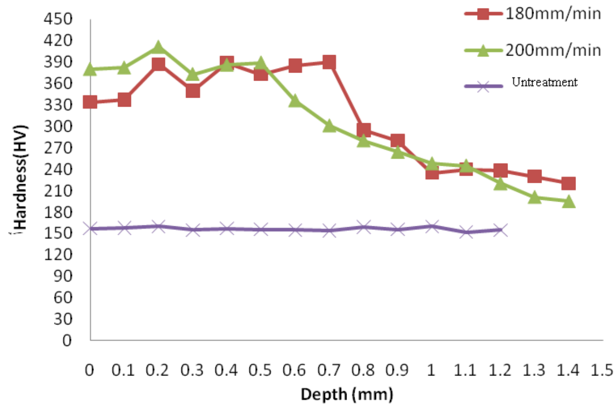


Fig. 3 Microhardness profile of the laser surface melted low carbon steel with different laser scanning rates and constant power (P=2000W)

For higher melting power the microhardess values and the melt pool are increased. In the HAZ the microhardness decreased from high values in the melted zone to relatively of the original matrix. As a result of the change in the microstructure from the fine microstructure in the melted zone to the relatively coarse microstructure of the original matrix[1-6]. The microhardness profile in Fig. 3 of laser surface melted at power of 2000W but with different scanning rate. The specimen irradiated at high scanning rate (200mm/min) was melted to a depth of 0.5mm. The specimen irradiated at lower scanning rate (180mm/min) was melted to a depth of 0.8mm. The sample surface hardness scanned at higher scanning rate (200mm/min) was higher the sample melted at (180mm/min).

IV. Conclusion

In this work the microstructure and microhardness of laser surface melted low carbon steel using CW CO_2 laser were studied as a function of the laser power, and scanning speed. Two distinct zones revealed in the melted surface are the melted zone MZ and the heat affected zone HAZ. The melted zone displayed a cellular structure the inner region being fine martensite. Microhardness showed significant enhancement in the average surface microhardness. However non-uniformities in microhardness were observed and wee related to the local microstructure. Changes in experimental the parameters of laser power and scanning speed caused changes in the microstructure and microhardness. The Optimal conditions for or laser surface melting of carbon steel are high scanning speed and relatively high laser power.

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