The Effect of LSM on the Microstructure and Corrosion Behavior of St-37 Low Carbon Steel

Sami I.J. Alrubaiey, Hussein S.A. Fakhar

***Abstract*—** The microstructure of st-37 low carbon steel is studied after and before laser surface melting (LSM) . Nd:YAG laser was used . Different laser energies are used (1.54,1.68,2.01,2.33) J .The energy of laser has more effected on the microstructure of the used steel. The pearlite grains in the pool zone become finer in size.

Low carbon steel st-37 , which used in this study was treated by LST using Nd:YAG laser , pulse mode. The aim of this work is to study the effect of LST on the microstructure and corrosion resistance of low carbon steel.the results of the corrosion behavior of treated specimens by Laser shows that some improvement in corrosion current density and corrosion potential are occurred. The results of the corrosion behavior of treated specimens by Laser shows that some improvement in corrosion current density and corrosion potential are occurred.

***Keywords*—** Low carbon steel ,corrosion, Nd:YAG laser ,Microstructure. , Ferrate, Pearlite..

I. INTRODUCTION

The corrosion resistance of metals and alloys can be govern by surface properties. The microstructure and/or composition of the surface are tailoring by some surface treatment. Laser surface treatment (LST) is consider one of new technology, which improve corrosion resistance [1]. In work [2] it was found that Laser surface melting improved also the pitting corrosion resistance of 304 stainless steel , when it had been treated at different Nd:YAG laser power density 850,1132,1415,1698,1981W/mm2. This improvement attributed to the formation of delta ferrite in the γ-matrix .

On the other hand ,this technology is favorite compared with the conventional heat treatment, because the later required high heat input and heating all the surface ,which often leads to distortion or deformation [6]. LST mostly used to produce new microstructure on the localize regions on the specimen with retaining the bulk microstructure unaffected. In work [7] reported that , The change in the laser power and scanning speed will cause changes in hardness and microstructure. LST led to refine and homogenize microstructure of low carbon steel st.37.

The treated structure by LST can be divided to three zones [3]: melted zone (MZ),consists of primarily fine grained martensite phase, heat effected zone (HAZ) consists of coarse martensite containing retained austinite, and the substrate which is (ferrite and pearlite) phases. In the research [1],. The results conform the presence of circular Plates of martensit in the upper part while bainitic structure was found in ferrite grains. With increasing scanning speed , the depth of the treated zone decrease. Furthermore ,the scanning speed has direct effect on the length of circular martensite which is more in length and fine circular martensite at lower scanning speed.

The aim of this work is to study the effect of LST on the microstructure and corrosion resistance of low carbon steel

II. EXPERIMENTAL WORK

Specimens of low carbon steel (St-37) within dimensions (15 length*15 width*6 thickness) mm are prepared by using wire cutting machine. The chemical composition of the used specimens show in table

TABLE I
CHEMICAL COMPOSITION OF USED STEEL ST-37

C%	Mn%	Cr%	Ni%	V%	Al%	Cu%	Fe %
0.131	0.432	0.010	0.032	0.002	0.038	0.020	Bal .

The microstructure of the specimens were examined by using optical microscope type (A. Kruss Optronic GmbH), the specimens at first grained within SiC papers (180,320,600,1000,3000) and polished within Alumina (Al2O3) solution then etched in Nital solution to investigate the microstructure of low carbon steel. Nd:YAG laser -pulse mode (made by Han's laser technology Co.,Ltd. Model Number :PB80) is used .Different laser energy had been used(1.54,1.68,2.01,2.33)J at pulse duration 1.2 ms and the peak power are(1.0,1.1,1.3,1.5)KW . The pulse diameter 0.767mm . Prior to LSM , the specimens were grinding with 180-paper grit SiC then the specimens were treated by Laser .After laser treatment , the microstructure is investigated for each laser energy.

The corrosion behavior was studied by Tafel extraplotation technique, using potentialstate type MLAB 200. The polarization cell consists of working electrode (low carbon steel), reference electrode (Calomel) . The lugging probe was kept at distance of 1 mm from the surface of working electrode, and PLATINIUM (AUXILIARY ELECTRODE), THESE electrodes were connected to a computerized potentiostat (Bank Electronics 200- German made). The solution of corrosion test was 3.5 %NaCl solution. The corrosion test

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with microstructure examination are performed before and after LSM treatment for each value of laser energy

III. RESULTS AND DISCUSSION

The microstructure of as received low carbon steel is consist of ferrite and pearlite as shown in Fig.1.

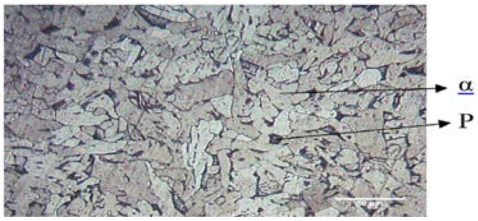


Fig.1 Microstructure of as received low carbon steel st-37.

The microstructure would be change after laser surface melting by using Nd:YAG laser , The new microstructure depends on the power of LSM as shown in Fig.2.

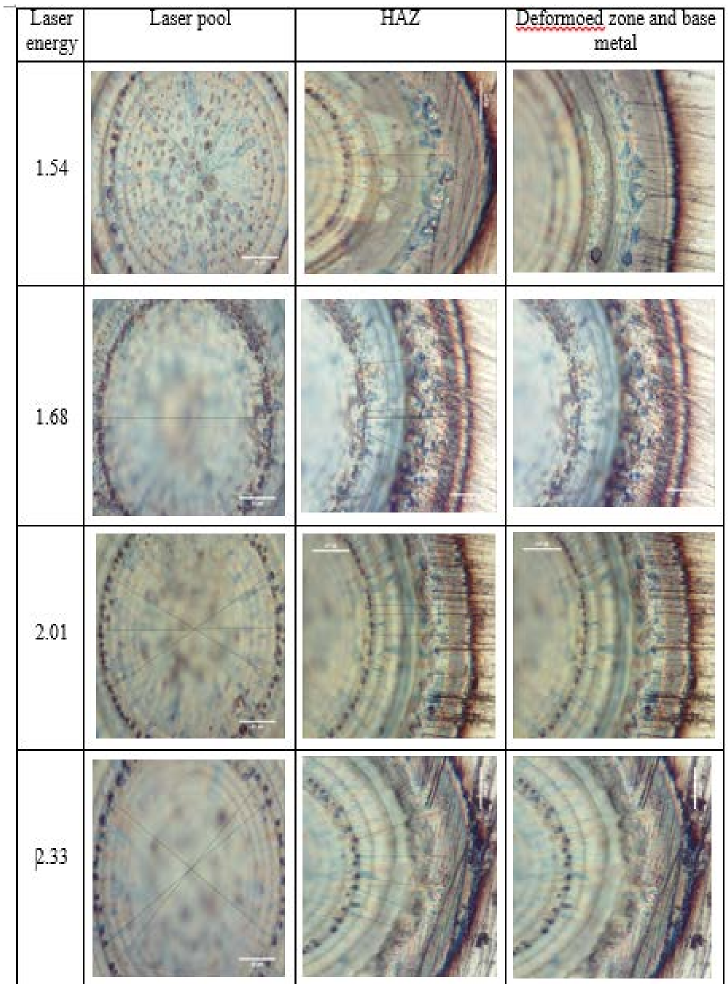


Fig.2 Microstructure of four zones after laser treatment

After LSM four zones were founded (melted zone, HAZ, deformed zone &base metal).

The width of these zones shows in Table II .

TABLE II
THE WIDTH OF DIFFERENT ZONES AFTER LASER TREATMENT

Spiecmen No.	Energy(J)	Width of diffusion zone(μm)	Width of HAZ (μm)	Width of deformation zone (μm)
1	1.54	263.091	102.02	66.00
2	1.68	238.025	104.32	45.07
3	2.01	253.26	102.725	44.57
4	2.32	267.1	88.034	48.39

In the fig.3 , it shows that the pearlite will be fine in size after LST at different energies .This may be due to rapid heating and cooling rates by laser treatment.The microstructures of pool zones are depended on the laser energy as shown in fig.3.

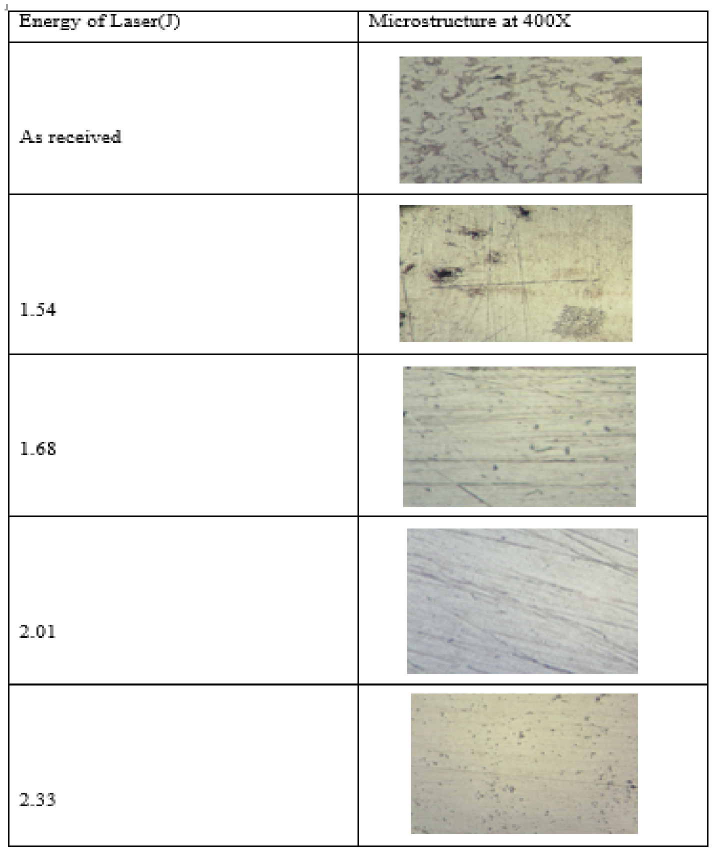


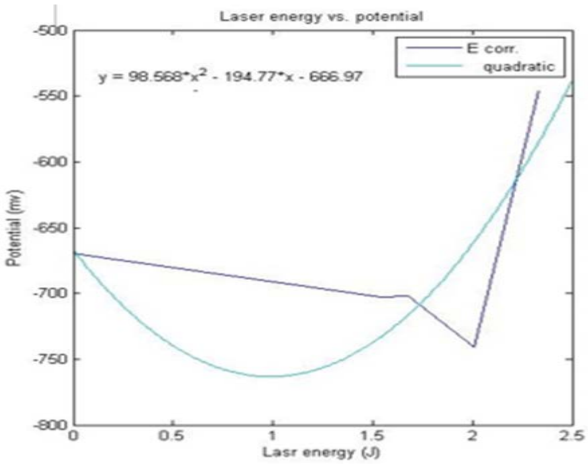
Fig.3 show the microstructure of pool zone after LST

The parameters (E°,Ecorr., i°,icorr.) are affected by the energy of laser . By using different laser energies from 1.54 J to 2.01 J, the E° will decrease in more negative values in compare to as received value. While with laser energy 2.33J, the E° and Ecorr will increase to higher value in a rate of 0.237. This means that the tendency of low carbon steel to corrosion will decrease after LSM as shown in fig. 4.

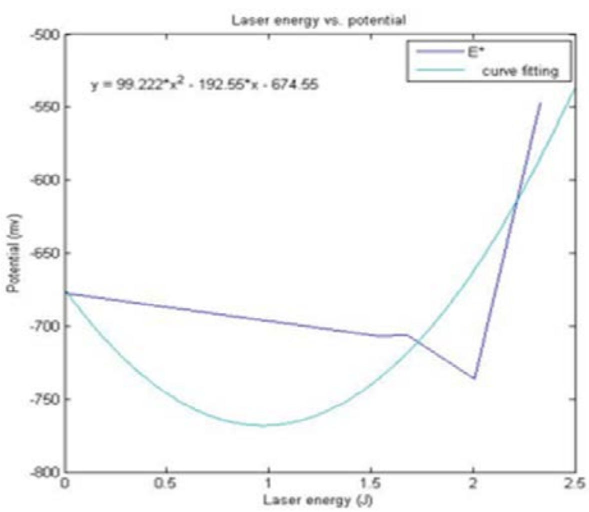
The current density, i° will begin to decrease at laser energy 1.54J and increases sharply at energy 1.68J then it decrease in the same value at higher laser energy 2.01J &2.33 J ,the rate of decreasing of i° in compare to as received case is 0.66 as shown in fig.5 . In the case of icorr., this value began to increase as the laser energy increase to (1.54 &1.68)J then it decrease at energy 2.01J & 2.33J. These results illustrated in table Ⅲ

TABLE III
THE PARAMETERS OF CORROSION TEST.

Laser Energy	As received	1.54 J	1.68J	2.01 J	2.33 J
E° (mV)	-677.4	-706	-706	-736	-547.4
i° (µA/cm²)	$3.0*10^{-3}$	$2.7*10^{-3}$	$5.0*10^{-3}$	$1.0*10^{-3}$	$1.0*10^{-3}$
E_{corr} (mV)	-670	-703	-702	-741	-546
i_{corr} (µA/cm²)	$2.4*10^{-2}$	$5.2*10^{-2}$	$3.2*10^{-2}$	$1.2*10^{-2}$	$2.0*10^{-2}$

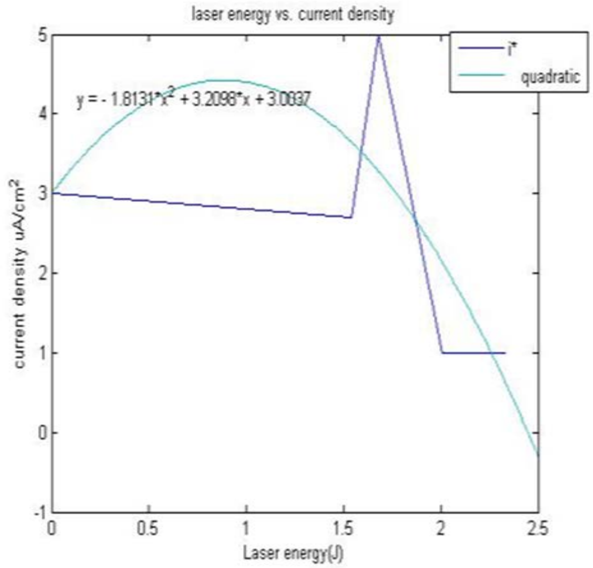


(A)

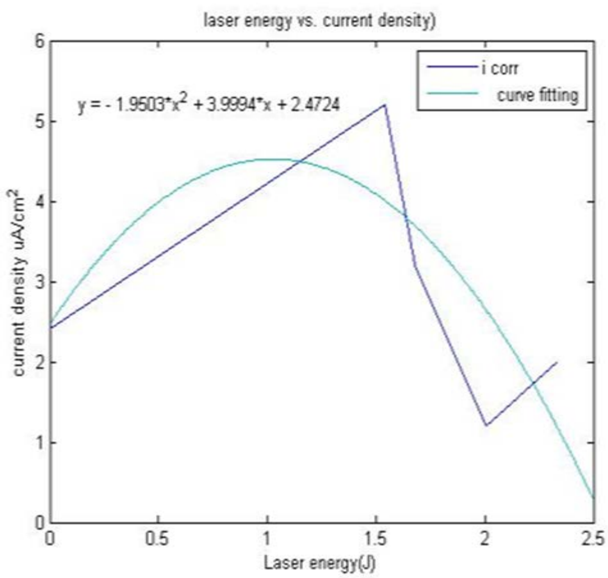


(B)

Fig.4 shows the relationship between laser energy and potential.(A) for Ecorr. ,(B) for E°



(A)



(B)

Fig.5 shows the relationship between laser energy and current density.(A) for $i_{corr.,}$ (B) for i°

IV. CONCLUSIONS

1. LSM have more affected on microstructure , four zones have appeared pool zone , HAZ zone , deformed zone and base zone . These zones have different widths, depending on the laser energies.
2. The Pearlite grains in pool zone will be fine in size and its depended on the laser energies.
3. The corrosion behavior is affected by laser energy and in general LSM led to some improvement in corrosion current density and corrosion potential.

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