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ENHANCEMENT OF THE WEAR RESISTANCE FOR C70275 CU- NI ALLOY BY LASER TREATMENT

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ABSTRACT

The effect of LSP technique to enhance wear resistance of C70275 Cu - Ni alloy was investigated. In this work, C70275 Cu alloy was hardened by using Nd: YAG laser (λ=1064 nm, t=10 ns). Four different laser number of pulses and energies have been used to perform hardening (40, 60, 80, and 100) (100, 300, 500 and 700mJ) respectively. A pin-on-disc technique was used to evaluate wear rate of the specimens untreated and specimens treated by Nd: YAG laser at different applied loads and with 750 r.p.m and 60.8 HRC of rotating disc. The findingsexplain that the wear rate increases with increasing applied load, wear rate for laser energy 700mJ less than another used energies. Also the wear rate for number of pulses 100 less than another used number of pulses, and the maximum value of micro-hardness for laser energy and number of pulses(700mJ and 100 pulses)in a row, more than another energies and number of pulses..

I. INTRODUCTION

The use of laser technologyin surface treatment of materials represents the main areas in which looks set special features enjoyed by the laser beam, which distinguish it from other energy sources and make it more than traditional technologies are all (even modern ones) in this type of heat treatments [1,2,3]. The increasing utilization of laser in material processing can be contributed to many unique advantages of laser called, high productivity, automation worthiness, non-contact processing, removal of finishing operation, decreased processing coast, improved product quality, maximum material utilization and minimum HAZ [4,5]. The process of laser material interaction is considered as a very complex thermos-physical processes under the interaction between temperature, phase transformation and stress-strain [6- 10].Victor G.In 1977 [11], H. E. cline and T. R. Anthony have described a thermal analysis for laser heating and melting materials was derived for a Gaussian source moving at a constant velocity. Calculations were presented for 304-stainless steel which are in agreement with experiment.At 2011 sameer R.paital [12]studied Improvement of corrosion and wear resistance of Mg alloys by using a highly intense laser beam from a continuous wave diode-pumped ytterbium laser source was used for synthesizing a corrosion and wear resistant aluminum coating rich in $Al_{12}Mg_{17}$ intermetallic phase by direct melting of aluminum precursor powders on $AZ_{31}B$ Mg alloy substrates*****.The effects of processing and materials parameters on the heat transfer and phase transformations aspects of laser hardening of plain carbon steel***** was analyzed by Arata, Li Ashby Easterling [13]. The peak pressure exceeds material yield strength, the transient shock pressure causes severe plastic deformation, refined grain size, compressive residual stresses, and increased hardness at the surface and in the subsurface. As a result, the mechanical properties on the work piece surface are enhanced [14]. The depth of the laser processed zone depends mainly on the laser power intensity, pulse length, and material properties [15]. Considerable research studies were carried out to examine the laser shock processing. A review of laser shock processing and examination of mechanical properties of metallic material and microstructural changes in the laser-irradiated region was conducted by I. B. Roman et al. [16].They indicated that laser shock processing had great potential as a means of improving the mechanical performance of components. Sanchez-Santana U. et al. [17] investigated the effect of LSP surface treatment on the wear of C70275 Cu- Nialloy. They showed that LSP reduces wear rate due to the compressive residual stress field induced.

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II. EXPERIMENTAL PROCEDURE

1. Sample preparation

Sample preparation all specimens were cut into disk shape with diameter of 20 mm and thickness of 4 mm. The chemical composition of C70275 Cu- Nialloy are shown in Table (1). Prior to the laser shock, the specimens were polished with SiC paper under different grades of roughness ranging from 400#, 600#, 800#, 1200#, 1600# to 2000# and thin polished by diamond best, then washing by distilled deionized water, where ethanol was used to degrease the specimen surface to be used in LSP experiments.

Table (1) Chemical Composition of C70275 Cu - Ni alloy

Composition	Element	Per. (wt. %)
Mg	Magnesium	0.03
Ca	Calcium	0.14
Ti	Titanium	0.07
Cr	Chromium	0.53
Mn	Manganese	0.00
Fe	Iron	0.07
Co	Cobalt	0.04
Ni	Nickel	0.43
Cu	Copper	97.2
Zn	Zinc	0.67
Cd	Cadmium	0.72
Sn	Tin	0.09

2. LSP setup

In figure(1), the sample (C70275 Cu- Ni alloy) in which had been treated inglorious in deionized water. The Q-switching Nd: YAG laser was used with changing values of laser energy and number of pulses with fixing values of other parameters. The focused laser beam passes through deionized water (as a rather transparent overlay) and reaches the sample surface. When a laser pulse with sufficient intensity collides the surface, the material vaporizes and converts to plasma. The plasma absorbs most of the laser energy, so the fast expanding plasma is trapped between the surface of work piece and the transparent overlay, which both are confining the generated plasma, causes a high plasma pressure that propagates into the metal surface as a shockwave [12].

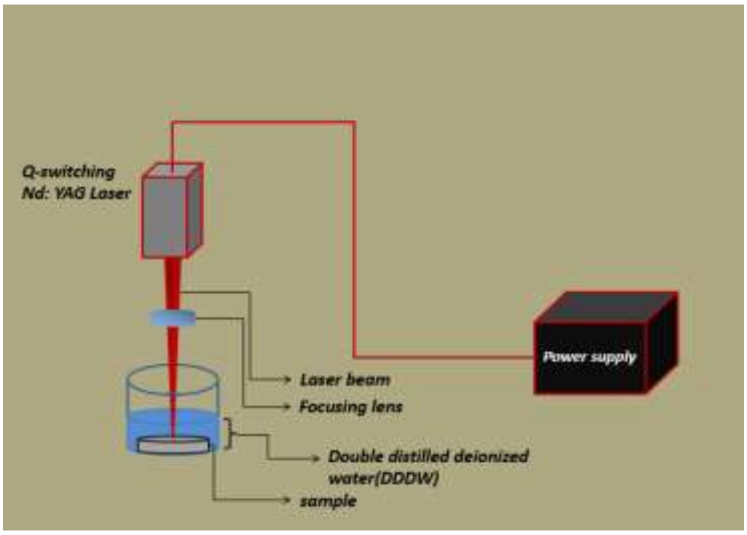

Fig. 1 Experimental Setup of LSP technique

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3. Measurements

Measurements of Vickers Micro-Hardness

The hardness of all samples were measured with the help of Vickers hardness testing machine model (HVS-1000) Germany made, in Metallurgical Laboratory \ Applied Sciences \ University of Technology. The measurement was made with 5N load and 30 sec hold time. Three measurement readings were taken and averaged to one value required to establish a suitable micro-hardness profile in the hardened layer andconsequently, a reliable micro-hardness variation. The surface hardness was measured before and after samples treatment. Micro-hardness was measured at the impact center of laser spot.

Wear Test

The specimens were prepared for wear test into disk shape with diameter of 20 cm and thickness of 4 mm. The wear rate has been measured by the weighing method, where wear testing system of flat specimen consists of hard disc from material type CK-45. The hardness of rotated hard disk about = 60.8 HRC, rotating of 750 rpm by multi speed electrical motor. The sample was subjected to a direct attachment with the rotating disk for normal load of (4, 8, 12, 16) N and under sliding time of 30 min as shown Figure (2). Weighting of the specimen mass was before and after operating the system by using a sensitive electronic balance type (KERN) with accuracy of 10-4 g.

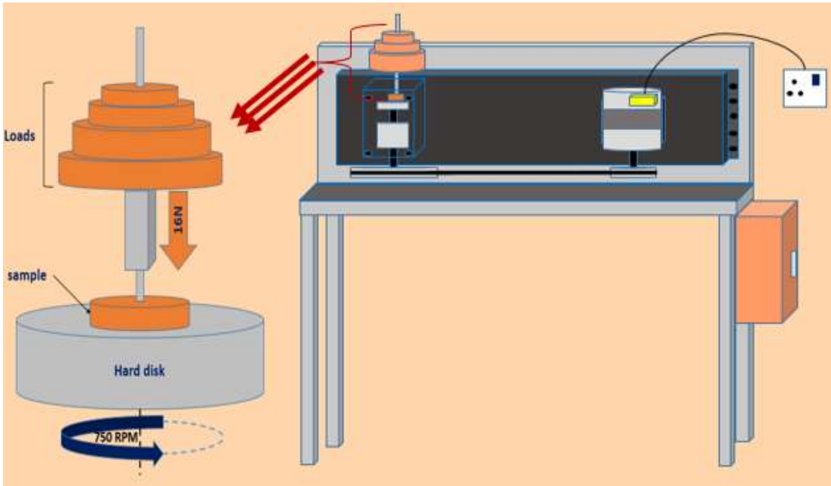

Fig.2 Schematic of wear flat system test

The wear rate was calculated according to the following equation [18]:

$$Wr = \Delta w/\pi rnt \ \ (g/cm) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where,W_r: Weight wear rate (g/cm), ΔW: weight loss (gm), and $\Delta W = W_1 - W_2$,W_1: weight before test, W_2: weight after test, 2πrnt: sliding distance, *r:* radius of abrasive wheel (cm), *n*: sliding speed (r.p.m.), *t:* running time (min.))

Morphology Analysis

QUANTA 450 Scanning Electron Microscope available inthe Pharmacy College / University of Babylon was employed to find out the impact of LSP on wear of surface before and after wear test.

III. RESULTS AND DISCUSSION

1. Micro-Hardness Results

The results of micro-hardness show the effect of various factors on the values of micro-hardness of the specimens C70275 Cu - Ni alloy used in this work as follows:

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The Effect of Laser Energy

Vickers hardness method was used to measure the micro-hardness for all samples before and after laser treatment. The average micro-hardness value before laser treatment about 125 Hv for C70275 Cu - Ni alloy.The measurements after laser processing were varied from 164 Hv to 338 Hv for C70275 Cu - Ni according to laser pulse energy as shown in figure(3). The increasing of laser shock processing pulse energy leads to further refined grain. Therefore, after LSP, the surface micro hardness increases mainly due to dislocation strengthening and grain refinement, this agrees with [19].

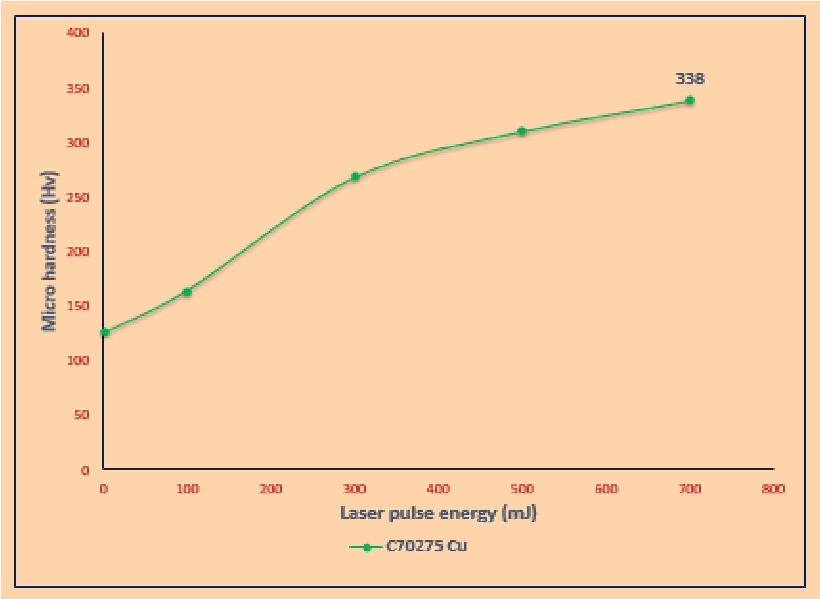

Fig.3 The micro-hardness as a function of laser pulse energy

Effect of No. of Pulses

Laser shock processing was carried out at the fixed conditions such as laser energy of 400 mJ, laser wavelength of 1064 nm and pulse repetition rate of 1 Hz. Figure (4) shows the relation between the micro-hardness and the No. of laser pulses and can be shown the increasing of micro-hardness for C70275 Cu samples from 125 Hv before laser shock processing (LSP) up to (389Hv) after laser treatment because of the pressure of induced plasma on sample surface increased when the number of pulses increased and this lead to increasing in micro-hardness, this agrees with [20].

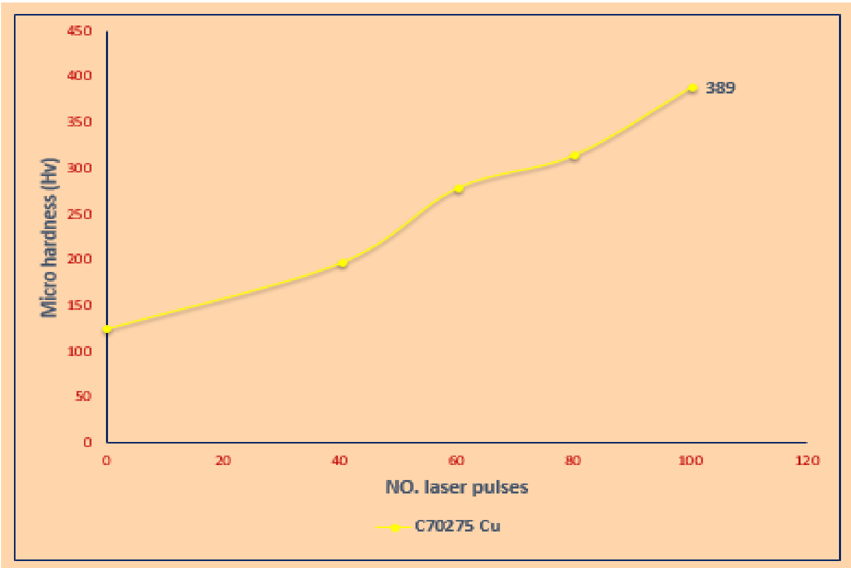

Fig.4 Micro hardness as a function of laser pulses number.

2. **Wear Rate**

Figure (5) represented the wear rate values as function of Normal Loads for (C70275 Cu alloy) by two cases (with changing laser pulse energy and changing number of pulses). Normal Load results were conducted at constant parameters as (sliding speed 750 r.p.m, sliding time 30 min) and values of different hardening. The specimens were in a two conditions, untreated and laser surface treatment withfourlevel of energies and number of pulses. The wear rate by increasing applied normal load. The curves of all the specimens' shows three distinct regions, mild, transition and severe wear.The mild wear is has been in terms of oxide layer formation which is the true contact zone of the matting surfaces, and finally leads to a low wear at load range of (4-8 N)[21]. The transition wear occurs within the load range of (8-16N) where a change from elastic to plastic deformation takes place and causes the fracture of the brittle oxide layer, leading the virgin metals to come into contact which increase the wear rate. The severe wear starts after 16N load. The increase of wear rate in this region is due to work hardening. These results in general are in agreement with the published data [22]. The curves of the samples treated by laser treatment show the low wear rates at all loads that used in this study due to the best wear resistance was obtained in specimen hardened by (pulse energy of 700 mJ and number of pulse of 100 pulses), where wear rate decreased from (3.75 * 10-8 gm/cm) before LSP treatment to (1.06 * 10-8 gm/cm) after LSP treatment (when changing pulse energy) and it decreased to (3.49 * 10-9 gm/cm) after LSP treatment (when changing number of pulses). That is because the direct relation between grain size and wear resistance of metal materials, after LSP, the grain size minimizes in the micrometer regime near surface by dislocation movement leads to substantial hardening of metal materials, as a result of the wear rate decrease. As results the wear resistance of the treated specimen is superior to that of the untreated specimen after wearing for a period of time. Similar results are also reported for LSP of duplex stainless steel by J.Z. Lu et al. [23] and of AISI 8620 steel by H. Lim et al. [24].

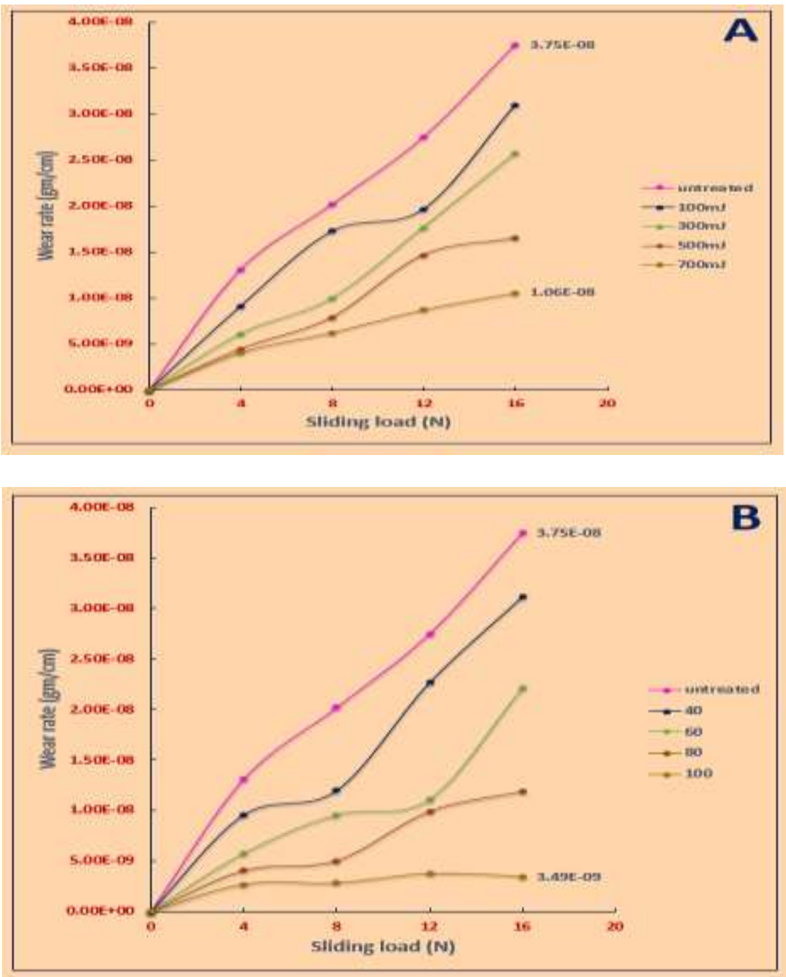

Fig.5 Relationship between applied load and wear rate with; A) different laser energies and B) different number of pulses

3. SEM Results

Figure (6) shows the SEM micrographs of C70275 Cu- Ni alloy treated and untreated LSP worn surfaces samples after sliding wear at room temperature. From these micrographs, it is clear that grooves running parallel to each other in the sliding direction are formed distinctly. It is important to notice that, comparing with the groove in the worn surface of the LSP treated sample; the width and the depth of the groove are bigger than of that of the untreated specimen. Increasing the load lead to make the grooves of wear more soft and fine because of increasing in micro-hardness.

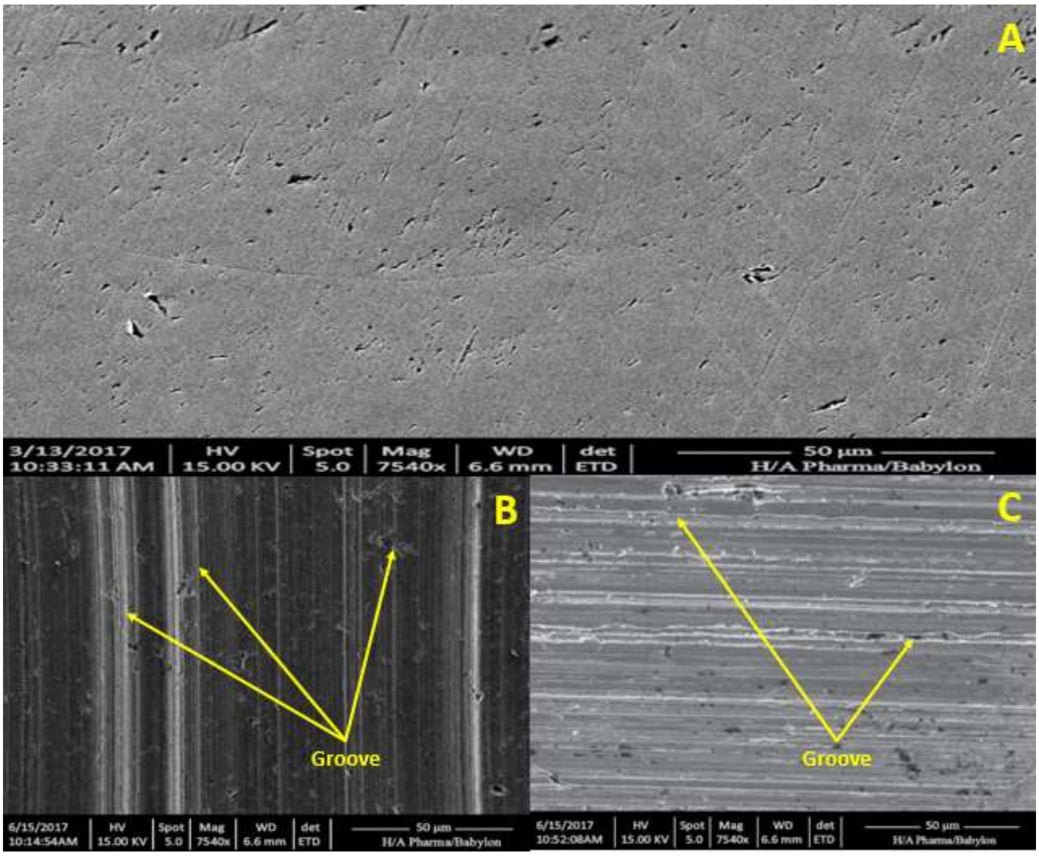

Fig. 6 SEM micrographs of A) before wear surface and LSP treated for C70275 Cu - Ni samples B) After wear test without LSP treated C) After wear test with LSP treated

IV. CONCLUSIONS

a. The best result for hardening obtained with laser energy (700 mJ)& number of pulses (100 pulses), that is due to the large gradient in heat due to more refining in structure and more increment in micro-hardness, also best result for wear resistance.
b. From wear test, it is shown that LSP applied wear rate could be reduced by 71 %(by changing pulse energies) and 90 %(by changing number of pulses) from that of untreated LSP samples.
c. SEM micrograph shows that, the grooves in LSP treated specimen is less, smaller and softer than in untreated LSP sample, because of increasing in micro-hardness..

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