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Laser shock processing by Q-switched Nd:YAG effects on mechanical properties of C86400 Cu-Zn alloy

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Abstract
X-ray florescence technique was used to analyze the chemical composition of this alloy. LSP treatment was performed with a Q-switched Nd: YAG laser with a wavelength of 1064 nm. The results show that laser shock processing can significantly increase the micro-hardness and surface roughness of the LSP-treated sample. Vickers diamond indenter was used to measure the micro-hardness of all samples with different laser pulse energy and different number of the laser pulses. It is found that the metal hardness can be significantly increased to more than 80 % by increasing the laser energy and the number of laser pulse irradiated per unit area.

Key words
Nd: YAG laser, laser shock processing, microhardness, surface roughness.

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تاثير صدمة ليزر Nd:YAG على خواص معدن النحاس C86400 Cu-Zn

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الخلاصة
تم استخدام تقنية X-ray florescence لتحليل التركيب الكيميائي لهذه السبيكة. تم إجراء علاج LSP مع ليزر Nd: YAG بتبديل يبلغ طول موجته 1064 نانومتر. أظهرت النتائج أن معالجة صدمة الليزر يمكن أن تزيد بشكل كبير من الصلابة الدقيقة وخشونة السطح للعينة المعالجة بـ LSP. تم استخدام Vickers diamond indenter لقياس الصلابة الدقيقة لجميع العينات باستخدام طاقة نبض الليزر المختلفة وعدد مختلف من نبضات الليزر. لقد وجد أنه يمكن زيادة صلابة المعدن بشكل كبير إلى أكثر من 80 ٪ عن طريق زيادة طاقة الليزر وعدد نبضات الليزر التي يتم تشعيعها لكل وحدة مساحة.

Introduction

At first, Industrial applications require portions of components with explicit surface properties full advance. Such great as is hardness. Compounds with those properties are generally over the top expensive. There is an incredible enthusiasm for decreasing the expense of parts for satisfying these requirements. In this sense, laser surface processing has been used as a cost-effective technique to improve the surface properties of materials. This can be achieved by using of the laser beam heat for modification of structure and its physical characteristics [1-3]. The solid surface hardening by laser treatment represents the structural transformations of the material; this can be established by irradiating the surface with a laser pulse. Surface heat treatment with laser beam uses the characteristics of self-quenching that cools rapidly into materials without cooling water unlike general surface heat treatment [4, 5].

Unalloyed copper and brass are widely used in the 3C (Computer, Communication, Consumer Electronics) field because of their good electrical and thermal conductivity and malleability. The Cu-Zn alloys also known as brasses are the most popular materials for these applications [6].

Micro- hardness of surface that can improve by laser peening without coating and surface roughness trivial increase. Microstructure evaluation proved there was no near-surface Solidification [7]. Dissimilar to other laser applicants, LSP is the process for treating materials mechanically without any thermal impacts [8]. Power and height of the transparent layer are the LPS parameters that may changed. A transparent overlay is used to confine the plasma expansion; in this work, water is used. Water tends to confine the energy and increase [9, 10]. LSP is generation of plasma when interaction of laser light with specimen, that produce shock waves and plastic shifts of atomic planes in the material [11]. Pulse pressure intensity against the base metal. Different parameters of LSP can evolution of micro-hardness and roughness. Their effect show that increases of roughness after LSP; no ablation was observed; the microstructure has no remarkable variation; hardness increase as the pulse density increases. And other researchers [10,12,13] also were scrupulous the increase of microhardness and surface roughness with the increase of laser pulse energy and the effect of the thickness of the confining layer on micro-hardness and surface roughness for different alloys. When a laser pulse with sufficient intensity collides the surface lead to, 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 [14]. The aim of this paper is to investigate the effects of Nd:YAG laser shock processing (LSP) on micro-hardness and surface roughness 86400Cu-Zn alloy.

Experimental procedure

1. Sample preparation

The samples were prepared from Copper alloys. Tablet circular with a diameter of 10 mm and thickness of 5 mm by using turning machine. Before laser treatment the samples were polished with metallographic paper with various grades of roughness and then polished by diamond paste with lubricated liquid on cloth paper, followed by washing by deionized water and ethanol.

2. Chemical composition analysis

The chemical composition analysis was carried out for all samples by using X-ray fluorescence (XRF) model Oxford Instruments (Foundry Master Xpert) to determine the elemental composition of samples.

3. Experimental setup

Fig.1, represents the experiment of setup. The Q-switching Nd: YAG laser was used at different values of laser energy (100-360) mJ and number of laser pulses (25-100) and fixed parameters laser wavelength of 1064 nm and pulse repetition rate of 2 Hz The focused laser beam passes through deionized water and reaches to the sample surface 4 mm height of the DW above the sample surface.

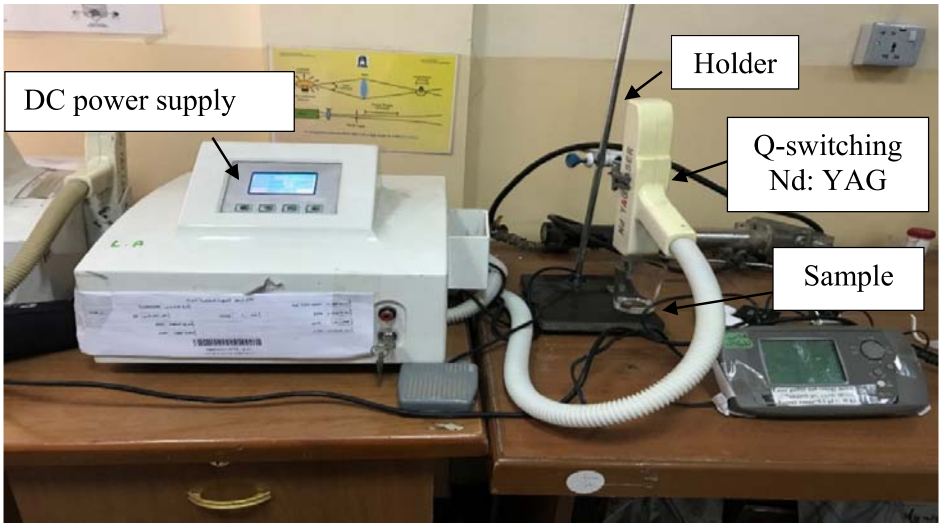

***Fig.1**: Nd: YAG laser system.*

4. Measurements

4.1 Micro-hardness

Micro-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 reading were taken and averaged to one value required to establish a suitable micro-hardness profile in the hardened layer and consequently. The surface micro-hardness was measured before and after laser treatment. Micro-hardness was measured at the impact center of laser spot.

4.2 Surface roughness test

The surface roughness test has been conducted for all samples before and after laser treatment. By using Roughness instrument model (TR-220) within micro range in the welding Laboratory/ Materials Engineering Department / University of Technology. This test was carried out for all samples before and after laser treatment on the irradiated surface.

Results and discussion

1. Chemical composition result

X- Ray fluorescence technique was used by Oxford Instruments (Foundry Master Xpert) to analyze the chemical composition of used alloys as shown in Tables 1.

Table 1: Chemical composition of C86400 Cu-Zn alloy.

Composition	Cu	Al	Si	Fe	Ni	Zn	Pb
Wt%	56.84	0.16	0.53	0.48	0.50	39.11	2.38

2. Micro-hardness results

The results of micro-hardness show the effect of two factors on the values of micro-hardness of the specimens C86400 Cu - Zn alloy samples used in this work.

2.1 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

110 Hv. The measurements after laser processing were varied from (210 to 450) HV according to laser pulse energy as shown in In Table 2. Further refined grain because increasing of laser shock processing pulse energy. Therefore, after LSP, the surface micro hardness increases mainly due to grain refinement, this agrees with [15].

Table 2: Relation between laser pulse energy and micro hardness.

Laser pulse energy (mj)	Micro hardness (HV)
0	110
150	210
220	270
290	360
360	450

2.2 Effect of number of laser pulses

Laser shock processing was carried out at the fixed conditions such as laser energy of 290 mJ. Table 3 show shows the relation between the micro-hardness and the number of laser pulses and can be shown the increasing of micro-hardness for C86400 Cu-Zn alloy samples from 110 Hv before laser shock processing (LSP) up to (520 Hv) after laser treatment because of the pressure of induced plasma on sample surface increased when the number of pulses increased and this lrad to increasing in micro hardness, this behavior agrees with [16].

Table 3: Relation between No. of laser pulse and micro hardness.

No. of laser pulse	Micro hardness (HV)
0	110
25	240
50	320
75	450
100	520

3. Surface roughness results

3. 1 Effect of laser energy

Surface roughness was measured for all samples before and after laser shock wave treatment. The average of Surface roughness value before laser of samples are 0.161 µm. Laser shock processing was carried out at the fixed conditions such as number of laser pulse 75 pulse and pulse repetition rate of 2 Hz. The measurements for same samples after laser shock wave processing were varied from 0.21 µm to 1.043 µm. This behavior is due to the ablation processes, which are associated with laser shock wave processing samples surface caused by the increasing of laser pulse energy [15]. Table 4 shows the relation between Surface roughness and laser pulse energy.

Table 4: Relation between laser pules energy and surface roughness.

laser pules energy(mj)	Surface roughness (µm)
0	0.0161
150	0.211
220	0.467
290	0.653
360	1.043

3. 2 Effect of number of pulses

The increasing of laser pulses led to increase of surface roughness as shown in Table 5 Laser shock processing was carried out at the fixed conditions such as laser energy of 290 mJ, laser wavelength of 1064 nm and pulse repetition rate of 2 Hz. This behavior backs to the reason of that the increasing of ablation process with increasing laser pulses. The values of surface roughness of C86400 Cu-Zn alloy samples were increased from 0.8 µm to 2.94 um in range of (0-100) pulses.

Table 5: Relation between Surface roughness and number of laser pulses

No. of laser pulse	Surface roughness (µm)
0	0.0161
25	0.8
50	1.3
75	1.92
100	2.94

Conclusions

The best result for micro-hardening obtained with laser energy of 360 mJ and number of laser pulses of 100 pulses due to the large gradient in heat due to more refining in structure and more increment in microhardness, while the best result for surface roughness obtained with laser energy of 360 mJ and number of laser pulses 100 pulses, due to the large gradient in heat due to more refining in structure and more increment in Roughness. The relationship between laser pulse energy and the value of surface roughness is a proportionality due to the increase in ablation processes which are associated with LSP at sample surface caused by the increasing of laser pulse energy.

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