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INVESTIGATION SHOT PEENING AND LASER SHOCK PEENING ON FATIGUE PROPERTIES FOR STEEL AISI 1010

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Abstract: In this study used a surface hardening processes by shot peening and laser shock peening to improve the mechanical properties of low-carbon steel (AISI 1010). Surface hardening operations, carried out on a sample fatigue attended according to the specifications (DIN 50113). The specimens subjected to the tensile test, Vickers hardness test and SEM examination for the microstructure of samples has been carried out to show the effect of surface hardening on the mechanical properties of fatigue and hardness. Results show an improvement in fatigue after the samples exposure for shot and shock peening, the samples which treated with laser shock peening have higher values of fatigue resisters and hardiness than sample treated with shot peening.

Keywords: *Laser, Fatigue, Shot peening, Low carbon steel AISI 1010.*

التحقيق في القصف بالكريات وبالليزر على خواص الكلال لفولاذ (AISI 1010)

الخلاصة: في هذه الدراسة تم استخدام عمليات التصليد السطحي بالضرب بالكرات الصلبة و بصدمة الليزر لتحسين الخواص الميكانيكية للفولاذ المنخفض الكاربون. عمليات التصليد السطحي نفذت على عينات الكلال حسب المواصفات الالمانية. العينات تم فحصها بالشد، صلاده فيكرز والمجهر الالكتروني لتوضيح البنية المجهرية للعينة، نفذت هذه الفحصوصات لتوضيح التحسين الحاصل في الخواص الميكانيكية للمعدن (الكلال والصلادة). اوضحت النتائج ان هناك تحسن في الكلال بعد تعرضها للضرب بالكرات والليزر، العينات المعاملة بالليزر هي الاعلى مقاومة للكلال و الصلادة من المعاملة بالضرب بالكرات.

1. Introduction

Laser shock peening (LSP) or laser peening generally increases the resistance of metals and alloys to fatigue. It does this by using a high energy pulsed laser to produce residual compressive stresses and strain hardening into the surface of a laser peened part. The residual compressive stresses from laser shock peening extend deeper below the surface than those from shot peening, usually resulting in a significantly greater benefit in after laser peening. Laser peening can also be used to locally strain harden thin sections of parts, and if the part is thin enough, it can be strain hardened through the

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section thickness**.** LSP can be applied to the finished surface of a part, or just prior to the final finishing step [1]. Laser shock peering is a mechanical process for treating materials, not a thermal process. The laser is a high-energy, pulsed neodymium-glass laser, producing a very short pulse, 15 to 30 nanoseconds long, having a wavelength of 1.06 mm, and with energy per pulse of 50 joules or more. The laser beam is directed from the laser through an optical chain of mirrors and lenses onto the surface of the part are integrated [2, 3 and 4]**.** Shot peening (SP), bombarding a surface with spherical shot or beads, is a surface treatment process aimed at increasing material's fatigue strength. Intense elastic-plastic deformation in the surface layer increases material fatigue properties by strain hardening and inducing favorable compressive residual stresses [5, 6].

Shot peening is a cold working process in which small spherical shots with velocities of 20-100 m/s are fired against a target surface .It is commonly used to produce a layer of compressive residual stress at the surface of components subjected to fatigue or stress corrosion failure. The stress distribution produced by shot peening depends upon the properties of the material being shot peened, prior processing, and the specific peening parameters used [2]. *L. D. Vo and R. I. Stephens* [9] presented that both shot and laser peening caused increased fatigue strengths in mild steel at 2x10^6 cycles with R = 0.1 and 0.5, but they had little effect at shorter lives in three different variable amplitude tests. The greater depth of compressive residual stresses and micro hardness from laser peening was beneficial with respect to shot peening for only R = 0.1 tests at long life. The current additional cost for laser peening of mild steel would not yet be justifiable. *S. M. H. Gangaraj and G. H. Farrahi* 2011 [10] studied the effects of shot peening on the fatigue life of mechanical components Using finite element method, a dynamic elastic plastic simulation of shot peening was presented. The effect of shot velocity and size on the surface morphology after shot peening was examined. Fatigue crack initiation life calculation of shot peened specimens revealed that the beneficial effect of shot peening significantly vanishes in the case of high velocities and bigger shots. *Yuji Sano and Koichi Akita* 2006 [1] described the effect and applications of laser peening without coating (LPWC) .Materials were peened in aqueous environment with laser pulses of about 100 m. J from a Q-switched and frequency-doubled N .d : YAG laser.

Surface roughness of the materials somewhat increased due to ablative interaction compressive residual stress nearly equal to the yield strength of the materials appeared at the surface after LPWC in spite of the possible heat effect by direct laser irradiation to the materials. The depth of the compression reaches 1mm or more from the peened surface. High-cycle fatigue properties were evaluated through rotating – bending or push-pull type testing for an austenitic stainless steel (SUS316L), a titanium alloy (Ti-6Al-4V) and a cast aluminum alloy (AC4CH). *Tania M. Zaleski* 2008 [11] investigated the effect of laser peening on the hydrogen penetration into metal alloys. The laser peening treatment did not exhibit much resistance to hydrogen embrittlement effect. Since the treatment did not delay the hydrogen permeation into the surface, the material was further embrittled due to the hydrogen which caused an additional decrease in ductility. Also, the various laser peening parameters inventors did not demonstrate a significant improvement in the crack growth rate for A286.

2. Experimental work

2.1. Metal selection

Low carbon steel 1010 AISI is chosen, chemical analysis of the steel was carried out by (Thermo ARL 3460, optical Emission spectrometer) as shown in table (1).

Table 1. Chemical analysis of the steel (AISI 10101)

Element weight %	*Slandered value*	*Actual value*
C	0.18-0.23	0.105
V	-	0.002
Mn	0.30-0.6	0.690
S	0.05 (max.)	0.03
Mo	-	0.002
Al	-	0.004
Cu	-	0.060
W	-	0.015
Si	-	0.180
P	0.04 (max.)	0.012
Cr	-	0.028
Ni	-	0.057
Co	-	0.015

2.2. Shot peening

The specimens were treated by shot peening from all sides using an air-blast machine. A steel ball shot with a hardness of 55 HRC and a nominal diameter of 1.25 mm was chosen. In order to avoid medium collision, the angle of nozzle inclination was shifted by 10° with regard to the vertical axis. A constant specimen distance from the nozzle of around 120 mm was maintained 5 bar average blasting pressure, the ball speed is 20 m/s and 100% coverage .Were employed the shot peening device used was shot Tumblast control (model STB-OB) machine No.03008 05 type. Figure (1) shows the shot peening device with the shot balls used.

Figure 1. Shot peening device with shot balls

2.3. Laser peening

Typical laser system was used in the present work, type (Q-Switched Neodymium YAG laser) at the University of Technology Laser Department. This device has the following properties as show in figure (2):

1- Laser wavelength is about 1.065 µm.
2- Pulse duration (7) nano seconds.
3- Pulse energy (1600 mJ).
4- Frequency (6) Hz.
5- The distance between the lens and the specimen is (13.5) cm.
6- Spot size (1.5) mm.
7- The laser spot is typically (10) in diameter.

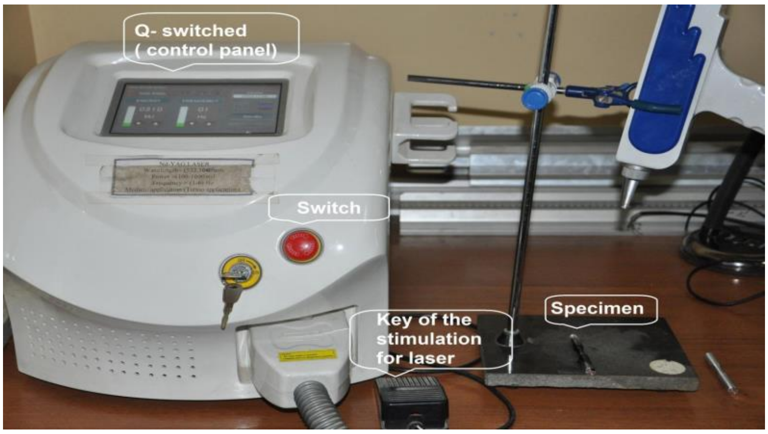

Figure 2. Laser-shock peening

2.4. Micro hardness test

Vickers hardness test was done with a load of 1.5 kg with a load holding time of 15 seconds. Indentations were made starting 0.25/mm from the edge end at an interval of 0.25/mm to a distance of 3/mm towards the middle and were repeated when specimens were turned at right angles from the first measurement.

2.5. Tensile test

Tensile properties were evaluated at room temperature using the computerized Tonus Olsen universal tensile testing machine. All tensile tests were carried out at a constant crosshead speed of 10 mm/min, and the average of three specimens was taken to evaluate the tensile behavior of each specimens.

2.6. Fatigue test

A rotating bending fatigue testing machine was used to execute all fatigue tests; the specimen was subjected to an applied load from the right side of the perpendicular to the axis of specimen, developing a bending moment. Therefore, the surface of the specimen is under tension and compression stresses when it rotates. The bending stress (σb) is calculated using the relation in equation [1].

$$\sigma b = \frac{p*L*32}{\pi*d\hat{}3} \quad (\text{MPa}) \qquad (1)$$

Where P: is the load measured in Newton (N)

L is the force arm is equal to 125.7 mm

d is the minimum diameter of the specimen in (mm).

The Test machine is depicted in figure (3).

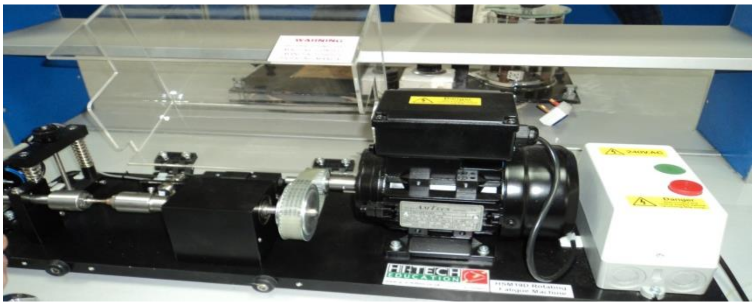

Figure 3. Fatigue testing machine

3. Result and discussion

3.1. Hardness Testing

The hardness of samples have been measured by using Vickers hardness method , and it has been found that the hardness values increased for samples in general for surface treated samples. The values of the hardness for samples treated with shot peening are higher than those which non-treated, also the hardness of the samples which treated with laser have higher values than samples treated with shot peening as shown in the table (2) below:

Table 2. Values of micro hardness for Vickers

Samples	*Micro hardness rate for vickers*
AISI 1010	117
Shot peening	110
laser	120

Where the surfaces of samples treated with the process of shot peening contain stresses compressive and emotions, as well as with increased density of dislocations, which led to increase the hardness of the alloy surface. The alloy untreated with the process of shot peening has few dislocations density compared to metal factories. The treatment of the alloy surface by laser pulse strikes has led to increased hardness of the alloy surface compared to untreated one. As can be seen that the hardness values increase toward the edge and as shown in the figure (4), (5), Include hardness values of the format given back to proliferation carbon atoms on the surface of the sample is composed carbide lead to an increase in the hardness of the sample at the surface.

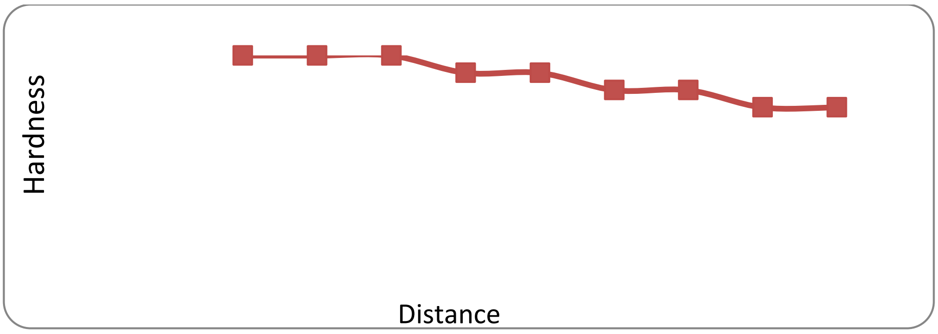

Figure 4. Relationship between the hardness of microscopic samples treated only with shot peening and the distance from the edge to core

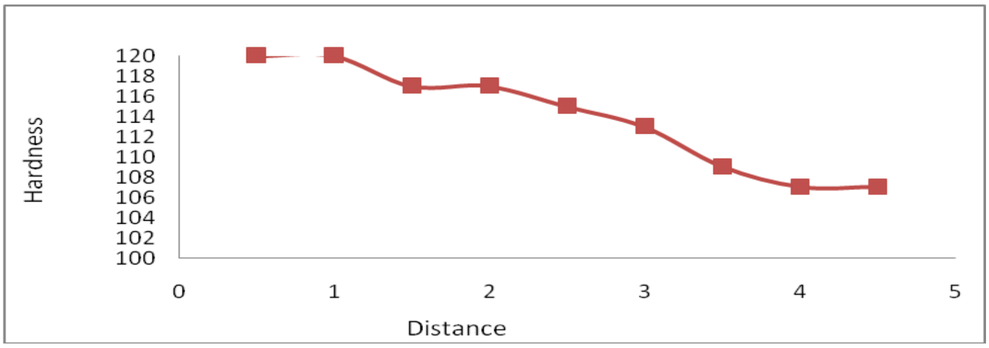

Figure 5. Relationship between the hardness of microscopic samples treated only with laser and the distance from the edge to core

3.2. Microscopic composition

Figures (6), (7) describe the microscopic images taken by scanning electron microscopy (SEM).

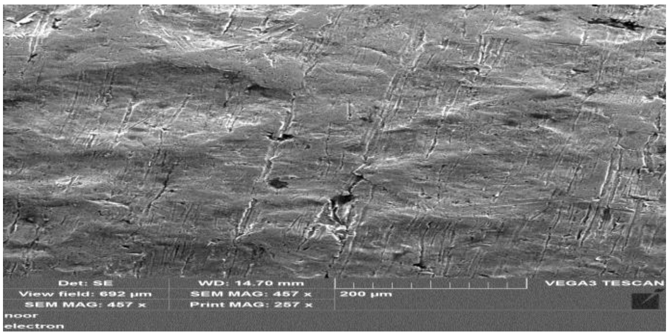

Figure 6. Shot peening

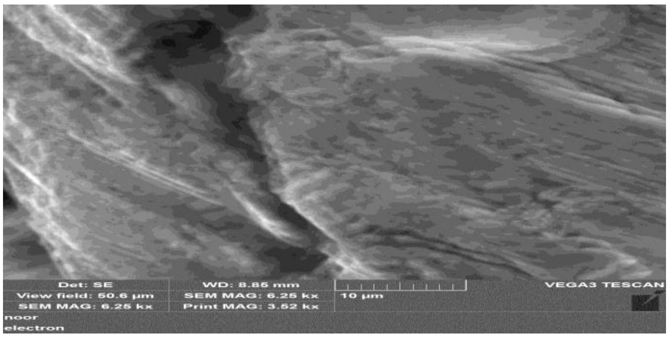

Figure 7. Laser

3.3. Fatigue strength

From previous forms, we note that the samples increased the resistance to fatigue, while untreated alloy is much less. This returns to the phases of solid, which are martensite phase, and be iron carbide, and compressive stresses, as a result of shot peening. And that will improve the fatigue resistance by stopping and blocking the cracking accurrence in the sample as shoe in figure (8).

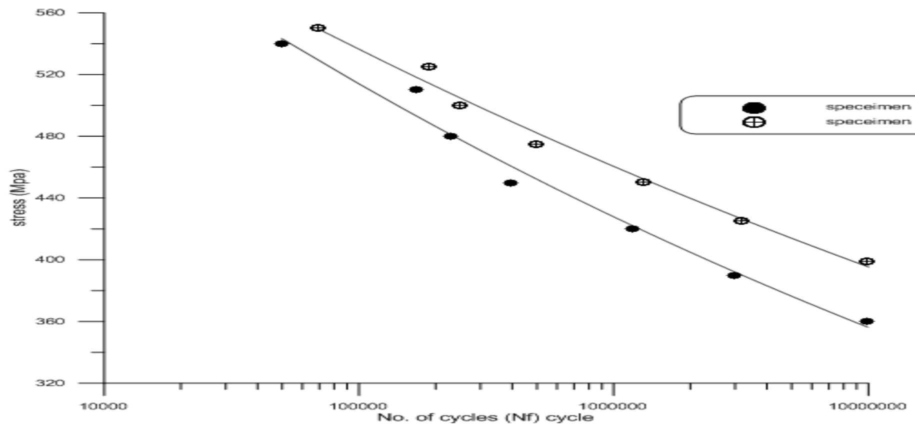

Figure 8. (S-N) curved for low carbon steel (AISI 1010) treatment of surface (B1: shot peening), (B2: laser)

4. Conclusions

1. Laser shock can increase the compressive residual stresses induced by laser shock.
2. The low-carbon steel treatment with shot peening has a fatigue limit higher than that of the non-treated alloy.
3. The hardness of the alloy surface of laser treated is higher than that shot peening .
4. The low-carbon steel treatment with laser has a fatigue limit higher than that of shot peening.

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