STUDY THE MECHANICAL PROPERTIES AND CONSTANT FATIGUE BEHAVIOR FOR 7349 AL- ALLOY UNDER WET LASER PEENING

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ABSTRACT:

Laser peening (LP) is an innovative surface enhancement process. In which creates residual compressive stresses deep into part surfaces, to improve the resistance of metal. It has particularly effective in compressor blades. The compressive surface stresses resist the fatigue cracks initiation and propagation. This paper outlines an experimental study on the effect of water laser peening (WLP) on mechanical and fatigue properties of 7349 Al-alloy. The results show that the WLP can improve the mechanical properties and fatigue strength and life. The WLP treatments gave increase in $б_u$ 3.36% , in бy by 1.4% and in HV by 5% compared to the as-received mechanical properties .While the endurance fatigue limit was increased by 4% compared to the dry endurance fatigue limit .

KEY WORDS : Fatigue, Wet laser peening, Al-alloy 7349

دراسة الخــواص الـميكانيكية وســلوك الكلال ثـابت السعة لسبيكة الالـمنيوم7349تحت التصـليد الليـزري الـمبلل

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الخـلاصــة :

عملية التصليد الليزري (LP) تستخدم لتحسين مقاومة المعدن .هذه العملية تخلق اجهادات ضغطية متبقية بعمق تحت السطح ،هذه الاجهادات الضغطية تؤخر نمو ونشؤ وتقدم شقوق الكلال .عمليا التصليد الليزري عملية مؤثرة في مراوح مكائن الطائرات واذرع الضاغطة ،هذا البحث يشرح الدراسة العملية لتأثير التصليد الليزري المبلل (WLP) على المواصفات الميكانيكية الكلال لسبيكة الالمنيوم 7349. النتائج اوضحت ان(WLP) يحسن المواصفات الميكانيكية ومقاومة عمر الكلال .معاملات (WLP) اعطت زيادة في (бu) بمقدار 3.36% وزيادة (бy) 1.4% وزيادة HV بمقدار 5% مقارنة مع المواصفات الميكانيكية للعينات بدون (WLP) وبينما حد الكلال ازداد بمقدار 4% مقارنة مع حد الكلال الجاف.

الكلمــات الافتتاحــية : الكــلال، التصـليد الليــزري المبــلل، سبيــكة الالمــنيــوم 7349

Received:10-4-2016
Accepted:22-9-2016

INTRODUCTION

Laser peening (LP) has been shown to be effective in improving the mechanical and fatigue properties of a number of metals and alloys .The applications of (LP) is expected to be widely used for improving the fatigue properties practically those that show a positive response to shot peening [Robio etal 2011]. LP is similar to shot peening, but laser pulses replaces the shot. The pressure of laser induced shock waves in which causes a several millimeters depth of residual stresses. As the local plastic forming causes a small area stretching. Stands under pressure by surrounding elasticity formed material after release of the pressure [Lim etal 2010] **. The** plastic deformation produced by the laser peening changes the internal structure of deformed grains. To the asses the effects of (LP) on mechanical and fatigue characteristics, Constant amplitude tests are being conducted on test specimens fabricated from 7349 Al-alloy .

For improving metals wear resistance and fatigue; Laser shock processing (LSP) used as a competitive alternative technology to the classical treatments. It has higher surface residual stress level than the conventional shot peening and wit greater depths. This method be applied to final metal products surface treatment [Gomez etal 2005].

To improve the fatigue limits of structures, high cycle fatigue tests carried out on shot – peened, untreated notched and laser –processed are promising method illustrated the efficiency of LSP. Especially in comparison with enhancements, fatigue performance improvements wit LSP mainly occurred during the crack initiation stage [Peyrea etal 1996].

Using 7049 aluminum alloy, a series of fully rotating bending fatigue specimens tested at room temperature. They found that the 7049 aluminum alloy fatigue strength at 10^7 cycles increased by 53% and improved the cumulative fatigue life by factors of 1.55 and 1.787 for low –high sequence and high low sequence due to black paint laser (BPL) treatment respectively [Al-alkawi etal 2016].

Shot-peening process used as a cold working to improve the fatigue life and strength of metallic structural components. It was found that an increase in shot–peening time (SPT) will increasing in fatigue life improvement percentage (FLI%) for 5 spt reducing the applied stress, increasing (FLI %) while at 10 and 15 SPT reducing the applied stress and (FLI%) [Hantoosh etal 2014] **.** studied the laser effect on strength and fatigue life of 7049 Al alloy under different conditions of laser coating surface. They concluded that significant important was occurred when using laser peening for the above alloy [Alalkawi etal 2016].

The aim of this paper is to explore the effects of wet laser peening (water laser peening WLP) on mechanical and fatigue performance of 7349Al-alloy at room temperature (RT) and R=-1 using rotating bending fatigue test.

EXPERIMENTA WORK:

AA 7349 aluminum alloy is used in highly stressed structural applications because of its high strength also its widely used in aircraft structural parts and aerospace applications where it is really required .The alloy composition has given in table (1).

In this work two groups of testing are designed. The first group (A) ,12 specimens were subjected to dry fatigue test .This group was tested under constant amplitude fatigue at room temperature .Group(B) ,12 specimens were subjected to wet laser fatigue test by using (Nd:YAG laser system) , laser conditions have already given in table(2) .Note that12 specimens without wet laser peening were examined at dry fatigue .Fig(1) shows laser technique with water while figure (2) shows laser penning device. A fatigue–testing machine of type (SCHENCK) PUNN rotating bending be used to execute all fatigue tests with applied stresses to the specimens 350, 275,225 and 175 (MPa) .

FATIGUE SPECIMEN PREPARING

By using CNC lathing Machine a cylindrical specimens with minimum diameter of (6.74mm) had been manufactured according to DIN 50113 standard specification, The shape and dimensions of test specimen are shown in figure(3).

RESULTS AND DISCUSSION

The mechanical properties results are presented in table (3) .It shows a summary of mechanical results conducted at RT and with (WLP) .The WLP specimens exhibit a slightly higher mechanical properties i.e 3.36% increase in ultimate stress ,1.4% increase in yield stress and 5% improvement in HV [Al-alkawi etal 2016] tested 7049 Al-alloy under tensile test with WLP and they found that an increase of 3.3%and 4.6% in σ_u and σ_y respectively .It can be said that WLP significantly improve the mechanical properties of 7349 Al-alloy [Arri etal 2013] related this improvement to the following parameters:

1-To cool the material

2-To increase plasma pressure

The coating of the surface by laser beam significantly increases the fatigue life and strength compared to the un peened specimens this concluded by [Rechard etal 2003] .They explained the improvement in fatigue life coming from increasing the compressive residual stress generated at the surface and subsurface of the specimen .The water is not used to cool the part but serves the key function of confining the plasma generated when the laser beam interacts with the surface of metal .Water increase the pressure developed by the plasma on the surface up to 10 times. The high pressure produced high compressive residual stresses gradient below the surface .Because the compressive residual stresses generated by the water laser peening (WLP) waves extends much deeper than that produced by conventional shot peening. In general, the deeper residual stresses the much more substantial property benefits. The S-N curve data obtained from testing three specimens at each stress level is illustrated in tables (4) (5) for both conditions i-e, dry laser and wet laser respectively. Figure (4) shows the behavior of 7349Al-alloy under the above tow conditions ,dry and WLP.This behavior can be described by the Basqun 's relation of the form:

$$\sigma_f = 996\, N_f^{-0.128} \quad \text{WLP} \qquad (1)$$

$$\sigma_f = 900\, N_f^{-0.124} \quad \text{dry} \qquad (2)$$

It is observed that the endurance fatigue limit at 10^7 cycles was improved by 4% (the endurance fatigue limit was increased from 122 MPa to 127 MPa under WLP) A-l alkawi etal [9] was obtained an improvement of 9% in fatigue strength of 7049 Al-alloy tested under (WLP). The improvement of mechanical and fatigue properties are coming from mechanical hardening which causes compressive residual stresses at the surface or sub-surface higher than the yield strength of metal [Lim etal 2010].

LIFE IMPROVEMENT FACTOR :

The parameter LIF% is introduced to quantify the amount of improvement in fatigue life at failure and to study wet laser effect on the hardening of specimen .LIF% is defined in equation (1), where N_{fwet} and N_{fdry} are the life at failure for WLP laser respectively[Al-alkawi et al. 2015].

$$LIF\% = \frac{Nf(wet) - Nf(dry)}{Nf(dry)} * 100 \qquad (3)$$

It is observed that LIF is high at high stress and reduce when the stress reduced as shown in fig(5), This means that the wet laser processing is an effective surface treatment technique to improve properties of Al 7349 aluminum alloy .This improvement may be related to the residual stress field induced at the surface. This finding is in well agreement with Ref [Robio etal 2011] **. The** reason for the improvement in mechanical and fatigue strength and life may be coming from generally WLP work to the heavily deformed the surface of the specimens. This finding is closer to that of Ameur [Ameur etal 2002].

CONCLUSIONS

Based on the experimental results on 7349 Al.alloy ,the following remarks can be drawn.

1. This work observed that the wet laser peening is better in improving the mechanical and fatigue properties that the dry laser peening.

2. It was observed that σ_u, σ_y and HV increase with the WLP surface treatment .The percentages of increase are 3.36% in σ_u ,1.4% in σ_y and 5%in HV.

2. The endurance fatigue limit was improved by 4% due to WLP treatment.

3. The life improved factor LIF% for 7349 Al.alloy could be described by the equation based on applied stresses

$$\sigma_f = 7*10^{-5}(LIF\%)^{2.267}$$

Table (1): Chemical compositions of aluminum alloy (AA7349) wt%

AA7349 (Standard)	Si	Fe	Cu	Mn	Mg
	0.12	0.15	1.4-2.1	0.2	1.8-2.7
	Cr	Zn	Ni	Ti	Al
	0.1-0.222	7.5-8.7	0.05	0.05	-
AA7349 Experimental	Si	Fe	Cu	Mn	Mg
	0.12	0.15	1.4-2.1	0.2	1.8-2.7
	Cr	Zn	Ni	Ti	Al
	0.074	7.266	1.8	0.042	2.52

Table (2): Laser and the experimental conditions of fatigue test with water laser peening (WLP).

Laser Condition			Condition	No. of Specimens tested	Constant Applied stress (MPa)
Energy (MJ)	Duration (nano second)	Wave length (µm)			
300	7	1.064	wetted water	12	350,275,225,175

Table (3):Mechanical properties at RT and at wet laser

Properties	**ɓu (Mpa)**	**ɓy (Mpa)**	**Elongation%**	**E(Mpa)**	**Micro-hardness**
Room Temp(RT)	**595**	**570**	**22**	**77**	**200**
Wet Laser Peening(WLP)	**615**	**578**	**20**	**77**	**210**

Table (4): basic S-N wet laser fatigue tests

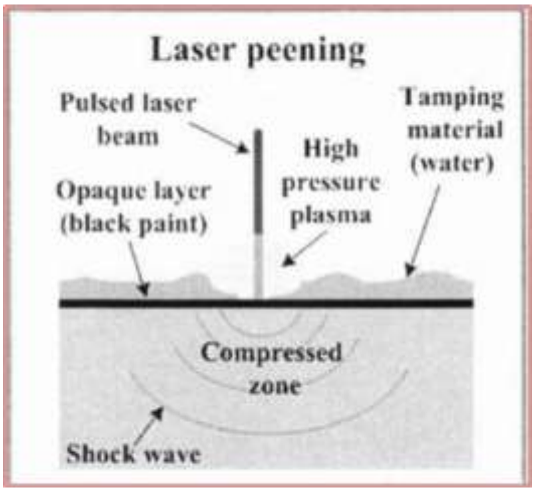
Specimens	Stress applied(MPa)	Nf (cycles)
A11,B12,C13	350	4200,3800,2900
A21,B22,C23	275	21600,28000,30000
A31,B32,C33	225	92500,95000,102000
A41,B42,C43	175	910000,852000,882000

Table (5): basic S-N dry fatigue tests(WLP)

Specimens	Stress applied(MPa)	Nf (cycles)
A51,B52,C53	350	1800,2500,2800
A61,B62,C63	275	19600,17500,20000
A71,B72,C73	225	82500,77000,84000
A81,B82,C83	175	720000,730000,800600

Table (6) LIF Life improvement Factor for 7349 Al alloy

Wet Laser				Dry laser			
400	300	200	150	400	300	200	150
1245	11787	279965	2649647	814	8773	250294	2497752
(LIF)% Life improvement Factor							
400		300		200		150	
52.9		34.35		11.85		6.08	



Fig(1): The laser peening technique with water[8]

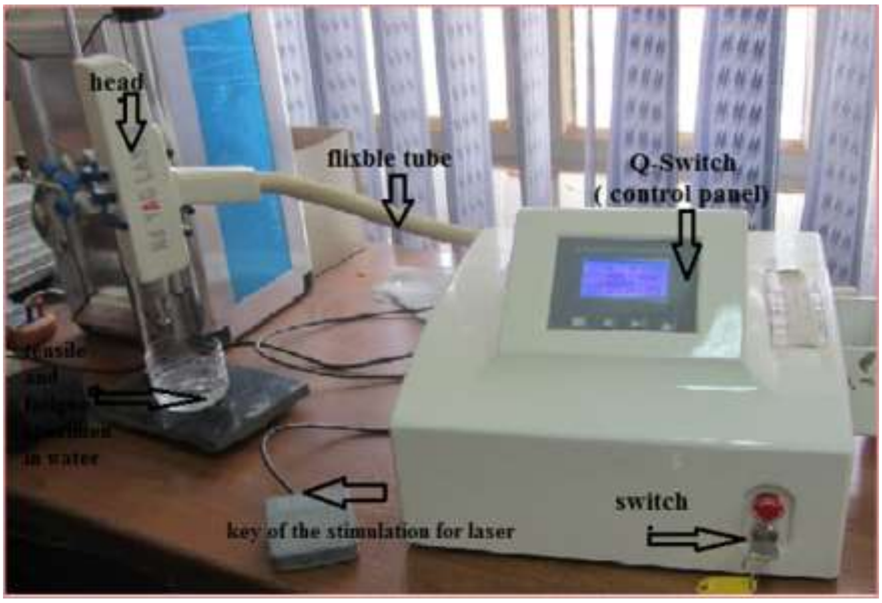


Fig (2):Laser peening test rig

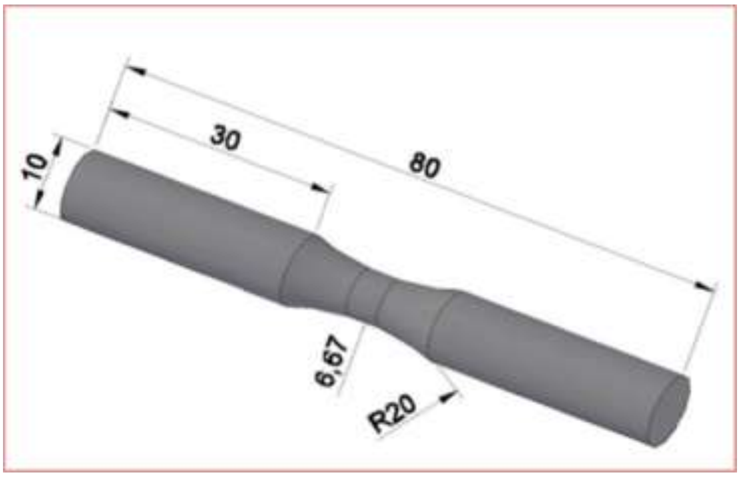
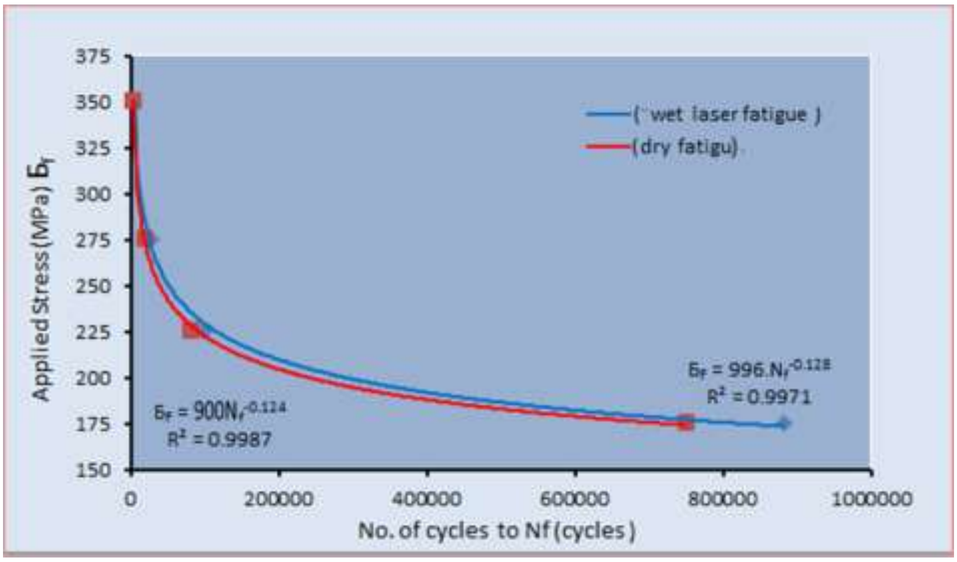
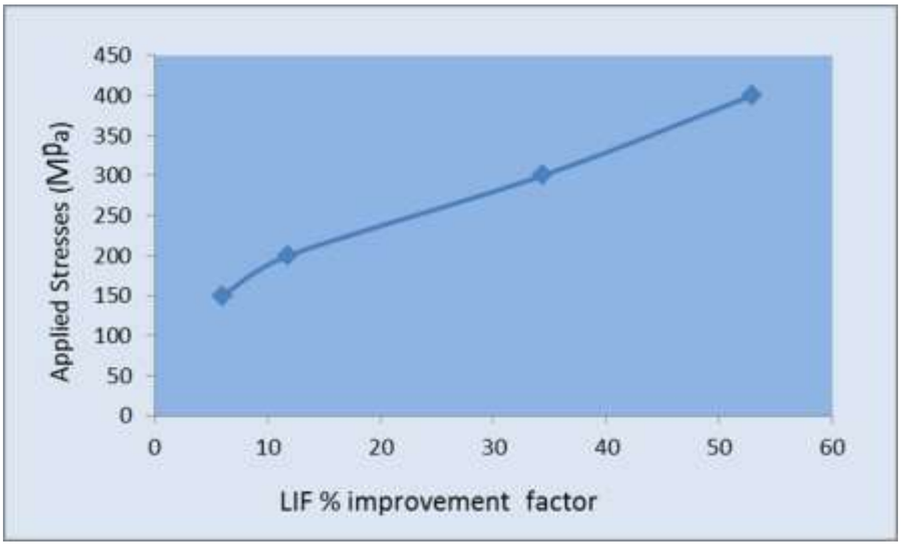


Fig (3): Fatigue test specimen dimensions in millimeter.



Fig(4) S-N curves for dry and wet laser fatigue



Fig(5):LIF% Life Improvement factor against applied stresses

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