Analysis of Prior Ultrasonic Impact Peening Treatment on Fatigue Behaviour of AA6063-T6

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Abstract

The mechanical and fatigue – ultrasonic impact peening interaction of AA6063-T6 were examined at room temperature (RT). This aluminum alloy is typically used in aerospace structural components such as wing spores of aircraft. The experimental results of un peened and peened samples were compared in both mechanical and fatigue tests. It was observed that the ultrasonic impact peening (UIP) treatment influenced the mechanical fatigue life and fatigue strength due to strain hardening of the surface and to the high compressive residual stresses. It was revealed that the improvement percentage (IP) due to application of (UIP) is recorded to be 6.8 for (UTS), 5.9 for (YS) and 6.25 for elongation. While for fatigue strength the IP was obtained to be 2.77. A comparison of the results was made with other researchers and the comparison was satisfactory.

Keywords: AA6063-T6, Ultrasonic impact peening (UIP), Mechanical properties, Fatigue behavior.

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1. Introduction

Ultrasonic impact peening was used to reduce the residual stresses in the welded parts for AA6063-T6. In the welded part a compressive and transvers residual stresses was created due to ultrasonic impact treatment. This treatment will harden the surface and improve the strength of the welded part of AA6063-T6 [Gou (2016)][1]. Three different treatment processes (two different beads size and Ultrasonic (UT)) were used to improve the fatigue life, residual stress shape, surface hardening and roughness of AA7475-T7351. The effect of ultrasonic treatment at different periods on the behaviour of low cycle fatigue of AA7075 at room temperature was studied. The effect of different strain capacities for surface microstructures on the low cycle fatigue was inspected. The treatment has no effect on the phase change. The Nano size grain of 16 – 20 nm at the surface region of specimen was improved by using ultrasonic treatment [vaibhav][3].

After using Ultrasonic peening treatment, the effects of needle size and topography on the surface finish of five groups with different steel plates D36 was studied. Moreover, micro-hardness, fold defects and stress-distribution influence on the surface quality was studied. The results show that the initial surface topography and size of peening needle has a good effect on the fold overlapping [Yanyan][4].

The effects of multiple (UIP) on the properties of surfaces was investigated. The results showed the influences of surface smoothing and hardening on the wear mechanism. [Liang][5]. components of high fatigue resistance can be manufactured by using ultrasonic treatment which leads to surface improvement process [Wang][6]. Fatigue life of material properties is extended by using ultrasonic peening, the number of beads effect in the treated surface, the residual stress was concentrated onto the treated surface when the number of beads increase [Thomas][7]. The low carbon steel based by powder metallurgy technique of cu-base material has been investigated by the effect of high ultrasonic peening process, the friction of cu-base material and the wear are reduced due to this process, also the coefficient of friction was decreased with increasing the sliding speed and in same time depends on normal load [Auezhan] [8].

The behavior of AA7075-T6 under ultrasonic impact (UI) and shot peening (SP) was investigated by [Marwa et al] [9]. They demonstrate a clear improvement in endurance fatigue limit. An increase of 3.46% and 8.57% at 10^7 cycles was recorded for UI and SP respectively.

The aims of this research are to study the effect of surface treatment on Aluminum alloy AA6063-T6 by Ultrasonic peening with comparison of original metal. Also, to get the optimum condition case for improving the mechanical properties for the surface treatment, and fatigue behaviour that used for designers and workers in

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this field. The specimens of the tensile test are prepared by CNC machine is shown in fig. 1

Fig. 1a Tensile test machine

Fig. 1 b Tensile test machine

2. Experimental Work

2.1 Material Selection

Aluminium alloys of 6063-T6 were selected in this research because of its good mechanical properties (strength, heat treatable and corrosion resistance). The demand for this alloy was increased in the industry of airframe of (airplane and aerospace).

2.2 Specimens preparation

2.2.1 Tensile test specimen

The tensile specimens were manufactured according to the standard (ASTM: B211 Testing Materials) as shown in Fig. 2.

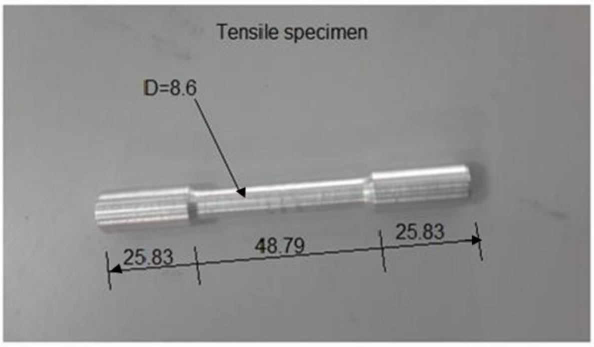

Fig. 2: Tensile test specimen dimension

2.2.2 Fatigue specimens

Rotating fatigue specimen rolled of 10mm diameter are prepared from 6063-T6 alloy as received and manufactured by CNC machine with the good finishing surface to avoiding the tensile residual stresses and concentration stresses. The shape and dimensions of fatigue specimen was prepared according to ASTM 5011 and shown in figure 3.

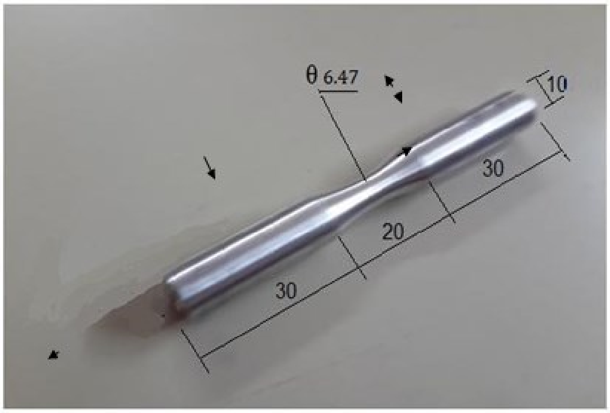

Fig. 3 Fatigue specimen dimensions

2.2.3 Roughness measurements

Emery paper has been used for polishing the specimens with different grade to reduce the scratch probably at the surface specimens and stress concentrations.

The selected specimens of surface roughness measurement was obtained by using the means of Perthmeter M3A device. Center line average reading (CLA) and maximum surface roughness (RT) results was illustrated in table 1.

$$CLA\ (in\ microns) = \frac{y1 + y2 + y3 + \cdots \ldots\ y_n}{n} \quad (1)$$

Where y_1, $y_2 \ldots y_n$ are the points selected on the both side of the center line and n is the number of points.

Table (1): Specimens roughness values

Spec. No	Min. diam. (mm)	CLS (µm)	Rt (µm)
1	6.35	0.24	0.741
2	6.40	0.34	0.811
3	6.372	0.191	0.644
4	6.411	0.124	0.444
5	6.374	0.27	0.841
6	6.371	0.36	0.611
7	6.405	0.41	0.842
8	6.401	0.43	0.901
9	6.336	0.28	0.769
10	6.405	0.37	0.889

2.2.4 Tensile Test

Tensile test was carried out to find the mechanical properties of AA6063-T6. The capacity of the tensile machine was 200KN. The deformation of the specimens was recorded by using this machine. The results was obtained by using automatic control system.

2.2.5 UIP test Machine

The overall UIP test machine can be illustrated in Fig. 4 While the impact hummer with different size of nozzle can be seen in fig. (5). The details of UIP specifications can be recorded in table (2).

Fig. 4 Ultrasonic Impact peening device.

Table (2): Details of UIP specifications

Items	Value
Major power supply	220V, 50 HZ
working current	4.5 A
wire diameter of DC fuse	4.55 A
Max. power pulse	1000W
transducer frequency	20 KH z
power working recommended	500 W
Dimensions of needle	4 sets, φ 3X25 mm

Table (2) shows the UIP extracts energy of ultrasonic and introduces it to the metal surface using surface impulse contact technology. This energy transfer to the metal by converting from harmonic to resonant of an acoustically body. This acoustically tuned body will change to mechanical impulse to the surface [10].

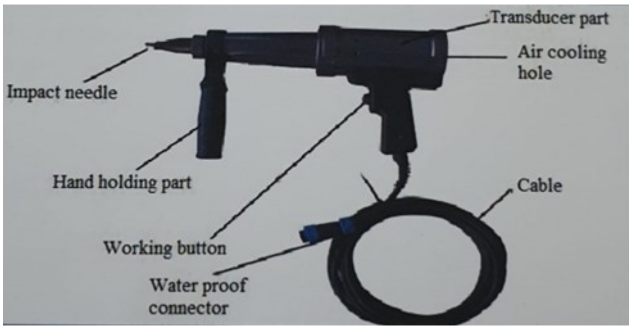

Fig. 5: Handheld parts of UIP device.

3. Experimental results and discussion

The effects of (UIP) on the mechanical and fatigue properties of AA6063-T6 evaluated. This alloy effectively reduces the wright and cast savings also it used in many applications such as transporters which is the major issues in the in-service life assessment of structures.

3.1 Tensile tests

The material AA 6063 –T6 as tested under tensile test for two cases dry and ultrasonic (UIP). The tensile properties given by the test rig are reported in table (3), and shown in figures (6, 7).

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Table (3): mechanical properties of AA6063-T6

Material	Dry			(UIP)		
	UTS MPa	YS MPa	Elongation	UTS MPa	YS MPa	Elongation
AA6063-T6	328	271	16	352	288	15

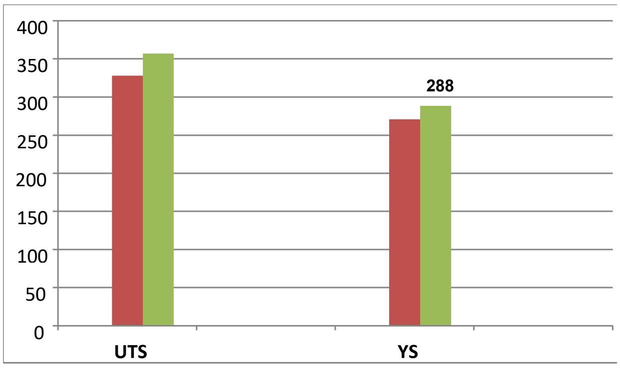

Fig. 6 summarizes the Strength results.

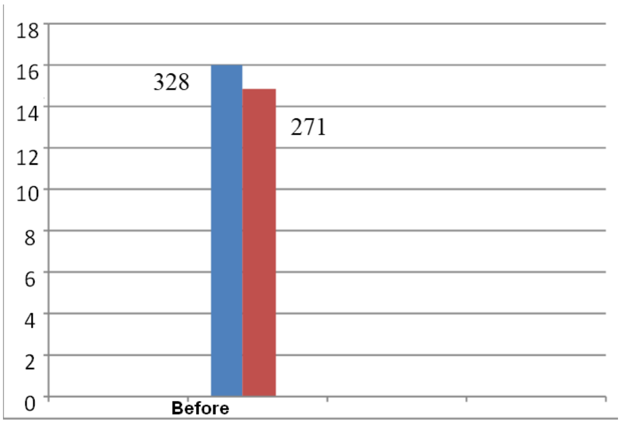

Fig. 7 The effect of (UIP) on the elongation of AA6063-T6.

The improvement percentage of the mechanical properties after applying the (UIP) are recorded in table (4).

Table (4): Improvement percentage IP in mechanical properties due to application of UIP

IP (due to application of (UIP)		
(UTS) MPa	(YS) MPa	Elongation %
6.8	5.9	6.25

3.2 Fatigue test results

The experimental results obtained from the fatigue test rig before and after UIP can be illustrated in table (5).

Table (5): experimental fatigue results under five constant stress levels

Before (UIP)		**After (UIP)**	
$\sigma f(MPa)$	Nf(cycles), Average of three tests	$\sigma f(MPa)$	Nf(cycles), Average of three tests
100	487355	100	610800
150	72951	150	115000
200	18959	200	35800
250	6666	250	11200
300	2837	300	6200

Constant fatigue equation's (A-N cure equation) were calculated according to basquin formula as

$$\sigma_f = ANf^{\alpha} \quad (2)$$

Where A , α are material constants . these constants can be determined by the equations

$$\alpha = \frac{h\sum log\delta_f logN_{f-}\sum log\delta_f \sum logN_f}{h\sum(logN_f)^2 - [logN_f]^2} \quad (3)$$

$$LogA = \frac{\sum log\delta_f - \alpha\sum logN_f}{h} \quad (4)$$

Where h is the number of test level applying the above equation the basquin equation can be obtained as given in table (6).

Table (6) Basquin equation before and after UIP for AA6063-T6

Before	After
$\sigma_f = 644Nf^{-0.2135}$	$\sigma_f = 2402Nf^{-0.235}$

However, these equations are plotted in Fig. 8.

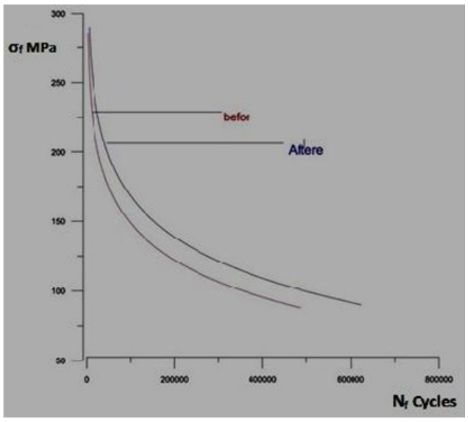

Fig. 8 S-N curves before and after (UIP) for AA663-T6

3.3 Endurance fatigue limit

The endurance fatigue limits are calculated at 10^7 cycles and given in table (7) Enounce fatigue limit before and after UIP

Table (7): Endurance fatigue limit before and after UIP at 10^7 cycles

Before	After
52.5	54

An increase in fatigue endurance limit 0f 2.77% was observed due to applying the UIP Comparison to that before applying the UIP. It is observed that the (UIP) increased the mechanical strength and fatigue life. The (UIP) treatment plays a good role in mechanical and fatigue behaviour of material. In the process (UIP) if the compressive residual stresses and the surface hardness are increased the mechanical and fatigue strength and life is increased.

The UIP process is widely used for producing plastic deformation at the surface. The plastic deformation leads to create both surface work hardening and high compressive stresses at the surface of metal just below the surface layer. This reason leads to enhance the mechanical and fatigue properties [8].

Huda et [11] tested AA7001-T6 under constant fatigue test and they found that the endurance fatigue limit at 10^7 cycles was improved from 229 MPa to 237 MPa at 10 min. shot peening time. This increase showed 3.37% enhancement in fatigue limit.

Conclusions

The experimental results indicate a significant Increasing in AA6063 –T6 mechanical and fatigue properties when applied the (UIP) such as:

1. The (UTS), (YS) and elongation increases were recorded to be 6.8%, 5.9%, and 6.25% respectively.
2. Fatigue strength was enhanced by 2.77%.
3. The equations of fatigue life were obtained based on Basquin equations as Follows:
4. $\sigma_f = 1644Nf^{-0.2135}\ before, \qquad \sigma_f = 2402Nf^{-0.235}\ after$
5. The (UIP) technique improve the properties of material surfaces of which in turns increased the mechanical and fatigue behaviour.
6. A compassion between the current work with others researchers has been done and reasonable agreement was obtained.

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