Effect of Surface Roughness and Shot Peening Treatments on The Mechanical Properties Of Aluminum Alloy 2024 – T4

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ABSTRACT

The objective of the present paper is to investigate the effect of surface roughness on mechanical properties of aluminum alloy 2024-T4. This paper describes the effect of surface roughness at values of (0.1 , 3.5 , 8) µm on hardness and yield strength and also estimate the effect of shot peening on the yield strength at period time of (5 , 10 , 15 , 20 , 25) min. The obtained results show that the low roughness improved the mechanical properties by 15.7% and also the low roughness is better than the shot peening treatments by 5.3% because the low roughness make surface more coherent. Empirical equations are formulated based on the experimental results to evaluate the yield strength with the surface roughness and the hardness.

$$Sy= 394.3 (Ra + 1.35)^{-0.1356}$$
$$Sy = 1 / 2.2227(10)^{-2} - 1.32(10)^{-4} HV$$

Keywords: surface roughness; shot peening; mechanical properties; aluminum alloy 2024-T4

تأثير خشونة السطح وعملية القذف بالكرات على الخواص الميكانيكية للالمنيوم (2024 – T4)

الخلاصة

يتناول هذا البحث دراسة عملية لمعرفة تأثير خشونة السطح على اجهاد الخضوع والصلادة لمعدن الالمنيوم (2024-T4). حيث يصف هذا البحث تحليل تأثير خشونة السطح عند قيم (0.1 ، 3.5 ، 8) مايكروميتر على اجهاد الخضوع وصلادة المعدن وكذلك تم تحديد تأثير القذف بالكرات على اجهاد الخضوع عند فترات زمنية (5 ، 10 ، 15 ، 20 ، 25) دقيقة . اظهرت النتائج التي تم الحصول عليها ان القييم الصغرى لخشونة السطح تؤدي الى تحسين اجهاد الخضوع بنسبة 15.7 والصلادة افضل من اجراء القذف بالكرات بنسبة 5.3 %. وبناءا على النتائج العملية تم تحديد معادلة لعلاقة اجهاد الخضوع مع خشونة السطح وكذلك معادلة لاجهاد الخضوع مع الصلادة .

$$Sy= 394.3 (Ra + 1.35)^{-0.1356}$$
$$Sy = 1 / 2.2227(10)^{-2} - 1.32(10)^{-4} HV$$

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INTRODUCTION

Srface roughness plays an important role in the evaluation of surface quality and mechanical properties. Surface roughness of a different metals is researched theoretically and empirically by many methods such as: the effect of surface roughness was determined by finite element (FE) calculations performed using FE code MARC 2007. An analysis of the combined effects of the thickness and surface roughness revealed that the yield and tensile strengths decreased when the number of grains over the thickness was decreased [1]. The effects of SP treatment by presenting analyses of surface roughness measurement, microhardness profiles, microstructure changes, residual stresses and material bending fatigue resistance. The obtained results show a favorable influence of shot peening treatment on fatigue properties as induced compressive residual stresses and hardened surface layer retarded the initiation of fatigue cracks. SP treatment nearly doubled the cycles to failure at the higher applied stresses when compared to the untreated specimens [2]. The influence of surface roughness parameter on the fatigue life is studied using rotary bending loading under room temperature and zero mean stress. Three levels of average surface roughness (Ra), namely smooth, medium and rough, are considered. For the above three levels, three equations which describe the S-N curve [3]. The effect of shot peening direction angle on the compressive residual stress. The results explain that the Amplitude of compressive residual stress is maximum when the shot direction is perpendicular to the surface of the part [4]. The Surface hardening plays an important role in the evaluation of surface quality and performance of wear-resisting of components. Surface hardening of aluminum alloy 7050 is researched in high speed milling by means of micro-hardness experiments and formula. It is greatly influenced by different cutting speed and material [5]. The optimization of the surface roughness of milling mould 6061-T6 aluminum alloys with carbide coated inserts. Optimization of the milling is very important to reduce the cost and time for machining mould. The purposes of this study are to develop the predicting model of surface roughness, to investigate the most dominant variables among the cutting speed, feed rate, axial depth and radial depth and to optimize [6]. The experimental study on the effect of shot peening on mechanical properties and residual stresses of 2024-T351 Aluminum alloy. Under the effects of shot peening time SPT the results show that the existence of SPT can improve the mechanical properties and fatigue life up to a limit value of SPT [7].

Experimental Work

1. Material

The material investigated in this paper was AA2024-T4, according to the ASME SB211 aluminum alloy whose composition is presented in table (1) and the Mechanical Properties is presented in table (2).

Table (1) Chemical composition of AA 2024-T4 wt% [7]

Elements / Composition	Si	Fe	Cu	Mn	Mg	Zn	Cr	Al
Nominal [7]	Max 0.5	Max 0.5	3.8-4.9	0.3-0.9	1.2-1.8	Max 0.25	Max 0.1	Rem

Actual	0.42	0.32	4.1	0.61	1.3	0.095	0.032	Rem

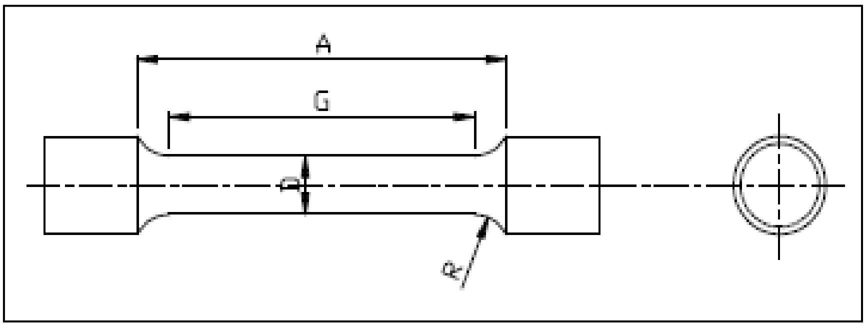
Table (2) Mechanical Properties

Modulus of Elasticity GPa	Hardness, Vickers	Elongation at Break %	Tensile Yield Strength MPa	Ultimate Tensile Strength MPa
73.1	137	19	324	469

2. Specimens Preparation

a) Three groups of specimens A , B , C prepared according to ASTM B557M-84[8] as shown in figure (1). Three specimens in each group.

b) Five groups of specimens D , E , F , G , K prepared . Two specimens in each group.



G: gage length (30mm) , D: diameter (6mm) ,
R:radius of fillet (6mm) , A: gauge length (36mm)
Figure (1) Tensile specimen configuration

3. Roughness Preparation

After machining, specimens were prepared using the silicon carbide papers as (1200,400, 80) to make three values of surface roughness, They are (0.1, 3.5, 8) µm for the groups (A,B,C) respectively.

4. Tensile Test

The tensile test operation was carried out in a tensile test device as shown in figure (2) to estimate the yield strength for each value of surface roughness (0.1 , 3.5 , 8) µm and the yield strength presented in table (3).

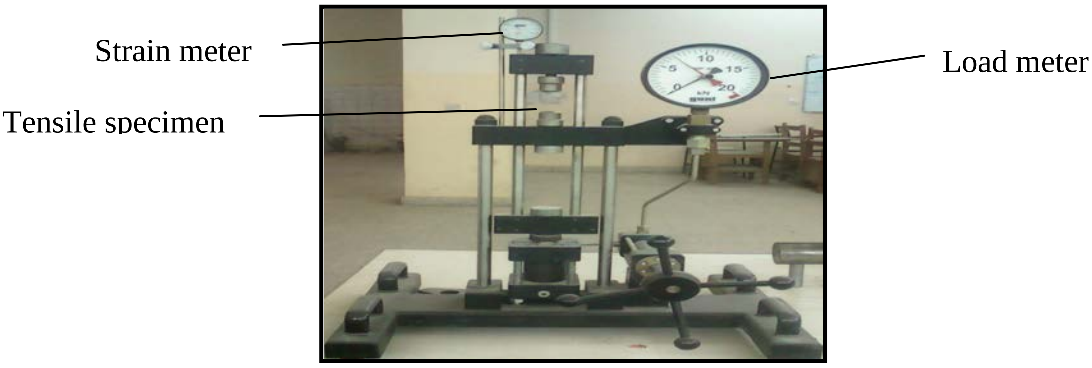


Figure (2) Tensile Test Device

Table (3) yield strength due to surface roughness

Specimen group		A Ra=0.1 μm	B Ra=3.5 μm	C Ra=8 μm
S_y MPa	1	370	325	289
	2	395	323	289
	3	359	306.57	295.96
	average	374.92	318.35	291.25

The Shot Peening Treatment

The peening operation was carried out the device as shown in figure (3). The material of the ball was steel with an average ball size of diameter 1 mm as shown in figure (4) and ball hardness of 50 HB. The number of balls at the whole operation time was kept constant for a wide range of peening pressure around 12 bar resulting in ball velocities of nearly 40 m/sec [7].

Figure (3) Shot Peening Treatment Device

Figure (4) Ball of Shot

The surface roughness of the groups D , E , F , G , K had been measured without polishing before and after the shot peening operation. And the surface roughness values are present in table (4).

Table (4) yield strength before and after shot peening

Group	Roughness before the shot peening (µm)	shot peening time (min)	Roughness after the shot peening (µm)	Yield strength after the shot peening (MPa)		Average of Yield strength after the shot peening (MPa)
				Specimen 1	Specimen 2	
D	2.9	5	3.4	359.8	352	355.9
E	3	10	4.4	351.2	346.6	348.9
F	3.3	15	4.7	333.5	328.9	331.2
G	4.1	20	4.9	315.6	308.8	312.2
K	4.1	25	4.9	306.3	304.1	305.2

Hardness Testing

Hardness tests have been conducted at room temperature in order to explore the relationship of yield strength due to the hardness. Tests performed with Zwik Roll ZHF machine type as shown in Figure (5). The Vickers Hardness values are given in table (5).

Figure (5) Hardness Measurement Device
Central Organization for Standardization and Quality Control

Table (5) Vickers Hardness due to surface Roughness

specimen	Roughness µm	HV (average)
A	0.1	148
B	3.5	146
C	8	142

Empirical Curves

1. Sy-Ra CURVE

Sy-R curve of laboratory specimens are presented in figure (6). The experimental equations of yield strength with surface roughness can be shown in table (3).

The relation between yield strength and surface roughness can be described by the shifted power- curve fitting formula[9].

The constants a,b and c can be estimated by the curve expert program [9] according to the data in table (3):

$S_y = a\ (Ra - b)^{c}$

a=394.3 b= -1.35 c= -0.1356

Therefore the relation between Sy and HV can be written as:

$$S_y = 394.3\ (Ra + 1.35)^{-0.1356} \quad \ldots (1)$$

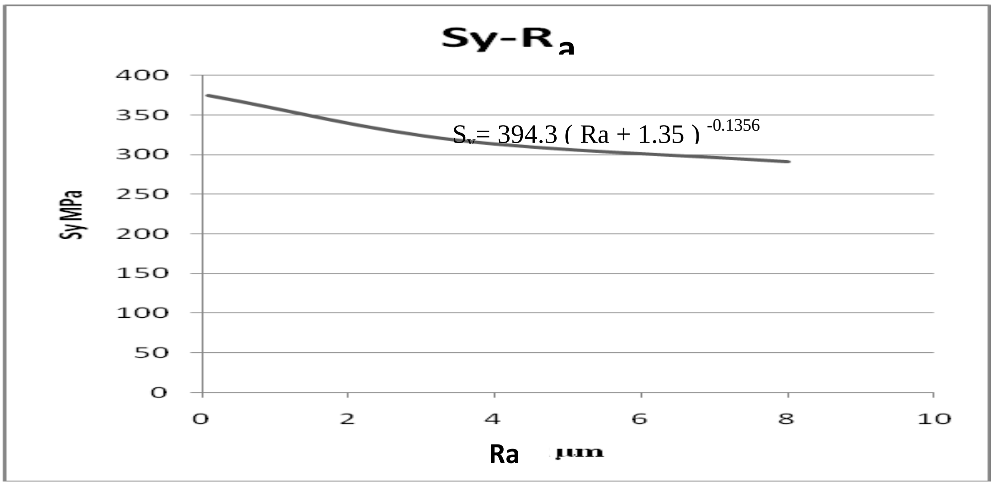


Figure (6) Sy – Ra curve

Sy-HV CURVE

Sy-HV curve of laboratory specimens are presented in figure (7). The experimental equations of yield strength with Vickers Hardness shown in table (5).

The relation between yield strength and Vickers Hardness can be described by the Reciprocal curve fitting formula [9].

Sy = 1/e+f HV

The e and f can be estimated by curve fitting technique with the curve expert program according to the data in table (5):

$e = 2.2227(10)^{-2}$

$f = -1.32(10)^{-4}$

Therefore the relation between Sy and HV can be written as:

$$Sy = 1 / 2.2227(10)^{-2} - 1.32(10)^{-4}\ HV \quad \ldots (2)$$

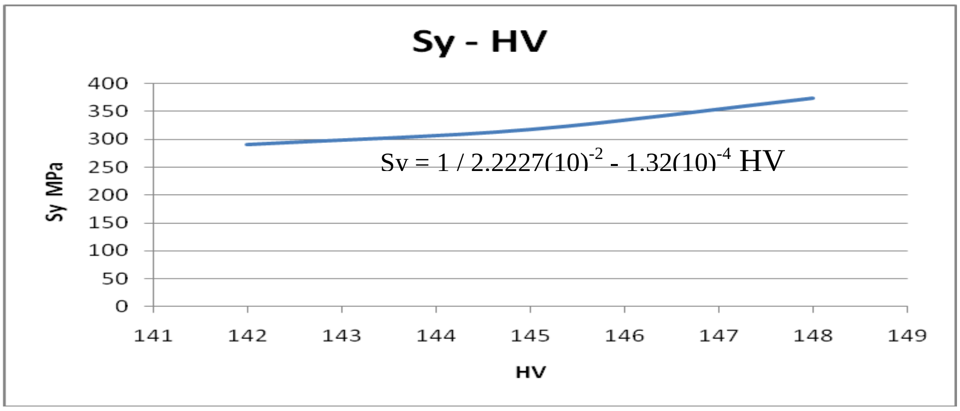


Figure (7) Sy – HV curve

Results and Discussion

The results of the tensile test are shown in table (3) and figure (7). The increase of surface roughness result to decrease the Sy (yield strength) value because the low surface roughness prevents the failure for the surface of specimen . This decrease in the Sy is due to surface roughness Ra is formulated according to equation (1). The increase of Hardness result to increase the yield strength value as shown in figure (7) and this is accepted with the direct proportional between the hardness and yield strength for materials. This increase in the Sy is due to Hardness HV have is formulated according to equation (2). The shot peening time shows the maximum yield strength at 15 minutes by comparing with the value of yield strength in group B.

By comparing the effect of mechanical properties on the yield strength show that the surface roughness is improving the yield strength better than shot peening 5.7%.

CONCLUSIONS

1.The surface roughness is improving the yield strength and the hardness better than shot peening treatment by 5.7%.

2.The shot peening is influence at low value of surface roughness while the influence of shot peening decrease due to increase of value of surface roughness as shown in table (4) .

3.The hardness is increasing due to decrease of value of surface roughness as shown in table (5) .

4.The shot peening time shows the maximum yield strength at 15 minutes.

List of Symbols			
No.	**Symbols**	**Description**	**Units**
1	Sy	Yield strength	MPa
2	Ra	Surface Roughness	μm
3	HV	Vickers Hardness	
4	a,b,c,e,f	Constants of curve fitting formula	

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