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Shot Peening Time Effect on Corrosion Behaviors of Al Alloy 2024-T_3

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Abstract

In this study many specimen s were prepared from 2024-T3 Aluminum alloy for corrosion test by the dimensions of (15*15*3) mm according to ASTM G71-31 and then subjected to shot peening process at different time (15, 30, 45) minutes using steel ball having a diameter of 2.75 mm and Rockwell Hardness of 55R_C to induce compressive residual stress which were measured using X-Ray diffraction method, surface roughness and hardness were tested before and after peening. Electrochemical corrosion test by Tafel extrapolation method was carried out in an environment of 3 .5% NaCl solutions (sea water) where Corrosion rate calculated using Tafle equation.

The obtained results show a favorable influence of SP treatment on improving corrosion resistance as induced compressive residual stresses and hardened surface layer, the best corrosion resistance was at SP time of 30 minutes since compressive stress was the highest.

Keywords: *aluminum, shot peening, surface roughness, residual stresses, corrosion resistance.*

1. Introduction

Aluminum and its alloys are being used successfully in a wide range of applications, from Packaging to aerospace industries due to their good mechanical properties and low densities. In 2024 aluminum alloy copper was the main element in the alloys (Cu) gives substantial increases in strength, permits precipitation hardening, reduces corrosion resistance, ductility and weld ability.[1,2]

Shot peening (SP) means bombarding a surface with spherical shot or beads, it is a surface treatment process aimed at increasing material's fatigue strength. Intense elastic to plastic deformation in the surface layer increases material fatigue properties by strain hardening an inducing favorable compressive residual stresses [3]

The number of influential parameters on the shot-peening process is large: type, size and shape of the shots, time of peening, stream velocity, air pressure on the peened element, distance from nozzle to material surface (peening distance), nozzle angle, peening intensity and surface coverage percentage. Experience showed that some of the parameters may be taken as constant while others must be evaluated through

Experiments and numerical simulations .Shot peening is commonly conducted in a closed cabinet designed to safely confine the media and provide proper aiming of the shot blast stream [4]. The mechanism generating the compressive stresses in the surface layer is associated with the properties of treated materials. In the case of hard materials (HV≥600), these stresses are generated by forces acting normal to the treated surface. The maximal tangent stresses (τ_{max}) due to normal stresses are situated underneath the surface, at the depth of ($z = 0.47 * a$) (Fig.1-a). In the case of plastic (low-hardness) materials, such as aluminum alloys (HV ≤300), considerable plastic strains are generated near the surface. The increase of the size of the shot-peened layer(A) is counteracted by the layer(B), which in consequence produces the internal stress distribution (Fig.1 -b). The maximal value of compressive stress is registered on the surface of the worked product. Thus generated state of stress will cause the changes in the structure of the surface layer, depending on the type of the worked material Fig. 1 [5].

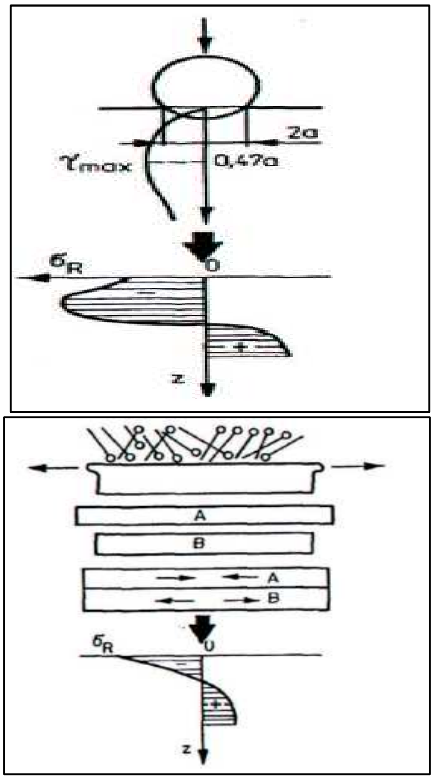


Fig.1-a the pressure effect in accordance.
Fig.1-b the effect of plastic deformation with the Hertz.
Fig. 1. Compressive stress generation as a result of shot-peening process [5].

Shot peening can only be reliably controlled and optimized by measuring the subsurface residual stress distributions produced. X-ray diffraction .(XRD) is the most accurate and best developed method of quantifying the residual stresses produced by surface treatments such as shot peening XRD offers a number of advantages when compared to the various mechanical methods, or the non-linear- elastic ultrasonic or magnetic methods currently available. XRD is a linear-elastic method in which the residual stress in the material is calculated from the strain measured in the crystal lattice [6].

Corrosion is a fundamental process which plays an important role in economics and safety. Apparently corrosion cannot be avoided, but its severity can be reduced to a lower magnitude. The term 'aqueous corrosion' describes the majority of the most troublesome problems encountered when metal material is in contact with sea water. Various methods have been employed to reduce corrosion. Several techniques and methods have been developed to combat corrosion efficiency are continually being sought after, as a result of exorbitant amount spent on corrosion annually [7].

The objective of the present paper is to study the corrosion properties of SP treated high-strength aluminum 2024-T3 at different penning times.

2. Experimental Work

Chemical composition in weight % of 2024-T3 Aluminum alloy which was conducted by using(Thermo ARL 3460, optical Emission spectrometer) is listed in Table (1). 20 specimens from this material were prepared in the dimensions of (15*15*3) mm according to ASTM (G71-31) to Corrosion test.

Table 1,
Chemical analysis of the used metal AA (2024-T3.

Element Wt%	Real Value	Standard Value
Al	92.6	Rem
Ti	0	0-0.15
Cr	0.05	0-0.1
Zn	0.1	0-0.25
Si	0.4	0-0.5
Fe	0.3	0-0.5
Mn	0.6	0.3-0.9
Mg	1.5	1.2-1.8
Cu	4.4	3.8-4.9

15 of These specimens were permit to Shot peening 5 specimens for each time which was carried out at (15,30,45) min using spherically ball of 2.75 mm in diameter at constant distance between the nozzle and the specimen of 10 cm. The specimen is rotating continuously during peening to ensure 100%, the ball speed is 20 m/s.

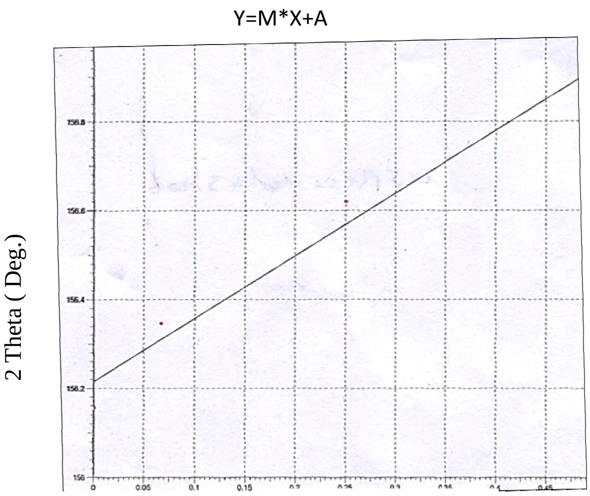
The shot peening device used was (shot tum blast control model (STB – OB) machine it was found in Institute of Technology Fig(2) , preparing specimens were classified into four series, three of them corresponded to appropriate shot time as shown in Table (2)

Fig. 2. Shot Peening Device with shot balls.

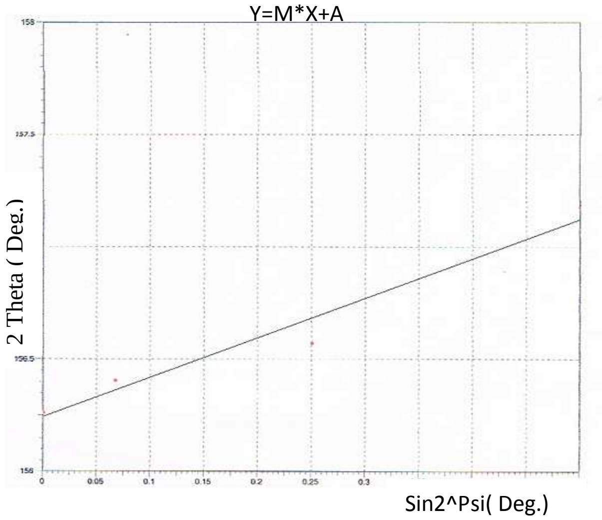
Table 2,
Classification of corrosion test specimens.

Symbol	conditions
A	As received
B	Shot peening for 15 minute
C	Shot peening for 30 minute
D	Shot peening for 45 minute

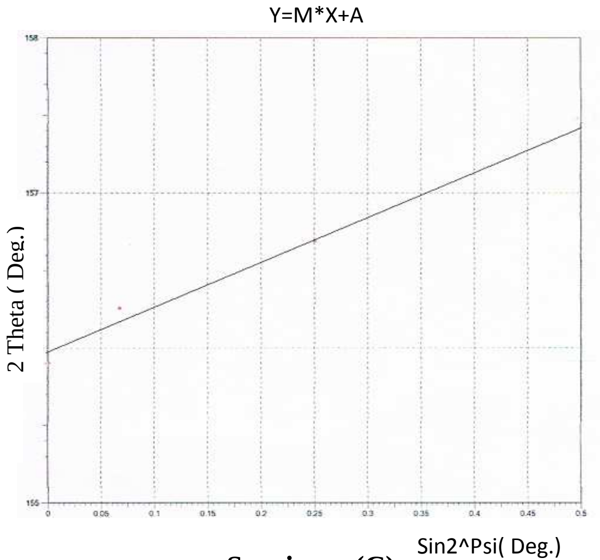
Residual stress were measured for all specimens in Table (2) by using Lab XRD-6000 Shimadzu X-ray Diffracto meter, the residual stress results are shown in Table(3) and Fig.(3) gives the relation between 2 Theta (deg) which presented strain in brag law to calculate compressive residual stress in Mpa ,while Sin2^Psi(Deg.) presents the specimen location and its incline with the axis.



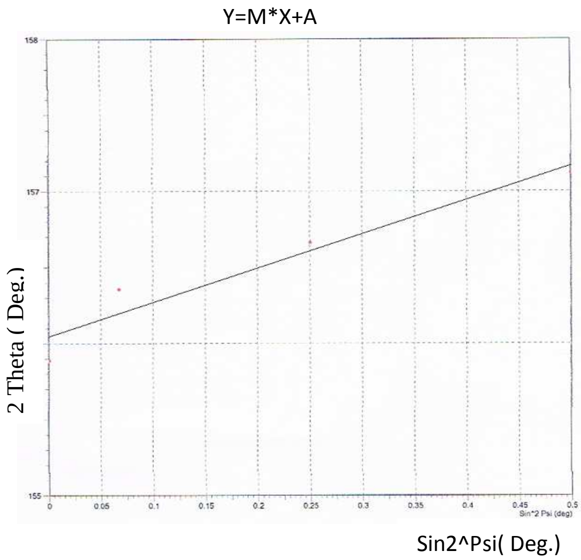
Specimen (A)



Specimen (B)



Specimen (C)



Specimen (D)

Fig. 3. photo graph of residual stress.

Surface Roughness

The average value of the free surface roughness was measured using (Perth meter) Type (S6P) at the surface area of specimens(A) and peened area for specimens (B,C,D) it is indicated by the parameter (Ra) which is the center-line average of adjacent peaks, the macro hardness by using Hardness Tester Waghtech international did vary depending on which peening treatment was used. Results are shown in table(3)

Table (3)
The result of Rockwell B hardness, surface roughness and compressive residual stress.

Symbol	HR_B Kg/mm^2	Surface Roughness Ra (μm)	Residual stress Mpa
A	76	0.016	-18
B	92	1.89	-162
C	120	2.2	-266
D	128	2.32	-206

(-) symbol referred to compressive stress and it has no effect on value

Corrosion Test

Cell current readings were taken during a short, slow sweep of the potential. The sweep was taken from (-100 to + 100) mV relative to (OCP). Scan rate defines the speed of the potential sweep in mV/sec and its taken (10 mv). In this range the current density versus voltage curve is almost nearly linear. The tests were performed by using a WENKING Mlab multi channels potentiostat and SCI-Mlab corrosion measuring system from Bank Electroniks-Intelligent control GmbH, Germany 2007, as shown in Fig.(4) In this test, aluminum alloy (2024-T3) shot peened and un shot samples were used as working electrode (WE), a saturated calomel electrode immersed in the salt solution was used as reference

Electrochemical corrosion test by Tafel extrapolation method was carried out on all samples of all time (15,30,45)min shot peening in sodium chloride solution of 3.5% NaCl with Ph of 6.8 to determine corrosion Parameters, such as corrosion potential (Ecorr) and corrosion current (Icorr) at each time . These parameters will leads to calculate the corrosion rate according to the equation below [9].

C.R (m.p.y) = 0.13 * Icorr * eq.wt / ρ (1)

Where

m.p.y= mille-inches per year

Icorr=corrosion current density (μA/cm2)

Eq .wt =equivalent weight of the corroding species,

ρ= density of the corroding specimens, (g/cm3).

Fig. 4. The electrochemical corrosion unit.

The values for the corrosion potentials and corrosion current densities were estimated from the intersection of the anodic and cathode Tafel lines. The corresponding corrosion potentials (Ecorr), corrosion current density (icorr), anodic listed in Table 4.and Fig .(5)

Table 4,
Corrosion result for all specimens.

symbol	I_{corr} [μA/cm^2]	E_{corr} [mV]	Corr. rate (M.p.y)
A	50.57	-707	21.751
B	33	-750.2	14.19
C	7.2	-648.1	3.096
D	11.7	-617.9	4.803

Corrosion Rate=0.43 i_{corr}

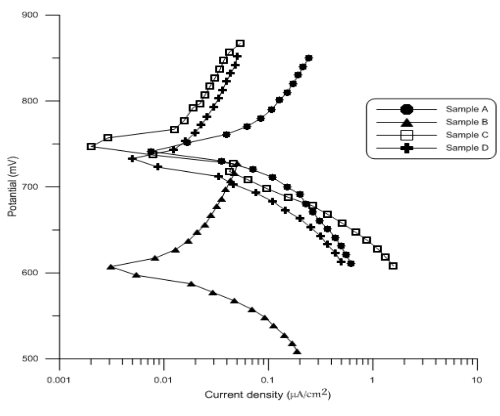
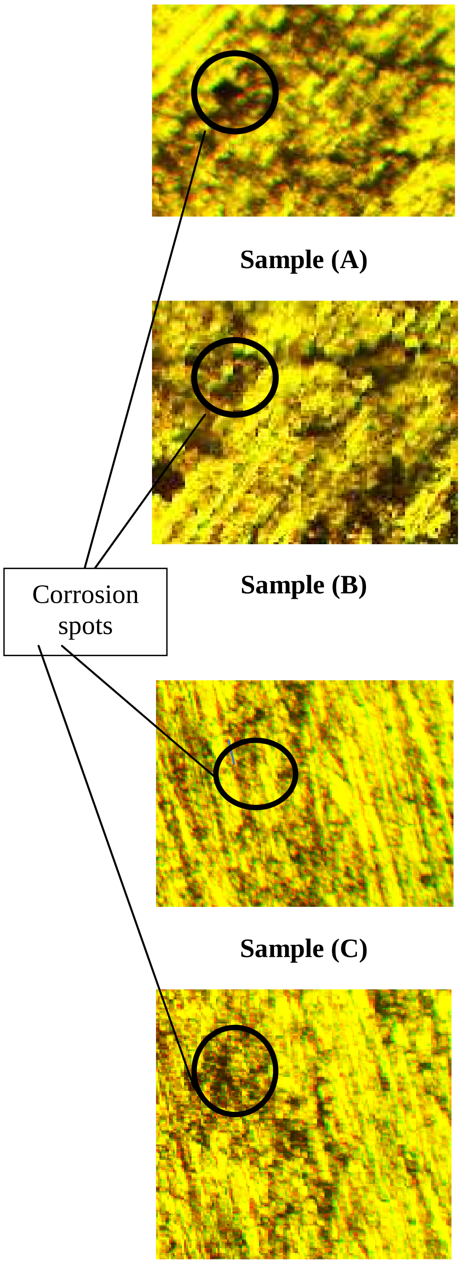


Fig. 5. Electrochemical behavior polarization for all specimens.



Sample (A)

Sample (B)

Sample (C)

Sample (D)

Fig. 6. corrosion photos.

3. Discussion

From chemical composition , in table (1) it is clear that copper is the controlling main element with percentage 4% , this was giving alloys good electrical conductively but poor corrosion resistance, it is often clad with aluminum or Al-Zn for protection [10] because of copper made for lower the hydrogen over voltage values since the hydrogen over voltage for copper and intermetallic compound is much lower than for aluminum in this case to the final corrosion potential is less noble than the initial value this might indicate that the material changed from the passive to the active state in furthermore This alloy shows much more general corrosion because copper waked the protective properties and anodizing use to improve the surface oxide stability when oxygen present in the aggressive medium is negligible [8, 11].

(Table 3). Show average surface roughness of base material (USP) sample (A) was 0.016 µm. It was found to be less as compared with the shot peened samples (B,C,D)

Shot peened contributed in increasing surface roughness which remaining hardness and compressive residuals stress to improvement mechanical properties and the shot time have more effect on its when increasing and this inagreament with Nashwa [12] which study the effect of shot peening time with steel balls on mechanical properties of AA2024-T4 alloyResults showed an increase in yield and tensile strength values with increasing peening time up to 15 minutes

Table (4) shows corrosion results & Fig.(5) the polarization curves of the all specimen which classified in Table(2),corrosion potential depends on the electrochemical behaviour of the microstructure and this is directly dependent on the quantity of the present phases for example in Fig.(5) specimen (A) has a corrosion potential of -0.707V and a corrosion current of 50.57 µA/cm2 and the corrosion rate is 21.751 m.p.y and as the shot peen 15 min there is a decreasing in corrosion rate in small values, this is because of the comparative residual stress which formed by shot peened process cases in reduce the corrosion properties. Specimen (B)

Fig .(5)shows that for specimens C ,D as increasing in time of shots there is a decreasing in I_{cor} value and then corrosion rate .

Corrosion rate in specimen C, D is lower than it in specimen (A) inducing favorable compressive residual stresses layer which was increasing in depth with increasing in shot time this is because this layer act as oxide film productive in aluminum and its alloys when aluminum react with dissolve oxygen to form it this is Partial Matches with Khaira Salman [13] , she studied the effects of shot peening time on corrosion behaviors of AA 6061-T6 in aqueous solutions results shows a favorable influence of shot peening (SP) treatment on corrosion resistance as induced compressive residual stresses lead to increase hardening of layer surface and decreasing in corrosion rate also Ali[14] studied the effect of shot peening time on the mechanical

Properties for two alumin um alloys AA2017-T4 and AA6063-T5The results showed that the percent elongation are increased to maximum value at 9 minute for AA 2017-T4while the minimum value was at the same time for AA 6063-T5.

Fig. (6) shows the corrosion photos which insist the result above.

4. Conclusion

1. Shot peening with variable time contributed in decreasing corrosion rate.
2. The shot peening improves corrosion resistance of the Al- Alloy 2024-T3 due to the homogenous cold worked surface layer and the compressive residual stresses produced during shot peening
3. Aluminum alloys 2024-T3 has high corrosion rate because of the alloy elements such as copper.
4. The best shot time which contributed in improvement in corrosion rate is 30 min.

5. References

[1] Benachour M., Hadjoui A., Benguediab M., "Heat Treatment Effect On Fatigue Crack Growth", 3rd International Conference on Integrity, Reliability and Failure, Portugal, 20-24 July 2009 .

[2] Mustafa Kemal Kulekci," Experimental Comparison of MIG and Friction Stir Welding Processes for EN AW-6061-T6 (Al Mg1 Si Cu) Aluminum Alloy", The Arabian Journal for Science and Engineering, 35, 2006, pp.321-330.

[3] Uroš Zupanc1, Janez Grum2,"Surface Integrity of Shot Peened Aluminum Alloy 7075- T651",Strojniški vestnik - Journal of Mechanical Engineering 57,5(2011), pp.379-384

[4] Roko Markovina, Branko Blagojević ario Ban," Investigation of influential parameters on shot-peening of aluminum alloys Trends in the Development of Machinery and Associated Technology", Istanbul, Turkey, 26-30 August, 2008

[5] A. fedoryszyn, p. zyzak," Characteristics of the outer surface layer in casts subjected to shot blasting treatment Archive of Metallurgy and Materials ", Vo.55 issue 3 year 2010 pp814-818

[6] Paul S. prevéy," X-ray diffraction characterization of residual stresses produced by Shot peening Theory and Application", series ed. A. Niku-Lari, IITT-International, Gournay-Sur-Marne, France, 1990, pp. 81-93

[7] W. B. Wan Nik1, O. Sulaiman , "Corrosion behavior of aluminum alloy in seawater" The International Conference on Marine Technology 11-12 December 2010, BUET, Dhaka, Bangla

[8] Metals Handbook, Vol.2 - Properties and Selection: Nonferrous Alloys and Special-Purpose Materials, ASM International 10th Ed. 1990.

[9] Annual Book of ASTMSTANDARDS, Standard Practice for Calculation of Corrosion Rates and Related Information, G102-89,Vol. 03.02, 2004.

[10] Aluminum Information at aircraftspruce.com accessed August 15, 2011.

[11] R.A. Higgins ,"Engineering metallurgy part 1 ", Applied Physical metallurgy 4th Edition universities press LTD (p340 – 353)1975.

[12] Nashwa Abdul –Hammied Saad" effect of shot peening time on mechanical properties of aluminum alloy aa2024 –t4" The Iraqi Journal For Mechanical And Material Engineering, Vol.14, No1, 2014.

[13] Kharia Salman Hassan, Abbas Sheyaa Alwan, Sawsan Abdulshaheed Abbas," Corrosion Behavior of Al alloys 6061-T6 Shot Peening in Different Aqueous Solution", International Journal of Engineering and Innovative Technology (IJEIT), Volume 4, Issue 8, February 2015.

[14] Ali A.Ali1, Esam A.Ebrahim2 "effect of shot peening time on mechanical properties of aluminum alloys aa2017-t4 and aa6063-t5" Diyala Journal of Engineering SciencesVol. 06, No. 02, pp. 1- 8, June 2013.

تأثير زمن القذف على سلوك التاكل لسبيكة الالمنيوم 2024-T3

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الخلاصة

في هذه الدراسة تم تحضير عدد من عينات اختبار التاكل من سبيكة المنيوم T_3–2024 بابعاد (3*15*15) ملم وفق المواصفة القياسية ASTM-(G71-31) وان هذه العينات تعرضت للقذف بكرات فولاذية وبازمان مختلفة (٤٥,٣٠,١٥) دقيقة بواسطة كرة من الفولاذ قطر ها (٢.٧٥) ملم وصلادتها HR_C=٥٥R_C لتوليد اجهادات ضغطية والتي تم قياسها بواسطة جهاز حيود الاشعة السينية X-Ray diffraction وكذلك تم قياس الخشونة السطحية والصلادة. اجري اختبار تاكل كهروكيمياوي بطريقة المجهاد الساكن في محلول كلوريد الصوديوم بنسبة ٣.٥% (ماء البحر) و تم حساب معدل التاكل بطريقة تافل ومن النتائج التي تم الحصول عليها وجد ان عملية القذف بالكرات ذات تاثير ايجابي على تحسين مقاومة التاكل وان معدل التاكل يقل كلما زاد زمن القذف بسبب الاجهادات الضغطية المتولدة. وان افضل مقاومة للتاكل تحققت عند زمن قذف ٣٠ دقيقة لكون ان الاجهادات الضغطيه كانت ذات قيمه عاليه عند هذا الزمن.