Journal of Mechanical Engineering Research and Developments
ISSN: 1024-1752
CODEN: JERDFO
Vol. 44, No. 1, pp. 50-56
Published Year 2021

Effect of the Shot Peening Surface Treatment on the Corrosion Behavior of 2024-T3 aluminum alloy

Abbas S. Alwan†, S. K. Fayyadh‡, Ameer Abed Jaddoa‡†*

†Department of Medical Instrumentation Techniques Engineering, Collage of Electrical Engineering Technical, M T U, Iraq.
‡Dept. of Engineering Mach. & Agri. Equip., Coll. of Agri. Engineering Science, University of Baghdad, Iraq.
‡†Department of Electromechanical Engineering, UOT, Iraq.

*Corresponding Author email: 50087@uotechnology.edu.iq

ABSTRACT: The aim of this work is to study the effects of mechanical surface treatment using shot peening (SP) with different time to solve the problem of corrosion rates in Aluminum Alloys (2024-T3) in sea water 3.5% NaCl Solution. The shot peening (SP) parameters are; the diameter of steel ball was 2.75 mm with hardness of 55 HRC, angle of nozzle was 10°, the distance from specimens surface to the nozzle was 120 mm and shot peening time at 15, 25, 35, 45, and 55min. Microstructure, residual stresses, surface roughness and micro-hardness were examined. All specimens were prepared for Corrosion test according to specification standard of ASTM G71-31with the dimensions of (15*15*3) cm. Corrosion test was also carried out by electrochemical methods for all specimens in sea water, and calculated rate of corrosion by using Tafel extrapolation method. The results shown that the appropriate affection of shot peening times on corrosion rates as generation of compressive residual stresses was effect to increase of metal surface hardness with decrease in corrosion rate.

KEYWORDS: Aluminum alloys; corrosion behavior; shot peening; residual stress; hardness.

INTRODUCTION

Aluminum alloys was commonly used in industrial aerospace, automobile, construction industries and structural applications, because of their high strength properties, low cost and good corrosion resistance. Aluminum alloy 2024-T3 hast high strength among all the wrought aluminum alloys [1-2]. Mechanical surface treatment by general shot peening caused to improve the mechanical properties such as hardness. This due to formation of compressive residual stresses in surface metal layer and local plastic deformation in the metal surface which is depended on type of ball, shot speed, volume of ball and ball hardness [3-4]. Shot peening surfaces treatments was effect to modify the surface roughness increased due to plastic deformation and lead to produce the residual stresses [5-6]. The stress distribution which produced during shot peening by plastic deformation relies on the material of shot peened and time peening parameters [7-8]. The phenomenon of corrosion resistant of metals relies on formation layer an oxide film to provide protection against corrosion. Corrosion happened when the film layer is degradation due to wrong of metal surface, such as rust on steel [9-10].

Abbas et al [11], Studied the effect of the mechanical and thermochemical surface treatment on surface characteristics of stainless steel grade 316 L such as hardness, roughness, residual stress, and microstructure and corrosion behavior. Corrosion test was done in corrosion cell content on sea water (3.5% NaCl solution). The result shows that thermochemical process by using (nitro-carburizing) was formation of hard inner layer (white layer) diffusion in metal surface. While the mechanical treatment by ultrasonic shot peening has produce of compressive residual stresses in surface layer of metal which effects to an increases roughness and hardness with increases the time of ultrasonic shooting. Also they noted Corrosion shown a decrease in pitting corrosion resistance for all samples after thermochemical and mechanical surface processes. Xinlong Wei et al. [12], studied the influence of shot peening on wear and corrosion behavior of AISI 304 stainless steel. Surface mechanical treatment was effect to modifications including microstructure, surface roughness, microhardness and residual stresses of metal surface. They noticed that shot peening process was produces grain boundary refinement because of intersection of plastic deformation twins at different directions and increases surface roughness due to generates of martensite phase.

Also they found improvement in wear and corrosion resistance after shot peening due to grain refinement, and increase a surface hardening. Dong Liang et al. [13], studied the experimental analysis of residual stress and bending strength of gear tooth surface under shot peening treatment affected, the experimental methods was explain the effect of shot peening treatment on a gear tooth surface. They noted that shot peening process can effectively to increase in the residual stress and bending fatigue strength on gear tooth surfaces. Prawoto et al. [14], studied the computational by finite element modeling and experimental of shot peening approaches, it is confirmed that the shot size has effect on the depth of the peak residual stress rather than the surface residual stress. The best results of this work are proved that academically in this field in experimental parameters such as, the number of individual impacts is linearly proportional to shot flow, exposure area, and exposure time, also the shot peening coverage is not linearly proportional because of the random nature of the process. The objective of this research was to evaluate the effect of the shot peening times on the superficial of surface properties of aluminum alloy 2024-T3 in sea water 3.5% NaCl solution, such as roughness, residual stress and hardness on corrosion resistance.

EXPERIMENTAL WORK

Materials

Table 1 show the chemical composition of aluminum alloy 2024-T3 was used in this study. The preparations of samples were classified as shown in Table 2.

Table 1. Chemical composition analysis of AA2024-T3.

Element (wt%)	**Ti**	**Cr**	**Zn**	**Si**	**Fe**	**Mn**	**Mg**	**Cu**	**Al**
measured value	-	0.05	0.1	0.4	0.3	0.6	1.5	4.4	Rem
standard value [14]	0-0.15	0-0.1	0-0.25	0-0.5	0-0.5	0.3-0.9	1.2-1.8	3.8-4.9	Rem.

Table 2. Specimens specifications, corrosion media and shot time.

Specimens	Corrosion solution	Time shot (min.)
A	As -received	
B	Sea water 3.5% NaCl	15
C	Sea water 3.5% NaCl	25
D	Sea water 3.5% NaCl	35
E	Sea water 3.5% NaCl	45
F	Sea water 3.5% NaCl	55

Shot peening process

Mechanical surface treatment using shot peening processes with parameters of ball steel diameter of 2.75 mm, hardness of 55 HRC, angle of nozzle inclination was shifted by 10° with regard to the vertical axis, the distance from the nozzle of around 120 mm was maintained in all Specimens at different shot time 15, 25, 35, 45 and 55 minutes. The shot balls and device was used model type STB – OB machine as shown in Figure 1.

Figure 1. Machine and shot balls

SPECIMEN PREPARATION FOR MICROSTRUCTURE

The samples base alloy AA2024-T3 was preparation by ASTME3 11(2017) stander guide for preparation of metallographic specimens. The operation as: grinding polished and etched. Grinding process with water by using the different grads of (220,320,500, and 1000) grits from emery paper of SiC. all the samples were Polishing operation, cleaning and etching . Etching was done by using solution consists of 2.5 ml HNO3, 1.5 ml HCl 95 ml distill water, and 1 ml HF and followed, washing by water and alcohol and dried in oven. Optical microscope type ME-600 was examined all the samples.

CORROSION TEST

Electrochemical corrosion test was done on all specimens were manufacturing according the standard specification ASTM G71-31 with dimensions (15×15×3) cm, which immersed in the sea water (3.5wt% NaCl) at temperature 25°C. Corrosion examination was carried out using SCI-Mlab model, Germany. The corrosion test was based on the standard of ASTM (G71-31). The tested specimens were immersed in 3.5% NaCl solution at 6.7 PH. The potential is obtained from (-100 to + 100) mV comparative to open circuit potential (OCP). The main corrosion parameters like corrosion potential (E_{corr}), corrosion current density (I_{corr}) and corrosion rate were estimated. Fig. 2, show the corrosion tests unit using a potentiostat cell type SCI-Mlab, Germany 2007**.**

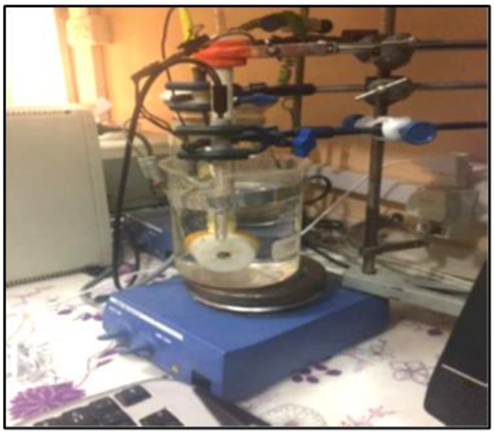

Figure 2. Electrochemical of corrosion unit used in this study

RESULTS AND DISCUSSION

Figure 3, show the microstructure of AA 2024-T3 alloy displayed a rough, elongate grain structure because of the presence of alloy elements such as magnesium and silicon precipitated by dark Mg2Si particles. Table 3 shown the effect of roughness, hardness and residual stress with shot time. The relationship between hardness and surface roughness, increasing the surface roughness from 0.13 to 2.83µm was effect to increase hardness from 120

(Kg/mm^2) to 152 (Kg/mm^2) these because an increase in shot time and residual stresses was increase from 20 to 168 (Mpa). This result was agreement with the result of [15].

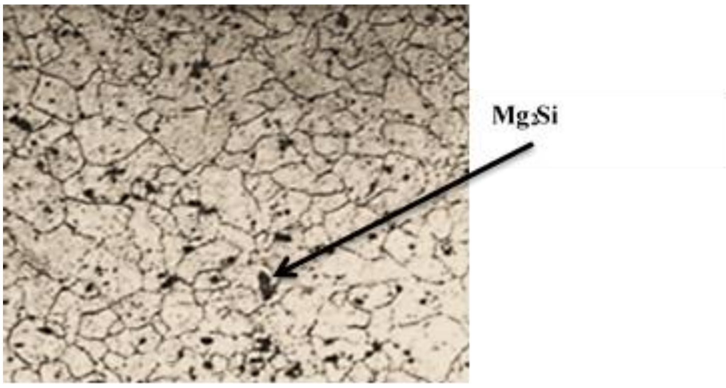

Figure 3. The microstructure of base metal AA 2024-T3, 500X

Table 3. Residual stress, surface roughness and Vickers hardness

Specimens	Hardness (Kg/mm^2)	roughness (µm)	stress (Mpa)
A	120	0.13	-20
B	130	2.12	-135
C	138	2.41	-145
D	142	2.57	-155
E	148	2.61	-163
F	152	2.83	-168

The results obtained from corrosion tests: (Ecorr) and (Icorr) at each time, contribute for all specimens. Table 4; show the main electrochemical data were obtained using analysis from calculated curves in Fig. 4. The total polarization curves of the specimens were shown in Fig. 4, corrosion rate in specimen is 25.55 m.p.y, corrosion current of 48.44 µA/cm2 and corrosion potential of -675 V. Significantly reduce the corrosion rate for specimens B , C , D, and F because of increase in surface hardness due to the shot-peened process, which contributes to increased hardness and reduced corrosion properties [16]. The Icorr value of specimen A was lower than in for specimens B, C, D, E and F. The compressive residual stress layer, increased in depth as increased in a shot-peening time due to the layer which acting as a productive film oxide in aluminum alloy reacts with dissolved oxygen to form it [16-18].

Table 4. Corrosion result for all specimens

Symbol	I_{corr}[µA/cm^2]	E_{corr}[mV]	Corrosion rate
A	48.44	-675	25.55
B	4.88	-673.1	3.271
C	3.32	-672.2	1.519
D	11.7	-611.5	1.324
E	8.12	-578.5	1.111
F	3.43	-445.1	1.012

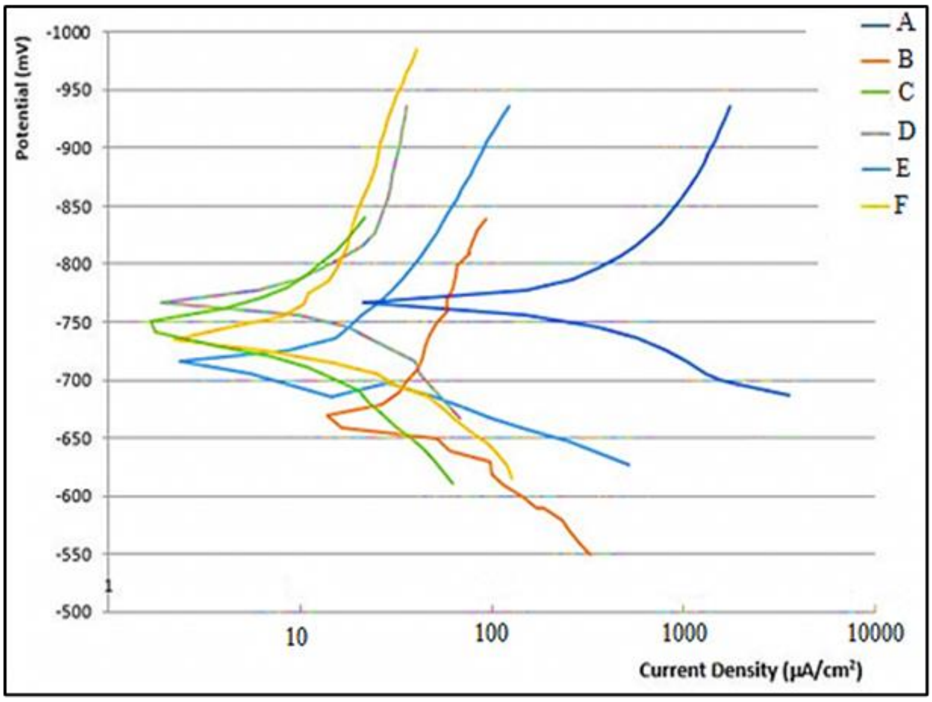

Figure 4: Polarization curves for specimens AA2024-T3 in 3.5% NaCl media.

In Fig. 5: Show the Surface morphology of Al- Alloy 2024-T3 was observed and the surfaces of specimens were totally different from the corrosion media. Fig. 5a, shown the damage surface becomes rough compared with another samples. The optical micrographs of the corroded surfaces of investigated base alloys and surface specimens totally with different shot times. From another side, Fig. 5b, c, d, e and f show specimens submerged in marine water solution, and surface were damaged due to pitting corrosion, which increases as shot peening time was increased. These findings agree with the results of [19].

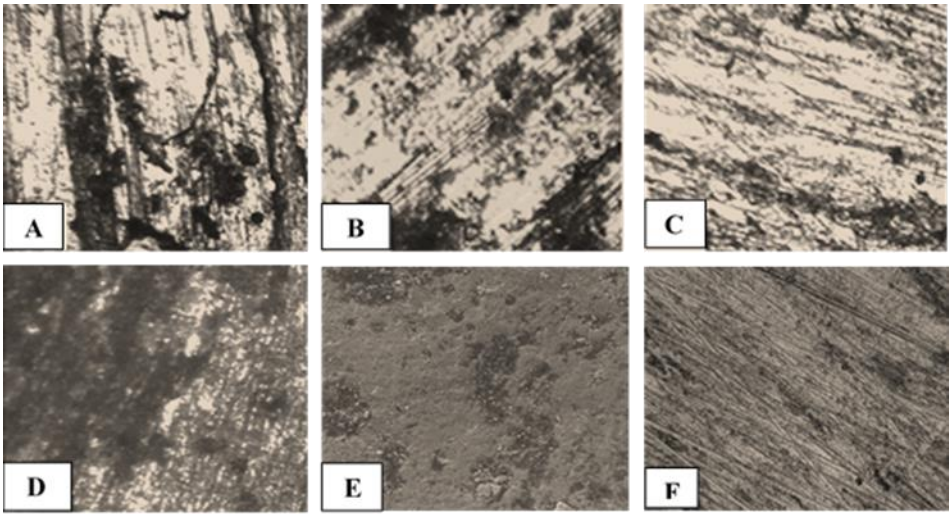

Figure 5. Micrographs indicating the pitting corrosion for all specimens of Al- Alloy 2024-T3 after corrosion test in sea water solution at 100 X.

CONCLUSIONS

Mechanical surface treatments by shot peening process produce the residual compressive stress distributions due to the relatively homogeneous deformation (cold work). Increases of surface hardness and roughness values with increase of the shot peening time. The shot peening process was effective to improve the resistance of pitting corrosion of the AA 2024-T3 by decreased in corrosion rate in sea water. Also increasing in shot time affected to increase in pressure of shot peening which affects to increase of the pitting corrosion resistance.

ACKNOWLEDGMENTS

Gratefully acknowledgments for Middle Technical university, university of technology and ministry of industry – Al- Faris company to help us for all experimental and metallography examinations of these study.

REFERENCES

[1] M. Trueba, and S.P. Trasatti, "Study of Al alloy corrosion in neutral NaCl by the pitting scan technique", Mater. Chem. Phys., Vol. 121, No. 3, Pp. 523-533, 2010.

[2] Pitting corrosion of aluminum, Vol. 41, Pp. 1743-1767, 1999.

[3] T.M. Yue, L.J. Yan, and C.P. Chan, "Stress corrosion cracking behavior of Nd: YA Glaser-treated aluminum alloy", 7075 252, Pp. 5026-5034, 2006.

[4] B.S.M. Daniel Steves, "Characterization of Residual Stresses and Mechanical Performance of Gas Tungsten Arc Welded Aluminum Alloy 6061-T6", Texas Tech University, Daniel Steves, 2010.

[5] A. Galiotto, A.R. Rosso, E.A. dos Santos de Almeida, and A.P. Krelling, "Characterization of Different Surface Layers Produced by Solid Boron-Nitro-Carburizing Thermochemical Treatment on AISI 1020", Journal of Materials Research, Vol. 22, No. 5, Pp. e20190316, 2019.

[6] A. Vedrtnam, "Effect of Novel Thermo-Chemical Treatment on Bending Strength of Laminated Glass". International Journal of Structural Glass and Advanced Materials Research, Vol. 40, No. 2, Pp. 112-120, 2018.

[7] P. JohnMaclins, "Tensile Behavior of Aluminium Alloy 6063 - T6 In Sea Water", Journal of Engineering Research and Development, Vol. 10, No. 5, Pp. 68-74, 2014.

[8] Y. Zhang, and K. Shin, "Effect of Shot Peening on Microstructural Evolution of 500-7 Ductile Cast Iron", Applied Microscopy, Korea, Vol. 48, No. 3, Pp.73-80, 2018.

[9] N. Birbilis, M. Cavanaugh, and R. Buchheit, "Electrochemical behavior and localized corrosion associated with Al 7 Cu 2 Fe particles in aluminum alloy 7075-T651", Corros. Sci., Vol. 48, Pp. 4202e4215, 2006.

[10] V. Pandey, J.K. Singh, K. Chattopadhyay, N.C.S. Srinivas and V. Singh "Influence of ultrasonic shot peening on corrosion behavior of 7075 aluminum alloy", Journal of Alloys and Compounds, Vol. 723, Pp. 826e840, 2017.

[11] A.S. Alwan and A.A. Jaddoa, "Effect of Thermochemical and Mechanical Surface Treatments on Metallographic of Biomaterial Stainless Steel Grad 316L", Journal of Mechanical Engineering Research and Developments, Vol. 43, No. 3, Pp. 324-332, 2020.

[12] X. Wei, D. Zhu, W. Zh, D. Wu, J. Li, and C. Zhang, "Effects of Surface Characteristics of AISI 304 Stainless Steel by Wet Shot Peening and its Wear and Corrosion Behavior", Int. J. Electrochem. Sci., Vol. 15, Pp. 4840 – 4852, 2020.

[13] D. Liang, S. Meng, Y. Chen and C. Hua, "Experimental Analysis of Residual Stress and Bending Strength of Gear Tooth Surface after Shot Peening Treatment", Shock and Vibration Volume 2020, Article ID 3426504, 10 pages.

[14] Y. Prawoto, P.G. Mazein, A.V. Kosterin and Z. Ahmad, "Effect of Shot Size in Surface Improvement via Shot Peening; Analytical, Modeling and Experimental Approaches", Int. J. Metall Met. Phys., Pp. 1-16, 2019.

[15] E. Avcu, "Surface Propertes of AA7075 Aluminum Alloy Shot Peened Under Different Peening Parameters", Acta Materialia Turcica, Vol. 1, Pp. 3-10, 2017.

[16] M. Ardelean, S. Lascău, E. Ardelean and A. Josan, "Surface treatments for aluminium alloys", IOP Conf. Series: Materials Science and Engineering, Vol. 294, Pp. 012042, 2018.

[17] W.B. Wan Nik, O. Sulaiman, A. Fadhli, and R. Rosliza, "Corrosion behavior of aluminum alloy in sea" The International Conference on Marine Technology Proceedings of MARTEC, BUET, Dhaka, Bangladesh, Pp. 175, 2010.

[18] L. Nie, Y. Wu, and H. Gong, D. Chen and X. Guo, “Effect of Shot Peening on Redistribution of Residual Stress Field in Friction Stir Welding of 2219 Aluminum Alloy”, MDPI, Materials, Vol. 13, Pp. 3169, 2020; doi:10.3390/ma13143169.

[19] M.K. Abbass, K.S. Hassan, and A.S. Alwan, “Study of Corrosion Resistance of Aluminum Alloy 6061/SiC Composites in 3.5% NaCl Solution”, International Journal of Materials, Mechanics and Manufacturing, Vol. 3, No. 1, Pp 31-35, 2015.