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INVESTIGATION OF THE EFFECT OF SHOT PEENING PROCESS ON THE CORROSION CHARACTERISTICS OF AA2024-T3 ALUMINIUM ALLOY

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ABSTRACT

The performance of components in many applications depends on the life of the materials. The durability of materials depends upon its strength. Many materials fail due to corrosion. Corrosion takes place in the materials extensively used in the field of marine, automobile and aerospace applications. Shot peening is one of the widely used surface treatment methods. An attempt is made to address the surface corrosion of Al 2024 T3 alloy by treating the material surface using shot penning process. Shot peening can affect the corrosion behaviour of aluminium, particularly if a ferrous medium is employed in the peening process. It is known that small additions of iron can significantly increase the corrosion rate of aluminium. This is generally attributed due to the transfer of iron between shot and work piece during the peening process. In this work the corrosion behaviour of Al alloy 2024-T3 was studied before shot peening and after shot peening condition. It is found that shot peening process using glass beads increased the surface corrosion resistance. Corrosion studies were carried out in a 3.5% NaCl solution using open circuit potential and potentiodynamic polarization technique. However, the potentiodynamic polarization study indicates there is an enhancement of corrosion potential (Ecorr) and a decrease of corrosion current density (Icorr).

Keywords: *Aluminium, Corrosion, Glass Beads, Polarization.*

1.Introduction

The growth of automotive and aerospace industries has demanded improvement in the properties of materials. Aluminium alloys are playing a major contribution in aerospace industry as well as in automotive industry. Most of the components that are exposed to outer environment in automotive industries utilize aluminium alloys. The performance of aluminium alloy will be better when its corrosion resistance and fatigue strength are improved. Special coating and surface treatment process are useful to obtain considerable improvements in the surface properties of materials. Shot peening process is one such process that results in better performance on surface properties. Kalainathan et al [1] found improvements in corrosion resistance by laser shot peening without coating on the surface. Hashemi [2] showed an increase of corrosion resistance in 316L austenitic stainless steel after shot peening process. The process of denoting the failure of a material under the simultaneous action of cyclic loads and chemical attack is termed as corrosion fatigue [3, 4]. Under cyclic loading, the aqueous environment can accelerate the initiation of a surface flaw and propagate it to a critical size, leading to fracture. The reduction in fatigue life of metallic implants under corrosion fatigue has been well documented [5-7]. The corrosion damage evolution is governed by the nature of the mechanically generated defects, i.e. craters, cracks or scratches, and their surrounding stress fields by Gerbert et al [8]. Shot-peening can, under certain conditions, affect the corrosion behavior of aluminium, particularly if a ferrous medium is employed in the peening process; it is known that small additions of iron can significantly alter the corrosion behavior of aluminium [9]. Wang et al [10] studied the microstructure of surface Nano crystallization of 1Cr18Ni9Ti stainless steel by shot peening and its effect on corrosion resistance in chlorine–ion-contained solution. The difference of the microstructure may affect the benefits of shot peening [11]. After testing, Hashemi et al [12] concluded that shot peening treatment for a long enough time causes a reduction in the corrosion rate. Corrosion is one of the most significant phenomena which happen for the alloys or metals used as implants in the body [12 - 14]. Shot-peening (SP)

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surface treatments can improve the pitting corrosion behavior of 316L steel in a NaCl 0.5 M solution [15]. From the literature, the need for corrosion resistance could be understand. In this paper, the corrosion properties of Al 2024 T3 aluminium alloy is analyzed before and after shot peening using glass beads. Al 2024 T3 aluminium alloy specimen is studied by the potentio-dynamic polarization technique (PDP). The objective of this paper is to explore the effects of shot peening using glass beads on corrosion performance of an Al 2024 T3 aluminium alloy.

2. Experimental

Out of different types of shot peening process, material shot peening process is preferred. In material shot peening process, the target material is fixed in a position. In the shot peening process, the following two parameters are taken in to account.

1. Distance (D) between the nozzle and target material.
2. Pressure (P) of the shot peening process.

Shot Material : Glass beads made from Soda Lime Glass Mesh size : 18-350
Diameter range : 0.6mm to 0.8mm
Nozzle diameter : 8mm.

Shot peening process was performed on Al 2024 T3 specimen size of 10 mm x 50 mm x 4mm with peening intensity of 4.44 mm/A. The chemical composition of Al 2024 T3 is given in Table 1.

Table 1. Chemical composition of Al 2024 T3 (% Wt.)

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
0.05	0.5	3.9	3.1	1.6	0.1	0.25	0.15	Bal.

The experiments are designed using Response Surface Method and the parameter ranges are shown in Table 2.

Minitab software is used for experimental design. The optimal combination of process parameters is identified from the available set of combinations obtained from Response Surface Method. The experimental set-up is shown in Fig. 1. The experiments are performed as per the results obtained from DoE as shown in Table 2. In the table pressure is given in bars. A total of thirteen experiments were performed as per the parameter combinations and their corrosion values are measured using PDP technique. The corrosion values are measured in amp/cm2. Photograph of a sample shot peened specimen is shown in Fig. 2.

Fig.1 Photograph of shot peening process

Table 2. Important factor and their levels

Sl. No	Parameters	Levels				
		-1.41	-1	0	+1	+1.41
1	Pressure (P)“MPa”	0.05	0.06	0.1	0.14	0.15
2	Distance (D)“mm”	50	65	100	135	150

Table 3. Design matrix and its experimental values

Sl. No	Coded Value		Actual Value		Corrosion
	Pressure " MPa"	Distance "mm"	Pressure "MPa"	Distance "mm"	
1	-1	-1	0.06	65	0.000015
2	1	-1	0.14	65	0.000013
3	-1	1	0.06	135	0.000020
4	1	1	0.14	135	0.000013
5	-1.41	0	0.05	100	0.000054
6	1.41	0	0.15	100	0.000015
7	0	-1.41	0.1	50	0.000019
8	0	1.41	0.1	150	0.000036
9	0	0	0.1	100	0.000015
10	0	0	0.1	100	0.000018
11	0	0	0.1	100	0.000015
12	0	0	0.1	100	0.000015
13	0	0	0.1	100	0.000014

Fig. 2 Photograph of specimen after Shot Peening Process

3. Corrosion Studies

The metals may be corroded as a result of electro- chemical or chemical reaction between a metal surface and the environment. Many corrosion phenomena are essentially electro- chemical in nature and have the presence of an electrolyte in contact with metal. Polarization measurement is performed using corrosion cell kit with power sine software. All tests were performed at room temperature. Measurement was carried out in a conventional three electrodes Pyrex cell with a platinum wire as counter electrode, saturated calomel electrode as a reference electrode and sample specimen as working electrode. All the reported potentials are referred to this electrode. A typical corrosion testing set-up is shown in Fig.3. All measurements are carried out using a pc controlled polarization sat (PARSAT 2273) instrument and are performed two times to assure reproducibility. Each sample is stabilized for about 1 hour in the solution with ±500mV stable open potential polarization. Here +500mV is anodic and -500mV is cathodic. A graph is plotted using the software to identify the relation between potential voltage and current intensity as shown in Fig.4 and Fig.5.

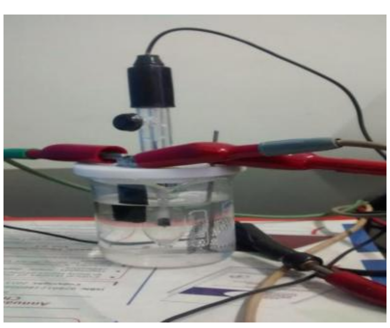

Fig.3 Photograph of corrosion Testing Set-Up

During the test, cathodic reaction is inhabited to higher resistance whereas anodic reaction is accelerated. This is one of the cathodic type coatings. The potential values were recorded at a scan rate of 10mV/s. Corrosion studies were carried out in a 3.5% NaCl solution using open circuit potential and potential dynamic polarization technique. However, the potentiodynamic polarization studies indicate there is an enhancement of corrosion potential (E_{corr}) and decrease in the corrosion density (I_{corr}) after shot peening process.

4. Results and Discussion

Response surface methods are used to examine the relationship between one or more response variables and a set of quantitative experimental variables or factors. These methods are often employed to identify the "vital few" controllable factors and to find the factor settings that will optimize the response. The outcome of the experiments are suitably measured and documented to obtain the regression equation which is shown in (1).

$$\text{Corrosion} = 0.000016 + 0.000010\,P - 0.000002\,D + 0.00005\,P{*}P + 0.0000001\,D{*}D - 0.00006\,P{*}D \quad (1)$$

The regression equation is optimized using the response surface method of mini-tab software and the optimum values of parameters and the response, viz., corrosion is as follows.

Pressure (P)	-	0.14 MPa
Distance (D)	-	64 mm

The optimum corrosion current density obtained from the test is 0.0000125 Amp/cm^2. Experiment is performed for the above combination again and the corrosion current density is measured as 0.00001248 Amp/cm^2. Therefore, it is concluded that the values obtained from tests are very close to the theoretical corrosion values. The corrosion plot for the specimen obtained using optimum parameter combinations is shown in Fig. 5.

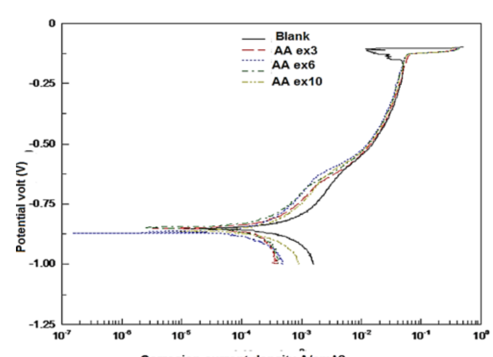

Fig. 4 Cyclic Polarization Curves of Different Specimens

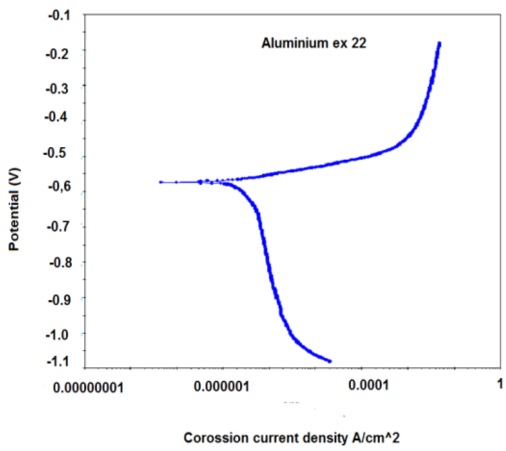

Fig. 5 Graphical representation of PDP results of a specimen after shot peening Process with optimal value.

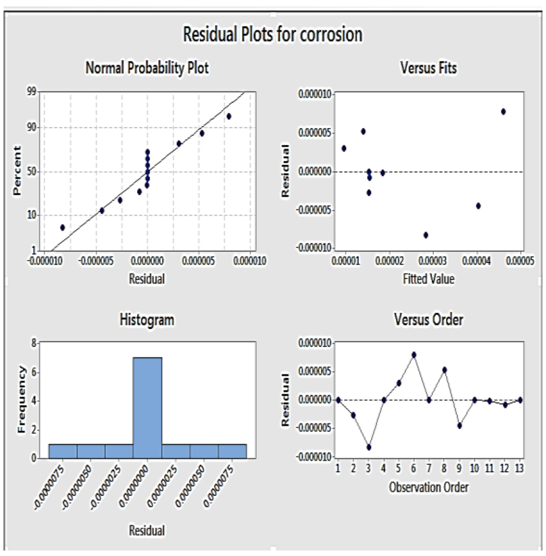

Fig.6 Residual Plots for Corrosion

Also, corrosion current density for a specimen which not shot peened is also tested using potential dynamic polarization technique. The corrosion current density value obtained for the specimen is 0.0001206 Amp/cm2. The specimens tested after shot peening process show lower values of current density in the potential dynamic polarization technique, which in turn confirms that the shot peening process improves the corrosion resistance. The residual plots for corrosion studies are also shown in Fig.6.

5. Conclusions

In this work, the shot peening process is performed using glass beads on AA2024 T3 aluminium alloy to study its corrosion properties. It can be concluded that the corrosion resistance of the AA2024 T3 aluminium alloy has improved considerably after shot peening process. In fact, all the shot peened specimens have a better corrosion resistance than the specimen which is not peened. More studies will be carried out in future using various other shot balls.

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