# Corrosion Resistance of Aluminum Alloy 7020-T6 in Sea Water

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**Abstract**

The present work is aimed to investigate the effect of heat treatment on corrosion resistance of Al-alloy 7020-T6 in sea water, the specimens which manufactured by (1.5*1.5*0.2) cm, according to ASTM (G31-72) [1] The heat treatment was carried out at 480°C and water quench after that artificial aging are implemented at temperature 150˚C for (1, 4) hours. Microstructure and phase properties after heat treatment and corrosion test were investigated by optical microscope; X-ray diffraction and computer potentiodynamic polarization technique have been used to study corrosion behavior in 3.5% NaCl. The results of corrosion resistance 7020-T6 decrease by solution heat treatment and, increase the holding time from 1- 4 hour would increase the corrosion rate, Intermetallics compounds containing zinc represent as the sacrificial anode and control pitting corrosion in 7020-T6 alloy also, the artificial ageing time increase the precipitation of zinc and decrease pitting corrosion at 1 hour.

**Keywords:** 7020-T6 alloy; Corrosion resistance; Potentiodynamic; Microstructure; Artificial aging; Heat treatment.

## مقاومة التآكل لسبيكة الالمنيوم 7020-T6 في ماء البحر

**الخلاصة**

يهدف البحث الحالي إلى دراسة تأثير المعاملة الحرارية على مقاومة التآكل لسبيكة الألمنيوم نوع 7020-T6 في وسط ماء البحر، عينات التآكل صنعت بأبعاد (1.5*1.5*0.2) سم حسب المواصفة ASTM (G31-72) [1] ثم اجري لها معاملة محلولية بدرجة حرارية 480˚م ثم التقسية المباشرة بالماء ثم يلي ذلك تعتيق صناعي انجز عند درجة حرارة 150˚م وبزمن (1 ، 4) ساعات. تم دراسة التركيب المجهري وخصائص الأطوار بعد عملية المعاملة الحرارية واختبار التآكل، عن طريق المجهر الضوئي والحيود بالأشعة السينية وكذلك استخدام طريقة الاستقطاب المعانة بالحاسوب في وسط ملحي 3.5% NaCl . بينت النتائج ان مقاومة التآكل لسبيكة 7020-T6 تقل عند إجراء المعاملة المحلولية وزيادة زمن التثبيت من 1 – 4 ساعات يؤدي الى زيادة معدل التآكل ، وجود المركبات الوسطية الحاوية على الزنك تتمثل بمناطق تضحية انودية وبذلك تسيطر على التآكل النقري في السبيكة 7020-T6 وايضا التعتيق الصناعي يزيد من ترسب الزنك وهذا بدوره يقلل من معدل التآكل عند زمن 1 ساعة.

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## Introduction

Aluminum alloys are widely used in different industry field owing to their excellent corrosion resistance to the barrier oxide film strongly bonded to the surface. Their tendency to corrosion in the presence of halide ions limits their applications especially in sea water and atmosphere condition.

Corrosion of aluminum involves the adsorption of these ions on the surface, reaction of the anion and with aluminum in the oxide layer thinning it by reaction /dissolution and attack of the exposed metal [2].

Alloying elements such as Zn, Cu, Mg, and Si added to aluminum to improved mechanical properties but frequently reduce localized corrosion resistance; in particular pitting and exfoliation corrosion stronger localized attack on alloys in comparison with aluminum has been ascribed to alloy surface microstructural heterogeneity precipitates presence, inclusions and intermetallic particles provoke discontinuities during the large growth and promote galvanic couples formation with the alloy matrix[3, 4].

Ternary and quaternary Al-base particles frequently found in these alloys exhibited different electrochemical characteristics compared to the surrounding microstructure Mg. containing particles tend to be anodic, while Cu, Fe, and Mn containing ones tend to be cathodic in relation to the matrix in both cases, localized dissolution are promoted since 7XXX aluminum alloys are used to have good mechanical performance as aeronautical material it's essential to improve localized corrosion processes understanding. Therefore this research aims to gain deeper in sight at Al-Zn-Mg alloys corrosion mechanism in 3.5% NaCl using electrochemical techniques [5, 6]. Alloys of Al-Zn-Mg structure to plastic alteration applied in shipbuilding are subjected to the liberated consolidation. The effective consolidation of aluminum alloys depends on insertion other atoms in result of thermal processing dislocation to the net of basic metal as well as creating suitable quantity of very strong and stable disengagements of intermetallic phases in form of small evenly disposed particles. To ensure high volumetric part of disengagements they should form with omission of basic metal atom and if it's possible beyond integrant and other defect of crystal structure, these defects reduce the energical barrier of building and by this they become privileged points of secondary phase's emission.

Many papers study the effect of heat treatment on corrosion resistance of aluminum alloy 7020-T6, Suhayla [7] studied the effect of perception heat treatment on corrosion resistance of Al-based alloy, Umoru and Ige [8] has investigated the effect of Tin composition on Al-Zn-Mg alloy as sacrificial anode in sea water, Birbilis and Buchheit [9] a survey of corrosion potential and electrochemical characteristics for intermetallic particles commonly presents in high-strength aluminum- based alloy.

## Metal Selected

In this research 7020 T6 alloy was used for test whose chemical composition shown in Table (1) The chemical composition analysis was carried out by using ARL-Spectrometer Metals Analysis (2500 series – England 2004) was done in

the Institute of Specialized Engineering.

**Preparation of Specimens**

The specimens were cut from sheet metal Al 7020-T6 by machine in dimensions (1.5*1.5*0.2) cm, according to ASTM (G31-72) [1]. The surface of all specimens was grinded using emery papers (400, 600, 1000, and 1200) and polished with alumina past having 5µm, and 0.5 µm the sample then cleaned with acetone then dried and saved with sealed container for next step.

**Classification of Specimens**

After preparation specimens was classified in mean group as shown in Table (2).

**Heat Treatment**

Solution heat treatment was applied at 480°C and water quenched was applied on specimen group B in Table (No. 2) and artificial aging was applied on specimen group C, D in the same Table by heating the specimen at 150°C for (1, 4) hour.

**X-ray Examination**

The measurements include the specimen group A, B, C and D in Table (2). X-rays are electromagnetic waves, the waves lengths of 0.1 mm when a monochromatic-X-ray beam incidence on the surface of crystal, it is reflect this reflection is well defined by Bragg's Law for constructive interference which is $2d\sin\theta = n\lambda$. The angle θ determined by Bragg's Law for a given interplanner distance (d) and X-ray wave length (λ) are the only angles at which reflection take place, The results shown in Table (4).

**Electrochemical Tests**

The prepared specimen (in Table 2) was fixed in the holder shown in Fig. (1). the reference electrode was fixed about (1 mm) apart from the surface of the specimen to be tested. The reference electrode used in this study was saturated calomel electrode (SCE). The auxiliary electrode used in the electrochemical cell was platinum type. The specimen holder (working electrode), together with the reference and auxiliary electrode were inserted in their respective positions in the electrochemical cell used for this purpose that can fit all these electrodes as shown in Fig. (2). the cell used was made of glass.

Constant potentials (anodic or cathodic) can be imposed on the specimen, by using the potentiostat (Mlab200 of Bank Eleck .Germany). This potentiostat is able to induce a constant potentials ranging from (-1 to +1V) the potentials of the standard reference electrode used in this study (SCE).

The potential difference between the working and the reference electrode (WE-RE) and any current passing in the circuit of working electrode were the auxiliary electrode can be measured by using the SCI computer software image. Any potential difference between the working and reference electrodes and also any current in the working electrode circuit can be automatically recorded. The results and plots were recorded using window XP. The scan rate can be selected also.

Polarization resistance tests were used to obtain the micro cell corrosion rates. In the tests, cell current reading was taken during a short, slow sweep of the potential. The sweep was taken from (-100 to +100) mv relative to (OPC). Scan rate defines the speed of potential sweep in mv /sec. In this range the current density versus voltage curve is almost nearly linear. A linear data fitting of the standard model gives an estimate of the polarization resistance, which used to calculate the corrosion current density

($I_{corr.}$) and corrosion rate. The tests were performed by using a WENKING MLab multi channels and SCI-Mlab corrosion measuring system from Bank Electronics- Intelligent controls GmbH, Germany 2007, as shown in Fig. (3).

**Results**

In Figure (4) and Table (3) shown the current density, with respect the potential for different samples uses in the current research. The current density of specimen (A) have good corrosion resistance because of the oxide film ($Al_2O_3$) gives good protection against environment attack. The corrosion in rate Table (3) in calculated according ASTM standard equation [11, 12] ;

$$CR = \frac{3.27 \times 10^{-3} \cdot i_{ox} \cdot E.W.}{d} \quad .... (1)$$

Where, **CR** is the corrosion rate in (mm/y), $\mathbf{I_{ox}}$ ($I_{corr.}$), is the corrosion current density ($\mu$ A/cm$^2$), **E.W.** is the equivalent weight in grams, and **d** is the density (g/cm$^3$).

**X- ray diffraction results**

The result of X-ray diffraction shown in Table (4) indicated with specimen as shown below; this test was carried out in Ministry of Science and Technology - Department of Materials, XRD Cu-Kα, wave length (λ) = 0.154nm, Philips.

**Microscopic structure**

The microstructure for aluminum alloy 7020-T6 which represented in the specimen group A, B, C and D in Table (2) where shown in Fig. (5), it can be observed that variation in size of corrosion area of alloy 7020-T6 depend on proportion of the zinc and magnesium elements causing different soluble or insoluble compounds in solid state which effected on current and potential in cell test as shown in Fig. (6).

**Discussions**

Figure (4) shows the effect of solution heat on the electrochemical behavior of 7020-T6 Al alloy in aqueous solution of 3.5% NaCl of various aging time (1, 4) hours. This indicate that the solution heat treatment increase the potential of corrosion to more negativity direction and the corrosion resistance of 7020-T6 Al alloy decrease with increasing of temperature due to the precipitation of phases and intermetallic compounds. It had been observed that when the holding time of aging heating increase. The precipitation process would have sufficient time to occur the kinetics of phase precipitations are usually affected by the variation in holding of aging time can be attributed to the different in the microstructure of the alloy. In other work had reported that aging time of heating must be chosen to give the proper precipitate size if time lower the critical dispersion is never achieved.

Zinc is the main alloying element in 7020-T6 and low percentage of magnesium. Zinc in which its diffuses readily at normal homogenization temperature this elements has high diffusion rates and low solubility in aluminum resulting formation of ($Mg_xZn_y$) containing phases along grain boundaries and deletion of Mg and Zn in the area adjacent to the grain boundaries. Diffusion and solubility increase when heating the specimen group (C, D) in Table (2) at 150°C for (1, 4) hours second phases ($Mg_4Zn_2$) is show the aging process improve of solubility of alloying elements and this was clear in peak patterns from figure (6) it can be seen that corrosion current density increased.

## Conclusions

The result of the current study reached to the following conclusions;

1- Corrosion resistance of 7020-T6 decrease by solution heat treatment.

2- Increase the holding time of specified heating temperature, for 1 hour to 4 hour would increase the corrosion rate.

3- Intermetallics compounds containing zinc in 7020 alloy play significant role as sacrificial anode in alloy and controlling the pitting corrosion.

4- The artificial ageing time increase the precipitation of zinc thus gives lower pitting corrosion at 1 hour.

## References

[1] Annual book of ASTM STANDARDS, Standard Practice for Laboratory Immersion Corrosion Testing of Metals, G31-72, Vol. 03.02, 2004.

[2] Chloride media, "International and Congress of ABM", January, p. 24-27, 2007.

[3] Wojcirch, jurczak, "Faculty of Mechanism and Electrics Influence of Heat Treatment in the electrochemical corrosion of Al – Zn – Mg alloys", revised2 p. 81-103, Glynia Poland. October, 1991.

[4] L.L Shreir RA Jarman &GT Burstein U., "Corrosion Control", Third edition Volume 2, Butterworth Heinemann Oxford, 2003.

[5] Aluminum and Aluminum Alloys Heat Treatment of Aluminum and Aluminum Alloys. The AZO journal of Materials on line". AZOM.com, 2008.

[6] Jon Perryman, "Corrosion Resistance of Aluminum", ACMI Technical White Paper, January 2007.

[7]Suhayla Noori Gareab, "Effect of Heat Treatment on Microstructure and Corrosion of Alloys (Al- 4%Cu) and (Al- 4.1%Cu-0.9%Mg)", M.Sc. Thesis, Production and Metallurgy Engineering, University of Technology, Baghdad-Iraq.

[8] L.E. Umoru and O.O. Ige, "Effects of Tin on Aluminum – Zinc Magnesium Alloy as sacrificial", Journal of Minerals & Materials Characterization & Engineering, Vol. 7, No. 2, pp 105-113, Jmmce. Org printed in the USA. 2007.

[9] N.Birbilis, Z and R.G Buchheit, "Electrochemical Characteristics of Intermetallics phases in Aluminum Alloys an Experimental Survey and Discussion", Fontana Corrosion Center, Department of Materials Science and Engineering, 2005.

[10] The Online Materials Database - MatWeb, "Aluminum 7020, 7000 series Aluminum Alloy, Aluminum Association, 2007. WWW.MatWeb.com.

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

[12] Metals Handbook, Vol. 13, "Corrosion", American Society for Metals, Metals Pack, Ohio, 1992.

**Table (1) chemical composition of 7020 T6 alloy**

| Elements | Standard value [10] | Measured value |
|---|---|---|
| Si | ≤ 0.35 | 0.121 |
| Fe | ≤ 0.40 | 0.290 |
| Cu | ≤0.20 | 0.200 |
| Mn | 0.05-0.5 | 0.0764 |
| Mg | 1-1.5 | 1.25 |
| Cr | 0.10-0.35 | 0.228 |
| Zn | 4-5 | 4.56 |
| Ti | 0.08 | 0.0319 |
| Al | Balance | Balance |

**Table (2) classification of specimens**

| Symbol | state |
|---|---|
| A | As received. |
| B | Solution heat treatment to 480°C and water quench. |
| C | Artificial aging at 150°C for 1 hour. |
| D | Artificial aging at 150°C for 4 hours. |

**Table (3) classification of samples**

| Specimen | $E_{corr}$. [mV] vs SCE | $I_{corr}$. [$\mu$ A/cm$^2$] | CR(mm/y) |
|---|---|---|---|
| A | -766.6 | 32.74 | 0.3607 |
| B | -802.9 | 36.53 | 0.4025 |
| C | -814 | 17.20 | 0.1895 |
| D | -817.2 | 18.75 | 0.2065 |

**Table (4) X-ray examination results**

| Symbol | Phases |
|---|---|
| A | $Mg_4Zn_{11}$, $MgZn_2$, Al |
| B | $AlMg_4Zn_{11}$, MgZn |
| C | $Mg_4Zn_2$, $Mg_4Zn_{11}$, $Mg_7Zn_3$ |
| D | $Mg_4Zn_{11}$, MgZn |

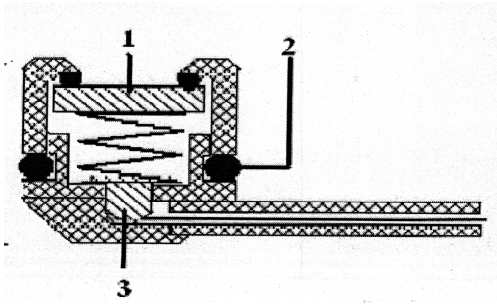


**Figure (1) Specimen holder shows; 1. Specimen; 2. Seal; 3. Electrical connection**

**Figure (2), Polarization Standard Cell.**


**Figure (3), Potentiostat Apparatus for Polarization Tests.**

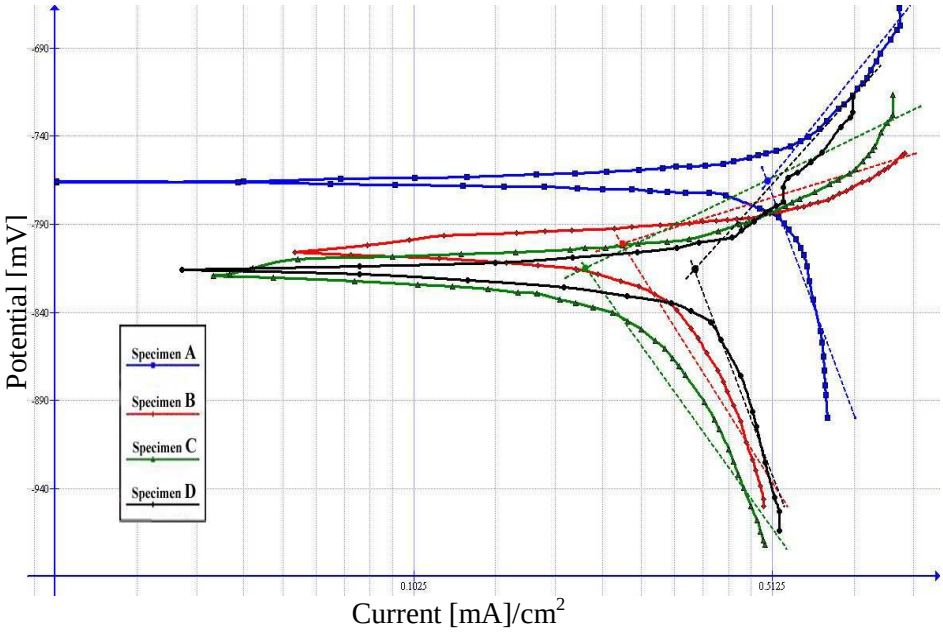


**Figure (4) Tafel and cyclic polarization curve for all**

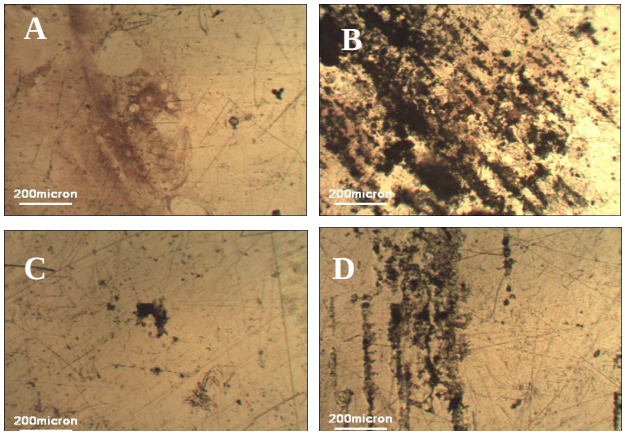


**Figure (5), Micrograph of different heat treatment specimens for aluminum alloy 7020-T6 shows the corrosion attack.**

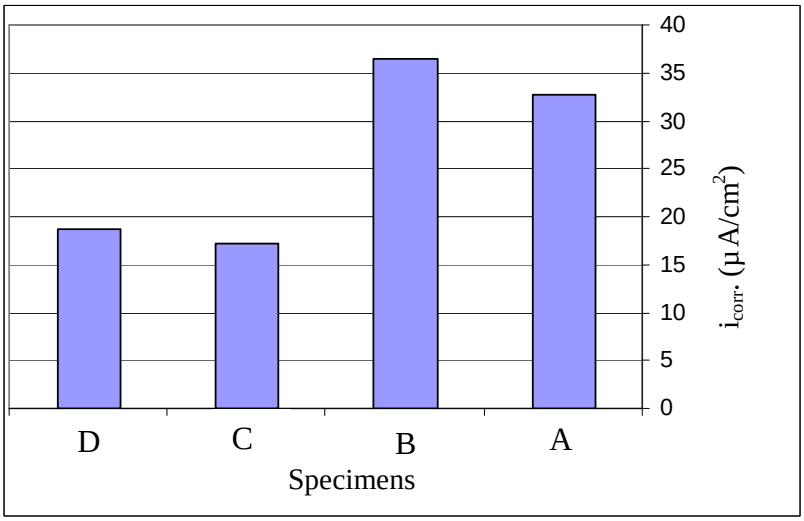


**Figure (6) bar chart of Icorr. Related of heat treatment for different specimens**