The Effect of Sea water on the Corrosion Resistance of Commercial Aluminum Alloys

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Abstract

The aim of this study is to test theeffect of sea water on Corrosion / Erosion Rate andthe hardness of commercial aluminum alloy .The specimen of this alloy was heat treated at (520ºC) for(1.5 hr) then quenched in water .The specimenwas exposed to ajet of see water at constant speed (3.2 m/sec) , and different periods of time (from 0.5 to 14.5 hrs) . Special system designed for this purpose , consist of two basins of water ,each one (50*50*25) cm ^{3}size , The specimen hold in the upper basin.The Jet of sea water from a source located at 2.5 cmstrike the specimen . The loss in weight of the specimendue to the effect of corrosion of sea water was measured.The Weight Loss per unit area , the Corrosion Rate, and the relation between each of them and exposed time , was calculated .The different happened in hardness of the specimen was calculated.

The results show that :

- The Weight Loss per unit area increase at the first hours of exposure time to the sea water (till 3.5 hrs) , then be constant at the remaining time .
- The Corrosion Rate was maximum after (0.5 hr) then decrease gradually , and be at low rate after more than 10 hrs of exposed time.
- Hardness increased with the increase of exposed time to the sea water .

Key Word: Commercial Aluminum Alloys

1- Introduction

Aluminum alloys are divided into two classes of alloys : Wrought alloys & Cast alloys .

Wrought alloys or mechanically worked produced by : rolling, extrusion , drawing and forging . are subdivided into two types: Heat treatable , and non heat treatable alloys .Aluminum alloy contains elements like (Fe, Mn, Zn, Cu,) to improve their mechanical properties[WWW.AluminumHT.Com,"Aluminum Heat TreatmentReference Guide" May.(18),(2004)

]. The corrosion resistance of Aluminum and its alloys is depend upon a protective oxide film , which is naturally self – renewing and accidental abrasion or other mechanical damage of the surface film is rapidly repaired [http://corrosion-doctors.org/matselect / corralumin.htm "Corrosion of aluminum alloys " .

] . Aluminum alloy is very active when exposed to a source of oxygen, it reacts to form a thin transparent oxide film over the whole of the exposed alloy surface. This film controls the rate of corrosion and protects the substrate metal allowing the production of long life components in

aluminum alloys, if the film is damaged and cannot be repaired , corrosion rate of the substrate occurs very rapidly [R.Kenneth. Trethewey, "Corrosion"1st &2end edition P.348. UK ,(2001).] . Amjadstudied the effect of graphite on corrosion rate of Al-Si alloy by using river ,tap, and sea water. He showed that corrosion rate in the river water is less than that in the tap and sea water [A,A. Amjad. " Effects of Graphite Addition on the Mechanical Properties of Al-Si Alloys " M.Sc. Thesis, University of Basrah Iraq , 2006.]. Maksimov studied the effect of small additions of Si and Ge on the hardness of commerical Al-Cu alloy .He found that for the same level of microalloying in alloy Al-Cu-Si-Ge, a maximum hardness was achieved 3 times faster than in alloy Al-Cu,the accelerated precipitation kinetics is a consequence of the presence of fine Si and Ge particles, serving as heterogeneous precipitation sites for θ" strengthening particles [V. Vesnamaksimovic ,S.Velimir,M.Jovanovic, "The effects of micro alloying with Si and Ge on microstructure and hardness of a commercial aluminum alloy" J.Serb. Chem .Soc.(Vol.68,No. 11, pp893-901), U.S.A.2003.

].Ohmori studied the effect of increasing Si content on the (Al-Mg-Si alloys) on the mechanical properties and aging behavior of(Al-Mg-Si) alloy [Y .Ohmori, Y .Matsuura ,Nakai& S. Kobayashi "Effect of excess Si content on the aging Behavior Solution-treated Al-Mg-Si alloys "

] . Tony Andersonstudied the effect of alloying elements on the pure aluminum and influence on the mechanical properties [] Tony Anderson CEng. " How and why alloing elements are added to aluminum"

] H.Snelson Engineers , study the effect of sea water on the loss in weight in the aluminum sheets and compare with other metals , and found that the average for the deepest corrosion on aluminum sheets was 0.07 mmafter 8 years , and the loss in weight become 7 g / m ² [H.Snelson Engineers " Aluminum Extrusions Aluminum Fabricators " Nat Lane , Wharto[1]WWW.Aluminum HT.Com,"Aluminum Heat Treatment Reference Guide" May.(18),(2004).

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Solution Heat Treatment

The purpose of this treatment in aluminum alloys is to obtain the maximum concentration of the hardening solute such as Zn, Si , Mg and Cu in solution by heating the alloy to a temperature in which a single phase will be created . This heat treatments effect solid solution of alloying constituents and improve mechanical properties [www.key-to-metals.com/Article7.htm " Heat treating of aluminum and aluminum alloys ".].

Corrosion Rate

The corrosion rate depends on both the metal type and corrosive media. The corrosion rate value has much importance in the mechanical parts choice or the interval between the beginning of their use and their

failures. Corrosion rate can be calculated by several methods, like the weight loss method in which the weight loss from unit area per unit of time represents the corrosion rate.

Weight loss = Δ **W** = the deference in weight of the specimen before and after exposed to the stream of see water

$$\Delta W = W1 - W2 \quad (gm) \quad \ldots\ldots\ldots\ldots (1)$$

Weight loss (per surface area) = **Δ W / A** (g/cm^2)……(2)

Where: A = surface area of the specimen exposed to the stream of see water

Corrosion Rate = **CR = Δ W /A. t** ($g/cm^2.hr$) ……(3)

Where t = exposed timeto the stream of see water

Mechanical Properties

The mechanical properties represent the most important informationto understand the properties of the materials. Generally dealing with materials requiring information about their mechanical behavior and how this behavior can be measured by mechanical tests.

One of this properties is the Hardness , which consider as one of the important mechanical properties , which represent as the resistance of metal to penetration of the other materials or resistance of metal to the crash . There are many process to determine the hardness , on of important way , is : Vickers process

Vickers Hardness(Hv) = p /a(Kgf / mm^2)a= d^2 / (sin { 136 / 2)

Hv = p / { d^2 / sin (2 sin 68) **= (1.8544*p) / d^2** (Kg f / mm^2)…….. (4)

Where :d = diameter of penetration (mm) p = lode (Kgf) a = surface area of the penetration (mm^2)

Experimental Work

This work included an evaluation of commercial aluminum alloys which are chemically analysed by using an atomic emission spectrum photometer.

The **chemical compositions** of alloy is listed in Table (1) .

Table (1) The chemical composition of alloy.

ELEMENTS %					Alloy
Sn	Mn	Cu	Fe	Al	1
0.01	0.8	0.06	0.44	98.64	

were ground by an emery paper of grades (100, 150, 500). Then the specimens were washed in deionized water and dried by air. After that the specimens were polished with nap cloth containing alumina particles size of (5μm) by using the polishing machine, washed in alcohol and dried.

Solution Heat treatment This Heat treatment done by heating the specimen to 520ºC for 1.5hrs& then quenched in water before test .

Machine Preparation of the Specimens

Square shape of specimen (1x1) cm was designed to measure the erosion / corrosion resistance and hardness .These specimens

each test were taken and the average of the diagonals of each indentation were measured from equation (5) as shown in Table (2).The hardnessof the other tests are shown intable (3)

Vickers hardness

The hardness test of the investigated specimens had been carried out by using the Vickers hardness instrument. The Vickers hardness tester type [Tokyo Testing Machine mfg Co., Ltd.].In this test(5-10)readings for

Table (2) Represents values of diameter and Vickers hardness

Test No.	Diameter mm	Vickers Hardness kg/mm²
1	4.56	62.427
	4.49	64.389
	4.61	61.080
	4.39	67.355
	4.58	61.883
	4.60	61.346
Average	4.548	63.080

Erosion - Corrosion Test

The erosion corrosion test was carried out by using a system specially designed for this purpose. A direct water jet was used to achieve the erosion/corrosion effect .This test was applied on the alloys that were heat treated for various intervals.Finally the specimen was dried and weighed to measure the weight loss .The corrosion rate was calculated as in equation (2). The results of erosion/corrosion were used for the following representation are listed in table (3) :

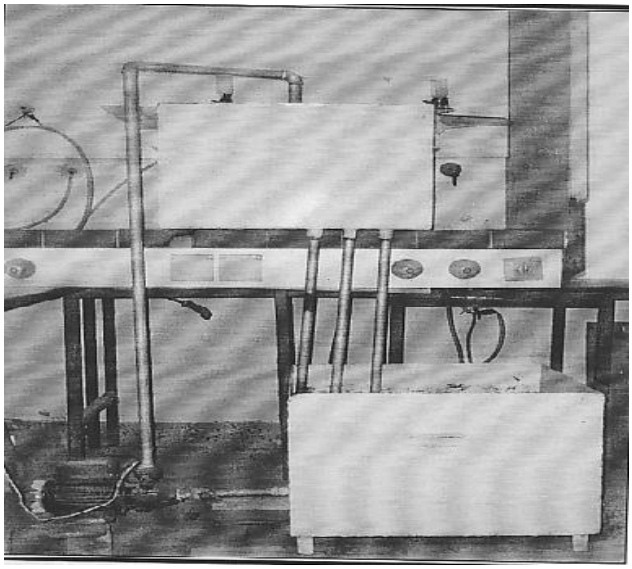
- The relationship between the weight loss(Δw/A) & expose time.
- The relationship between the corrosion rate(CR) & expose time.

Table (3) Represented weight loss & corrosion rate for alloy

Exposed Time (hr.)	Δ w/A (g/mm²)	CR (g/mm² .hr)	Hardness Hv
0.0	0.0000	0.0000	63
0.5	0.0004	0.0008	63
1.5	0.0007	0.000467	66
3.5	0.0010	0.000286	70
7.5	0.0010	0.000133	78
8.5	0.0010	0.000118	84
9.5	0.0010	0.000105	100
10.5	0.0010	0.000095	100
11.5	0.0010	0.000087	116
12.5	0.0010	0.000080	123
13.5	0.0010	0.000074	128
14.5	0.0010	0.000069	133

Erosion corrosion system

In this study a special system figure (1) was designed to measure the erosion/corrosion resistance for the tested alloys specimens, which consist of two basins of water. The size of each basin is (50 x 50 x 25) cm^3. One of these two basins is placed in a position of (80) cm height .A little clipper is used to hold the specimen inside the upper basin while the other basin is placed on the ground. A water pump (0.5 HP) is used to circulate the water between the two basins. The water strikes the specimen by a jet which is about (2.5 cm) apart from the specimen. The water speed is (3.2) m /sec and the flow rate is (0.9) m3 / hr. The weight loss is measured at different times interval by four digits sensitive balance type (Sartorius BL 210S).



Water Composition Analysis: The sea water analyzed as shown in a Table (4)

Table (4) the chemical analysis of sea water

Type of analysis	Measuring limit	Sea Water
pH	----	7.5
Electrical Conductivity	mμs/cm	6620
TDS	ppm	4634
TH	ppm	2000
Cl^-	ppm	1200
Ca^{2+}	ppm	900
Ca as $CaCO_3$	ppm	1000
Mg as $CaCO_3$	ppm	1100
SO^{2-}_4	ppm	1284
P-Alkalinity	ppm	0.0
M- Alkalinity	ppm	235
Fe^{2+}	ppm	1.5

TDS : Total Dissolve Solid TH : Total Hardness

Fig. 2

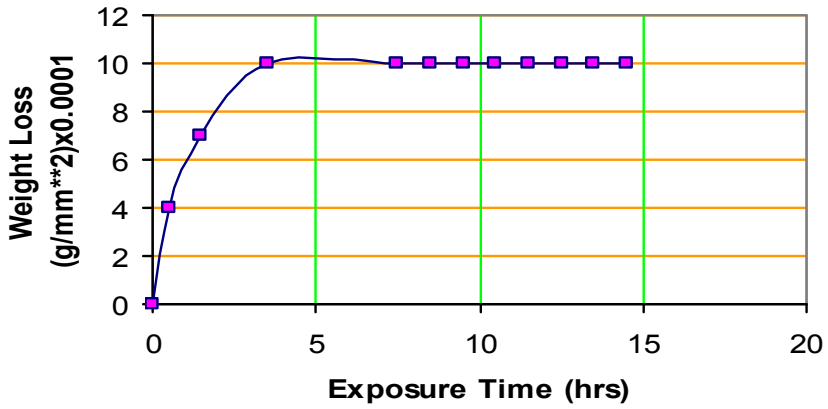


Fig. 3

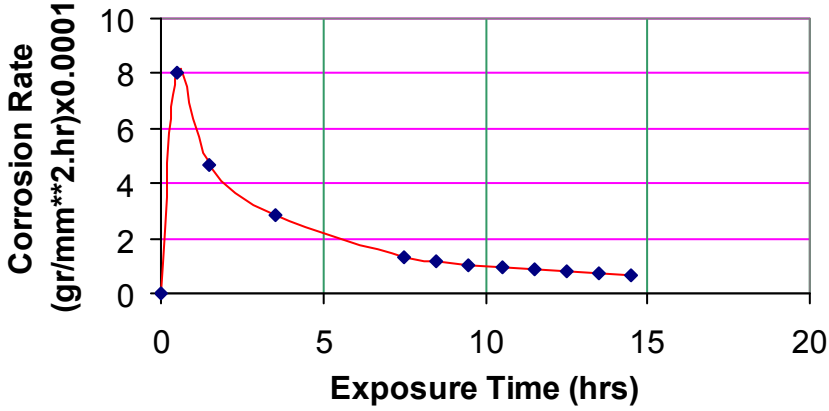
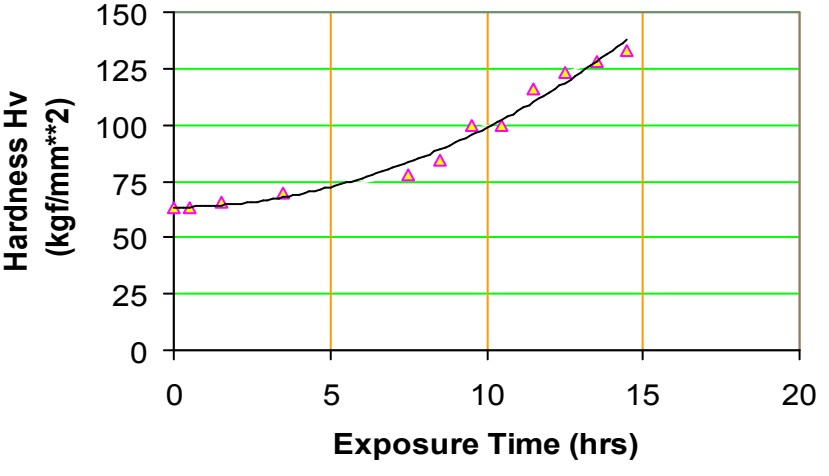


Fig. 4



DISCUSSION

The results of the present experimental work concerning the mechanical properties (hardness) and corrosion rate of the aluminum alloy.In figure (2) shows the weight loss of specimen as a function of exposure time .It can be seen that the weight loss increase with increasing exposure time (0.0- less3.5)hr because of continuously destroyed the forming oxide layer by collision of dissolving solid particles and the chemical reaction of water with surface of alloy continuously as well as the oxide layer be weak adhesive and will be destroyed the layer.After that(3.5 hr) the alloy forming new and hard oxide layer and weight loss (0.0010 g/mm²) almost remains constant at long exposure times and which leads to high resistance to the reaction of both chemical and mechanical corrosion of water. Which is noticed high corrosion rate (0.0008g/mm² .hr) at (0.5 hr) and then decreasing the corrosion rate(0.000069 g/mm² .hr) at the exposure time (14.5hr) due to forming new and hard oxide layer which is decreasing the corrosion rate as shown in fig.(3).In the figure(4) show the relation between hardness and exposure time noticed increasing semi linear relation ship due to continuous collision between high speed sea water and specimen which is lead to increasing strain hardening like forging process[Ullmanns "Encyclopedia of Industrial Chemistry Release Corrosion " 6th Edition,2002.], [A,N. Taher. "Study The Effects of Addition Cu , Cd) on some Mechanical Properties And Corrosion Resistance of Al-Si-Mg Alloys " M.Sc. Thesis, University of Basrah , Iraq , 2006.].

Conclusion

1- Weight loss increased at first hours (till 3.5 hrs) , then be constant .
2- Corrosion Rate increased and be maximum after (0.5 hr) then decrease gradually , and be at low rate after more than (10 hrs) of exposed time.
3- Increasing the Hardness with increasing exposedtime.

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تأثير المياه البحرية على معدلات التآكل في سبائك الألمنيوم التجارية

الخلاصة

يهدف هذا البحث لدراسة تأثير ماء البحر على معدلات التآكل الكيمائي والميكانيكي ، وعلى الصلادة ، الحاصلة في سبيكة الألمنيوم التجارية ،والتي تم إجراء المعالجة الحرارية لها عند درجة حرارة = 520 م º وزمن = 1.5 ساعة ، حيث .تم تعريض السبيكة إلى تيار ماء البحر وبسرعة ثابتة (3.2 م / ثانية) لفترات زمنية مختلفة مقدارها

(من 0.5 إلى 14.5) ساعة ، باستخدام جهاز خاص مصنع لهذا الغرض يتكون من حوضين سعة كل منهما 50*50*25 سم ³ ، وضعت العينة في الحوض العلوي مقابل تيار الماء الذي يبعد عنها 2.5 سم . وتم قياس الفقدان بالوزن من العينة الحاصل من تآكل السبيكة بتأثير ماء البحر عليها . وتم حساب مقدار الفقدان بالوزن لوحدة المساحة Weight Loss ، وكذلك معدل التآكل Corrosion Rate ، وعلاقة كل منهما مع زمن التعرض للماء ، كذلك قياس صلادة العينة والتغير الحاصل بالصلادة بعد كل فترة من فترات التعرض للماء ، حيث لوحظ :

- زيادة الفرق بالوزن المفقود لوحدة المساحة خلال الساعات الأولى من زمن التعرض لتيار الماء(لغاية 3.5 ساعة) ، ثم ثبات الفرق بالوزن خلال الفترة الباقية
- ارتفاع معدل التآكل الحاصل في بداية زمن التعرض لتيار الماء (لغاية 0.5 ساعة) ، ثم انخفاضه بشكل تدريجي ، وثباته على معدلات تآكل قليلة بعد مضي أكثر من 10 ساعات من زمن التعرض .
- زيادة الصلادة معزيادة زمن التعرض لماء البحر

عبد الخالق عبد علي حسن