The Measurements of Some Mechanical Properties And Corrosion Resistance of Commercial Aluminum Alloys

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Abstract:

The aim of this study is to test the different mechanical properties. hardness , tensile strength , and the corrosion resistance of commercial aluminum alloys. After recasting in a gasoline furnace. The steel mold is heat treating by an electric furnace. Using homogenization heat treatment at(500ºC) for(15 hrs).This heat treatment objective is to remove thermal stresses resulting from casting .The ingot is prepared by cutting the alloys in order to proper specimen . These specimens were examined for chemical composition and their mechanical properties were measured ;including hardness , tensile strength , and corrosion rate are taken.

Key Words: Commercial Aluminum Alloys

Introduction:

Aluminum alloys can be classified into wrought alloys and cast alloys. The first type was produced by rolling, extrusion drawing and forging, and the second type was produced by casting processes. Pure Aluminum alloy contains elements like (Fe, Mn, Zn, Cu,) to improve their mechanical properties [1].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 cant be repaired corrosion rate of the substrate occurs very rapidly [2]. Aluminum alloys have a number of characteristics, the most important are light-weight and high strength .Amjad[3] studied 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. Ravi [4] studied the effect of (Fe) element on the mechanical properties of Al-Si-Mg alloys. He showed an improvement in mechanical properties. Ganmer [5] studied the effect of (Eu , Sr) elements on mechanical properties of Al-Si-Mg alloys. He showed an improvement in mechanical properties . Chakrabarti [6] studied the effect of Cu element on the mechanical properties of Al-Mg-Si alloy. He found an increasing the Cu element that leads to an increasing the strength of these alloys. Maksimov [7] 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 . Kwon [8] studied the effect of Cu & Ni particles on Al-Si alloy ,he showed an increase in ultimate tensile strength & hardness. Deschamps [9] studied the effect of strain hardening on the mechanical properties of Al-Mg-Si-Cu alloys. He found an increase in their yield strength. Hirth [10] studied the effect of Si content on the Al-Mg-Si-Cu alloys on the mechanical properties & the aging behavior. He found an increasing strength, Formability. Ohmori [11] 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. Kowwai [12] improved the Al-Mg-Si alloys as shock absorbers on aging behavior. He found an increase in yield strength.

1-Heat treatment :

The term "heat treatment" for Aluminum alloys is frequently restricted to the specific process employed to increase the strength and the hardness for wrought and cast alloys. These are usually referred to heating and cooling. Heat treatment employed to increase the strength of Aluminum alloys can be classified as:- Homogenizing heat treatment , Solution heat treatment and Quenching heat treatment .

2- Homogenization :

Is a high temperature treatment to eliminate solute concentration gradient. In the super cooled as cast matrix and to take into solid solution. As many as possible of the crystals and intermetallics formed or precipitated at the grain boundaries. Due to evolve rapidly towards the state of thermodynamic equilibrium ,without eliminating all surviving effects of the casting process, and to relieve internal casting stresses [2].

3- 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 .

4-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. If the weight loss is constant and homogenous on the metal surface during the exposure interval, the corrosion rate does not depend on the surface area or time .So the corrosion rate is expressed by means of the loss in thickness (millimeter) per year(mpy) .

$$C = WL / At \quad .....(1)$$

$$R = (WL * K) / (\rho A t) \quad ....(2)$$

Where:

C: corrosion rate (g/cm^2 h)

R: corrosion rate (mpy)

WL: weight loss (gm)

K: constant

ρ: metal density (gm/cm^3)

A: specimen area (cm^2)

t : exposure time (h.)

5-Mechanical Properties

The mechanical properties may be considered as one of the most important properties of a material for most applications. Generally dealing with materials requiring information about their mechanical behavior and how this behavior can be measured by mechanical tests e.g. ultimate tensile strength and hardness.

Tensile Strength of the material is the value of a load applied to break the specimen at a constant strain rate, it can be expressed by:

$$\text{Ultimate Tensile Strength} = \frac{\text{Maximum tensile load}}{\text{Original cross-section area}}$$

and it is usually expressed in (N/mm^2),so it is a very important test which gives an indication of the strength of the material. Toughness is represented by the area under the stress-strain curve and gives an indication of the energy per unit volume that the material can absorb before fracture. The hardness is defined as the mechanical property of a metal which is able to resist penetration & scratching by harder bodies. The hardness of the investigated specimens had been carried out by using Vickers hardness instrument

Experimental Work

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

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

Table (1) The chemical composition of alloy.

ELEMENTS %					Alloy
Zn	Mn	Cu	Fe	Al	1
0.09	0.11	0.15	0.66	98.99	

2-Heat treatment

Alloys under investigation were homogenized and subjected to solution heat treatment before testing as shown in Table (2).

Table (2) Conditions for Heat Treatments of Alloys

Condition	Alloy Code
homg. at 500ºC for 15 hrs + Q + S.H.T at 500ºC for 1hr + Q .	1

Where:

homg : homogenize
S.H.T : Solution Heat Treatment
Q : Quenching

3-Machine Preparation of the Specimens:

The specimens were cut as dumbbell shape for the tensile test 65 mm length , 14 mm diameter , 45 mm gauge length and to rectangular form (24.7 x34x3) mm^3 in order to tested for erosion / corrosion resistance and hardness. These specimens 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.

4-Mechanical Properties:

Ultimate Tensile Strength

The maximum tensile stress for specimens were estimated under a load ,and the cross section area for the specimen was (64) mm^2, the results of which are shown in table (3).

Table (3) Values of Load, Change in Length Tensile strength, Strain and Elastic modulus for alloy

Tensile strength kg/mm²	Elastic modulus kg/mm²	Strain * 0.01	Stress kg/mm²	Length Change mm	Load kg	alloy No.
2.34	523	0. 44	2.30	0.20	150	1
3.91	447	0. 88	3.93	0.40	250	
5.47	423	1. 30	5.50	0.60	350	

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 each sample were taken and the average of the diagonals of each indentation were measured from equation (1) which is shown in Table (4).

Table (4) Represents values of diameter and Vickers hardness

Specimen No.	Diameter mm	Vickers Hardness kg/mm²
1	4.60	63.08
	4.46	67.40
	4.73	59.16
Standard deviation		± 5.84
2	4.20	74.60
	4.60	63.08
	4.66	61.47
Standard deviation		±3.36

5-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 which are listed in Table (2) .Finally the specimen was dried and weighed to measure the weight loss .The corrosion rate was calculated as in equation (1).

The results of erosion/corrosion were used for the following representation are listed in table (5) :

1-The relationship between the weight loss(Δw) & corrosion time.

2-The relationship between the corrosion rate(CR) and corrosion time.

Table (5) Represented weight loss & corrosion rate for alloy

Time (hr.)	Δ w (g/mm²)	CR (g/mm² .hr)
0.0	0.00000000	0.00000000000
1.5	0.00577478	0.00384985330
2.0	0.00577478	0.00288739000
3.0	0.00577478	0.00192493000
5.0	0.00577478	0.00115495600
7.0	0.00577478	0.00082496857
9.0	0.00577478	0.00064164222
15.0	0.00577478	0.00038498533

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) cm³. 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) m^3 / hr. The weight loss is measured at different times interval by four digits sensitive balance type (Sartorius BL 210S).

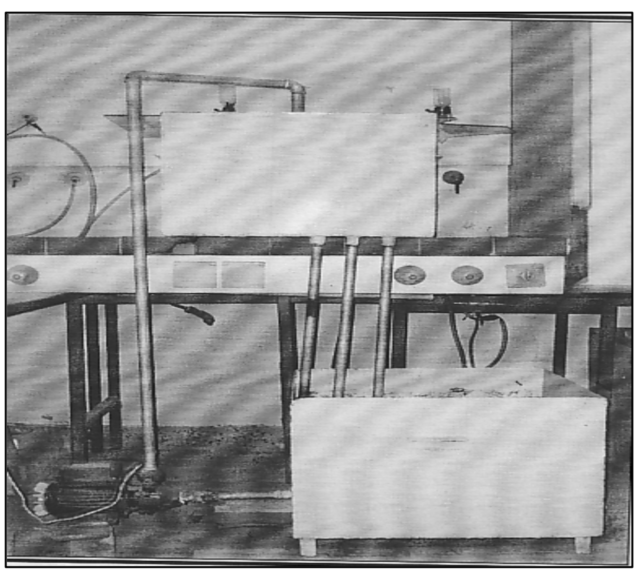


Figure (1) Erosion-corrosion system

Water Composition Analysis

The raw water analyzed as shown in a Table (6) was carried out in the chemical laboratory of Al-Najibiya Power Station for electricity production during 7/2007.

Table (6) the chemical analysis of raw water

Raw water	Measuring limit	Type of analysis
7.4	---	pH
4560	μs/cm	Electrical Conductivity
		TDS
3192	ppm	TH
1500	ppm	Cl^-
640	ppm	Ca^{2+}
650	ppm	Ca as $CaCO_3$
800	ppm	Mg as $CaCO_3$
850	ppm	SO^{2-}_4
760	ppm	P-Alkalinity
0.0	ppm	M- Alkalinity
150	ppm	Fe^{2+}
2.05	ppm	

TDS: Total Dissolve Solid
TH : Total Hardness

DISCUSSION:

This section involves the results of the present experimental work with its discussion concerning the mechanical properties (hardness, ultimate tensile strength) and corrosion rate of the commercial aluminum alloy. From Table (3) or fig.(4) a linear relation can be noticed between the applied load and change in length .Also ,there is an increase in the tensile strength with the increase of the applied load until the point of failure fig.(5) ,where the maximum tensile strength has reached a value of about (5.47 kg/mm²).This behavior resembles the behavior of brittle materials, due to the chemical composition of aluminum samples, which have different impurities such as (Mg & Si) elements. The two elements form the phase (Mg2Si) which provides a change in the of increasing strength of alloy, when precipitated, thus resisting the dislocations movement and resulting in higher strength .Since, the casting alloy contains porosity resulting from the casting process which dose not have vacuum champers or using an inert gas (He.N2) during casting .Elastic modulus has been evaluated for material in order to establish the resistance of this material to the applied loads .Table (3) or fig.(6) shows that the elastic modulus decreases with the increases of the applied load, due to the decreasing resistance of the alloy for being a brittle material[3].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- less1.5)hr because of continuously destroyed the forming oxide layer by collision of dissolving solid and the chemical reaction of ions in water with surface of alloy continuously .After that(1.5 hr) the alloy forming new and hard oxide layer and weight loss (0.00577478 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 low corrosion rate (0.00384985330 g/mm² .hr) at (1.5 hr) and then decreasing the corrosion rate along the exposure time (15 hr) due to forming new and hard oxide layer which is decreasing the corrosion rate as shown in fig.(3) [13,14].

Fig (2) Show the relation between weight loss & time

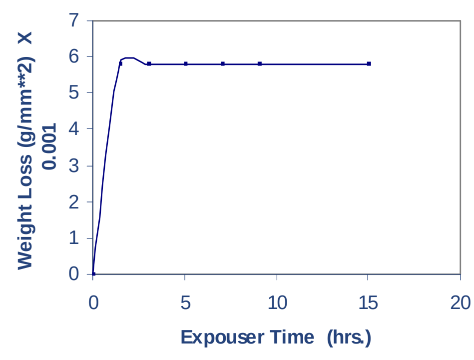
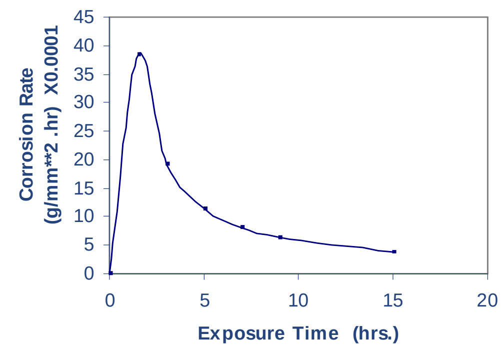
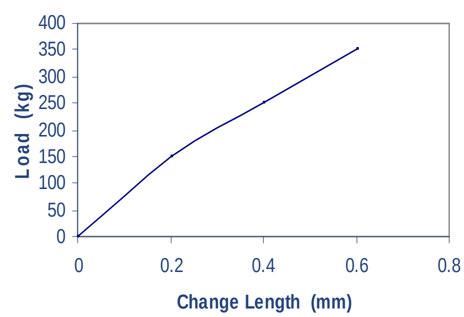


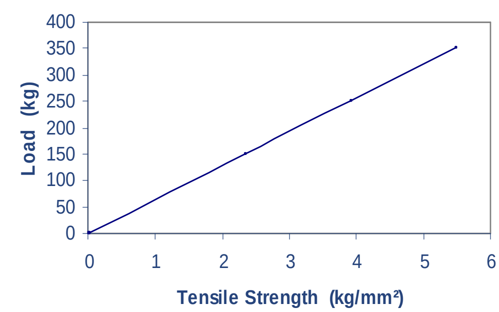
Fig (3) Show the relation between Corrosion Rate & time



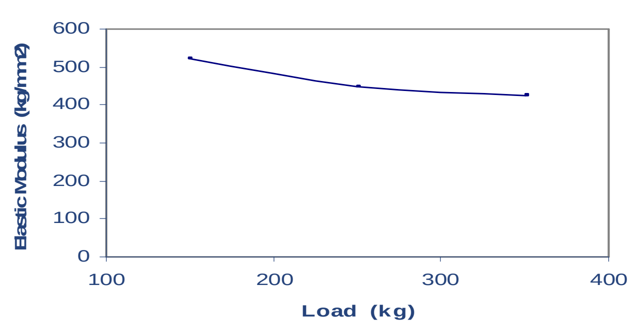
Fig(4) Show the relation between Change Length & Load



Fig(5) Show the relation between Tensile Strength & Load



Fig(6) Show the relation between Elastic Modulus & Load



Conclusion:

1- Alloy have low corrosion rate .
2- Alloy have linear relation ship between tensile strength and Load.
3- Decreasing elastic modulus with increasing load

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قياس بعض الخصائص الميكانيكية ومقاومة التاكل لسبيكة الألمنيوم التجارية

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الخلاصة:

يهدف البحث إلى دراسة بعض الخصائص الميكانيكية لسبيكة الألمنيوم التجاري وقياس الصلادة و مقاومة الشد ومعدل التآكل عند التعرض لماء الإسالة ولفترة زمنية 15ساعة ,حيث يمكن ملاحظة إن معدل الصلادة ومقاومة الشد لسبيكة ألمنيوم المصبوبة يزداد بزيادة الحمل المسلط على العينة كعلاقة طردية إما معامل المرونة فيقل عند ازدياد الحمل والعلاقة تكون عكسية نتيجة كون العينة ذات سلوك هش وليس مطيلي وان الشوائب ولو غير كافية نسبيا "أدت إلى إعاقة الانخلاع عن الحركة ما أدى إلى زيادة الصلادة إما معدل التآكل فان السبيكة تمتلك معدل نأكل عالي نسبيا وذلك لصلادتها العالية على نحو نسبي .