THE EFFECT OF (AQUAFINA) DRINKING WATER ON THE CORROSION RATE &HARDNESS OF (Al-Si) & (Al-Mg-Si) ALLOYS

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Abstract

The present work investigates the effects of drinking water on the erosion- corrosion rate and Vickers hardness of (Al-Si) and (Al-Mg-Si). (Al-Si) alloy Which is well-known as casting alloy with high wear resistance, low thermal expansion coefficient, good corrosion resistance and improved hardness at a wide range of temperatures .While (Al-Mg-Si) alloys have good formability ,weld ability ,machine ability and corrosion resistance .The alloys specimens which are used for piping and containing water and carbonated water were exposed in erosion-corrosion system in factories by using drinking water type AQUAFINA as exposure media for different exposure time (1-30)h. to measure the erosion–corrosion rate . The results show that there is small different in the rate of corrosion, moreover (Al-Mg-Si) alloy have high resistance to erosion-corrosion in drinking water due to the consisting of (Mg_2Si) phase which is precipitate as fine particles due to resist dislocations movement lead to high corrosion strength and the (Al-Si) alloy have high Vickers hardness at natural aging due to the present of high ratio hardening silicon element.

تأثير ماء الشرب (اكوافينا) على معدل التآكل والصلادة للسبيكتين ألمنيوم-سليكون و ألمنيوم- مغنسيوم-سليكون

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الملخص

يهدف البحث إلى دراسة تأثير ماء الشرب (اكوافينا المستخدم في صناعة المشروبات الغازية نوع بيبسى كولا) على الصلادة و معدل التآكل /بلى أولا للسبيكة ألمنيوم-سليكون والتي تمتاز بمقاومه عالية للبلى وذات معامل تمدد حراري قليل ومقاومه جيده للتآكل وتتحسن صلادتها على مدى واسع من درجات الحرارة. وثانيا للسبيكة ألمنيوم- مغنيسيوم- سليكون والتي تمتاز بخواص تشغيل جيده و قابليتي لحام و تشكيل جيدتين مع مقاومه جيدة للتآكل، واللتان تستخدمان في بعض الخطوط الإنتاجية للمصانع المنتجة للماء و المشروبات الغازية والتي تتعرض للتآكل / بلى ،حيث تم تعريض العينات للماء و بسرعة ثابتة ولفترات زمنيه مقدارها (1-30) ساعة وتم قياس الفقدان بالوزن ومعدل التآكل كداله لزمن التعرض للماء،[و لوحظ إن هناك فرق قليل في معدل التآكل بين السبيكتين جدير بالاهتمام وهو أن السبيكة ألمنيوم – مغنيسيوم – سليكون ذات مقاومة تأكل اكبر من السبيكة الأخرى ويعزى ذلك إلى وجود الطور الثنائي سيليكات المغنيسيوم والذي يترسب في البنية البلورية بشكل دقائق صغيره تعيق حركة الأنخلاعات وتؤدي إلى زيادة مقاومة السبيكة للتآكل]. وقيست صلادة فكرز للسبيكتين عند التعتيق الطبيعي وبأزمان مختلفة ولوحظ أن معدلات الصلادة للسبيكة ألمنيوم-سليكون اكبر من سبيكة ألمنيوم-مغنيسيوم-سليكون عند التعتيق الطبيعي وذلك لوجود عنصر السليكون بنسبه اكبر وهو من العناصر المصلدة.

Introduction

Aluminum alloys have a number of characteristics, the most important are light-weight and high strength[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 alloys 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 can not be repaired corrosion rate of the substrate will be very rapid. When the aluminum alloys content magnesium, manganese, chromium and silicon it will have good corrosion resistance, but aluminum alloys content copper, magnesium and zinc improving the machine ability . All aluminum alloys can be machined usually easily and rapidly in high speeds [2].

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 among 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) [3,4].

$$C = WL / At \qquad \text{........(1)}$$

$$R = (WL * K) / (\rho A t) \qquad \text{..........(2)}$$

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.)

Age Hardening

After heat treatment and quenching, hardening is achieved either at room temperature (natural ageing). In some alloys sufficient precipitation occurs in a few days at room temperature to yield stable products with properties that are adequate for many applications. These alloys sometimes are precipitation heat treated to provide increased strength and hardness in wrought and cast alloys. Other alloys with slow precipitation reactions at room temperature are always precipitation heat treated before being used [5].

Research progress in the field of the erosion corrosion

Al-Mtori [6] studied the effect of the addition of Zr &Te elements to (Al-Cu) and (Al-Zn) alloys on erosion-corrosion behavior , he is found that the erosion-corrosion rate of (Al-Zn) alloy is less than (Al-Cu) alloy, Abtehal [7] studied the erosion behavior of Al-Li alloy ,she showed that the erosion rate of the (Al-Li) alloy is increased . Gawdat [8] studied the effect of Cu , Mg and Y2O3 particles on the wear resistance for Al-Si alloy. He suggested that wear resistance have improved after adding Mg and Y2O3 particles .Taher [9] studied the effect of Cu & Cd elements on corrosion resistance of Al-Mg-Si alloy by using sea water .He showed that there is a relative improvement in corrosion resistance. Amjad[10] 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 is less than that in the tap and sea water. Csanady[11] studied the effect of (Cu , Cr, Li) elements on stress corrosion of Al-Zn-Mg alloy .He suggested that (Cu ,Cr) improved stress corrosion resistance . Miao[12] studied the effect of natural aging on Al-Mg-Si alloy .He showed that natural aging improved corrosion resistance. Tu [13] studied the effect of erosion/corrosion on Al- alloys by oil slurry which are produced by pressure .He found that erosion corrosion resistance improved with increasing hardness .Ravi [14] studied the effect of (Fe) element on mechanical properties of Al-Si-Mg alloys .He showed an improvement in mechanical properties .Ganmer [15] 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 strength of Al-Si-Mg alloys .He found that there was an increasing in the strength of the alloy .

Research progress in the field of the hardness

Maksimov [17] studied the effect of small additions of Si and Ge on hardness of commercial Al-Cu alloy .He found that for the same level of micro alloying 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 .Brook [18] studied the effect of equivalent amounts of Si and Ge on hardness of Al-Cu alloys after aging at 165 °C ,he showed that the higher peak hardness of Al-Cu-Ge alloy appears at shorter aging time compared to that of Al-Cu-Si alloy. Closset [19] studied the effect of equivalent amounts of Se on hardness of Al-Si-Mg alloys after aging at 155 °C ,he noticed an increasing in the hardness .Kim [20] studied the fracture behavior of Al-Si alloy by varying aging condition under resonant vibrations, he showed that strength of alloy can be improved by aging. Surappa [21] studied the effect of the particles of Al2O3 on relative expansion & tension resistance of pure Al & Al-Si alloys , he noticed decrease in relative expansion and rises tension resistance with increasing of the particles of Al2O3. Yang [22] studied the effect of the Bauxite particles on Al-Cu alloy ,he showed an increasing in the strength and hardness. Guden [23] studied the effect of the SiC particles on Al-Cu alloy ,he showed an increasing in the stress , strain and hardness. Kwon [24] studied the effect of Cu & Ni particles on Al-Si alloy ,he showed an increasing in ultimate tensile strength & hardness. Krishnan [25] studied the effect of graphite particles on Al-Si alloy ,he showed an decreasing in the rate of wear of the alloy. Gibson [26] studied the effect of Si & graphite particles on Al-Si alloy ,he showed that graphite increasing solidification & friction factor of alloy. Etter [27] studied the effect of Al & graphite particles on Al-Si alloy ,he noticed that additive graphite and Al particles composite increasing strength and fracture toughness of alloy . Silcock [28] studied the effect of aging temperature on hardness of different ratios of Cu particles on high pure Al , he showed that the precipitation phases will changed with aging temperature . Vietz [29] studied the effect of aging temperature on hardness of different ratios of Ag particles on Al-Zn-Mg alloy, he showed that the effect of Ag particles will change with the Zn and Mg content .Makin[30] studied the effect of aging temperature on Al-Zr-Li alloy .He found that Zr element highly effected the hardness of Al-Li alloy. Polmear[31] studied the effect of Ag element on Al-Zn-Mg-Cu & Al-Cu alloys .He found that Ag element is increasing the hardness of alloys. Chaturvedi [32] studied the effect of Si on Al-Cu-Mg alloy .He found that Si is increasing the strength and hardness of the alloy.

Experimental Work

This work included evaluation of some alloys .The Al –Si and Al-Mg-Si alloys used in present study were chemically analysed by using atomic emission spectra photometer at" Nasser State Company for Mechanical Industries". The chemical composition of this alloy were as listed in the table (1) below.

Table (1) the Chemical composition of Al-Si &Al-Mg-Si alloys[9,10]

Type		Al-Si	Al-Mg-Si
Elements%	Al	rest	rest
	Si	4.35	0.77
	Fe	0.85	0.23
	Cu	0.93	0.03
	Mn	0.19	0.44
	Mg	0.36	0.58
	Zn	0.08	0.01
	Cr	0.03	0.01
	Ti	0.02	0.006
	Sn	0.001	------
	Graphite	0.30	------

Heat treatment

Alloys under investigation were homogenized and subjected to solution heat treatment before natural ageing as showed in table (2).

Table (2) conditions of Heat Treatment of Alloys

type	Condition
Al-Si	Homogenous at 550°C for 18 hrs. + Quenching + Heat treatment at 500°C for 1hr. + Quenching + natural aging at room temperature for different time .
Al-Mg-Si	Homogenous at 550°C for 24 hrs.+ Quenching + Heat treatment at 500°C for 1hr. + Quenching + natural aging at room temperature for different time.

Preparation of the Specimens

The alloys were cut to circular form specimens of 4mm thickness with 2cm diameter in order to be tested erosion corrosion resistance and hardness. These specimens were ground by emery paper of grades (100, 150, 500, 1000). Then the specimens were washed in de ionized water and dried by air. After that the specimens were polished with nap cloth containing alumina particles size of (5µm) by using polishing machine, washed in alcohol and dried.

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 whish is 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 :

1- The relationship between the weight loss and corrosion time.

2- The relationship between the corrosion rate and corrosion time.

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 consists of two basins of water. The size of each basin in (50 x 50 x 25) cm. 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 h the water between the two basins. The water impact the specimen by a jet which is about (2.5 cm) 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 time by four digits sensitive balance type (Sartorius BL 210S).

Figure (1) erosion-corrosion system

Water composition

The AQUAFINA water was produced in united company for Pepsi cola in state of Kuwait which is contract with Pepsi company in New York (U.S.A.) and the chemical composition are analysis in the chemical laboratory of the produced company and labeled on the bottles as shown in the table (3).

Table (3) The water analysis of (AQUAFINA)

Type of analysis	Units	Drinking water
pH	-------	6.8
T.D.S	ppm	110
T.H (as CaCO3)	ppm	53
Ca+2	ppm	< 5
Mg+2	ppm	13
Na+	ppm	16
K+	ppm	1.0
$NO3^-$	ppm	< 0.1
$SO4^{-2}$	ppm	51

Hardness test

Specimens which were naturally aged are measured hardness .The hardness test of investigated specimens had been carried out by using Vickers hardness instrument The Vickers hardness tester type [VKH-1 ,TOKYO TESTING MACHINE MFG CO., LTD]. In this test a load of (1 Kg) was applied for alloys. In this test 5-readings for each specimen were taken and the average of the diagonals of indentation was calculated. Vickers hardness number was measured according to the following equation:

$$\mathbf{Hv = 1.8544 \times P/ (dav)^2} \quad [Kg/mm^2] \qquad (3)$$

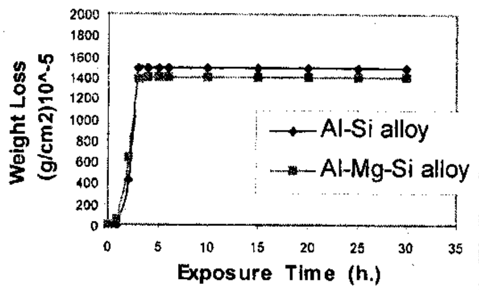
Where:

P : the amount of the load placed on the specimen

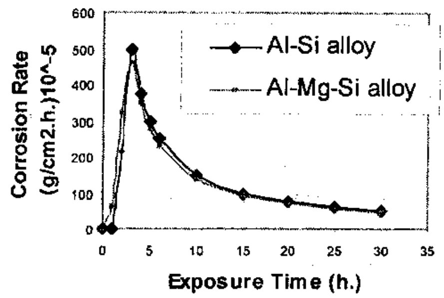
dav: the average of the diagonals of indentation

Results and Discussion

For Al-Si & Al-Mg-Si specimens are tested by exposing them to water with a constant flow for an interval of (30 h.) ,the results presented in terms of the weight loss and corrosion rate against exposure time plotted as function of corrosion time. Fig. (3) represents the relationship between the weight loss and exposure time for all specimens. It had been noticed that the weight loss in Al-Mg-Si specimen was less than Al-Si . But in Fig. (4)which represent the relationship between the corrosion rate against exposure time; it is found that corrosion rate for the specimen Al-Mg-Si is less than Al-Si at the same previous percentage so that is mean alloys have high resistance to this type of water because it contain low TDS and no chlorine atoms which are a charge of corrosion in metal surface[33].



Figure(3) the relation between weight loss& exposure time



Figure(4) the relation between corrosion rate & exposure time

Erosion/corrosion behavior of alloys specimens

It was found that the weight loss rate decreases so that the corrosion resistance is improved due to the presence of Mg and Mn and precipitation of (Mg_2Si) phase like the form of anti-fluorite system which represented in fig.(2)[34,35].So some other phases produced as the result of graphite addition [17,36]. From curves had been plotted there was incubation period at which the oxides layer resists the current water stroked for limited interval. After that this layer will start to break with the repeated water knocks, new period will start in which breaking of this layer accelerate rapidly (acceleration period). This occurs due to the effect of fatigue stress. After that the weight loss will decrease until growth new oxide layer is called deceleration period. Later the weight loss rate will be gradually constant and increasing the exposure time of corrosive media will be not effected on weight loss because the new oxide layer be very hard, high resistance, high adhesive with the surface and increasing the protection of alloy, this period called "steady period" [18].

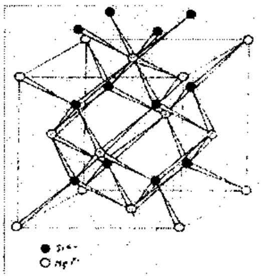


Figure (2) anti fluorite system (Mg_2Si) phase

The effect of natural ageing on the hardness

Fig. (5) shows the relationship between the hardness and the ageing time for the present alloys. The behaviour of these alloys at room temperature was noticed to be no similar, where two peaks of Vickers hardness appeared for Al-Si alloy, one represented the minor value (83) kg/mm^2 and the other was the major(112) kg/mm^2 for Al-Si alloy the highest average hardness, this means that the hardness increased as alloying elements silicon ,copper and iron percentage increased[1].Which are lead to formed two additional constituents α (FeSi) and β (FeSi) from FeAl3[34] in addition to present graphite lead to and accelerated to appear two peaks in Al-Si alloy one at high value (112)kg/mm^2 at aging time (50) hours and other at low value (83)kg/mm^2 This change in hardness during natural ageing due to precipitate phases as a result of graphite and resisting the movement of dislocation[8] , but Al-Mg-Si alloy has semi constant hardness with minimum average hardness (78 kg/mm^2) due to low temperature be useless in diffusion the impurities and to consist precipitate phases due to resisting the movement of dislocation which lead to change in hardness[12].

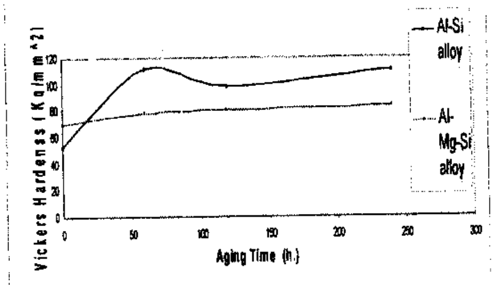


Figure (5) the relation between vickers hardness & aging time at room temperature

Conclusions

1- It has been noticed that the weight loss in Al-Mg-Si specimen is less than Al-Si alloys.
2- It is found that corrosion rate for the specimen Al-Mg-Si is less than Al-Si alloys.
3- The specimen Al-Mg-Si have high resistance to this type of water
4- The presence of alloying elements Mg and Mn improving the corrosion resistance.
5- The Al-Si alloy have high rate of hardness at natural aging.

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