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Research Article

The Effect of Additions Ag and Cd on Corrosion Resistance of Al- Cu-Mg Alloys

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Abstract

Aluminum alloys are used in advanced applications because of their combination of high strength, low density. Due to excellent strength vs. density ratio, Al-Cu-Mg alloys are used in aerospace applications. The objective of this work is to improve the properties of Al-Cu-Mg alloys such as corrosion resistance in 3.5%NaCl solution by using quenching medium of 30% polyethylene glycol and addition alloying elements, such as Cd , Ag and Cd & Ag together to this alloy and to determine the effects of artificial ageing on the properties. An improvement of corrosion resistance in 3.5% NaCl solution when the alloys quenched in polymer solution have been higher corrosion resistance than these quenched in water and better of them corrosion resistance was in D alloy (containing 0.4 Cd and 0.3 Ag together) at aging temperature 150 ºC.

Keywords: *Aluminum Alloys, Quenching Polyethylene Glycol.*

1. Introduction

Aluminum alloys are used in advanced applications because of their combination of high strength, low density, durability, mach inability, availability and the cost is also very attractive compared to competing materials[L.F. Mondolfo,1976]. Due to excellent strength vs. density ratio, formability and corrosion resistance, Al-Cu-Mg alloys are potential candidates for a numerous aerospace applications [X.Yang *et al*, 1993]. The alloys of the 2000 series, structural hardening, form a wide range of alloys characterized by good heat resistance, resistance to corrosion in relatively low corrosive atmosphere, average strength in the quenched condition matured, but relatively high condition revenue dipped.

Aluminum is the second most used metal in the world mainly because of its lightness and its excellent corrosion resistance in many quarters. It is indeed one of the lightest materials with a density of 2700 kg.dm-3 [Shaymaa,2011] This property makes aluminum and its alloys materials highly acclaimed in the aviation industry and especially in the design of aircraft (up to 73% on the A340) [J.M. Salman, 2007]. The "Duralumin", is the first aluminum alloy having mechanical properties comparable to those of ordinary steel. Aluminum alloy 2024 is an alloy that is in the 2000 series, a type alloy Al-Cu-Mg. The copper alloy element content is added to the order of 2 to 6% by mass. Copper enhances the mechanical properties and in particular the hardness, improved flow ability compared to pure aluminum for copper concentrations between 7 and 8%, but the addition of copper induces a poor corrosion resistance. It allows, during the thermo mechanical process, the precipitation hardening phase called phases, the origin of the mechanical properties of alloys of this series.

The addition of magnesium alloy Al-Cu also caused a significant increase in the mechanical properties of the alloy during the maturation stage or income. The 2024 alloy contains spherical particles rich in Cu and Mg that correspond to S phase or Al2CuMg. They have an average size of about 5 microns and regular shape. Also present are irregularly shaped particles rich in Cu, Fe and Mn. These particles have an average size of 30 microns and occupy a surface fraction of 2.8% while the surface fraction covered by particles Al2CuMg is only about 1% [J. H. Ghazi ,2007]. Aluminum alloy 2024 is an aluminum alloy, with copper as the primary alloying element. It is used in applications requiring high strength to weight ratio, as well as good fatigue resistance and high strength. It is weld able only through friction welding, and has average machinability. Due to poor corrosion resistance [B.Zlati anin *et al*, 2003].

Quenching of aluminum alloys includes heating to 465- 565 ºC and rapid cooling in order to obtain a supersaturated solid solution. Then the alloys are subjected to aging at different temperatures in order to obtain the requisite strength and plasticity. Minimum warping and minimum internal stresses are obtained

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by changing the cooling rate in quenching. It is known that well-mixed cold water is a good quenching medium that provides high strength characteristics for the alloys. All alloys of the 2XXX series are susceptible to atmospheric corrosion, especially in industrial or seacoast atmospheres. These alloys should be protected, at least on faying surfaces, when exposed to these conditions. Alcladding of these alloys provides high resistance to atmospheric corrosion. The clad surface is resistant to corrosive attack and also provides additional cathodic protection to the core alloy [N. B. Sofyan ,2008; N.Raduioiui *et al*,2010].

Electrochemical methods in corrosion testing have been used ever since the electrochemical nature of corrosion processes was discovered. These methods are used both for corrosion monitoring and as laboratory techniques. One of the most important applications has been the estimation of corrosion rate instantaneously by means of polarization resistance, being of special relevance the relationship between mass loss and polarization resistance, which cannot always be deduced from Tafel parameters, because the constancy of electrochemical parameters with time cannot a priori be assumed. The polarization resistance measurements can also be a very useful technique for the determination of time effect on corrosion. Usually electrochemical techniques have been employed to both speed data development and to better understand corrosion mechanisms [A.Y. Musa *et al*,2011; A.LIPSKI , S. Mrozinski,2012].

2. Experimental Part

A- Chemical Composition of the Alloys: The Al-based alloys used in this research are shown in table .1.

Table 1 The composition of Al- alloys used in research

Alloy %	Cu	Mg	Cd	Ag	Al
A	2.0	1.7	-	-	Bal
B	2.0	1.7	0.4		Bal
C	2.0	1.7		0.3	Bal
D	2.0	1.7	0.4	0.3	Bal

B- Casting Process: Casting process includes the die designing and manufacturing. These ingots were prepared by melting aluminum at 660°C then remain for 5 minutes after each element addition and then cast in especially design. Steel die is designed and manufactured with dimension and tolerance with respect to the required ingot.

C- Heat Treatment of Specimens: Heat treatment usually includes three main stages namely:

1-Solution Heat Treatment: Heating alloys into solid solution at 500°C for one hour, then the specimens quenched by different ways of cooling (water and polymer).

2-Quenching:water and polymer solutions are common quenching mediums for aluminum alloys. The mediums differ in the rate at which they dissipate heat out of a quenched part. Medium of polymer have [30%PAG +70% water

3-Aging: The final stage to optimize properties in the heat-treatable aluminum alloys was aging. The aging used only artificial at temperature 150 °C for 5 hour.

D-Corrosion Test: Calculated current of corrosion in this study depends on electrochemistry route.

The tester consists of electrochemical corrosion test cell and electrodes In this study was used (3.5% NaCl) solution, with specimens dimensions (diameter = 8 mm, thickness = 2 mm) and aged at temperature 150 ºC.

E-Specimen Preparation For Microscopic Analysis: This is the process for abrading the sectioned specimen in a sequence of steps using progressively finer abrasive papers (180, 220,400, 600, 800, 1000, 1200, 2000, 2500 grit size).

Polishing stage is highly required to ultimately produce a scratch-free, highly polishing and flat surface ready for subsequent etching and microscopy, by using cloth polishing and diamond paste type (nature diamond, with size 0.1 micron). Polishing has done with using of polishing machine.

Etching: This was the last step before visual inspection. It involved a short treatment for(15-20) sec in (Keller's Reagent) prepared as follows by volume:
(1%HF, 1.5% HCl , 2.5%HNO_3 and 95%H_2O)
It revealed various structural characteristics of the samples by the preferential attack of the constituents and grain boundaries.

Etching was performed by repeated dipping of the sample in the reagent. It would be stopped by immediate washing with distilled water, rinsed with ethyalcohol, dried by air and finally preservation in desicator.

3. Results and Discussion:

A- The Corrosion Test by Electrochemical Method: This method which used to calculate corrosion rates in (3.5% NaCl solution. The samples of test quenched in two medium (water and 30% polyethylene glycol) and aged at 150 ºC.)

Fig. (1) shows that A alloy (quenched in water) have :
I corr. =9.922 μA/cm^2 , E corr. =-973 mV

The values of corrosion current density above indicates that A alloy have low resistance to corrosion. Fig. (2) shows that A alloy (quenched in 30% PAG) have :

I corr. =8.166 μA/cm^2 , E corr. =-726 mV

From figures (1) and (2), it is obtained that value of corrosion current density values of A alloy (quenched in 30% PAG) then aged at 150 °C indicate that undergoes lower corrosion than the base alloy that quenching in water.

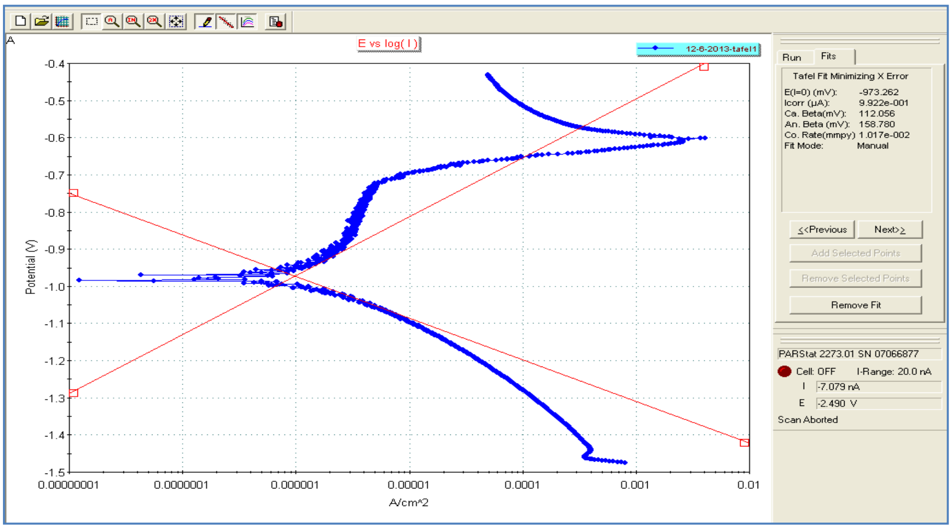


Fig.1: Tafel curve for A alloy that quenched in water

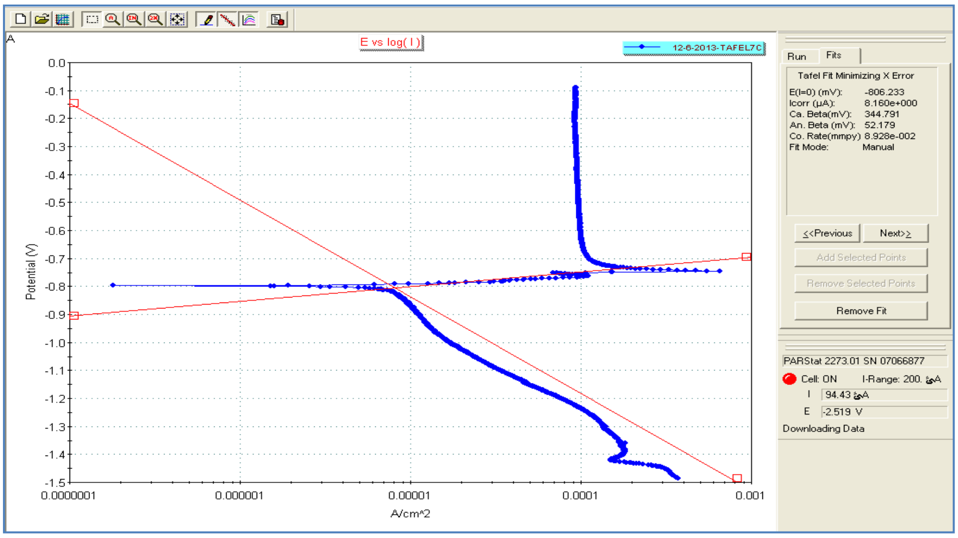


Fig.2: Tafel curve for A alloy that quenched in pAG

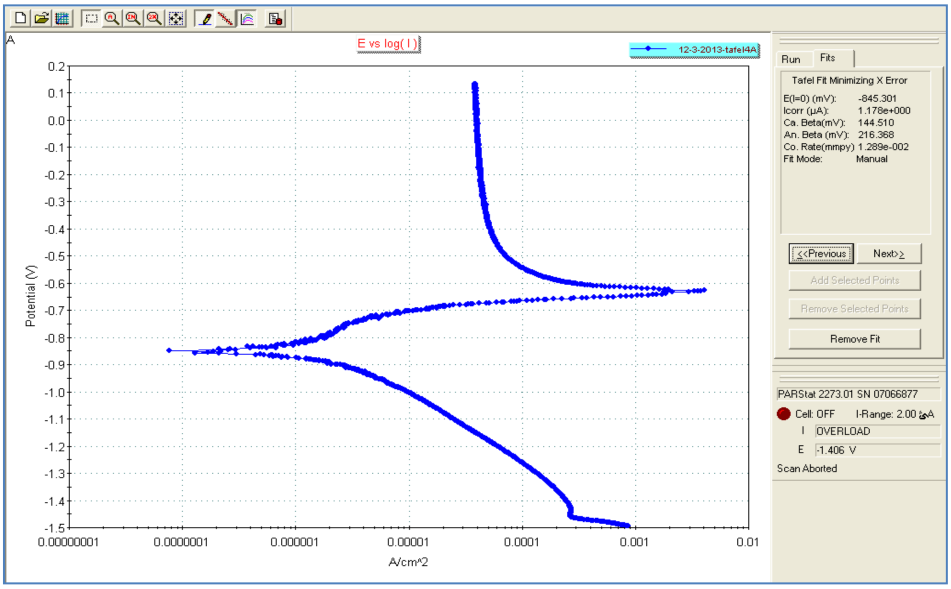


Fig.3: Tafel curve for D alloy in pAG

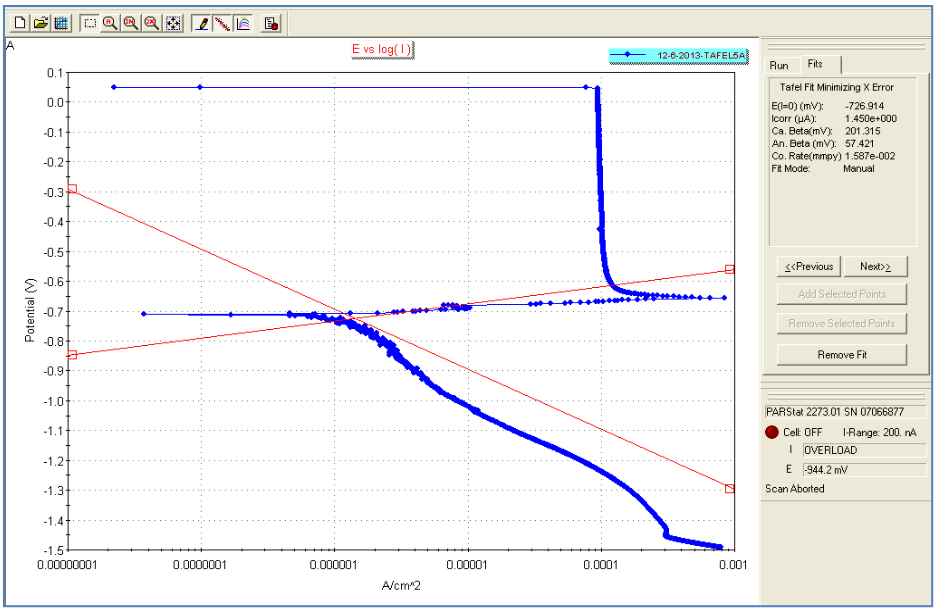


Fig.4: Tafel curve for D alloy that quenching quenched in water

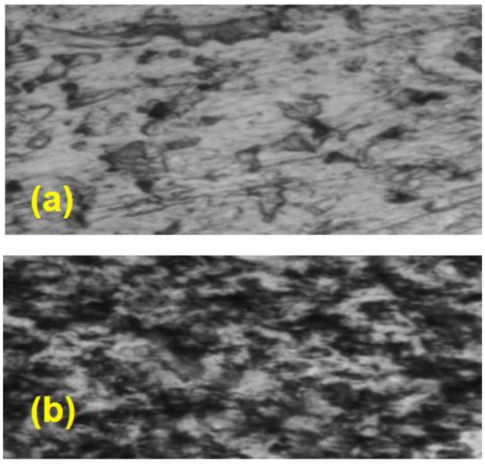


Fig.5: Microstructure of A alloy (base alloy) sample: (a) quenching in water, (b) quenching in 30% polyethylene glycol. (ageing time at 150 °C), 150X

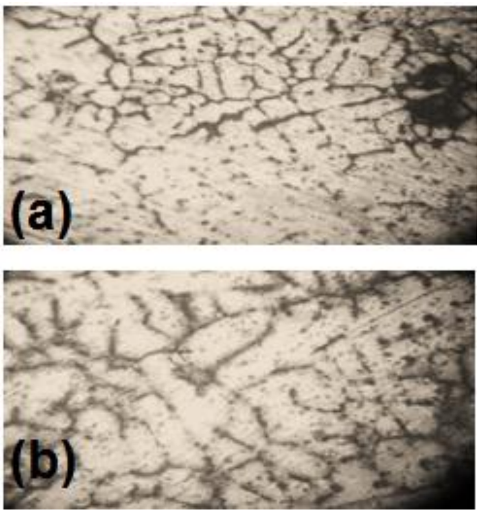
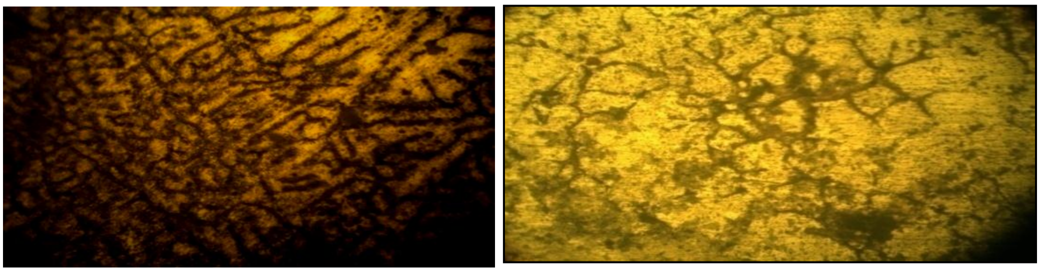
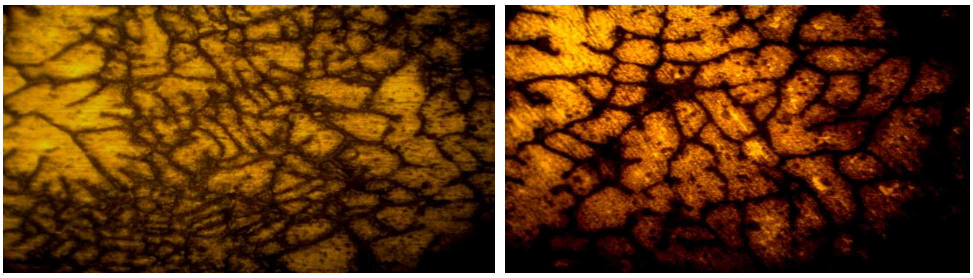


Fig.6: Microstructure of B alloy (contain Ag alloy) sample: (a) quenching in water, (b) quenching in 30% polyethylene glycol (ageing time at 150 °C), 150X



(a) (b)

Fig.7: Microstructure of C alloy (containing cd) sample: (a) quenching in water, (b) quenching in 30% polyethylene glycol (ageing time at 150 °C), 150X



(a) (b)

Fig.8: Microstructure of D alloy (containing Ag and Cd) sample: (a) quenching in water, (b) quenching in 30% polyethylene glycol (ageing time at 150 °C), 150X

Fig.3 shows that D alloy (quenched in water) have :

I corr. =1.778 μA/cm^2 , E corr. =-845.301 mV

Fig.4 shows that D alloy (quenched in 30%PAG) have :

I corr. =1.450 μA/cm^2 , E corr. =-726.9 mV

From values of corrosion current density , the D alloy (quenched in 30% PAG) have higher value of corrosion resistance compared with all alloys (quenched in water and 30%PAG) because it contains elements of Cd and Ag together and these elements work in best efficiency to prevent corrosion. In general, from Tafel curves above, it could be concluded that the alloys that quenched in polymer solution have been higher corrosion resistance than these quenched in water. This is because of the uniform precipitates and low residual stresses or deformation in lattice when the quenching is applied in polymer solution.

B -Optical Microscope Testing

The following Figures.5,6,7 and 8 shows microstructure of alloys (A, B,C and D) samples that quenching in two different mediums (water and 30% polyethylene glycol) with aging temperature at 150°C. From these figures noted that the precipitates were distributed in structure, the grains sizes homogenizing and did not find any cracks in alloys that quenched in polymer compared with alloys that quenched in water.

Conclusions

According to the results and discussion remembered in previous chapter, the following points can be concluded:

1. Quenching in medium of 30% polyethylene glycol improves corrosion resistance in 3.5% NaCl solution for alloys at the most aging times especially at 150ºC.
2. Corrosion resistance in 3.5% NaCl solution improved by addition 0.4% Cd (B alloy) by (21.255 %), when adding 0.3% Ag (C alloy)by (28.36 %) and when adding 0.4% Cd and 0.3% Ag together (D alloy) by (17.9 %) at aging temperature 150ºC in comparison to the base alloy.
3. No cracks in alloys that quenching in polyethylene glycol compared with alloys that quenching in water.

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