CORROSION PROTECTION IN A SPECIFIC KIND OF AL ALLOY IN MARINE ENVIRONMENT

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ABSTRACT

Compared to iron and steel, aluminum alloys have the advantages of lower density, higher specific strength and superior corrosion resistance. Therefore, lightweight aluminum alloys are being considered for use in aircraft, automobiles, railroad cars, and ships. In this study we are going to protect a specific Aluminum alloy which is used in marine industries such as submarines against corrosion. Thus, early studies on the corrosion behaviour of this alloy in two different seawater solutions (x, y) was carried out to find how to protect it according to the results of previous studies conducted by researchers. Pitting is the main part of the corrosion of this alloy in marine environments and we are going to minimize this type of corrosion.

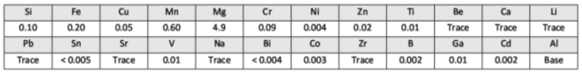
1 Introduction

Corrosion is one of the biggest maintenance problems in vessels of all sizes, particularly in saltwater. Corrosion above the water line is one thing; your only defence there is frequent inspection and careful attention to painting, cleaning, and greasing. Corrosion of hull fittings and metals below the water line, however, is another matter. It can be controlled by cathodic protection. Adequate protection can be achieved by using either zinc sacrificial anodes or impressed current systems. Corrosion is an electrochemical process in which a chemical reaction takes place, creating a flow of electrical charge, or current, between two unlike metals. This chemical action between two unlike metals can destroy one of the metals. When that metal is a propeller, strut, or shaft, the damage can grow expensive. One cannot understand or design an adequate cathodic protection system without a basic knowledge of direct-current (D.C.) electrical theory. Ohm's Law is a handy starting point: Briefly, it states that current (I) in a circuit is proportional to the potential difference (E) across a circuit. Voltage is often compared to water pressure. Then, the water flowing under pressure through a pipe behaves like electricity. The amount of water moving through the pipe is analogous to the current. The frictional resistance to water flow within the pipe is the counterpart of the electrical resistance. Most of the discussion that follows relates to factors on and around boats in saltwater (and to a less severe extent, to those in freshwater) that can reduce the unwanted current that causes corrosion [1]. Al–Mg alloys are not heat-treated, and show high strength and good welding properties. They are often used in high pressure vessels, ships, and other marine structures because they have good corrosion resistance in seawater environments. In this study to find the corrosion protection in a specific Al alloy the Chemical compounds and elements in this alloy were studied and then by using accepted standards, it was surveyed.

2. Materials and Methods

In the beginning by using emission spectrometry the chemical compounds and elements in the alloy were studied and then by using accepted standards, it was surveyed. The results of the analysis Quantometre are given in table (1). As shown the main elements in this alloy are Al and Mg which according to the standards of Al alloy, this is very near to AA5083. The percentage of this composition is given in table (2)[2].

Table 1: Chemical composition of the sample in elements weight percentage



Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Be	Ca	Li
0.10	0.20	0.05	0.60	4.9	0.09	0.004	0.02	0.01	Trace	Trace	Trace
Pb	Sn	Sr	V	Na	Bi	Co	Zr	B	Ga	Cd	Al
Trace	< 0.005	Trace	0.01	Trace	< 0.004	0.003	Trace	0.002	0.01	0.002	Base

Table 2: Standard chemical composition of the alloy

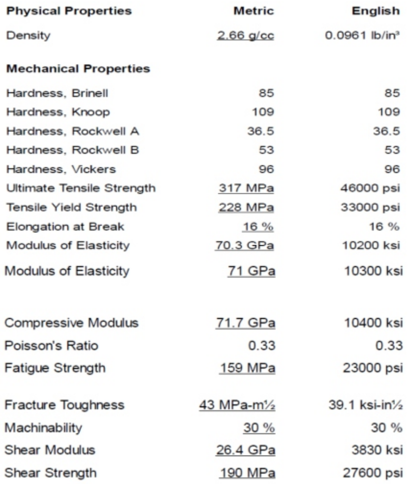
	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other each	Other total	Al
Min	*	*	*	0.40	4.0	0.05	*	*	*	*	Rem
Max	0.40	0.40	0.10	1.0	4.9	0.25	0.25	0.15	0.05	0.15	*

Before testing 5083 alloy it is necessary to study the properties of this alloy and its corrosion behaviour in several environments especially in marine environments.

2-1 Physical Properties of alloy 5083

Aa5083 Al- Mg alloys for high corrosion resistance, low density and good mechanical properties are widely used in the marine industry to manufacture vessels and submarines [3, 4]. Mechanical properties of these alloys are given in table (3).

Table 3: Mechanical properties of AA5083 alloys



Physical Properties	Metric	English
Density	2.66 g/cc	0.0961 lb/in³
Mechanical Properties		
Hardness, Brinell	85	85
Hardness, Knoop	109	109
Hardness, Rockwell A	36.5	36.5
Hardness, Rockwell B	53	53
Hardness, Vickers	96	96
Ultimate Tensile Strength	317 MPa	46000 psi
Tensile Yield Strength	228 MPa	33000 psi
Elongation at Break	16 %	16 %
Modulus of Elasticity	70.3 GPa	10200 ksi
Modulus of Elasticity	71 GPa	10300 ksi
Compressive Modulus	71.7 GPa	10400 ksi
Poisson's Ratio	0.33	0.33
Fatigue Strength	159 MPa	23000 psi
Fracture Toughness	43 MPa-m½	39.1 ksi-in½
Machinability	30 %	30 %
Shear Modulus	26.4 GPa	3830 ksi
Shear Strength	190 MPa	27600 psi

These alloys owe their strength to intermetallic compounds. But the existence of this particular type of compound will cause corrosion so that by oxygen reduction on the intermetallic compounds and based on the following equation the hydroxide ion will be generated and as a result the environment of metal compounds changes to alkaline [5,6].

$$H_2O + 1/2O_2 + 2e \leftrightarrow 2OH^{-1} \qquad (1)$$

10 years studies on different kinds of Al alloys in sea water and the depth of corrosion show that 5083 Alloy is more resistant against corrosion (table 4).

Table 4: Aluminum alloys Corrosion in seawater after 10 years

Alloy (Russian analog)	The maximum pit depth, mm		
	Harbor island (North Carolina)	Halifax (Nova Scotia)	Ixvimolt (British Columbia)
1100–H14 (АДН)	1.02	0.81	0.76
3003–H14 (АМцН)	0.53	0.56	0.51
5052 (АМг2)	0.10	0.30	0.40
5083 (АМг4)	0.25	0.36	0.45
5056 (АМг5)	0.44	0.49	0.57
6061–T4 (АД33Т)	0.36	0.84	1.27
6061–T6 (АД33Т1)	2.41	1.37	2.95
7072 (АЦпл)	1.42	3.81	0.66
7075T6 (В95Т1)	1.68	(through)	(through)*

* The specimen thickness was 6.4 mm.

3 Experimental Observations

Aluminium alloy sample was cut to dimensions 1 × 1 *cm* and then was mounted by particular resin polystyrene in specific frames. So as to leave an exposed area was polished with (400-2500) emery paper. Each specimen was first put in acetone for 5 min. and then in (200) KOH and HNO_3 50% during 30 s and then washed completely by distilled water. According to the previous studies the specimen was put in two differe $g.L^{-1}$ eawater solutions (x, y) about 10 hours. First, to check the quality of corrosion rate, ectrochemical impedance tested (EIS) 5083 alloy in both the open circuit potential of the sample dissolved in a solution of x and y respectively.

Electrochemical techniques of corrosion measurement are currently experiencing increasing popularity among corrosion engineers, due primarily to the rapidity with which these measurements can be made. Long term corrosion studies, such as weight loss determinations, may take days or weeks to complete, while an electrochemical experiment will require, at most, several hours. The speed of electrochemical measurements is especially useful for those metals or alloys that are highly corrosion resistant [7].

As is clear from figures (1) and (2) , the corrosion behaviour of the alloy in the two solutions x and y has not significant difference. It seems that charge transfer resistance in the solution x is greater than y.

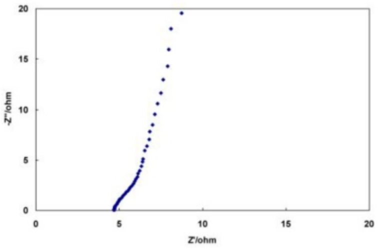


Fig.1: Impedance diagram of the specimen alloy in the solution x

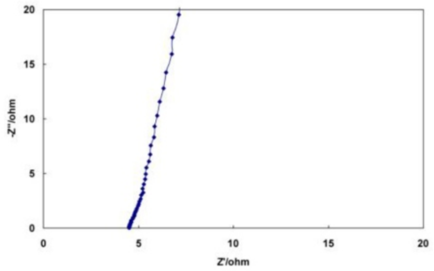


Fig. 2: Impedance diagram of the specimen alloy in the solution Y

The next test was Tafel to investigate the corrosion of the 5083 alloy in the range of -2 to 0 V relative to the reference electrode Ag / AgCl, respectively. Tafel plots can provide a direct measure of the corrosion current, which can be related to corrosion rate. The technique is extremely rapid compared to weight loss measurements. The Tafel constants, β_A and β_C, obtained from Tafel plots can be used with Polarization Resistance data to calculate corrosion rates. Tafel analysis is a conventional DC technique in which larger, applied potentials are used. This produce a measurable current which the current-potential is nonlinear and a semi- log plot which is called "Tafel" plot, is used. It shows an Anodic branch for the oxidation reaction and a Cathodic branch for the reduction reaction. The slopes of these two lines (Anodic and Cathodic) are the Tafel coefficients [7,8].

Figures (3) and (4) show Tafel diagram in two solutions x and y. As follows from the figure, corrosion potential, corrosion current and the slope of the cathodic and anodic corrosion of this specimen in both solutions X and Y are nearly the same as each other. Corrosion current in solution x is rather less than in solution y. However, the similarity of the corrosion current in two solutions will cause the type of corrosion protection in the alloy to be the appropriate one. The higher relative corrosion current in solution y with respect to x may be due to the high pH of the solution y (about 8.5) than the solution x (about 7.5).

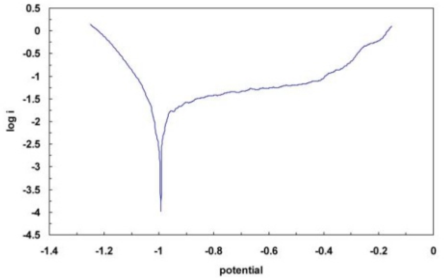


Fig. 3 : Tafel diagram of the specimen alloy in the solution x

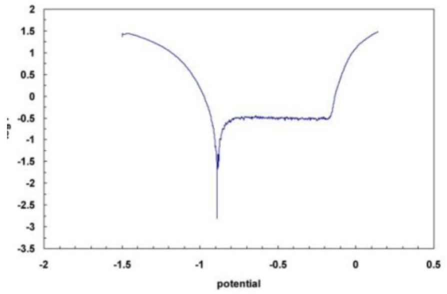


Fig. 4: Tafel diagram of the specimen alloy in the solution Y

4 Discussion

According to the previous studies and the results of these tests we can come into conclusion that the best way for corrosion protection of this alloy is sacrificial anodes with polymer coatings. Sacrificial anodes for corrosion protection due to the potential difference between the anode and alloy are Zn or Mg anodes.

But the corrosion rate of magnesium in the marine environment is too high, so this type of anode is not affordable. Zn anode is suitable for corrosion protection of the alloy but one of the most important issues is the use of pure Zn metal may cause the Zn to be passivated during the protection and thus loses its protective properties. So to avoid this problem it is necessary to use Zn alloys.

5 Conclusion

Generally, sacrificial anodes used must meet the following conditions:

1- corrosion potential to be more negative for cathodic polarization structures

2- uniformly corrosion in environment and stability of the current with the construct under the protection

3- inactivation of the anode

4- convenient and cost-effectiveness in terms of electrical capacity

For example, Zn-In sacrificial anodes due to uniform corrosion, make stable potential for cathodic protection relatively so they are profit for environments such as sea water with high corrosion and conductivity. The main factor in steady corrosion of Zn-In alloy in NaCl and seawater environments is its inactivation due to in activating effect in breaking the passive layer.

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