PAPER REF: 3939

# EFFECT A WEAK MAGNETIQUE FIELD AND IMPOSED POTENTIAL ON CORROSION BEHAVIOR OF ALUMINIUM WIRE (AA1370)

Rabeh SLIMANI[1] , Nacer ZAZI[1,(*)], Ali Bilek[2], J-P.Chopart[3]
[1]LMSE, Département de Génie Mécanique, Université Mouloud Mammeri, 15000 Tizi-Ouzou, Algérie
[2]Département de Génie Mécanique, Université Mouloud Mammeri, 15000 Tizi-Ouzou, Algérie
[3]LISM EA 4695 UFR SEN, BP1039, Université de Reims Champagne Ardenne, Moulin de la Housse, 51687 Reims, Cedex, France
[(*)]*Email:* zazi@yahoo.fr

## ABSTRACT

The motivations to study the corrosion behavior of aluminum wire (AA1370) in NaCl 0.3% solution are its good electric conductivity, lightness and excellent corrosion resistance which make him an attractive candidate to replace conducting electric wires used on aircrafts. This study was made in presence and absence of a weak magnetic field and under an imposed potential of 1.5 Volt. Potensiostatic study and the open circuit potential (OCP) measurement showed that the presence of a weak magnetic field (42mT) and imposed potential influence the morphology and the corrosion kinetics. Microscopic observations after twenty four hours of corrosion showed that, under an imposed potential, the corrosion of external surface and internal surface are different. And under a weak magnetic field the corrosion of a half of the wire surface is different from that of the other half.

**Keywords:** Aluminium, corrosion, week magnetic field, imposed potential

## INTRODUCTION

In spite of its very electronegative potential (-1.66 V/ENH), aluminum has a high corrosion resistance. The good aluminum corrosion behavior depends on the formation and maintenance of an alumina film on its surface. However, this resistance is limited to environments where these oxides are slightly soluble in the interval of pH from 4 to 9 [1-4].The problem encountered in this interval of pH is the localized corrosion [1].Several theories of pitting are connected to the rupture of passive film. In aluminum, corrosion appears when aggressive ions such as chlorides, break local protection [1]. Pitting starts in defects of the oxide film which generally appears at the site of physical or chemical heterogeneities at the surface, such as inclusions, second phase particles, flaws, mechanical damage, or dislocations.

Due to the low solubility of iron impurity element in aluminum matrix, the excess iron will be present as the intermetallic phase $Al_3Fe$. The phase diagram for Al-Fe shows a maximum solubility around 0.04 wt% at 655°C decreasing to <0.001 wt% below ~430°C if equilibrium is not reached, iron can also be present in supersaturated solid solution and/or in the form of number of non- equilibrium intermetallic phases [5].Many studies have demonstrated that the presence of iron-containing intermetallic particles has unfavorable effect on corrosion resistance. Therefore, the phases rich in iron made a favorable site for cathodic reactions and represent an adequate site for the formation of pitting [5-6]. Moreover, iron is nobler than aluminum; its presence in an aluminum solid solution affects the kinetics of anodic dissolution and make up a significant factor in the corrosion of aluminum. N.Zazi et al.

[7]noticed a ratchet effect of the thermomechanical history after a homogenization annealing (1.5 hours at 420°C) on corrosion behaviour of AA5083- H321alloy . G. Svenningsen and al [8] studied effect of cooling rate after extrusion, solution heat treatment, mechanical deformation and aging on intergranular corrosion of two models AlMgSi alloys with different Cu content. They found that slow cooling in air introduced intergranular corrosion. The susceptibility to this type of corrosion was reduced by artificial aging, peak aging (T6) however; the slight aging (under aging) introduced a severe corrosion of this form. Water quenching prevented intergranular corrosion. Over aging further reduced intergranular corrosion, usually at the expense of introducing pitting.The tests of corrosion carried out by A. Afseth [9] revealed that the hot rolled material presented poor filiform corrosion of aluminum alloy AA3005 resistance and that heat treatment of both the hot rolled and subsequently cold rolled samples resulted in a drastic loss of corrosion resistance [9]. Shuangping Lin et al [10] studied the annealing behavior of a modified 5083 aluminum alloy,at the temperature range of 125–375°C with different holding times, the results showed that corrosion resistance properties depend on annealing treatment due to different dislocation configuration in the matrix and the second phase interface.

Electrochemical behavior during deposition in applied magnetic field sis mainly influenced by magneto hydro dynamic convection [11-12]. Aluminum wire having undergone a nickel deposit have been proposed to replace the electric copper wire used on aircrafts however, the electrolytic deposit of nickel can be done only after the wiredrawing of the aluminum wire. This is due to the cracking of the layer of nickel during wiredrawing. This brought us to investigate the corrosion behavior of aluminum wire without nickel deposit.

## EXPERIMENTALPROCEDURES

Pure aluminum samples with 99.70% purity of AA1370 have been taken from a wire of 2 mm diameter. The main chemical compositions in the samples are presented in Table 1.

Table 1 Composition of aluminum material AA1370

| Al | Fe max | Si max | Cu max | Zn max | Ti max | V max | Ga max | Mg max | Mn max | Cr max | B max |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 99.70 | 0,25 | 0,10 | 0,020 | 0,040 | 0,020 | 0,020 | 0,03 | 0,020 | 0,010 | 0,010 | 0,020 |

The samples were prepared by standard metallographic procedures: mechanically polished on emery paper (120-4000 mesh) and finished with alumina suspensions, cleaned with alcohol then water and cool-dried before each experiment.

Hardness measurements were taken with the ZWICKROELZHV1M model hardness tester; the scale HV, under a load of 25g, was chosen for the testing of this specimen: five measurements were taken at various distances starting from the external surface.

The electrochemical measurements have been undertaken with 3.14mm$^2$ samples immerged in a sodium chloride solution (0.3% weight) at room temperature. An assembly of four-electrode method has been used. The reference electrode was silver/silver chloride electrode; the auxiliary electrodes were two graphite electrodes. Potential curves have been obtained by means of a radiometer potentiostat (PGP 201) controlled by Voltamaster 4 software. The studies of corrosion, were carried out by immersion of the cylindrical surface of the aluminum AA1370 wire in 0.3% NaCl solution (pH=7), in presence and in absence of a weak magnetic field (42 mT), and an imposed potential of 1.5V , at a temperature 30°±2°C.

To study the influence of a weak magnetic field when it is directed according to a direction perpendicular to the electrode surface, we positioned the ring shape magnet on the resin surrounding the sample surface.

The optical microstructures after twenty four hours of corrosion were taken by using Carl Zeiss ICM405 microscopy with different magnifications up to 1000x.Scanning electronic microscopy microphotographies have been performed by means of a Philips ESEM–XL30SEM apparatus.
The measurement of the magnetic field value created along the ring magnet axis was made with the Hall Effect probe which is always placed in the axis of the magnet.

## RESULTS

The SEM micrograph of aluminum wire samples AA1370 surfaces, in the polished condition, in the central longitudinal surface and in the circular surface of the wire Fig.1, revealed the presence of another phase.

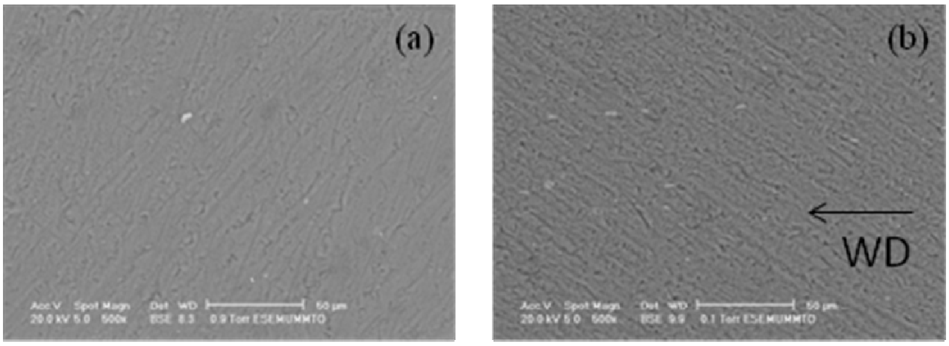


Fig. 1 SEM Microstructure of aluminum material AA1370: (a) circular surface, (b) central longitudinal surface.

The metal can thereby be considered as a two phase material: the α-phase matrix and the particles of a second phase. These particles result from some impurities among (Al, Fe, Si, Cu, Zn, Ti, V, Ga, Mn, Mg, B, and Cr) present in the material. The number of particles in the central longitudinal surface differs from the number of particles in the circular surface (Fig. 1 a-b). The intermetallic phase is lengthened in the wiredrawing direction (WD). This shows that the distribution of the second phase particles is heterogeneous thus the electrochemical properties of the two phases are different.
Hardness (HV) at different distances from the surface was determined Table. 2 The hardness was found to be the highest at the surface; it decreases then gradually as we move towards the center of the wire and finally becomes constant. This evolution is due to the variation of the residual stresses on the section of the wire, caused by the deformation during the wiredrawing.

Table 2 Hardness (HV) according to the distance from surface of wire

| Distances from surface of wire (μm) | 51,5 | 54 | 56 | 78 | 1000 |
|---|---|---|---|---|---|
| Hardness (HV) | 52 | 50 | 47 | 45 | 45 |

Fig. 2 shows the variation of the magnetic field value of a ring shaped permanent magnet along the axis measured by a probe with Hall Effect. The value of the magnetic field on the surface of the magnet is 42 mT and at 1.5 cm from the magnet the value of the magnetic field is 0 mT. Thus to see the effect of a weak magnetic field on the corrosion of the aluminum wire (AA1370), we positioned the permanent magnet on the resin surrounding of the sample.

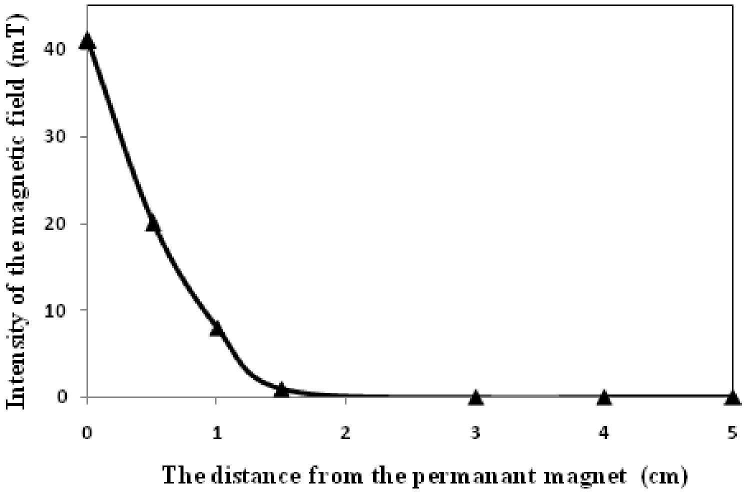


Fig 2 Intensity of permanent magnetic field according to the distance from the permanent magnet.

Knowing that the electronic apparatuses used on the aircraft induce a weak magnetic field and the electric wire is used to lead an electrical current, to understand the behavior of aluminum wire used as electric wire on aircrafts we carried out corrosion tests in an NaCl solution of small concentration (0.3%), in presence and in absence of a weak magnetic field (42mT), under an imposed potential (1.5V), and in presence of a weak magnetic field under an imposed potential.
Fig.3 represents the microstructure of aluminum wire after 24 hours of corrosion in 0.3% NaCl solution, in absence of the magnetic field and the imposed potential Figure 3.a, in the presence of an imposed potential Fig.3.b and in the presence of weak magnetic field Fig.3c.

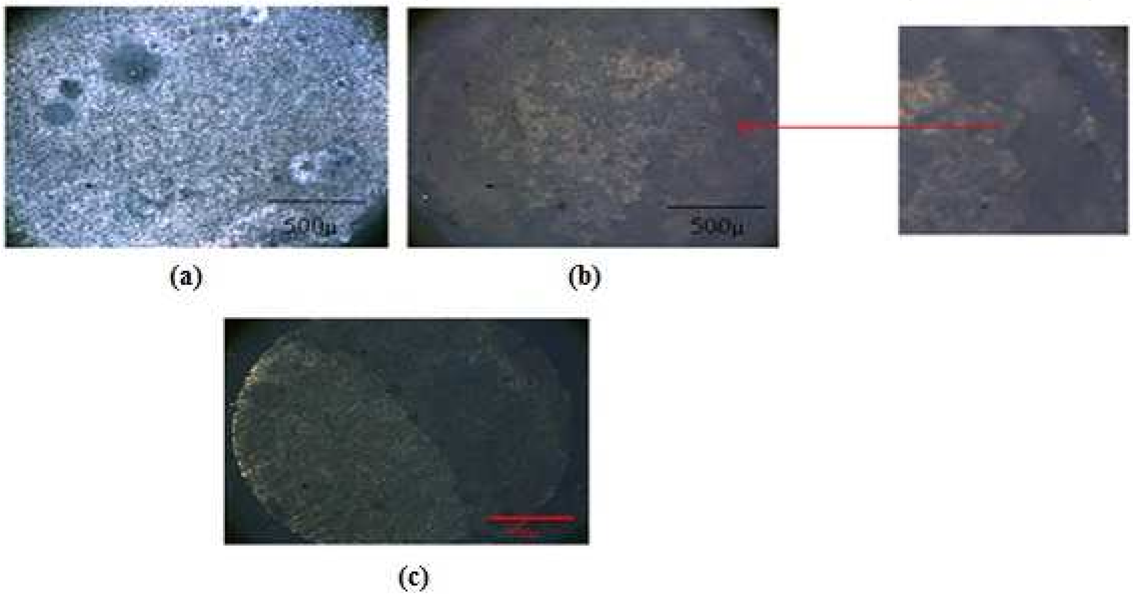


Fig.3 Microstructure after 24 hours corrosion in 0,3%NaCl solution: (a) absence of magnetic field and imposed potential, (b) presence of weak magnetic field (42mT), (c) presence of imposed potential (1.5V).

The corrosion form of the aluminum wire in absence of magnetic field and an imposed potential is a located corrosion by pitting on all the surface sample Fig. 3.a On the other hand after imposing of a potential of 1.5 V we observe a generalized corrosion on the external surface of the wire. A test of corrosion in the presence of a magnetic field of intensity of

(42mT) revealed that the corrosion of a half of the wire surface is marked than the other half surface Fig.3.c.

Fig.4 shows that the open circuit potential of aluminum (AA1370) is the same one for the samples corroding in absence of magnetic field and imposed potential and the samples corroding in the presence of a weak magnetic field. The open circuit corrosion, increases during the first hours and decreases thereafter for the samples which corrode in absence of magnetic field and imposed potential. But for the samples which corrode in presence of a weak magnetic field, the open circuit potential (OCP) decreases relatively slowly from the immersion time and continues to decrease until the end of the test. At the end of the test, for both cases, The OCP converges towards the same value after 24 hours of immersion. We can therefore; say that a magnetic field of low intensity (42mT) induced a change in the kinetics of corrosion of the aluminum wire (AA1370).

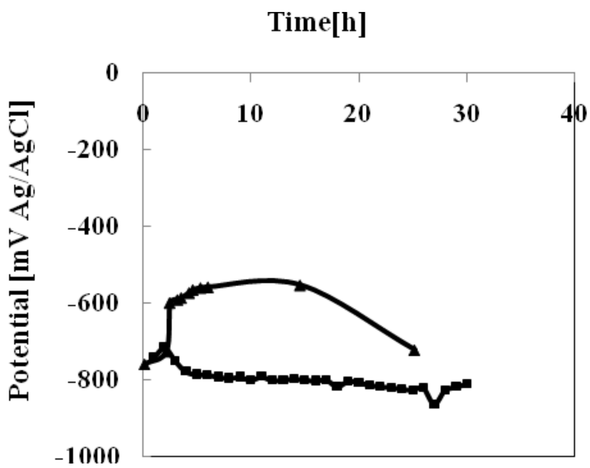


Fig. 4 Corrosion potential vs. exposure time in 0.3% NaCl solution of aluminum wire (AA1370): (▲) Samples corrode in absence of magnetic field and imposed potential, (■) Samples corrode in presence of weak magnetic field.

The potensiostatic study carried out in the solution of 0,3% NaCl Fig.5 shows that the presence of the magnetic field increases the corrosion current recorded when a potential of 1.5V is imposed. We noticed that the two curves at the beginning of the immersion are different. The metal which corrodes in the presence of a magnetic field shows a peak of anodic current during the first minutes, followed by a decrease in time and then stabilization. On the other hand, for the metal which corrodes in absence of the magnetic field, we observe relatively, an opposite effect in the presence of the field.

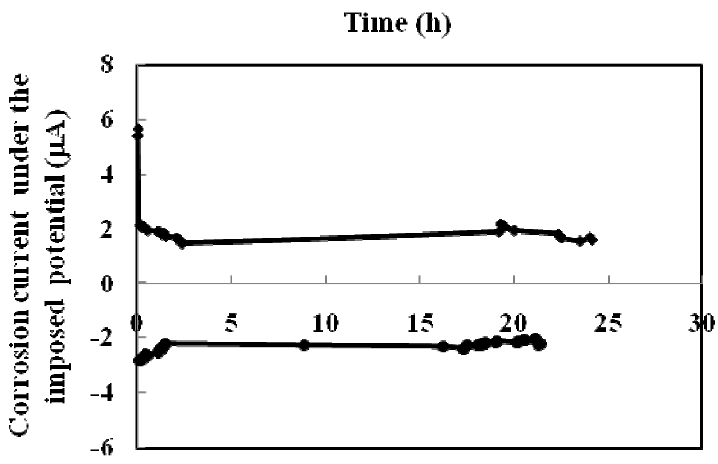


**Fig. 5** Corrosion current vs. exposure time in 0.3% NaCl solution of aluminum wire (AA1370): (●) under an imposed potential of 1.5V in absence of the field, (◆) under an imposed potential of 1.5V in presence of the field.

## CONCLUSION

1-The impurities (Al, Fe, Si, Cu, Zn, Ti, V, Ga, Mn, Mg, B, and Cr) present in the material give birth to a second phase lengthened in the direction of wiredrawing. These particles are partly responsible of the corrosion occurring within the metal. The second reason, of the appearance of corrosion, is the difference between the mechanical state of wire external surface and the mechanical state of wire internal surface.

2- The corrosion form of the circular surface of aluminum wire (AA1370) in 0.3%NaCl is corrosion by pitting on the entire surface of the samples, but the application of an imposed potential of 1.5 V shows that external surface does not corrode such as the internal surface and the application of a magnetic field of 42mT intensity causes a change in the corrosion form of the surface.

3- The application of magnetic field of 42mT and an imposed potential changes the kinetics of corrosion of the aluminum wire (AA1370).

## REFERENCES

[1] M.Pourbaix, Atlas d'équilibre électrochimiques à 25°C, 1963, Villard.

[2] Elboudjaini.M, Ghali.E, Galibois.A , Corrosion par piqûres des alliagesd'aluminium 5083-H321, J of Applied Electrochemistry 1988,.18,p. 257-267,

[3] Ladislav Vrsalović, Maya Kliškić, Jagoda Radošević and Senka Gudić, The effect of electrolyte flow rate and temperature on corrosion and protection of Al-2.5 Mg alloy by(+) catechin" J of Applied Electrochemistry, 2005, 35, p.1059-1065.

[4] S. Berrada, M. Elboujdaini, E. Ghali, Comportement electrochimique des alliages d'aluminium 2024 ET 7075 dans un milieu salin, Journal Of Applied Electrochemistry 1992,22, p. 1065-1071.

[5] Rajan Ambat, Alison J.Davenport, Geoff M. Scamans, Andreas Afseth, Effect of iron-containing intermetallic particles on the corrosion behavior of aluminium, Corrosion Science 2006, 48(11), p. 3455-3471.

[6] WANG Guan1, JIAO Hui-sheng, Microstructural effects in corrosion of aluminium tube alloys, Trans. Nonferrous. Met.China 2011, 21, p. 1193-1198.
[7] Nacer Zazi, Ahcène Bouabdallah, Omar Aaboubi, J-P.Chopart, Pretreatment effects on the electrochemical responses for aluminium–magnesium alloy AA5083 corrosion behavior, J Solid State Electrochem 2010, 14, p.1705–1711.
[8] G Svenningsen G, LarsenM.H, Nordlien J. H, Nisancioglu K, J. Corros.Sc, i2006, 48, p 3969-3987,. doi:10.1016/j.corsci.2006.03.018.
[9] A. Afseth, J.H. Nordlien, G.M. Scamans, K. Nisancioglu, Effect of thermo-mechanical processing onfiliform corrosion of aluminium alloy AA3005, Corrosion Science, 2002, 44**,** p.2491–2506.
[10] Shuangping Lin, ZuorenNie, Hui Huang, Bolong Li, Annealing behavior of a modified 5083 aluminum alloy, Materials and Design 2010, 31, p.1607–1612.
[11] O. Devos, O. Aaboubi, J-P. Chopart, A. Olivier, C. Gabrielli, B. Tribollet, Is there a magnetic field effect on electrochemical kinetics?, J. Phys. Chem. A, 2000, 104, p.1544.
[12] O. Aaboubi, J-P.Chopart, A. Olivier, P. Los, Electrochemical investigation of the magnetic field influence on mass transport toward on ultramicrodisk, Journal of theElectrochemical Socity, 2003, 150 (2), p E125-E130.