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THE DIFFERENCE BETWEEN CORROSION BEHAVIORS OF PERPENDICULAR ROLLING SURFACE AND THE ROLLING SURFACE AFTER HOMOGENISATION ANNEALING OF AA5083-H31 ALLOY

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

ABSTRACT

The surface state, the phase composition and the thermomechanical history have a significant effect on the kinetics of aluminum alloy 5083-H321corrosion, the studied alloy has undergone respectively, hot rolling, cold rolling and stabilization in industry, and a homogenization annealing in laboratory. In this work we plotted the electrochemical impedance curves and we approached the electrical equivalent circuit of the corrosion kinetics for the rolling surface and the surface perpendicular to the rolling direction of AA5083-H321 aluminum alloy. We studied the effect of surface state and phase's composition on corrosion behavior. We approached the electrical equivalent circuit by using the experimental curves and the electrical equivalent circuits proposed by other researchers or by using ZSimpwin 3.21 software. The results showed that the phase shapes and composition of the surface chosen for the corrosion tests have considerably influenced the electrochemical impedance response of 5083-H321 alloy; the thermomechanical history controls the corrosion kinetic witch gives a specific electrical equivalent circuit.

Keywords: thermomechanical treatments, corrosion, aluminium alloy 5083-321, electric equivalent circuits

INTRODUCTION

Among the most used aluminum alloys are those with magnesium (5000 series). The aluminum 5083-H321 alloy has many applications in the automobile, marine, aeronautic and food industries. This is due to its lightness, mechanical resistance and high plasticity, and its good corrosion resistance.

Generally these alloys are utilized in thin sheet shapes. To obtain these sheets, the materials must undergo preliminary thermomechanical treatments. The applied thermomechanical treatments are hot rolling, cold rolling and stabilization annealing. Cold rolling and stabilization annealing are the last treatments carried out during the sheets manufacturing. During deformation, such as rolling, the grains obtained are flattened and the intermetallic particles are fragmented or flattened. The rolling surface undergoes a tensile stress, but the surface perpendicular to rolling undergoes a compressive stress [1]. The application of homogenization annealing removes the mechanical properties acquired during the manufacturing of these sheets.

The presence of intermetallic particles (Al6 (Fe, Mn) and Mg_2Si)) in the alloy matrix improves mechanical properties, but increases the susceptibility to localized corrosion [1-6]. The nobler particles compared to aluminum matrix are responsible for pitting formation surrounding the alloy matrix, but the elements with lower electrochemical potential than the matrix witch exist in the intermetallic particles less noble than the matrix, dissolve [3].

During rolling, the intermetallic particles undergo a fragmentation and dispersion in the rolling direction.

The main types of intermetallic particles observed and reported by several authors in 5083-H321 aluminum alloy are $Al_6(Fe,Mn)$ and Mg_2Si [1-7].

In this work we plotted the electrochemical impedance curves and approached the equivalent circuit of the corrosion kinetics, of the rolling surface and the surface perpendicular to the rolling direction of AA5083-H321 aluminum alloy, stabilized and homogenized. We studied the effect of surface composition on the corrosion behavior. Normally, after homogenization annealing, the material converges towards the isotropic state. The stress state of the surface, the material phases, the shape and the size of the grains and intermetallic particles, the distribution and the chemical composition of the intermetallic particles, build the impedance response.

TECHNICAL AND EXPERIMENTAL PROCEDURES

The material investigated is AA5083-H321aluminum alloy; the chemical composition of this alloy is given in Table 1, cold-rolled to a 12.7mm thickness and stabilized in industry, and homogenized in laboratory (90 minutes at 420°C in a salt bath furnace) and then cooled in air. The electrochemical measurements have been undertaken with $1cm^2$ samples immersed in a sodium chloride solution (3 % w eight) at room temperature. The electrochemical impedance spectroscopy measurements were carried out by means of a frequency response analyzer Solartron 1250, in a frequency range from 20 kHz down to 1 mHz and a 20 mV peak to peak potential modulation amplitude. To obtain accurate values of the electrochemical impedance, integration has been performed for ten cycles. We approached the equivalent circuit by using the experimental curves, electric equivalent circuits proposed by other researchers and ZSimpwin 3.21 software. Optical microscopy and scanning electronic microscopy (SEM) was made by using the JEOL JSM 6460LA SEM were used to reveal the microstructure of surface.

Table 1 Chemical composition of 5083-H321 aluminum alloy

Elements	Cu	Mg	Fe	Mn	Cr	Si	Zn	Ti	other
% en masse	0.1	4-4,9	0.4	0.3-1	0.25-0,5	0.4	0 .25	0 .15	0 .15

RESULTS AND DISCUSSION

Fig.1 and Fig. 2 show two types of intermetallic particles distributed in a heterogeneous way in the surface, the white phase is rich in (Al-Fe-Mn), and the dark phase is rich in (Al-Mg-Si). Grains with equiaxes shape [4]. These parameters make more complex the mathematical model of the corrosion kinetics.

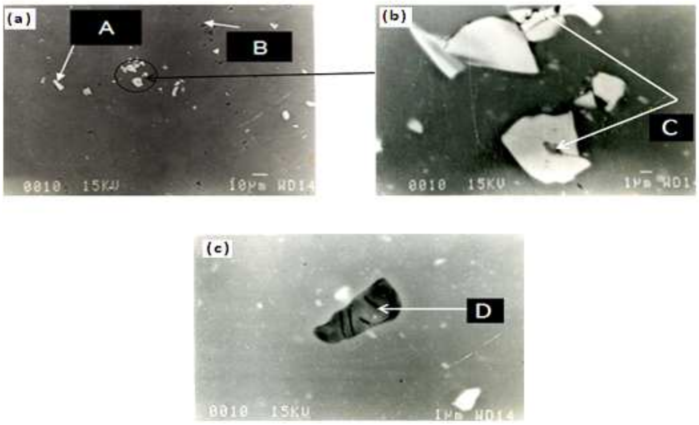

Fig. 1 SEM Rolling surface microstructure of 5083-H321 stabilized and homogenized aluminum alloy.

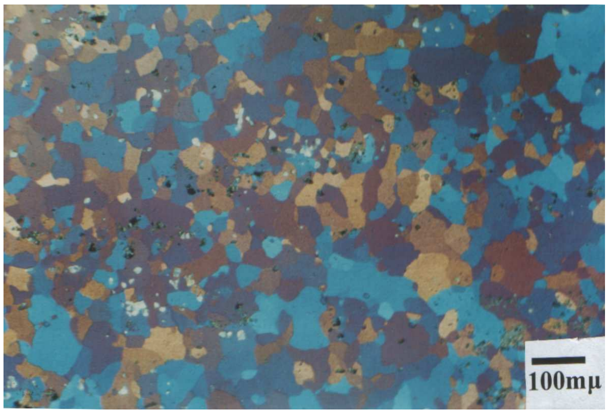

Fig. 2 Optic rolling surface microstructure of 5083-H321 stabilized and homogenized aluminum alloy.

Fig. 3 shows the impedances curves in rolling surface of 5083-H321 aluminum alloy in 3% NaCl solution; these curves comprise several loops than the mathematical model of corrosion kenetic is complex. The last loop of these curves is an inductive loop.

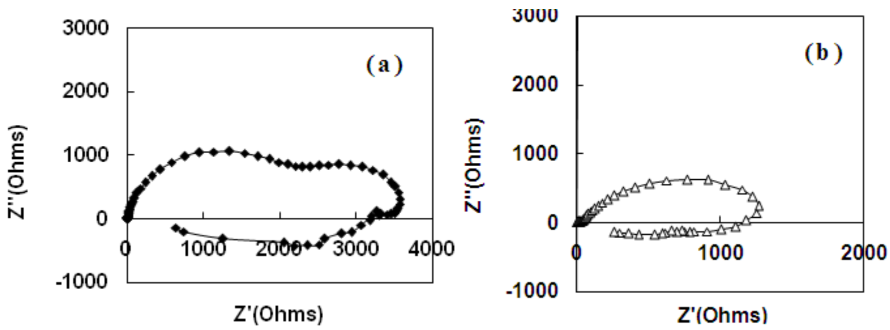

Fig. 3 Impedance curve of rolling surface of 5083-H321 aluminum alloy in 3% NaCl solution (a) 1h after immersion, (b) one week of corrosion

Fig.4 reveals the difference between corrosion kinetics of the surface perpendicular to the rolling surface and the rolling surface of the stabilized and homogenized 5083-H321 aluminum alloy. The shape of the impedance spectra appears to be as complicated as the rolling surface one. The mathematical model and the equivalent electrical circuit of this corrosion alloy in the rolling surface and in the surface perpendicular to rolling surface is complex. We applied all equivalent electric circuits quoted by the literature for the 5083-

H321 alloy and aluminum-magnesium alloys, but we couldn't find an equivalent electrical circuit approaching the impedance curves obtained. We think that the reason of this difference is due to the thermomechanical history of each sample.

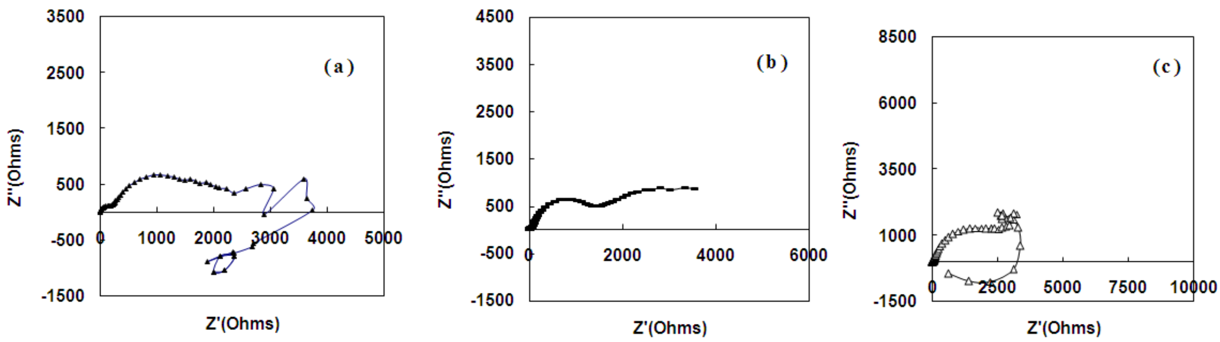

Fig. 4 Impedance curves of 5083-H321 aluminum alloy in 3%NaClsolution of perpendicular surface to rolling surface in 3% NaCl (a) 27h of immersion, (b) 6 days of corrosion (c) 9 days of corrosion.

According to the shape of the experimental impedance curves and the equivalent circuit proposed by J.R.Scully [8] we build the equivalent electrical circuit represented by Fig.5. This circuit allowed us to simulate the impedance curves up to a frequency of 130mHz Fig.6.The equivalent electrical circuit parameters are given by table 2

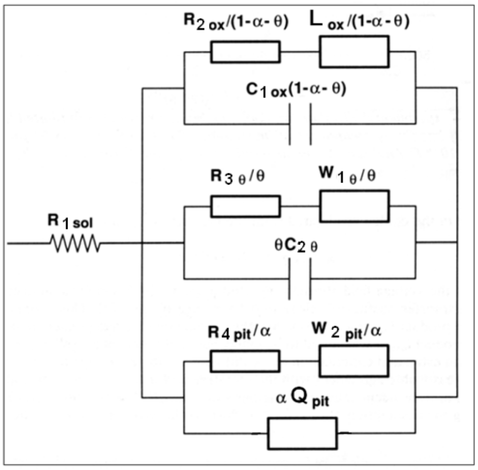

Fig.5 Equivalent electric circuit proposed for modeling impedances curves of perpendicular surface to rolling surface of 5083-H321 aluminum alloy in 3%NaClsolution.

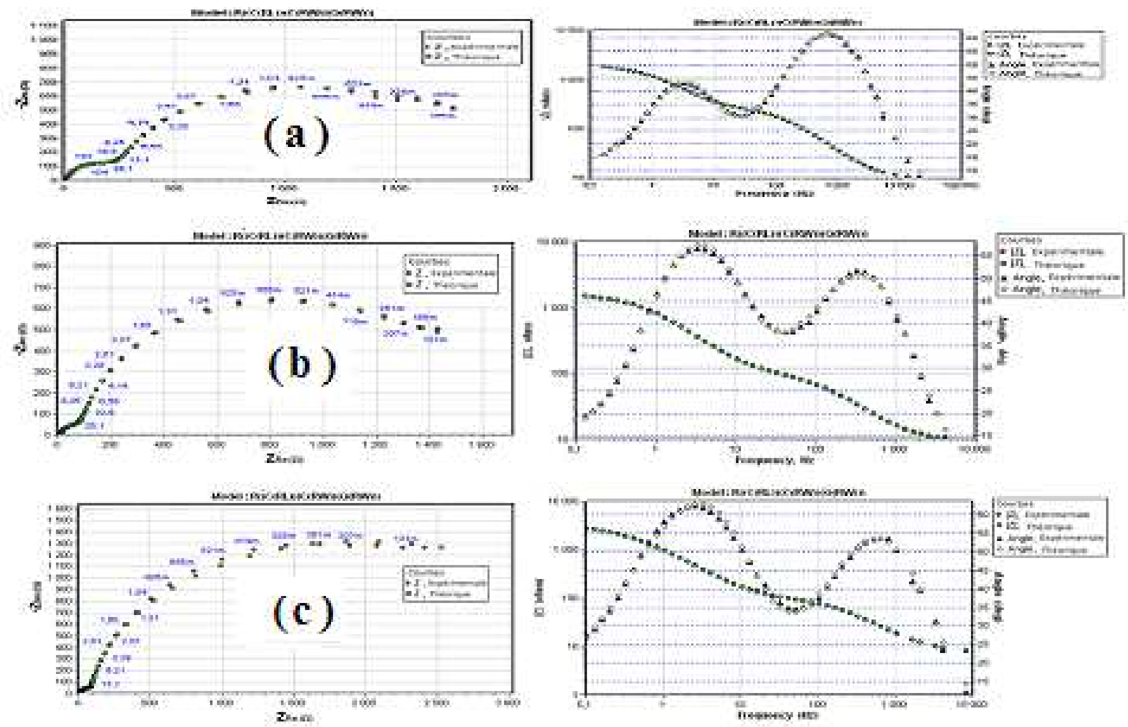

Fig. 6 NYQUIST Diagram and BODE Diagram of 5083-H321 aluminum alloy corrosion in 3%NaCl solution: Perpendicular surface to rolling surface : (a) 27h of immersion, 6 days of corrosion , 9 days of corrosion experimental diagrams and simulated diagrams.

Table 2 Evolution of electrochemical characteristics according to the time of corrosion of AA5083-H321 aluminum alloy in 3% NaCl solution.

Time of corrosion / Circuit element	27 h	144 h	216 h
R_1	10,61	9,535	7,582
C_1	$3{,}84.10^{-5}$	$6{,}859.10^{-5}$	$7{,}987.10^{-5}$
R_2	532,2	153,2	138
L	$9{,}2.10^{+5}$	26,45	$2{,}119.10^{+19}$
C_2	$4{,}405.10^{-6}$	$1{,}249.10^{-5}$	$8{,}345.10^{-6}$
R_3	$4{,}681.10^{+12}$	$1{,}22.10^{+6}$	0,553
W_1	$2{,}391.10^{+7}$	0,01854	$1{,}745.10^{-19}$
Q-Y_0	0.001885	0,02893	0,02477
Q-n	0,1583	1	1
R_4	1631	1998	4458
W_2	0.0001863	0.0001947	0,000168

CONCLUSION

1- The corrosion kinetics of the 5083-H321 aluminum alloy depends on the thermomechanical history of material.
2- The corrosion kinetics of the rolling surface is different from the corrosion kinetics of the surface perpendicular to rolling direction.
3- The equivalent electrical circuit of 5083-H321 aluminum alloy is complex.

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