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Influence of the Dissolved Oxygen Concentration on the Passive Oxide Film of Al Alloy in Different Media

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ABSTRACT

 \mathbf{y} his paper employs the electrochemical current noise (ECN) and electrochemical impedance spectroscopy (EIS) techniques to better evaluate the dissolved O_2 concentration on the passive oxide film of AA6162 Al alloy. The ECN measurements were done on the asymmetrical electrodes with different sizes $(2-200 \text{ mm}^2)$ after 5 min from immersion in each of 0.4% NaCl, 0.4% NaCl + 0.1% NaNO₂ and 3.5% NaCl solutions containing different O_2 concentrations (5-25 ppm). EIS measurements were used to calculate the thickness of the passive oxide film. In dilute NaCl solution, the dissolved oxygen played an active role with an increase in oxygen concentration up to 15 ppm, while with further increase of oxygen concentration it acted as a passive factor to decrease the corrosion activity. With increasing the concentration of oxygen from 5 to 25 ppm, in the concentrated NaCl solution, the oxide film thickness decreased as an evidence of the active role of the oxygen reduction reaction. The behavior of nitrite-containing NaCl solution was in accordance with the property of nitrite ion which assists the formation of the passive film according to the adsorption theory. Prog. Color Colorants Coat. 14 (2021), 187-197[©] Institute for Color Science and Technology.

1. Introduction

Financial damages and decreasing of our normal sources come from the corrosion of metals and alloys [1]. This is a key issue worldwide, and thereby the corrosion investigation of metals and alloys is very important.

The current fluctuations arising from corrosion events, called electrochemical current noise (ECN) signals, have been used broadly for the investigation of general and localized corrosion processes [2-12]. For recording the ECN signals, two identical working electrodes (WEs), called symmetrical electrodes, are connected by a zero-resistance ammeter (ZRA). The asymmetrical electrodes made of two identical WEs with a large difference in size between them can enhance the ECN detection [9]. Wavelet transform (WT) as a mathematical approach is a popular tool for analyzing ECN signals [11, 13-21]. It is possible to obtain the standard deviation of partial signal (SDPS) from the wavelet transform [19]. SDPS is a criterion of the corrosion activity of the electrodes surface within a particular time interval. The maximum peak in the SDPS plot represents the predominant transients for each signal.

Aluminum alloys have a high resistance to corrosion due to the formation of a passive oxide film on their surface [22]. The localized attack by the aggressive anions like chlorides causes the breakdown of the passive film. The formation of the passive film on the aluminum alloys requires the cathodic process of oxygen reduction reaction (ORR) to occur. The dissolved oxygen concentration is also an important parameter that is worthy of scientific research efforts because it can significantly affect the oxidation behavior and hence the service performance of the materials [23].

For EN current signals from pitting corrosion not only the kinetics of the anodic reaction but also the rate of the cathodic process arising from different oxygen concentrations will determine the time width and the amplitude of EN current transients [24]. The influence of the cathodic process of ORR on the passivation of Al alloys proves the importance of the cathodic process along with the anodic dissolution process in the corrosion processes [23-26]. It was proved previously that the increase of the dissolved oxygen concentration can lead to both the enhancement of current noise detection and the increase of corrosion activity [24].

In general, the dissolved oxygen can lead to two opposite effects on the corrosion of Al alloy electrodes: (1) the increase of corrosion activity due to an increase in the rate of cathodic reaction (i.e. oxygen reduction reaction) and (2) the decrease of corrosion activity arising from the thickness of the passive oxide layer. Therefore, it can be concluded that oxygen can act as an active or a passive factor in the corrosion of Al alloys.

There are two theories for the mechanism of the passivation: the oxide-film theory and the adsorption theory [27]. The first presents the passive film as a barrier layer made of metal oxide. The barrier layer decreases the corrosion rate by separation of metal or alloy from its media. The second states that the alloy surface is covered by a chemisorbed film of oxygen. This layer decreases the corrosion activity by increasing the overvoltage of the anodic reaction $M \rightarrow M^{z+} + ze^{-}$. Despite having the passivating effect, this adsorbed layer cannot act as a barrier layer. The nitrite ion is an anodic corrosion inhibitor, which adsorbs on the surface of the Al electrodes to assist the formation of passive film according to the adsorption theory (Eq. 1) [27]:

$$2NO_2^- + 2H^+ + Al_{surface} \rightarrow 2NO + H_2 + 2O_{ads} \tag{1}$$

The present work employs the wavelet analysis of ECN signals resulting from localized corrosion on the asymmetrical electrodes made of AA6162 alloy to get a better understanding of the active and passive effects of ORR and the behavior of two types of passivators, called oxide-film passivators and adsorption passivators.

2. Experimental

The ECN measurements were conducted on asymmetrical electrodes made of AA6162 with the surface area of 2 and 200 mm² (i.e. surface area ratio of k=100). The chemical composition of the alloy obtained by optical emission spectrometer type GNR Metal Lab 75-80 is given in Table 1.

The experimental conditions are listed in Table 2. After connecting the disk shape specimens to a copper wire and sealing them using resin, the prepared WEs were polished by wet abrasive papers with grit sizes from 600 to 2500. Then, they were washed by distilled water and ethanol. The electrodes were immersed in the solution by facing each other vertically. The reference electrode was a saturated (KCl) Ag/AgCl electrode.

An Autolab 302N potentiostat equipped with Nova software was employed to conduct 19 the electrochemical current noise and electrochemical impedance spectroscopy (EIS) tests. The ECN signals were recorded for 10 min after 5 min soaking and the EIS tests were performed when the open circuit potential (OCP) was stabilized after 15 min from immersion time (Figure 1). The OCP gives the needed immersion time until the potential of the electrochemical cell becomes stable without the possibility of current passing [28]. A sinusoidal potential perturbation of 10 mV versus OCP in the100 kHz-10 mHz frequency range was used in the EIS measurements.

Table 1: Chemical composition (in weight percent) of AA6162 aluminum alloy.

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
AA6162	0.36	0.34	0.25	0.09	0.89	0.06	0.07	0.02	Bal.

Run	Solution
C04(5)	0.4% NaCl + 5 ppm O_2
C04(15)	0.4% NaCl + 15 ppm O_2
C04(25)	0.4% NaCl + 25 ppm O ₂
CN(5)	0.4% NaCl + 0.1% NaNO ₂ + 5 ppm O ₂
CN(15)	0.4% NaCl + 0.1% NaNO ₂ + 15 ppm O ₂
CN(25)	0.4% NaCl + 0.1% NaNO ₂ + 25 ppm O ₂
C35(5)	3.5% NaCl + 5 ppm O ₂
C35(15)	3.5% NaCl + 15 ppm O ₂
C35(25)	3.5% NaCl + 25 ppm O ₂

Table 2: Experimental conditions.



Figure 1: The OCP plot for AA6162 in 0.4% NaCl solutions containing 15 ppm oxygen concentration during 15 min from immersion time.

An Oxi 340 oximeter (WTW) was employed to control the oxygen concentration of the solution. The bubbling of oxygen was paused during the ECN and EIS tests to prevent the influence of the hydrodynamic noise on data. The oxygen concentrations of 15 and 25 ppm (mg/L) were prepared by bubbling oxygen. The naturally aerated solution containing 5 ppm oxygen was also considered.

The ECN data was collected with the sampling frequency of 8 Hz. The wavelets of orthogonal Daubechies with the fourth order (db4) were used for analyzing the ECN data by wavelet technique. The Matlab software was employed for constructing the SDPS plots. The surface of each specimen was observed in a scanning electron microscope (SEM, CamScan MV2300, Czech & England) equipped with an energy dispersive X-ray spectrometer (EDX, Link,

Oxford, U.K.).

3. Results and Discussion

3.1. Dilute NaCl solution

ECN measurements were performed on asymmetrical electrodes (2-200 mm²) made of AA6162 Al alloy in a 0.4% NaCl solution containing 5, 15 and 25 ppm oxygen. The recorded ECN signals are shown in Figure 2. The asymmetrical electrodes of Al alloys usually produce unidirectional ECN signals while the symmetrical electrodes present bidirectional ECN records [9]. The bidirectional ECN signals arise from the corrosion pits taking place on each of two WEs, but the unidirectional ECN signals appear from the corrosion pits occurring only on the small WE.



Figure 2: ECN signals of asymmetrical electrodes made of AA6162 after 5 min soaking in 0.4% NaCl solutions containing 5, 15 and 25 ppm oxygen concentrations.

The ECN signals were constructed from wavelet transform (Figure 3). The crystal corresponding to the maximum SDPS value in the SDPS plot presents the predominant transients of each signal [19]. The SDPS plots of Signals C04(5), C04(15) and C04(25) peaks at the crystals of d5, d5 and d3, respectively (Figure 3). The SDPS plots of Signals C04(15) and C04(25) show another maximum peak at the crystals of d7 and d6, respectively. A closer inspection of the ECN signals revealed that [9] the latter crystals (i.e. d7 and d6) corresponded to the overlapped transients while the former crystals (i.e. d5 and d3) corresponded to the single transients.



Figure 3: SDPS plots of ECN signals in Figure 1.

Table 3 outlines the timescales and the SDPS values of the predominant transients of ECN signals arising from the asymmetrical electrodes of AA6162 in 0.4% NaCl solutions containing different oxygen concentrations. Signal C04(25) showing crystal d3 contains the transients with a timescale shorter than those underlying Signals C04(5) and C04(15). An increase in the oxygen concentration from 5 to 15 ppm resulted in the increase of SDPS values as an evidence of the enhancement of corrosion activity. On the other hand, the increase of oxygen concentration from 15 to 25 ppm caused a decrease in the time width of the ECN transients (d5 vs. d3) and thereby the decrease of corrosion severity of Al alloy.

The oxide layer thickness (D_{ox}) can be determined by EIS measurements according to the following equation (Eq. 2):

$$D_{ox} = \varepsilon \varepsilon_0 A / C_{ox}$$
(2)

where \mathcal{E} , \mathcal{E}_0 and A represent the dielectric constant of Al₂O₃ (8.5), the permittivity of vacuum $\left(8.854 \times 10^{-14} \ F \ cm^{-1}\right)$ and the geometric surface area, respectively. The oxide layer capacitance (C_{ox}) is calculated from the intercept of the high-frequency linear part of the Bode plot by the following equation (Eq. 3) [29]:

$$\log |Z| = -\log(\omega C_{ox}) \tag{3}$$

with $\omega = 2\pi f$. The Bode plots for AA6162 in 0.4% NaCl solutions containing various oxygen concentrations are shown in Figure 4. The thickness values of the oxide film are listed in Table 4. According to Table 4, the increase of the dissolved oxygen from 5 to 15 ppm causes the decrease of the thickness of the oxide layer and thereby the increase of corrosion severity. A further increase in the dissolved oxygen from 15 to 25 ppm is accompanied by the increase of the oxide film thickness and thereby the decrease of corrosion activity. These results arising from EIS measurements are in agreement with the ECN data listed in Table 3. Therefore, in dilute NaCl solutions, the dissolved oxygen played an active role on increasing the concentration up to 15 ppm and then it acted as a passive factor to decrease the corrosion activity by further increasing the oxygen concentration.

Figure 5 shows the SEM images of AA6162 sample

in 0.4% NaCl solutions containing various oxygen concentrations. According to the figure, the increase of the dissolved oxygen from 5 to 15 ppm causes the increase of corrosion severity and a further increase from 15 to 25 ppm causes the decrease of corrosion activity.

3.2. Nitrite-containing NaCl solution

ECN tests were done on asymmetrical electrodes of AA6162 Al alloy in 0.4% NaCl + 0.1% NaNO₂ solution containing different oxygen concentrations. The obtained ECN signals are shown in Figure 6 and the corresponding SDPS plots are given in Figure 7. Table 5 outlines the maximum timescales and the corresponding SDPS values of the predominant transients of ECN signals.

Table 3: The maximum time scales and the
corresponding SDPS values of the predominant
transients of ECN signals corresponding to
asymmetrical electrodes of AA6162 in a 0.4% NaCl
solution containing different oxygen concentrations.

Signal	d _{max}	SDPS/nA
C04(5)	d5	2.5
C04(15)	d5	6.1
C04(25)	d3	6.3

 Table 4: Parameters obtained from EIS measurements

 in 0.4% NaCl solutions containing different oxygen

 concentrations.

	C04(5)	C04(15)	C04(25)
$C_{ox} (\mu F Cm^{-2})$	31	38	27
D _{ox} (nm)	0.49	0.39	0.56



Figure 4: The Bode plots for AA6162 in 0.4% NaCl solutions containing 5, 15 and 25 ppm oxygen concentrations.



Figure 5: SEM images of AA6162 in 0.4% NaCl solutions containing (a) 5, (b) 15 and (c) 25 ppm oxygen concentrations.



Figure 6: ECN signals of asymmetrical electrodes made of AA6162 after 5 min soaking in 0.4% NaCl + 0.1% NaNO₂ solutions containing 5, 15 and 25 ppm oxygen concentrations.



Figure 7: SDPS plots of ECN signals in Figure 4.

 Table 5: The maximum time scales and the corresponding SDPS values of the predominant transients of ECN signals corresponding to asymmetrical electrodes of AA6162 in a 0.4% NaCl+0.1%NaNO₂ solution containing different oxygen concentrations.

Signal	d _{max}	SDPS/nA
CN(5)	d4	1
CN (15)	d4	3.3
CN(25)	d2	2.4

The maximum peak of the SDPS plots arising from Signals CN(5), CN(15) and CN(25) locates at the crystals of d4, d4, and d2, respectively. This proves that the time width of the predominant transients of Signal CN(25) is shorter than that of Signals CN(5) and CN(15). From the fact that Signals CN(5) and CN(15) showed the same maximum crystals (i.e. d4), it can be concluded that an increase in the dissolved oxygen from 5 to 15 ppm can not affect the time width of the ECN transients. However, with increasing the dissolved oxygen from 5 to 15 ppm the SDPS values increased (Table 5) as an evidence of more intense corrosion processes. On the other hand, the decrease of the time width (from d4 to d2) with increasing the dissolved oxygen from 15 to 25 ppm can be attributed to the decrease of corrosion activity on the surface of Al alloy.

The Bode plots arising from AA6162 in 0.4% NaCl +0.1% NaNO₂ solution with different oxygen concentrations are observed in Figure 8. Table 6 gives the values of the oxide film thickness. It is clear that the thickness of the oxide film decreased by increasing the dissolved oxygen from 5 to 15 ppm, while it remained constant by increasing the dissolved oxygen from 15 to 25 ppm.



Figure 8: The Bode plots for AA6162 in 0.4% NaCl + 0.1% NaNO₂ solutions containing 5, 15 and 25 ppm oxygen concentrations.

 Table 6: Parameters obtained from EIS measurements in 0.4% NaCl+0.1%NaNO2 solutions containing different oxygen concentrations.

	CN(5)	CN(15)	CN(25)
$C_{ox} (\mu F Cm^{-2})$	28	37	37
D _{ox} (nm)	0.53	0.41	0.41

When the concentration of oxygen increased from 5 to 15 ppm the result arising from the Bode plots (i.e. decreasing the thickness of the oxide layer) is in accordance with that obtained from **ECN** measurements (i.e. increasing corrosion activity). However, by increasing the dissolved oxygen from 15 to 25 ppm the result of the ECN is in agreement with that of the EIS measurements because the Bode plots revealed that the thickness of the oxide film remained unchanged while the SDPS plots proved the decrease of corrosion activity. To see the agreement of these results it should keep in mind that the passive film formed by nitrite ions cannot act as a barrier layer (Eq. 1) causing a significant increase in the thickness of the passive layer.

SEM images shown in Figure 9 are in agreement with the ECN data listed in Table 5. Figure 9 shows the

increase of corrosion severity on the surface of Al alloy with increasing the dissolved oxygen from 5 to 15 ppm and the decrease of the corrosion activity with increasing the dissolved oxygen from 15 to 25 ppm.

3.3. Concentrated NaCl solution

Figure 10 shows the ECN signals corresponding to asymmetrical electrodes made of AA6162 alloy in 3.5% NaCl solution containing different oxygen concentrations. Figure 11 presents the SDPS plots corresponding to the ECN signals shown in Figure 10. Table 7 outlines the timescales and the SDPS values of the predominant transients of ECN signals. According to Figure 11, the maximum in the SDPS plots of Signals C35(5), C35(15) and C35(25) locates at the crystals of d3, d4, and d6, respectively.



Figure 9: SEM images of AA6162 in 0.4% NaCl+ 0.1% NaNO₂ solutions containing (a) 5, (b) 15 and (c) 25 ppm oxygen concentrations.



Figure 10: ECN signals of asymmetrical electrodes made of AA6162 after 5 min soaking in 3.5% NaCl solutions containing 5, 15 and 25 ppm oxygen concentrations.



Figure 11: SDPS plots of ECN signals in Figure 7.

Table 7: The maximum time scales and the corresponding SDPS values of the predominant transients of ECN signals corresponding to asymmetrical electrodes of AA6162 in a 3.5% NaCl solution containing different oxygen concentrations.

Signal	d _{max}	SDPS/nA
C35(5)	d3	14
C35 (15)	d4	25
C35(25)	d6	18.4

An increase in both the time width and the SDPS values of the ECN transients with increasing the dissolved of oxygen from 5 to 25 ppm is due to the increasing of the corrosion severity.

The Bode plots for AA6162 sample in 3.5% NaCl solution containing different oxygen concentrations are shown in Figure 12. The values of the oxide film thickness were calculated from Bode plots presented in Table 8. The results reveal that by increasing the dissolved oxygen from 5 to 25 ppm the thickness of the

oxide film decreased. Therefore, in the concentrated NaCl solutions the thickness of oxide film decreases with increasing the dissolved oxygen from 5 (i.e. naturally aerated solution) to 25 ppm (i.e. saturated with O_2) and then the corrosion severity increases as the predominant effect. The SEM images shown in Figure 13 support the findings. According to Figure 13 the increase of the dissolved oxygen from 5 to 25 ppm causes the increase of corrosion severity.

 Table 8: Parameters obtained from EIS measurements in 3.5% NaCl solutions containing different oxygen concentrations.

	C35(5)	C35(15)	C35(25)
C_{ox} (µF Cm ⁻²)	44	47	53
D _{ox} (nm)	0.34	0.32	0.28



Figure 12: The Bode plots for AA6162 in 3.5% NaCl solutions containing 5, 15 and 25 ppm oxygen concentrations.



Figure 13: SEM images of AA6162 in 3.5% NaCl solutions containing (a) 5, (b) 15 and (c) 25 ppm oxygen concentrations.

4. Conclusions

The ECN and EIS tests were performed on AA6162 Al alloy in each of 0.4% NaCl, 0.4% NaCl + 0.1% NaNO₂ and 3.5% NaCl solutions containing different dissolved O₂ concentrations (5-25 ppm) to obtain an understanding of the active and passive roles of the oxygen reduction reaction on the corrosion of Al alloy. The electrochemical noise employs the asymmetrical electrodes with different sizes (2-200 mm²). In the dilute NaCl solution, the dissolved oxygen played an

active role in the corrosion of alloy at moderate concentrations while it acted as a passive factor to decrease the corrosion activity at high oxygen concentrations. In the concentrated NaCl solution the corrosion activity of the Al alloy increases with increasing the oxygen concentration due to thickening of the oxide layer. Investigation of the nitritecontaining NaCl solution proved the property of nitrite ion causing the formation of the passive film according to the adsorption theory.

5. References

 K. I. Aly. M. G. Mohamed. O. Younis. M. H. Mahross. M. Abdel-Hakim, M. M. Sayed, Salicylaldehyde azinefunctionalized polybenzoxazine: synthesis, characterization, and its nanocomposites as coatings for inhibiting the mild steel corrosion, *Prog. Org. Coat.*, 138(2020), 105385.

2. P. C. Pistorius, Design Aspects of Electrochemical Noise Measurements for uncoated metals: electrode size and sampling rate, CORROSION, 53(1997), 273-283.

- M. Leban. A. Legat, V. Dolecek, Electrochemical noise during non-stationary corrosion processes, *Mater. Corros.*, 52(2001), 418-425.
- R. A. Cottis, Interpretation of electrochemical noise data, *Corrosion*, 57(2001), 265-285.
- S. Ritter. T. Dorsch, R. Kilian, Using thionates for noise Experiments –a reasonable combination?, *Mater. Corros.*, 55(2004), 781-786.
- X. F. Liu. H. G. Wang, H. C. Gu, Fractal characteristic analysis of electrochemical noise with wavelet transform, *Corros. Sci.*, 48(2006), 1337-1367.
- H. S. Klapper, J. Goellner, Electrochemical noise from oxygen reduction on stainless steel surfaces, *Corros. Sci.*, 51(2009), 144-150.
- 8. H. S. Klapper. J. Goellner, A. Heyn, The influence of the cathodic process on the interpretation of electrochemical noise signals arising from pitting corrosion of stainless steels, *Corros. Sci.*, 52(2010), 1362-1372.
- M. Shahidi. A. H. Jafari, S. M. A. Hosseini, Comparison of symmetrical and asymmetrical cells by statistical and wavelet analysis of electrochemical noise data, *Corrosion*, 68(2012), 1003-1014.
- 10. D.H. Xia. S. Song. Y. Behnamian. W. Hu. Y. F. Cheng. J.L. Luo, F. Huet, Review-Electrochemical Noise Applied in Corrosion Science: Theoretical and mathematical models towards quantitative analysis, *J. Electrochem. Soc.*, 167(2020), 081507.
- H. Arabzadeh. M. Shahidi Zandi, M. M. Foroughi, Interpretation of electrochemical noise signals arising from symmetrical and asymmetrical electrodes made of polypyrrole coated mild steel, *Prog. Color Colorants Coat.*, 12(2019), 25-32.
- 12. B. Ramezanzadeh. M. Mehdipour, S. Y. Arman, Application of electrochemical noise to investigate corrosion inhibition properties of some azole compounds on aluminum in 0.25 M HCl, *Prog. Color Colorants Coat.*, 8(2015), 69-86.
- K. Darowicki, A. Zielinski, Joint time-frequency analysis of electrochemical noise, *J. Electroanal. Chem.*, 504(2001), 201-207.
- A. Aballe. M. Bethencourt. F. J. Botana, M. Marcos, Using wavelets transform in the analysis of electrochemical noise data, *Electrochim. Acta*, 44(1999), 4805-4816.
- A. Aballe. M. Bethencourt. F. J. Botana, M. Marcos, Wavelet transform-based analysis for electrochemical noise, *Electrochem. Commun.*, 1(1999), 266-270.
- 16. X. F. Liu. H. G. Wang. S. J. Huang, H. C. Gu, Analysis of elctrochemical noise with wavelet

transform, CORROSION, 57(2001), 843-852.

- 17. M. Attarchi. M. S. Roshan. S. Norouzi. S. K. Sadrnezhaad, A. Jafari, Electrochemical potential noise analysis of Cu–BTA system using wavelet transformation, *J. Electroanal. Chem.*, 633(2009), 240-245.
- M. T. Smith, D. D. Macdonald, Wavelet analysis of electrochemical noise data, *Corrosion*, 65(2009), 438-448.
- M. Shahidi. S. M. A. Hosseini, A. H. Jafari, Comparison between ED and SDPS plots as the results of wavelet transform for analyzing electrochemical noise data, *Electrochim. Acta*, 56(2011), 9986-9997.
- 20. D. H. Xia. S. Z. Song, Y. Behnamian, Detection of corrosion degradation using electrochemical noise (EN): review of signal processing methods for identifying corrosion forms, *Corros. Eng. Sci. Techn.*, 51(2016), 527-544.
- 21. D.-H. Xia, Y. Behnamian, Electrochemical noise: a review of experimental setup, instrumentation and DC removal, *Russ. J. Electrochem.*, 51(2015), 593-601.
- Z. Szklarska-Smialowska, Pitting corrosion of aluminum, *Corros. Sci.*, 41(1999), 1743-1767.
- 23. W. Kuang. X. Wu, E.H. Han, Influence of dissolved oxygen concentration on the oxide film formed on Alloy 690 in high temperature water, *Corros. Sci.*, 69(2013), 197-204.
- 24. M. Shahidi. R. F. Moghaddam. M. R. Gholamhosseinzadeh, S. M. A. Hosseini, Investigation of the cathodic process influence on the electrochemical noise signals arising from pitting corrosion of Al alloys using wavelet analysis, *J. Electroanal. Chem.*, 693(2013), 114-121.
- H. Ezuber. A. El-Houd, F. El-Shawesh, A study on the corrosion behavior of aluminum alloys in seawater, *Mater. Design*, 29(2008), 801-805.
- 26. F. Ozturk. A. Sisman. S. Toros. S. Kilic, R. C. Picu, Influence of aging treatment on mechanical properties of 6061 aluminum alloy, *Mater. Des.*, 31(2010), 972-975.
- R. W. Revie, H. H. Uhlig, Corrosion and corrosion control: an introduction to corrosion science and engineering, John Wiley & Sons, New Jersey, 2008.
- 28. K. I. Aly. O. Younis. M. H. Mahross. E. A. Orabi. M. Abdel-Hakim. O. Tsutsumi. M. G. Mohamed, M. M. Sayed, Conducting copolymers nanocomposite coatings with aggregation-controlled luminescence and efficient corrosion inhibition properties, *Prog. Org. Coat.*, 135(2019), 525-535.
- 29. J. Hitzig. K. Juttner. W. J. Lorenz, W. Paatsch, AC-Impedance measurements on porous aluminium oxide films, *Corros. Sci.*, 24(1984), 945-952.

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