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Application of Aloe Vera as Green Corrosion Inhibitor for Aluminum Alloy Types AA8011 and AA8006 in 3.5% NaCl

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Abstract: This paper presents testing data on application possibilities of Aloe Vera as green corrosion inhibitor for aluminum alloy types AA8011 and AA8006 in 3.5% NaCl. Electrochemical DC linear polarization method has been used in the first phase of testing process, with the goal of determining the optimal concentration of Aloe Vera as inhibitor of mentioned alloys in 3.5% NaCl, by polarization resistance value. During first testing process, only one aluminum alloy type AA8011 was used. By adding the inhibitor in 3.5% NaCl, the polarization resistance increases, and the highest result was recorded in Aloe Vera concentration of 5 cm^3dm^{-3}. During second phase of testing, the inhibition effect of optimal Aloe Vera concentration was tested for aluminum alloy type AA8011 and AA8006 in 3.5% NaCl by curves of Taffel extrapolation method. The results of conducted tests show that Aloe Vera in concentration of 5 cm^3dm^{-3} can be used as green inhibitor for aluminum alloys type AA8011 and AA8006 of the Al-Fe-Si-Mn system, in 3.5% NaCl at room temperature (20 ± 2 ºC). All tested samples of aluminum alloy in 3.5% NaCl solution with the presence of inhibitor show significant shifting of Open Circuit Potential (E_{OCP}) towards positive values in respect with Open Circuit Potential (E_{OCP}) of treated aluminum alloy samples in 3.5% NaCl solution without inhibitor presence. Likewise, most of the samples treated in 3.5% NaCl solution with the presence of inhibitor lead to decrease of corrosion current density in relation to samples tested in 3.5% NaCl solution without inhibitor presence.

INTRODUCTION

The growing concern about the environment preservation has led to the setting of stricter provisions regarding the use of chemicals that can have a harmful impact on the environment, which led to a reduction of a number of effective corrosion inhibitors. Uses of non-toxic and natural products as corrosion inhibitors have become important because of the advantages of their environmentally friendly and biodegradable in nature, readily availability, renewable sources, and ecological aspects and can be synthesized by simple procedure with low cost (Gaber et al. 2008, Afidah et al. 2008). Environmentally friendly inhibitors are biodegradable substances which do not contain heavy metals or other toxic components (Amitha et al. 2012). Lately, research of plant extracts is an area of high interest when it comes to corrosion inhibitors. Aloe Vera is an important medicinal plant which belongs to the family of Liliacea (Rajendran et al. 2007). The leaf of Aloe Vera contains over 240 nutritional and medicinal ingredients. Chief among these are polysaccharides, glycoproteins, vitamins, mineral and enzymes (Ekpendu et al. 2004). Aloe Vera as commonly called is organic in nature and can be used in the production of green corrosion inhibitors. This paper tested application possibilities of Aloe Vera as green corrosion inhibitor for aluminum

alloys type AA8011 and AA8006 of the Al-Fe-Si-Mn system, in 3.5% NaCl. Aluminum alloys have proved to high quality metal material for many purposes, and by use, they are located immediately after the iron alloy, with continued growth in production and application (Delijić 2016, Birbilis 2011, Davis 1999). AA8000 series represents a special group of Al-alloys whose typical representatives are the AA8006 and AA8011. These alloys are suitable for the process of a continuous casting strips - cold rolling, could be deformed by rolling to form foil dimensions and successfully used in the packaging industry, microelectronics and heat exchangers (Zhong-wei et al. 2012). For their use in the packaging industry, eventual corrosion appearance at these alloys can be entirely controlled by use of green inhibitor that is non toxic to the human body.

EXPERIMENTAL

A commercial product of Aloe Vera with 66.3% of fresh Aloe Vera leaf juice was used as inhibitor in conducted testing. The testing of application possibilities of Aloe Vera as green corrosion inhibitor was conducted on aluminum alloys type AA8011 and AA8006 of the Al-Fe-Si-Mn system, intended for deformation shaping. Continuously casted strips of examined alloys, thickness 7 mm, are produced in industrial conditions on device "3C" at a speed of 1 m/min, and a casting temperature of 690° C. One part of continuously casted sample strips was annealed homogenously in the laboratory at a temperature of 580 ° C with the effective annealing time of 6 hours in an electric laboratory furnace with internal air circulation. Homogenized and non-homogenized samples of continuously casted alloys are deformed by cold rolling on a laboratory rolling stand, in same deformation conditions, for production of thin strips of 0.5 mm thickness, representing the material for production of thin strips and foils by subsequent cold rolling. Chemical composition of tested alloys are shown in Table 1.

Table 1. Chemical composition of test alloys, by weight % (the rest is Al)

Alloy tags	**Fe**	**Si**	**Mn**	**Mg**	**Cu**	**Zn**
AA8011	0.74	0.52	0.077	0.001	0.062	0.051
AA8011*	0.66	0.58	0.37	0.003	0.002	0.034
AA8006	1.34	0.14	0.43	0.012	0.002	0.035

Table 2 shows the used aluminum alloy sample tags depending on the manner of processing.

Table 2. Used aluminum alloy sample tags

Alloy tags	Sample tags	
	Initial state: continuously casted strips Deformed state	Initial state: homogenized continuously casted strips Deformed state
AA8006	1DX	1CX
AA8011*	2DX	2CX
AA8011	4DX	4CX

Investigations were conducted in the corrosion cell according to ASTM G5, on instrument potentiostat/galvanostat PAR 263A-2, with the software PowerCORR®. Basic solution used for testing was 3.5% NaCl, and the testing was conducted at a room temperature (20 ± 2 °C). Electrochemical DC linear polarization method has been used in the first phase of testing process. Linear polarization method implies scanning of working electrode potential on the order of ± 20 mV material polarization in relation to its Open Circuit Potential (E_{OCP}), at the speed of 0.2 mVs^{-1}. Final result of the above method is polarization resistance (Rp). By polarization resistance, our goal was to determine the optimal concentration of Aloe Vera as inhibitor of mentioned aluminum alloys in 3.5% NaCl. Aluminum alloy type AA8011, tag 4DX, was used for testing purposes. During second phase of testing, the inhibition effect of optimal Aloe Vera concentration was tested for aluminum alloy type AA8011 and AA8006 in 3.5% NaCl by curves of Taffel extrapolation method. Taffel extrapolation method implies scanning of working electrode potential on the order of ± 250 mV in relation to its Open Circuit Potential (E_{OCP}), at the speed of 0.2 mVs^{-1}.

RESULTS AND DISCUSSION

Table 3 show polarization resistance (Rp) testing results depending on inhibitor Aloe Vera concentration in 3.5% NaCl.

Table 3. Results of polarization resistance of aluminum alloy tag 4DX depending on inhibitor Aloe Vera concentration in 3.5% NaCl

Concentration of the inhibitor (cm^3dm^{-3})	Rp (Ω)
0	2208.704
1	13 679.302
2.5	14 394.375
3.5	12 077.83
4.5	29 895.970
5	**75 371.998**
6	18 053.171
6.5	14 203.357

Table 3 results show that optimal concentration of used Aloe Vera inhibitor is 5 cm^3dm^{-3}. At that inhibitor concentration, the polarization resistance amounts to 75 371.998 Ω. Solution without inhibitor shows smaller polarization resistance and amounts to 2208.704 Ω. Table 4 and Figures 1-6 show Open Circuit Potential (E_{OCP}) value and corrosion current density ($i_{cor.}$) of aluminum alloy samples type AA8011 and AA8006 treated in 3.5% NaCl solution with and without inhibitor presence. The inhibitor was added in the determined optimum concentration of 5 cm^3dm^{-3}.

Table 4. Values of Open Circuit Potential (E_{OCP}) and corrosion current density ($i_{cor.}$) of aluminum alloy samples treated in 3.5% NaCl solution with inhibitor (5 cm^3dm^{-3} of Aloa Vera) and without inhibitor presence

Alloy tags	Sample tags	E_{ocp}(mV)	Corrosion current density, $i_{cor.}$ (μAcm^{-2})
AA8006	1DX	-899.525	$4.393 \cdot 10^1$
	$1DX_{(with\ inh.)}$	-720.418	7.82
AA8011*	1CX	-1010.039	$1.746 \cdot 10^1$
	$1CX_{(with\ inh.)}$	-742.966	3.912
	2DX	-945.102	3.239
	$2DX_{(with\ inh.)}$	-724.389	8.47
	2CX	-756.438	6.028
	$2CX_{(with\ inh.)}$	-755.792	$4.081 \cdot 10^1$
AA8011	4DX	-791.438	5.625
	$4DX_{(with\ inh.)}$	-738.508	2.616
	4CX	-1004.118	7.993
	4CX (with inh.)	-746.762	2.605

Table 4 results show that all tested aluminum alloy samples treated in 3.5% NaCl solution with the presence of inhibitor significantly shift Open Circuit Potential (E_{OCP}) towards positive values in respect with Open Circuit Potential (E_{OCP}) of treated aluminum alloy samples in 3.5% NaCl solution without inhibitor presence. The shifting of Open Circuit Potential (E_{OCP}) towards positive values demonstrates that Aloe Vera in concentration of 5 cm^3dm^{-3} can be used as green inhibitor for aluminum alloys type AA8011 and AA8006 of the Al-Fe-Si-Mn system, at room temperature.

Figures 1-6 show Taffel polarization curves of aluminum alloys type AA8011 and AA8006 treated in 3.5% NaCl solution with and without inhibitor presence. All Figures show that tested aluminum alloy samples treated in 5% NaCl solution with the presence of 5 cm^3dm^{-3} concentration of inhibitor significantly shift Open Circuit Potential (E_{OCP}) towards positive values in respect with Open Circuit Potential (E_{OCP}) of treated aluminum alloy samples in 3.5% NaCl solution without inhibitor presence.

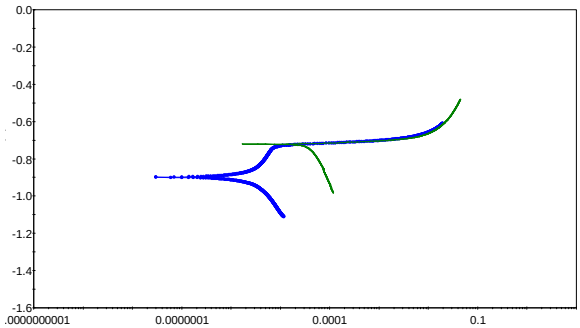

Figure 1. Taffel curves of Al-alloy sample tag 1DX
1 – sample treated in 3.5% NaCl solution with inhibitor presence (5 cm^3dm^{-3} of Aloa Vera)
2 – sample treated in 3.5% NaCl solution without inhibitor presence

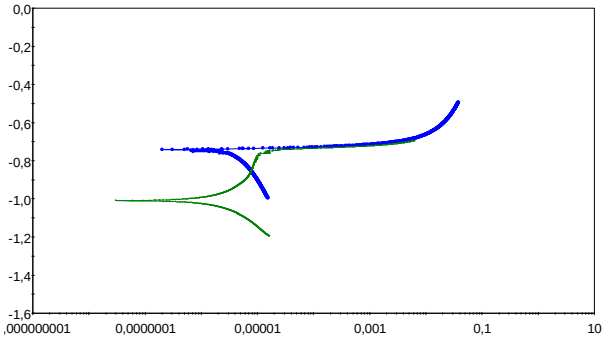

Figure 2. Taffel curves of Al-alloy sample tag 1CX
1 – sample treated in 3.5% NaCl solution with inhibitor presence (5 cm^3dm^{-3} of Aloa Vera)
2 – sample treated in 3.5% NaCl solution without inhibitor presence

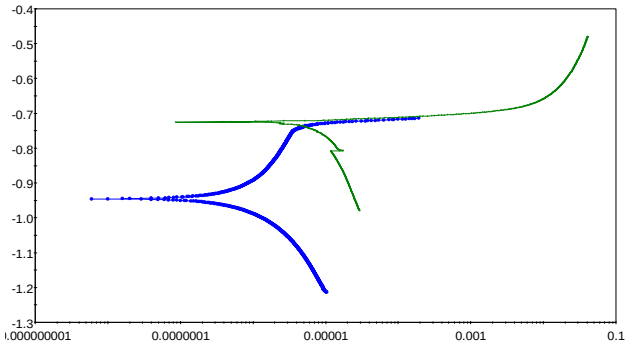

Figure 3. Taffel curves of Al-alloy sample tag 2DX
1 – sample treated in 3.5% NaCl solution with inhibitor presence (5 cm^3dm^{-3} of Aloa Vera)
2 – sample treated in 3.5% NaCl solution without inhibitor presence

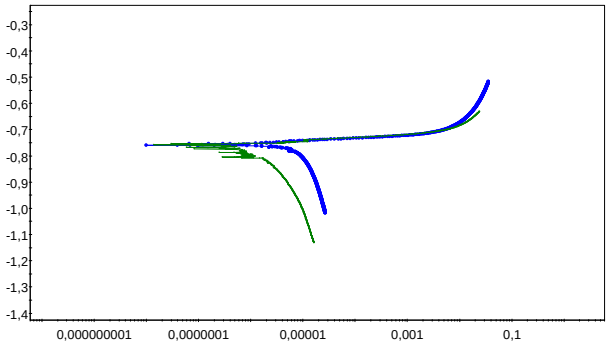

Figure 4. Taffel curves of Al-alloy sample tag 2CX
1 – sample treated in 3.5% NaCl solution with inhibitor presence (5 cm^3dm^{-3} of Aloa Vera)
2 – sample treated in 3.5% NaCl solution without inhibitor presence

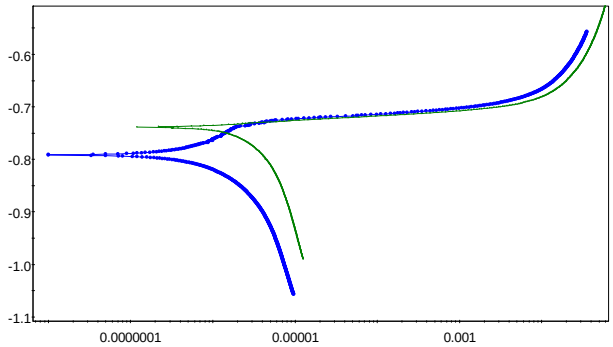

Figure 5. Taffel curves of Al-alloy sample tag 4DX
1 – sample treated in 3.5% NaCl solution with inhibitor presence (5 cm^3dm^{-3} of Aloa Vera)
2 – sample treated in 3.5% NaCl solution without inhibitor presence

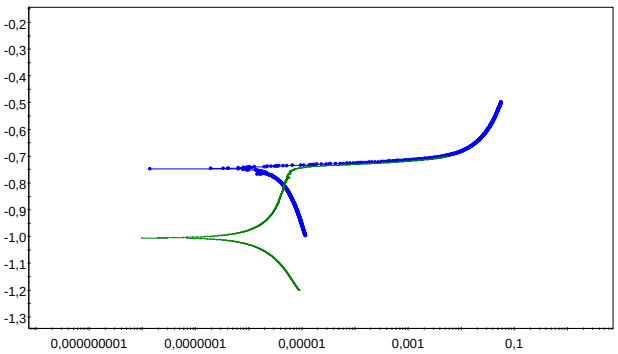

Figure 6. Taffel curves of Al-alloy sample tag 4CX
1 – sample treated in 3.5% NaCl solution with inhibitor presence (5 cm^3dm^{-3} of Aloa Vera)
2 – sample treated in 3.5% NaCl solution without inhibitor presence

Likewise, most of the samples treated in 3.5% NaCl solution with the presence of inhibitor lead to decrease of corrosion current density in relation to samples treated in 3.5% NaCl solution without inhibitor presence, with the exception of aluminum alloy sample type AA8011* (table 4).

CONCLUSIONS

Aloe Vera can be used as green corrosion inhibitor for aluminum alloy types AA8011 and AA8006 of the Al-Fe-Si-Mn system, in 3.5% NaCl, at room temperature (20 ± 2 ºC), confirmed by following test results:

- The polarization resistance (Rp) of aluminum alloy sample type AA8011 tag 4DX, table 3, is the smallest for sample treated in 3.5% NaCl solution. By increasing the inhibitor, the polarization resistance increases. The highest polarization resistance was obtained for the solution of 3.5% NaCl with the addition an inhibitor of Aloe Vera in a concentration of 5 cm^3dm^{-3}. The stated concentration is optimal for the stated inhibitor.
- All tested aluminum alloy samples type AA8011 and AA8006 treated in 3.5% NaCl solution with inhibitor presence (table 4) significantly shift Open Circuit Potential (E_{OCP}) towards positive values in respect with Open Circuit Potential (E_{OCP}) of treated aluminum alloy samples in 3.5% NaCl solution without inhibitor presence.
- Most of the samples treated in 3.5% NaCl solution with the presence of inhibitor lead to decrease of corrosion current density in relation to samples treated in 3.5% NaCl solution without inhibitor presence, with the exception of aluminum alloy sample type AA8011* (table 4).

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Summary/Sažetak

U ovom radu su prikazani rezultati ispitivanja mogućnosti primjene Aloe Vera kao zelenog inhibitora legura aluminija tipa AA8011 i AA8006 u 3.5% NaCl. U prvoj fazi ispitivanja korištena je elektrohemijska DC metoda linearne polarizacije, gdje se preko vrijednosti polarizacijskog otpora željelo vidjeti koja je to optimalna koncentracija Aloe Vera kao inhibitora navedenih legura aluminija u 3.5% NaCl. Pri tome je korištena samo jedna legura aluminija tipa AA8011. S dodatkom inhibitora u 3.5% NaCl dolazilo je do povećanja polarizacijskog otpora, a najveći polarizacijski otpor je zabilježen kod dodatka Aloe Vera u koncentraciji 5 cm^3dm^{-3}. U drugoj fazi ispitivanja, metodom ekstrapolacije Tafelovih krivih ispitivan je efekat inhibicije utvrđene optimalne koncentracije inhibitora Aloe Vera na legure aluminija tipa AA8011 i AA8006 u 3.5% NaCl. Rezultati provedenih ispitivanja pokazuju kako se Aloe Vera u koncentraciji 5 cm^3dm^{-3} može koristiti kao zeleni inhibitor legura aluminija tipa AA8011 i AA8006 iz sistema Al-Fe-Si-Mn, u 3.5% NaCl na sobnoj temperaturi (20 ± 2 ºC). Kod svih ispitivanih uzoraka legura aluminija tretiranih u otopinama 3.5% NaCl s prisustvom inhibitora došlo je do značajnog pomijeranja potencijala otvorenog kruga (E_{OCP}) u pozitivnije vrijednosti u odnosu na E_{OCP} uzoraka tretiranih u otopinama 3.5% NaCl bez prisustva inhibitora. Također, kod većine uzoraka tretiranih u otopinama 3.5% NaCl s prisustvom inhibitora došlo je do smanjenja gustine struje korozije u odnosu na uzorke tretirane u otopinama 3.5% NaCl bez prisustva inhibitora.