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Effect of Inhibition by Honey on Corrosion Behavior of Composite Materials from Al-4% Si Alloy Reinforced with Y_2O_3 Particles

Abstract- *this work focuses on the preparation specimens of metal matrix composite materials exemplified alloy (Al-4%Si) reinforced by yttria particles Y_2O_3 with different weight percentage (1,2and 3). Effect of yttria particles on polarization behavior of (Al-4% Si alloy) in sulfuric acid (0.5 M) was studied by using potentiostat in the presence and the absence of natural honey with different concentration (1and 2gm/L) as inhibitor. The results show that the values of tafel slops and corrosion rate (Rmpy) of composite materials reinforcing with particles of yttria with three percentage decreases with increasing the concentration of honey, and the efficiency of inhibition (El%) of composite materials in the acidic solution was more than that of base alloy after adding 2gm/L of inhibitor corrosive medium are (64.79%, 77.49% and 88.79%) respectively.*

Keywords- *natural honey, yattria particles (Y_2O_3), efficiency of inhibition (El%) .*

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1. Introduction

Aluminum alloys and metal matrix composites (MMCs) exhibit attractive tribological and mechanical properties at a wide range of temperatures improved thermal stability, high wear or corrosion resistance, high specific modulus, good strength and long fatigue life, which allow these alloys to have numerous applications in the aerospace, automobile and military industries especially for cylinder blocks, cylinder heads, pistons, and valve lifters [1].

Many researches have been focused on the corrosion problem in corrosive solutions of aluminum matrix composite reinforced with common ceramic particles such as SiC،Y_2O_3 and Al_2O_3[2].Using the corrosion inhibitors are considering one of the most effective methods for the protection of metallic surfaces against corrosion.

Various works in the last years focused on the investigation of the anticorrosive characterizations of natural materials on aluminum, steel, tin and different alloys in various aggressive media [3,4]. Considered using the natural inhibitors to reduce the corrosion are interesting because of their safe use and excellent solubility in water [5].

Many researchers have found that a honey is good corrosion inhibitor for most of the metal in acidic and alkaline media solutions. The chemical composition of honey, it shows that natural honey should be good corrosion resistant for aluminum alloy refer to their organic compound containing in the polar group [6]. Honey containing many of nutritiously important elements: saccharides, organic and amino acids, polyphenols, colors, and some valuable but unstable compounds such as enzymes, substances of hormonal character, and some vitamins [7]. In this study the electrochemical measurements were done in natural inhibitor on corrosion of aluminum alloys in (0.5 M H_2SO_4) solution compared with alloys reinforced by (1,2 and 3%) Y_2O_3 particles in absence and with the natural honey as inhibitor with two different concentrations (1and 2gm/L).

2. Experimental

I. Composite preparation

(Al-4% Si) alloy with good properties, high strength-to-weight ratio owing to low density and low coefficient of thermal expansion is used as the matrix [6].Chemical composition of the alloy was carried out in the ministry of science and technology using the atomic absorption as show in the Table 1.

The reinforcement by yttra oxide (Y_2O_3) particles provided by BDH laboratory (99.0% pure-45-75μm particle size), in three different weight percentage (1, 2 and 3) to the fused alloys in the same previous method with the continuous stirring. Melting the sample of the matrix from alloy at 670 °C in a furnace type carbolite, after that, the melt was stirred inside the furnace at 250 rpm speed and 4 min times to make a vortex to disperse the modifier in the melt. The controlled of melt temperature before pouring into a carbon steel die by using thermocouple.

Then the crucible is returned to the furnace and after the casting is completed, the process is repeated three times to ensure the homogeneity of the alloying elements completely, after each time of mixing the crucible is returned back to the furnace to ensure that the fluidity of the melt is maintained, after that the crucible content is poured in a steel cylindrical shaped containers with a diameter of (20mm) and height of (150mm) to get the samples at the given dimensions.

Table 1: show chemical composition of Al-4%Si alloy

Name	Wt%. element	Standard chemical composition
Si	4.083	4.5 -5.5
Cu	1.2	1.5
Fe	0.65	0.85
Zn	0.9	1.2
Mg	0.45	0.6
Mn	0.83	0.75
Ti	0.27	0.25
Al	Rem.	Rem.

II. Electrochemical Measurement

Corrosion experiments were carried out in (0.5 M H_2SO_4) solution with presence of honey and absence it. All solutions were prepared from distilled water and all experiments were carried out at room temperature (25°C). The Al-4% Si alloy was used as working electrodes with rod shape, then the specimens backing by hot mounting type using with epoxy resin at 140ºC for 10 min to collected all but one side (with surface area 1cm2) to electrical connection.

All specimens were polished, degreased with methanol and washed with distilled water. The microstructure estimate was achieved by using optical microscope type (BEL photonics) connected to computer.

Polarization experiments were carried out by using WINKING MLab 200 Potentiostat from Bank-Elektronik with electrochemical standard cell. Electrochemical measurements with a potentiostat were measured by SCI electrochemical software at a scan rate (0.5 mV.sec-1). The experiments of polarization were started when the rate (Eocp) changed was less and more200mV.

The rate of corrosion (penetration rate) is calculated from the corrosion current by the following equation [8]:

$$R\ (mpy)\ = 0.13\ *\ i(corr)\,\frac{\rho}{e} \qquad (1)$$

Where:

R (mpy) : - corrosion rate (mil per year or mm per year)

i(corr) - corrosion current density (microamp/cm^2 or amp/cm^2)

ρ = density of alloy (gram/cm^3)

e = equivalent weight of alloy (gram/equivalent)

And the Efficiency of Inhibitor [8].

$$EI\% = [\,1\ -\ (\mathrm{i\,(inh.)}\ /\ \mathrm{i(corr.)}]*100 \qquad (2)$$

Where:

EI% :- Efficiency of Inhibitor

i(corr.) :- Current density

i(inh.) :- Current density with adding of inhibitor.

3. Result and Discussion

I. Polarization Behavior

The corrosion behavior of the aluminum -4% silicon alloys in 0.5 M H_2SO_4 solution after and before adding of different concentrations from honey is illustrates in Figure 1. electrochemical corrosion parameters such as corrosion potential (Ecorr), corrosion current density (Icorr), (βa) and (βc) Tafel constants and resistance of polarisation (Rp), are illustrates in Table 2. These curves consist of two main regions were cathodic and anodic Tafel regions. At cathodic region, below section, reduction reactions involves reduction of hydrogen ions in addition to reduction of oxygen, while at anodic region, upper section; dissolution of alloy can occurs which involves oxidation the aluminum and silicon metals to metal ions and produce electrons.

Addition increasing amounts of honey to 0.5 M H_2SO_4 solution effecting on the values of corrosion parameters, where its decreases obviously after natural inhibitors are added in all test solution at all concentrations. Note the adding of these inhibitors lead to clearly decrease in the rate of impetration or corrosion. The addition of honey shifts the Ecorr towards more noble values and decreasing the (icorr); The corrosion rate values were deceased after adding honey for Al-4%Si alloy before and after reinforced with yttra particles due to reduces the anodic dissolution of aluminum, corresponding to a noticeable decrease in the current densities of the passivation plateau, and also retards the cathodic reactions that occurs on the aluminum surface. These result shows that honey is able to inhibit corrosion process mainly retarding the oxygen evolution reaction and increasing the charge transfer resistance of the anodic dissolution of aluminum. Best addition of honey when (2gm/L) was used. All the additions of honey concentrations decreased the anodic and cathodic current of corrosion; this means that the additive of honey affected on corrosion processes and illustrates that molecular of inhibitor acts as a mixed-type. The values of (icorr) decreased with increasing honey concentration, but Ecorr values changed in values to anodic. This transformation in Ecorr is means to happen a growth in a passive layer on the specimen surface. The molecules of the honey contain oxygen atoms within functional groups (oxygen–hydrogen, carbon with oxygen and hydrogen), which meet the general consideration of typical corrosion inhibitors.

These compounds was adsorbs on surface of the aluminum lead to reduces the surface area that is available for the attack of the aggressive ion from the corrosion solution [9,10].

The inhibition efficiencies (IE %) were calculated from (icorr) data in the Tafel plots by using (2) equation for all specimens in 0.5 M H_2SO_4 solutions containing 1and 2gm/L of honey is illustrates in Table 2. The inhibition efficiency of honey increases with increasing of its concentration as shows in the figure.2. The effect of molecular inhibiting can be illustrates depending on the basis of the competitive adsorption between these molecules and the aggressive ions on the surface ,The results show that the values of tafel slops and corrosion rate (Rmpy) of composite materials reinforcing with particles of yttria with three percentage decreases with increasing the concentration of honey, and the efficiency of inhibition (El%) of composite materials in the acidic solution was more than that of base alloy after adding 2gm/L of inhibitor corrosive medium are (64.79%,77.49% and 88.79%) respectively.

The molecular of inhibition may be embedded into the passive layer on surface of alloy, forming a more improved stability against the aggressive ions type and addition to ability of the organic molecules from honey to absorb on electrode and to form a passive (protective) layer on the specimen surface [11]. Maximum value of inhibition efficiencies (IE %) was 88.79% at 2gm/L of honey concentration.

Figure (3) shows the microstructure of as received alloy and metal matrix composite of Al-Si alloy reinforced by Y_2O_3 particles before and after corrosion test with different concentrations of honey. The microstructure consist of solid solution as a uniform distribution of solids and homogeneous with fine sizes of grains, since most of the silicon is present in the solid solution which increase the corrosion resistance of aluminium, and this can be lead to the consist nature of passive film covering surface. While the microstructure of composites material show the distribution of reinforced ceramic particles in based metal material and precipitate it at grain boundaries and within grains which increase the resistance of corrosion in corrosive medium[12].

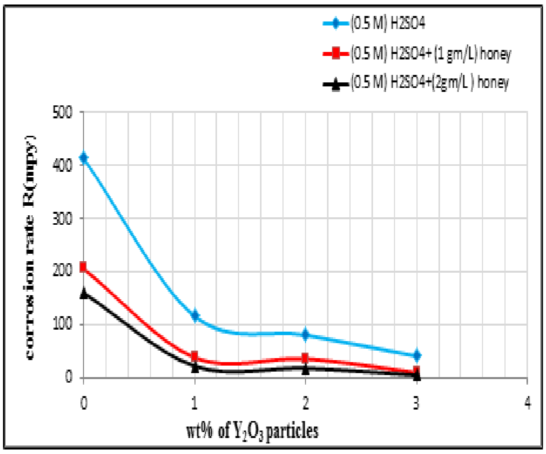

Figure1. Variation of corrosion rate for Al-4%Si alloy compared with alloys reinforced by (1,2 and 3%)Y_2O_3 particles in (0.5 M) H_2SO_4 solution with different concentrations of honey.

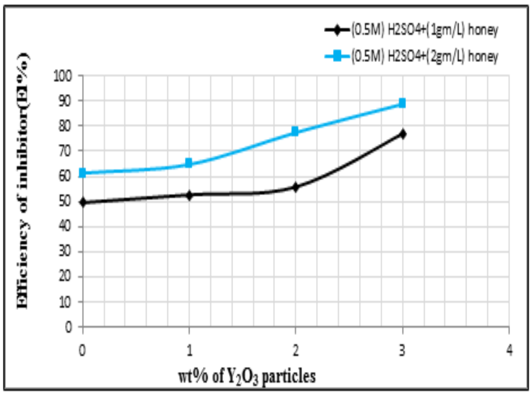

Figure2. IE (%) of natural inhibitors (honey) at various concentrations for Al-4%Si alloy compared with alloys reinforced by Y_2O_3 particles in (0.5 M) H_2SO_4 solution with different concentrations of honey.

Table 2: Effect of varying concentrations of honey on the corrosion behavior of Al-4%Si alloy compared with alloys reinforced by (1, 2 and 3%) Y_2O_3 in (0.5 M) H_2SO_4 solution with different concentrations of honey evaluated by polarization and EI% studies

No.	Type of alloy	Type Solution	Con. inhibitor	-Ecorr	Icorr ($\mu A.cm^{-2}$)	R(mpy)	-bc	-ba	EI%
1	As. received	0.5M H_2SO_4	0	660.7	414.05	15.98	78.0	169.7	0
		0.5M H_2SO_4 +honey	1	593.9	205.47	7.772	111.2	68.6	49.624
			2	577.0	160.03	6.178	62.5	65.9	61.350
2	Al-4%Si+1%Y_2O_3	0.5M H_2SO_4	0	544.1	116.40	4.494	77.3	97.7	0
		0.5M H_2SO_4 +honey	1	470.9	38.02	1.467	55.0	112.4	52.71
			2	463.2	21.93	0.846	110.5	116.9	64.79
3	Al-4%Si+2%Y_2O_3	0.5M H_2SO_4	0	600.5	80.40	4.104	75.6	189.2	0
		0.5M H_2SO_4 +honey	1	563.8	35.49	1.368	72.9	122.3	55.86
			2	519.6	17.73	0.684	88.4	190.2	77.49
4	Al-4%Si+3%Y_2O_3	0.5M H_2SO_4	0	472.8	40.98	1.582	56.0	59.9	0
		0.5M H_2SO_4 +honey	1	454.2	9.43	0.364	99.4	133.4	76.99
			2	437.9	4.56	0.176	96.7	131.1	88.79

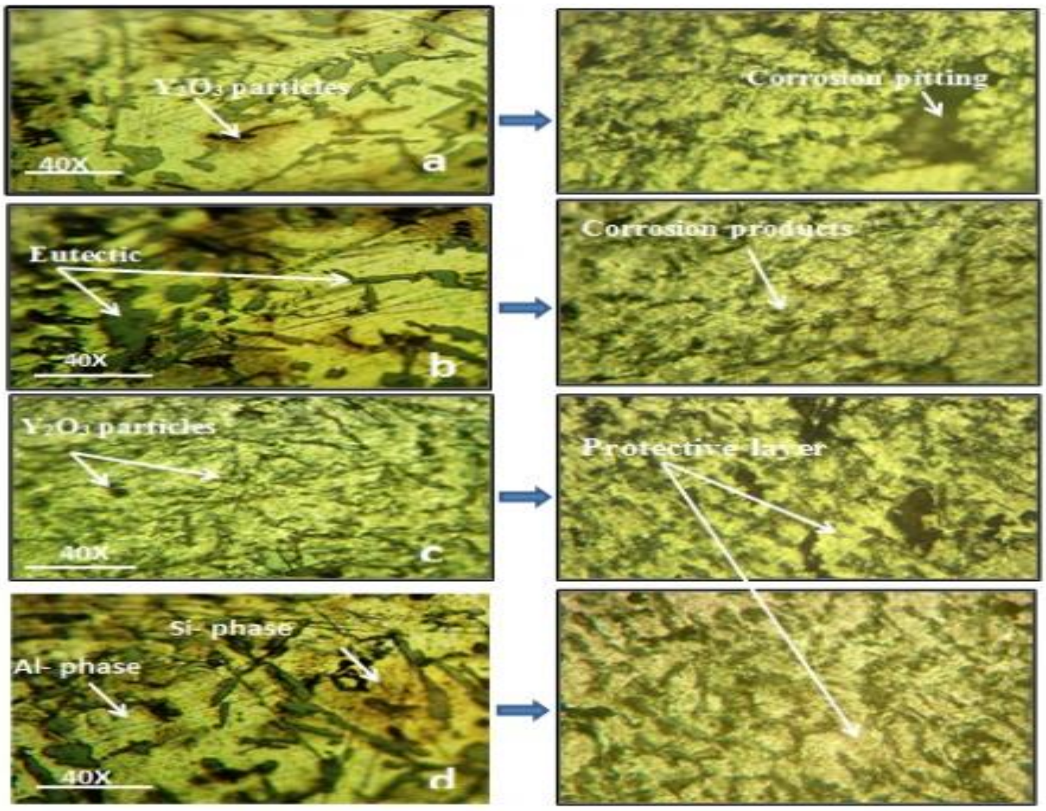

Figure 3: Microstructure of Al-4%Si alloy reinforced by Y_2O_3 particles with three weight percent in 0.5 M H_2SO_4 solution in the absence and presence of different concentrations of honey. (a): as received Al -4%Si alloy before and after corrosion. (b): Al-4%Si alloy reinforced by 1% Y_2O_3 particles in 0.5 M H_2SO_4 solution with 2gm/L from honey. (c): Al-4%Si alloy reinforced by 2% Y_2O_3 particles in 0.5 M H_2SO_4 solution 2gm/L from honey. (d): Al-4%Si alloy reinforced by 3% Y_2O_3 particles in 0.5 M H_2SO_4 solution with 2gm/L from honey.

4- Conclusion

1- The corrosion resistance of Al -4% Si alloys is Improving in acidic medium can be achieved by adding Y_2O_3 particles to fabricate Al -4%Si composites due to protective layer, which covered the surface (decreases corrosion rate).

2- Natural honey in acidic medium acts as corrosion inhibitor for Al -4%Si alloy.

3- Inhibition efficiency of honey increase with increasing its concentrations for Al-4%Si alloy reinforced by Y_2O_3 particles in acidic solution.

References

[1] W. Xu, X. Wu, T. Honma,; S.P. Ringer, K. Xia, “Nanostructured Al–Al_2O_3 composite formed in situ during consolidation of ultrafine Al particles by back pressure equal channel angular pressing,” Acta Mater., 57, 4321–4330, 2009.

Ph.D.2017,

[2] H. Ahamed, V. Senthilkumar, “Consolidation behavior of mechanically alloyed aluminum based nanocomposites reinforced with nanoscaled Y_2O_3/Al_2O,” Mater. Charact. 62, 1235–1249, 2011.

[3] I. Radojcic, K. Berkovic, S. Kovac, J. Vorkapic-Furac, “Natural honey and black radish juice as tin corrosion inhibitors”, Corrosion Science, 50, 1498-1504, 2008.

[4] R. Rosliza, W.B. Wan Nik, S. Izman, Y. Prawoto, “Anti-corrosive properties of natural honey on Al-Mg-Si alloy in seawater,” Current Applied Physics, 10,923-929, 2010.

[5] I. Radojcic, K. Berkovic, S. Kovac and J. Vorkapic-Furac “Natural honey and black radish juice as tin corrosion inhibitors”. Corrosion Science. 2008; 50:1498-1504,”

[6] A. El-Etre Y., “Natural Honey as Corrosion Inhibitor for Metals and Alloys. I. copper in neutral aqueous solution”. Corrosion Science, 40:1845-1850, 1988.

[7] E. Oguzie, “Corrosion Inhibition of Aluminium in Acidic and Alkaline Media by Sansevieria trifasciata Extract,” Corrosion Science, 49, 1527-1539, 2007

[8] N.G. Fontana, “Corrosion engineering,” 4th edition Mac Graw-Hill. pp. 287, 1994.

[9] W. Nik, M. Zulkifi, M.Ghazali and K. Khaled, “potential of honey as corrosion inhibitor for Aluminium alloy in seawater,” World applied sciences journal, 14, 2, 215-220, 2011.

[10] H. Gerengi, “Anticorrosive Properties of Date Palm (Phoenix dactylifera L.) Fruit Juice on 7075 Type Aluminum Alloy in 3.5% NaCl Solution,” Industrial & Engineering Chemistry Research, 51:12835-12843, 2012.

[11] R.A. Majed, M. Mahdi, H.A. Al-Kaisy and S.A. Abdul Maged,” Corrosion Behavior for Al-Cu-Mg Alloy by Addition of SiO2 Particles in Seawater,” Eng. & Tech. Journal , Vol. 32, Part (A), No.2, 354-364, 2014.

[12] J.T. Al-Haidary, M.M. Hanon and Y.M. Abdulsahib, “Effect of Sodium Chloride on Microstructure and Mechanical Properties of Al-Si alloy,” Eng. & Tech. Journal, Vol. 33, Part (A), No. 9, 2187-2197, 2015.

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