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Biochemistry

NATURAL INHIBITOR OF CORROSION OF ALUMINIUM ALLOY EN AW-2011 IN ACIDIC ENVIRONMENT

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Abstract. Lavender essential oil was used as a natural corrosion inhibitor for the aluminum alloy EN AW-2011 in 1M H_2SO_4 and 1M HCl. A gravimetric and electrochemical studies were carried out to determine the inhibitory effect of the of Lavender oil. The results from the gravimetric test show that the optimum of the inhibitory effect of the Lavender oil in 1M H_2SO_4 is 85.3%, while in 1M HCl it is only 47.8 %. As the concentration of Lavender oil increases, its inhibitory effect in both acids increases. Lavender essential oil is a better natural corrosion inhibitor for EN AW-2011 alloy in 1M H_2SO_4 than it is when the alloy is immersed in 1M HCl.

Keywords: corrosion inhibition, aluminum alloy, Lavender essential oil, electrochemical technique.

AIMS AND BACKGROUND

Aluminium alloy EN AW 2011 is among the most preferred in machine building and in the automotive industry due to the fact, that it is easy to process, has high mechanical strength and allows colouring in various colours. The high content of copper (up to 5%), used as an alloying element, is one of the reasons why this alloy exhibits lower corrosion resistance than the rest of the alloys in this series. Various methods of corrosion protection are sought for in order to reduce the destruction of metals under the action of different corrosive media. One of the methods to control, prevent or slow down the corrosion of metals and alloys is the use of corrosion inhibitors. Both inorganic and organic substances are used in this role. However, most of them have a proven harmful effect on the environment, because of which the idea of using natural/ecological (inorganic and organic) corrosion inhibitors has become increasingly popular in the recent years.

The use of organic ecological inhibitors began in the early 1930s of the last century, when an extract from the *Chelidonium majus* plant was first used as an inhibitor in a process of etching by sulphuric acid (H_2SO_4) (Ref. 1). After a series of successful experiments with plant extracts and oils, an increase in the interest in using environmentally friendly anti-corrosion compounds, extracted from various plant parts – seeds, fruits, leaves, flowers, and roots has been observed[2].

Plant extracts and oils are products of natural origin, they are biocompatible, inexpensive, biodegradable, and last but not least, non-toxic. Extracts and oils can be obtained from many parts of the plant and the literature review confirms their high efficiency in inhibiting corrosion in different corrosive media.

Essential oils, containing aldehydes (geranial, citronellal, etc.), ketones (pulegone, carvone, pinocarvone, etc.), alcohols (geraniol, citronellol, nerol, menthol, carveol etc.) esters (linalyl acetate, isobornyl acetate etc.), ethers (1,8-cineole, menthofuran etc.), hydrocarbon terpenes (isoprenes) and terpenoids (isoprenoids), have a great importance in their use as environmental anti-corrosion products[3].

In the role of natural corrosion inhibitors for aluminium alloys in an acid medium (HCl) plant materials from *Mentha pulegium*[4]; *Thymus algeriensis*[5]; *Aloe extract*[6]; *Jasminum nudiflorum*[7]; *Rosmarinus officinalis*[8] are used, and inhibitors, made of *Vigna unguiculata*[9]; *Chrysophyllum albidum*[10] are implemented in H_2SO_4.

The corrosion of the aluminum alloy EN AW-2024 and the inhibitory effect of the Lavender essential oil in 1M H_2SO_4 and 1M HCl are studied in the present paper by gravimetric and electrochemical measurements.

EXPERIMENTAL

Aluminum alloy EN AW-2011 (AlCuBiPb) with a composition (mass %) Cu 5.0–6.0; Fe 0.7; Pb 0.2–0.6; Bi 0.2–0.6; Si 0.4; Sn 0.2; Zn 0.3 and remainder of Al was used for conducting the measurements. The corrosion medium was prepared by water solutions of 1M H_2SO_4 and 1M HCl. 100% pure essential oil from *Lavandula angustifolia* (Rivana) was used as an inhibitor.

Gravimetric technique. Before carrying out the gravimetric test, the metal samples were polished by abrasive paper with different size of the grains. After that, they were immersed in ethanol solvent for 5 min, washed with distilled water and left to dry. After weighing on analytic scales (Acculab ATILON), they were immersed into the studied corrosive media – 1M H_2SO_4 and 1M HCl – both in the absence and in the presence of an inhibitor (от 0.01 до 0.05 g l^{-1}). 4 h later they were taken out of the solution, cleaned from the corrosion products, washed with distilled water, dried and weighed again. The corrosion rate (CR) of EN AW-2011 aluminum alloy was calculated using the following equation:

$$CR = (m_1 - m_2)/(S\,t), \qquad (1)$$

where m_1 is the weight of the sample, g; m_2 – the weight of the sample after the corrosion test, g; S – the area of the sample, m^2, and t – the test time, h.

Elecrtochemical technique. The electrochemical measurements were carried out by means of a Princeton Applied Research potentiostat/galvanostat (model 263A) at room temperature. The obtained data were processed by the Power Suite program. A three-electrode cell was made, composed of a working electrode of the studied aluminium alloy, an auxiliary electrode of a platinum conductor, and a reference electrode of Ag/AgCl, sat. KCl. The area of the working electrode was 1 cm^2 and the rest of its surface was covered with varnish. The open circuit potential and the magnitude of the corrosion current of the working electrode were written as a function of the time for 200 s.

RESULTS AND DISCUSSION

Gravimetric technique. The obtained data about the corrosion rate of the aluminum alloy EN AW-2011 and the inhibitory effect of Lavender oil on the corrosion of the studied alloy in 1M H_2SO_4 and 1M HCl are summarised in Tables 1 and 2.

The analysis of the obtained data showed that after being immersed for 4 hours in 1M H_2SO_4 the studied alloy corroded at a rate of (0.0041 g/m^2 h)), about two and a half times lower than in 1M HCl (0.0110 g/m^2 h).

It is observed that in the presence of an inhibitor, as the concentration of Lavender oil becomes higher, the corrosion rate decreases, while the inhibitory effect increases.

It is noteworthy that in 1M H_2SO_4 the inhibitory effect of Lavender oil at a concentration of 0.05 g l^{-1} is about twice as high (η = 85.3 %), compared to that, in 1M HCl (η = 47.8 %). This can be taken as a confirmation of the better inhibitory action of Lavender oil in 1M H_2SO_4.

Table 1. Corrosion rate of aluminium alloy EN AW-2011 and inhibitory effect of Lavender oil on the corrosion of the aluminium alloy after immersion in 1M H_2SO_4 for 4 h

Concentrations of *Lavandula angustifolia* (g l^{-1})	CR (g/m^2 h)	Surface coverage (θ)	Inhibition efficiencies (%)
Blank	0.0041	–	–
0.01	0.0017	0.585	58.5
0.03	0.0015	0.658	65.8
0.05	0.0006	0.853	85.3

Table 2. Corrosion rate of aluminium alloy EN AW-2011 and inhibitory effect of Lavender oil on the corrosion of the aluminium alloy after immersion in 1M HCl for 4 h

Concentrations of *Lavandula angustifolia* (g l^{-1})	CR (g/m^2 h)	Surface coverage (θ)	Inhibition efficiencies (%)
Blank	0.0110	–	–
0.01	0.0091	0.167	16.7
0.03	0.0073	0.332	33.2
0.05	0.0057	0.478	47.8

Lavender oil contains linalool, linalyl acetate, 1-,8-cineole and camphor, which are the likely reason for its good inhibitory effect[11]. These organic compounds contain active centres (aromatic rings, oxygen atom, double bonds etc.), by means of which Lavender oil is adsorbed on the surface of the studied alloy[12]. The layer of adsorbed inhibitor molecules, formed in result, isolates the alloy from the aggressive medium of 1M H_2SO_4 and reduces corrosion.

Elecrtochemical technique. The open circuit potential (OCP) of the aluminium alloy EN AW-2011 in 1M H_2SO_4 both in the absence and in the presence of Lavender oil, is shown in Fig. 1. When comparing the E_{OCP} values of the studied alloy, it is noticed that with increasing the concentration of the inhibitor from 0.01 to 0.05 g l^{-1}, the E_{OCP} values shift in a more positive direction (from –0.400 to –0.360 V, respectively), compared to the E_{OCP} values without an inhibitor. This deviation of the E_{OCP} is probably due to the inhibitory effect of the Lavender oil, and is related to the reduction of the destruction of the studied alloy. As the concentration of Lavender oil goes up to 0.05 g l^{-1}, an increase in its inhibitory effect on alloy corrosion is observed.

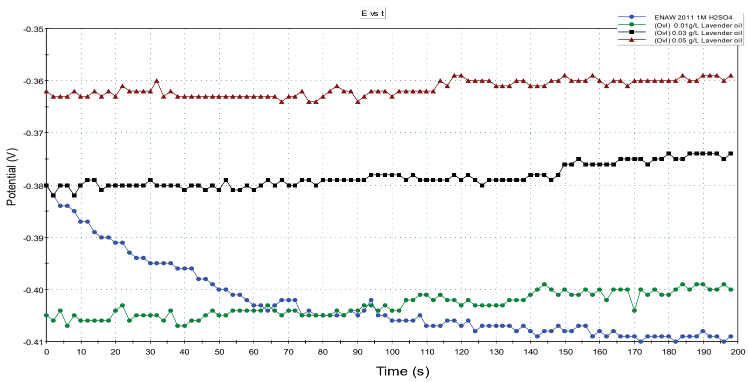

Fig. 1. Open circuit potential of aluminium alloy EN AW 2011 in 1 M H_2SO_4 in the absence and in the presence of Lavender oil

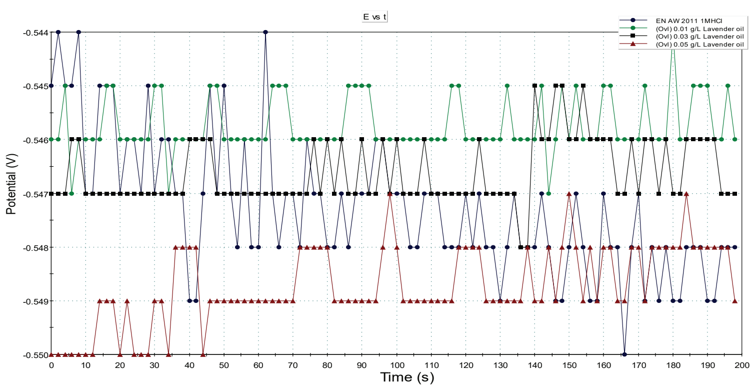

Fig. 2. Open circuit potential of aluminium alloy EN AW 2011 in1 M HCl in the absence and in the presence of Lavender oil

When comparing the open circuit potential values of the aluminum alloy EN AW-2011 in 1M HCl in the absence of an inhibitor (–0.548 V), and in the presence of an inhibitor, it is noticed that with increasing the Lavender oil concentration from 0.01 to 0.05 g l^{-1}, the E_{OCP} values remain almost unchanged (from –0.546 to –0.549 V, respectively) (Fig. 2).

For both of the used acids the observed considerable fluctuations in the magnitude of the EN AW 2011 current in the absence of an inhibitor are related to the destruction of the alloy in the indicated corrosion media. After adding an inhibitor these fluctuations decrease, which is probably due to the adsorption of the inhibitor on the surface of the aluminium alloy. It is observed that in the case of immersion of the EN AW 2011 alloy in 1 M H_2SO_4 in the absence of an inhibitor, the magnitude of the corrosion current is about twice as high as it is in the presence of an inhibitor, while for 1 M HCl this difference is smaller. The magnitude of the corrosion current is proportional to the corrosion rate and therefore a more significant decrease in the corrosion rate is observed in 1 M H_2SO_4 in the presence of Lavender oil than in 1 M HCl, i.e., the corrosion resistance of the studied alloy is higher in 1 M H_2SO_4, in the presence of the natural inhibitor.

CONCLUSIONS

On the basis of the results, obtained from the conducted gravimetric study, it can be concluded that Lavender oil demonstrates a better inhibitory effect on the corrosion of the aluminium alloy EN AW-2011 in sulphuric acid (85.3%) compared to that in hydrochloric acid (47.8%). The results, obtained in this study show that Lavender oil can be successfully used as a natural corrosion inhibitor of EN AW-2011 alloy in sulphuric acid, as it provides good protection from the studied corrosive medium. The good inhibitory effect of Lavender oil is probably due to the organic compounds linalool, linalyl acetate, 1–8-cineole and camphor, contained in it.

When Lavender oil is present in 1 M H_2SO_4, the magnitude of the corrosion current of the studied aluminium alloy decreases, and therefore its corrosion resistance goes higher, compared to the that, in 1 M HCl.

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