Etude de l'inhibition de la corrosion de l'acier C38 par l'huile d'argan en milieu NaCl 3%.

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RESUMÉ

Mots clés :
huile d'Argan, corrosion, inhibiteur, électrochimie, environnement.

La corrosion des métaux et alliages est un problème universellement connu, qui entraîne chaque année pour l'industrie et la collectivité des pertes matérielles considérables. L'inhibition de ce phénomène peut être réalisée par la présence de produits inhibiteurs dans le milieu corrosif. L'objectif de ce travail est de déterminer l'efficacité inhibitrice d'une huile d'argan vis-à-vis de la corrosion de l'acier C38 en milieu NaCl 3%, en utilisant des méthodes électrochimiques. Les résultats obtenus montrent que cette huile est un inhibiteur mixte. Elle induit une diminution des densités de courant de corrosion et par conséquent une diminution de la vitesse de corrosion de l'acier C38. L'efficacité inhibitrice augmente avec l'augmentation de la concentration de l'huile et la meilleure efficacité a été obtenue à la concentration de 3g/L.

ABSTRACT

Keywords :
Argan oil, corrosion, inhibitor, electrochemical, environment.

Evaluation of Argane oil as corrosion inhibitor for steel C38 in NaCl 3% medium.

Corrosion of metal is a common problem across many industries. The inhibition of this phenomenon can be achieved by the presence of inhibitors in the corrosive medium. Argan Oil (AO) was tested as inhibitor for C38 steel corrosion in NaCl 3% solution. The techniques used in this work were electrochemical techniques (I-E and EIS). The obtained results reveal that Argan oil acts as a mixed inhibitor without modifying the hydrogen reduction mechanism. The inhibition efficiency was found to increase with inhibitor content to attain 91% at 3g/L of argan oil. The inhibition efficiency E (%) obtained from the various methods is in good agreement.

Introduction :

The C38 steel is a material with excellent electrical and thermal conductivity and is often used in heating and cooling systems. Corrosion is one of the major problems encountered in the industrial application of materials. Millions of dollars are spent by the oil industry, for instance, on the prevention of corrosion process in metals (Ahamad et al., 2010). Among the procedures used to prevent corrosion (Singh et Quraishi, 2010), the use of inhibitors is the most common and presents economic and environmental advantages, as well as a great efficiency and high applicability (El Hajjaji et al., 2003). It is well known that organic molecules containing heteroatoms act efficiently as corrosion inhibitors (Labjar et al., 2010; Labjar et al., 2011; Maofari et al., 2014; Tang et al., 2003; Saufi et al., 2014; Zarrouk et al., 2012; Elbakri et al., 2012; Herrag et al., 2010).

Nevertheless, most of these compounds are not only expensive but also toxic to living beings (Bendaha et al., 2012; Liet al., 2012; Ghazoui et al., 2012). It is needlessto point out the importance of cheap, safe inhibitors of corrosion. Plant extracts are environment friendly, biodegradable, non-toxic, easily available and of potentially low cost (Lowmunkhong et al., 2010). Most of the naturally occurring substances are safe and can be extracted by simple procedures. Recent literature is full of researches that test different extracts for corrosion inhibition applications (Soltani et al., 2010; Ben Hmamou et al., 2012). The examples are numerous such as Argan Hulls (Afia et al., 2012), Eugenol oil (Azzouyahar et al., 2013) Cosmetic Argan Oil (Mounir et al., 2014), Harmal Extract (Bammou et al., 2014), Chenopodium Ambrorsioides Extract (Belkhaouda et al., 2013), Hibiscus sabdariffa (Emeka and Portug, 2008), Oxandraasbeckii (Lebrini et al., 2011), Citrus paradise (Olusegun et al., 2004, Selles et al., 2012).

In this work, the inhibitive action of argan oil (AO), as an eco-friendly and naturally occurringsubstance, on the corrosion of C38 steel in NaCl 3% has been studied by electrochemical techniques.

Materials and methods :

1. Argan oil (AO) :

The solution tests are freshly prepared before each experiment by adding the oil directly to the corrosive solution.

2. Fatty acid methyl esters composition :

The analyses performed for the purpose of this study were carried out in the laboratory of the Autonomous Establishment of Control and Coordination of Export, which applies the official methods of analysis for the determination of fatty acid methyl esters (FAME) in oil (Bligh et al., 1959, Pavithra et al., 2012). The fatty acid methyl esters were analyzed with an Agilent Technologies 6890N gas chromatograph equipped with a capillary column (30 m x 0.32 mm; Supelco, Bellefonte, PA, USA) and flame ionization detection. The column was programmed to increase from 135 to 160°C at 2°C/min and from 160 to 205°C at 1.5°C/min; the detection temperature was maintained at 220°C, injector temperature 220 °C. The vector gas was helium at a pressure of 5520 Pa. Peak was identified by comparing retention times with those of standard fatty acid methyl esters (Pavithra et al., 2012).

3. Tocopherols composition :

For the determination of tocopherols compounds, a solution of 250 mg oil in 25 mL n-heptane was used for HPLC analysis. The analysis was conducted using an Agilent low-pressure gradient system, fitted with an 1100 pump, an Agilent 1100 Fluorescence Spectrophotometer (detector wavelengths for excitation 290 nm, for emission 330 nm). The sample (20 µL) was injected by a Agilent LC -1100 auto sampler onto a phase HPLC column 25 cm x 4 mm ID (Merck, Darmstadt, Germany) used with a flow rate of 1 mL/min and hexane/tetrahydrofuran (98:2, v/v) as mobile phase (Balz et al., 1992).

4. Sterols composition :

Sterol was determined by the method (Selles et al., 2012). Sterol composition was evaluated by GLC-FID/ capillary column. Briefly, sterols purified from the unsaponifiable matters by HPLC were transformed into their trimethylsilyl ethers counterparts using pyridine, hexamethyldisilazane, and trimethylchlorosilane 9:3:1 (v/v/v). The sterol profile was analyzed using a gas-phase chromatograph fitted with a chroma pack CP SIL 8 C B column (30 m x 0.32 mm i.d.) and a flame ionization detector. The temperature of the injector and detector were both 300 °C. The column temperature was 200 °C and programmed to increase at the rate of 10 °C/min to 270 °C. The carrier gas was dry oxygen-free nitrogen, and the internal pressure was 8.6 bars. Sterol quantification -cholestanol.α was achieved by use of an internal 0.2% chloroform solution ofα-cholestanol.

5. Materials preparation :

The material used in this study is C38 steel. Prior to all measurements, the iron samples were polished with different emery paper up to 2000 grade for removing metal oxides, rinsed with distilled water, and dried at room temperature before introducing it directly into the cell. The aggressive solution (NaCl 3%) was prepared by dilution of 30 g of NaCl (solid) with distilled water. The corrosion inhibition solution was prepared by dissolving natural argan oil in NaCl 3% solution.

6. Electrochemical Methods :

The electrochemical study was done with a potentiostat PGZ 301 controlled by a PC and supported by Voltamaster 4.0 software. This potentiostat connected to a cell with three electrodes. The working electrode was carbon steel with the surface area of 1 cm2. A saturated calomel electrode (SCE) was used as a reference. All potentials were given with reference to this electrode. The counter electrode was a platinum plate of surface area of 1 cm2. For polarization curves, the working electrode was immersed in a test solution without and with different concentrations of Argan oil during 60 min until a steady state opens circuit-potential was obtained. The chronoamperometry measurements were carried out at 0.1V/SCE. The electrochemical measurements were recorded from -1000 to 500 mV/SCE. The inhibition efficiency E (%) is calculated according to equation (1):

$$E\% = \frac{i^{0}_{corr} - i_{corr}}{i^{0}_{corr}} \times 100 \qquad (1)$$

Results and discussion :

The cathodic and anodic polarization curves of the C38 steel immersed in NaCl 3%in the presence and absence of inhibitor at different concentrations at 298 K are presented in fig. 1. Values of the associated electrochemical parameters are given in Table 1.

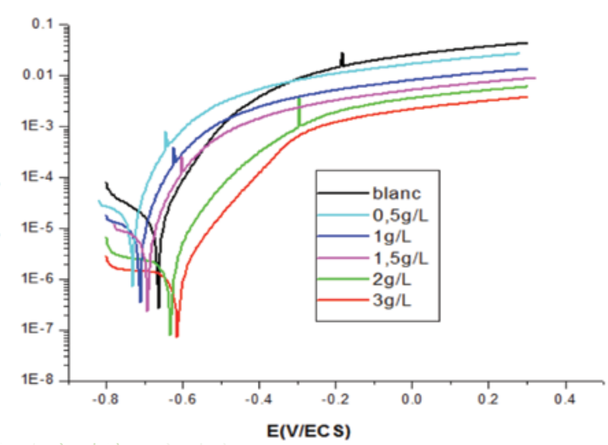

Figure 1 : *Polarization curves for iron in NaCl 3% at various concentrations of Argan oil.*

It was observed that both the cathodic and anodic curves showed lower current density in the presence of the Argan Oil than that recorded in the NaCl solution without the oil. This indicates that the addition of AO to NaCl solution reduces the anodic dissolution of metal and impedes the cathodic hydrogen evolution reaction (Lebrini et al., 2011).

In Table 1, the potentiodynamic polarization parameters including corrosion current densities (Icorr), corrosion potential (Ecorr), and inhibition efficiency (IE %). It can been seen from the Table 1 that Icorr decreased noticeably with increase in AO concentration which implies that AO behaves as a very good corrosion inhibition for C38 steel in NaCl 3% solution.

An inhibitor, in general, can be classified as an anodic-type or cathodic-type when the change in Ecorr value is larger than 85 mV (Li et al., 2008). However, in this study we can be concluded that AO acts as a mixed type inhibitor. On the other hand, the anodic and cathodic slope values of inhibited solution have changed with respect to uninhibited solution, which also reiterates that the oil has mixed type effect (Jiali et al., 2013).

Table 1. *Electrochemical parameters of C38 steel at various concentrations of OA in NaCl 3% and the corresponding inhibition efficiency.*

	E (mV/ECS)	I (µA/cm²)	E%
Sans inhibiteur	-662	1400	*******
0.5g/L	-734	852	39
1g/L	-710	656	53
1.5g/L	-692	453	67
2g/L	-634	192	86
3g/L	-615	118	91

2.2. Electrochemical impedance spectroscopy measurements :

EIS measurements were carried out to determine the kinetic parameters for electron transfer reactions at the steel/electrolyte interface and simultaneously about, the surface properties of the investigated system and the shape of the impedance diagram will provide mechanistic information. The Nyquist impedance plots obtained for C38 steel electrode in the absence and presence of AO in NaCl 3% are shown in Fig 2.

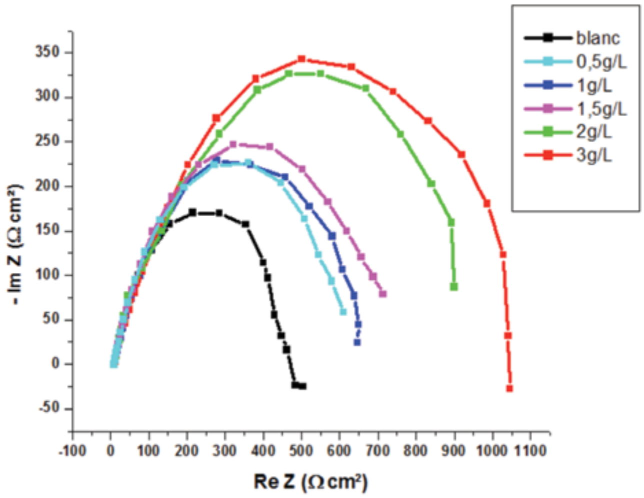

Figure 2. *Nyquist diagrams forC38 steel electrode in NaCl 3% with and without AO.*

The inhibition efficiency can be calculated by the following formula :

$$E_{Rt}\% = \frac{(R_t - R_t^0)}{R_t} \times 100 \qquad (2)$$

Where Rt and R0t are the charge transfer resistances in inhibited and uninhibited solutions respectively. The values of the charge transfer resistance were calculated by subtracting the high frequency intersection from the low frequency intersection (Ouachikh et al., 2009). Double layer capacitance values Cdl were obtained at the frequency (fmax), at which the imaginary component of the Nyquist plot is maximum, and calculated using the following equation.

$$C_{dl} = (2\pi f_{max} . R_t)^{-1} \qquad (3)$$

Figure 2 shows that a single semicircle has been observed at high frequency. This can be attributed to charge transfer of the corrosion process, and the diameter of the semicircle increases with increasing AO concentration. It is apparent from the Table 2 that the presence of AO in NaCl media leads to decrease in Cdl values. The decrease in Cdl values can be attributed to the decrease in local dielectric constant and/or an increase in the thickness of the electrical double layer (Tang et al., 2003). Meanwhile the increase in Rt values indicates that the extent of adsorption with increase in oil concentration and also the adsorbed oil forms a protective film on the steel surface which becomes a barrier to hinder the mass and charge transfer processes.

Table 2. *Impedance parameters for corrosion of C38 steel in NaCl 3% at various concentrations of AO.*

Conc. g/L	Rs ($\Omega.cm^2$)	L1 ($sn\,\Omega^{-1}.cm^{-2}$)	a2	c2 ($\mu F.cm^{-2}$)	Q2	R2 ($\Omega.cm^2$)	E%
Blanc	9.164	$0.813.10^{-6}$	0.763 3	883	$0.886\ 1.10^{-3}$	482	******
0.5	9.145	$1.156.10^{-6}$	0.724 3	680	$1.013.10^{-3}$	689	30.00
1	8.996	$1.385.10^{-6}$	0.686	464	$0.571.10^{-3}$	963	49.00
1.5	9.471	$1,385.10^{-6}$	0.763	209	$1.246.10^{-3}$	1255	61
2	9.205	$0.483.10^{-6}$	0.745 6	67	$1.237.10^{-3}$	1891	74
3	9.475	$0.415.10^{-6}$	0.766 7	32	$2.037.10^{-3}$	2854	83

It can be concluded that AO exhibits good inhibitive performance for C38 steel in NaCl 3% solution, and the data obtained from EIS are in good agreement with those obtained from potentiodynamic polarization method.

Conclusion :

The obtained results show that Argan oil (AO) present excellent inhibition properties for the corrosion of steel C38 in NaCl 3% at 298K. The inhibition efficiency (IE) increases with the increase of the AO concentration. At 3 g/L, the inhibition efficiency (IE) of AO is about 91%. AO is a mixed inhibitor and its molecules block both the anodic and cathodic sites of the metal surface. For the protection of metals such as iron in an aqueous medium, based inhibitors of vegetable oils exhibit satisfactory protective powers. Therefore, they can be widely used in various industries.

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