Study of Inhibitory Efficacy of Natural Extract of Opuntia Ficus Indica as Green Inhibitor for Corrosion of Mild Steel in Drilling Water

Oulabbas Amel, Achouri Sihem, Meddah Soumaya, Remichi Nasser, Ramoul Chems Eddine, Tiili Samira

1 Research Center In industrial technologies CRTI P.O.Box 64, Cheraga 16014 Algiers, Algeria

a.oulabbas@ctri.dz

Abstract

The purpose of this study is to evaluate the anti-corrosive effect of natural extract of Opuntia Ficus Indica (O.F.I) for X60 mild steel in drilling water environment used in petroleum engineering. Experimental work has been achieved by weight loss, potentiodynamic polarization and EIS measurement, as well as SEM surface characterization. Among the results obtained, we can mention an inhibitory efficiency of 90% by gravimetric method and 80% by electrochemical method at 20% (v/v) of O.F.I. Moreover, The O.F.I extract acts as a mixed inhibitor; however, adsorption free enthalpy indicates a physisorption. The adsorption obeys the Langmuir isotherm model.

Keywords: Corrosion, mild steel, green inhibitor, Opuntia Ficus Indica and Electrochemical Impedance spectroscopy.

1-Introduction:

All mild steels are degrading superficially when subjected to corrosive media [1, 2]. Corrosion is the deterioration of materials by physicochemical interaction with their environment, resulting in changes in the properties of the metal often accompanied by his functional degradation (Alteration of its mechanical, electrical, etc. properties). The mechanisms involved are diverse and lead to different forms of corrosion. This steel is used in the petroleum industry for pipelines in the first place and other industrial plants, hence the extent of the damage.

Knowing that the green inhibitors are the subject of great attention in the world of the industry and seen their no toxicity and efficiency in the field of corrosion [3], our work is based on the use of plant extract based on Cactus Cladode (O.F.I.), often called Opuntia Ficus Indica. In many countries with a semi-arid climate (Chili, Mexico), O.F.I is cultivated in its own right [4, 5], It is presented in many rural areas in Algeria, often in the form of a fence limiting the plots of the rods. Best plantations this finds rather in coastal areas such as the town of Annaba located in eastern Algeria.
The O.F.I was largely ignored by scientists until early 1980, when interest in multifunctional plants attracted their attention [6]. The O.F.I is becoming more and more targeted for its ecological, environmental and socio-economic interest, without forgetting the industrial, medicinal, pharmaceutical and cosmetic fields.

In our study we are interested in the anti-corrosive properties of this plant thanks to the high percentages of amino acids, proteins, polyphenols, fiber sugars and vitamin C [7, 8], knowing that O.F.I is a plant rich in minerals such as, magnesium, calcium and potassium. The Betalain, which is a vegetable pigment derived from indole and contains nitrogen, provides excellent food properties, and large commercial importance [9]. It is found largely in the family of cactaceas [10, 11] including betalamic acid, which is the main chromophore of betalain pigments [12] marketed as organic food colorants [13, 14].

Our study is based on the results obtained from electrochemical techniques, stationary and transient, and to determine the inhibitory and protective efficacy of O.F.I. with mild Steel in drilling water.

2. Experimental method:

In our work, the mild steel plates used are cut in cubic form and with a surface of 1 cm$^2$ in contact with the electrolyte. The electrical conductivity is ensured by a copper cable directly in contact with the steel.

Table 1: Chemical composition in mass% of mild steel X60

<table>
<thead>
<tr>
<th>Elements</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>P</th>
<th>S</th>
<th>Cu</th>
<th>Ni</th>
<th>Cr</th>
<th>Mo</th>
<th>V</th>
<th>Fer</th>
</tr>
</thead>
<tbody>
<tr>
<td>mass%</td>
<td>0.18</td>
<td>0.60</td>
<td>0.311</td>
<td>0.008</td>
<td>0.010</td>
<td>0.09</td>
<td>0.03</td>
<td>0.04</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td></td>
</tr>
</tbody>
</table>

The mild steel was immersed in drilling water. The O.F.I is used as a green inhibitor, was firstly washed with distilled water and then cut into small pieces to be crushed right after and recovered the fresh liquid which is used directly as a fresh extract.

In our work, we used a cell with three-electrode, platinum as counter electrode, reference electrode Ag/AgCl, and working electrode made of mild steel. The plots of the polarization curves are done with a potentiostat AutoLab linked directly to a computer controlled by NOVA 2.0. In our case, the constant sweep rate was performed between ($\pm 250$ mV/ Ecorr)/Ag/AgCl. It should be noted that for all the tests a waiting period of 1 hour after immersion corresponds to the time of formation and stability of the electrical double layer has been observed.

The curve $I = f (E)$ is studied at the neighborhood of the corrosion potential $\pm 10$ mV, this method is fast and particularly adapted to the study of the inhibitory efficiency of molecules whose effect is not known with a scan of 0.001 V/s.

A study of the behavior of mild steel X60 in drilling water under hydrostatic conditions was carried out by electrochemical impedancimetry in order to specify the mechanism of action of the extract of O.F.I. The frequency sweep was carried out from high frequencies (HF) (100 KHz) to low frequencies (BF) (10 mHz) with a sinusoidal disturbance of 1 mV amplitude around the free potential. Over this potential interval, the system is quasi-stationary.
Results and discussion:

*Potentiodynamic polarization measurements:*

The polarization curves of the cathodic and anodic regions of mild steel in drilling water in the absence and presence of O.F.I at different concentrations as a corrosion inhibitor are plotted at 1mV/s scan rate.

![Figure 1](image)

**Figure 1.** Potentiodynamic polarization curves of mild steel in drilling water in absence and presence of O.F.I at different concentrations.

As seen with the polarization curves in Figure 1, the concentrations of O.F.I influences the corrosion potential, and they tend towards positive values at 5, 10, 15 and 20%. Also, the cathodic and anodic plots of the Tafel curves decrease with increasing concentrations, therefore a decrease in $I_{corr}$ indicating an adsorption of the O.F.I molecules on the surface. The electrochemical parameters deduced from these curves (Figure.1), the efficiencies calculated from the curves of $I=f(E)$ by the relation (1), are presented in Table 2.

\[
E\% = \frac{i_0 - i}{i_0} \times 100 \quad (1)
\]
Table 2: Parameters deduced from the polarization curves of X60 steel in the absence and presence at different O.F.I concentrations.

<table>
<thead>
<tr>
<th>C (%)</th>
<th>$E_{corr}$ (mV/Ag/AgCl)</th>
<th>$i_{corr}$ (mA.cm$^{-2}$)</th>
<th>$\beta_a$</th>
<th>$\beta_c$</th>
<th>E (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank</td>
<td>-604.87</td>
<td>0.417</td>
<td>214.0</td>
<td>205.2</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>-585.52</td>
<td>0.247</td>
<td>98.5</td>
<td>122.5</td>
<td>40.76</td>
</tr>
<tr>
<td>1</td>
<td>-568.04</td>
<td>0.115</td>
<td>88.4</td>
<td>98.7</td>
<td>72.42</td>
</tr>
<tr>
<td>15</td>
<td>-542.74</td>
<td>0.065</td>
<td>86.9</td>
<td>89.3</td>
<td>84.41</td>
</tr>
<tr>
<td>20</td>
<td>-507.08</td>
<td>0.028</td>
<td>74.8</td>
<td>87.5</td>
<td>93.28</td>
</tr>
</tbody>
</table>

Firstly, it can be seen that the values of the polarization resistance increase with increasing inhibitor concentration, reflecting the change in the surface state and the presence of a film on the metal surface. This is confirmed with the inhibitory efficiency which reaches a maximum of 93.28% at a concentration of 20% of O.F.I. It is clear that the anodic region has linear part from which the values of $\beta_a$ are calculated. The variation of these values reflects the change in the mechanism of metal’s dissolution.

**Impedance spectroscopy SIE**

The electrochemical impedance diagrams, in Nyquist representation, of X60 steel in drilling water, were plotted in the absence and in the presence of O.F.I at different concentrations.

![Electrochemical impedance diagrams with Nyquist representation](image)

**Figure 2.** Electrochemical impedance diagrams with Nyquist representation of X60 steel in drilling water in absence and presence of O.F.I at different concentrations.

In the absence of inhibitor, we noticed the presence of a capacitive loop which can be due to the
adsorption of the products of corrosion which play the role of a barrier, limiting the growth of the reduction of the oxygen. While in the presence of O.F.I at different concentrations, it is found that the size of the loop increases with increasing concentration of O.F.I up to 20% (v/v).

**Table 3. Parameters deduced from the Nyquist representation curves of X60 steel in the absence and presence at different O.F.I concentrations.**

<table>
<thead>
<tr>
<th>Inhibiteur</th>
<th>C% (v/v)</th>
<th>R_e (Ω.cm^2)</th>
<th>CPE_e (mF.s^{1/n}.cm^2)</th>
<th>R_et (Ω.cm^2)</th>
<th>CPE_{dl} (mF.s^{1/n}.cm^2)</th>
<th>E (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>O.F.I</td>
<td>0</td>
<td>23.15</td>
<td>6.25</td>
<td>9625</td>
<td>8.25</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>22.14</td>
<td>3.14</td>
<td>15478</td>
<td>2.15</td>
<td>37.81</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>19.85</td>
<td>3.57</td>
<td>19177</td>
<td>2.01</td>
<td>49.80</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>23.54</td>
<td>2.24</td>
<td>32510</td>
<td>1.27</td>
<td>70.39</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>26.01</td>
<td>2.85</td>
<td>46203</td>
<td>1.98</td>
<td>79.16</td>
</tr>
</tbody>
</table>

According to Table 3, we notice that the increase in the concentration of O.F.I induces the reduction of the capacity of the layer and the double layer, the increase of the charge transfer resistance, the inhibitory efficiency up to 79.16% corresponding to 20% (v / v). An equivalent circuit can be schematized for the different concentrations, where a mode, describing the electrochemical behavior of the interface (fer-solution+ drilling water + inhibitor), can be proposed. **Figure 3**

![Equivalent circuit of steel immersed in drilling water in the absence and presence of O.F.I.](image)

**Figure 3.** Equivalent circuit of steel immersed in drilling water in the absence and presence of O.F.I.

**Conclusion:**

The inhibition effect of O.F.I. as green inhibitor on the corrosion of X 60 steel, in drilling water, was evaluated by potentiodynamic polarization, EIS measurement in this paper. The following insightful conclusions were made:

- O.F.I. has an excellent inhibition performance for corrosion of X60 steel in drilling water solution.
- The inhibition efficiency could be up by 93.28 % at 20% O.F.I.
- Potentiodynamic polarization studies show that O.F.I. molecules act as a mixed –type inhibitor.
- The EIS results indicate that, the presence of O.F.I in drilling water increases the value of R_et and reduces the value of C_{dl}. Whereas the EIS spectra reveal one capacitive loop which suggests that the corrosion of steel is controlled by charge transfer process.
These results clearly indicate that X60 steel corrosion can be inhibited by the O.F.I. adsorption on steel surface.

References:


Biographies

Oulabbas Amel Research master, actually in research center of industrial technologies, Algiers, Algeria. She obtained her engineering degree, her Master's degree and her Ph.D. in physic-chemical and materials at Badji Mokhtar University, Annaba, Algeria. His research focuses on the corrosion science and electrochemical study of materials.

Meddah Soumaya is a research master in the physical metallurgy team, Material Properties Division, at research center of industrial technologies, Algiers, Algeria. She obtained her engineering degree, her Master's degree and her Ph.D. in metallurgy and materials engineering at Badji Mokhtar University, Annaba, Algeria. His research focuses on the characterization of materials (ferrous and nonferrous), tribology (friction, lubrication and wear), and corrosion of materials.

© IEOM Society International