Inhibitors using Aloe Vera to Reduce Corrosion of Carbon Steel HSLA X70 in saline media 3.5 M NaCl

Janeth Marlene Quispe-Avilés

[1] Universidad Tecnológica del Perú (UTP), Av. Tacna y Arica, Arequipa, Perú.
[2] Coordinación de investigación, Facultad de Ingeniería, Universidad Continental, Av. Los Incas s/n, Arequipa, Perú. jquispeaviles@gmail.com

Abstract: The damage caused by corrosion in saline media affects carbon steel structures, so the use of inhibitors is a great alternative, however, industrial inhibitors have a high environmental impact. In search of sustainable alternatives, the present investigation investigated the inhibitory effect of aloe vera to reduce the corrosion of HSLA X70 steel by means of potentiodynamic polarization techniques and agar-agar gel, complementing microstructure characterization studies, the results show that 10%/V allows an efficiency of 82% to be able to protect X70 steel with great efficiency.

Keywords: Corrosion, sustainable inhibitors, aloe vera, EIS, HSLA Steel

1. INTRODUCTION

Carbon steel metallic structures are used mainly for the production of oil and natural gas, whose material has high mechanical resistance and hardness, low manufacturing and maintenance costs. (1) X70 steels have excellent mechanical properties, which is why there is great industrial interest in inserting them in the sour gas industry, that is, for the oil and natural gas industry. (1-3) On the other hand, in marine environments, that is, with a high concentration of Sodium Chloride (NaCl) in a humid phase medium, it can accelerate the corrosion process [4]. The impact of corrosion is usually high, generating economic problems, damage to structures, direct and indirect economic losses. (4-5) At the engineering level, to control the speed of corrosion, the use of industrial inhibitors is used, formulated to protect metallic structures for an extended period of time, prolonging the life time and reducing costs due to corrosion problems. (5) However, the use of industrial inhibitors on the current market is formulated based on arsenates, chromates, phosphates, molybdates, acetylenic alcohols, amides, aromatics, amines and thiols, generating a high environmental impact from its production and the waste generated in the chain. industrial production [4-5]. For this reason, there is a need to reduce the high environmental impact of traditional inhibitors, so green (natural) inhibitors are emerging as great potential to promote the protection of structures, in addition to reducing the environmental impact that can be used in instead of toxic inhibitors and give excellent effect, these extracts are effective, abundant, cheaper. (6-7) In this context, the present investigation seeks to study the inhibitory effect of aloe vera to control the corrosion of X70 steel in 3.5M NaCl media, for which an electrochemical and metallurgical study must be complemented. Additionally, it was accompanied by a superficial characterization by optical (OM) and electronic microscopy and (SEM).

2. METHODS

In this work, a high-strength low-alloy steel -HSLA grade X70 was used. The chemical composition is: C (0.04%); Mn (1.37); P (0.009).

2.1 Microstructural Analysis and Classification of Inclusions

For the classification of the inclusions, samples of the HSLA X70 steel from the longitudinal region to the rolling direction were analyzed, sanded up to 1200 with silicon carbide paper and polished 1 with diamond paste. All the procedures were carried out according to the recommendations of the ASTM E-45. (8) After surface finishing, these surfaces were characterized using optical and Scanning-SEM microscopy. The Image J software was applied to

determine the grain size and inclusions respectively. For the microstructural characterization of the HSLA X70 steel, the samples were extracted from the region perpendicular to the rolling direction. Surface finish similar to the one mentioned above with the addition of a final metallographic attack stage with Nital 2% (2ml HNO_3/100ml ethyl alcohol) to later carry out a characterization by MO and SEM according to the recommendations of the ASTM E-112 standard. [9]

2.2 Electrolytes for electrochemical test:

In this investigation two electrolytes were used, one in the absence and presence of aloe vera, for the first electrolyte it was a solution composed of 3.5 M NaCl and the second electrolyte to this preparation consisted in the extraction of the leaves (500 g), liquefied with 10 ml of distilled water and finally add 10% /V of aloe vera to the 3.5M NaCl solution. Figure 1 shows the sequential procedure for the preparation of the electrolyte in the presence of the inhibitor.

Figure 1.- Sequence of the elaboration of the electrolyte 1 and 2 used for the electrochemical and immersion tests.

2.3 Agar-agar gel test for visual examination of the inhibitory effect of aloe vera

Visual examination with the help of agar-agar gel was used as a preliminary diagnostic measure to verify if there is an inhibitory effect of the aloe vera formulation (10%/V and compare it with the 3.5M NaCl solution. The gel was prepared with agar - Agar dosolve 20g in hot water and let it cool, place 3 drops of methyl orange and phenoltalein. After the condition with the inhibitor, add the aloe vera formulation. A sample of the HSLA X70 steel was placed in a petri dish and until covered. The agar-agar solution should be placed in. Let it dry in the open air, the fresh surface (1h) and after 24 hours (maximum time of electrochemical tests) were accompanied by photographs.

2.4 Electrochemical test

All the electrochemical tests were evaluated in two electrolytes (1) solution made up of 3.5 M/1L NaCl and (2) and (2) electrolyte made up of a 3.5 M NaCl solution with the addition of 10%/V of Aloe Maculata. An electrochemical cell composed of three electrodes was used: (1) Working electrode (WE): they were the HSLA X70 steel samples (ASTM G106 -89 -2015 standard) [(10)]; Counter electrode (CE): a sinker wire, Reference electrode (RE): an Ag/AgCl electrode. Once the three electrodes and the respective electrolyte were placed to cover the samples, the OCP (900s) and Polarization curves (1h and 24hours) tests were recorded for PDP, tests were carried out at potential of -250 and mV + 250 mV vs OCP and scan rate of 1 mV/s. Tests performed on a Gamry 600™ brand potentiostat. Applying the Tafel extrapolation in the polarization curves, the corrosion rate was obtained, an important parameter to be able to calculate the inhibition efficiency (IE). The inhibition efficiency percentage, (% IE), was calculated according to equation 1:

$$\% \text{ IE} = \frac{\text{Vcorr } 0\text{- Vcorr } inhibitor}{\text{Vcorr } 0} \text{ x } 100$$

Where:

- **V_{corr} 0:** corrosion rate in the absence of aloe vera (solution composed of 3.5M NaCl).
- **V_{corr} inhibitor**: corrosion rate in the absence of aloe vera (solution composed of 3.5M NaCl and 10% /V of Aloe Vera.

3. RESULTS

3. 1-Microstructural Analysis and Classification of Inclusions

Figure 2(a) presents a micrograph obtained by an optical microscope (OM) of the microstructure without the presence of bands, and by scanning electron microscopy (SEM) (Figure 2(b)) it is observed that the HSLA X70 steel presents a ferrite matrix with presence of perlite in low proportion. Figure 2(c) shows EDS analysis of round-shaped inclusions rich in Mn, S, Mg, Ca (Figure 2(c)).

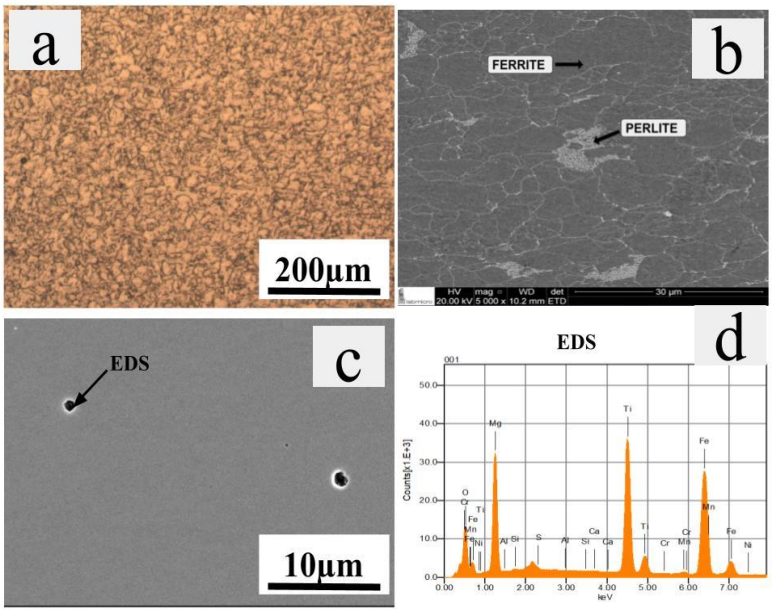

Figure 2- (a) MO micrograph with the distribution of inclusions in HSLA X70 steel - longitudinal section, (b) example of the inclusions (SEM), (C) Composition chemical -EDS and (d) microstructural analysis.

3.2-Agar-agar gel test for visual examination of the inhibitory effect of aloe vera

Figure 3 shows the results of the visual examination of the effect of surface corrosion using agar-agar gel in the absence and presence of the inhibitor formulated in aloe Maculata base. It can be observed that initially the fresh surface remains clean of the corrosion process when the surface of the HSLA X70 steel spends 24 hours in the presence of agar gel - agar with sun. 3.5 M without aloe Maculata (electrolyte 1) presents a superficial attack with intense corrosion points, the attack is observed in a light brown coloration, presence of localized attack, on the other hand, (electrolyte 2) the sample of the HSLA X70 steel exposed in Agar-agar gel in 3.5M solution with aloe vera shows more preserved surfaces, whose corrosion process was controlled and a greenish-colored film was formed, helping to protect the steel surface, showing an anticorrosive barrier.

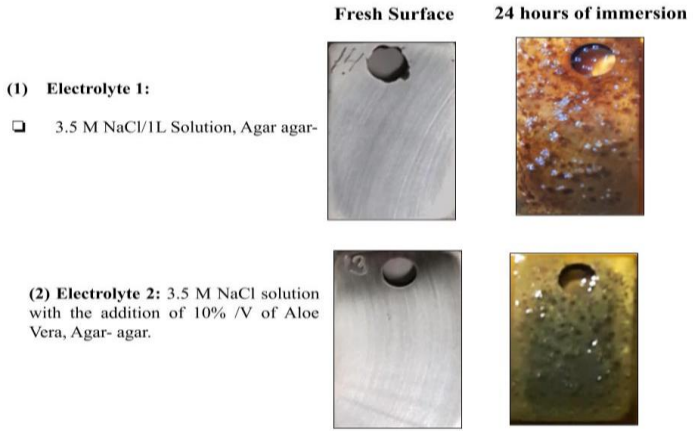

Figure 3-Superficial comparison using Agar-agar gel of HSLA X70 steel in: (1) 3.5M NaCl solution and (2) 3.5M NaCl solution with the addition of 10%/V of aloe vera.

3. 3- Electrochemical test

Results of the electrochemical tests carried out on a fresh surface (recently sanded #1200), and 24h of electrolyte exposure composed of: (1) 3.5M NaCl solution and (2) 3.5M NaCl solution with the addition of 20% /V of Aloe Maculata.

3.3.1 Open Circuit Potential -OCP

Figure 3 (a) shows the results of the OCP, whose OCP potentials become more negative (active regions) in the condition of electrolyte 1: 3.5M NaCl solution, the potential becomes more active, reducing its potential depending on the exhibition time. On the other hand, in the electrolyte composed of a 3.5M NaCl solution with the addition of 10%/V of aloe vera, the potential variations remain more uniform, there is an increase in the OCP with the increase in immersion time, it was also observed. that the potentials are nobler than in the absence of the inhibitor. Results of the polarization techniques (Figure 3(b)) to obtain the corrosion potentials (E_{corr}) obtained at 1h and 24h of exposure in electrolytes composed of: (1) 3.5 M NaCl solution and (2) 3.5 M NaCl solution with the addition of 10%/V of aloe vera. The results show higher corrosion potentials when the inhibitor is not present, on the contrary, in the presence of the inhibitor the corrosion potentials are lower, indicating lower corrosion kinetics.

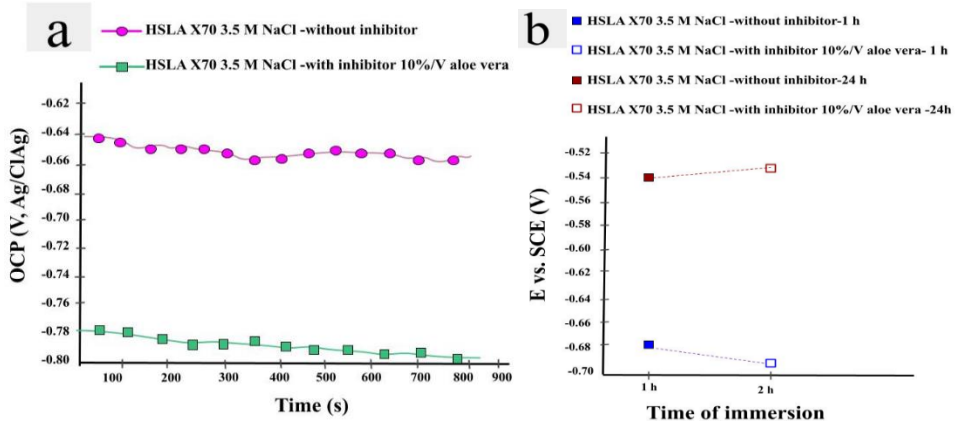

Figure 3- (a) Open Circuit Potential (OCP) of HSLA X70 steel exposed to 3.5 M NaCl in the absence and presence of 10%/V of aloe Vera, fresh surface exposure periods 900 seconds. (b) E_{cor} of polarization test of HSLA X70 steel exposed to 3.5 M NaCl in the absence and presence of 10%/V of aloe Vera, 1h and 24hrs of immersion.

Applying equation 1, the efficiency values are obtained as a function of the respective time applied in the absence of the inhibitor to monitor whether or not the behavior against corrosion really improves. Table 4 shows the efficiency values in the three times evaluated in the present investigation, the results show that the inhibitor made from 10%/V

of aloe vera reaches an efficiency of 87.06 ± 0.64% approximately when compared with the samples that were exposed without inhibitor that present higher corrosion speed. The results confirm the inhibitory effect of aloe vera to reduce the speed of corrosion.

Table 4.-Values of the efficiency calculations of the inhibitor formulated at 0%/V of aloe vera applied to HSLA X70 steel exposed to 3.5 M NaCl, exposure periods 1 hours and 24 hours (Figure 4)

Material- HSLA X70 (Condition)	Efficience value (%)
· 3.5M NaCl+ 20%/V of aloe vera-1h	80%
· 3.5M NaCl+ 20%/V of aloe vera-24 h	85 %

4. DISCUSSION

4.1 Microstructural Analysis and Classification of Inclusions

The formation of inclusions in carbon steels is inevitable, since they are C-Fe alloys and the interaction of matrix elements. Inclusions rich in Ca, Al is expected for this type of carbon steel, the presence of both Ca and Al reduce the formation of MnS inclusions. On the other hand, the type of microstructure is important to guarantee the quality of the material, in addition to contributing to the mechanical properties. (11)

4.2 Agar-agar gel test for visual examination of the inhibitory effect of aloe vera

This type of test is effective for preliminary studies of surface corrosion, it allows complementing corrosion resistance studies, they are effective because they allow simulating real media and conditions and can be monitored visually without the need for sophisticated or expensive equipment, it is easy to use, practical. They are also low cost; whose inputs are low cost. (12) In the case of this study, it allowed verifying the behavior of the inhibitor before starting larger conventional studies and thereby reducing analysis costs to verify if the inhibitor formulation was viable.

4.3 Electrochemical test

Corrosion is a process that involves the deterioration or degradation of the metal, it occurs in the form of oxides, this process being facilitated by the presence of NaCl. The presence of saline media accelerates the corrosion of carbon steels, which is why studies are necessary to protect metal structures with anticorrosive coatings or paints. (13) The use of natural inhibitors is an alternative that allows reducing the corrosion rate at a low cost. Electrochemical tests facilitate investigations regarding corrosion rate. (14) The results obtained in the present investigation appear favorable to be used as an inhibitor.

5. CONCLUSIONS

1. The addition of the aloe vera inhibitor in a 3.5M NaCl solution showed favorable inhibitory efficiency results, evidenced by obtaining a greater resistance to corrosion, reducing the speed of surface attack.
2. HSLA X70 steel exposed in 3.5M NaCl solution is shown to be more susceptible to corrosion in the absence of the inhibitor based on aloe Maculata (zebra aloe), a higher corrosion rate and lower impedance.
3. The behavior compared as a function of exposure time shows that corrosion resistance improves with longer exposure time, which shows that the film formed in the presence of the inhibitor is effective and has protective characteristics.

Conflicts of Interest: The authors declare that they have no conflicts of interest.

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CONFLICT OF INTEREST
"The authors declare that there is no conflict of interest".

AUTHORSHIP CONTRIBUTION:
1. Conceptualization: Janeth Marlene Quispe-Avilès
2. Data curation: Janeth Marlene Quispe-Avilès
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