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Mild Steel Corrosion Inhibitor in An Acidic Media Study by Using a Natural Inhibitor (Ascorbic Acid)

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Abstract

The study investigates ascorbic acid prevents mild steel from corroding in a 1 M HCl solution. Weight loss and electrochemical methods (Potentiodynamic Polarization) were used to assess the inhibition's effectiveness. Results indicated that ascorbic acid is an appropriate mixed-type inhibitor, its strength depends on the concentration. It showed a maximum inhibition found at 94 % with concentration 500 ppm. The Langmuir adsorption isotherm was found to describe the adsorption of the ascorbic acid molecules that occurred on the surface of the steel. SEM (scanning electron microscopy) was used to analyze the surface of the metal which is covered with protective layer which acts as inhibitor. Among the studies that can be cited is that ascorbic acid has high potential to become a low-cost, non-toxic yet effective corrosion inhibitor in the industrial cleaning of the acidic environments.

Keywords: Mild Steel, Corrosion, Inhibition, Ascorbic Acid, Electrochemical Methods.

1. Introduction

Corrosion is a form of chemical electron transfer and leads to slow deterioration of metals due to interaction of the metals and the surroundings. It is a global issue and the impact of the same has colossal economic and safety implications because it costs billions of dollars a year [1-3].

The use of mild steel in construction industry, manufacturing industry and even in chemical industry is quite popular due to its sheer mechanical properties as well as low cost. However, it is very likely to be affected by the corrosion process especially when subjected to tough socialization used in pickling, descaling and cleaning [4-6]. Toward prevent corrosion, and a small amount of corrosion inhibitor is added to the corrosive media. Which are compounds, which when used in an atmosphere, which effectively inhibit the corrosion rate. The organic inhibitors that are synthetic are most times not biodegradable, besides being both toxic and expensive even though they are very powerful.

The need to develop green inhibitors has led to the studies of green inhibitors of natural origin that are environmentally friendly [7-9]. Ascorbic acid ($C_6H_8O_6$) is an example of a green inhibitor; is a non-toxic water-soluble molecule that is present in fruits and vegetables and has more than one hetero atom O and p-electron on its aromatic ring. These properties, enabling it to be in the list of potential candidates of adsorption to metal surfaces to develop a protective coat [10].

The present study aims to evaluate the ability of ascorbic acid to prevent the corrosion of mild steel in 1 M HCl, study the adsorption mechanism of the inhibitor, and study the morphology of the surface of the metal under conditions where with and without the inhibitor will be examined.

2. Experimental Methodology

2.1 Materials and Solution

Mild steel coupons were prepared (Fe 99.21, Mn 0.05, Si 0.38, C 0.21, P 0.09, S 0.06) %. Just before preparing a corrosive solution, a 1M HCl solution was prepared with distilled water. The ascorbic acid was used as the inhibitor and the concentrations were 100, 200, 300, 400 and 500 ppm.

2.2 Weight Loss Measurements

The manufactured two steel coupons were tested in either the presence or absence of various doses of ascorbic acid. in a 200 mL solution of 1 M HCl and allowed to react for six hours at 25 °C. A post immersing of the coupons was followed by washing and drying and reweighing. The ability to inhibit (IE% and corrosion rate CR) was determined [2-5].

2.3 Electrochemical Measurements

Performed by using three traditional electrode configurations for potentiodynamic polarization, mild steel was to serve as the working electrode, saturated calomel electrode as the standard electrode, and platinum as the intended counter electrode. The plot of Tafel was made with the scan rate at 1 MV/s. The corrosion parameter was measured using the corrosion current density (Icorr) [4-7].

2.4 Surface Morphology Analysis

The surface of steel coupons submerged in 1 M HCl without and with 500 ppm ascorbic acid added was examined using scanning electron microscopy (SEM) [2-4].

3. Results and Discussion

3.1 Weight Loss Measurements

The weight loss data in table 1 shows that the corrosion inhibition increased as the inhibitors' concentration raised the corrosion rate indefinitely [6-9].

Table 1: Mild steel weight loss results using 1 M HCl with varying ascorbic acid concentrations.

Inhibitor Conc. (ppm)	Weight Loss (mg)	Corrosion Rate (mm/year)	Inhibition Efficiency (IE%)
Blank	252.5	11.82	-
100	45.8	2.14	81.9%
200	35.2	1.65	86.1%
300	25.1	1.17	90.1%
400	18.9	0.88	92.5%
500	15.1	0.71	94.0%

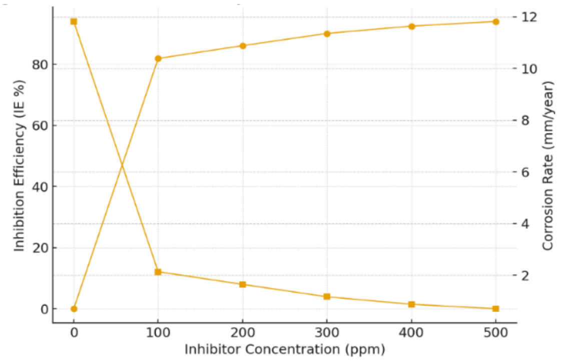

Figure 1: Inhibition efficiency and corrosion rate against inhibitor concentration.

The inhibition efficiency is found to be proportional to the inhibitor's concentration, as shown in figure 1. The rate of corrosion also falls to insignificant amounts at low concentration which implies that the surface coating is performed [10-12].

3.2. Polarization Dynamic Measurements

Tafel plots for mild steel in 1 M HCl with and without ascorbic acid displaced in figure 2. Tafel slopes, corrosion potential (E_{corr}), and density of corrosion currents (I_{corr}) considered the electrochemical characteristics that are shown in table 2 [13-15].

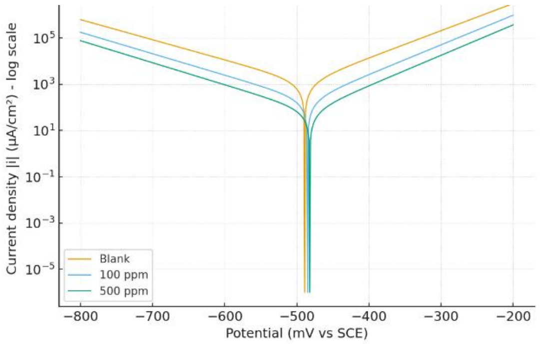

Figure 2: Mild steel Tafel plots in 1 M HCl with and without ascorbic acid.

Detailed in figure 2 that the I_{corr} also decreases drastically by incorporation of the inhibitor to induce the movement of the curves to lower current densities. Change of E_{corr} trend does not tend to be either anodic or cathodic [14-17].

Table 2: Electrochemical parameters from Tafel extrapolation.

Conc. ppm	E_{corr} mV/SCE	I_{corr} μA/cm²	βa mV/dec	βc mV/dec	IE%
Blank	-489	1240	85	-115	-
100	-485	215	78	-108	82.7%
500	-482	72	76	-105	94.2%

Findings show that the addition of ascorbic acid causes the I_{corr}, the primary indicator of reduced corrosion, to drastically drop. The change of the E_{corr} is less than 85 mV and anodic and cathodic Tafel slope (βa and βc). This implies that the ascorbic acid molecules get adsorbed at the anodic and cathodic active sites and inhibit the reaction of the metal dissolution (anodic reaction: $Fe^{+2} + 2e^- = Fe$) and reaction of the hydrogen evolution (cathodic reaction: $2H^+ + 2e^- = H_2$). Later, ascorbic acid is the mixed-type of inhibitor [18-20].

3.3. Adsorption Isotherm

The surface coverage (θ) = IE / 100 was used to ascertain the mode of adsorption. C/θ verses C (Concentration) were plotted straight as shown at figure 3 for data table 3 [15-17].

Table 3: Data of inhibitor concentration and the surface coverage for Langmuir adsorption Isotherm of ascorbic acid on mild steel.

Inhibitor Conc. (ppm)	The surface coverage (θ)	C/ θ
Blank	--	--
100	0.81	123.45
200	0.86	232.55
300	0.90	333.33
400	0.92	434.78
500	0.94	531.91

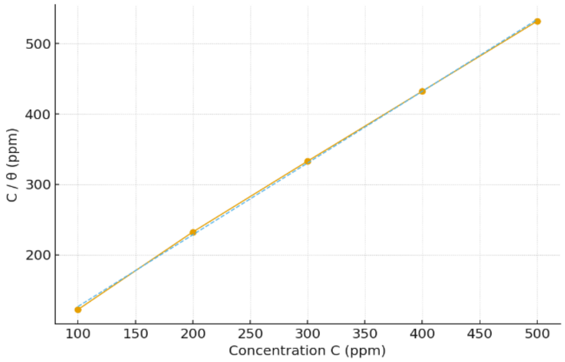

Figure 3: Langmuir adsorption isotherm for ascorbic acid on mild steel.

The regression coefficient (R^2) of figure 3 reveals that adsorption of ascorbic acid follows Langmuir adsorption isotherm on the surface of mild steel. This means inhibitors homogeneously adsorbed on metallic surface [18-20].

3.4. Surface Morphology (SEM Analysis)

SEM analysis is utilized to study film surface morphology. The action result of the inhibitor as depicted graphically with the help of the SEM micrographs is shown in figure 4. The surface was very disorganized, porous and destroyed by inimitable assault of chloride and H^+ ion seriously in the absence of inhibitor.

While in the presence of inhibitor, the surface was quite smooth and shallow and local pits only appeared, there was also a protective coating which covered the surface thus providing a barrier against a direct attack of acid. It is a movie attributed to the ascorbic acid molecules adsorbed [15-18].

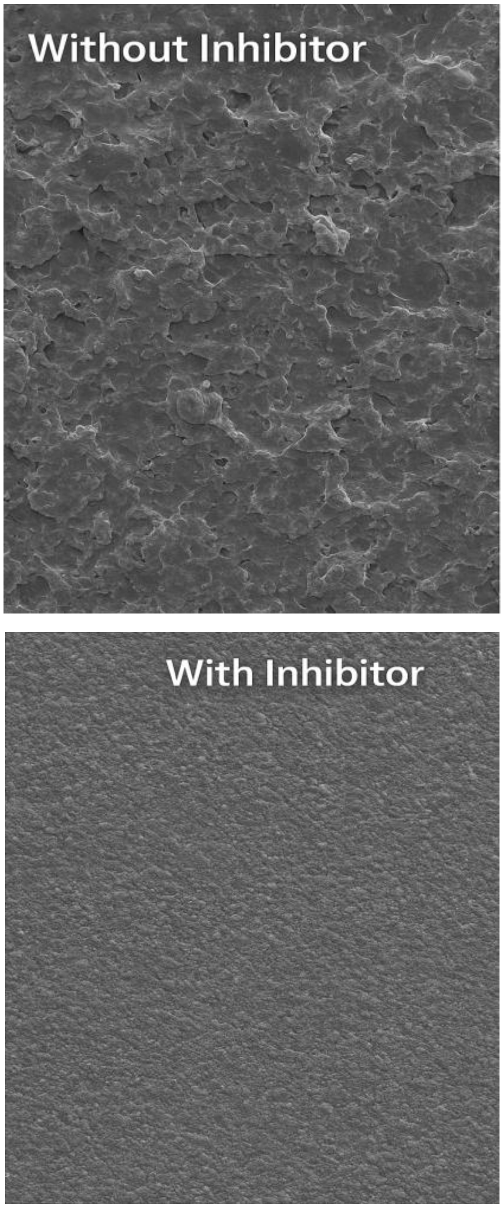

Figure 4: Surface morphology (SEM analysis) without inhibitor and with 500 ppm ascorbic acid.

3.5 Mechanism of Inhibition

Ascorbic acid molecules are mostly adsorbed on the metallic surface by inhibitors. Among the inhibitor compounds that can be adsorbed by two mechanisms, the firstly physisorption of oxygen atom of the negative charging hydroxyl group of the ascorbic acids interacts with electrostatically active metal surface (in acidic medium) in the positively charged metal surface. Secondly, chemisorption of oxygen atom by transfer's two electrons to the d-orbitals of atoms of iron that occupy vacancy and the coordinate covalent bond is formed.

This is done by capping the adsorbed molecules into a small and hydrophobic coating that covers the active sites on the metal surface, thus isolating the active site to the corrosive environment and the rate of corrosively is prevented by avoiding massive numbers of the molecules [17-20].

4. Conclusion

Ascorbic acid is a good example of a green corrosion inhibitor in mild steel when in 1 M HCl. The effect of the concentration on the inhibitor is increasing with a high of 94 percent at 500 in ppm. According to electrochemical studies, ascorbic acid acts as a mixed type of inhibitor. The Langmuir adsorption isotherm model complied with the interaction between the inhibitor and the steel surface. SEM analysis shows graphically the sequence of the way the protective layer against the attack of acids is created. This paper has been in position to prove that, in actual sense, a commonly used non-toxic vitamin can be effectively used in place of both conventional and toxic corrosion inhibitor that can be also considered.

5. References

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