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Study the Effect of "Di-dodecyl amine" as a Corrosion Inhibitor for Carbon Steel in HCl Medium

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Abstract

Numerous organic compounds have been investigated for their potential to reduce corrosion under various circumstances. This study investigated the effects of di-dodecyl amine, an organic chemical, on carbon steel metal corrosion at different temperatures while HCl acid was present. The examination was carried out using accepted methods for polarization, weight loss, and corrosion process testing. The obtained findings demonstrated that the corrosion rate reduces with increasing inhibitor concentration, leading to increased inhibition efficiency. Furthermore, as shown in the weight loss technique, the corrosion rate lowers with increasing surface coverage with organic inhibitor at 313 °C. In the anodic and cathodic polarization methods, as well as in the inhibition efficiency, it is observed to see the cathodic and anodic curves through which the occurrence of the potential and corrosion current is known. The current and corrosion potential decreases with increasing inhibitor concentration. The amines and methyl motiveless in this inhibitor's composition give it their efficacy since they may coat the metal surface and stop corrosion.

Keywords: Di-dodecyl amine, weight loss, corrosion rate, inhibition, polarization, carbon steel.

1. Introduction

One major problem that many organizations face is metal corrosion. Consequently, a great deal of money is being spent by scientists and engineers on corrosion research, with an emphasis on methods to protect metals against corrosion as well as metal corrosion behavior under various conditions [1–6]. Carbon steel is considered one of the most widely used metals in many industries for various purposes because of its cheapness, excellent mechanical qualities, strength, stability in the environment, low weight, and high thermal and electrical conductivity. Sulfuric acid is used for industrial cleaning, acid cleaning, and removal of acid deposits. It is also more economical and effective.

One of the main industrial challenges is preventing metal corrosion; moreover, it may be able to use inhibitors to stop metal corrosion in acidic environments [7–10]. There are several documented uses for both organic and inorganic materials as corrosion inhibitors. Because these compounds include heteroatoms in their long-chain structure, they offer anti-corrosive properties [11–15]. Because these inhibitors are harmful, there are often hazards to human health and the environment when employing them, which is one of the main problems. They are also quite expensive. Numerous authors [16–19] have reported that a few naturally occurring chemicals could stop metal corrosion in a variety of strong acids, aiding in the management of corrosion assaults.

Metal corrosion is a severe issue that arises in many facets of daily life. This has detrimental effects on that. As a result, researchers and scientists have endeavored to give research studies that specifically address metal corrosion behavior in various settings. In this research, inhibitors were used due to the lack of effective methods and techniques available at the present time to shield metals against corrosion, which may cause major damage and abnormalities, and to preserve them [13–19]. The chemical formula for the organic molecule "di-dodecyl-amine" is $[CH_3(CH_2)_{11}]_2NH$, making it a secondary amine. To ascertain its effectiveness and capacity to prevent corrosion, it was employed in this study as an inhibitor of corrosion.

2. Experimental work

The test solution synthesis process involved the addition of double-distilled water diluted with 1M hydrochloric acid. Polished mild steel samples, measuring 3.5 × 2.5 × 0.2 cm each, were physically pressed into different coupons to be tested for corrosion. Following the acetone cleaning, distilled water rinsed the metal surface, and it was then preserved in a desiccator.

2.1 Weight loss technique

Metal corrosion rates have been measured and determined using weight loss technologies. The carbon steel sample was immersed in volume 100 ml of 1 M hydrochloric acid solution at different temperatures of 313, 323, and 333 K without and in the presence of a corrosion inhibitor for a period of 6 hours. These samples were cleaned of grease with acetone and washed with Distilled water and dried [5-9].

$$C.R = 87.6 \times W / D.A.T$$

Where A is the sample area (cm2), T is the time (hour), W is the weight loss (mg), D is the sample density (gm/cm3), and C.R. is the rate of corrosion (millimeter per year, mmpy). Equations following were used to compute the inhibitory effectiveness (% IE) and degree of surface covering (θ) [8-11].

$$IE\,\% = [W1-W2] / W1 \times 100$$
$$\theta = [W1-W2] / W1$$

W1 and W2, respectively, represent the corrosion rates when the inhibitor is present and absent.

2.2 Polarization technique

After the carbon steel samples were washed in 1 M hydrochloric acid, for 30 minutes, dynamic polarization was performed with variable inhibitory concentrations 100-600 ppm. By connecting a standard calomel electrode, a carbon steel working electrode, and a platinum electrode in the cell for laboratory experiments. Polarization curvatures were discovered because of polarization research. By calculating a cathodic and anodic curve, one may determine the density of corrosion current prior to adding the inhibitor as well as the prospective corrosion current density following the addition of the inhibitor. The following calculation was also used to compute the corrosion rate.

$$\eta\,\% = (Icorr\ w - Icorr\ I \ / \ Icorr\ w)\ *100$$

(Icorr) w and (Icorr) i, denote the corrosion current density without and with inhibitor. The results show the differences in anodic and cathodic polarization [5-10].

3. Results and Discussions

3.1 Weight loss method

After six hours of immersion, experiments on weight loss at three distinct temperatures 313, 323, and 333 K were carried out to examine the impact of different concentrations of (Di-dodecyl-amine) on the rate of corrosion on carbon steel in a 1M solution of HCl tables 1-3 display the corrosion rate (C.R) and inhibitory efficiency (% IE) attained using the weight reduction technique. The outcomes demonstrated that chemical component above inhibits corrosion more effectively at low concentrations as well as that the rate of corrosion is proportional to the inhibitor concentration [4-9].

Table 1: Carbon steel corrosion characteristics in 1M HCl at 313 K in existence and absence of several amounts of (Di-dodecyl amine).

Conc. of inhibitor ppm	Weight loss mg	Rate of Corrosion mmpy	Efficiency of inhibition % E	Surface coverage Θ
blank	1077	252.41	-----	------
100	685	154.33	36.4	0.36
200	567	135.40	47.3	0.47
300	501	115.91	53.4	0.53
400	442	95.11	58.9	0.58
500	294	64.47	72.7	0.72
600	223	47.44	79.3	0.79

Table 2: Carbon steel corrosion characteristics in 1M HCl at 323 K in existence and absence of several amounts of (Di-dodecyl amine).

Conc. of inhibitor ppm	Weight loss mg	Rate of Corrosion mmpy	Efficiency of inhibition % E	Surface coverage Θ
blank	1356	310.70	-----	----
100	945	220.58	30.3	0.30
200	781	183.46	42.4	0.42
300	679	160.85	49.9	0.49
400	562	130.17	58.5	0.58
500	422	100.56	68.8	0.68
600	387	92.52	71.4	0.71

Table 3: Carbon steel corrosion characteristics in 1M HCl at 333 K in existence and absence of several amounts of (Di-dodecyl amine).

Conc. of inhibitor ppm	Weight loss mg	Rate of Corrosion mmpy	Efficiency of inhibition % E	Surface coverage Θ
blank	1623	390.43	-----	----
100	1211	277.71	25.3	0.25
200	1080	260.22	33.4	0.33
300	915	210.66	43.6	0.43
400	801	181.43	50.6	0.50
500	630	140.02	61.1	0.61
600	544	126.90	66.4	0.66

With a rise in inhibitor concentration, molecules of inhibitor are adsorbed on the carbon steel surface, increasing its surface area, and impeding the transfer of mass and charge. As the concentration of the inhibitor rises, its inhibitory effectiveness (% IE) falls as the temperature rises. Additionally, the better the reaction site and reaction protection, the greater surface area covered. by molecules adsorption on the metal's surface, the relationship between inhibitor concentration and variations in corrosion rate and inhibition efficiency at 313, 323, and 333 K is depicted in figures 1, and 2 [6-13].

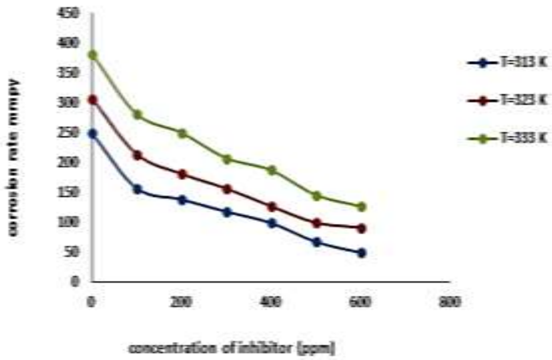

Figure 1: Relationship between carbon steel corrosion rate and inhibitor concentration in different temperatures and Di-dodecyl amine concentrations in a solution of 1M HCl.

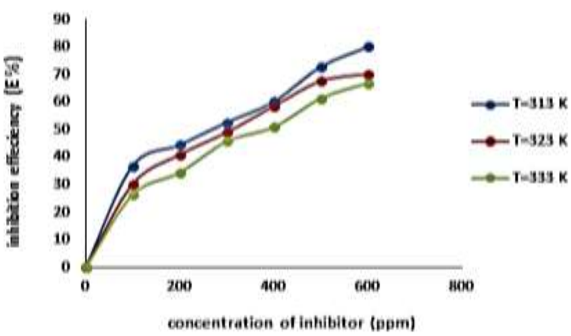

Figure 2: Correlation between an inhibitor's concentration and efficiency in carbon steel at 1M HCl at different temperatures and (di-dodecyl amine) concentrations.

3.2 Effect of temperature

Di-dodecyl amine was dissolved in 1M HCl and the effect of this solution on carbon steel was observed over a six-hour period at three different temperatures (313, 323, and 333 K). The results are shown in figure 2, and table 4 demonstrate that molecules of inhibitor adsorb on the surface of the metal at all investigated temperatures and that the efficiency of inhibition declines with rising temperature. The temperature at which metal corrosion occurs in acidic environments frequently rises in tandem with the formation of H_2 gas. This typically speeds up the processes of corrosion, which increases the pace at which metal dissolves. As the test solution's temperature rises, inhibition efficiency decreases [4-8].

3.3 Isotherm of Adsorption

The growth of the isotherm of adsorption sheds some light on the mechanism of preventing corrosion on metal surfaces. Adsorption and isotherm methods were used to study the inhibitor chemical interactions with metallic surfaces. The experimental results are consistent with the Langmuir's adsorption isotherms, a basic isotherm that describes the adsorption process for inhibitor at 313, 323, and 333 K. To study the Langmuir adsorption isotherm, use the following equation [6-10].

$$C / \theta = (1/ K_{ads}) + C$$

The symbols C stand for the inhibitor concentration, K_{ads} for the adsorption coefficient, and θ for the surface coverage.

Figure 3 plots of C/θ and C show a straight path with a slope of roughly one, indicating Langmuir adsorption. Each inhibitor molecule replaces the H_2O molecules that cover the carbon steel surface in the acidic solution, demonstrating that each adsorption site includes one adsorbate amines and methyl molecule. At all temperatures. The practical unity values of the regression line coefficient (R_2) suggest that the adsorption behavior adhered to the adsorption Langmuir isotherms. The adsorption equilibrium constant was used to calculate the free energy of adsorption, or ΔG_{ads}, using the following equation [6-9].

$$\Delta G_{ads} = -2.303.R.T.Log\ [55.5K_{ads}]$$

Where the universal gas constant is R, and the absolute temperature, T.

Nevertheless, ΔG_{ads} values of about 40 KJ/mol denotes to a coordinated kind of interaction between inhibitor compounds and metals. Gads value up to 20 KJ/mol frequently reflect physical adsorption that is the electrostatic attraction between charge molecules of inhibitors and charged metal. $G_{ads's}$ value indicates the limited adsorption capacity. The negative readings of ΔG_{ads} indicate that the inhibitor molecule adsorb naturally on the metal surface [9-12]. According to table 4, the average slope of the intersection of the Langmuir curves is 0.0049 l/g. This proves that each inhibitor molecule has one active site on the metal surface. Table 4 shows the values of ΔG_{ads}, which increase with increasing temperature. These results show that the molecules are adsorbed by physical adsorption on the metal surface, while a negative value of ΔG_{ads} means spontaneous adsorption [10-13].

Table 4: Show relation ΔG_{ads} values with Temperature and K_{ads}

Temperature K	K_{ads}	Slope	$-\Delta G_{ads}$ kJ /mol
313	0.0058	0.951	4.131
323	0.0049	1.043	4.603
333	0.0042	1.030	4.849
average	0.0049	1.008	4.536

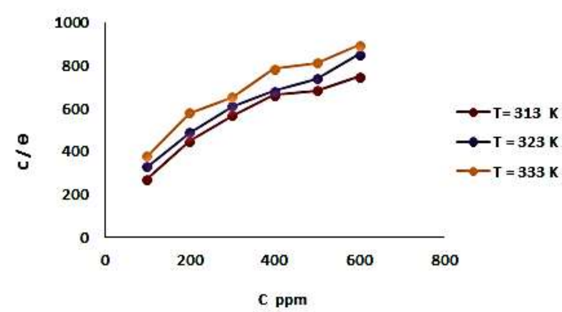

Figure 3: Relationship between the plot Different quantities of (Di-dodecyl amine) were adsorbed using Langmuir adsorption isotherms on carbon steel in 1M HCl in a range of temperatures for six hours.

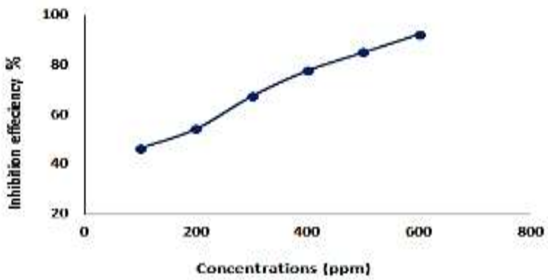

Figure 4: Efficiency of inhibition: Carbon steel inhibitor concentration curve in HCl solution at 313 K.

3.4 Polarization Measurement

The inhibitor covers the metal in a film layer, protecting it from the environment. The polarization curve shifts with increasing inhibitor concentration, decreasing corrosion current and potential, and increasing efficiency, as table 5 illustrates [6-12].

Table 5: Corrosion characteristics: inhibition efficiency, potential, and density of current corrosion.

Concentration of inhibitor ppm	Potential E_{corr}, mV	Corrosion current density $\mu A/cm^2$	efficiency of inhibition %
Blank	-455	148.52	--
100	-408	98.43	33.37
200	-373	63.14	57.48
300	-368	51.89	65.06
400	-361	40.38	72.81
500	-342	33.87	77.19
600	-312	24.66	83.39

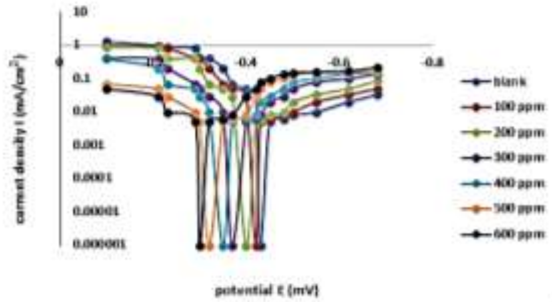

Figure 5: Polarization curves, the relationship between current density and potential at varying inhibitor concentrations.

4. Conclusions

Two methods of testing corrosion processes were used to evaluate the organic compound inhibitor di-dodecyl amine on carbon steel metal in HCl acid at different temperatures are polarization and weight loss. The rate of corrosion lowers as inhibitor concentration increases. Surface coverage rises with organic inhibiting agents at 313 °C, like the weight loss process. An increase in inhibition efficiency is also shown in the corrosion potential and current are measured using anodic and cathodic curves, since the amount of the inhibitor falls with rising current and corrosion potential. Given that the corrosion potential and current drop as the inhibitor concentration rises. This inhibitor works by forming a coating on the surface of the metal to prevent corrosion; it is made effective by the methyl and amine molecules that make up its makeup.

5. References

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