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## Corrosion inhibition of mild steel in 0.5N HCl by using cocodiethanolamide

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### Abstract

Corrosion engineering is the application of science and art to prevent or control corrosion damage economically and safely. A corrosion must be well versed in the practices and principles of corrosion, the chemical, metallurgical, physical and mechanical properties of materials; corrosion testing; the nature of corrosive environments; the availability and fabrication of material; computer and design etc to perform their function properly. Percentage inhibition efficiency of CDEA as corrosion inhibitor at various concentrations (50, 100, 150, 200, 250, 300 and 350ppm) in 0.5M hydrochloric acid solution was determined by weight loss method at temperature 25°, 35° and 45°C. In addition of this, the micrographs of mild steel samples in 0.5N HCl solution with and without the optimal concentration of the CDEA as corrosion inhibitor were obtained at different temperatures. Results obtained from weight loss experiments show that CDEA acts as excellent corrosion inhibitor for mild steel in hydrochloric acid.

**Keywords:** Corrosion engineering, economically and safely

### 1. Introduction

Corrosion represents a tremendous economic loss and much can be done to reduce it. Estimate of annual cost of corrosion in the United State vary between \$8 billion and \$ 126 billion. According to the Wall Street Journal, cost of oil and gas producers is nearly \$2 billion. Costs are increasing because of deeper wells and more hostile environment- higher temperature and corrosive sulfur gases. Corrosion of bridges is a major problem as they age and require replacement, which costs billions. Proper design and use of Cathodic protection reduces costs substantially. One large chemical company which spent a more than \$ 400,000 per year for corrosion maintenance in its sulfuric acid plants, even though the corrosion condition were not considered to be particularly severe. Another spend \$ 2 million per year on painting steel to prevent rusting by a marine atmosphere. Corrosion touches all-inside and outside the home, on the road, on the sea, in the plant, and in aerospace vehicles.

Today annual costs of floods, hurricanes, tornadoes, fires, lightning and earthquakes are less than the costs of corrosion. Costs of corrosion will escalate substantially during the next decade because of worldwide shortage of construction material, higher energy costs, aggressive corrosion environments in coal conversion processes, large increase in numbers and scope of plants and other factors production of metals used for corrosion resistance and to replace corroded parts require large amount of energy thus compounding the nation's energy problem.

Infact, our economy would be drastically changed if there were no corrosion. For example, automobiles, ships, underground pipelines and household's appliances would not require coatings. Most metallic plants, as well as, consumer products, would be made of steel or cast iron. Although corrosion is inevitable, its cost can be considerably reduced. For example, an inexpensive magnesium anode could double the life of a domestic hot water tank. Washing a car to remove deicing salts is helpful. Acidic solutions can reduce the rate of the corrosion in mild steels. Corrosion engineer has primary function to combat corrosion.

The most common form of corrosion is aqueous metallic corrosion in which the material is a metal or metal alloy and the environment (corrodent) is an aqueous solution. In daily life, such corrosion is present in various forms: corroded nails, tools, reddish-orange spots in car bodies, leaking hot-water tanks, murky potable water are common examples.

The economic cost of corrosion is enormous, and has been estimated to be in the range of 2-5% of an industrialized country's gross national product.

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In addition to these direct costs, there are also indirect costs associated with plant shutdown, lower efficiency of equipment, contamination and overdesign. Parts and labor to replace corroded equipment are often minor compared to the loss of production while the plant is non-operational. Thus leaks in pipelines and tanks result in loss of costly products and these leaks can also pose a serious environmental problem. Accumulation of undesirable corrosion products on heat exchanger tubing and pipelines decreases the efficiency of heat transfer and reduces pumping capacity. Soluble corrosion products can contaminate a system and decontamination is costly.

In the absence of adequate corrosion rate information (metal weight loss/ unit area / unit time) overdesign (e.g., thicker tube wall) is required to ensure reasonable service life. This leads to waste of resources and, for moving parts, greater power requirements.

Corrosion engineering is the application of science and art to prevent or control corrosion damage economically and safely.

Element	C	Si	Mn	S	P	Ni	Cu	Cr	Fe
Weight%	0.16	0.03	0.32	0.05	0.20	0.01	0.01	0.01	Balance

Density of mild steel = 7.88 gm/cm<sup>3</sup>

Area = 0.6976 inch<sup>2</sup>

Time = 48 Hrs.

## 2.2. Sample preparations

For weight loss measurements, mild steel specimens of 3.0 X 1.5cm size were cut from the sheet. All the specimens were mechanically polished successively with the help of emery papers of grades 150, 330 and 600 and then thoroughly washed with double distilled water and then with acetone. The specimens were dried and stored in desiccators over silica gel. The acidic solution used was of 0.5N concentration and prepared by using double distilled water. The concentration range of CDEA, the inhibitor employed was 50 to 350 ppm in acid.

## 2.3. Techniques employed

Experiments were carried out by using the following techniques.

### 1. Weight loss techniques

After recording the initial weights of carbon steel specimens, they were immersed in tilted position in 250ml beaker having 200ml of 0.5N hydrochloric acid solution as corroding medium with or without the inhibitor. Experiments were carried out in an electronically controlled air thermostat at temperature 25°, 35° and 45°C with an accuracy of  $\pm 1^\circ\text{C}$ . After exposing the specimens for 48 hours, the specimens were taken out from the beaker and washed with water. Loosely adhering corrosion products were removed by rubbing the specimen surface with rubber cork and the specimen was again washed thoroughly with distilled water and dried and then weighed again. Corrosion rate in mils per year (mpy) and percentage inhibition efficiency were calculated using the following equations.

### 2. Scanning Electron Microscopy Techniques (SEM)

To study the growth kinetics of corrosion formed on mild steel samples in 0.5N hydrochloric acid. Samples of mild steel having dimension 3.0 X 1.5cm were cut from carbon steel sheet and the specimens were mechanically polished successively with the help of emery paper of grades 150, 320 and 600 and then thoroughly washed with water and acetone.

A corrosion must be well versed in the practices and principles of corrosion, the chemical, metallurgical, physical and mechanical properties of materials; corrosion testing; the nature of corrosive environments; the availability and fabrication of material; computer and design etc to perform their function properly.

## 2. Experimental

The normality and strength of Hydrochloric acid vary in industries. So, they have variable effects of corrosion. In order to overcome this problem hydrochloric acid of 0.5N strength is prepared. Hydrochloric Experiments were planned carefully for measuring the inhibitor. Utmost care was taken to check the consistency of the data by carrying out duplicate, in some cases even triplicate experiments.

### 2.1. Materials

Carbon steel used for investigations was in the form of sheet (0.25mm thick) and had the following composition.

The specimens were dried and stored in desiccators over silica gel until exposed to 0.5N hydrochloric acid with and without inhibitor. The samples were removed after 48 hrs. and morphology of specimens was studied under metallurgical research microscope attached with a computer and the micrograph were taken.

This technique was also used to study the morphology of the corroded specimen of the mild steel exposed to 0.5N hydrochloric acid for 48 hrs at 25°, 35° and 45°C with and without corrosion inhibitors. The comparison of micrographs of the corroded specimens with and without corrosion inhibitors clearly gave an idea about the effectiveness of the corrosion inhibitor.

## 3. Results and Discussion

Cocodiethanolamide (CDEA) has been studied and described as corrosion inhibitor to control the corrosion of mild steel in 0.5N hydrochloric acid. Effectiveness of a corrosion inhibitor depends upon the efficiency with which it control either the electrolytic reactions like hydrogen evolution, oxygen electronation reactions etc. or is bounded to the metal surface through adsorption. Adsorption of organic compounds to the electron sink areas (deelectronation sites) usually involves compounds with excess of electrons or unshared pairs of electrons. These include aliphatic, aromatic or aliphatic aromatic amines, sulphur containing compounds, oxygen containing compounds. Several proposed mechanism exists for the adsorption efficiency of these derivatives, most of which involve pi cloud bonding capability of electron rich heteroatom of organic compounds.

Percentage inhibition efficiency of CDEA as corrosion inhibitor at various concentrations (50, 100, 150, 200, 250, 300 and 350ppm) in 0.5M hydrochloric acid solution was determined by weight loss method at temperature 25°, 35° and 45°C and have been recorded in Table 3.1.1,3.1.2,3.1.3 respectively. Percentage inhibition efficiency against concentration of CDEA at various temperatures 25°, 35° and 45°C in 0.5M hydrochloric acid solution has been plotted in Figure3.2.1. Inhibition efficiency increases with increase in

concentration of CDEA.

It provides 97.17 percent corrosion inhibition efficiency at a concentration of 350ppm at 35°C. Percentage inhibition efficiency of CDEA versus solution temperature for various concentrations (50, 100, 150, 200,250,300 and 350ppm) has been plotted in Figure 3.2.2. It is evident from the data and figure that inhibition efficiency increases when the temperature is increased from 25° to 35°C and inhibition efficiency decreases when the temperature is increased from 35° to 45°C.

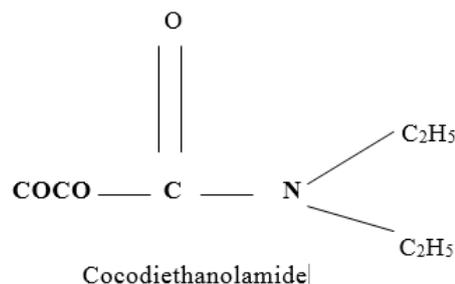
According to table 3.1.1, 3.1.2, 3.1.3 corrosion rate decreases with the increase in the percentage inhibition efficiency (PIE). According to Fig. 3.2.1, as we increase the concentration of inhibitor (CDEA), the corrosion rate decreases and percentage inhibition efficiency increases. According to Fig. 3.2.2, as the temperature increases, P.I.E changes. The P.I.E. at 35°C show better results than 25°C while P.I.E. decrease at 45°C as compared to 35°C. This is due to slow rate of adsorption by corrosion inhibitors on mild steel samples at 45°C.

Secondly, the micrographs of mild steel samples in 0.5N HCl solution with and without the optimal concentration of the CDEA as corrosion inhibitor were obtained at different temperatures. These micrographs show the effectiveness of the corrosion inhibitors by the studying the surface morphology.

We observed that as we increase the concentration of corrosion inhibitors at different temperature, micrographs show the decreasing level of corrosion or less decay of mild steel sample surfaces. This effectiveness is due to adsorption of corrosion inhibitor on the surface of mild steel sample as CDEA forms a protective layer on the surface and decreases the rate of decay of metal surface by putting a barrier layer between metal and environment.

The phenomenon of higher concentration of any molecular species at the surface than in the bulk of a solid is known as adsorption. Solids have a large surface area and therefore, show this property to a large extent. Adsorption type inhibitors represent the largest class of inhibiting substances. In general, these are organic compounds which adsorb on the metal surface and suppress metal dissolution and reduction reactions. In most cases, it appears that adsorption inhibitors affect both the anodic and cathodic processes. Typical of this class of inhibitors are the organic amines.

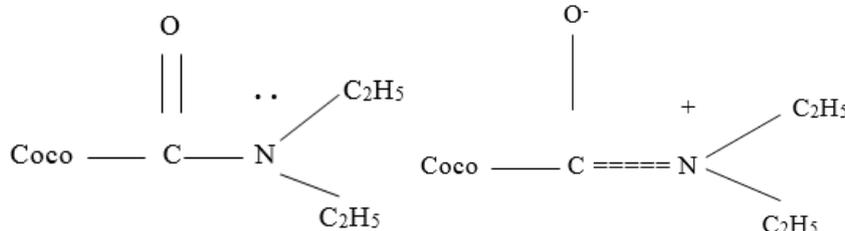
The structure of CDEA is given as



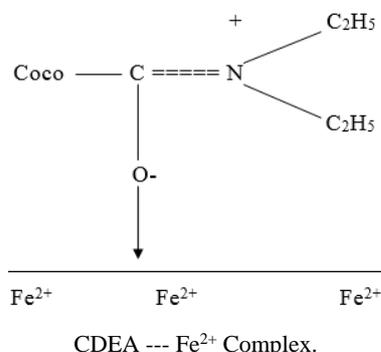
Where Coco group is having the following composition.

- C<sub>12</sub> (Lauric acid) 46-50%
- C<sub>14</sub> (Myristic acid) 17-20%
- C<sub>16</sub> (Palmitic acid) 8-10%
- C<sub>8</sub> (Caprylic acid) small amount.
- C<sub>10</sub> (Capric acid) Small amount.
- C<sub>11</sub> (Oleic acid) Small amount.

The resonating structure of CDEA is as following



The resonating structure of CDEA is much stable as the positive charge density is alternated by +I effect of the ethyl group. CDEA form Fe<sup>2+</sup>--- CDEA complex with iron atom with its carbonyl oxygen in following manner



It results in the formation of adsorbed layer of inhibitor molecule on the surface of mild steel protecting it from corrosion.

Optical micrograph in Figure 3.3.1, 3.3.2 and 3.3.3 shows the morphology of the mild steel specimen s immersed for 48 hours in 0.5N Hydrochloric acid solution in absence and presence of 50, 150, 200, 250, 300 and 350ppm of CDEA at 25°C, 35°C and 45°C. Mild steel specimen has been damaged appreciably and pits were formed in 0.5N hydrochloric acid in the absence of inhibitor at 25°C however in presence of CTMAC, a significant protection is provided to mild steel sample at 25°C. Similar results were also shown at 35°C and 45°C. The protective film present on the surface of mild steel in presence of CDEA appears to be very smooth and covering the steel surface almost completely.

**Table 3.1.1:** Percentage inhibition efficiency of CDEA in 0.5N hydrochloric acid by weight loss method at 25<sup>0</sup> C.

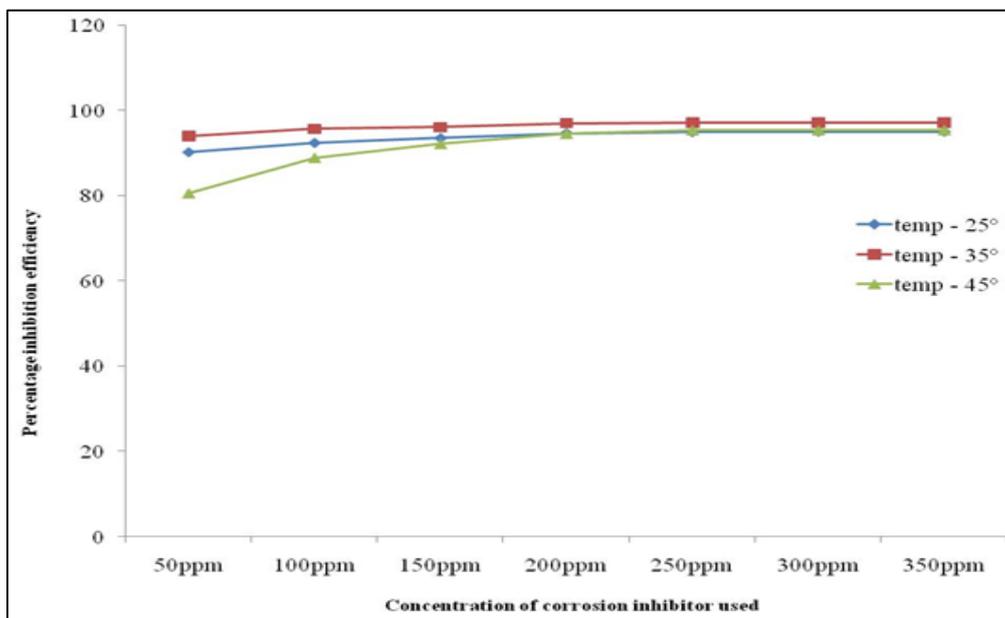
S. No	Initial weight of sample(mg)	Inhibitor conc.	Wt. of sample after 48 hours	Wt. Loss	Corrosion rate	% inhibition efficiency
1	708.1	O	590.1	118.0	238.8	00
2	735.0	50ppm	723.4	11.6	23.47	90.17
3	672.2	100ppm	663.2	9.0	18.21	92.37
4	683.4	150ppm	675.8	7.6	15.38	93.5
5	732.4	200ppm	726.1	6.3	12.75	94.66
6	613.2	250ppm	607.2	6.0	12.14	94.9
7	725.2	300ppm	719.3	5.9	11.94	95.0
8	675.8	350ppm	670.0	5.8	11.73	95.0

**Table 3.1.2:** Percentage inhibition efficiency of CDEA in 0.5M hydrochloric acid by weight loss method at 35<sup>0</sup>C.

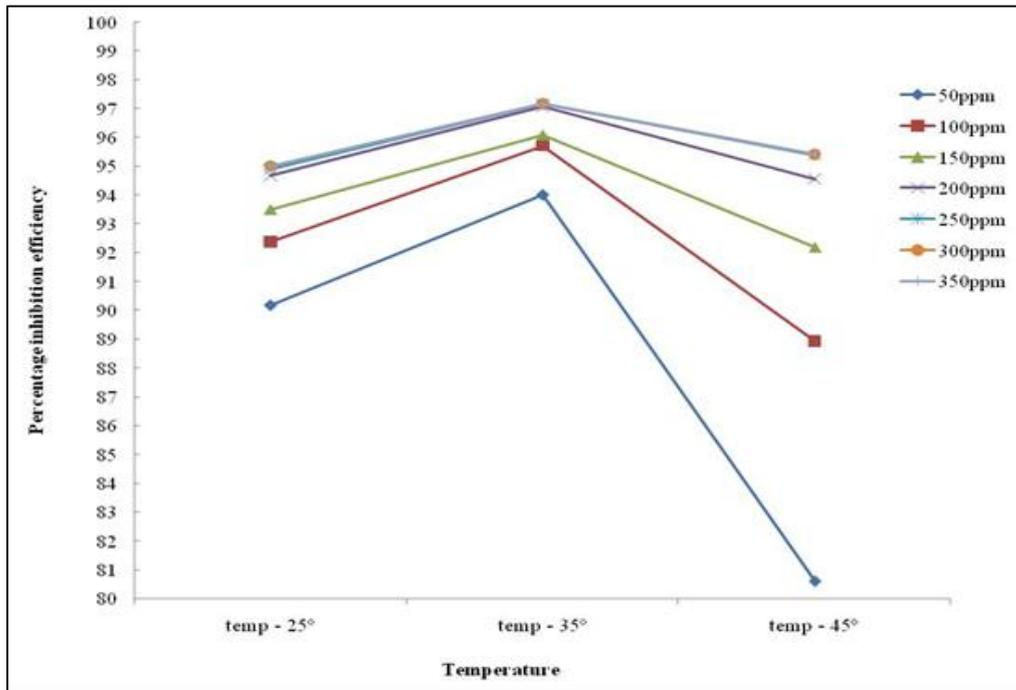
S. No	Initial wt. Of Sample (mg)	Inhibitor conc.	Wt. Of sample after 48 hours	Wt. Loss	Corrosion rate	% inhibition efficiency
1	694.9	O	270.3	424.6	859.3	00
2	731.8	50ppm	706.3	25.5	51.606	93.99
3	678.3	100ppm	660.1	18.2	38.833	95.7
4	703.0	150ppm	686.4	16.6	33.59	96.09
5	725.6	200ppm	713.2	12.4	25.095	97.07
6	714.9	250ppm	702.8	12.1	24.487	97.15
7	675.3	300ppm	663.2	12.1	24.487	97.15
8	700.1	350ppm	683.1	12.0	24.285	97.17

**Table 3.1.3:** Percentage inhibition efficiency of CDEA in 0.5M hydrochloric acid by weight loss method at 45<sup>0</sup>C.

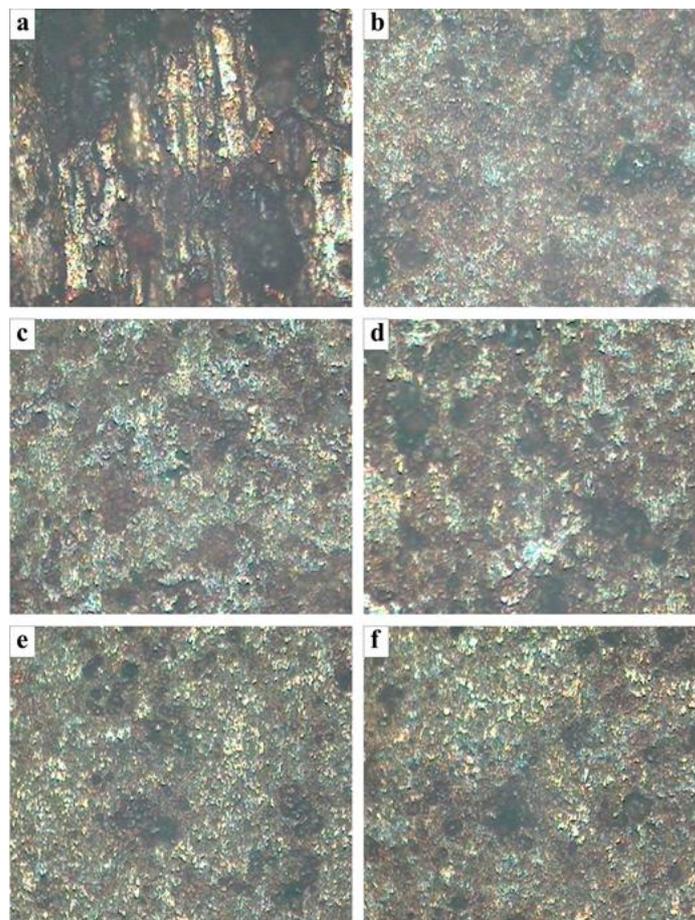
S. No	Initial wt. Of sample(mg)	Inhibitor conc.	Wt. Of sample after 48 hours	Wt. Loss	Corrosion rate	% inhibition efficiency
1	720.6	O	200.4	520.2	1052.78	00
2	720.0	50ppm	619.1	100.9	204.20	80.6
3	685.4	100ppm	627.8	57.6	116.57	88.92
4	714.1	150ppm	673.5	40.6	82.17	92.19
5	701.3	200ppm	673.0	28.3	57.27	94.56
6	694.5	250ppm	670.5	24.0	48.57	95.39
7	695.5	300ppm	671.6	23.9	48.36	95.40
8	715.9	350ppm	692.1	23.8	48.16	95.42



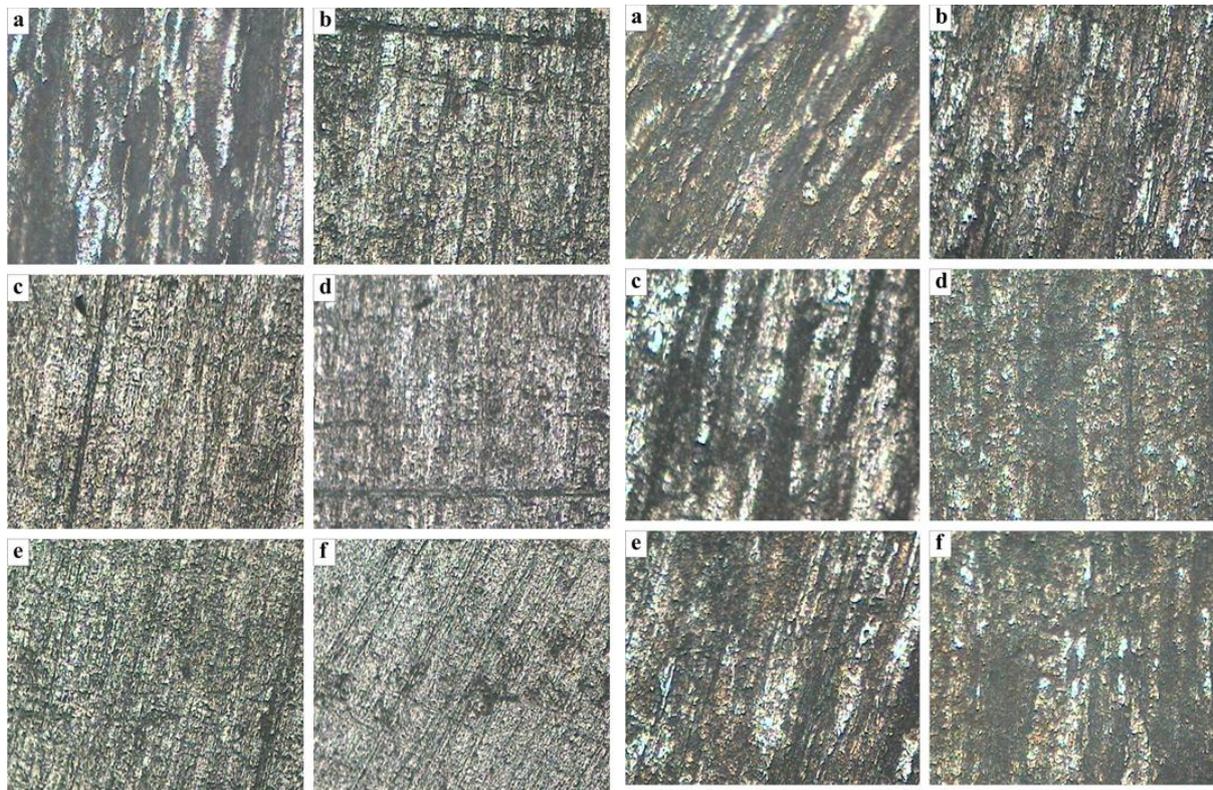
**Fig 3.2.1:** Variation of Inhibition efficiency with CDEA concentration for 50-350 ppm of CDEA at various temperature (25<sup>0</sup>C, 35<sup>0</sup>C and 45<sup>0</sup>C).



**Fig. 3.2.2:** Variation of inhibition efficiency with solution temperature in 0.5N HCl for 50-350 ppm concentration of CDEA.



**3.3.1 Micrographs recorded at 25°C without and with the presence of corrosion inhibition at different conc. (a) at 0ppm(blank), (b) at 50ppm, (c) at 100ppm, (d) at 150ppm, (e) at 200ppm, (f) at 250ppm.**



**3.3.2 Micrographs recorded at 35°C without and with the presence of corrosion inhibition at different conc. (a) at 0ppm(blank), (b) at 50ppm, (c) at 100ppm, (d) at 150ppm, (e) at 200ppm, (f) at 250ppm.**

**3.3.3 Micrographs recorded at 45°C without and with the presence of corrosion inhibition at different conc. (a) at 0ppm(blank), (b) at 50ppm, (c) at 100ppm, (d) at 150ppm, (e) at 200ppm, (f) at 250ppm.**

### Conclusion

1. Corrosion inhibition efficiency increases with the increase in inhibitor concentration at all temperatures (25°, 35° and 45 °C) under study.
2. Corrosion inhibition efficiency of CDEA increases when the temperature is raised to 25 °C to 35 °C and after that inhibition efficiency decreases when temperature is raised from 35° to 45 °C
3. Results obtained from weight loss experiments show that CDEA acts as excellent corrosion inhibitor for mild steel in hydrochloric acid.
4. Morphology of corroded specimen surfaces further confirms the result obtained from weight loss experiments and the protective film present on the surface of mild steel in presence of CDEA appears very smooth and covering the steel surface almost completely.
5. The inhibition efficiency decreases when the temperature was increased from 35° to 45 °C due to desorption of inhibitor layer.

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