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Study of Corrosion Inhibition of Mild Steel in 0.01M HCl by Corrosion Inhibitors: A comparative Study

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Abstract : Mild steel is the raw material for the construction and fabrication of weapons and equipments. In order to study synergistic effect, various combinations of caffeine, acetamide and benzalkonium chloride (BKC) were investigated as corrosion inhibitors for mild steel. Corrosion rate and percentage inhibition efficiency of various combination of corrosion inhibitors(100,200,300 ppm of different concentration of caffeine, acetamide and benzalkonium chloride (BKC) in 0.01 M HCl) at two different temperature 298K and 318K by weight loss method, SEM. The results obtained revealed the value of inhibition efficiency decreases to a large rate in case of caffeine and acetamide but to a slight decrease in case of BKC with the increase in temperature. The protection of metals from corrosion is analyzed by technologies such as weight loss, Scanning Electron Microscope (SEM).
Keywords : Corrosion inhibitors, Caffeine, Acetamide, Benzalkonium Chloride.

Introduction

Corrosion of steel is the major form of corrosion, especially in acid solution [1].Mild steel is widely used in many industrial applications. In most of industrial processes, the acidic solutions are commonly used for pickling, industrial acid cleaning, acid descaling, oil well acidifying, etc. [2-6]. The aim of the present work is to study the behaviour of mild steel in 0.01N hydrochloric acid in the absence and presence of caffeine, acetamide, benzalkonium chloride (BKC) as a corrosion inhibitor for mild steel using weight loss method and SEM. Further the study also focuses on the inhibition mechanism based on the adsorption isotherms, activation and thermodynamic parameters obtained.

The main advantage of this acid over other acids in cleaning and pickling operations lies in its ability to form metal chloride, which is extremely soluble in aqueous medium, compared to sulphate phosphate and nitrate. The higher solubility of chloride salt causes the least polarizing

effect and does not hinder the rate of corrosion [7-8]. Various protective methods have been adopted; one of the frequently used measures is the use of organic compounds containing nitrogen, oxygen and sulphur atoms **[9-13]**.The use of organic compounds containing oxygen, sulfur and especially nitrogen to reduce corrosion attack on steel has been studied in some detail [14-16]. Unsaturated bonds and/or aromatic rings[17-19] . The compounds having the C,N group, electron donating groups, polar groups, and p electrons are reported to behave as effective inhibitors of mild steel in acid medium[20-22].

The adsorption of corrosion inhibitor depends mainly on physico-chemical properties of the molecule such as functional groups, steric factor, molecular size, molecular weight, molecular structure, aromaticity, electron density at the donor atoms and p-orbital character of donating electrons [23-27] and also on the electronic structure of the molecules [28-29]. Many studies have been made on the corrosion and inhibition of

steels in acid media [30-34]. In the present work, the electrochemical behaviour of mild steel in 0.01M HCl in the absence and presence of Caffine, BKC, Acetamidehas been investigated by weight-loss measurements and Scanning electron microscopy.

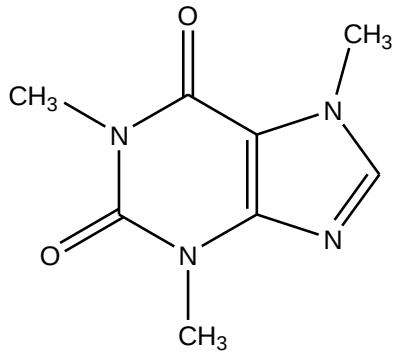
Experimental

Mild steel used for the investigation was in the form of sheet (0.25mm thick) and had the following composition. C, 0.14;Si, 0.03;Mn, 0.32; P, 0.02; Ni, 0.01; Cu 0.01; Cr, 0.01; Fe, balance(w/w)

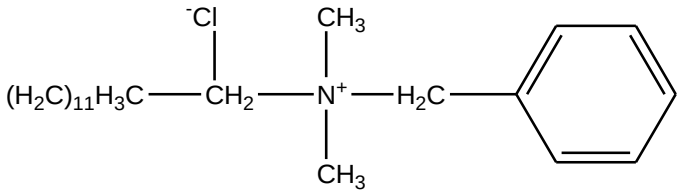
Sample Preparation:

For weight loss measurements, carbon steel specimen of 3cm x 2.0 cm size were cut from the sheet were used. All the specimens were mechanically polished successively with the help of emery papers of grades 80, 100, 220, 320 and 400 and then thoroughly washed with distilled water and then acetone.The specimen were dried and stored in a desicator over silica gel. All the chemicals used were of A.R. grade and solution were prepared using double distilled water,Duplicate or in some cases triplicate experiments have been performed to verify the experimental data.

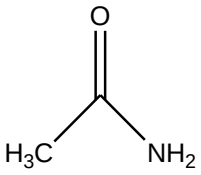
Table1: Name and structure of Corrosion Inhibitors



Caffine : Mol Wt. 194.19g/mol



Benzalkonium Chloride(BKC): Mol Wt. 283.88g/mol



Acetamide : Mol Wt. 59.07 g/mol

The following techniques are generally employed for investigating the inhibition action and mechanism of inhibitor action on the metal surface.

1. Weight Loss Technique
2. Scanning Electron Microscopy (SEM) Technique

Weight Loss Technique

After recording the initial weights of mild steel specimens, they were immersed in tilted position in 100 ml beaker having 80 ml of corroding solution as corroding medium with or without the inhibitor. After exposing the specimen for 24hours at 298K,308K and 318K, 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 wash thoroughly with distilled water, acetone and dried and then weighted again. Corrosion rate in miles per year (mpy) and percentage inhibition efficiency were calculated using the following equations.

Corrosion Rate (mpy) = $\frac{534 \text{ x } W}{DAT}$

Where W = weight loss (mg)D = Density of mild steelA = Area of specimen (sq. inch) T = Exposure time (hours)

Percentage inhibition efficiency = $\frac{B-A}{B}$ X 100

Where B = Weight loss in absence of inhibitor, A = Weight loss in presence of inhibitor

Scanning Electron Microscopy (SEM) Technique:

SEM is used for the study of surface of mild steel coupons to know the nature and type of corrosion. The micrograph of the corroded specimens were taken after exposure of 24 hours. Micrographs of the blank mild steel were also taken for the comparison study.

Results and Discussion

1.Weight Loss Technique

The value of weight loss (mg), corrosion rate (MPY) and percentage of corossion inhibition efficiency (PCIE) for all the three inhibitors are shown in Table 2 and Table 3 at temperature 25°C and 45°C.The temperature is thermostaticaly conrolled. The corrosion rate is found to be decreased. PCIE (percentage of corossion inhibition efficiency) of these three inhibitors are shown in figure 1 and 2 at temperature 25°C and 45°C respectively. It is clear from the figure 1 and 2 that PCIE of caffine is highest at 25°C and PCIE of BKC is highest at 45°C.

2. SEM Technique

SEM images of mild steel coupons treated with different inhibitors by weight loss method after exposure of 24 hrs at 25°C were shown in figure 3. Pits are visible in images of blank coupons of mild steel. But the image obtained after using the Acetamide is almost smooth.

Table 2 Weight loss, corrosion rate and percentage inhibition efficiency in 0.01 N HCl at 25^0C

VPCI	Concentration (ppm)	Weight loss (mg)	CR (mpy)	PCIE
Blank		10	0.8366	
Caffine	200 300	6.0 14.3	0.502 1.1964	40.00 43.00
Acetamide	200 300	7.15 6.8	0.5982 0.5689	28.5 32.0
BKC	200 300	9.8 14.1	0.8199 1.1797	20.00 41.00

Table 3 Weight loss in mg, corrosion Rate in mpy and percentage inhibition efficiency in 0.01 N HCl at 45^{0}C

VPCI	Concentration (ppm)	Weight loss (mg)	CR (mpy)	PCIE
Blank		13.6	1.1378	
Caffine	100 300	14.6 11.0	1.2215 0.92034	7.35 19.12
Acetamide	100 300	13.8 12.5	1.1546 1.0458	1.47 8.08
BKC	100 300	9.4 8.95	0.7864 0.7488	30.88 34.19

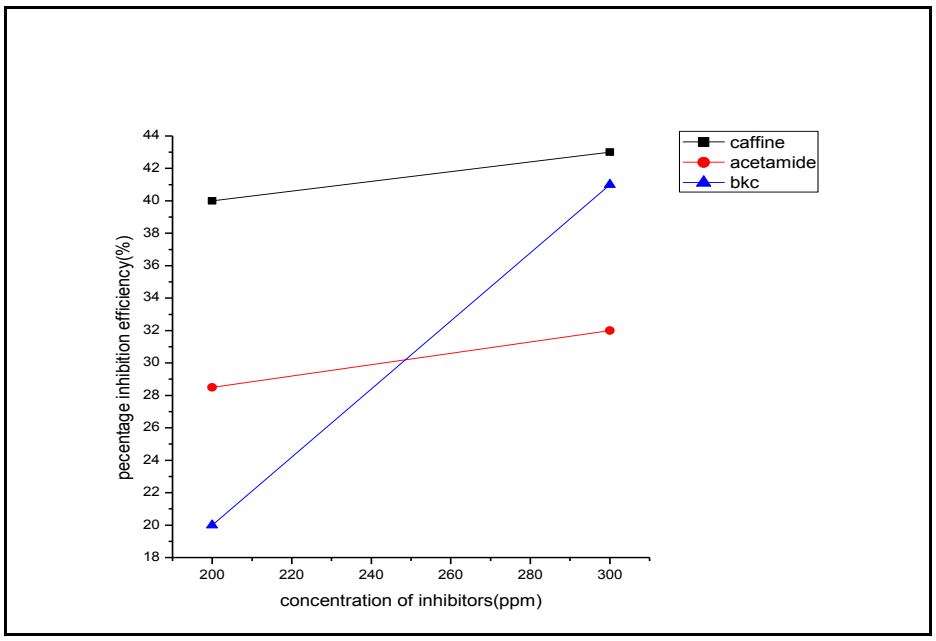


Figure 1 Percentage inhibition efficiency of Caffine, Acetamide & BKC at 200 and 300-ppm in 0.01N HCl at 25^{0}C.

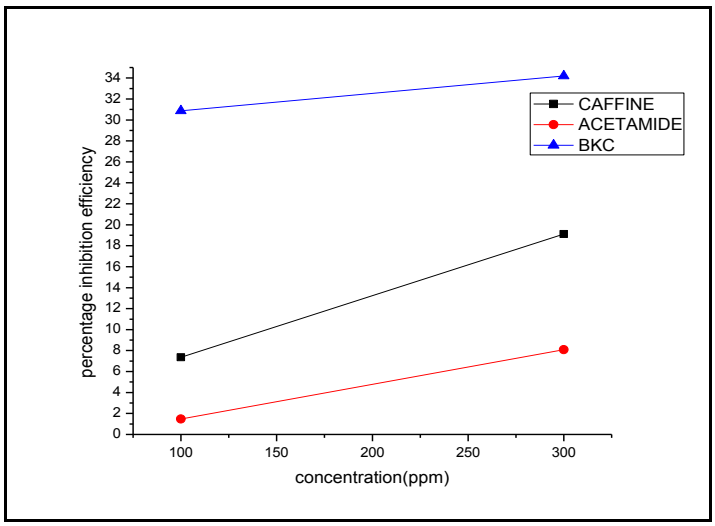


Figure 2Percentage inhibition efficiency of Caffine, Acetamide & BKC at 100 and 300-ppm in 0.01N HCl at 45^{0}C.

Scanning electron microscopy (SEM) studies

The SEM images of polished mild steel specimen were obtained after immersing them in 0.01M HCl solution at 45^0 C for 24 hours. Then they were washed with distilled water, dried in desiccator and therefore subjected to SEM examination. The SEM images are given below.

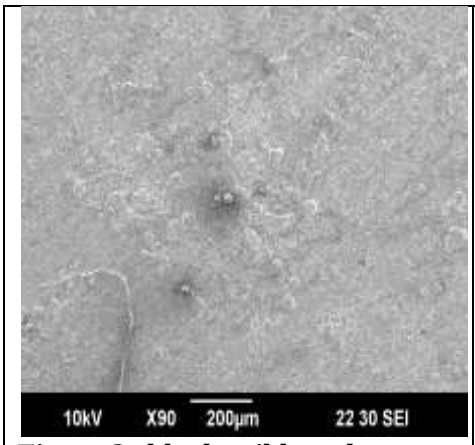


Figure 3: blank mild steel coupon SEM with 200µm resolution after treated with 0.01N HCl for 24 hour at 25ºC

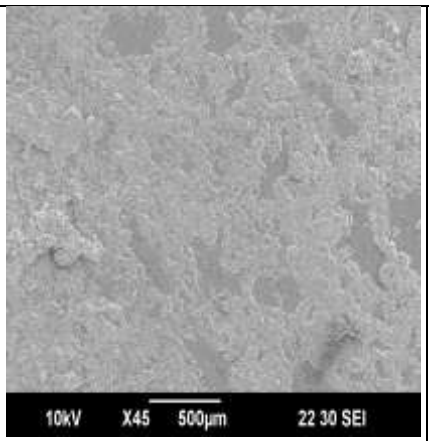


Figure 4: Blank mild steel coupon SEM with 500µm resolution after treated with 0.01N HCl solution for 24 hour at 25ºC

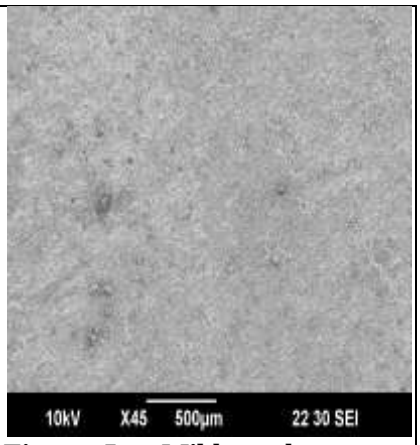


Figure 5: Mild steel coupon treated with Acetamide at 500µm resolution after immersion for 24 hour in 0.01 N HCl and Acetamide(200ppm) at 25°C

Conclusion:

The three investigated corrosion inhibitors show a high percentage corrosion inhibition efficiency toward mild steel at two different temperature 25°C and 45°C. From these three different inhibitors Caffine shows the best corrosion inhibition efficiency at 25°C and BKC at 45°C. Percentage corrosion inhibition efficiency was found in the order of Caffine >Acetamide> BKC and Caffine > BKC> Acetamide at lower and higher concentration of inhibitor respectively at temperature 25°C andBKC> Caffine > Acetamide at temperature 45°C. These result obtained by weight loss technique are further supported by SEM technique.

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