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Investigational and Conceptual Study of HCl-H_2CRO_4 Acid Mixture towards Corrosion Behavior of Mild Steel Using Chemical and Polarization Methods

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Abstract: ***The accomplishment of corrosion of mild steel in mixed acid solution was explored by using various criterions. The tests pointed out that due to adsorption of mixture of acids on the surface of mild steel, it served as a good medium for pickling as well as inhibition. The investigation of the surface morphology of the protective layer on the mild steel surface established that adsorption of molecules occurred via chemical adsorption following the model of Langmuir's isotherm. The effect of temperature and period of exposure on the corrosion performance in the presence of mixture of acids was studied in the range of 30°C-60°C and 10 minutes to 180 minutes, showing an increase in efficiency. The computed theoretical criterions presented remarkable support for cognizance of the mechanism revealed by the molecules of the acid mixture with mild steel surface and are in good accordance with the results.***

Keywords: corrosion; mild steel; pickling; morphology; adsorption; isotherm.

1. Introduction

Various industries have been using iron and its allies since long. All forms of metals tend to deteriorate when exposed to ordinary environmental conditions. This degradation of metals is known as Corrosion and is a matter of high concern since it leads to performance and economic losses. The unwanted products of this environmental degradation and mainly, rust and scale. Acid is used to remove these products by the advanced processes as pickling and etching. During the use of acid, the metal surface tends to come in contact of it and hence loss of pure metal is observed. This causes corrosion of metals. Mild steel is employed widely in most of the industries due to its low cost and high availability. Mineral acids like, nitric acid, sulphuric acid, hydrochloric acid, etc. have been used in many industries since long in different concentrations [1-9].

However, mixture of acids seems to be less explored for this purpose.

Therefore, this study will investigate the effect of mixed acid environment toward mild steel. The intent of the present work is to explore the effects of mixture of acids in various concentrations towards mild steel using chemical and electrochemical methods. For the ease of handling, paste state was used for all the experiments.

2. Experimental Layout

Mild steel panels of equal size (10 cm * 7.5 cm) were cut from single sheet of pickled cold rolled closed annealed mild steel and used in all experiments. The panels were mechanically polished, degreased, washed in double distilled water, dried, and stored in a desiccators and were used for the experiments. For demarcation of mild steel panels, all were numbered and a suspension hole of about 2 mm diameter near upper edge was made. The corrosive acidic solutions and other chemicals that were used in this work were prepared by diluting AR quality reagents in double distilled water. Soil of clay nature was cleaned and powered. The soil soaked acid in the uniform proportion and the pickling paste was obtained with 100 gm soil soaking 31.3 cc acid.

Chemical Studies

The cleaned and pre weighed panels were subjected to paste containing mixed acids at different concentrations for a pre-planned time. After the exposure the specimens were washed with de-ionised water, dried and weighed. From the initial and final masses of the specimen, the weight loss was calculated as per the following equation:

$$\text{Rate of Corrosion (mpy)} = \frac{W * K}{ATD}$$

W =Weight loss; K = Rate Constant; A = Area of the mild steel panel; T = period of exposure; D = Density of mild steel.
From the weight loss, determination of surface coverage can be done using the following formula:

$$\text{Surface Coverage } (\theta) = \frac{W_i - W_f}{W_i}$$

W_i and $W_f$are the initial and final weight loss of mild steel.

The various criterions for the experiment are:
- Concentration of Mixed Acids
- Period of Exposure
- Effect of Temperature

Polarization Studies

Corrosion current was measured using ammeters of ma range by making galvanic couples of mild steel and platinum. Mild steel and platinum couple was put in mixed acid solution; they were connected through ammeter to record the corrosion current flowing through couple. Corrosion current as a function of time was measured. The electrochemical studies were made using a conventional three electrode glass cell with mild steel specimen as a working electrode at room temperature. Platinum electrode and calomel electrode served as auxiliary and reference electrodes. This experiment was repeated three times to ensure reproducibility and least error.

The various criterions for the experiment are:

- Corrosion Current as a function of time
- Anodic Polarization
- Cathodic Polarization

Surface Analysis

The surface morphologies of mild steel specimens after exposure to mixed acid solutions were examined by scanning electron microscope.

3. Result and Discussion

(i) Chemical Experiments

a) Effect of Change of Concentration of Mixed acids:

Results show that when the quantity of HCl was decreased from 100 to 0 parts in mixed acids, rust dissolution increased from 1 gm/dm^2 to 3.5 gm/dm^2 in 10 minutes. Attack due to paste having different proportions of HCl and H_2CrO_4 showed variation in weight loss, however the weight loss was minimum in HCl: H_2CrO_4:: 10: 90.

Table 1: Effect of change of ratio of HCl (4N) and H_2CrO_4 (4N) on the rate of dissolution of rust and on the rate of attack of mild steel [RT; 1 hr.; 3.0 gm paste/dm^2 = coating thickness] [For comparison dissolution rate of mild steel in liquid state also determined]

Volume of Acid (HCl + H_2CrO_4)	Rate of Dissolution of Rust (gm/dm^2/10 min)	Weight Loss (mg/dm^2/hr)	
		Paste State	Liquid State
100+0	1	24.8	220
90+10	1.3	20.1	172.8
80+20	1.6	7.9	13.1
60+40	1.7	3.7	11.4
40+60	2.1	3.3	8.3
20+80	2.4	3.2	7.7
10+90	3	1	4.5
0+100	3.5	0.6	0.2

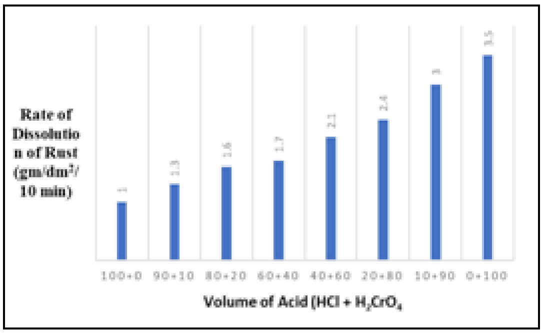

Figure 1: Effect of change of ratio of HCl (4N) and H_2CrO_4 (4N) on the rate of dissolution of rust [RT; 1 hr.; 3.0 gm paste/dm^2 = coating thickness]

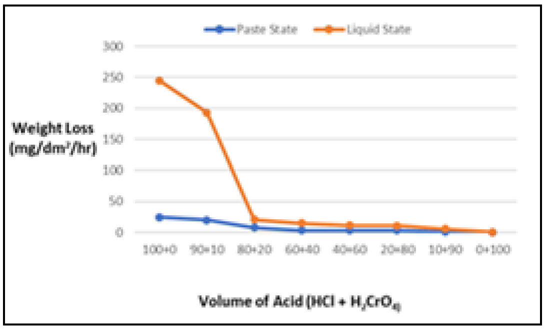

Figure 2: Effect of change of ratio of HCl (4N) and H_2CrO_4 (4N) on the rate of dissolution and on the rate of attack of mild steel [RT; 1 hr.; 3.0 gm paste/dm^2 = coating thickness]

b) Effect of Time of Application:

Table 2 and figure 3 show the effect time of exposure on the rate of dissolution of rust and corrosion of mild steel due to 4N HCl (10 parts) + 4N H_2CrO_4 (90 parts) in paste as well as liquid state. It is evident that rate of dissolution of rust increased with time. Results show that the attack in liquid state was higher than that in paste state.

Table 2: Effect of time on the rate of dissolution of rust and on the rate of attack of mild steel [RT; 4N HCl (10 parts) + 4N H_2CrO_4 (90 parts); 3.0 gm paste/dm^2 = coating thickness]

Time of Application (min.)	Rate of Dissolution of Rust (gm/dm^2)	Weight Loss (mg/dm^2)	
		Paste State	Liquid State
10	2.5	0.6	2.9
30	3.1	0.8	3.5
60	3.2	1.2	4.1
120	3.6	1.7	4.8
180	3.4	2.0	5.1

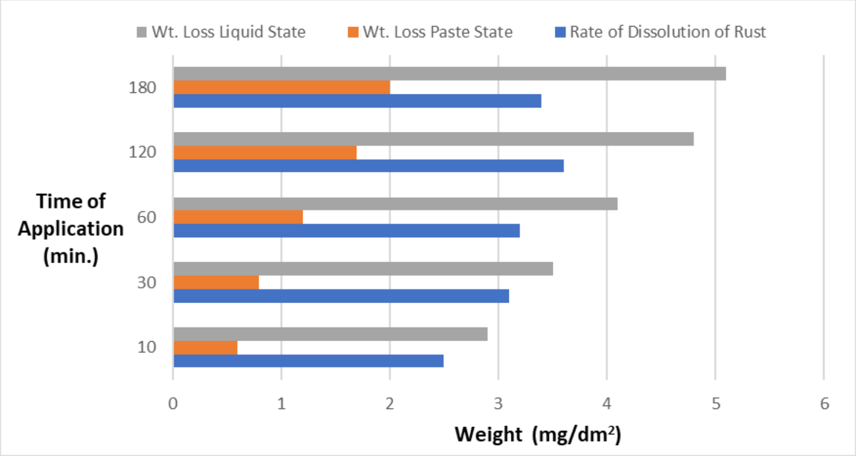

Figure 3: Effect of time on the rate of dissolution of rust [4N HCl (10 parts) + 4N H_2CrO_4 (90 parts); RT.; 3.0gm paste/dm^2 = coating thickness]

c) Effect of Temperature

Inspection of Table 3 and figure 4 reveals that rate of dissolution of rust varied from 3.0 gm/dm^2/15min at 30°C to 3.7 gm/dm^2/15min at 60°C. In paste state, weight loss ranged from 0.8 gm/dm^2/15min at 30°C to 2.9 gm/dm^2/15min at 60°C and in liquid state it was much higher from 4.2 gm/dm^2/15min at 30°C to 6.8 gm/dm^2/15min at 60°C.

Table 3: Effect of temperature on the rate of dissolution of rust and on the rate of attack of mild steel [4N HCl (10 parts) + 4N H_2CrO_4 (90 parts); 1 hr.; 3.0 gm paste/dm^2 = coating thickness]

Temperature (°C)	Rate of Dissolution of Rust (gm/dm^2/15 min)	Weight Loss (mg/dm^2/hr)	
		Paste State	Liquid State
30	3.0	0.8	4.2
35	3.2	1.1	4.7
40	3.3	1.4	5.0
45	3.4	1.9	5.4
50	3.7	2.2	5.7
55	3.8	2.5	6.3
60	3.7	2.9	6.8

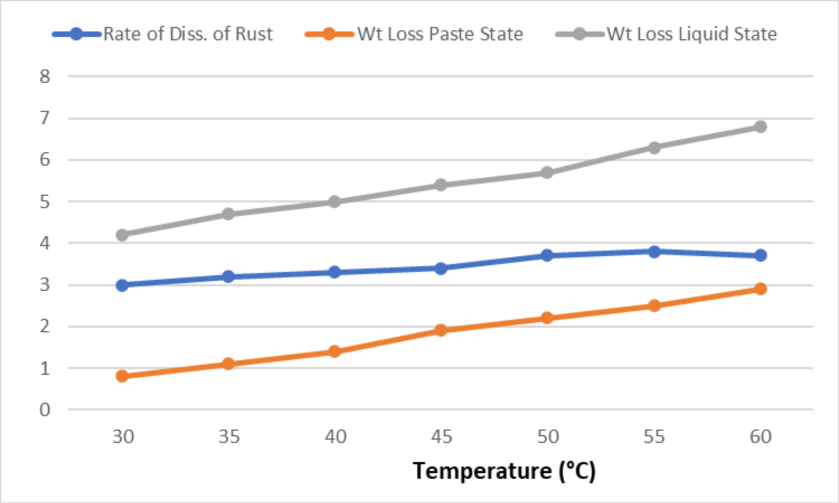

Figure 4: Effect of temperature on the rate of dissolution of rust [4N HCl (10 parts) + 4N H_2CrO_4 (90 parts); 1 hr.; 3.0gm paste/dm^2 = coating thickness]

(ii) Polarization Experiments

The corrosion current was measured up to one hour and the current was 84 ma which gradually reduced to 70 ma. The anodic polarization gave a ΔV of 62 mV while potential drop, ΔV for cathodic polarization was reported to be 13 mV when current was raised from 1.6*10-3 to 21.3*10-3 respectively.

Table 4: Corrosion Current in steel – platinum couple placed in paste [4N HCl (10 parts) + 4N H_2CrO_4(90 parts); RT]

Time (min)	Current (ma)
00	84
10	83
20	83
30	80
40	77
50	74
60	70

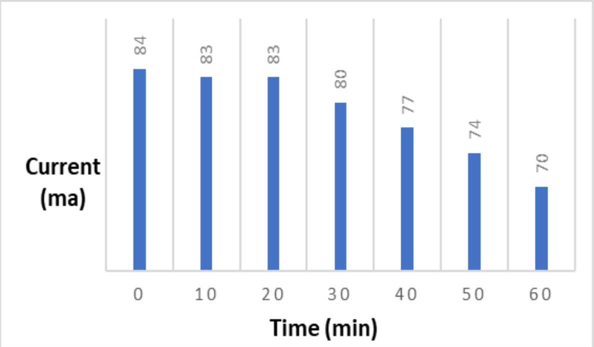

Figure 5: Corrosion Current in steel-platinum couple placed in paste [4N HCl (10 parts) + 4N H_2CrO_4 (90 parts); RT]

Table 5: Anodic and Cathodic Polarization data for mild steel placed in paste [4N HCl (10 parts) + 4N H_2CrO_4 (90 parts); RT]

Current Density (ma/cm2)	Log Current Density	Potential (for Anodic Polarization) (mV vs SCE)	Potential (for Cathodic Polarization) (mV vs SCE)
$1.6 * 10^{-3}$	- 3.2095	- 642	- 510
$1.8 * 10^{-3}$	- 3.2648	- 641	- 510
$2.5 * 10^{-3}$	- 3.4082	- 640	- 511
$3.2 * 10^{-3}$	- 3.5105	- 638	- 512
$5.0 * 10^{-3}$	- 3.6998	- 633	- 513
$7.9 * 10^{-3}$	- 3.8976	- 628	- 515
$12.1 * 10^{-3}$	- 2.0828	- 617	- 516
$16.1 * 10^{-3}$	- 2.2068	- 608	- 520
$21.3 * 10^{-3}$	- 2.3284	- 580	- 523

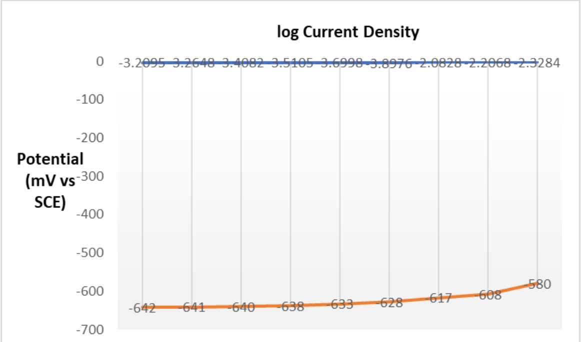

Figure 6: Anodic Polarization data formild steel placed in paste [4N HCl (10 parts) + 4N H_2CrO_4 (90 parts); RT]

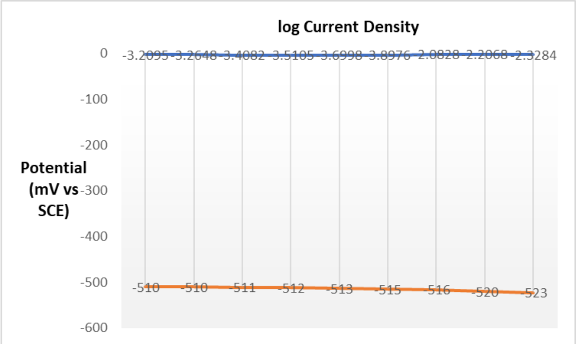

Figure 7: Cathodic Polarization data formild steel placed in paste [4N HCl (10 parts) + 4N H_2CrO_4(90 parts); RT]

(iii) Surface Micrograph

The surface morphology of mild steel immersed in the corrosion solution for 1h in 4N HCl (10 parts) + 4N H_2CrO_4 (90 parts) in paste state is shown in Figure8 and 9. It can be observed that the mild steel surface was strongly damaged as a result of heavy rust deposition. Observation of Figure 9 reveals that the metal surface immersed in the mixed acid solution gave smooth surface to the mild steel panels. This upgradation of surface morphology is due to the dissolution of good amount of rust from the mild steel surface by the mixed acids.

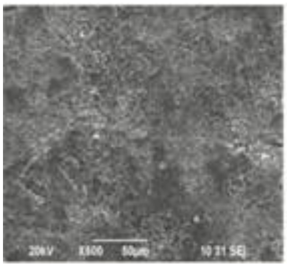

Figure 8: Rusted Mild Steel

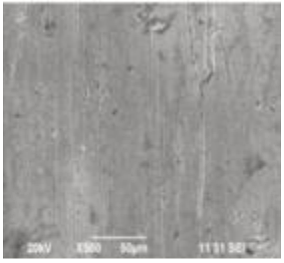

Figure 9: Mild Steel in mixed acids

4. Conclusion

The present study shows the effect of HCl-H_2CrO_4 acid mixture towards corrosion behaviour of mild steel. The paste having composition of acids HCl: H_2CrO_4:: 10: 90 showed minimum weight loss and maximum rust dissolution. There was more change in potential (ΔV) observed during anodic polarization as compared to cathodic polarization. Scanning electron microscopic studies confirm that the surface is smoother in the presence of the mixture of acids.

Declaration of Conflicting Interests

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References

[1] WIERSMA, B. J., Corrosion Testing of Carbon Steel in Acid Cleaning Solutions.10.2172/805803, 2002.

[2] ABD EL-AZIZ S. FOUDA, EL-SAYED EL-GHARKAWY, HEBA RAMADAN, AHMED EL-HOSSIANY, Corrosion Resistance of Mild Steel in Hydrochloric Acid solutions by Clinopodiumacinos as a Green Inhibitor, Volume 11, Issue 2, 9786 – 9803, 2021. https: //doi. org/10.33263/BRIAC112.97869803.

[3] EHTERAM A. NOOR AND AISHA H. AL-MOUBARAKI, Corrosion Behavior of Mild Steel in Hydrochloric Acid Solutions, Int. J. Electrochem. Sci., 3, 806 – 818, 2008.

[4] MORAD, MAHMOUD, Corrosion inhibition of mild steel in sulfamic acid solution by S-containing amino acids. Journal of Applied Electrochemistry-J APPL ELECTROCHEM.38.1509-1518.10.1007/s10800-008-9595-2, 2018.

[5] W. W. FRENIER, 20 Years of Advances in Technology for Chemically Cleaning Industrial Equipment: A Critical Review, NACE 338, NACE International Conference, San Diego, Carlifornia, USA, March 1998 22–27.

[6] T. HODGKIESS, K. H. AL-OMARI, N. BONTEMS, B. LESIAK, Acid cleaning of thermal desalination plant: do we need to use corrosion inhibitors? Desalination 183, 209–216, 2005.

[7] P. R. VIJAYALAKSHMI, R. RAJALAKSHMI AND S. SUBHASHINI, PortugaliaeElectrochimica Acta, 29 (1), 9, 2022.

[8] A. D. NESBIT, A History of Chemical Cleaning as a Business, CORROSION/93, NACE International, Houston TX, 362, 1993.

[9] W. W. FRENIER, F. B. GROWCOCK, Inhibitors for chemical cleaning applications, in: A. Raman, P. Labine (Eds.), Reviews on Corrosion Science and Technology, NACE International, Houston, TX, 2013.