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CORROSION INHIBITION STUDY ON LOW CARBON STEEL IN SULFURIC ACID MEDIUM USING A PIPERAZIN DERIVATIVE FOR INDUSTRIAL APPLICATIONS

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ABSTRACT
Corrosion is nothing but the deterioration of metals, and preventing the metals from the aggressive environment is essential in industrial applications. For that, herein we use Piperazin derivative for corrosion inhibition. At two different temperatures (303 K and 313 K), the impact of the inhibitor (4-4-APFM) - [4-(4-aminophenyl)piperazin-1-yl)(furan-2-yl) methanone on MS (mild steel) material corrosion in 1N H_2SO_4 medium was examined using mass loss data and electrochemical studies, such as Potentiodynamic polarization. This investigation shows that the inhibitor functions as a mixed-type inhibitor. The findings pertaining to microbial activity verify the presence of an inhibitory layer protecting an MS surface. These findings demonstrate the inhibitor's effectiveness in preventing mild steel corrosion. (4-4-APFM) at two different temperatures (303K) has been shown to reduce mild steel (MS) corrosion in 1 N H_2SO_4 solutions.

Keywords: Mild Steel, Polarization Resistance, Mixed-Type Inhibitor, Corrosion Inhibition, Piperazine Derivative.
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INTRODUCTION

The world GDP for corrosion is 3.4% and is still increasing. There are a lot of challenges to prevent the metals from the acidic environment. Acid solutions containing sulfuric acid are commonly utilized in a variety of industrial operations, including chemical cleaning, pickling iron, decaling boilers, and acidification of oil wells during petroleum exploration.[1] One of the most convenient ways to protect metallic items from corrosion in acidic environments and to minimize the amount of acids consumed during the corrosion process is to utilize inhibitors.[2] The majority of compounds that contain delocalized π electrons and elements like N, O, and S atoms have hindered reactions in acidic conditions.[3-6] In various acidic media, the inhibitors with more than one heteroatom perform better than those with only one (MS)[7,9] aluminum[10,11], copper[12,13], and zinc.[14] In the field of corrosion prevention, Schiff bases have a unique position because of their ecologically favorable properties and simplicity of synthesis from relatively inexpensive starting materials.[15,17] The greatest inhibitory effectiveness of 4-(N, N-diethylamino) benzaldehyde thiosemicarbazone (DEABT) was found to be 95% at 1.2 × 10−3 M by Poornima *et al*.[18] in a phosphoric acid solution. Based on the above data discussion on this investigation, mild steel corrosion was studied in 1N sulfuric acid using 4-4-APFM inhibitor at two different temperatures by mass loss data and electrochemical studies, as well as surface analysis studies.

EXPERIMENTAL

Coupon Preparation

The mild steel (MS) arrangement (weight rate) that was utilized in each examination was as follows: C = 0.253; Si = 0.12; P = 0.013; S = 0.024; Cr = 0.012; Mn = 0.03; Fe = 99.548 %. Weight reduction estimations were led utilizing coupons cut into 5 × 1 × cm^2 aspects, while working anodes for polarization and EIS estimations were 1 × 1 cm^2 coupons. The coupons were mechanically polished by using 320, 400, 600, 800, 1000, 1500, and 2000 grade emery sheets preceding the tests. From that point forward, they were cleaned with two-fold refined water, ultrasonication with acetone, allowed to air dry before being lowered in a destructive arrangement.

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Inhibitor Solutions

To carry out the de-aeration of the electrolytes, all of the solutions were made using NICE brand AR-grade chemicals in triple-distilled water and bubbled with nitrogen gas for thirty minutes. Solutions of 1N H_2SO_4 were made by triple-distilled water. Additionally, solutions of [4-(4-aminophenyl)-piperazin-1-yl]-(furan-2-yl) methanone (4-4-APFM) at various concentrations (PPM) were made.

Weight Loss Measurement

Finely polished and dehydrated MS were weighed using a digital balance after being submerged for 24 hours in 1 N H2SO4 at 303 K and 313 K with varying inhibitor concentrations (PPM) present or absent. The specimens that were corroded or inhibited underwent a thorough washing with liquid soap, several rinses with distilled water, cleaning, acetone drying, and reweighing. The specimen's weight before and after immersion in corrosive fluid was used to compute the weight loss. From this data, Corrosion Rate (CR) and Inhibition Efficiency (ɳ).

$$\text{Inhibition Efficiency } (\eta) = \frac{\Delta W}{st}$$

Rate, ΔW- Difference in coupon weight, s-total area of the specimen (MS), t-time

$$\eta\,\% = \frac{CR^\circ - CR}{CR^\circ} X100$$

In the presence and absence of an inhibitor, where CR° are the corrosion rates, respectively.

Electrochemical Studies

Both Impedance and Polarization studies were carried out using the Electrochemical Workstation (Model No. CHI 600D, CH Instruments, USA) at various temperatures using 1N sulfuric acid as the electrolyte. A platinum electrode and an SCE-saturated calomel electrode were employed as auxiliary and reference electrodes, respectively, and a mild steel specimen with a 1 cm^2 exposed area served as the working electrode. In order to minimize the ohmic potential drop, the tip of the reference electrode was carefully positioned very close to the working electrode's surface using a fine Luggin capillary. The electrochemical workstation also reduced the residual uncompensated resistance. The potentiodynamic polarization investigation used a scan rate of 0.01mV/s and a potential range of -800 to -200.

$$IE\% = \frac{I_{corr} - I_{corr(i)}}{I_{corr}} \times 100$$

Where, I_{corr}=Corrosion current density in the absence of inhibitor and $I_{corr(i)}$=Corrosion current density in the presence of inhibitor.

Screening of Antibacterial Activities

To examine the samples (4-4-APFM) for antibacterial activity, two strains of gram-negative [Pseudomonas aeruginosa (MTCC 2486) and gram-positive Bacillus subtilis (MTCC 441)] were prepared as test organisms. The Microbial Type Culture and Collection (MTCC) in Chandigarh, India, was used to get all of the strains. Nutrient agar (Difco, USA) was kept at 4 °C while bacterial strains were grown at 37 °C. The disc diffusion method was used to test the antibacterial activity of the samples (4-4-APFM) was assessed using the disc diffusion method. Muller Hinton Agar was used to make the 60 mm-diameter petri dishes, which was then infected with test organisms. Six-millimeter-wide sterile discs were impregnated with 10 mL of various samples at concentrations ranging from 20 to 100 g/mL. The agar plates' top layer was covered with prepared discs, which were then left at room temperature for 30 minutes to allow chemical diffusion. The experiment was repeated after the dishes had been incubated for 24 hours at 37°C. The zone of inhibition was measured in millimeters.

RESULTS AND DISCUSSION

Mass Loss Data

Weight loss was observed at two different temperatures when using (4-4-APFM) as a corrosion inhibitor against 1 N H2SO4. The results are shown in Table-1. Figures-1 and 2 show the corrosion rate and

inhibitor efficiency on adding inhibitors, which rise with increasing inhibitor concentration, as evidenced by the graph. The inhibitor 4-4-APFM was reported to be inhibited with 77.47% efficiency at 303K and 69.75% efficiency at 1 N H_2SO_4.

Table-1: Mass Loss of MS in 1 N $H_2SO_4$with (4-4-APFM) at two Different Temperatures

S. No	Conc of inhibitor PPM	Temperature			
		303K		313K	
		CR	IE	CR	IE
1.	Blank	25.9892	---	28.5421	---
2.	10	17.0028	34.57	19.3425	32.23
3.	20	14.4516	44.39	17.9874	36.97
4.	40	12.9872	50.02	14.8763	47.87
5.	60	10.6879	55.87	13.0123	54.41
6.	80	8.9872	65.41	10.9632	61.58
7.	100	5.8542	77.47	8.6335	69.75

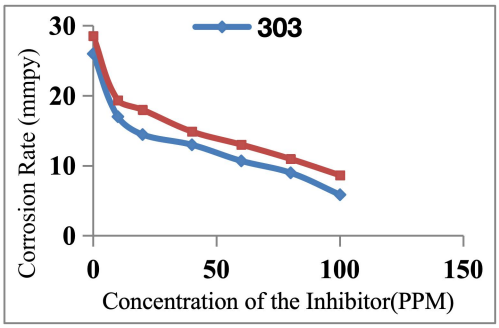

Fig.-1: Corrosion Rate of (4-4-APFM) in 1 N H_2SO_4at different Temperatures

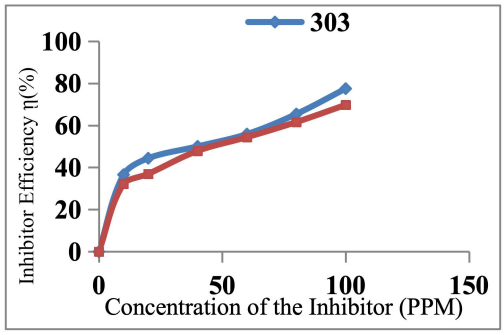

Fig.-2: Inhibition Efficiency of (4-4-APFM) in 1 N H_2SO_4 at different Temperatures

Potentiodynamic Polarization Resistance

Potentiodynamic polarization was investigated for the inhibitor (4-4-APFM), which was utilized to test and estimate the corrosion potential (Ecorr), corrosion potential current (Icorr), cathodic and anodic Tafel slopes (α and β), and corrosion current (Icorr) in 1 N H2SO4 by applying -0.1 to +0.1 V. Figures-3 and 4 demonstrate the experimental results at three different temperatures, with and without the inhibitor. Table- 2 displays the matched Tafel parameters. The nobler shift blank to 100 PPM demonstrates that raising the inhibitor increases corrosion resistance.

Antimicrobial Activity

The first step in understanding the overall impact of microbial communities on corrosion is to investigate the function that biofilms play in both the occurrence and the suppression of corrosion.

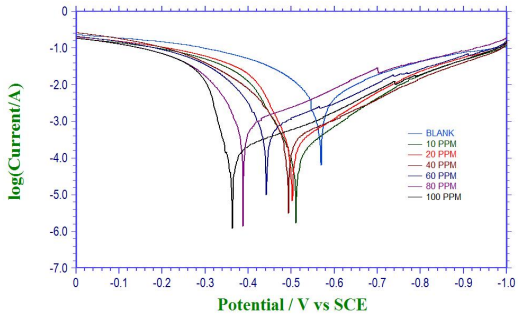

Fig.-3: Tafel curves(4-4-APFM) for Mild steel in 1 N H_2SO_4 at 303K

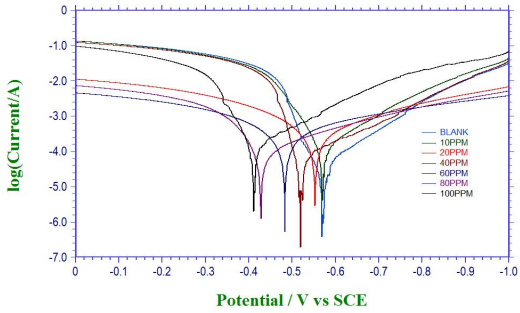

Fig.-4: Tafel Curves (4-4-APFM) for Mild Steel in 1 N H_2SO_4 at 313K

Table-2: Tafel Curve of MS- Immersed in 1 N H_2SO_4 in the Absence and Presence of the (4-4-APFM) at two different Temperatures

Temperature	Conc. (PPM)	-βa (mV dec^{-1})	-βc (mV dec^{-1})	Ecorr (mV)	i_{corr} (mA cm^{-2})	Corrosion rate (mmpy)	IE %
303K	Blank	23.539	7.712	-579	29.861	196.83	---
	10	7.590	3.905	-508	17.153	107.65	42.53
	20	11.756	5.205	-491	15.825	98.78	46.98
	40	20.791	8.240	-483	15.063	97.93	49.54
	60	11.433	3.858	-465	13.297	94.65	55.45
	80	10.135	4.627	-441	11.002	91.87	63.14
	100	18.159	7.515	-434	6.345	68.46	78.74
313 K	Blank	7.016	5.900	-570	18.103	210.360	---
	10	16.314	7.610	-594	14.210	92.465	21.50
	20	17.106	7.509	-572	13.499	88.686	25.43
	40	23.539	7.709	-568	10.125	71.075	44.07
	60	9.062	5.182	-519	9.216	42.053	49.09
	80	14.795	6.048	-482	7.421	13.316	59.00
	100	16.573	5.593	-411	5.846	10.668	67.70

This study focused on two separate bacterial species, *Bacillus subtilis* and *Pseudomonas aeruginosa*, from the Gram-positive and Gram-negative groups. Based on the minimum inhibitory concentration (MIC) tests performed on the provided compounds, (4-4-APFM) in 100 g/mL concentration showed maximum activity against *Pseudomonas aeruginosa* with a zone of inhibition noted as 10 mm, as well as moderate activity against *Bacillus subtilis* with a zone of inhibition noted as 5 mm, as shown in Fig.-5 and 6. Zones of inhibition for both *Bacillus subtilis* and *Pseudomonas aeruginosa* were measured as 6 mm for (4-4-APFM) at a concentration of 100 g/mL, as shown in Table-3. Therefore, it was determined that the (4-4-APFM) compound was an excellent anticorrosive compound for preventing the formation of bacterial biofilm on the surface of mild steel.

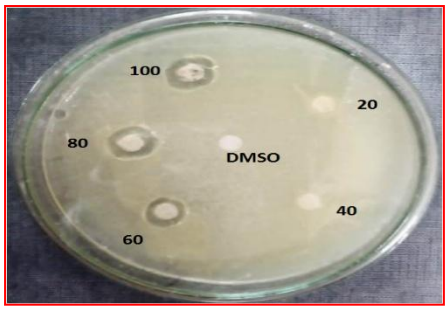

Fig.-5: MIC Zone of Inhibition *Pseudomonas aeroginosa*

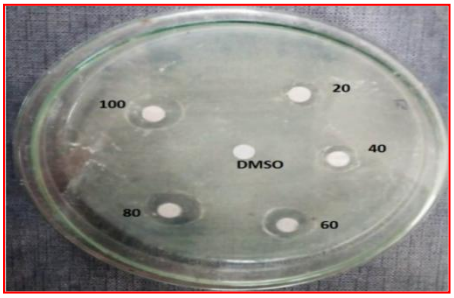

Fig.-6: MIC Zone of Inhibition *Bacillus subtilis*

Table-3: Antibacterial Activity of all Three Inhibitors

Samples	Concentrations (µg/ml)	Organisms/Zone of inhibition (mm)	
		Pseudomonas aeroginosa	*Bacillus subtilis*
[4-(4aminobenzoyl) piperazin-1-yl)(furan-2-yl)methanone	20	0	1
	40	0	2
	60	2	4
	80	4	5
	100	6	6
DMSO	10 µl/disc	0	0

CONCLUSION

The current study's findings about the use of (4-4-APFM) in an acid solution of 1 N H_2SO_4 to prevent mild steel corrosion are as follows. In an acidic medium, (4-4-APFM) has a greater inhibitory effect. The efficiency of (4-4-APFM) in 1 N H_2SO_4 at 303K was determined to be 77.47%. Polarization investigations show that the chemical under examination, which uses the (4-4-APFM) inhibitor in 1 N H_2SO_4, acts as a mixed-type inhibitor, reducing both anodic and cathodic processes. Similarly, microbial activity demonstrates the inhibitor's improved efficacy.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

The present work is related to *SDG-9: Industry, Innovation and Infrastructure*. All the authors contributed significantly to this manuscript, participated in reviewing/editing and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

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