CORROSION BEHAVIOUR OF CARBON STEEL IN SEA WATER BY USING AMINO BENZOIC ACID INHIBITOR

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ABSTRACT

Galvanization is often applied to carbon steel. People worry that metals will corrode in seawater and liquids containing sodium chloride if exposed to these environments. It was feasible to compute the amount of mass lost as a result of carbon steel corroding in saltwater. If the weight of mild steel decreases, this may impact the pace of corrosion and the effectiveness of any countermeasures. When there is a higher concentration of amino benzoic acid, both the rate of corrosion prevention and the overall efficiency of the process drop proportionally. Increasing the concentration of the inhibitor solution causes the creation of a barrier on the surface of the carbon steel, which reduces the quantity of the material's active site. Finding a solution to the corrosive process is one of the primary objectives of electrochemistry research. Electrochemical research has shown that carbon steel has a protective covering on its surface. Utilizing both the FTIR and the SEM, the surface layer of the carbon steel was analysed. Utilizing a technique known as atomic force microscopy, it is possible to evaluate the surface roughness of carbon.

Key words: Benzoic acid, carbon steel, rust, corrosion, FTIR, SEM, and weight loss

INTRODUCTION

Corrosion turns a refined metal into its oxide, hydroxide, or sulphide. It's when materials, usually metals, break down chemically or electrochemically over time. Carbon steel is often galvanised. People worry about metal corrosion in seawater and sodium chloride solutions. It is also used in die-casting. In recent years, industrial cooling water systems, especially in India, have had a lot of problems. A package of treatments that only controls corrosion, scale, or microbiology is not enough. Carbon steel is safe in both quakes and strong winds. Acidic media is important for studying carbon steel corrosion because it is used in many industrial processes, such as cleaning, acid pickling, acid descaling, petrochemical processes, and oil recovery from oil wells [1].

Metals and alloys don't rust because of corrosion inhibitors. Corrosion inhibitors control how much metal dissolves in acidic, neutral, and basic environments. Most known inhibitors are organic molecules with O, N, S, and many bonds between them. Corrosion can make it hard for equipment or buildings to work in a safe, reliable, and efficient way [2]. Several studies looked at how organic compounds stop copper, aluminium alloys, mild steel, carbon steel, and composites from working in acidic, alkaline, and neutral environments. [3,4]. Rusting is stopped by organic chemicals. A lot has been learned about how to stop organic materials from corroding. Organic molecules with a lot of heteroatoms work well as inhibitors.

This study looks at benzoic acid as a way to stop carbon steel from rusting in sea water. The weight loss technique looks at how fast amino benzoic acid corrodes and how well it stops corrosion. Electrochemical tests, like polarisation and AC-impedance spectra, have helped Fig. out how corrosion inhibition works. The protective coating on carbon steel has been looked at with FTIR and SEM. Atomic force microscopy compares the roughness of carbon steel that has been polished, corroded, and treated with an inhibitor (AFM).

MATERIALS AND METHODS

Preparing carbon steel

Carbon steel pieces that were 1 cm by 4 cm by 0.2 cm were polished and cleaned with trichloroethylene for weight loss and surface evaluation tests.

Preparing stock solutions

To make a solution, you had to use water that had been distilled twice. A stock solution of amino benzoic acid was made by dissolving it in ethanol and adding sea water until it was full. The inhibitor stock solution was added to the sea water solution until it had the right amount of inhibitor in it.

Weight loss

As shown [5,6], the amount of weight loss was measured. After a day, the carbon steel samples were taken out, cleaned, dried, and properly weighed. The following equation is used to Fig. out the inhibition efficiency (IE%).

$$\mathbf{IE\ (\%) = \frac{W_o - W_1}{W_o} \times 100}$$

Where W1 and Wo are weight loss in grammes with and without benzoic acid.

Polarisation Potentiodynamics

On a H & CH electrochemical work station impedance analyser model CHI 643 B, made in Austin, USA, polarisation tests were done. The working electrode was made of carbon steel, but only 1 cm^2 of it was exposed. The rest was covered in red lacquer. A saturated calomel electrode (SCE) was used as the reference electrode, and a platinum foil was used as the counter electrode. The area of the counter electrode was bigger than that of the working electrode. This keeps the same potential at the counter electrode. Both the working electrode and the platinum electrode were put in SCP with and without an inhibitor. The calomel electrode was linked to the test solution by a salt bridge. E vs I plots were made. E vs. log I plots of corrosion potential (Ecorr) and corrosion potential (Icorr) Tafel slopes ba, bc [7].

AC impedances

A H & CH electrochemical work station impedance analyzer model CHI 643 B from Austin, USA, was used to measure AC impedance. The way the cell was set up was the same as for measuring polarisation. It takes the system 5 to 10 minutes to reach steady-state open circuit potential. Then an AC potential of 10 mV was added. At an AC frequency of 100 kHz to 100 MHz, ohms were used to measure the impedance of both real and made-up cells. Both Rt and Cdl were worked out. Cdl values were found by using the following formula.

$$\mathbf{Cdl = 2 \times 3.14 \times Rfmax}$$

Looking at surfaces

Carbon steel pieces were put in blank and amino benzoic acid solutions for a day. After one day, the samples were dried. Several methods were used to look into the surface layer of carbon steel.

FTIR-based analysis of the surface

Perkin Elmer Spectrum Version captured FTIR spectra. After the film was taken off and mixed with KBr, FTIR spectra were taken.

The samples were dried after a day of being in different conditions. Scratching and mixing the surface film made it uniform. The FTIR spectrum of the powder was taken with a Perkin Elmer Spectrum Version spectrophotometer [8,9].

SEM

It was used to compare the surface of the metal before and after it came in contact with a corrosive solution and to Fig. out how well an inhibitor worked. SEM was used to look at the surface topography of carbon steel after it had corroded with and without an inhibitor. To study the shape of zinc's surface, a CAREL ZEISS EVO 18 Hitachi computer-controlled scanning electron microscope was used.

AFM analysis

The piece of carbon steel was put in blank and inhibitor solution for a day, then washed, dried, and looked at [10]. Atomic force microscopy (AFM) was used to look at the surface morphology of carbon steel.

RESULTS AND DISCUSSION

Weight loss

We looked at how much weight lost in sea water with and without amino benzoic acid inhibitor. Carbon steel is put in sea water with and without an amino benzoic acid inhibitor that helps people lose weight. Table-1 shows how well the corrosion is stopped and how fast it happens. The rate of corrosion was affected by the amount of inhibitor. IE% goes up as inhibitor concentration goes up.

At 250 ppm, carbon steel's ability to stop corrosion is at its best. 250 ppm amino benzoic acid inhibits 81.56 percent. As amino benzoic acid concentration rises, corrosion rate falls. This is because higher inhibitor concentrations cover more of the surface, which stops carbon steel from breaking down by blocking corrosion sites and lowering the rate of corrosion. Oxygen and nitrogen give up electrons, which makes inhibition stronger. This monitoring backs up what many studies have found [11].

1 Corrosion rates (CR) and effectiveness of corrosion inhibitors (IE%) for carbon steel submerged in sea water with and without corrosion inhibitors.

Table 1. Corrosion rates (CR) and inhibition efficiency (IE %) data obtained from weight loss measurements for carbon steel is immersed in sea water without and with various concentration of inhibitor.

- Inhibitor System: Amino benzoic acid (ppm)
- Immersion period: One Day

Blank	Amino benzoic acid (ppm)	CR (mdd)	IE (%)
Sea water	-	60.27	-----
	50	50.21	36.25
	100	41.56	45.14
	150	31.54	56.10
	200	20.86	68.88
	250	14.01	81.56

Analysis of Potentiodynamic Polarisation

Polarization tests show that a protective coating is made on the surface of carbon steel when corrosion is stopped. Carbon steel's linear polarisation resistance (LPR), corrosion current (Icorr), and corrosion potential (Ecorr) all go up when a protective coating forms on it [12].

Fig. 1 shows the potentiodynamic polarisation curves of carbon steel in sea water and the inhibition efficiencies (IE) with and without an inhibitor (a, b). Table 2 contains corrosion parameters.

The corrosion potential of carbon steel in seawater was -601mV vs. SCE. When 250 ppm amino benzoic acid was added, the corrosion potential went from SCE to -731 mV, which is the cathodic side. The protective coating forms on carbon steel's cathodic sites. This film regulates carbon dissolving by producing Fe2+-ABA complex on carbon steel's cathodic sites. LPR rises from 530 to 1499 ohm cm2 and corrosion current drops from 8.001 to 2.102 A. A study of polarisation shows that a protective coating is forming on carbon steel [13]. The potentiodynamic polarisation method is used to measure the corrosion of carbon steel in sea water and the effectiveness of inhibitors (IE) when inhibitors are present and when they are not.

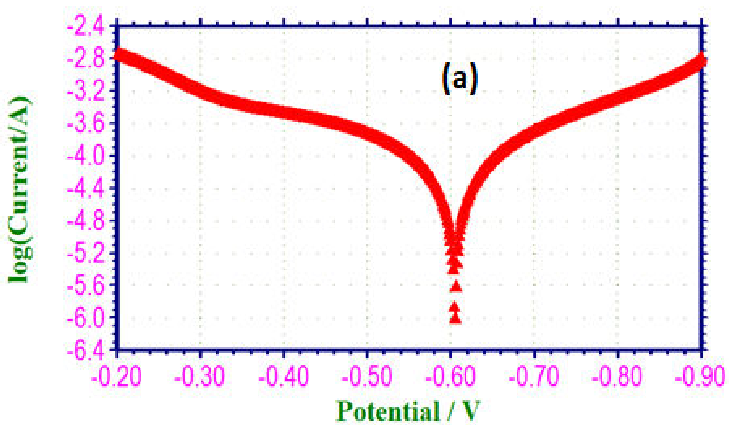

Fig. 1: Polarization curves of carbon steel immersed in Sea water (blank)

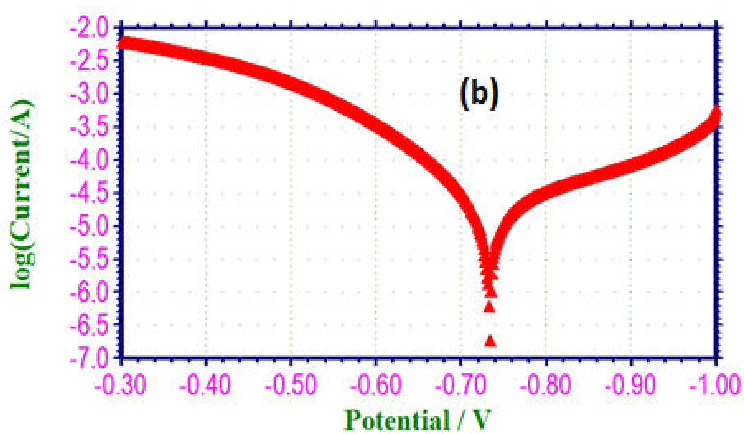

Fig. 1(b): Sea Water + 250 ppm of amino benzoic acid

Table 2: Corrosion parameter of carbon steel is immersed in sea water and inhibition efficiencies (IE) in the absence and presence of inhibitor system obtained by potentiodynamic polarization method.

Systems	E_{corr} vs SCE (mV)	I_{corr} (A/cm^2)	b_a (mV/dec)	b_c (mV/dec)	LPR (ohm cm^2)
Blank (Sea water)	- 601	8.101×10^{-5}	469	555	530
Blank + 250 ppm of ABA	- 731	2.201×10^{-5}	961	425	1499

Impedance Spectra Analysis

AC impedance spectra demonstrate the establishment of a protective coating on carbon steel. Carbon steel's charge transfer resistance (Rt), double layer capacitance (Cdl), and impedance log (z/ohm) all improve when it has a protective coating [14].

Fig. 2 (a and b) shows the AC impedance spectra of carbon steel in seawater with and without amino benzoic acid (Nyquist plots). Table 3 shows the characteristics of AC impedance, such as charge transfer resistance (Rt) and double layer capacitance (Cdl). When the inhibitor (250 ppm of ABA) is introduced to the aforesaid system, Rt rises from 34.98 cm2 to 44.94 cm2 and Cdl lowers from 57.336410-6 F cm-2 to 73.4255 10-6 F cm-2. Impedance rises from 0.530 to 0.590. From 28.4o to 31.0o, the phase angle changes. These data suggest a protective coating forms on carbon steel. 3 AC impedance spectra of zinc in sea water solution with and without inhibitors.

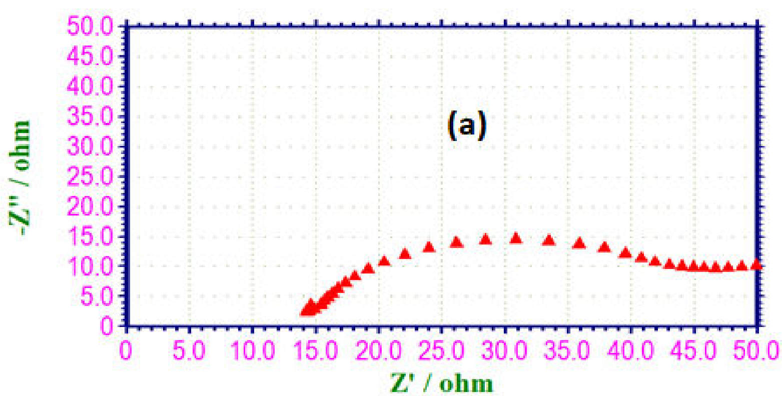

Fig. 2a: AC impedance spectra of carbon steel immersed in sea water (blank)

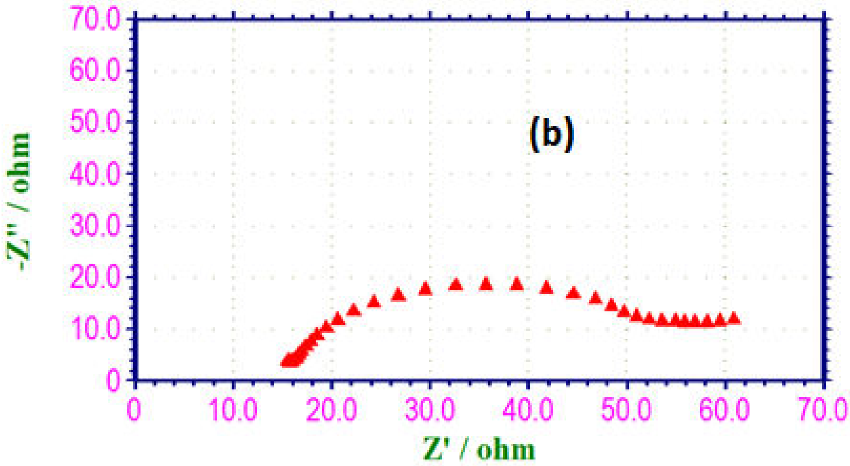

Fig. 2b: AC impedance spectra of carbon steel immersed in sea water (blank)+ 250 ppm of amino benzoic acid

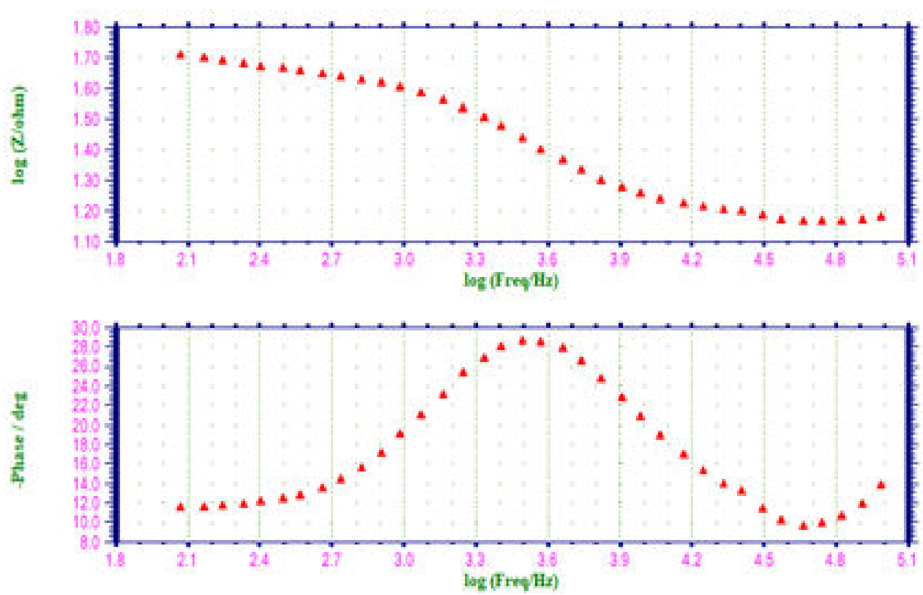

Fig. 3a: Bode plot of AC impedance spectra of carbon steel immersed in sea water (blank)

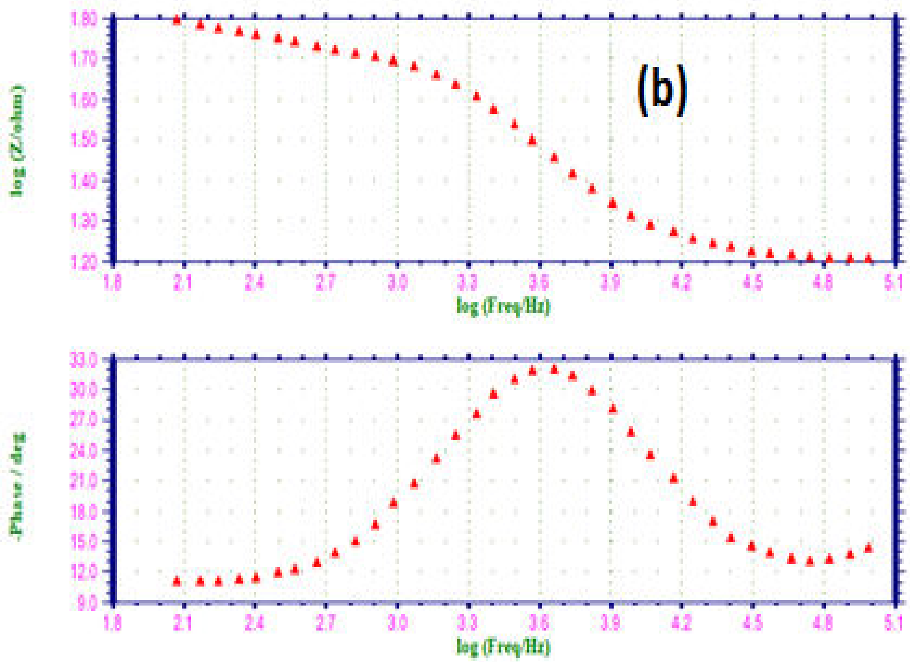

Fig. 3b: Bode plot of AC impedance spectra of carbon steel immersed in sea water and 250 ppm of amino benzoic acid

Table 3: Corrosion parameters of zinc metal immersed in sea water solution in the absence and presence of inhibitor system obtained from AC impedance spectra.

System	Nyquist plot		Impedance Log (z/ohm)
	R_{ct}, Ω/cm2	C_{dl}(μF/cm^2)	
Sea water	34.98	57.3364 ×10^{-6}	0.530
Sea water + 250 ppm benzoic acid	44.94	73.4255 ×10^{-6}	0.590

FTIR analysis

FTIR spectra are utilised to assess carbon steel's protective film [Branham 1963]. The FTIR spectrum of pure amino benzoic acid is shown in Fig. 4a. At 2918.60 cm-1, CH stretches. At 1626.32 cm-1, CO stretches. NH has a frequency of 3363.49 cm-1. CN stretches at 1410.32 cm-1. The FTIR spectrum (KBr) of the film produced on carbon steel following immersion in sea water and 250 ppm amino benzoic acid is shown in Fig.4b and Table 4. The frequency of CH stretching has gone from 2918.60 to 2923.38 cm-1. CO is now stretching at a rate of 1630.88 cm-1. The number of times NH stretches is 3363.49 cm-1.

The CN stretching frequency goes from 1410.32 cm-1 to 1423.32 cm-1 because there is a complex on the surface of the carbon steel. At 620.76 cm-1, a new peak appears. On carbon steel, the oxygen or nitrogen atom of amino benzoic acid has joined up with Fe2+. Analysis of the FTIR spectrum shows that the coating is made of Fe2+ – amino benzoic acid [15,16].

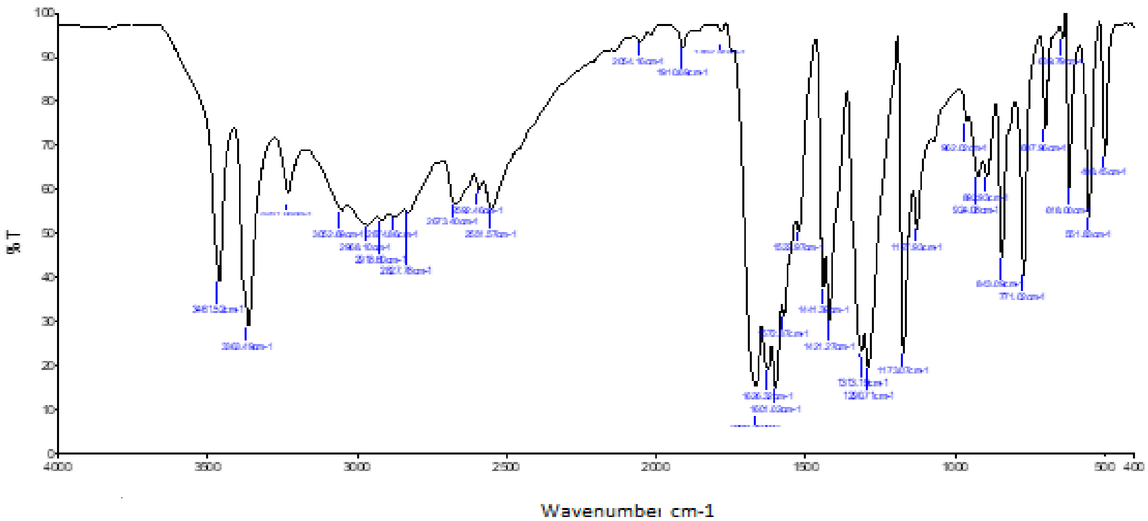

Fig. 4a: FTIR spectrum of pure amino benzoic acid

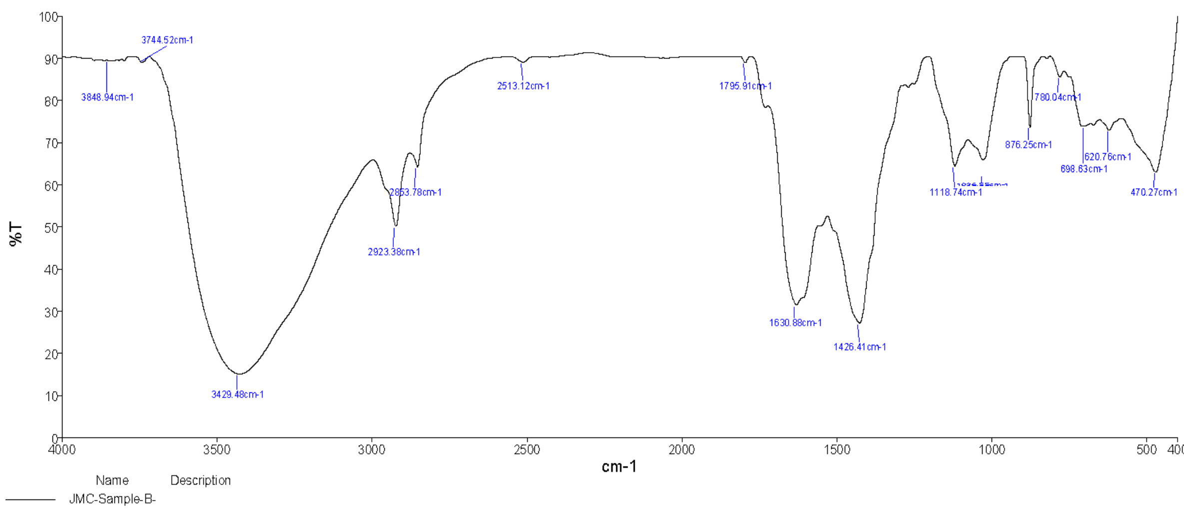

Fig. 4b: FTIR spectrum of film formed on the carbon steel surface after immersion in sea water solution containing 250 ppm of amino benzoic acid

Table 4: IR spectral values of amino benzoic acid and film formed over the carbon steel surface is obtained from IR Spectra

Functional group	Pure amino benzoic acid compound (peaks appears at cm^{-1})	The protective film is formed after immersion of carbon steel in sea water solution containing 250 ppm of amino benzoic acid (peaks appears at cm^{-1})
C-H	2918.60	2923.38
N-H	3363.49	-
C-O	1626.32	1630.88
C-N	1410.32	1423.32
M-O	-	620.76

SEM examination

SEM surface morphology was used to analyse the surface state of carbon steel specimens. Fig. 5 (a, b, and c) shows SEM images of carbon steel that was submerged in sea water for one day with and without an inhibitor. Fig. 5a is a SEM micrograph of carbon steel that has been polished (control). This shows that carbon steel doesn't have any corrosion products or inhibitor complexes [17].

The roughness of the carbon steel surface in Fig. 5b demonstrates heavily corroded carbon steel in sea water. In Fig. 5c, the presence of an inhibitor (250 ppm of ABA) suppresses corrosion, as indicated by the reduction in corroded regions. The creation of insoluble complex on carbon steel's surface prevents corrosion. In the presence of ABA, a thin layer of inhibitors inhibits carbon steel disintegration [18,19].

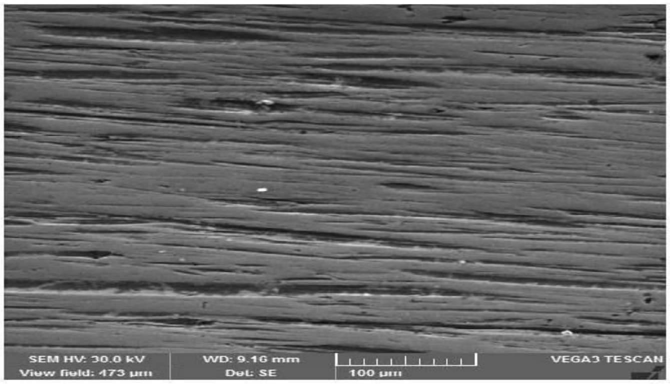

Fig. 5: SEM analysis of (a) Carbon steel ; Magnification 100 µm (control)

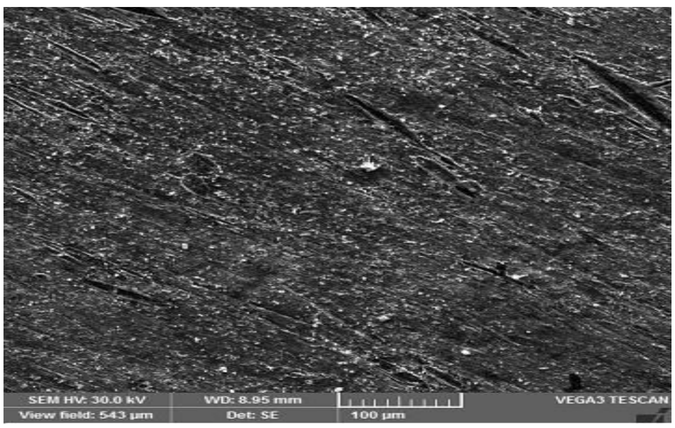

Fig. 5: SEM analysis of (b) Carbon steel ; Magnification 100 µm (control) in sea water

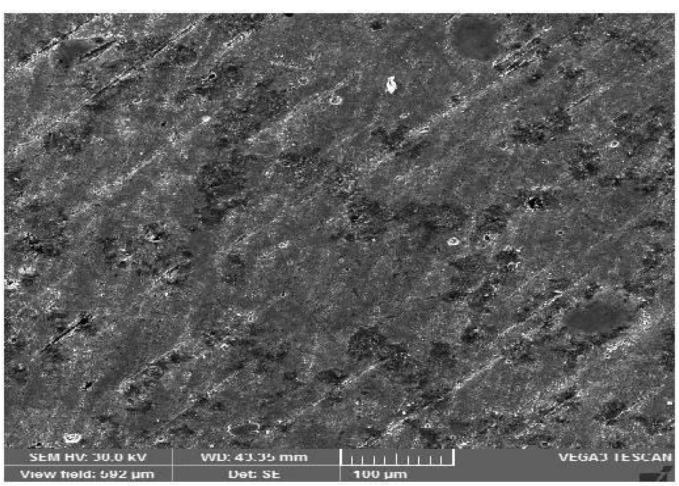

Fig. 5 (c)***) Carbon steel in sea water solution + 250 ppm ABA solution Magnification 100 µm***

AFM data analysis

With atomic force microscopy, you can measure how rough the surface is. AFM is becoming the standard way to test for roughness. Atomic force microscopy showed that corrosion is stopped when something sticks to the surface of the metal. Atomic force microscopy was used to study the surface roughness of seawater-immersed carbon steel and polished carbon steel (reference) [20,22].

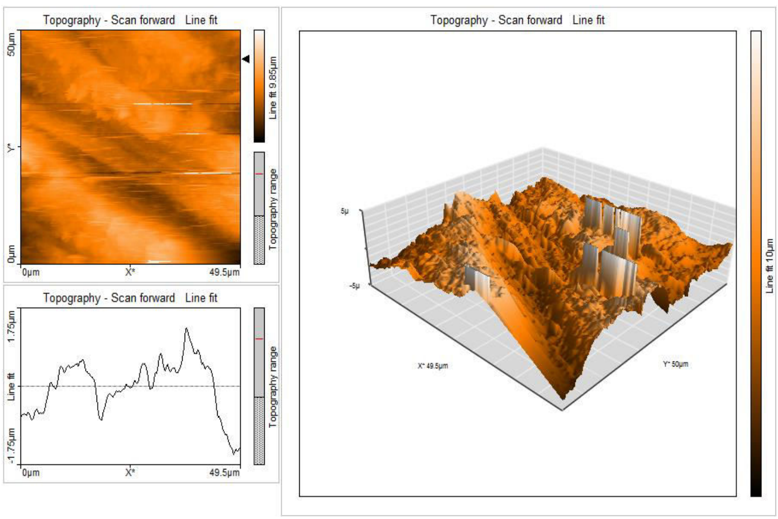

Fig. 6a: AFM image of polished carbon steel specimen (control)

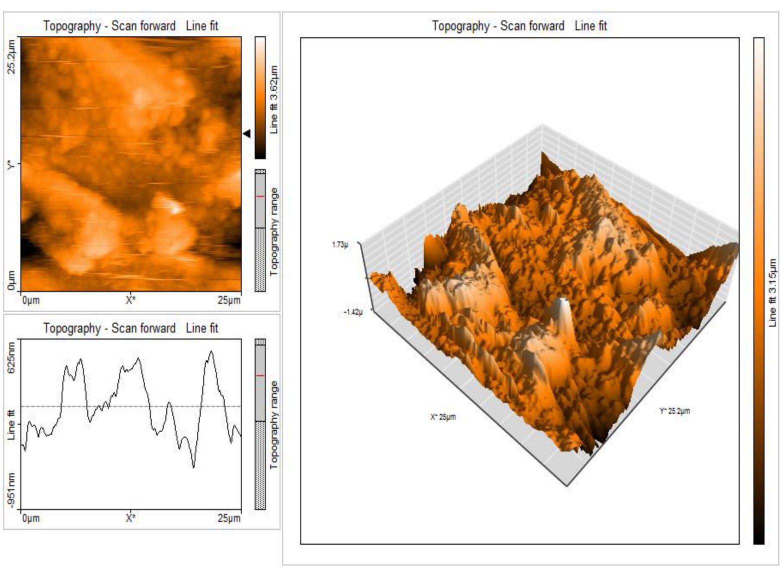

Fig. 6b: AFM image of carbon steel specimen immersed in sea water

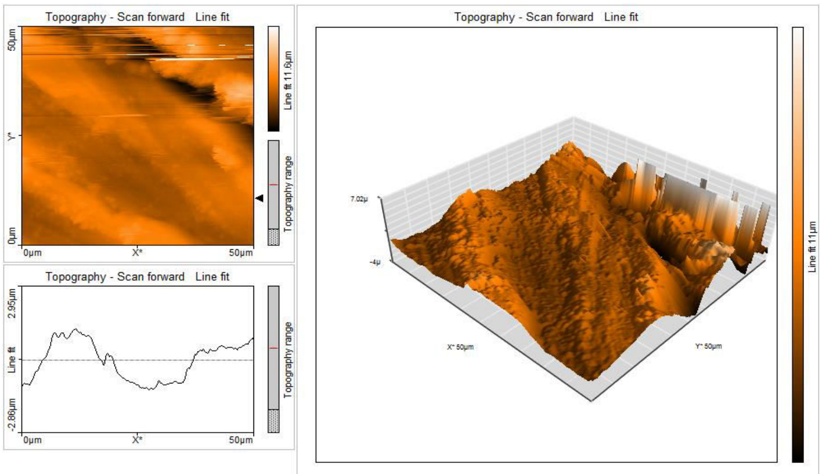

Fig. 6c: AFM image of carbon steel specimen immersed in sea water with inhibitor (ABA)

Table 5: AFM data for carbon steel immersed in the presence and absence of inhibitor systems

Samples	**Value in nm**			
	S_p	**S_{q}.**	**S_a**	**S_y**
Carbon steel surface	702.5	107.18	836.65	107.68
Carbon steel surface immersed in sea water	1979	456.13	953.24	376
Carbon steel surface immersed in sea water + 250 ppm of ABA	715	118	881	134

Table 5 shows that the AFM technique gave values like Sp, Sq, Sa, and Sy for the polished carbon steel surface (reference) of 703.5, 107.18, 836.65, and 107.68 nm, which show a more uniform surface than for the blank (1979, 456.13, 953.24 and 376) nm, which shows that the roughness of the blank surface is higher than that of the polished carbon steel surface. Corrosion from salt water makes the surface of exposed carbon steel rougher (Fig. 6a, 6b).

From table 5, it's clear that the average roughness (Sa) goes down from 881 nm to 953.24 nm when a corrosion inhibitor is added to sea water. Large separameter differences demonstrate that the surface is smoother (Fig. 6c) owing to a compact protective coating [23-25].

CONCLUSION

In this study, amino benzoic acid was used as a corrosion inhibitor to stop carbon steel from rusting in sea water. Based on weight-loss method, polarisation studies, AC impedance measurements, and surface inspection methods including FTIR spectroscopy, SEM, and AFM, the mechanistic elements of corrosion inhibition have been proposed. With more ABA, the rate of corrosion slows down because amino benzoic acid sticks to the surface of carbon steel. This study shows that

- Carbon steel in seawater doesn't rust because of amino benzoic acid.
- Studies of polarisation show that amino benzoic acid systems that work well are cathodic inhibitors.
- The weight-loss approach inhibits 81.56 percent.
- Experiments on electrochemical impedance show that Rt, Cdl, and corrosion all go up as Rt goes up because the absorbed layer is thicker.
- The protective film is Fe2+-ABA, according to FTIR.
- SEM micrographs show surfaces of carbon steel that have been polished.
- AFM microscopes measure carbon steel's roughness and smoothness.

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