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Data Article

Effect of water-soluble chitosan on the electrochemical corrosion behaviour of mild steel

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ABSTRACT

This article outlines the role of chitosan as a potent inhibitor on mild steel in 3.65% NaCl. The protective ability of chitosan was evaluated by potentiodynamic polarization (PP) measurements in 36.5% sodium chloride medium. The outcome of the experiment shows that mild steel in sodium chloride solution containing chitosan nanoparticles exhibit better corrosion protection than mild steel in NaCl solution alone because the anodic and cathodic site of the steel were blocked by chitosan nanoparticles, thereby minimising the incursion of the salt solution by forming a thin film on the mild steel surface. The inhibitive efficiency of chitosan nanoparticles was also studied using weight loss. The weight loss by mild steel in NaCl solution was found to be higher than those immersed in NaCl-chitosan nanoparticulate solutions. The loss in weight reduces as the concentration of chitosan nanoparticles increases, indicating the fortifying ability of chitosan nanoparticles. Results obtained show that chitosan could offer inhibition efficiency above 90%. The mixed inhibition characteristic of chitosan was demonstrated by the Tafel curve. The Langmuir isotherm possesses an R^2 value of 0.9957 indicating the effectiveness of chitosan as an inhibitor.

Specifications table

Subject area:	Mechanical engineering science, Material science and engineering, Chemical engineering
Compound:	Chitosan, NaCl
Data category:	Corrosion rate by potentiodynamic polarization (PP) instrument (NOVA 2.1.2)
Data acquisition:	Potentiodynamic polarization measurement and weight loss
Data type:	Raw, analysed
Procedure:	Mild steels were immersed in 3.65% NaCl containing chitosan nanoparticles of different concentration. The corrosion rates were examine and analysed using potentiodynamic polarization measurement and weight loss.

1. Rationale

Corrosion of metals and alloys is an underlying process playing vital functions in safety and economic advancement. Mild steel has been found to have versatile applicability in a production of engines and tools despite its ability to corrode [1–3]. Due to this setback, a lot of defensive techniques have been adopted to enhance the service life of mild steel, not only

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Table 1
Chemical composition of mild steel used (wt.%).

Element	Mn	C	S	Si	P	Ni	Al	Fe
Composition	0.45	0.15	0.031	0.18	0.01	0.008	0.005	99.346

Table 2
Electrochemical parameters from Tafel curve.

Samples	E_{corr} (V)	I_{corr} (A/cm^2)	CR (mm/year)	b_a (V/dec)	b_c (V/dec)	PR (Ω)	IE (%)
Control	−1.1655	0.00074955	8.7097	0.088705	0.045097	17.323	0
MS_1-0.3CH	−1.1841	0.0003073	3.5708	0.027093	0.02074	17.902	59
MS_2-0.6CH	−1.1875	0.00020887	2.4271	0.019162	0.011755	18.148	72.13
MS_3-0.9CH	−1.1945	0.00011895	1.3822	0.011944	0.00955335	19.357	84.13
MS_4-1.2CH	−1.1951	0.00007356	0.8548	0.0082416	0.0080543	24.049	90.19

against corrosion but also against operational wear [4–6]. The study of the corrosion repression of mild steel has, therefore, gained momentum across multidisciplinary fields [7]. Because of the attack of mild steel in aggressive acidic and saline environments, inhibitors are commonly used to suppress the damaging effect of corrosion. The impact of corrosion on steel is chiefly a surface event [8,9]. However, the medium is one of the main factors that influence corrosion, having a large tendency to alter material properties and behavioural performance in operation [10–12].

A lot of methods have been used to combat the attack of corrosion on mild steel but the use of inhibitive particulates have been found effective and applicable [11–13]. Most inhibitors have been found to be relatively cheap, environment-friendly and also pave way for easy reproducibility [14,15]. A good example is the chitosan found to be richly available in the [16]. Its broad range of application can be attributed to its unique properties, which include non-toxicity, bio-compatibility, bio-degradability and great film forming capability on steel [15–17]. Chitosan's anti-corrosion capability is also a function of its molecular structure. Chitosan is naturally equipped with amino and hydroxyl that have the propensity to form bonding on the surface of steel metal [18,19] resulting in corrosion protection. The bond formed on the increase the surface energy of the steel and further aiding molecular adhesion after a long period of immersion thereby resulting in corrosion inhibition [20–22].

2. Procedure

The corrosion experiment was executed in a standard three-electrode cell using potentiostat (PGSTAT 101) in connection with NOVA 2.1.2 software. The working electrode is a mild steel specimen of dimension (20 × 20 × 2) mm whose composition is stated in Table 1. Saturated Ag/AgCl electrode and platinum electrode were used as reference and counter electrode, respectively. Different grades of emery papers were used to clean the working electrodes and rinsed quickly with distilled water. A copper wire was fused to the sample, which was afterwards implanted in epoxy resin. This was allowed to immerse in the electrolyte solution (3.65% NaCl) for about 10 min to attain the steady state potential. The polarization plots were obtained from the cathodic potential of −1.5 V to anodic potential of 1.5 V at a scan rate of 0.005 m/s.

The same procedure was carried out with four other mild steel samples varying the concentration of chitosan nanoparticles in four different 3.65% NaCl solution and the effects were noted. To check for reproducibility each experiment was repeated four times. Values of the electrochemical parameter obtained from the extrapolation of the polarization curves are indicated in Table 2. The polarization curves are an indication that both the cathodic and anodic metal dissolution reactions have been influenced by the addition of chitosan nanoparticles. After the corrosion experiment, weight loss measurement of each of the samples was carried out so as to note the influence of chitosan on the dissolution of mild steel in the saline medium.

3. Data, values and validation

The corrosion experiment data are represented graphically in Figs. 1 and 2 These figures are the plot of data after varying the concentrations of water-soluble chitosan in the saline medium. Each of the plots shows indispensable details. The values in Table 2 indicate the parameters from the polarization curve in Fig. 2.

The values of the data presented graphically and in tables include:

- The OCP in Fig. 1. There was a shift in potential towards more positive values with respect to the control as the concentration increases. This could be attributed to the adsorption of chitosan molecules on the anodic site of the mild steel. It is important to note that the OCP vs. time curve for the inhibited and uninhibited samples were near straight line indicating that steady state potential was attained [23].
- Tafel plot in Fig. 2 suggesting that polarization has taken place because of the presence of both cathodic and anodic branch [24].

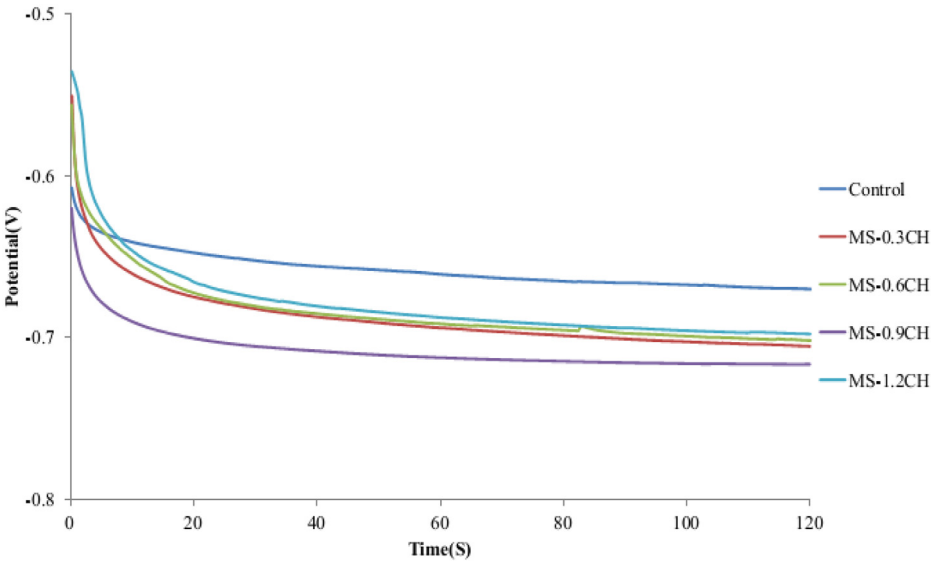

Fig. 1. Graphical plot of open circuit potential of mild steel with and without inhibitor versus time.

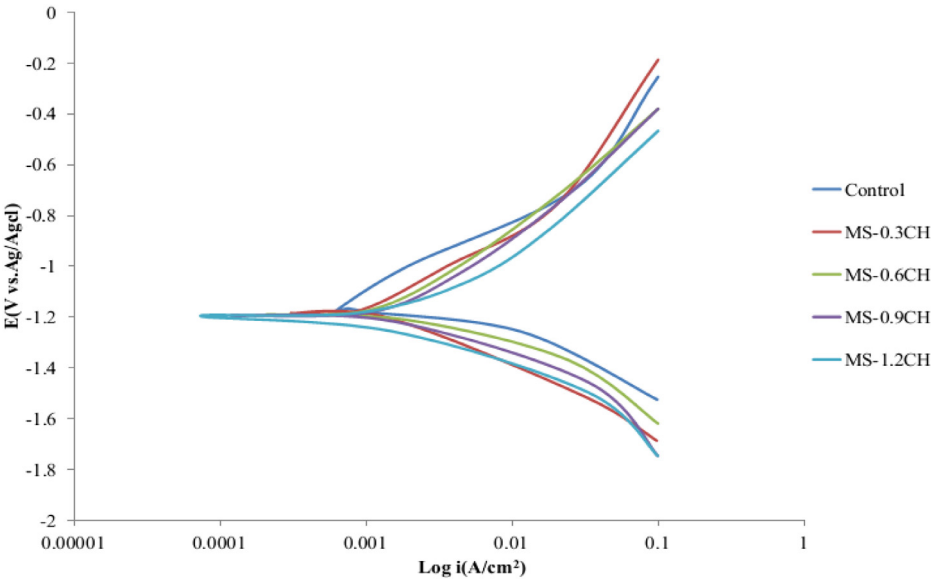

Fig. 2. Potentiodynamic polarization curve of uninhibited and inhibited samples.

- Evaluation of b_c and b_a (cathodic and anodic slope), as well as I_{corr}; the values of the corrosion current densities and corrosion potential (E_{corr}) were obtained by Tafel extrapolation of the current and potential lines. It is worthy of note that addition of chitosan hindered the exchange of current density, this was confirmed by movement of the anodic and cathodic curves to the direction of lower current density [25,26]. Table 2 indicates that an increase in chitosan nanoparticles from 0.3 g through 0.6 g, 0.9 g and finally 1.2 g significantly minimise the corrosion rate of mild steel. However, E_{corr} for the varying concentrations is closed, suggesting that polarization is a mixed type which shows that the water-soluble chitosan is a mixed-type inhibitor [27–29].

It is also worthy of note in Table 2 that the corrosion rate per year was on the decline as the concentration of the chitosan nano inhibitor increases. It was highest for the control and lowest for MS_4-1.2CH which shows that corrosion rate reduces with increase in chitosan [30]. The surface coverage (θ) by molecules of the inhibitor was obtained using Eq. 1 [31]

$$\theta = (I_{0,corr} - I_{corr})/I_{0,corr} \quad (1)$$

The value of (θ) was maximum when chitosan concentration reaches the maximum values of 1.2 g [32,33].

$$\text{Inhibitorefficiency, IE} = (1 - I_{corr}/I_{0,corr}) \times 100 \quad (2)$$

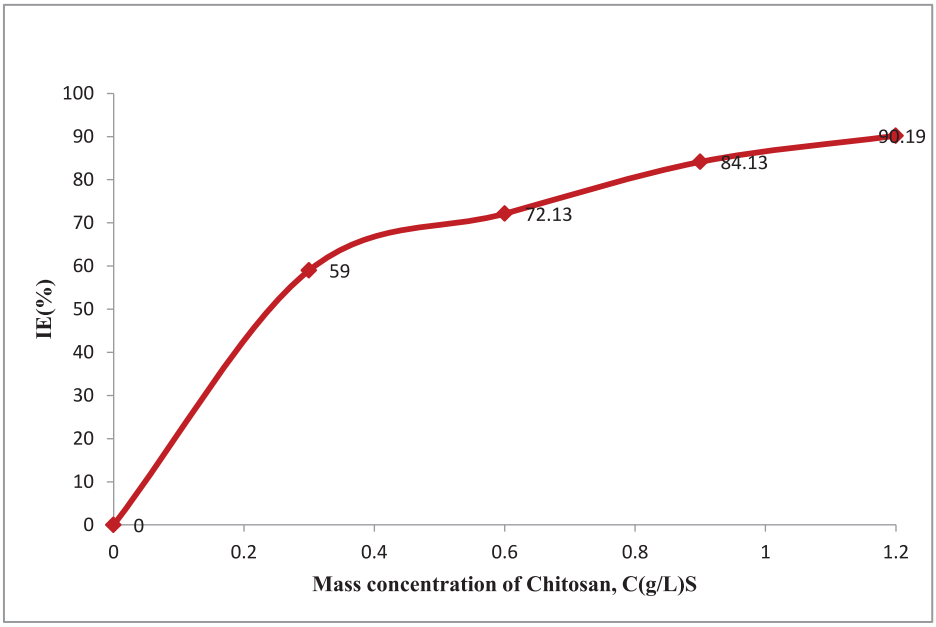

Fig. 3. Inhibition efficiency of chitosan inhibitors in 36.5% NaCl.

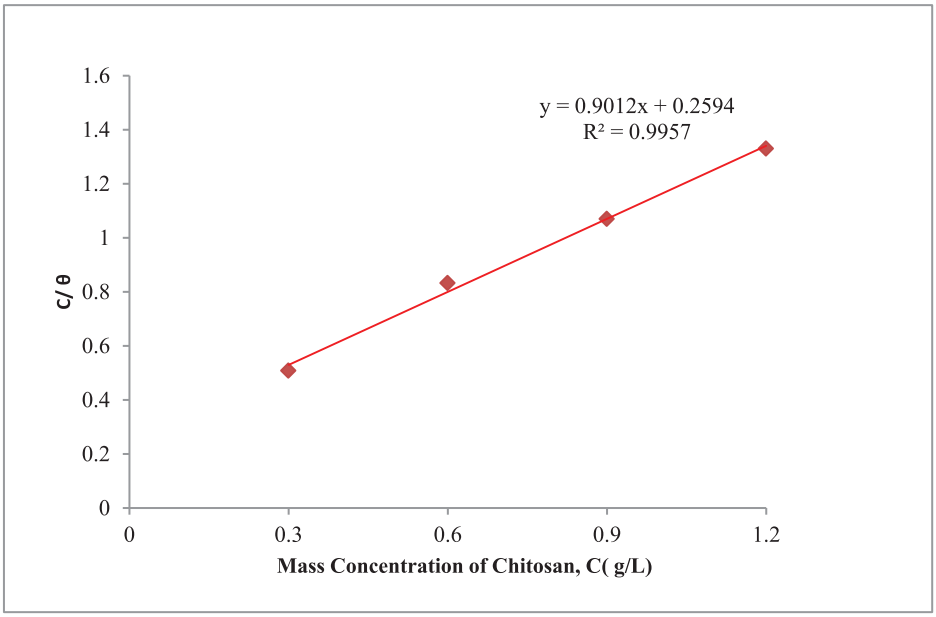

Fig. 4. Langmuir adsorption isotherms for the inhibited samples.

From the variation of the corrosion inhibition efficiency of chitosan inhibitors with their concentration in 36.5% NaCl shown in Fig. 3, a conclusion could be reached that the water-soluble chitosan is highly efficient. There was an improvement in the inhibition effectiveness as the concentration of chitosan increases. The improvement results from the chitosan adsorption on the steel surface. The resistance to polarization was also found to have increased with an increase in the mass concentration of chitosan as shown in Table 2, ascertaining the corrosion retardation potential of chitosan. Fig. 4 shows the Langmuir isotherm with an R^2 value of 0.9957. The closeness of R^2 to unity confirms the validity of the experiment [34–36].

After the electrochemical experiment, loss in masses was observed, it was highest for the uninhibited mild steel used as the control and lowest for MS_4 (Mild steel immersed in NaCl containing 1.2 g of chitosan) as showed in Table 3. This is an indication that chitosan offers an excellent resistance to corrosion and wear resistance to mild steel.

Table 3
Mass of steel loss after immersion, surface coverage and C/θ.

Samples after immersion	Loss (g)	Surface coverage (θ)	C/θ
Control	0.0186	0	0
MS_1	0.0152	0.5900	0.5085
MS_2	0.0123	0.7210	0.8322
MS_3	0.0121	0.8410	1.0702
MS_4	0.0110	0.9020	1.3304

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.cdc.2018.10.006.

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