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Influence of Polyacrylamide on Corrosion Resistance of Mild Steel Simulated Concrete Pore Solution Prepared In Well Water

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Abstract: *Corrosion resistance of mild steel in simulated concrete pore solution (SCPS) Prepared in well water in the absence and presence of polacrylamide (PAA) and Zn^{2+} has been evaluated by weight loss method. It is observed that when PAA is added the corrosion inhibition efficiency (IE) increases. As the concentration of PAA increases , inhibition efficiency also increases . Addition of Zn^{2+} improves of IE further. 50 ppm of PAA has 60% IE . 100 ppm of PAA shows 75% IE. When 50 ppm of Zn^{2+} is added to the above system , both system shows 80% and 90% IE. The mechanistic aspects of corrosion inhibition have been investigated by polarization study and AC impedance spectra. . Polaraization study suggests that the PAA-Zn^{2+} system functions as a mixed inhibitor system .AC impedance reveal the presence of a protective film on the metal surface.*
Keywords: *concrete corrosion , simulated concrete pore solution, mild steel, polyacrylamide.*

I. Introduction

Corrosion is the destruction of metals and alloys by chemical and electro chemical reaction with its environment. It is a natural phenomenon which cannot be avoided ,but it can be controlled and prevented using appropriate techniques like metallic coating, anodic protection,cathodic protection and using inhibitors,etc. Inhibitors have very good role in the presence of corrosion inhibition.The organic inhibitors contain hetero atom like oxygen , nitrogen, sulphide and phosphorous. It shows better corrosion efficiency of the compounds containing hetero atom follows O<N<S<P.[1-4] Application of polymers as corrosion inhibitors have been attracted several researchers.[5-7] Corrosion inhibition by conducting polymer has been studied[8].The studies on corrosion inhibition of polyacrylamide grafted with fenugreek mucilage[9]and polyvinyl prolidone have been reported.[10] A saturated solution of calcium hydroxide is used as simulated concrete pore solution.[11-15] The aim of the present study is to investigate the corrosion resistance of mild steel in simulated concrete pore solution in presence of polyacrylamide and Zn^{2+}combination to mild steel in well water.The physico-chemical parameters of the well water taken in preset study are given (Table-1). The corrosion inhibition efficiency was collected using weight loss, polarization and AC impedance studies. The protective film formed on the metal surface .

Table 1. Parameters of well water.

Parameter	Value
pH	8.38
Conductivity	3110 1/cmΩ
TDS	2013 ppm
Chloride	665 ppm
Sulphate	14 ppm
Total hardness	1100 ppm

II. Materials And Methods

Preparation of specimens

Mild steel specimen was used in the present study.(Composition (wt%):0.026 S, 0.06% P, 0.4% Mn, 0.1% C and balance iron[16]) of the dimensions 1.0X4.0X0.2 cm were polished to a mirror finish and decreased with trichloroethylene and used for the weight loss method.

Simulated concrete pore solution (SCPS)

A saturated calcium hydroxide solution is used in the present study,as SCP solution. The electrodes made of mild steel wire were immersed in the SCP solution polarization study and AC impedance was carried out.

Mass-loss method

Mild steel specimens in triplicate were immersed in 100 mL of simulated concrete pore solution (SCPS) containing various concentrations of the inhibitor in the presence and absence of Zn^{2+} for one day. The weight of the specimens before and after immersion was determined using Shimadzu balance, model AY 210. The corrosion products were cleansed with Clarke's solution .[17] Then the inhibition efficiency (I.E.) was then calculated using the equation(1)

$$I.E = 100\ [1-(W2/W1)]\ \%\ \ldots\ldots\ldots\ldots\ldots(1)$$

Where W_1 and W_2 are the corrosion rates in the absence and presence of the inhibitor respectively. The corrosion rate(CR) was calculated using the formula(2).

CR= [(Weight loss in mg) / (Area of the specimens in dm^2 x immersion period in days) mdd-----.-------------------------(2)

Potentiodynamic Polarization

Polarization stud was carried out in Electrochemical impedence Analyser model CHI 660 A using a three electrode cell assembly was used. The woring electrode was used as a rectangular specimen of mild steel with the one face of the electrode of constant $1cm^2$ area exposed.A saturated calomel electrode(SCE) was the reference electrode and platinum was the counter electrode . From the polarization study, corrosion parameters such as corrosion potential (E_{corr}) correction current(I_{corr}) and tafel slopes (anodic= ba and cathodic=bc) were calculated.

AC impedance spectra

The instrument used for polarization study was used to record AC impedance spectra also.The cell setup was the same. The real part(Z^1) and imaginary part (Z^{11}) of the cell impedance were measured in ohms at various frequencies. The values of the charge transfer resistance (R_t) and the double layer capacitance(C_{dl}) were calculated.

III. Results And Discussion

Analysis of weight loss study

The calculated inhibition efficiencies (IE) and corrosion rates (CR) PAA in controlling corrosion mild steel immersed in simulated concrete pore solution in the absence and presense of Zn^{2+} ion are given in **Table 2.**The calculated value indicates the ability of PAA to be a good corrosion inhibitor.PAA alone shows some IE. But the combination of PAA 100 ppm and Zn^{2+} 50 ppm shows 90% IE. This suggest a synergitic effect exists between PAA and Zn^{2+} ion.[18]

Table 2

Inhibition efficiencies (IE%) and corrosion rates (CR) obtained from PAA-Zn^{2+} system, when mild steel immersed in simulated concrete pore solution prepared in well water

System	*IE* %	*CR* mdd
50 ppm PAA	60	15.6
100 ppm PAA	75	9.75
50 ppm PAA+Zn^{2+} 50 ppm	80	7.8
100 ppm PAA+Zn^{2+}50 ppm	90	3.9

Analysis of polarization curves

The potentiodynamic polarization curves of mild steel immersed in simulated concrete pore solution prepared in well water in the absence and presence of inhibitor are shown in **Figure -1.** The corrosion parameters such potential(E_{corr}) ,Tafel slopes (b_c= cathodic ; b_a= anodic),Linear polarization resistance(LPR) and corrosion current (I_{corr}) are given in Table –3. When mild steel is immersed in SCPS the corrosion potential is -591 mV vs

SCE (Saturated calomel electrode) When 100 ppm of PAA and 50 ppm of Zn $^{2+}$ are added to the above system the corrosion potential shifted to the cathodic site -658 mV vs SCE . This indicates that the PAA-Zn^{2+}system control the cathodic reaction predominantly. Further, the LPR value increase from 7965 ohmcm^2 to 17235 ohmcm^2 ,the corrosion current decreases from 4.187 x10^{-6} A/cm^2 to 1.877 x10^{-6}A/cm^2. Thus polarization study confirms the formatiom of a protective film on the metal surface.The anodic reaction is controlled by the formation of Fe^{2+}- PAA confirms on the anodic sites. The cathodic reaction (generation of OH^-) is controlled by the formation of $Zn(OH)_2$ on the cathodic sites on the metal surface.Thus anodic reaction and cathodic reaction are controlled. This accounts for synergistic effect.[19,20]

Table 3
Corrosion parameters of mild steel immersed in SCPS prepared well water in the absence and presence of inhibitor system obtained from potentiodynamic polarization study

System	Ecorr mV vs. SCE	b_c mV/decade	b_a mV/decade	LPR ohmcm^2	Icorr Acm^{-2}
SCPS (blank)	-591	107	269	7965	4.187 x10^{-6}
SCPS + 100 ppm PAA + 50ppm Zn^{2+}	-658	97	319	17235	1.877 x10^{-6}

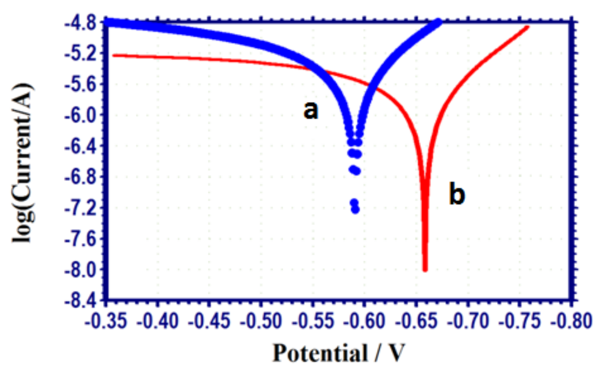

Figure 1. Polaraization curves of mild steel immersed in various test solution (a) SCPS (blank) (b) SCPS + PAA 100 ppm + Zn^{2+} 50 ppm

Analysis of AC impedance spectra

AC impedance spectra of mild steel immersed in simulated concrete pore solution prepared in well water in the absence and presence of inhibitor and Zn^{2+} are shown in the figs 2 to 4. The nquist plots are shown in Fig 2. The Bode plots are shown in Fig 3 and 4 . The charge transfer resistance (R_t) and double layer capacitance (C_{dl}) values are derived from Nquist plots . Impadance values, log (z / ohm) are derived from bode plots .The results are summarized in Table 4 .

Table 4
Impadance parameters of metals immersed in simulated concrete pore solution prepared in well water, obtained by AC impedance spectra

System	Nquist plot		Bode plot
	R_t ohm. cm^2	C_{dl} Fcm^{-2}	log (z/ ohm)
SCPS (blank)	3045	6.305 x 10^{-9}	3.4
SCPS + 100 ppm PAA +50ppm Zn^{2+}	7315	2.624 x 10^{-9}	3.9

When corrosion rate decreases .due to formation of protective film, the charge transfer resistance value increases and double layer capacitance value decreases , the impedance value log (z/ohm) increases. [21-25] . It is observed from Table 4, the R_t value 3045 ohm. cm^2, the C_{dl} Value is 6.305 x 10^{-9} Fcm^{-2} and the impedance value is 3.4 log (z/ ohm). When 100 ppm PAA and 50ppm $Zn^{2+}$are added to simulated concrete pore solution . The R_t value 7315 ohm. cm^2 increases, the C_{dl} Value is 2.624 x 10^{-9} Fcm^{-2} decreases and the impedance value is 3.9 log (z/ ohm) increases. The increases charge transfer resistance (R_t) value , tha double layer capacitance (C_{dl}) value decreases and the impedance value (z) increases . This confirms the formation of protective film formed on the metal surface . This accounts for the better inhibition efficiency of the PAA –Zn^{2+}

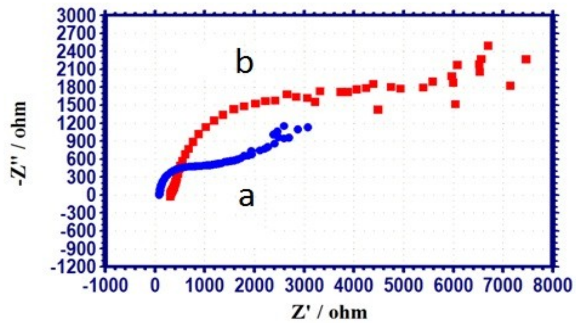

Figure 2. AC impedance spectrum of mild steel immersed in various test solution (a) SCPS(blank) (b) SCPS + PAA 100 ppm + Zn^{2+} 50 ppm (Nquist plot)

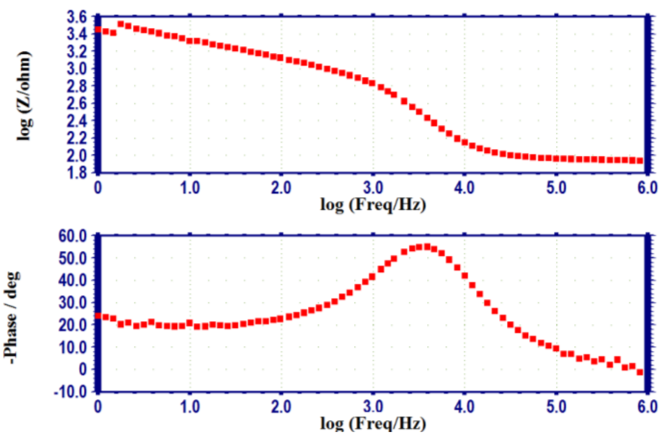

Figure 3. AC impedance spectrum of mild steel immersed in SCPS (Bode plot)

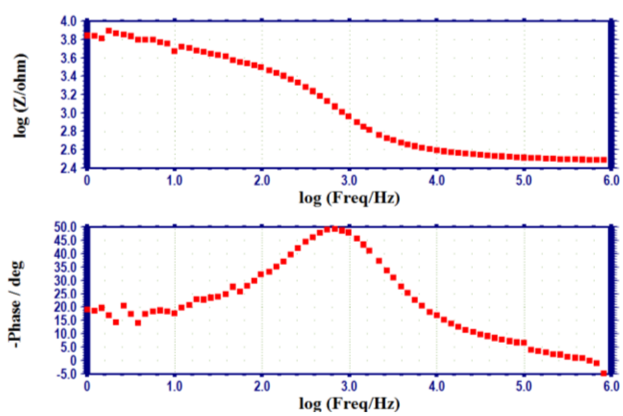

Figure 4. AC impedance spectrum of mild steel immersed in SCPS + PAA 100 ppm Zn^{2+} 50 ppm (Bode plot)

IV. Conclusion

The inhibition efficiency (IE) of polyacrylamide (PAA) in controlling corrosion of mild steel immersed in simulated concrete pore solution prepared in well water in the absence of Zn^{2+} has been evaluated by weight loss method . The formulation consisting of 100 ppm PAA and 50 ppm Zn^{2+} has 90% corrosion inhibition efficiency. Polarization study reveals that PAA-Zn^{2+} system controls the cathodic reaction predominantly. AC impedance spectra reveal that the formation of protective film on the metal surface.

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