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Corrosion resistance of mild steel immersed in simulated concrete pore solution in the presence of sodium potassium tartrate

ABSTRACT

The corrosion resistance of mild steel in simulated concrete pore solution (SCPS) in the absence and presence of sodium potassium tartrate (SPT) has been investigated by polarization technique and AC impedance spectra. The present study leads to the following conclusions. Polarization study reveals that sodium potassium tartrate system functions as anodic type of inhibitor. AC impedance spectra reveal that a shielding film is formed on the metal surface. When mild steel is used as rebar, sodium potassium tartrate may be mixed with concrete. Thus the mild steel will be protected from corrosion. The protective film consists of ferrous tartrate complex formed on metal surface. In the presence of sodium potassium tartrate the linear polarisation resistance increases from 226 Ohmcm^2 to 455 Ohmcm^2, corrosion current decreases from 1.901x10^{-4}A/cm^2 to1.096 x10^{-4}A/cm^2, charge transfer resistance (R_t) increases from 49 Ohmcm^2 to 77 Ohmcm^2, impedance increases from 1.807 to 2.084, phase angle increases from 33.92° to 35.31° and double layer capacitance (C_{dl}) value decreases from 1.040x10^{-7}F/cm^2 to 0.662 x10^{-7}F/cm^2. Corrosion potential shifts from -973 mV/SCE to -867 mV/SCE .This confirms that the inhibitor system functions as anodic type of inhibitor controlling anodic reaction predominantly. This formulation may find application in concrete technology. This may be used in the construction of bridges and concrete structures.

Keywords: *sodium potassium tartrate, corrosion resistance, mild steel, simulated concrete pore solution, electrochemical studies, electrochemical impedance spectra*

1. INTRODUCTION

Concrete technology addresses the properties of concrete needed in construction applications, including strength and durability, and provides guidance on all aspects of concrete from mix design to batching, mixing, transporting, placing, consolidating, finishing, and curing. In concrete technology, rebars are used to strengthen the structure of concrete.

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To have power over the corrosion of rebars, numerous corrosion inhibitors have been used along with concrete admixtures [1-10]. Naderi et al. have reported the use of licorice plant extract for controlling corrosion of steel rebar in chloride-polluted concrete pore solution [1]. Passivation and depassivation properties of Cr–Mo alloyed corrosion-resistant steel in simulated concrete pore solution have been reported by Jin et al. [2]. Liu et al. have investigated the Corrosion Behavior of Steel Subjected to Different Corrosive Ions in Simulated Concrete Pore Solution [3]. Kim et al. have proposed electrochemical evaluation of epoxy-coated-rebar containing pH-responsive nanocapsules in simulated carbonated concrete pore solution. The corrosion product analysis indicated that the inhibiting action has delayed the further oxidation of the exposed surface [4]. Sreelekshmi and Kumar have investigated the Effect of reduced graphene oxide nanoparticles as anticorrosion material on mild steel substrate. It has been found that epoxy coating containing 1.0 wt.% reduced graphene oxide had better corrosion resistance in concrete pore solution medium containing 0.5M NaCl solution [5]. Jin et al. have analysed the Comprehensive properties of passive film formed in simulated pore solution of alkali-activated concrete [6]. Sajid et al. have reported the use of Soy-protein and corn-derived polyol based coatings for corrosion mitigation in reinforced concrete [7]. Consequences of stray current and silicate ions on electrochemical behavior of a high-strength prestressing steel in simulated concrete pore solutions have been studied by Ming et al. Silicate ions were proven to be an eco-friendly corrosion inhibitor for steels subjected to coupling effects of stray current interference and chloride attack [8]. Song et al. have made use of ultrasonic wave to trigger microcapsule inhibitor alongside chloride-induced corrosion of carbon steel in simulated concrete pore solution. Electrochemical results revealed that the ultrasound trigger measure could exert most of the corrosion inhibition effect of the core materials in microcapsules [9].

Sajid et al. have proposed soy-protein and corn-derived polyol based coatings for corrosion alleviation in reinforced concrete. The projected soy protein coating materials can be used for in-situ repairs of spoiled rebar coatings in hostile chloride environments and as a standalone coating in reasonably corrosive environments [10].

In the present study, the influence of sodium potassium tartrate (SPT) (Figure 1) [11,12] on the corrosion resistance of mild steel immersed in simulated concrete pore solution has been evaluated by electrochemical studies, such as polarization study and AC impedance spectra.

2. EXPERIMENTAL

2.1. Preparation of Simulated Concrete Pore Solution (SCPS)

A saturated solution of calcium hydroxide is used as SCPS.

2.2. Inhibitor

200 ppm of sodium potassium tartrate (SPT) is used as corrosion inhibitor.

Potassium sodium tartrate tetrahydrate, also known as Rochelle salt, is a double salt of tartaric acid first prepared (in about 1675) by an apothecary, Pierre Seignette, of La Rochelle, France.

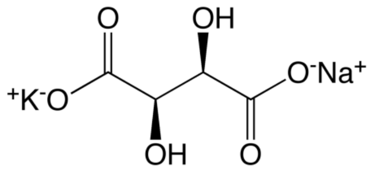

Figure 1. Sodium potassium tartrate

Slika 1. Struktura natrijum-kalijum tartarat

2.3. Electrochemical studies

The corrosion resistance of mild steel immersed in various test solution has been measured by electrochemical studies such as Polarisation study and AC impedance spectra [13-22].

2.4. Polarisation study

A CHI electrochemical work station with impedance model 660A was used for this purpose. A three-electrode cell assembly electrode was used in the present study. Mild steel was used as working electrode; saturated calomel electrode was used as reference electrode and Platinum electrode was used as counter electrode . From the Polarisation study corrosion parameters such as corrosion potential (E_{corr}) corrosion current (I_{corr}) and Tafel slope values (anodic = b_a and cathodic = b_c) and Linear polarisation resistance (LPR) were calculated. The scan rate (V/S) was 0.01.

2.5. AC impedance spectra

AC impedance spectral studies were carried out on a CHI – Electrochemical workstation with impedance, Model 660A. A three – electrode cell assembly was used. The working electrode was mild steel, A saturated calomel electrode (SCE) was the reference electrode and platinum was the counter electrode.

The real part (Z') and imaginary part (-Z'') of the cell impedance were measured in ohms at various frequencies. Values of the charge transfer resistance (R_t) and the double layer capacitance (C_{dl}) were calculated from Nyquist plots and Bode plots.

3. RESULTS AND DISCUSSION

3.1. Analysis of polarisation curves (Tafel plots)

Polarisation study has been used to detect the formation of protective film on the metal surface. When a protective film formed on the metal surface, the linear polarisation resistance (LPR) increases and the corrosion current (I_{corr}) decreases [13-22]. The potentiodynamic polarisation curves of mild steel immersed in various test solutions are shown in Figure 2. The corrosion parameters namely, corrosion potential (E_{corr}), Tafel slopes (b_c= cathodic; b_a= anodic) linear polarisation resistance (LPR) and the corrosion current (I_{corr}) are given in Table 1.

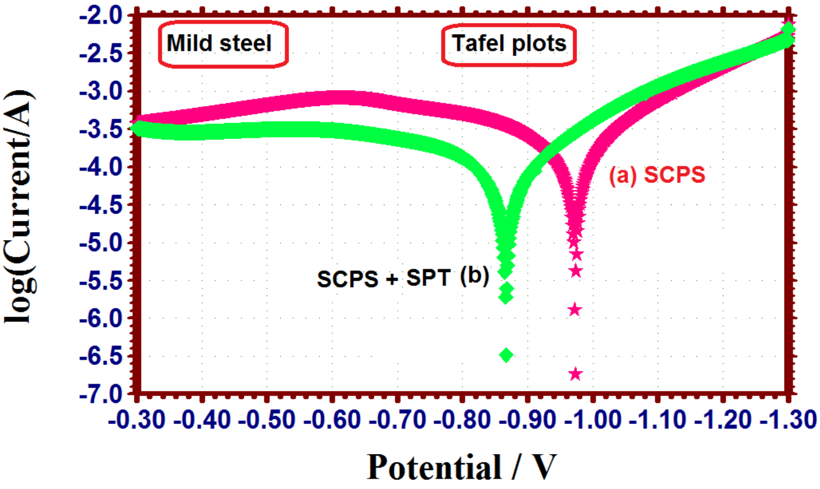

Figure 2. Potentiodynamic polarization curves of mild steel immersed in various test solutions: (a) SCPS, (b) SCPS + SPT

Slika 2. Potenciodinamičke polarizacione krive mekog čelika potopljenog u različite test rastvore: (a) SCPS, (b) SCPS + SPT

Table 1. Corrosion Parameters of mild steel immersed in various test solutions containing SCPS and sodium potassium tartrate (SPT) obtained by Polarization technique

Tabela 1. Parametri korozije mekog čelika uronjenog u različite test rastvore koji sadrže SCPS i natrijum-kalijum tartarat (SPT) dobijeni tehnikom polarizacije

System	E_{corr} mV/SCE	b_c mV/decade	b_a mV/decade	LPR Ohmcm^2	I_{corr} A/cm^2
SCPS	-973	165	248	226	1.901x10^{-4}
SCPS + SPT 200 ppm	-867	189	291	455	1.096 x10^{-4}

3.2. Influence of sodium potassium tartrate (SPT) on the corrosion résistance of mild steel immersed in SCPS

The formulation consisting of 200 ppm of SPT shifts the corrosion potential to from -973 to -867 mV vs SCE. The shift in corrosion potential is 106 mV. This indicates that the inhibitor functions as anodic type of inhibitor, controlling anodic reaction predominantly. The LPR value increases from 226 to 455 Ohmcm^2, and the corrosion current decreases from 1.901x10^{-4} to 1.096 x10^{-4} A/cm^2. In the presence of inhibitor, LPR value increases and corrosion current decreases. These results suggest that a protective film is formed on the metal surface and probably the protective film consists of Fe^{2+}-inhibitor complex (ferrous tartrate) (Figure 3) apart from $CaCO_3$ and CaO[23].

It is seen from Figure 1 that in the SPT, the oxygen atoms of the carbonyl groups are on opposite sites, to avoid electronic repulsion and to increase the stability of the molecule. During the formation of ferrous sulphate, the carbon atoms having the carbonyl groups have to rotate. The ferrous sulphate produced is a 7 membered ring (Figure 3). The atoms lie in different planes. Thus a stable puckered structure is produced based on Sachse-Mohr theory of strainless puckered complexes [24].

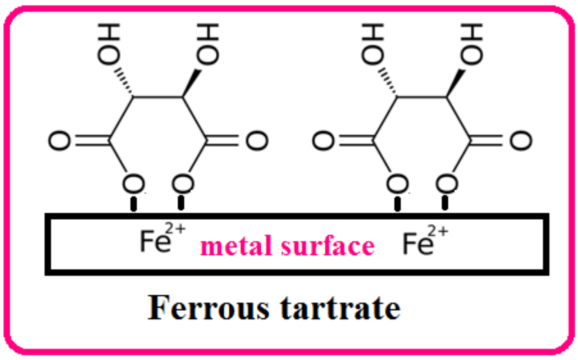

Figure 3. Structure of ferrous tartrate

Slika 3. Struktura fero-tartarata

3.3. AC impedance spectra

AC impedance spectra have been used to detect the formation of the film formed on the metal surface. If a protective film is formed, the charge transfer resistance (R_t) increases, impedance increases, phase angle increases and double layer capacitance (C_{dl}) value decreases. The AC Impedance spectra of mild steel immersed in various solutions are shown in Figures 4-7. The AC Impedance parameters, namely charge transfer resistance (R_t), impedance, phase angle and double layer capacitance (C_{dl}) are given in Table 2.

Table 2. Corrosion Parameters of mild steel immersed in various test solutions containing SCPS obtained by AC Impedance spectra

Tabela 2. Parametri korozije mekog čelika uronjenog u različite test rastvore koji sadrže SCPS dobijeni spektrom naizmenične impedanse

System	R_t Ohmcm^2	C_{dl} F/cm^2	Impedance Log(Z/ohm)	Phase angle°
SCPS	49	1.040x10^{-7}	1.807	33.92
SCPS + SPT 200 ppm	77	0.662 x10^{-7}	2.084	35.31

It is observed from the Table 2 that when mild steel is immersed in simulated concrete pore (SCPS) solution, the charge transfer resistance (R_t) increases, impedance increases, phase angle increases and double layer capacitance (C_{dl}) value decreases. These results propose that a protective film is formed on the metal surface and probably the protective film consists of Fe^{2+}-inhibitor complex (Figure 3) apart from $CaCO_3$ and CaO [23].

It is observed from Nyquist plots that the corrosion processes in the absence of inhibitor and presence of inhibitor are found to be mixed control systems consisting of a charge transfer reaction and a diffusion controlled process [23].

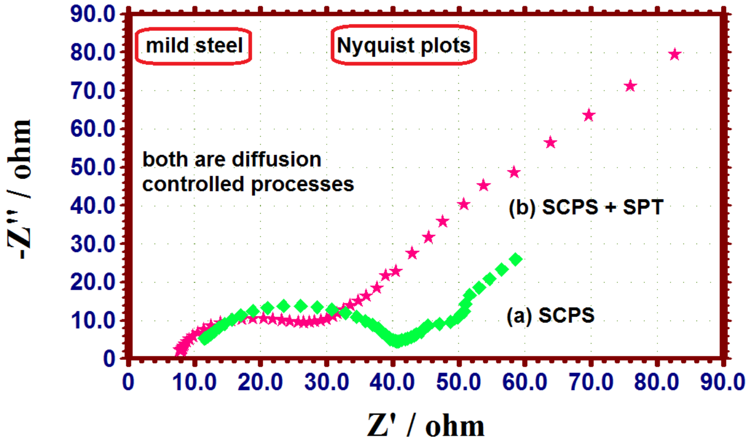

Figure 4. Nyquist plots of mild steel immersed in various test solutions: (a) SCPS, (b) SCPS + SPT

Slika 4. Nyquist-ove krive mekog čelika uronjeni u različite test rastvore: (a) SCPS, (b) SCPS + SPT

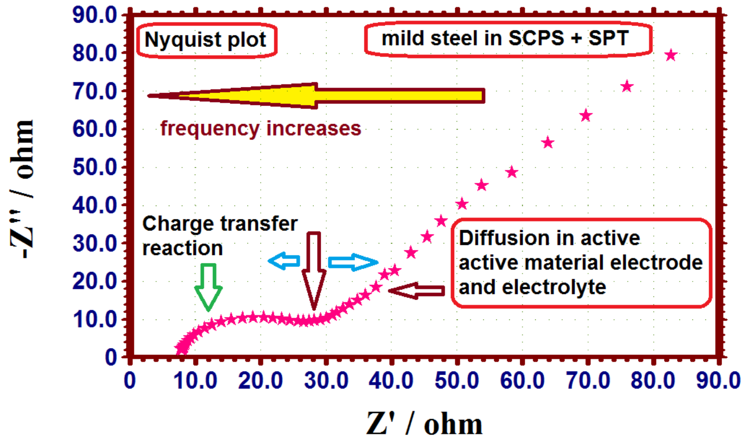

Figure 5. Characteristics of a charge transfer reaction and diffusion controlled process

Slika 5. Karakteristike reakcije prenosa naelektrisanja i procesa kontrolisanog difuzijom

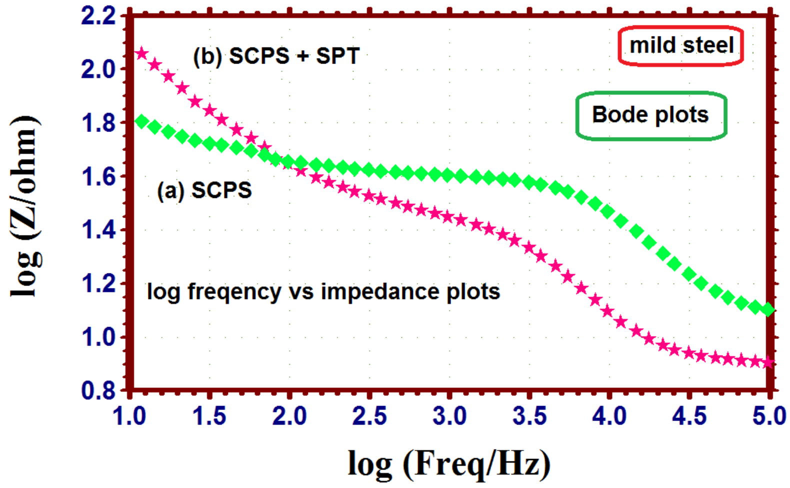

Figure 6. Bode plots (log frequency vs impedance) of mild steel immersed in various test solutions: a) SCPS, (b) SCPS + SPT

Slika 6. Bode-ove krive (log frekvencija u odnosu na impedansu) mekog čelika uronjenog u različite test rastvore: (a) SCPS, (b) SCPS + SPT

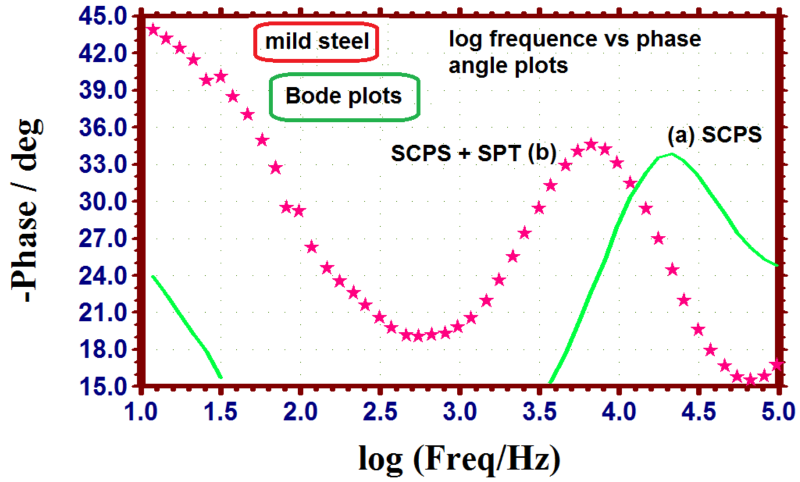

Figure 7. Bode plots (log frequency vs phase angle) of mild steel immersed in various test solutions: a) SCPS, (b) SCPS + SPT

Slika 7. Bode-ove krive (log frekvencija u odnosu na fazni ugao) od mekog čelika uronjenog u različite test rastvore: (a) SCPS, (b) SCPS + SPT

3.4. Implication

When mild steel is used as rebar, sodium potassium tartrate (SPT) may be mixed with concrete. Thus the mild steel will be protected from corrosion.

4. CONCLUSIONS

The corrosion resistance of mild steel in SCPS in the absence and presence of sodium potassium tartrate (SPT) has been investigated by polarization study and AC impedance spectra.

The present study leads to the following conclusions

- Polarization study reveals that SCPS + sodium potassium tartrate (SPT) system functions as anodic type inhibitor.
- Anodic reaction is controlled predominantly.
- AC impedance spectra reveal that a protective film is formed on the metal surface.
- When mild steel is used as rebar, sodium potassium tartrate (SPT) may be mixed with concrete.
- Thus the mild steel will be protected from corrosion.
- This formulation may find application in concrete technology.

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IZVOD

OTPORNOST NA KOROZIJU MEKOG ČELIKA URONJENOG U SIMULIRANI RASTVOR BETONSKIH PORA U PRISUSTVU NATRIJUM-KALIJUM TARTARATA

Otpornost mekog čelika na koroziju u simuliranom rastvoru pora betona (SCPS) u odsustvu i prisustvu natrijum-kalijum tartarata (SPT) je ispitana tehnikom polarizacije i spektrom impedanse naizmenične struje. Studija polarizacije otkriva da sistem natrijum-kalijum tartrata funkcioniše kao anodni tip inhibitora. Spektri impedanse naizmenične struje otkrivaju da se na površini metala formira zaštitni film. Kada se kao armatura koristi meki čelik, natrijum-kalijum tartarat se može mešati sa betonom. Tada će meki čelik biti zaštićen od korozije. Zaštitni film se sastoji od kompleksa ferotartarata formiranog na metalnoj površini. U prisustvu natrijum-kalijum tartarata, otpor linearne polarizacije raste sa 226 Ohmcm^2 na 455 Ohmcm^2, struja korozije se smanjuje sa 1,901k10-4 A/cm^2 na 1,096 k10-4A/cm^2, otpor prenosa naelektrisanja (Rt) raste sa 49 Ohmcm^2 na 77 Ohmcm^2, impedansa se povećava sa 1,807 na 2,084, fazni ugao se povećava sa 33,92° na 35,31° i vrednost kapacitivnosti dvostrukog sloja (Cdl) se smanjuje sa 1,040k10-7 F/cm^2 na 0,662 k10^{-7} F/cm^2. Potencijal korozije se pomera sa -973 mV/SCE na -867 mV/SCE. Ovo potvrđuje da inhibitorni sistem funkcioniše kao anodni tip inhibitora koji kontroliše anodnu reakciju pretežno. Ova formulacija može naći primenu u tehnologiji betona. Ovo se može koristiti u izgradnji mostova i betonskih konstrukcija.

Ključne reči: *natrijum-kalijum tartarat, otpornost na koroziju, meki čelik, simulirani rastvor pora betona, elektrohemijska ispitivanja, spektri elektrohemijske impedanse*

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