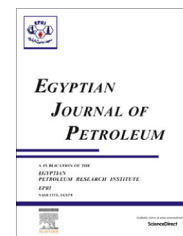




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FULL LENGTH ARTICLE

Surface active properties of gelatin and their effect on the electropolishing and corrosion behavior of steel in orthophosphoric acid



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Abstract Electropolishing behavior of steel was studied in orthophosphoric acid in the presence of gelatin for improving the finish obtained. This was inspected by surface tension measurement and potentiodynamic polarization by measuring the limiting current in solutions containing different concentrations of gelatin. Gelatin addition to electropolishing solution results in a lower limiting current. The gelatin surface parameters were calculated from its surface tension. The parameters considered include critical micelle concentration (CMC), maximum surface excess (Γ_{\max}), minimum surface area (A_{\min}) and effectiveness (π_{CMC}). Thermodynamic parameters of micellization (ΔG_{mic} , ΔS_{mic}) for gelatin were also calculated. Gelatin records greatest reduction of surface tension (effectiveness, π_{cmc}) and higher minimum area (A_{\min}). This behavior agrees with the highest inhibition efficiency results obtained from a potentiodynamic method. Scanning electron microscope (SEM) was used to investigate steel surface after electropolishing in the absence and presence of gelatin. The addition of a higher concentration of gelatin was successful to enhance steel surface quality.

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1. Introduction

Steel has found a wide application in a broad spectrum of industries and machinery, but it has a tendency for corrosion, which is a fundamental industrial concern that has received a

considerable amount of attention [1]. Because of higher hardenability, better wear resistance, and suitable toughness, steel is widely used as the material for cutting tools, forging and punching dies.

A leveling and brightening surface can be achieved through anodic dissolution in a suitable electrolyte by electrochemical polishing [2–4]. The electropolishing was performed in the limiting-current plateau of the anodic polarization curve, in which anodic dissolution was under mass-transfer limitation. However, the species governing the mass-transfer limitation is appreciably dependent on both the metal electrode and electrolyte [5–7]. Two polishing mechanisms, the salt-film precipitation mechanism and the acceptor-limited of the species anion

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and water and/or their complexes mechanism were proposed [8–10].

The surface phenomena of electropolishing are generally classified into two processes: anodic leveling and anodic brightening. Anodic leveling results show a difference in the dissolution rate between peaks and valleys on a rough metal or alloy surface depending on the current circulation or mass-transport conditions [11–18]. On the other hand, anodic brightening was found to be achieved under the tertiary current distribution conditions only [2]. Since anodic brightening indicates the absence of crystallographic dissolution related to the metal microstructure [19–22], a shift in the dissolution mechanism from the surface-kinetic control of the diffusion control conditions [2] was proposed for the course of this microstructure-insensitive phenomenon.

In general, micro-finishing or surface refining of steels in industries through electropolishing is performed in a mixed electrolyte containing concentrated phosphoric and sulfuric acid [7] with the addition of glycerol [23,24] to suppress the influence of the metal microstructure on the dissolution rate. In general, two typical mechanisms of electropolishing have been proposed in the literature, which are mentioned above; the acceptor mechanism announced that the acceptors (water or water-related species) are the key factors starting the effective electropolishing process [25]. Based on this mechanism, the electrolyte, usually contained a small quantity of acceptor species, and the adsorbed ions would accumulate on the anode surface to form an absorbent layer. This layer increased the overpotential of metal dissolution and hindered the solvation of metal ions with acceptors. Theoretically, the mechanism of preferential adsorption of shielding molecules [26,27] is considered to involve the acceptor mechanism because the quantity of water in the electrolytes is small.

In this study, an attempt is extended to improve the surface quality by decreasing the etched pits and defects formed over the surface, consequently, the surface smoothness could be increased. Accordingly, the current work is aspired to study the effect of addition of gelatin to orthophosphoric acid solutions used as electrolytes for electropolishing of steel. The surface parameters of gelatin were calculated (from its surface tension profile) to correlate the inhibition efficiency of gelatin with their surface parameters.

Gelatin is a mixture of peptides and proteins produced by partial hydrolysis of collagen extracted from the skin, bones,

and connective tissues of animals such as domesticated cattle, chicken, pigs, and fish. Photographic and pharma grades of gelatin are generally made from beef bones, although some beef bone gelatin is used by the food industry. Gelatin forms a solution of high viscosity in water, thickening agent. The layer of adsorbed shielding molecules dominates the anodizing behavior in our system. The structure of the adsorbed shielding layer is determined by molecular interactions which are a complicated function of the molecular thermal motions and intermolecular forces, especially the strong hydrogen bonds and electrostatic forces. Thus, the bath temperature significantly influences the thermal motions of molecules and the gelatin content provides strong hydrogen bonds.

2. Experimental

2.1. Materials

Steel specimens [0.0267% S, 0.06% P, 0.4% Mn, 0.1% C and the rest iron] of dimensions 10.0 cm × 5.0 cm × 0.2 cm were degreased with trichloroethylene. 8 M orthophosphoric acid was prepared from annular grade H₃PO₄ (85%). Different concentrations of gelatin solutions with 8 M H₃PO₄ are used, ranging from 20 to 350 ppm. 160 bloom numbers, 50,000 g/mol gelatin (Fig. 1) of pure quality (>97%) was used, Medizen pharmaceutical industries (Barranquilla – Colombia). Doubly distilled de-ionized water with a measured resistivity > 18 MΩ/cm was used in the preparation of solutions.

2.2. Potentiodynamic polarization

The cell used in the present work consists of the rectangular container having the dimensions of 5 × 10 cm with electrodes fitting the whole cross section. The electrical circuit (Fig. 2) consisted of a 6 V D.C. power supply, a variable resistance and a multi range ammeter connected in a series with the cell. A high impedance voltmeter was connected in parallel with the cell to measure its potential. The steady state anode potential was measured against a reference electrode consisting of a steel piece immersed in a cup of lugging tube filled with orthophosphoric acid-organic solution similar to that in the cell. The tip of the lugging tube was placed 0.5–1 mm from anode wall. Polarization curves, from which the limiting current was

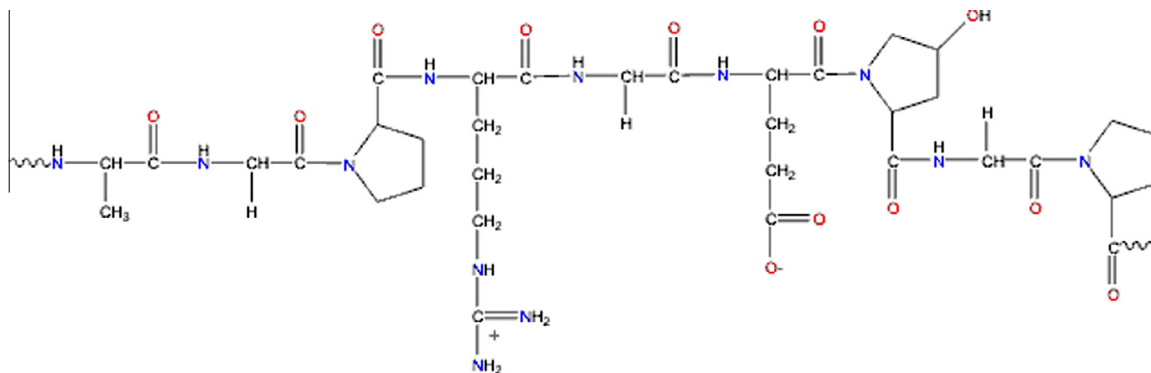


Figure 1 Gelatin structure.

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