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EFFECTS OF SODIUM PHOSPHATE AND SODIUM SULPHATE ON CORROSION RESISTANCE OF AISI 316L STAINLESS STEEL IN 3.5 wt% SODIUM CHLORIDE SOLUTION

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ABSTRACT

The effects of sodium phosphate and sodium sulphate on the corrosion resistance of AISI 316L stainless steel in 3.5 wt.% NaCl solution were investigated by the potentiodynamic technique. The addition of sodium phosphate and sodium sulphate with concentrations between 0.01-1.0 M in 3.5 wt.% NaCl decrease the corrosion potential of AISI 316L stainless steel. The pit density on the surface of AISI 316L stainless steel was found to decrease with increasing sodium phosphate and sodium sulphate concentrations. The increase of sodium phosphate and sodium sulphate concentrations resulted in the increase of pitting potential and passive current density, indicating the inhibitive effects of sodium phosphate and sodium sulphate on the pitting attack. The addition of sodium sulphate in 3.5 wt.% NaCl solution provides a better general corrosion resistance but lower pitting resistance of AISI 316L stainless steel when compared with the addition of sodium phosphate.

Keyword: Stainless steel, Phosphate, Sulphate, Corrosion resistance.

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INTRODUCTION

Stainless steels are widely used in the industrial process because of their excellent corrosion resistance, high strength oxidation resistance at high temperature and resistance to creep. Stainless steel alloys contain a minimum of 11.5% chromium, sufficient to form a passive film on metal surface. The three main types of stainless steels identified by microstructure or predominant crystal phase are austenitic, ferritic, and martensitic. Austenitic stainless steels are more or less resistant to general corrosion, crevice corrosion and pitting, depending on the quantity of alloying elements. However, when stainless steels are exposed to an aggressive environment, it is required to use a corrosion inhibitor.

A corrosion inhibitor is a chemical added to the corrosive environment in small amounts to reduce the corrosion rate. There are numerous inhibitor types and compositions (Jones, 1991). Most inhibitors have been developed by empirical experimentation and many inhibitors are proprietary in nature and thus their composition is not disclosed. Inhibitors generally interact with the metal surface in the same way to form a passive film or a barrier film of adsorbed inhibitor that may be only a monolayer or less, or to form a thick barrier layer of reaction products or inhibitors (Sedriks, 1996; and Bradford, 1993).

Pitting corrosion of stainless steel is of great practical interest and concern. The most significant environmental conditions, which influence the pitting corrosion behavior of stainless steel, are the chloride ion concentration, temperature and pH (Bradford, 1993; and Fontana, 1987). Among anions that reduce the pitting tendency of stainless steels in chloride solutions are sulphate, hydroxide, chlorate, perchlorate, nitrate, chromate, molybdate, phosphate, carbonate and acetate. It is known that phosphate and sulphate ions in amounts large enough can prevent chloride caused pitting of stainless steel. Hakkarainen (1999), and Abd El Meguid, *et al.* (2000) However, the effects of phosphate and sulphate in the sodium chloride solution to the anodic polarization curve have not been displayed clearly. The present work investigated the effects of phosphate and sulphate ions in 3.5 wt.% NaCl solution on the corrosion resistance of AISI 316L stainless steel by the potentiodynamic polarization method. The corrosion potential and pitting potential were evaluated from the polarization curve to study the corrosion behavior.

EXPERIMENTAL PROCEDURE

The test material was AISI 316L austenitic stainless steel which had a chemical composition of (wt.%) : C <0.006%, Si 0.366%, Mn 1.43%, P 0.029%, S 0.003%, Mo 2.14%, Cu 0.342%, Cr 17.18%, Ni 11.15%, N 0.038%, and balance Fe. The specimens (6x6x60 mm) were ground with silicon carbide paper up to 600 grit all sides, washed with distilled water, cleaned in acetone with ultrasonic cleaner, dried in air and stored in a desiccator for at least 24 hours before conducting the polarization curve measurements with a potentiostat.

Potentiodynamic polarization experiments were performed by using the Autolab potentiostat model PGSTAT20 which was controlled by a computer. The specimen was immersed in the solutions 1 cm^2. The applied potentials were in the range of -1.0 V to 1.0 V with the scan rate of 1 mV/s. From the polarization curves, the pitting potential was determined at a slight increased current density from the passive range, and corrosion potential was determined following the Tafel slope method.

The electrolytes were 3.5 wt% NaCl aqueous solutions containing various sodium phosphate (Na_3PO_4 12 H_2O) and sodium sulphate (Na_2SO_4) concentrations 0, 0.01, 0.03, 0.05, 0.08, 0.1, 0.3, 0.5 and 1 M. A silver/silver chloride electrode (Ag/AgCl) and platinum electrode were used as the reference electrode and counter electrode, respectively. All the experiments were conducted at 27°C.

RESULTS AND DISCUSSION

Examples of polarization curves in 3.5 wt.% NaCl solution with sodium phosphate.

Figure 1 shows the polarization curves of AISI 316L austenitic stainless steel in 3.5 wt.% NaCl solutions containing sodium phosphate concentrations of 0, 0.01, 0.1 and 1 M. The polarization curves exhibit active and passive regions. An increase of sodium phosphate concentrations extended the passive potential region. Pit initiation was revealed by the first sharp increase of current from the passive region. The rapid increase of current was continued, which indicated the pit propagation. After the polarization measurements, the pit density (pit number/area) on the sample surface decreased with increasing sodium phosphate concentrations.

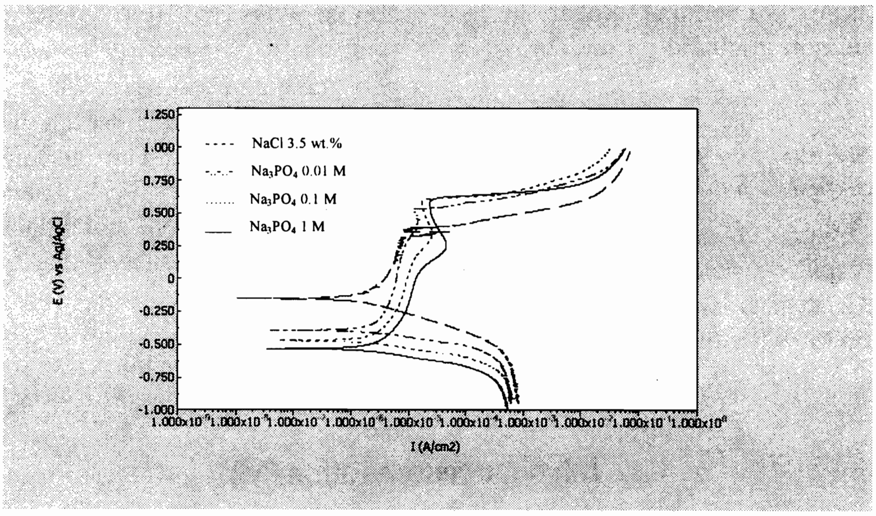

Figure 1 Potentiodynamic polarization curves of AISI 316L SS in 3.5 wt.% NaCl solutions containing various sodium phosphate concentrations.

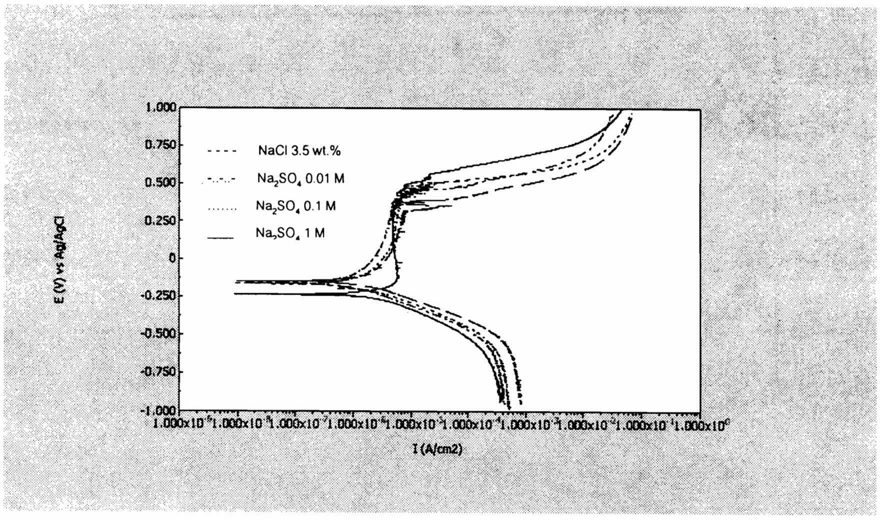

Figure 2 Potentiodynamic polarization curves of type AISI 316L SS in 3.5 wt.% NaCl solutions containing various sodium sulphate concentrations.

Examples of polarization curves in 3.5 wt.% NaCl solution with sodium sulphate.

The polarization curves in 3.5 wt.% NaCl solutions with sodium sulphate concentrations of 0, 0.01, 0.1, 1M are shown in Figure 2. Increasing sodium sulphate concentration in 3.5 wt.% NaCl solution extended the passive region of AISI 316L stainless steel. The density of pit corrosion on AISI 316L surface decreased with an increase of sodium sulphate concentrations. It should be noted that additions of sodium sulphate in 3.5 wt.% NaCl solution inhibited pitting corrosion of AISI 316L stainless steel.

Effects of sodium phosphate and sodium sulphate on corrosion behavior.

From Figures 1 and 2 the corrosion potentials, the pitting potentials and average passive current density were interpreted and plotted in relation with the concentrations of sodium phosphate and sodium sulphate as shown in Figures 3-5, respectively.

From Figure 3, the decrease of corrosion potentials of AISI 316L stainless steels in the given environment was observed. In general, a less positive corrosion potential means that the metal has less general corrosion resistance in that electrolyte. Therefore, increasing sodium phosphate and sodium sulphate concentrations in 3.5 wt.% NaCl solution resulted in a decrease of general corrosion resistance of AISI 316L stainless steel. This showed that increasing sodium phosphate and sodium sulphate concentrations in 3.5 wt.% NaCl solution retarded the cathodic process. The addition of sodium sulphate in 3.5 wt.% NaCl solution resulted in a higher corrosion potential than sodium phosphate. This indicated that sodium sulphate provides a better corrosion resistance of AISI 316L stainless steel in 3.5 wt.% NaCl solution than sodium phosphate.

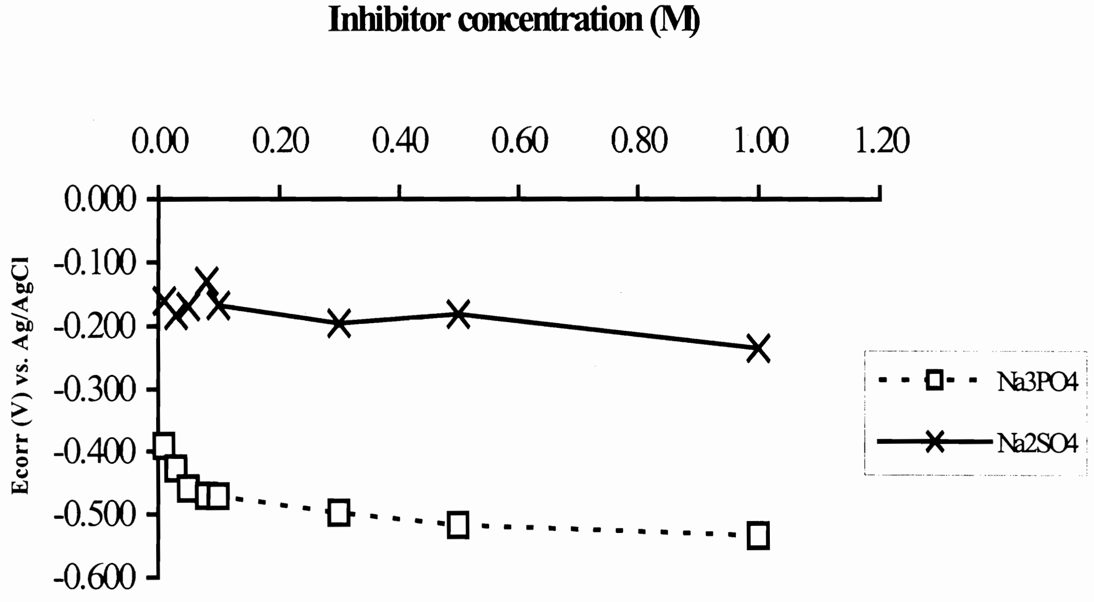

Figure 3 Corrosion potential of AISI 316L SS in 3.5 wt.% NaCl containing various sodium phosphate and sodium sulphate concentrations.

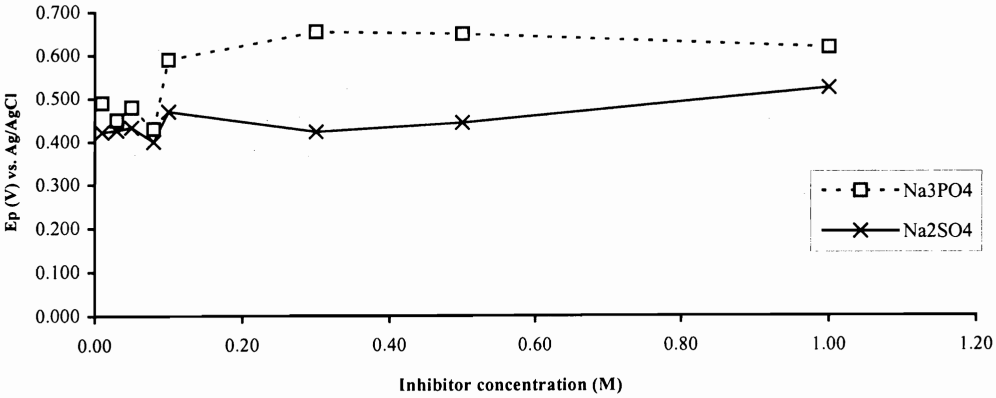

Figure 4 Pitting potential of AISI 316L SS in 3.5 wt.% NaCl containing various sodium phosphate and sodium sulphate concentrations.

When increasing the concentrations of sodium phosphate and sodium sulfate in the 3.5% NaCl solution, a higher pitting potential for the AISI 316L stainless steel was observed (Figure 4) leading to a better pitting resistance. It is believed that sulfate and phosphate ions can adsorb onto the stainless steel surface whether as a covalently binded layer or as a precipitated product leading to an increase in pitting corrosion resistance. Meguid Abd El Meguid, *et al.* (2000) already suggested that sodium sulfate introduced in chloride solution can decrease the pit diameter on 304 stainless steel and retard the pitting propagation. From these hypothesiss, the addition of sodium phosphate resulted in a greater increase of the pitting potential indicating that it has a higher effect on pitting corrosion resistance than sodium sulfate. However, these results should be confirmed by further investigations of the passive films using an appropriated surface analysis technique.

From Figure 5, the increase of passive current density of AISI 316L stainless steels in the given environment was observed. Increasing sodium phosphate and sodium sulfate concentrations in 3.5 wt.% NaCl solution resulted in an increased passive current density of AISI 316L stainless steel. This indicated that the passive film has an increased dissolution rate.

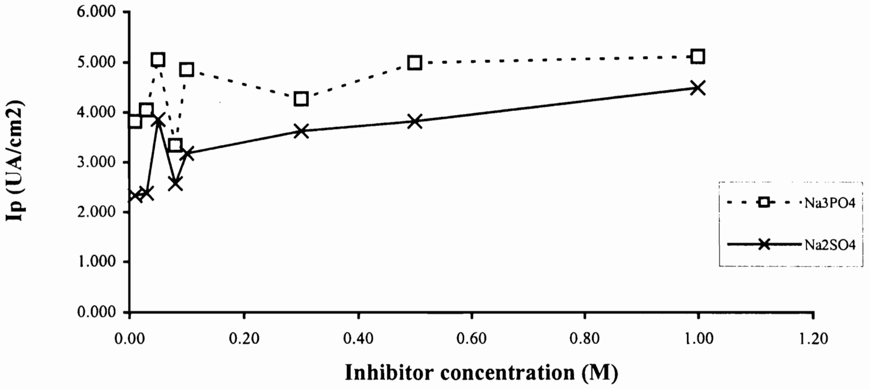

Figure 5 Passive current density of AISI 316L SS in 3.5 wt.% NaCl containing various sodium phosphate and sodium sulfate concentrations.

CONCLUSIONS

1. The addition of sodium phosphate and sodium sulfate with concentrations between 0.01-1.0 M in 3.5 wt.% NaCl solution decreases corrosion potential but increases the pitting potential and passive current density of AISI 316L stainless steel.
2. Sodium sulfate in 3.5 wt.% NaCl solution provides a better general corrosion resistance of AISI 316L stainless steel than sodium phosphate.
3. Sodium phosphate in 3.5 wt.% NaCl solution provides a better pitting corrosion resistance of AISI 316L stainless steel than sodium sulfate.

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