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Synergistic inhibitive effect of tartarate and tungstate in preventing steel corrosion in aqueous media

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Abstract

The inhibitive effect of tartarate was studied as a coinhibitor with tungstate in preventing carbon steel corrosion in aqueous solutions. Open circuit potential measurements, weight-loss measurements and polarization studies were conducted to understand the domains of corrosion and passivation. Tartarate ions, even at low concentration, showed excellent synergistic corrosion inhibition characteristics. A mixture of 500 ppm each of the inhibitors was found to be optimum inhibitor combination. This inhibitor combination showed inhibition efficiency as high as 98%. Tartarate in the synergistic inhibitor combination did not reveal any dominant role in shifting the surface potential, even though it showed substantial passivation effect. The present study explores and evaluates the synergistic combination as a potential inhibitor system in combating corrosion on carbon steel surface.

Keywords: Tartarate; Tungstate; Corrosion inhibitors; Steel corrosion

1. Introduction

The first published information of corrosion inhibition by tungstate appeared as a patent describing its use in organic antifreeze solution [1]. Robertson, in his first published report, confirmed that tungstate lacked the oxidizing property of both chromate and nitrite [2]. It was also reported that sodium tungstate at 300-ppm concentration is an effective inhibitor of steel and it becomes more effective when the concentration exceeds 1200-ppm [3]. Later Pryor and Cohen proved that both tungstate and molybdate could passivate iron only in the presence of air [4]. Many other workers also did numerous studies in early days [5,6]. A decade back, Sastri et al. found that sodium tungstate is equally effective as chromate for coal water slurries [7,8].

Earlier prediction of non-oxidation of metal surface by tungstate has been proven to be incorrect recently. Tungstate actually oxidizes ferrous ions to ferric state where a higher valence state facilitates more passivation [9,10]. The observation of lower valence tungsten oxide incorporated in the rust of corroding metal also reveals the favorable nature of metal oxidation from lower valence to higher valence state [11]. Abdul El Kadher et al. have reported that adsorption of oxygen

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on the metal surface is very strong only when tungstate also coexist with it, even though both of them are held in the lattice by physical forces [11].

Generally, low concentration of tungstate cannot shift the surface potential to passive range. However, the weak oxidizing action of tungstate yields synergistic inhibitive effect with a variety of organic compounds, whichever can act by way of adsorption. All successful inhibitor formulations described in literature include tungstate with one or more coinhibitors [7,8]. Sodium potassium tartarate, which is widely used as complexing agent in Ni–B and Ni–P electroless bath, can be used as a coinhibitor too [12]. There are reports that sodium potassium tartarate, individually, is not a good inhibitor but it is very effective when it is used as a coinhibitor [13,14]. Tartarate can also act as a good coinhibitor with phosphonates in combination with zinc ions [14]. With this background of knowledge and previous experimentations with other tungstate based inhibitor systems, the present study was designed to explore and evaluate the mixture of tungstate and tartrate as a potential inhibitor combination in combating carbon steel corrosion [15,16]. The results are discussed in this brief report.

2. Methodology

2.1. Materials and preparation of coupons

Solutions of tungstate and tartarate were prepared from the respective analytical grade reagents using distilled water. Commercial grade carbon steel coupons having the composition of Fe + C-0.19, Mn-0.54, Si-0.28, Cr-2.75, Ti-0.006, Ni-0.148, Cu-0.043, and Al-0.358% were used in this study. Rectangular coupons of the size 20 mm × 30 mm × 1 mm were used for mass loss experiments. The coupons having an exposed surface of 1 cm × 1 cm were used for polarisation studies. The surfaces of the coupons were successfully polished using 1/0 to 6/0 emery papers, degreased and washed with distilled water before immersing them into the test solutions.

2.2. Weight loss measurements

The carbon steel coupons in triplicate were immersed in 200 ml of test solution for a period of 3 months. The change in weight was measured with an accuracy of ± 5%. The inhibition efficiency was calculated from the weight loss values of the steel in the uninhibited and inhibited solutions. The studies were carried out at a pH of 7.5–8 at 30 °C.

2.3. Electrochemical studies

2.3.1. Open circuit potential measurements

Different batches of the coupons were immersed in 300 ml inhibitor solution contained in a test cell of 500 ml capacity. The open circuit potential of the coupons was monitored with reference to a saturated calomel electrode. The OCP of the coupons were monitored for longer periods. The long-term performance of the different inhibitor combinations was evaluated based on the respective plots of OCP versus time relation.

2.3.2. Polarization studies

The coupons were potentiostatically polarized against a very large surface area platinum counter electrode. The potential values are reported here as measured with respect to saturated calomel electrode. Prior to the commencement of each polarization experiment the OCP of the working electrode was monitored and allowed to reach a stable equilibrium value. The scan rate of the polarization was fixed at 1 mV/s, using a potentiostat [BAS, USA]. Tafel plots were constructed in the potential range of −250 to +250 mV with respect to the initial OCP. The experiments were repeated to ensure reproducibility.

3. Results

3.1. The inhibitive effect of tartarate

At the first stage of the present work, the individual inhibitive effect of tartarate was evaluated under different experimental conditions. The OCP decay of the carbon steel coupons immersed in different concentrations of tartarate, was continuously monitored for a period of 90 days. Fig. 1 shows the OCP decay curves. The initial OCP corresponding to 200, 500, and 1000 ppm of tartarate was −0.240, −0.300, and −0.350 V, respectively. The initial OCP was found to deteriorate day by day in the cathodic region.