Effectiveness of Acrylic Acid Based Terpolymer as a Corrosion Inhibitor in Water Treatment

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ABSTRACT: A breakthrough in polymer technology has dramatically increased the range of conditions for phosphate-based water treatment programs. Phosphate is good complexing agent whether introduced alone or in combination with other metal cations, eg Zn^{2+}, Mg^{2+}, or Mb^{2+} in neutral aqueous media. In addition, their hydrolytic stability and scale inhibiting property are reasons why it is widely used as corrosion inhibitors. Results from recent water treatment simulations and used in several chemical plants demonstrated an improved performance. A study was carried out on the corrosion of metal by analyzing the metal immersed in tab water containing zinc polyphosphate in the absence and presence of terpoly (arylamide/acrylic acid/acrylonitrile) with various formulations for a period of five days at 40°C. The effectiveness of the terpolymer in inhibiting the corrosion of metal in water is discussed based on scanning electron microscope (SEM) and weight loss results. A formulation consisting of phosphate-based which is sodium polyphosphate, metal ions (Zn^{2+}), and poly (arylamide/acrylic acid/acrylonitrile) are observed to increase inhibition efficiency, increased tolerance to environmental, and generally longer plant run times.

KEYWORDS: Water Treatment, Corrosion Inhibitor, Terpolymer, SEM, Weight Loss

INTRODUCTION

The application of polymer in water treatment technology has been a tremendous advances in the recent years. A variety of monomers and functional groups can be incorporated into single polymer capable of handling a variety of problems. The development of water treatment polymers is traced through the design stage, screening and optimization, and in final application.

Synthetic polymers have been used for more than 25 years, when low molecular weight polycyclic acids were introduced as dispersants (1). NACE (2) described the used of polymers in chromate and phosphate technology provide excellent protection of steel in water treatment system. Han and Robertson (3) found that terpolymer of acrylic/sulfonate/nonionic had been extremely effective to decrease corrosion rates and provide superior iron transport properties in both cooling water and natural water treatment application. The application of co and terpolymer of acrylic acid with different monomers was described by Chen, F (4). Major improvement was observed when terpolymer was used compared to the copolymer especially in inhibiting corrosion of metal parts which is in contact with water system and deposition of certain scale forming salts. Amjad et al (5) studied the effect of different dosage of acrylic based especially polyacrylic in inhibiting corrosion and scaling in water treatment. Experimental results showed that acrylic based copolymer and terpolymer has the ability to provide superior performance and greatly increased the percentage of corrosion inhibitions.

In this research, the application of terpolymerization of acrylamide, acrylic acid and acrylonitrile is studied to determine its effectiveness as corrosion inhibitor in water treatment applications.

EXPERIMENTAL

Preparation of terpolymer of Acrylic Acid, Acrylamide and Acrylonitrile

Terpolymerization of acrylic acid, acrylamide and acrylonitrile is prepared using the Mathakiya method through free radical terpolymerization (6).

Corrosion Immersion Test (Weight Loss Method)

This experiment describes a simple method for measuring the effectiveness of corrosion inhibitor (phosphate based/ zinc ion/polymer) by measuring the weight loss of metal specimens, by immersing in the test solution. In accordance to the suggested procedure for handling metal specimens in laboratory immersion corrosion testing of metals (7), the range of conditions is prepared to obtain consistent result. The corrosion rate, as an average penetration in mils per year (mpy), based on the weight loss, is calculated by the following equation (8):

$$\text{Penetration (mpy)} = 22.3 \cdot w / d \cdot a \cdot t$$

Where,

w = Weight loss in milligrams
d = Specific gravity of the specimens in gram per cubic centimeter
a = Exposed area of coupon in square inches
t = time in days

A versatile and convenient apparatus which is used consist of 1000mL glass flask, a reflux condenser, a sparger for controlling atmosphere, a thermometer to control temperature, a heating device (mantle), and a specimen support system. Figure 1 shows a setup for static or stagnant test solution which is used in the corrosion immersion test.

The selection of the conditions for this corrosion test is based on the conditions of water treatment system. The temperature is 40ºC and was run for five days (9, 10).

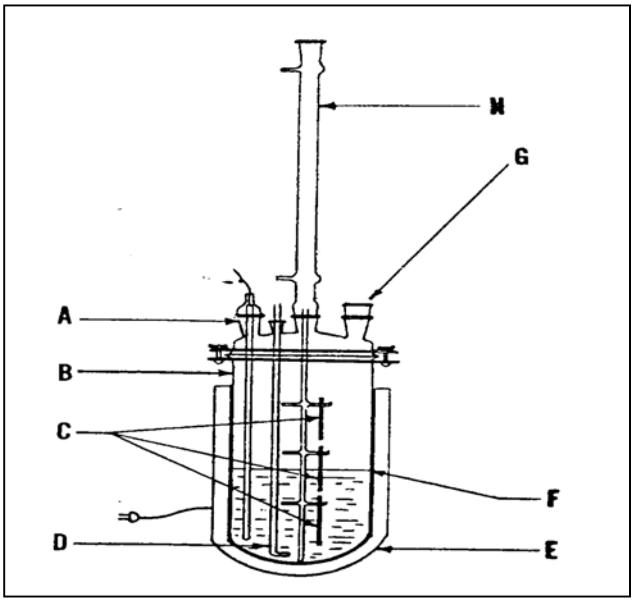

Figure 1: Laboratory Immersion Corrosion Testing Rig
(A= Thermometer, B= Glass Flask, C= Carbon Steel Specimens, D= Air Inlet, E= Heat Mantler, F= Test Solution, G= Polymer Inlet, and H= Condenser.)

RESULT/ DISCUSSION

Corrosion Rate (Weight Loss Measurement)

Figure 2 shows the results of weight loss of carbon steel in blank solution (without any treatment), in the absence and presence of terpolymer in zinc polyphosphate treatment. The weight loss of carbon steel is highest at the first day of immersion. This is consistent to that obtained by McCoy, J.W (11) starting that the corrosion rate of steel is highest in an early stage of immersion. The weight loss of carbon steel also decreases immediately when the terpolymer is applied in the treatment compared with a blank and zinc polyphosphate without terpolymer. The result shows that the terpolymer tends to stabilize the formation of complexes zinc polyphosphate and also the iron phosphate thin layer on the metal surface. The formation of these layers helped to decrease the oxidation potentials of metals.

Surface examination study using Scanning Electron Microscope (SEM) as shown in Figure 3,4 and *5*, demonstrate that pitting corrosion which formed under blank sample is larger compared to the other two samples containing zinc polyphosphate and terpolymer. It is believed that the blank sample has no protection agent to protect the metal surface from bulk water.

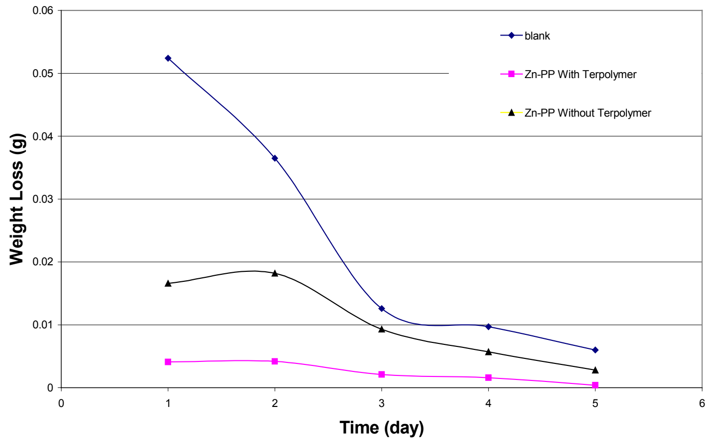

Figure 2 : Weight loss of carbon steel in the presence and absence of terpolymer in 2.5 ppm Zn^{2+}(Zn) and 50 ppm Polyphosphate (PP) and blank tab water samples.

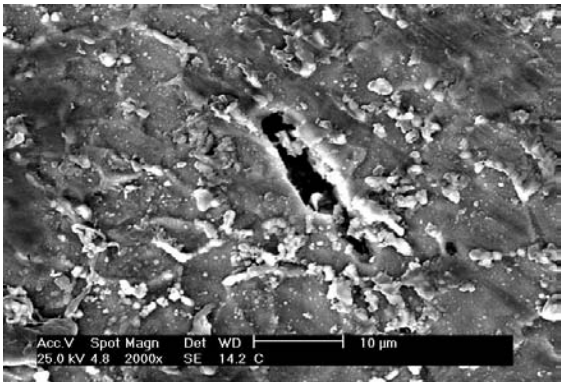

Figure 3: Photo-micrograph of carbon steel surface shows the pitting problem formed after immersion in tab water (blank) at 40°C for five days.

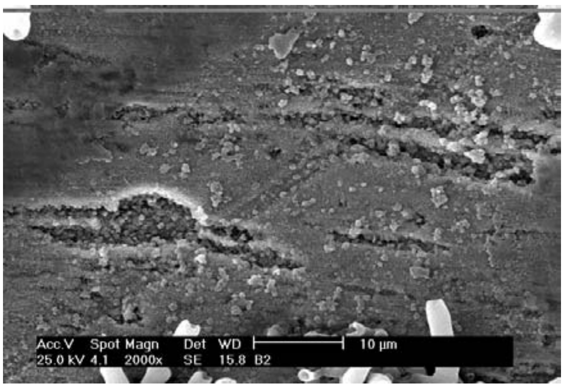

Figure 4: Photo-micrograph of carbon steel surface show an uniform corrosion formed after immersion in the tab water containing Zinc Polyphosphate in absence of terpolymer at 40°C for five days.

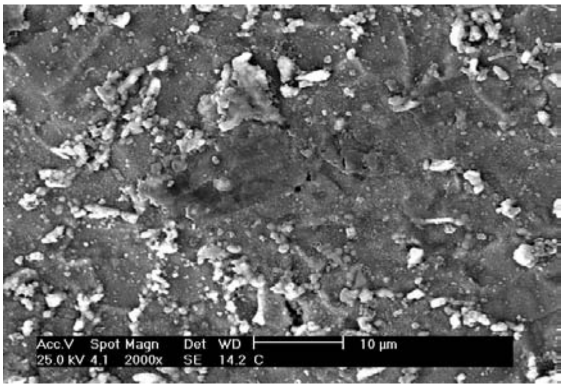

Figure 5: Photo-micrograph of carbon steel surface shows small pits forms after immersion in tab water containing Zinc Polyphosphate in the presence of 50 ppm terpolymer at 40°C for five days.

In experiment is created by varying the concentration of the terpolymer to study the effectiveness of terpolymer compositions. Result shown in figure 6, illustrate that the corrosion rate of carbon steel decreased from 10 ppm to 50 ppm concentration of terpolymer but increased as the concentration is more than 50 ppm. This phenomena is probably due to the growth of microorganisms which will increase the corrosion rate. Bragadish et al (12) explained that the terpolymer of acrylic acid, acrylamide and acrylonitrile undergo biodegradable if the amount of this terpolymer is applied at highest level in the water. Surface examination using SEM *figure 7* shows the formation of microbial on the carbon steel surface, after immersion in tab water containing zinc polyphosphate in presence of 100 ppm terpolymer at 40°C for five days.

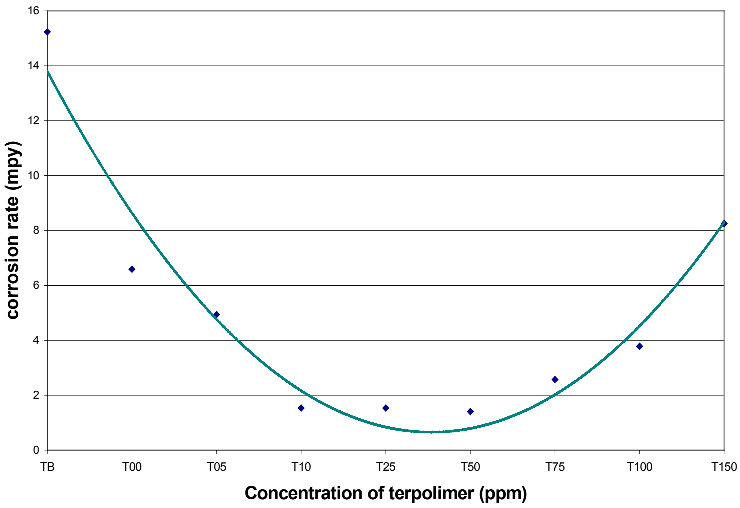

Figure 6 : Corrosion rate of carbon steel in difference concentration of terpolymer in 2.5 ppm Zn^{2+} and 50 ppm Polyphosphate.

This photo-micrograph help to confirm and support the proposed reason, there is corrosion rate increased due to the growth of microorganism. The microorganisms degrade the terpolymer, since according to Bragadish et al this terpolymer act as substrate for the microorganism. Therefore, the amount of the terpolymer decreased as the microorganisms grow resulting in increasing the corrosion rate of the carbon steel.

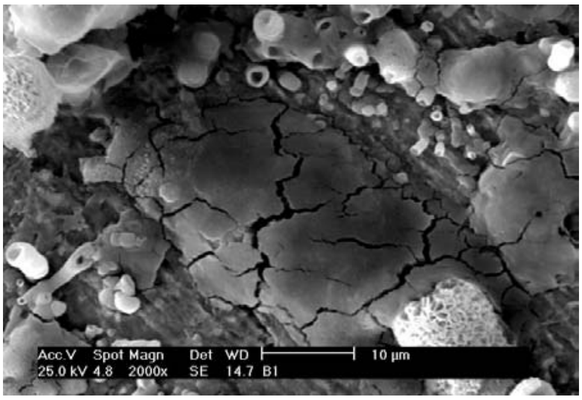

Figure 7: Photo-micrograph of carbon steel resulted shows the microbial growth after immersion in tab water containing Zinc Polyphosphate in present of 100 ppm terpolymer at 40°C for five days.

CONCLUSION

Based on the result of our experiment, terpolymer of acrylic acid, acrylamide and acrylonitrile shows its effectiveness in reducing the corrosion rate of carbon steel. The best inhibition efficiency is zinc polyphosphate with 50 ppm terpolymer and an application of this terpolymer in water treatment application should be less or equal to 50 ppm to minimize the microorganism problems.

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