INTERNATIONAL JOURNAL OF NANO CORROSION SCIENCE AND ENGINEERING.

Title of PhD Thesis: INHIBITION OF CORROSION OF CARBON STEEL IN SOTHUPARAI DAM WATER

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VIVA DATE: 07.07.2014

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Abstract

Corrosion is a phenomenon that occurs naturally. It deteriorates a metallic substance or its properties because of a reaction with its environment. Corrosion can cause dangerous and expensive damage to everything from pipelines, bridges and public buildings to vehicles, water and wastewater systems, and even home appliances. It is one of the most serious problems in the oil and gas industry. The purpose of studying the processes of corrosion is to find methods of minimizing or preventing it. Studies on the corrosion of metals in different environment have attracted considerable interest in recent years due to their wide applications. The cost of corrosion has been reported from many studies to be in the order of 1–5% of GNP for any country. Corrosion never stops but its scope and severity can be lessened. Corrosion inhibitors are of great practical importance, being extensively employed in minimizing metallic waste in engineering materials.

The use of inhibitors is one of the best–known methods of corrosion protection. Organic compounds used as inhibitors act through a process of surface adsorption, so the efficiency of an inhibitor depends not only on the characteristics of the environment in which it acts, the nature of the metal surface and electrochemical potential at the interface, but also on the structure of the inhibitor itself, which includes the number of adsorption active centers in the molecule, their charge density, the molecule size,

the mode of adsorption, the formation of metallic complexes and the projected area of the inhibitor on the metallic surface.

In the present study the following compounds have been studied as corrosion inhibitors: sodium butanesulphonate (SBS), sodium pentanesulphonate (SPS), sodium hexanesulphonate (SHXS), sodium heptanesulphonate (SHS) and sodium octanesulphonate (SOS). The synergistic effect of SBS / SPS / SHXS / SHS / SOS with Zn^{2+} on the inhibition of corrosion of carbon steel in dam water has been evaluated.

The mechanistic aspects of corrosion inhibition are based on the results obtained from weight loss method, polarization study, AC impedance measurements, UV–Visible absorption spectroscopy, and surface examination techniques like FTIR spectroscopy, fluorescence spectroscopy, SEM, EDAX and AFM.

SBS–Zn^{2+} system

The results of the weight loss study show that the formulation consisting of 250 ppm of SBS and 30 ppm of Zn^{2+} has 61% IE in controlling the corrosion of carbon steel in dam water. A synergistic effect exists between Zn^{2+} and SBS. Polarization study reveals that SBS–Zn^{2+} system functions as cathodic inhibitor controlling the cathodic reaction predominantly and to some extent controlling the anodic reaction. AC impedance spectra reveal that a protective film is formed on the metal surface. FTIR spectra reveal that the protective film consists of Fe^{2+}–SBS complex and $Zn(OH)_2$. The SEM micrographs, EDAX and AFM images confirm the formation of protective layer on the metal surface. The formulation consisting of 250 ppm of SBS, 30 ppm of Zn^{2+} and 150 ppm of SDS has 73% of corrosion IE and 100% of BE.

SPS–Zn^{2+} system

From the weight loss study, it is clear that this inhibitor system (concentration 250 ppm of SPS and 30 ppm of Zn^{2+}) has 68% IE in reducing the corrosion of carbon steel in dam water. There is lack of synergistic effect between 15 ppm of Zn^{2+} with various concentrations of SPS and a synergistic effect exists between 30 ppm of Zn^{2+} and various concentrations of SPS. Polarization study reveals that SPS–Zn^{2+} system functions as mixed inhibitor controlling the anodic reaction and cathodic reaction, to the same extent. AC impedance spectra reveal that a protective film is formed on the metal surface. FTIR spectra reveal that the protective film consists of Fe^{2+}–SPS complex and $Zn(OH)_2$. The SEM micrographs, EDAX and AFM images confirm the formation of protective layer on the metal surface. The formulation consisting of 250 ppm of SPS, 30 ppm of Zn^{2+} and 150 ppm of SDS has 79% of corrosion IE and 100% of BE.

SHXS–Zn^{2+} system

The weight loss study reveals that this inhibitor system (concentration 250 ppm of SHXS and 30 ppm of Zn^{2+}) has 70% IE in decreasing the corrosion of carbon steel in dam water. A synergistic effect exists between Zn^{2+} and SHXS. Polarization study reveals that SHXS–Zn^{2+} system functions as cathodic inhibitor controlling the cathodic reaction predominantly and to some extent controlling the anodic reaction. AC impedance spectra reveal that a protective film is formed on the metal surface. FTIR spectra reveal that the protective film consists of Fe^{2+}–SHXS complex and $Zn(OH)_2$. The SEM micrographs, EDAX and AFM images confirm the formation of protective layer on the metal surface. The formulation consisting of 250 ppm of SHXS, 30 ppm of Zn^{2+} and 150 ppm of SDS has 93% of corrosion IE and 100% of BE.

SHS–Zn^{2+} system

From the weight loss study, it is clear that this inhibitor system (concentration 250 ppm of SHS and 30 ppm of Zn^{2+}) has 75% IE in decreasing the corrosion of carbon steel in dam water. A synergistic effect exists between Zn^{2+} and SHS. Polarization study reveals that SHS–Zn^{2+} system functions as cathodic inhibitor controlling the cathodic reaction predominantly and to some extent controlling the anodic reaction. AC impedance spectra reveal that a protective film is formed on the metal surface. FTIR spectra reveal that the protective film consists of Fe^{2+}–SHS complex and $Zn(OH)_2$. The SEM micrographs, EDAX and AFM images confirm the formation of protective layer on the metal surface. The formulation consisting of 250 ppm of SHS, 30 ppm of Zn^{2+} and 150 ppm of SDS has 98% of corrosion IE and 100% of BE.

SOS–Zn^{2+} system

The results of the weight loss study show that the formulation consisting of 250 ppm of SOS and 30 ppm of Zn^{2+} has 88% IE in controlling the corrosion of carbon steel in dam water. A synergistic effect exists between Zn^{2+} and SOS. Polarization study reveals that SOS–Zn^{2+} system functions as mixed inhibitor controlling the anodic reaction and cathodic reaction, to the same extent. AC impedance spectra reveal that a protective film is formed on the metal surface. FTIR spectra reveal that the protective film consists of Fe^{2+}–SOS complex and $Zn(OH)_2$. The SEM micrographs, EDAX and AFM images confirm the formation of protective layer on the metal surface. The formulation consisting of 250 ppm of SOS, 30 ppm of Zn^{2+} and 150 ppm of SDS has 98% of corrosion IE and 100% of BE.

The present study leads to the following conclusions:

- All the five inhibitors exhibit synergism with Zn^{2+} ions in the corrosion inhibition of carbon steel in dam water.
- The corrosion IE of the sulphonic acids used is in the order–
  SOS > SHS > SHXS > SPS > SBS

The corrosion IE of different sulphonic acids at various concentrations is shown in the following graph.

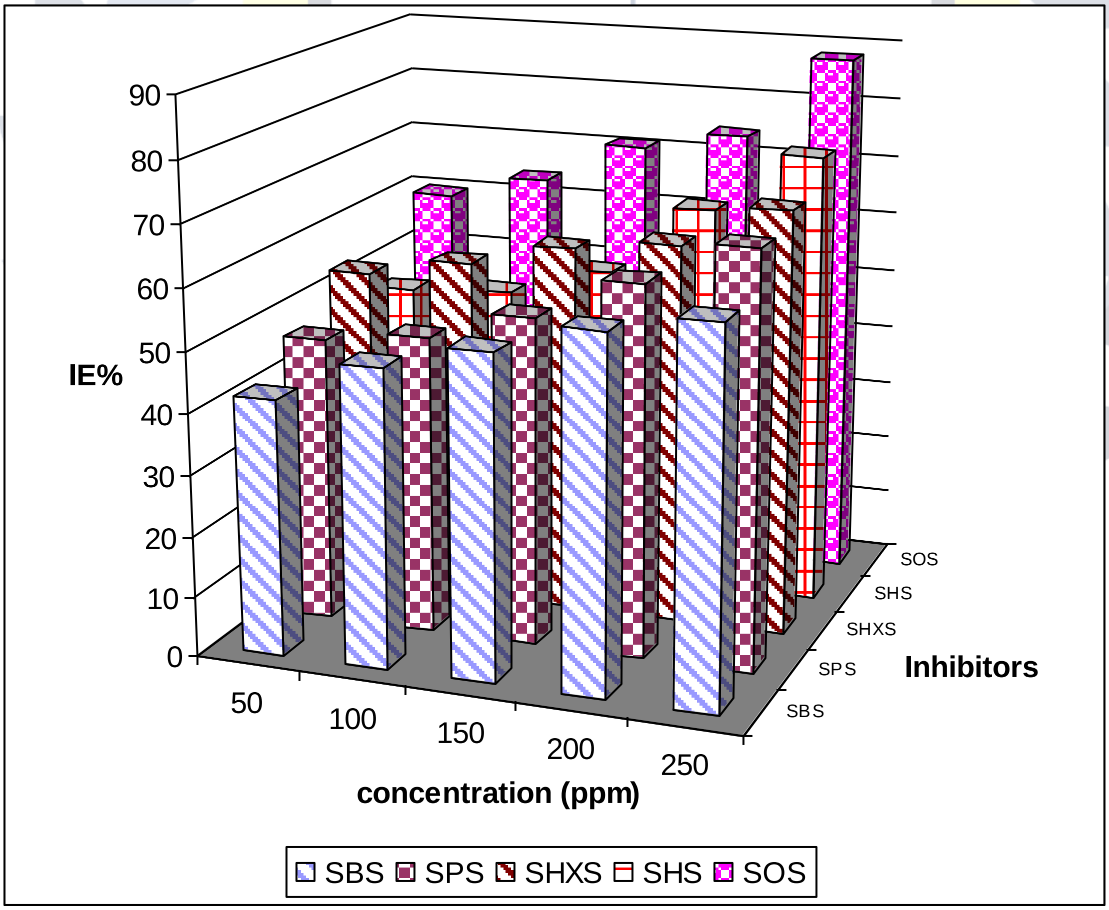

Fig. 6.1 Graph of IE of various inhibitors

The IE value is minimum for SBS and maximum for SOS. This difference in IE can be explained based on the +I effect of alkyl group. As the size of the alkyl group increases +I effect increases. Another reason is as the molecular size increases, IE increases.

- All the inhibitor formulations are effective in neutral aqueous medium and also in basic medium.
- All the inhibitor formulations are effective in acidic, neutral and basic environment, the IE increasing with increasing pH.
- The stability of the film formed on the surface of the carbon steel immersed in dam water in the presence of the inhibitors decreases with increase in immersion period.
- Addition of SPT and TSC to all the inhibitor–Zn^{2+} systems increases the IE up to 150 ppm of SPT and TSC, and on further increasing the concentrations of SPT and TSC, IE decreases.
- SEM, EDAX and AFM studies confirm the presence of the protective film on the surface of the metal.
- BE and corrosion IE of the biocide SDS in all the effective synergistic inhibitor –Zn^{2+} system has been studied. The corrosion IE of SDS with various inhibitors in the presence of Zn^{2+} is in the order of

  SOS =SHS > SHXS > SPS > SBS

- Based on the weight loss method, electrochemical studies and spectroscopic techniques, a suitable mechanism has been proposed for all the synergistic inhibitor and Zn^{2+} systems.

Scope for further study

- The study of corrosion inhibition of carbon steel at different temperature and under dynamic conditions can be carried out.
- The maximum duration of the stability of the protective film formed on the surface of the metal by inhibitor complex may be found.
- An investigation in elucidation of the coordination of the inhibitor compound with Fe^{2+} metal ion may be done.
- The protective film formed on the metal surface may be analysed by EPR spectroscopy.
- IE of the selected inhibitors may be evaluated in combinations with other synergistic metal ions such as Mn^{2+}, Mg^{2+}, Ba^{2+} etc.
- In AFM analysis, specific roughness properties can be investigated in detail through spectral roughness analysis i.e., determining the power spectral density (PSD) provides valuable

information not only on the height deviation of the roughness profile, but also on its lateral distribution, and hence it gives more general description than the rms roughness alone.

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How to cite this Paper?

C. Mary Anbarasi, S Rajendran and A. Thamaraichelvan, "Book of Abstracts of PhD Theses of Eminent Scientists", Int.J.Nano Corr.Sci.and Engg. (2014) 7-11