ABSTRACT

Copper and its alloys are widely used in industries, particularly as condensers and heat exchangers in power plants because of their excellent resistance to corrosion in neutral aggressive media. Brass has also been widely used in marine environment as tubing material for condensers and heat exchangers in various cooling water systems due to excellent thermal and electrical conductivity. However, it is susceptible to corrosion process known as dezincification and this tendency increases with increasing zinc content of the brass. Dezincification of brass is one of the well-known and common processes by means of which brass looses its valuable physical and mechanical properties leading to failure of structure. Thus, the study of its corrosion inhibition has attracted much attention.

During the past decade, many techniques have been used to minimize the dezincification and corrosion of brasses. One of the techniques for minimizing corrosion is the use of inhibitors. The effectiveness of the inhibitor varies with its concentration, the corrosive medium and surface properties of the alloy. Many inhibitors have been used to minimize the corrosion of brass. Particularly heterocyclic organic compounds containing nitrogen, sulphur and oxygen atoms are often used to protect brass from corrosion due to chelating action of heterocyclic molecules and the formation of a physical blocking barrier on the surface of brass. Among them, azoles have been intensively investigated as effective copper corrosion inhibitors.

Benzotriazole (BTA) has been proved to be one of the most important corrosion inhibitors for copper and copper alloy in neutral, acidic and alkaline solutions. The action of BTA as a corrosion inhibitor for copper and its alloys in
aqueous chloride media has long been of great interest to corrosion scientists and numerous studies have been performed. The effectiveness of BTA has been related to the formation of a \([\text{Cu}^+ \text{BTA}^-]_n\) film and the film formed is considered to be insoluble and polymeric.

Based on this, the new class of substituted benzotriazole derivatives have been considered and synthesized in the laboratory. In the present study, the performance of the BTA derivatives on the corrosion of brass alloy in artificial sea water and in natural sea water have been investigated by various corrosion monitoring techniques. Preliminary screening of the corrosion inhibition efficiency was carried out using weight-loss measurements. Polarization studies were carried out to study the corrosion behaviour of brass in marine environment and also to evaluate the corrosion inhibition efficiency of the BTA derivatives. Polarization measurements showed that the inhibitors are mixed-type, inhibiting the corrosion of brass by blocking the active sites of the metal surface. The inhibitors easily adsorb on the brass surface and form a protective complex with the Cu (I) ion, controlling brass from corrosion. The investigated benzotriazole derivatives showed good inhibition efficiency in artificial sea water and in natural seawater.

An Electrochemical impedance measurement was carried out to identify the formation of compact surface layer in the presence of inhibitors. Impedance studies showed that the change in double layer capacitance \((C_{dl})\) are related to the adsorption of inhibitors on the brass surface, leading to the formation of a protective film, which grows with increasing exposure time.
The adsorption of these inhibitors on the brass surface in artificial and natural seawater obeyed Langmiur adsorption isotherm. The values of the thermodynamic parameters such as activation energy ($E_a$), the adsorption equilibrium constant ($K_{ads}$), the free energy of adsorption ($\Delta G_{ads}$), the heat of adsorption ($\Delta H_{ads}$) and the entropy of adsorption ($\Delta S_{ads}$) were calculated and discussed. The increase in activation energy after the addition of studied inhibitors to the natural seawater and the value of free energy of the adsorption indicated that the adsorption is more chemical than the physical adsorption. The negative $\Delta G$ values indicate the spontaneity of the adsorption of studied inhibitors on brass. The values of $\Delta H$ of inhibitors indicate that the adsorption is an exothermic process and confirm the chemisorptions mode. The negative values of $\Delta S_{ads}$ are expected as the adsorption process is accompanied by a decrease in the disorder of the system due to the adsorption of the free inhibitors onto the brass surface.

Inductively Coupled Plasma Atomic Emission Spectroscopic (ICP-AES) measurement was used to determine the copper and zinc leached out from the brass. Solution analysis revealed that the inhibitors excellently control the dezincification of brass.

The characterization of film formed on the surface of the brass was carried out by Energy Disspersive X-ray Analysis (EDAX) and Scanning Electron Microscopy (SEM). EDX analysis revealed that the ingress of chloride ions into the brass surface has been considerably reduced in the presence of inhibitors. Scanning electron microscope was used to understand the surface morphological change. SEM micrographs showed that the rate of corrosion have been minimized in the presence of inhibitors.