

Application of Electrochemical Impedance Spectroscopy to a study of CO₂/H₂S corrosion of mild steel

Abstract

This paper consists of two parts, the first part of the paper discusses the general theory of Electrochemical Impedance Spectroscopy (EIS) response of a system involving a preceding first order rate-limiting homogeneous chemical reaction coupled to a two-step charge transfer step in a turbulent flow (i.e. finite boundary layer). The theoretical derivation of relationship between applied sinusoidal current and diffusion overvoltage response in this system is accomplished.

In the second part of the paper, EIS technique was used to study the mechanism of CO₂ corrosion of carbon steel in the presence of a trace amount of H₂S in film forming conditions (T=80°C, pH6). Experimental results have shown that, in addition to the common high-frequency capacitive loop, the Nyquist diagram exhibited a low-frequency capacitive loop which gradually transformed into a Warburg-type straight line characteristic as the specimen immersion time increased. A mechanistic approach was pursued by applying the theory discussed in the first part of this paper. A model that gives an electrochemical impedance response was established based on the fundamental equation of electrochemistry on the surface, transport, and water chemistry in the bulk of the solution. This model was able to capture complicated experimental EIS curves to provide a theoretical analysis of the impedance. A mechanism was proposed to explain the results in which a mixed layer of iron carbonate (FeCO₃) and iron sulfide (FeS) film was formed. The effective diffusivity of the film was evaluated by the model and it was in good agreement with the results from the surface analysis of the specimen.

This model was able to capture complicated EIS curves to provide some quantitative information on the mechanism of CO₂/H₂S corrosion at various temperature, pressure, pH, liquid and gas velocities, flow regimes and H₂S concentrations.