Electrochemical Impedance Spectroscopy for Corrosion Study

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Abstract

Cast iron water main failures have largely been as a result of corrosion damage that takes place when the metal is exposed in aggressive environment, resulting in gradual corrosion and loss of structural material and mechanical strength and ultimately leading to failure. In this study, Electrochemical impedance Spectroscopy (EIS) approach was used to determine polarization resistance of steel under various environments.

1. Introduction

Studies have shown that in excess of 25% of all the water losses in the water distribution networks are as a result of pipeline leaks and most of them occur due to pipeline breakages. Corrosion of the piping material severely reduces the mechanical and structural strength of the pipes leading to pipe breakages. The corrosion is an electrochemical process due to the formation of internal anode-cathode pair within the pipe leading to corrosion reaction where the metal is released from the surface of the pipe at the anode into the external media. This formation of the internal cell is because of varied factors like the differential concentration of the salts in the media, differential speed of water within the pipe, differential temperature and pressure and also because of differential material composition along the pipe [1] [2].

The degree and the rate of corrosion of a surface exposed to corrosive environments are measured using the parameter 'corrosion rate'. The corrosion rate represents the rate of loss of material over the corroding surface. Electrochemically the corrosion rate represents the rate of the reaction in the local electrochemical corrosion cell formed.

The corrosion rate (CR) cannot be directly measured experimentally hence the parameter 'polarization resistance' (Rp) is measured that directly relates to the corrosion rate. The polarization resistance simply represents the resistance to the corrosion process at the electrode surface. The higher the polarization resistance, lower will be the corrosion rate of the metal surface while lower polarization resistance means that the metal surface is corroding at a slow rate.

The polarization resistance is related to the corrosion rate (eqn 1)

$$\text{Corrosion rate (CR)} = (B\ M / \rho\ A) * 1/Rp \quad \text{----------} \quad (1)$$

Where M, ρ and A are the electrode parameters representing the Molecular weight, electrode material density and electrode surface area respectively.

The polarization resistance is obtained experimentally obtained EIS data from the Bode plot. The Bode plot is the log plot between the total impedance in the corrosion cell and the external AC frequency (Fig 1).

2. Objective

The objective of the project is to develop test setup by modeling the equivalent circuit for the corrosion cell to evaluate corrosion of the metal in different environments and quantify the corrosion rate.

3. Results

Based on the test requirements the initial test setup was built according to the equivalent circuit modeled and the polarization resistance measurements are conducted using Electrochemical Impedance Spectroscopy procedure.

The impedance measurements are done at increasing frequency of the AC input voltage whose amplitude was kept constant. The *log Z – log f* plots are generated, called the Bode plots [1].

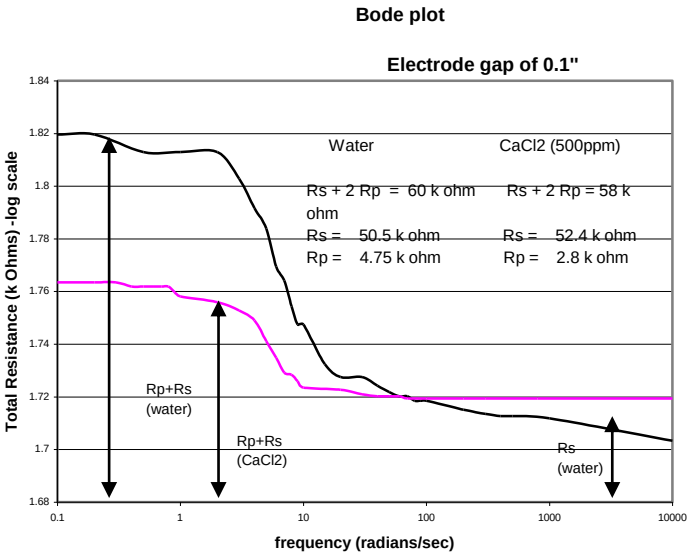
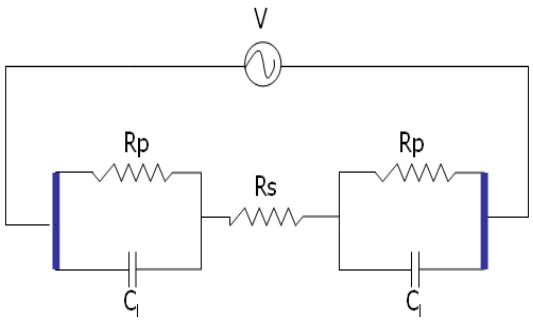


Fig 1: Bode plot for distilled water



$$R_T = Rs + 2Rp/ (1+\omega RpC_1)$$

Fig 2: Equivalent circuit of the corrosion cell

4. Discussions

At low frequencies the solution resistance and the polarization resistance are measured while at higher frequencies the polarization resistance goes to zero and only the bulk resistance of the solution was measured. Polarization resistance was obtained as the difference of the two cases. It can be observed from the plots that the polarization resistance value has significantly decreased in the salt media.

5. Conclusions

EIS measurement is an effective way of quantifying the corrosion rate of the metals corroding in an aggressive environment which can further be improved to various surfaces undergoing the process of corrosion.

6. Acknowledgement

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7. References

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