Characterizing Polarization Effect in Steel-Cement

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Abstract: Characterizing the electrical properties at interface level between steel and cement helps understand the integrity of the interface condition. The presence of corrosion products is one of the problems that undermine the integrity of the interaction between steel and cement. In this study, the electrical properties at interface level between oil well cement and corroded steel bar, and oil well cement are used to detect presence of corrosion at the interface.

1. Introduction: One of the main needs that arises in the gas and oil industry during drilling and distributions of crucial energy sources is maintaining the longevity and reliability of drilling piles and distribution pipelines. Such objective is compromised mostly because of the presence of corrosion. Corrosion is a naturally occurring phenomenon commonly defined as the deterioration of a substance (usually a metal) or its properties because of a reaction with its environment. For the past two decades, there has been a tremendous amount of research focused on smart coatings for structural applications; coatings the can sense certain conditions and then respond (Harovel G. Wheat, 2012). These are coatings that typically contain one or more indicators that can sense condition such as corrosion and respond by means of changes in pH, color, fluorescence or a combination thereof (Harovel G. Wheat, 2012). In the industry of gas and oil, corrosion of steel casing in cement mortar or reinforced concrete is of concern because it requires almost immediate repairs and rehabilitation to extend the service life of the structures.

2. Objective

The objective of this study was to establish an electrical method to characterize electrical properties between cement and steel bar.

3. Literature Review: The literature reviews revealed that some research works have been done so far by using electrical resistance as a measure of corrosion protection provided by coatings. And hence they focused on the interaction of the metal-coating system with corrosive fluid environments such as NaCl solution and H_2SO_4 solution. (F. Mansfeld et al, 1985). The studies mainly focused on the change in the coating that arises from presence of corrosion products. However, those studies did not address the interface piezoresistivity properties. Other research studies have been focused on coatings that typically contain one or more indicators that can sense condition such as corrosion and respond by means of changes in pH, color, fluorescence or a combination thereof (Harovel G. Wheat, 2012). The applicability of such coatings for the steel casing in oil wellbore is difficult and impractical to monitor the changes that the coatings may exhibit due to the inaccessible nature of wellbore.

4. Discussion: Cement specimens embedding two kinds of steel have been prepared for laboratory tests to characterize the piezoresistivity properties of the interface between the steel and the cement. The size of the specimens was cylindrical with diameter of 2 inches and height of 4 inches. Corroded and non-corroded steel were used with the size of #3 and #4 respectively. Both steel types had a length of 5 inches. Specimens were instrumented with 5 silver-paint wires connected to the embedded steel and 2 silver-paint wires connected to the cement (illustrated in Figure 2). To improve the piezorestivity properties of the cement, carbon fiber with 0.315gm was added. The electrical resistances and capacitance of the cement, steel, and transitional contact between the cement and steel were measured with impedance analyzer precision LCR meter. The equivalent circuit adopted based on expected behavior of the material under this study is shown in Figure 1. The total impedance of the equivalent circuit is given as follows:

$$Z = R_b + \frac{R_c}{1 + \omega^2 {R_c}^2 {C_c}^2} + \frac{R_i}{1 + \omega^2 {R_i}^2 {C_i}^2} - j(\frac{\omega {R_c}^2 C_c}{1 + \omega^2 {R_c}^2 {C_c}^2} + \frac{\omega {R_i}^2 C_i}{1 + \omega^2 {R_i}^2 {C_i}^2})$$

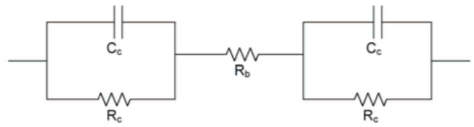

Figure 1. Equivalent circuit

In the equation, ω is the angular frequency of the applied signal. Applied signal was carried out with frequency range of 20 Hz to 300 kHz. Bode plot of the real impedance versus frequency is shown in Figure 2. From the bode plot, it can be seen that the difference in electrical resistance of corroded and non-corroded specimens was captured and particularly that of the interface between the steel and cement, where corrosion products are present.

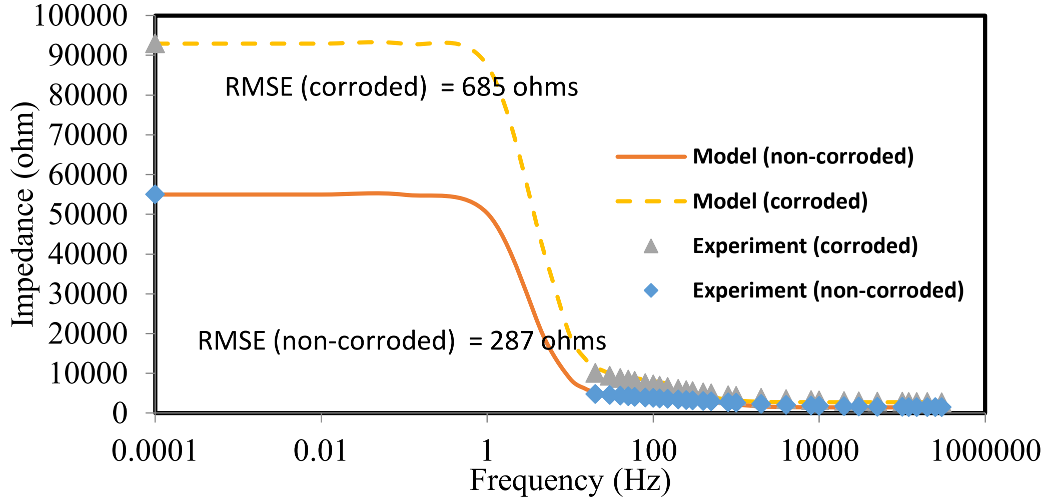

Figure 2. Impedance vs Frequency

5. Conclusion: In conclusion, characterizing electrical properties between steel and cement was established and was used to characterize the presence of corrosion between steel and cement. This electrical and relatively simple test method could be effective in determining the presence of corrosion at the steel-cement interface.

6. Acknowledge: This study was supported by the Center for Innovative Grouting Materials and Technology (CIGMAT), University of Houston, Houston, Texas with funding from the Ultra Deepwater Program DOE/NETL/RPSEA (Project No. 10121-4501-01).

7. References:

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