Effect of Foam on the Resistivity Behavior of Bentonite Drilling Mud

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Abstract: In this study, it is shown that resistance measurement represents the sensitivities of materials. The material used in this study was 4% bentonite based drilling mud the 2% additive named sodium dodecyl sulfate (surfactant). Bulk resistance, contact resistance and contact capacitance were derived from the model (Vipulanandan & Prashanth, 2013) fitted to measured resistance from low to high frequencies.

1. Introduction: In the oil industry, foams have been used for oil well drilling, enhanced oil recovery, oil well fracturing and etc. In underbalanced drilling operations, foam's cuttings carrying capacity and Equivalent Circulation Density (ECD) management capability is so significant (Chen et al., 2005). Rheological properties such as viscosity of drilling foams was characterized by Chen et al., 2005. In this study, it is focused on the characterization of drilling foam by using resistance rather than rheological properties.

2. Objective: The objective of this study was capturing the circuit model and also derivation of bulk resistance, contact resistance and contact capacitance according to the model.

3. Materials and Methods: Materials were used in this study were 4% bentonite drilling mud with (2%) and without surfactant Sodium dodecyl sulfate with the formula: $CH_3(CH_2)_{11}OSO_3Na$.

Case 1. General Bulk Material—Resistance and Capacitor in parallel

In figure 1 the left and right resistances and capacitances are related to contacts which interfere the bulk resistance and capacitance. The impedance related to this case of circuit is defined in equation (1) (Vipulanandan & Prashanth, 2013). According to equation (2), at infinite frequency (f = ∞, or ω = ∞) the impedance is equal zero $Z = 0$. At zero frequencies (f = 0, or ω = 0) the impedance is equal to bulk resistance with twice of contact resistance $Z = R_b + 2R_c$. In this case DC measurements is shown $R_b + 2R_c$.

Case 2. Bulk Material—Resistance Only

According to equation (2), at infinite frequency (f = ∞, or ω = ∞) the impedance is equal to the bulk resistance R_b. At zero frequencies (f = 0, or ω = 0) the impedance is equal to bulk resistance with twice of contact resistance $Z = R_b + 2R_c$. In this case DC measurements is shown $R_b + 2R_c$ and with LCR meter used in this study, the highest frequency was 300 kHz which is considered to be R_b.

Figure 1 shows the Comparison of typical responses of equivalent circuits for case 1 and case 2.

Following figures show the results of the experiments in which it is proved that the drilling mud acts as circuit case 2. Because at high frequencies in AC measurements (300 kHz) the resistance never got zero.

$$Z_1(\sigma) = \frac{R_b(\sigma)}{1+\omega^2 R_b^2 C_b^2} + \frac{2R_c(\sigma)}{1+\omega^2 R_c^2 C_c^2} - j\left\{\frac{2\omega R_c^2 C_c(\sigma)}{1+\omega^2 R_c^2 C_c^2} + \frac{\omega R_b^2 C_b(\sigma)}{1+\omega^2 R_b^2 C_b^2}\right\} \quad (1)$$

$$Z_2(\sigma) = R_b(\sigma) + \frac{2R_c(\sigma)}{1+\omega^2 R_c^2 C_c^2} - j\frac{2\omega R_c^2 C_c(\sigma)}{1+\omega^2 R_c^2 C_c^2} \quad (2)$$

4. Results and Analyses: Figure 2, figure 3 and figure 4 show the impedance, real part of impedance and absolute of imaginary part of impedance (equation (2)) versus frequency, respectively. In drilling mud with surfactant the bulk resistance, contact resistance and contact capacitance were 2490 **Ω**, 19005 **Ω** and 4.59e-6 F, respectively. In the case without foam (surfactant) the bulk resistance, contact resistance and contact capacitance were 418 **Ω**, 14391 **Ω** and 8.63e-6 F, respectively. By comparison cases the bulk resistance was increased by 495%, the contact resistance increased by 32% and contact capacity decreased by 46%. In the other hand the more bulk resistant the less contact resistance was found. By comparison of figure 1 and 2, it was found that the material used in this study acted as case 2, Due to nonzero results from AC measurement at highest frequencies.

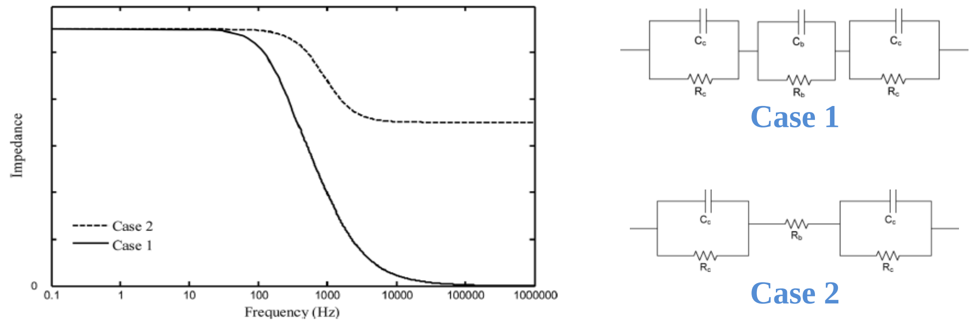

Figure 1 Comparison of typical responses of equivalent circuits for case 1 and case 2 (Vipulanandan & Prashanth, 2013)

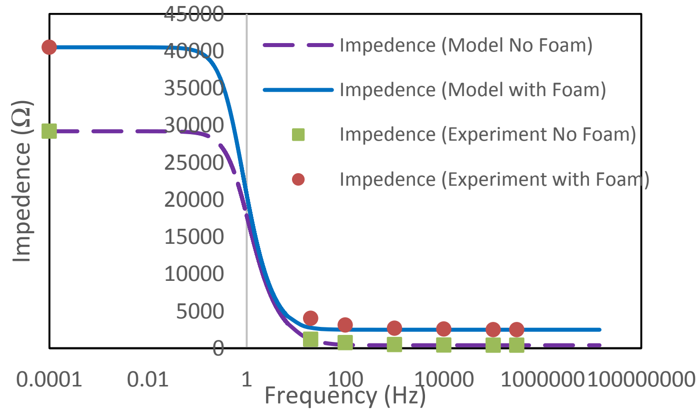

Figure 2. Impedance versus frequency

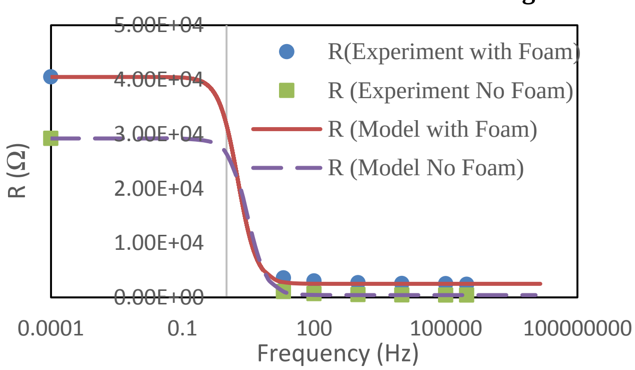

Figure 3. Real part versus frequency

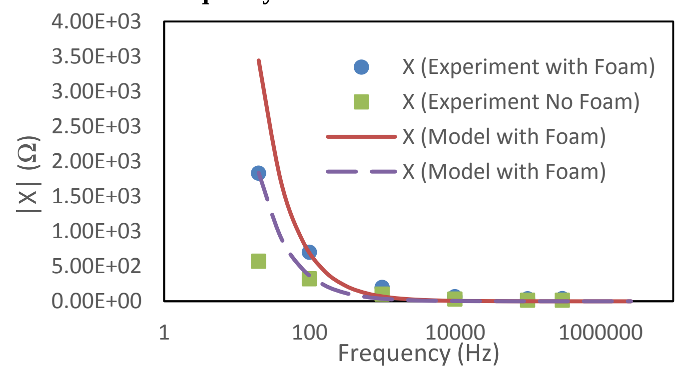

Figure 4. Imaginary part versus frequency

6. Conclusion: Measuring resistance is an ability by which the existence of foam in the drilling mud can be sensed. According to the figures, resistance are lower in high frequencies which is close to the bulk resistance and is higher in low frequencies due to the existence of contact resistance in low frequencies (DC measurement). Existence of 2% foam in the drilling mud led to increasing bulk resistance by 495%.

7. Acknowledgements: This study was supported by the Texas Hurricane Center for Innovative Technologies (THC-IT), University of Houston, Houston, Texas with funding from the Ultra Deepwater Program DOE/NETL/RPSEA (Project No. 10121-4501-01).

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