Experimental and Numerical Evaluation of Salt Contamination Diffusion in Drilling Mud Using Electrical Resistivity and FEM Analysis

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Abstract: Salt diffusion in drilling mud is critical and in need to be quantified. Hence, both experimental and numerical assessment of salt contamination diffusion in 6% bentonite drilling mud was investigated using electrical resistivity method and finite element analysis (FEM). The electrical resistivity decreased as the contamination diffused in the drilling mud with highest recorded concentration of 0.48% after almost two days. Finally, a precious analytical model was suggested to correlate the measured electrical resistivity from experimental study and the calculated salt concentration from FEM analysis.

1. Introduction: Generally, diffusion osmosis is unrecognized driving force which is determined by the difference in concentrations of the solutes in the drilling fluid and shale pore fluid. Diffusion osmosis results in transfer of solutes and associated water from higher to lower concentration for each species. Interactions of water-based drilling and completion fluids with shale formations have been considered as a major factor in the cost of finding and producing oil and gas (Simpson and Dearing 2000). Much progress has been made in understanding the mechanisms responsible for the destabilization of shale and subsequent problems such as high torque, stuck pipe, lost circulation and cementing failures (Chenevert 1970). Hence, studying salt diffusion in drilling mud is needed.

2. Objective: The main objective was to study the salt diffusion to 6% bentonite drilling mud with time through electrical resistivity measurement. The salt concentration change with the time has been verified through finite element analysis.

3. Materials and Methods: Water-based drilling mud with 6% of bentonite was used. The electrical resistivity was studied using 2 probe electrical resistivity method. Finite element analysis was also implemented.

4. Finite Element Analysis (FEM): The particle transport governing equation is given in

Equation 1 (CTRN/W 2007):

$$\Theta \frac{\partial C}{\partial t} + \rho_d \frac{\partial S}{\partial C}\frac{\partial C}{\partial t} = \Theta D \frac{\partial^2 C}{\partial x^2} - U\frac{\partial C}{\partial x} - \lambda \Theta C - \lambda S \rho_d \quad (1)$$

Where: Θ is volumetric water content, C is the concentration, S is the adsorption, t is the time, ρ_d is the dry density of the solid particles, D is hydrodynamic dispersion coefficient, x is distance, U is the specific discharge, and λ is decay coefficient.

Equation 1 can be re-written in matrix form for FEM analysis as Equation 2:

$$[K]\{C\} = \{Q\} \quad (2)$$

Where:

[K] = a matrix of coefficients related to geometry and materials properties,

{C} = a vector of the concentration at the nodes, and

{Q} = a vector of the contaminant flux quantities at the node.

FEM analysis included 663 triangular elements with 728 nods of 2 mm average element size.

5. Results: The experimental evaluation of salt concentration vs. electrical resistivity is shown in Fig. 1 with a very good agreement of the following proposed model:

$$Concentration \quad (\%) = \frac{\rho}{A + B * \rho} \tag{3}$$

Where: ρ is the electrical resistivity, A and B are model parameters.

The electrical resistivity of salt diffusion in drilling mud over the time can be seen in Fig.2. Finally FEM analysis vs. experimental results of concentration vs resistivity with a very good agreement is shown in Fig.3.

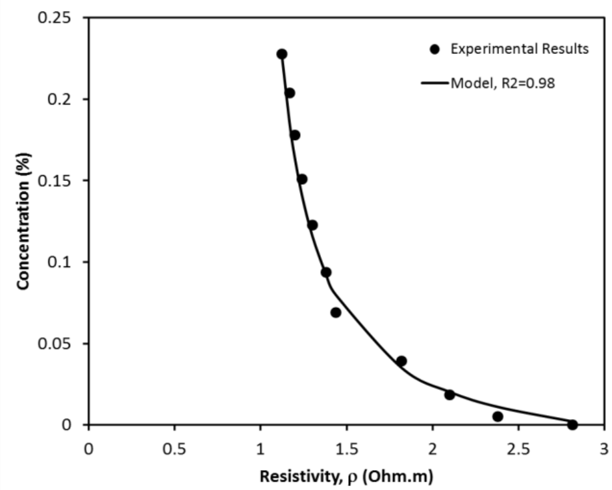

Fig. 1 Concentration vs. Resistivity Relationship.

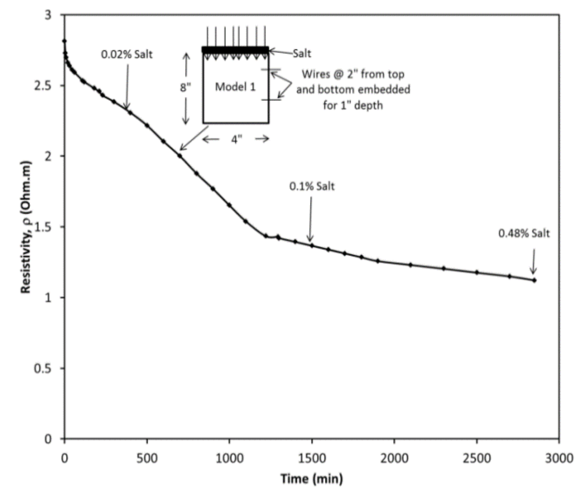

Fig. 2 The Variation of Electrical Resistivity over the Time.

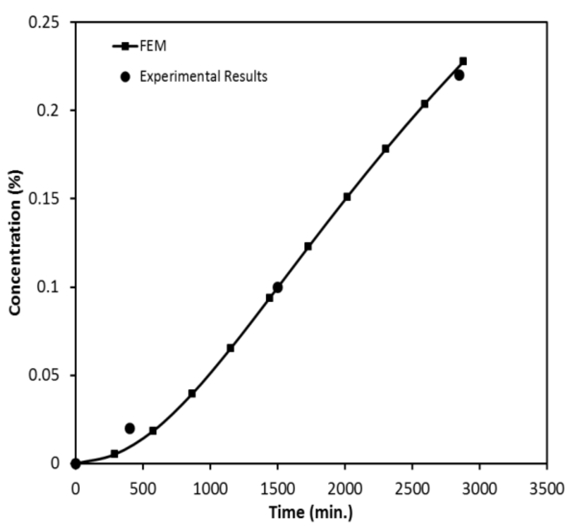

Fig. 3. FEM Analysis of Salt Contamination Concentration over the Time.

6. Conclusion: The electrical resistivity decreased as the contamination increased over the time. A correlation between the concentration and electrical resistivity was suggested with a very good agreement with experimental results.

7. Acknowledgements: 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).

8. References:

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