CFD Simulation of Pore Pressure Oscillation Method to Measure the Permeability of Tight Formations

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Abstract

Accurate estimation of rock permeability and porosity play a crucial role in the evaluation of oil and gas reservoirs. This evaluation is, however, challenging in tight formations such as shale due to the slow transition of fluid in such formations with extremely-low permeability. To overcome the long experimental time of conventional technique for permeability measurement (steady-state method), transient methods such pore pressure oscillation method has been proposed for laboratory measurement of permeability in tight formations. In this method, sinusoidal pore pressure oscillation is applied at upstream side of reservoir core sample and the response of the sample at the downstream side is evaluated. The attenuation of pressure wave amplitude as well as phase shift in pressure wave is used to calculate permeability and porosity (Figure 1). The considerable shorter time of experiment along with the ability of measuring permeability and porosity simultaneously are the advantages of this method.

The objective of this paper is to simulate this experimental technique for permeability measurement using the CFD Module of COMSOL Multiphysics® software and to compare the results with analytical solutions. Then, we conduct an extensive parametric study on the effect of downstream reservoir volume (Figure 2), core sample length, pressure wave frequency, pressure wave amplitude, pore pressure, and fluid viscosity and compressibility on pressure wave behavior for the calculation of permeability and porosity. Moreover, we determine by numerical simulations how to improve the calculation of permeability and porosity from laboratory data by overcoming an assumption in the derivation of analytical solution. Finally, recommendations are provided for laboratory set-up and laboratory data analysis of pore pressure oscillation method using the extensive parametric study of this method using COMSOL software.

Reference

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Figures used in the abstract

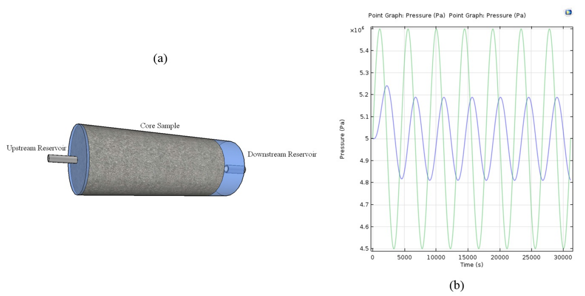

Figure 1. (a) Schematic of test setup, (b) Pressure wave at upstream and downstream sides of a core sample with porosity of 0.15 and permeability of 1e-18 m^2 (green line: upstream pressure wave, blue line: downstream pressure wave.

Figure 1

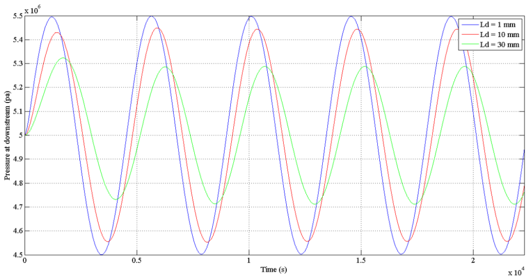

Figure 2. Effect of downstream reservoir size on pressure response in downstream reservoir.

Figure 2