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New Method for Supercharging Estimation

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Abstract

Formation testers are used to measure formation pressures at discrete depths to determine pressure gradients for zones of interest. The gradients are used to identify fluid types, to estimate the level of pressure depletion, and to check connectivity between different zones. Pressure supercharging is often observed during formation testing while drilling or wireline formation testing, especially when the permeability of the formation is low. The pressure measurement is greatly affected by supercharging, and accurate initial formation pressure can not be obtained directly.

In order for the supercharged pressures to be used for reservoir management purposes, the amount of supercharging has to be estimated and subtracted from the measured pressures. We present a single-phase invasion model which couples a mudcake growth model with an analytical formation fluid-flow model. Supercharging is a function of mudcake quality, pressure overbalance, and properties of fluid and formation. In a while-drilling operation, the time exposed to the overbalance is also a factor. Inversion is conducted to fit the invasion model with pressure measurements. The inverted five model parameters include initial formation pressure, compaction factor, mudcake permeability, mudcake thickness (at an arbitrary time before the testing), and skin (internal mudcake). The non-uniqueness of the inversion result is quantified with a statistical method that uses a Monte Carlo sampling method.

In addition to the statistical method, a deterministic method is developed to estimate initial formation pressure. This method assumes that flow resistance of mudcake grows at a constant rate during the test interval. Initial pressure and growth rate are calculated deterministically from at least three pressure measurements. Field cases are presented to demonstrate the robustness of both statistical and deterministic methods. The estimated initial formation pressure has good agreement with time-lapse LWD pressure measurements.

In this paper, a more accurate analytical formation fluid-flow model was used instead of line-source approximation. The internal mudcake is represented by the skin factor in the analytical model. The coupled invasion model has five parameters. While the previous seven-parameter model requires two sets of pressure measurement under two different hydrostatic pressures, the new model can be applied without the practical limits, it needs only one set of pressure measurements.

Introduction

Mud filtrate invasion takes place in permeable rock penetrated by a well that is hydraulically overbalanced. Mud filtrate invasion is responsible for supercharging, which is defined as the increased pressure observed at the wellbore sandface. The pressure measurement of a Formation Testing While Drilling (FTWD) tool can be affected by supercharging, especially when the permeability of the formation is low.

A forward model is required to estimate the supercharging pressure, given overbalance pressure, as well as mud and formation properties. Ideally, this model will couple the fluid flow model and the mudcake growth model. There are two types of forward models. The first type combines a numerical reservoir simulator with a mudcake growth model.[1] This finite difference simulator can deal with multi-phase fluid flow as well as complicated formations. The second type assumes single-phase flow, and uses an analytical model to represent the formation response.[2-4] Although the first type of forward model can deal with more complicated formations and fluids, it requires much more CPU time (several minutes) than the second model type (several seconds). Therefore, the first type model is not appropriate for inversion (which may require hundreds of forward evaluations). The single-phase flow assumption used in the second model type is usually valid to simulate invasion during drilling. The analytical solution of formation response will yield a good approximation in cases where supercharging is significant. The influences of cross flow between layers (possibly important) and neighboring well interference (unlikely to be important) are not considered in this single-phase model.

Improvements have been made to the single-phase forward model in a paper by Wu et al.[4] The model includes the following new features: overbalance pressure and mud properties are treated as functions of time; skin is introduced to account for internal mudcake; mudcake permeability is treated as a function of pressure as described by Dewan et al.[5] The internal mudcake forms during the period of rapid fluid invasion (spurt loss), when the drill bit first makes contact