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Modeling Reservoir Temperature Transients and Matching to Permanent Downhole Gauge Data for Reservoir Parameter Estimation

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Abstract

Permanent downhole gauges (PDGs) provide a continuous source of downhole pressure, temperature and sometimes rate data. Until recently, the measured temperature data have been largely ignored. However, a close observation of the temperature measurements reveals that the temperature responds to changes in flow rate and pressure, which implies that the temperature data may be a source of reservoir information.

In this work, the Alternating Conditional Expectations (ACE) technique was applied to temperature and flow rate signals from PDGs to establish the existence of a functional relationship between them. Then, performing energy, mass and momentum balances, reservoir temperature transient models were developed for flow of single- and multiphase fluids, as functions of formation parameters, fluid properties, and changes in rate and pressure. The pressure fields in oil and gas bearing formations are usually transient. This gives rise to pressure-temperature effects appearing as temperature changes in the porous medium when the pressure field changes. The magnitudes of these effects depend on the properties of the formation, flow geometry, time and other factors and result in a reservoir temperature distribution that is changing in both space and time. Therefore, in this study, reservoir thermometric effects were modeled as convective, conductive and transient phenomena with consideration for time and space dependencies. This mechanistic model included the Joule-Thomson effects due to fluid compressibility, and viscous dissipation in the reservoir during fluid flow in accounting for the reservoir temperature dependence on changing pressure/flowrate fields.

Numerical solution schemes as well as the semianalytical scheme - Operator Splitting and Time Stepping (OSATS) were used to solve the models, and the solutions closely reproduced the temperature profiles seen in real measured data. By matching the models to different temperature transient histories obtained from PDGs, reservoir parameters namely porosity and saturation and fluid Joule-Thomson coefficient could be estimated. Hence the normally unused temperature data record can be used to estimate reservoir parameters not usually available from conventional well test analysis. Analysis of temperature may also provide a less expensive substitute for downhole flow rate measurement.

Introduction

Long-term reservoir monitoring using permanent downhole devices provides a continuous source of downhole data in the form of pressure, temperature and sometimes flow rate. These permanent downhole tools provide access to data acquired continuously over long periods of time, which provides reservoir information at a much larger radius of investigation than conventional wireline testing.

The behavior of pressure transients in reservoir and wellbore flow has been studied extensively, and applied in conventional well test analysis for reservoir description, parameter estimation for formation characterization and evaluation of well and field performance. In recent times, with data convolution and deconvolution techniques as well as data filtering and tuning, pressure transient analysis methods have also been applied to pressure data from permanent downhole gauges (PDGs), increasing the usefulness of these data.

However, in most conventional pressure transient analysis methods, the temperature distributions in the reservoir and wellbore have been assumed isothermal. The temperature changes associated with fluid flow have been considered to be relatively small and hence negligible for any consideration in the analysis of flow behavior. However, an analysis of temperature measurements, at a fine scale using continuous data from PDGs, has shown that the temperature of the fluid responds to changes in flow conditions in the reservoir. Generally, the flow is not isothermal when the scale of observation and resolution of the temperature data are refined. This study attempts to identify the underlying physical phenomena