Crisman Week Review

The Harold Vance Department of Petroleum Engineering recently hosted a series of Crisman Institute for Petroleum Research meetings to offer Crisman company members the opportunity to see student researchers and faculty advisors present their findings in research projects currently sponsored by the institute. These meetings were held December 7-9 in room 309 of the Richardson Petroleum Engineering Building on the Texas A&M University campus.

The December 7 meeting covered Heavy Oil, Stimulation/IOR, Environmental, and Well Construction. The December 8 meeting covered Shale Reservoirs, Reserves, Modeling, and Stimulation. The December 9 meeting covered Shale Properties, Productivity, and Water Issues. The meetings were attended (online and in person) by a total of 54 industry, 50 students, 19 faculty, and 3 visiting scholars. A total of 34 presentations and 6 electronic posters were presented. Champions and mentors were discussed. Feedback from industry representatives has been compiled and will be used to improve the future meetings. All agendas, attendee lists, and pdf files of the presentations, along with video recordings of the meetings, can be found on the Crisman Institute Meetings page located here.

A goal of the Crisman Institute is to link each active project with at least one industry member champion or mentor from among those industry personnel who are especially interested in a particular project. The mentor’s role is to provide feedback from our industry representatives on direction, progress and relevance of current research projects. The intention is for mentors to have one or two additional direct contacts with their projects (beyond the Crisman Week reviews) during the year. This contact can be at Texas A&M, the mentor’s company location, by telecom or by a combination of these. In addition to providing valuable feedback to our projects, mentors will have more direct contact with some of our strongest students—and thus gain the potential for additional recruiting opportunities.
Diagnosis of Multiple Fracture Stimulation in Horizontal Wells by Downhole Temperature Measurement for Unconventional Oil and Gas Wells

Introduction

Horizontal wells with hydraulic fracture treatments have been proven to be an effective method for developing unconventional oil and gas reservoirs. During the last several years, fracturing methods have evolved and improved rapidly, however many uncertainties in fracture design still exist. Several fracture diagnostic techniques have been developed to improve the understanding of the fracturing process, such as microseismic and tiltmeter. Other diagnostic methods include local measurement of the fracture at the wellbore such as radioactive tracer, temperature log, and borehole image, and indirect diagnostic methods such as pressure transient analysis and production data analysis. Proper understanding of the fracturing process can help operators to optimize field development and well economics.

Distributed temperature sensing technology (DTS) is recently applied to hydraulic fracturing of unconventional reservoirs as a complementary tool for real-time fracture diagnostics. DTS has enabled us to observe the dynamic temperature profile along the wellbore during and after the treatment. However, quantitative interpretation of dynamic temperature data is very challenging and requires an in-depth mathematical modeling of heat and mass transfer during the treatment.

Li et al. (2010) present a model to solve for flow in horizontal well using downhole pressure and temperature sensor data. The wellbore model is based on a horizontal well model developed by Yoshioka et al. (2005) to predict temperature and pressure in the wellbore. The reservoir model is a 3-D, multiphase reservoir thermal model to calculate reservoir temperature. Tabatabaei and Zhu (2011) developed a thermal model to simulate the temperature behavior along the wellbore during a treatment as well as during a shut-in period (Fig. 1). Further studies are needed to estimate the temperature behavior in fractured horizontal wells integrating with fracture geometry models.

Objectives

The main objective of this study is to relate the wellbore temperature changes as measured by DTS data to the wellbore and fracture injection rate (or flow rate) during treatment (or production period). The tasks are:

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• Develop a forward model, based on mass and energy conservation, for calculating the temperature profile and temperature history in the wellbore and fractures, and also in the reservoir near the wellbore. The model will allow for liquid flow in fractures.

• Integrate the model with an inverse estimation algorithm which is used to estimate flow rates both in the wellbore and into the fractures.

• Estimate the fracture initiation points and length, number of created fractures, distribution of fluid along each fracture, and the effectiveness of fracturing. This information can be used for more accurate fracture modeling and better estimation of fracture conductivity and fracture geometry, and will therefore optimize future treatments and also evaluate the well performance.

Significance
This procedure should be fast and applicable for fracture stimulation diagnostics. It will provide valuable information for design and optimization of stimulation treatments.

Reference


Introduction

The petroleum industry is under an increasing demand to develop new well-log interpretation and core measurement techniques to evaluate hydrocarbon reserves accurately in unconventional reservoirs such as organic-shale formations. The current well-log interpretation techniques are highly dependent on calibration using core measurement. Meanwhile, experience still shows there is uncertainty in core measurements obtained from conventional techniques for organic-shale formations (Sondergeld et al. 2010). Furthermore, some petrophysicists believe that conventional physical models such as resistivity models used in petrophysical evaluation of organic shale might not be reliable in these unconventional formations. Quantifying the influence of rock and fluid properties on the electrical resistivity measurements improves the assessment of formation petrophysical properties from joint inversion of well logs (Heidari et al. 2010).

In the case of conventional formations, resistivity of the formation depends on the conductive portion of the formation which usually consists of water. (Matrix is assumed to have no effect on the resistivity of the formation.) Thus, in conventional reservoirs, resistivity is a function of porosity, water saturation, salt concentration, and volumetric concentration of shale/clay. However, in the case of organic shale, the presence of conductive minerals such as pyrite and semi-conductive materials such as kerogen affect resistivity of the matrix-fluid system. Moreover, it is believed that highly-mature organic-rich rocks might be much more electrically conductive due to other mineral phases than formation water, clay, and pyrite (Passey et al. 2010). The effect of matrix minerals and kerogen has not yet been included in any conventional resistivity model (e.g., Archie’s equation, dual-water model, and Waxman-Smits equation).

We intend to improve estimates of petrophysical properties of organic shale by investigating and quantifying the effects of rock and fluid properties on electrical resistivity of hydrocarbon-bearing shale. Data requirements for this research include well logs, core measurements, and core plugs in different organic-shale formations. The outcome of this project will significantly improve the interpretation of electrical resistivity logs to assess formation properties.

Objectives

The long-term goal of this research is (a) to provide a reliable electrical resistivity model for organic shale using both experimental and analytical approaches and (b) to verify the model in different organic-shale formations with different levels of maturity. Development of such a model will improve the interpretation of borehole electrical resistivity measurements to assess fluid saturations and possibly to detect and to quantify kerogen. To achieve the long-term goals, we propose objectives for the current project as follows:

Objective No. 1: Investigate the reliability of conventional resistivity-saturation-porosity models in organic-shale formations.

Objective No. 2: Determine the parameters affecting resistivity of organic shale and quantify their effect.

Objective No. 3: Investigate the existence of a physical relationship between petrophysical properties of the formation (i.e., porosity, water saturation, electrical properties of fluids and minerals, and volumetric/weight concentrations of mineral constituents and kerogen) and electrical resistivity in organic shale using available well logs and core measurements.

Approach

To achieve these objectives, we propose a quantitative combined evaluation of well logs and core measurements. We investigate the possible relationships between core resistivity at
different depths and water saturation, porosity, volumetric/weight concentrations of kerogen and conductive minerals, and maturity of kerogen. Unlike conventional methods, we do not use core measurements for the purpose of model calibration. Core measurements will be used to obtain a physical model for electrical resistivity of organic shale. Development of a reliable resistivity model improves the results obtained from the joint interpretation and inversion of all available well logs to assess petrophysical properties (i.e., porosity, water saturation, TOC, volumetric/weight concentrations of mineral constituents) of organic-shale formations. The required data for this project include (a) well logs including GR (Gamma Ray), GR-spectroscopy, density, neutron porosity, PEF (Photo Electric Factor), electrical resistivity, and neutron capture spectroscopy logs (b) core measurements, and (c) core plugs.

**Significance**

The findings of this project will significantly affect the quantitative interpretation of electrical resistivity logs as a part of the combined interpretation of well logs to estimate petrophysical properties of organic-shale formations. We expect to improve the assessment of hydrocarbon saturation and organic matter, which has a great impact on estimates of hydrocarbon reserves. Reliable interpretation of resistivity logs in combination with other logs will also improve decisions for completion zones and candidates for hydraulic fracturing in organic-shale formations.

**References**


Introduction

Unconventional resources, such as tight gas sands and shale gas reservoirs, are reshaping the energy supply structure in the United States and are being established as the main cleaner energy sources in the twenty-first century. The growing production trends in unconventional resources can be related to the advancements in horizontal drilling and hydraulic fracturing technologies. Production optimization in this setting has been performed primarily through a knowledge-based process involving production engineers and hydraulic fracturing experts in an ad hoc fashion. To date, numerical optimization schemes have not been employed to maximize production from unconventional resources.

Objectives

This research intends to develop novel optimization algorithms that can be used to improve the design and implementation of hydraulic fracturing to increase production and the net present value of unconventional assets by considering multiple optimization problems in designing the hydraulic fracturing system.

Approach

One of the key challenges in unconventional resources is how to best manage reservoirs under different conditions, constrained by production rates based on various economic scenarios, in order to meet energy demands and maximize profit. To address the energy demand challenges while maximizing profit, a paradigm shift in production optimization from unconventional resources is needed as one changes from a static decision making to a dynamical and data-driven management of production in conjunction with real-time risk assessment. To this end, new production strategies that involve simultaneous improvement of well trajectories and hydraulic fracturing need to be based on integrating engineering and geologic judgments as with model-based numerical optimization techniques.

This project will translate the hierarchical long-short-term production optimization framework, often encountered in the conventional reservoir management arena, to well trajectory and fracture placement in unconventional resources. The hierarchical optimization can be posed as a multi-objective optimization strategy to balance the objectives of the inner and outer loop. The proposed hierarchical optimization for the unconventional reservoirs is described next.

Fracture Placement Optimization (outer loop): The outer loop of our hierarchical optimization approach deals with finding the best trajectory for drilling wells. The optimization will include constraints to ensure drilling feasibility of the well trajectory as well as geologic considerations including pay zones and spatial variability in reservoir properties. Each iteration of the outer loop is used to update the well trajectory, which will be followed by an inner loop (next section) in which fracturing design (e.g., interval and intensity) is optimized.

Fracture Design Optimization (inner loop): The inner loop of the hierarchical optimization assumes a fixed (solution of the outer loop) well trajectory and optimizes the fracturing design. Here, the decision variables of the optimization include fracture intervals, fracturing intensity (length scale, connectivity, and geometric attributes), and fracturing sequence. Once these decision variables are optimized, they are reported back to the outer loop where an updated well trajectory with the given design variables is sought to further improve the objective function. The sequence of outer and inner loop optimizations continue until no significant improvement in the objective function (NPV) is observed (or a stopping criterion such as maximum number of iterations is reached).
Significance

The significance of the proposed developments for optimization of unconventional reservoirs can be readily appreciated by observing the latest trends and emerging technologies in developing conventional reservoirs and the limitations and challenges of the current practices in producing unconventional resources. We are planning to develop advanced optimization workflows to improve production strategies and the economic life-cycle value of unconventional resources. The ultimate goal of the project is to enhance the current industry practices in producing unconventional gas resources.

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