This issue of the Crisman newsletter contains brief descriptions of five new projects started late in 2009:

1. **Combustion Assisted Gravity Drainage (CAGD): An In-Situ Combustion Method to Recover Heavy Oil and Bitumen from Geological Formations using a Horizontal Injector-Producer Pair**

2. **Transient Multiphase Sand Transport in Horizontal Wells**

3. **Performance Driven Hydraulic Fracture Design for Deviated Wells**

4. **Evaluation of Polymer-Based In-Situ Gelled Acids during Well Stimulation**

5. **Application of Unstructured Upscaling for Improved Tight Gas Reservoir Simulation**

For more information on these and other Crisman projects, please visit our website at: [http://www.pe.tamu.edu/crisman/index.html](http://www.pe.tamu.edu/crisman/index.html). A compiled list of the projects, including categories and links to each project’s web page, is available at: [http://www.pe.tamu.edu/crisman/projects.html](http://www.pe.tamu.edu/crisman/projects.html). For detailed information, contact one of the key investigators listed on the project.
Combustion Assisted Gravity Drainage (CAGD): An In-Situ Combustion Method to Recover Heavy Oil and Bitumen from Geologic Formations using a Horizontal Injector-Producer Pair

Objectives
In-situ combustion (ISC) is a recovery process particularly suitable for heavy oil reservoirs at depths greater than 3500 ft when steam injection is not feasible due to severe wellbore heat losses. We have developed a method in which a horizontal air injector is placed above a horizontal producer (Fig. 1). In this Combustion Assisted Gravity Drainage (CAGD) method, a heated chamber is created that would more uniformly transfer heat from the combustion front. Mobilized oil is produced by gravity drainage to the lower horizontal well.

Gravity segregation enhances air flow to propagate the combustion front. Main research objectives are as follows:
» Assess CAGD using Computer Modelling Group (CMG) simulator
» Conduct experiments using a scaled 3D physical model to test viability of CAGD for heavy oil and Cold Lake bitumen
» Compare CAGD and toe-to-heel air injection (THAI) processes
» Using CMG simulator, history-match laboratory CAGD results and scale up to field conditions

Approach
We will conduct a simulation using CMG for a preliminary evaluation of CAGD. If simulation results show CAGD to be promising, we will conduct experimental runs using a physical model to evaluate performance of CAGD. We will also history match experimental results and scale up to field conditions and evaluate CAGD.

Accomplishments
A 50 cm x 15 cm x 35 cm Cartesian simulation model was constructed representing the half symmetry element of a 750 m long x 56 m width x 35 m thick drainage volume; we placed the injector at 7 m above the reservoir base with a producer 5 m below the injector. The model was based on typical Athabasca oil and rock properties. Runs

Fig. 2. Oil production rate for CAGD, THAI and SAGD.
were made to compare CAGD with steam assisted gravity drainage (SAGD) and THAI. Results indicate CAGD to have the highest oil production with the lowest energy consumption (Figs. 2 and 3).

The physical model, measuring 60 cm x 40 cm x 15 cm, is nearly completed (Fig. 4). The steel sides will be lined with ceramic fiber insulation. Seventy two thermocouples will measure temperature in the sandmix with an operating pressure at about 30 psig.
Transient Multiphase Sand Transport in Horizontal Wells

Introduction
Multiphase technology solutions have enabled the process industries, such as the petroleum industry, mining industry and nuclear industry, to improve their production performance, extend their operation, and address previously insoluble problems.

Objectives
The objective of the dissertation is to develop a dynamic simulation tool for sand transport and control in oil-gas and oil-water multiphase flow systems through horizontal and vertical wellbores, pipelines, and production rises.

Approach
Unsteady state multiphase flow and optimal sand transport control models will be developed based on a multi-fluid modeling approach in the CFX Ansys, STAR CCM+ and MATLAB platforms to predict sand particle transport and hydrodynamic behavior under various system, operation, and geometric conditions. New data from sand transport and entrainment experimental flow loops will be used to validate the developed model(s) and to achieve a better understanding, and to improve project performance and value creation. The new design and engineering analysis tool will provide best practices guidelines and performance assessment of gas-oil-sand and oil-water-sand multiphase flow system design options and optimal operational methodologies.

Accomplishments
» Reviewed literature of current multiphase models and their limitations
» Developed a mechanistic model for predicting effect on the pressure drop of sand transport in horizontal wells
» Placed a purchasing order for flange gaskets to be used in the flow loop facility in Room 601.

Future Work
» Continue with the literature review of sand transport and multiphase models.
» Jump-start the flow loop in Room 601.
» Modify the flow loop to accommodate sand transport mechanism.

Project Information
2.4.23 Transient Multiphase Sand Transport in Horizontal Wells

Contacts
Gioia Falcone
979.847.8912
gioia.falcone@pe.tamu.edu

Ime Udong
Performance Driven Hydraulic Fracture Design for Deviated Wells

Introduction
Unrestricted fracturing, long-established for low-permeability reservoirs, is not applicable to high-permeability formations where the resulting width would be far less than indicated by rigorous design approaches such as the Unified Fracture Design (UFD). Thus, tip screenout (TSO) treatments are necessary, in which the lateral migration of the fracture is arrested followed by inflation of the fracture to the desired/optimum width. The term high-performance fracturing (HPF) better reflects the high performance standard targeted by this completion technique.

Connectivity between the well and the fracture is a very important issue and has been addressed repeatedly in the literature. Because HPF’s dominate Gulf of Mexico well completions where well deviation angles established for extended reach drilling are maintained through the productive zone, the issue of well to fracture connectivity becomes even more serious. Ehlig-Economides et al. introduced a new model for hydraulically fractured wells, hypothesizing that only those perforations in the intersection between the far field hydraulic fracture plane and the wellbore actually connect flow through the fracture to the well. In turn, Zhang et al. introduced a new model allowing for flow both through the fracture and bypassing the fracture through perforation that are not connected to the fracture.

Objectives
This research is intended to provide new computational tools to quantify how the presence of the deviated wellbore open to flow impacts the expected performance of the hydraulic fracture, allowing a design of the system “deviated wellbore open to flow + transverse hydraulic fracture” to maximize overall productivity.

Approach
The problem is approached by combining the UFD technique with the “Method of Distributed Volumetric Sources” (DVS). We are developing a convenient implementation/methodology that will iteratively find the optimal fracture geometry that would result in a maximum productivity index of the deviated and fractured wells.

Future Work
1. Provide analytical/empirical expression(s) for the mechanical skin that includes all contributing factors (i.e. well deviation, perforation density, phasing, penetration depth and diameter, minimum in-situ stress direction, proppant permeability, halo effect, production rate, and turbulence beta factors).
2. Provide analytical/empirical expression(s) for the composite productivity index (JD) that includes all previously mentioned major contributing factors.
3. Generate simplified correlations and benchmarking plots for the composite productivity index (JD) versus well deviation and reservoir permeability.

Project Information
2.4.24 Hydraulically Fractured Well Performance in High Rate Wells

Related Publications

Contacts
Christine Ehlig-Economides
979.845.0797
c.economides@pe.tamu.edu

Matteo Porcu
Evaluation of Polymer-Based In-Situ Gelled Acids during Well Stimulation

Introduction
An in-situ gelled system based on a polymer that is stable in an aqueous acid environment can be cross-linked in the presence of ferric ions or zirconium ions at a pH of about 2 or greater. The polymer should contain carboxyl groups; such polymers include acrylamide and acrylamide copolymers. Initial spending of the live acid, during leak-off and worm-holing, produces a rise in pH to a value of above, or about, 2, which initiates cross-linking of the polymer (resulting in a rapid increase in viscosity). This increase in viscosity creates the diversion from wormholes, from fissures, and from within the matrix. As the acid spends further and the pH continues to rise, the reducing agent converts the ferric ions to ferrous ions. The gel structure will collapse and the acid system reverts back to a low viscosity fluid.

Objective
In-situ gelled acids that are based on polymers have been used in the field for several years, and were the subject of many lab studies. There are conflicting opinions about using these acids. These acids were used in the field, with mixed results, yet recent lab work indicated that these acids can cause damage under certain conditions. There is no agreement on when this system can be successfully applied in the field, therefore the objective of this research is to recommend the best conditions where polymer-based acids can be used.

Approach
Three commercial acid systems from three different companies were evaluated under normal and severe contamination of iron and salt. Experimental studies were conducted to measure the rheological properties for in-situ gelled acid using an oscillation rheometer and a rotational viscometer. To the best of our knowledge, this is the first time that the elastic properties were measured for these acids. Finally, a coreflood study was conducted using Indiana limestone cores (1.5” diameter, 20” long) at 250°F. Propagation of the acid, polymer, and cross-linker inside the long cores was examined for the first time in detail.

Project Information
2.5.17 Viscosity of Polymer-based In-situ Gelled Acids during Well Stimulation

Related Publications


Contacts
Hisham A. Nasr-El-Din
979.862.1473
hisham.nasreldin@pe.tamu.edu
Ahmed Gomaa
**Future Work**

A parallel coreflood study will be conducted using multistage acid injection. Propagation of each acid stage, polymer, and cross-linker inside the long cores will be examined in detail. Also, reaction rate measurement for the in-situ gelled acid using a rotating disk apparatus will be conducted under different conditions.

![Image of CT scans showing core samples filled by gel.](image)

Determination of CT number for gel residue.
Application of Unstructured Upscaling for Improved Tight Gas Reservoir Simulation

Objectives
The objective of this research is to improve the flow simulation of tight gas reservoirs through the application of unstructured upscaling of detailed 3D geo-cellular models. The techniques are designed to preserve the high resolution well productivity and connectivity of the reservoir description while at the same time reducing the cost of the reservoir simulation computation.

Accomplishments
We have completed the conversion of the tight gas Eclipse field model (made available to us through an MCERI project) to the VIP and Nexus simulators. We have provided our own high resolution transmissibility upscaling algorithms for simple grid coarsening geometries as a pre-requisite to more difficult upscaling problems. We have also compared our transmissibility upscaling algorithms with the VIP and Nexus simulators’ cell property-based upscaling, to determine under what circumstances the high resolution algorithms provide better flow characterization.

Future Work
We will work on the understanding of VIP/Nexus’s underlying theory for the upscaling, and replace its upscaled properties (transmissibility and well index) with our own upscaled properties to get more accurate results.

Medium Resolution 75 Layer 3D Geologic Model of the 10x10x375 test volume of a Tight Gas Reservoir. This model was developed using the VIP simulator’s built-in grid and property coarsening algorithms, here for 1x1x5 coarsening. Our research project will provide improved coarsened representations of the fine scale reservoir model that better preserve the reservoir connectivity and properties.

High Resolution 375 Layer 3D Geologic Model of a 10x10 test area of a Tight Gas Reservoir. This model shows the intermittent connectivity associated with the fluvial nature of these reservoirs.

Detailed View of the High Resolution 375 Layer 3D Geologic Model, giving a better perspective of the variation of sand thickness associated with the individual simulation layers.

Project Information
3.1.22 Application of Unstructured Upscaling for Improved Tight Gas Reservoir Simulation

Contacts
Michael King
979.845.1488
mike.king@pe.tamu.edu

Yijie Zhou