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Simulation-Based Hydraulic Fracture Workflows for Optimizing Unconventional Asset Development

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Summary

The emergence and exponential growth of unconventional oil and gas has dramatically changed the global energy mix and has ushered in a new era of oil and gas development. Its production methods, particularly rapid development in hydraulic fracturing technology, has revolutionized the oil and gas sector. Depending on the methods and tools used, forecasting future production and estimating ultimate recovery (EUR) in unconventional reservoirs is often full of uncertainty. One of the issues is the current reliance on analysis from analog fields, which often fails to address geological variability and uncertainty. Additionally, analytical methods frequently lack the required physics; limiting their predictability and reliability. This lack of predictability has somewhat restricted energy companies from making optimum business and field development decisions. Some of the other inaccuracies comes from tedious and inconvenience in moving between multiple tools and software packages with risk of over-predicting production from infill wells, and not managing well interference. Reservoir simulation encapsulates the downhole and reservoir behavior; empowering engineers to assess and plan development strategies efficiently. Reservoir simulation is a powerful tool that allows operators to be creative and plan strategies to minimize the risk of economic failure. Geological and economic uncertainty can be captured, quantified, and managed using the appropriate simulation tools.

This presentation discusses the different methods used to model the complete lifecycle of hydraulically fractured wells in a dynamic reservoir model. Various workflows such as production-only modelling for fast and accurate results, as well as more-in-depth geomechanical simulations for fracture initiation and propagation, are explained. AI and machine learning based optimization of hydraulic fracture design, spacing, well spacing and field development can be achieved with greater confidence. Two case studies with properties analogous to the Montney area, are presented in order to demonstrate the use of these workflows. The inclusion of hydraulic fractures with unconventional reservoir simulation enhances the accuracy of the model, leading to better and reliable production forecasts.

Theory / Method / Workflow

Modelling of Production-Only Hydraulic Fractures in a Dynamic Reservoir Simulator

The simplest method of simulating hydraulic fractures is to use the production-only modelling approach. This technique focuses only on the flow and production of hydrocarbons after the creation of hydraulic fractures. Within the domain of the production-only modelling, planar bi-wing hydraulic fractures or complex stimulated reservoir volume (SRV) or a combination of the two can be used. Hydraulic fractures could be designed directly in the reservoir simulation tool or imported from 3rd party hydraulic fracture design tools. Alternatively, hydraulic fractures or a stimulated reservoir volume (SRV) may be modelled by incorporating microseismic data.

Using the planar fracture methodology, the fracture is represented by a simple bi-wing fracture of specified height, half-length and fracture conductivity. The ease and intuitiveness of the method enables engineers to easily develop field-scale operating strategies. Fracture properties can be easily parameterized for sensitivity analysis, history matching, optimization studies as well as uncertainty analysis.

A case study highlighting the overall workflow incorporating geologic and economic uncertainty will be discussed in this presentation. In this study a net present value and oil recovery optimization was performed in order to determine the optimal fracture design and well configuration. From a recovery stand-point the optimal fracture spacing and well spacing is to be as close as possible. An economic perspective reveals the optimal well spacing and fracture spacing is larger due to the increased capital costs. The comparison of oil recovery and net present value for various fracture and well spacing scenarios can be viewed in Figure 1.

Complete Life Cycle Modelling with Geomechanics-Based Hydraulic Fracture Creation and Production Phase.

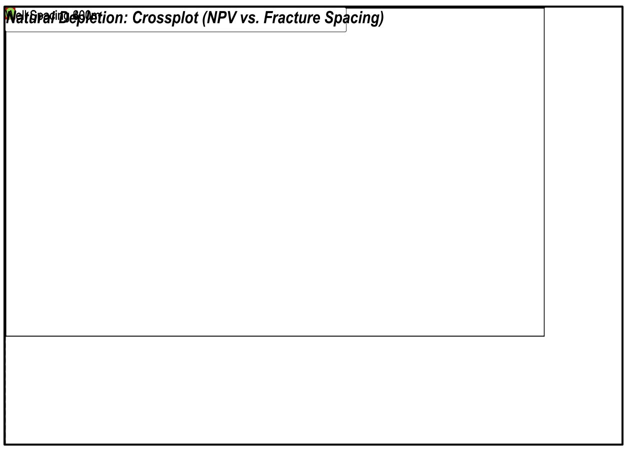
Alternative to assuming the hydraulic fractures being present at the start of the simulation, the creation of the hydraulic fractures by injecting frac fluid can be modelled in the reservoir simulator. This allows the full life cycle of an unconventional asset to be modelled: from injection of fracture fluid to flow back leading into the production phase. The modelling of hydraulic fracture creation and design can be done either using a standalone dedicated hydraulic fracture creation tool or using a 3D dynamic reservoir simulator with integrated geomechanics capability. The use of dynamic reservoir simulator allows for accurate prediction of hydraulic fracture growth because it considers effects of reservoir and fluid flow geomechanics, stress change, stress shadowing, and fracture hits.

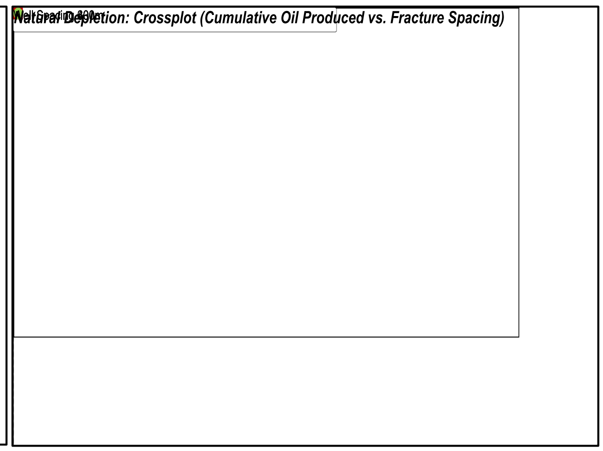
As a second example case study, a history matching study will be demonstrated. A 3D black oil reservoir simulator was used to model the fracture creation and production periods. To model the fracture creation, the fracture permeability was made to be an exponential function of pressure. Each stages' frac fluid injection rates were used as an operating constraint and the exponent in the pressure-perm relationship was adjusted to match the historical injection pressures. Once the injection phase was matched the production phase can be matched. In this study, a total of 2 different pressure-permeability functions were used to describe the fracture closure behavior. Multiple closure curves were used to describe the different potential regions of a fracture such as propped and un-propped. The final history matched permeability relationships are shown in figure 2. Once a history match is obtained this approach can be used to predict the growth of re-fracs for existing wells or new fracs in infill wells.

A further enhancement to this approach can be done by coupling geomechanics to the models. This allows fracture growth to be predicted from in-situ stresses as opposed to the pressure. When stresses are introduced the fracture growth will be more accurate which is important for capturing well to well interactions such as fracture hits.

(a) (b)

Figure 1: Plots of (a) NPV and (b) Cumulative Oil versus fracture spacing for various well spacing scenarios.





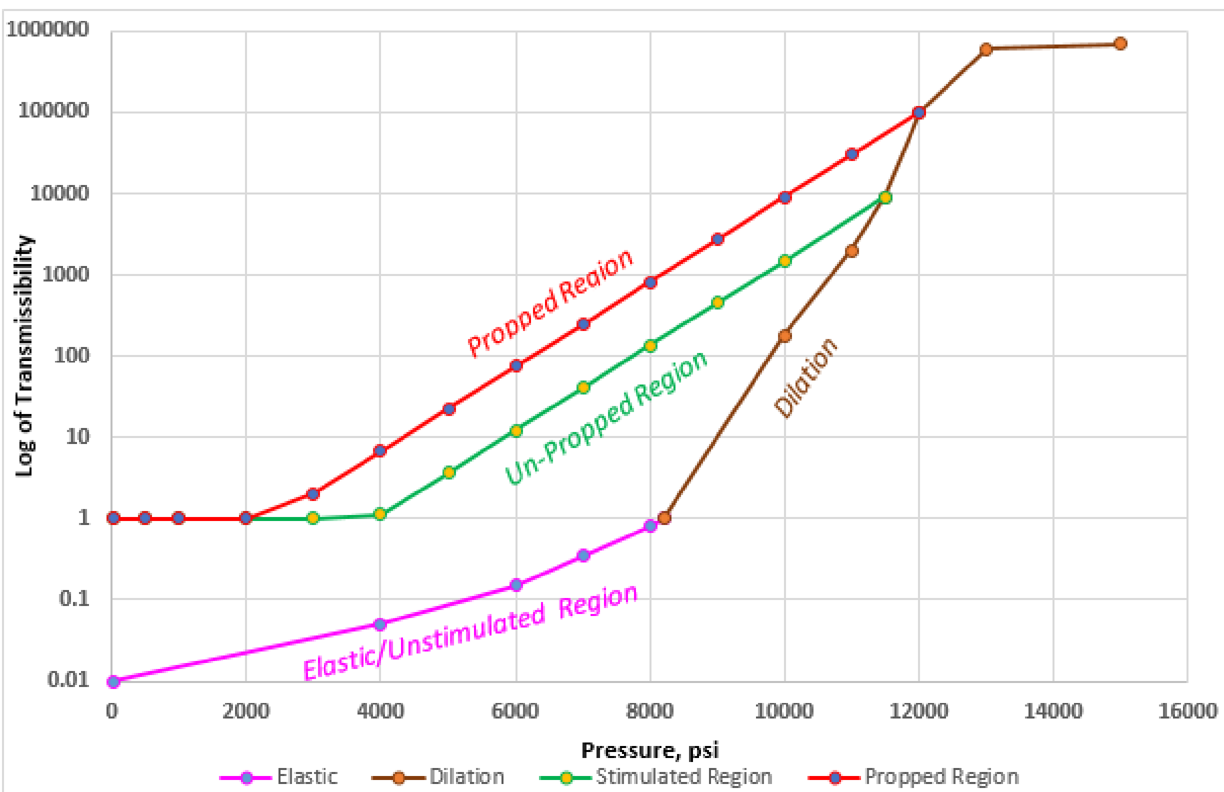


Figure 2: Transmissibility Multiplier versus pressure for the injection-production approach.

Results, Observations, Conclusions

Reservoir simulation modelling of unconventional assets allows for answers to questions that may not be resolved through simpler approaches. Engineers can easily optimize the well spacing, fracture spacing, and fracture design which is paramount in developing these assets. Accounting for increased physics such as well interactions will further improve the decisions made.