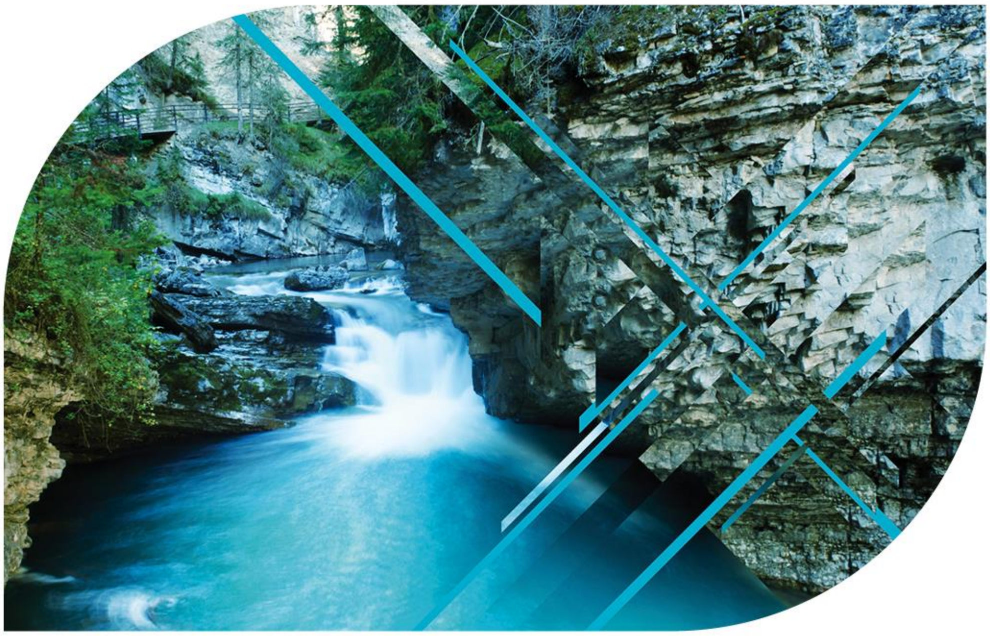
TightFlow™



IFPen and Beicip-Franlab
Methodology to address

Characterization and Modeling of the Impact of Hydraulic Stimulation on the Production of Shale or Tight Reservoirs

TightFlow Project

BeicipFranlab

1 INTRODUCTION

Nowadays, many wells are hydraulically fractured to enhance production. It's true in unconventional reservoirs like Shale Gas and Shale Oil formations but also in tight reservoirs. However, hydraulic fracturing is an expensive operation and needs to be designed carefully to maximize the impact on the formation and the future production. Up to now, industry was relying mainly on statistical computation or mono disciplinary approach (mainly geomechanics) or even empirical practices on the field. It appears to be insufficient and a need for integration emerges now to understand complex interactions in sub-surface to optimize current practices.

TightFlow aims at understanding and predicting how the formation is impacted by hydraulic fracturing and use this information to give an accurate production forecast and therefore test various development scenarios. The strength of TightFlow is to address the challenge of characterizing stimulated unconventional plays through an approach that combines classical reservoir characterization techniques, geomechanics, and reservoir simulation. It benefits from decades of expertise in natural fracture modeling and flow simulation by both IFPEN and Beicip-Franlab, supported by dedicated industrial software FracaFlow™ and PumaFlow™.

Compared to many single discipline solutions delivering a proxy calibrated on real data, TightFlow follows a predictive method based on a precise fracture characterization and realistic simulation of the effect of hydraulic fracturing on all stages of the well delivering a tool able to answer the challenges of all specialists like finding the optimal number of stages or well spacing.

TighFlow is a methodology applied on real data as a consulting offer exclusively. It uses a plug-in on the industrial product FracaFlow™ to prepare a data deck for the reservoir simulator PumaFlow™.

This document aims at presenting our methodology. It describes the current approach of Beicip-Franlab and IFPen for hydraulic fracturing. The current plug-in is presented, as well as the main guideline for upcoming evolution and improvements.

2 HYDRAULIC FRACTURING: WHAT ARE THE CHALLENGES

2.1 Static characterization of fractures

Being able to understand interactions between natural fractures and hydraulic fracturing implies to know perfectly the state of the formation before stimulation. FracaFlow is recognized by industry as a leading tool to study and model any type of fractures. Realistic geological models with thousands of fractures from metric to kilometric size can represent all kind of formations.

Potential propagating fractures resulting from stimulation must be added before the frac job into the DFN according to stress and rock properties. They represent the possible pathways for the injected fluid among the network. The propagating fractures that will be really opened have to be identified by a proper dynamic simulation.

2.2 Hydraulic simulation of frac job

Dynamic simulation of the frac job on the DFN is the key part of the methodology. The initial DFN is meshed so that all the possible connections between natural and potential propagating fractures are already present in an unstructured grid. Hydraulic simulation is processed and the injected fluid is propagated from node to node according to dynamic evaluation of aperture and conductivity related to realistic geomechanical behavior.

The simulation delivers BHP profil with time and cloud of microseismic events related to fractures activated in shearing mode. Hydro mechanical properties can be tuned to obtained a good matching with measured data (BHP and microseismic) in a classical calibration workflow.

2.3 Production Forecast for stimulated wells

The simulation of each stage along the well trajectory give access to a DFN after stimulation. It could feed directly an unstructured 3 phase simulator like PumaFlow, or be upscaled in a dual medium model. Specific physics for unconventional plays like adsorption or pressure dependant permeability are availbale in PumaFlow for better reliability of the simulations.

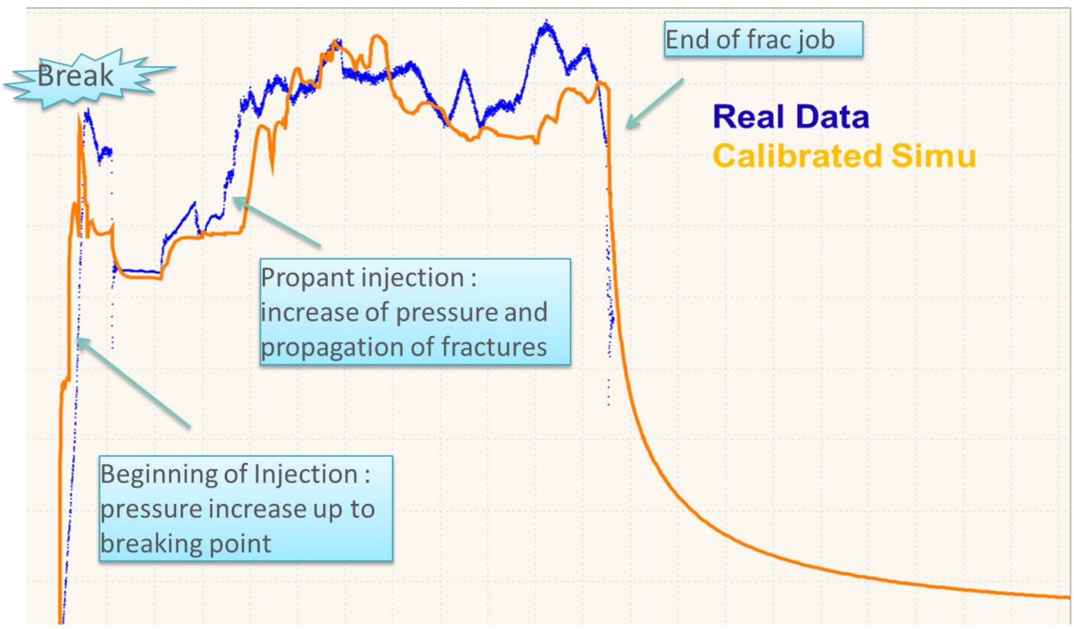
3 WHAT IFPEN/BEICIP HAVE DONE SO FAR

IFPen and beicip-Franlab worked with an operating company providing a complete set of data that allowed building a plug-in implementing this workflow on a real case. Very promising results were obtained with this multi-disciplinary approach. Illustration of the workflow is done below.

3.1 First Stage Calibration

The well Test simulator from the industrial product FracaFlow has been extended to fluid injection cases. Mechanical laws have been added to all fractures to represent elastic and plastic deformations for natural and propagating fractures. A rupture criteria is calculated from the Mohr-Coulomb diagram and is used to generate synthetic microseismic events. Injection of proppant is modelled as a variation of fluid properties.

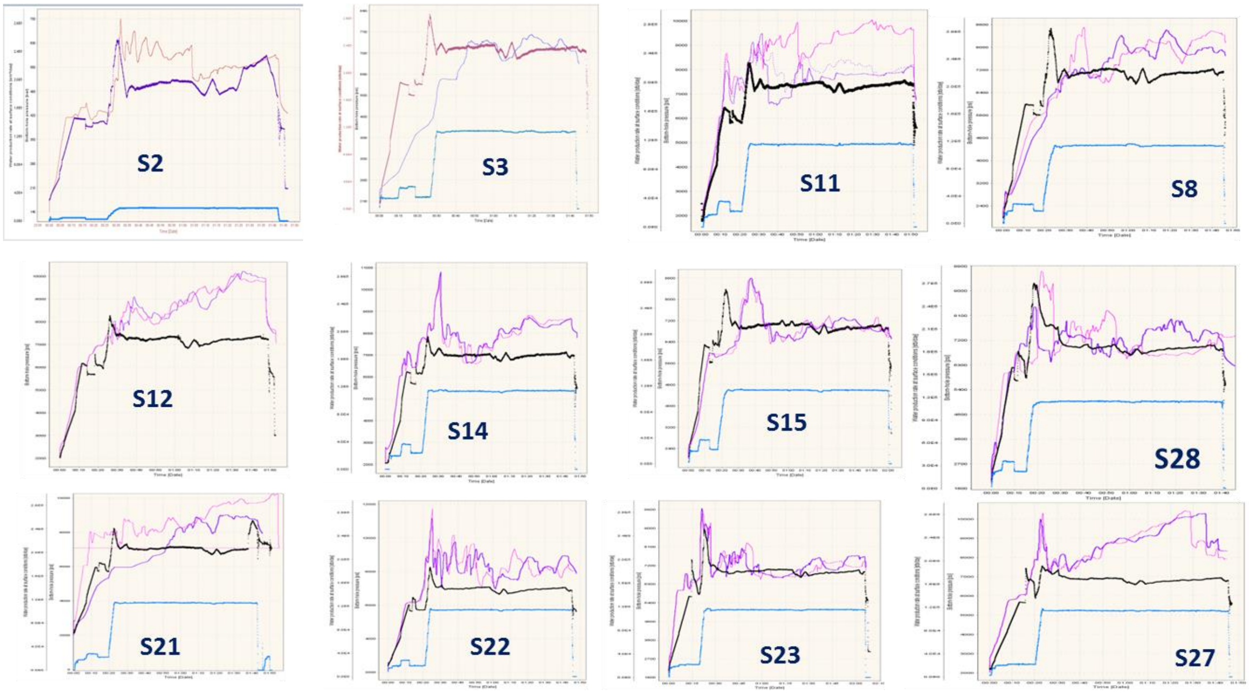
Hydro mechanical parameters, static and dynamic characteristics of fractures, stress orientation are used as matching parameters to reproduce BHP and microseismic envelop. A methodology has been experimented to achieve a good match following a sequential tuning of parameters on specific parts of the BHP.



3.2 Multi Stage simulation using calibrated parameters

Parameters tuned in the first stage match can be used to simulate the other stages as they are. The quality of the model can be evaluated by its capacity to reproduce the BHP of the other stages. It does not exclude several iterations on some parameters to improve the overall match.

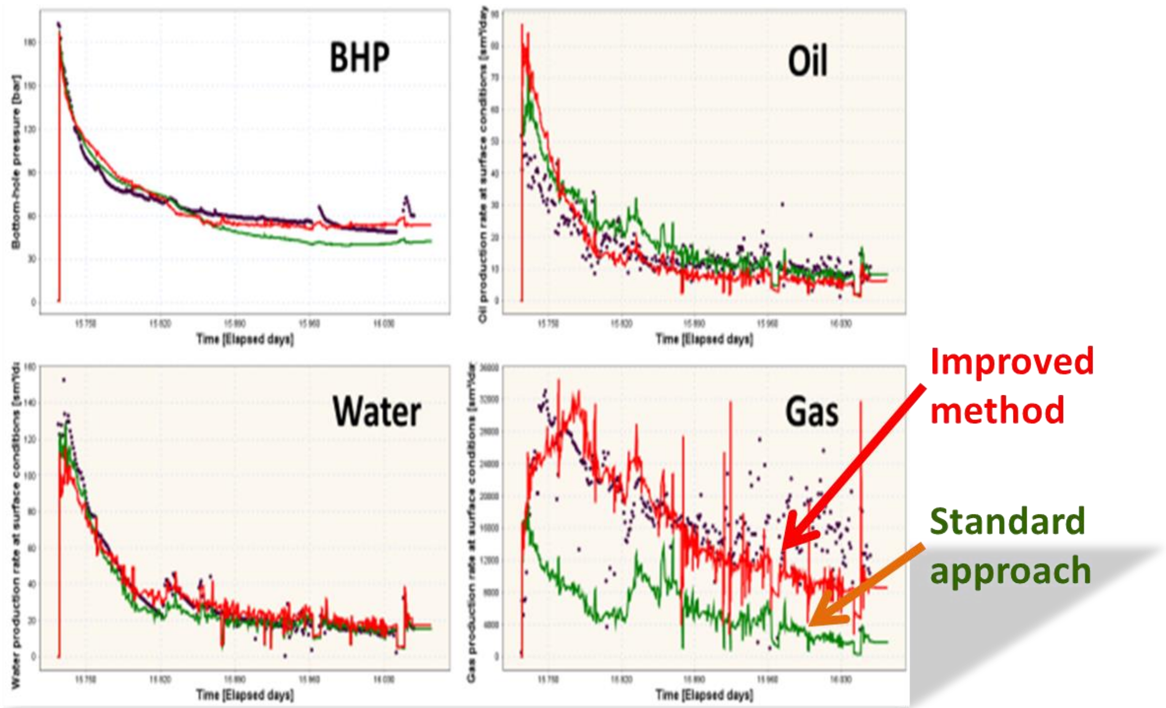
The results obtained after the first stage calibration are very promising, as shown in the next figure.



3.3 Dynamic 3 phases unstructured grid simulation

The resulting stimulated DFN is a reliable input for the prediction forecast. We have tested two different workflows: the first one consists in doing a dual medium upscaling in a CPG grid. The advantage is to be compatible with all standard reservoir simulators with dual medium option. The second is to use the 3D unstructured grid of the DFN directly into an adapted reservoir simulator. We prefer this second solution that enables to avoid the upscaling and thus preserve the contrast between matrix and fractures. PumaFlow is the simulator we used to conduct these tests.

We manage to reproduce pretty well Oil, Water and Gas production, and BHP. Furthermore, logical and physically sound results were obtained by changing the fracking scenario. The simulator is forecasting an increase of production with scenarios showing a better extension of the SRV.


BHP
Oil
Water
Gas
Improved method
Standard approach
Time [Elapsed days]
Bottom-hole pressure [bar]
Oil production rate at surface conditions [sm³/day]
Water production rate at surface conditions [sm³/day]
Gas production rate at surface conditions [sm³/day]

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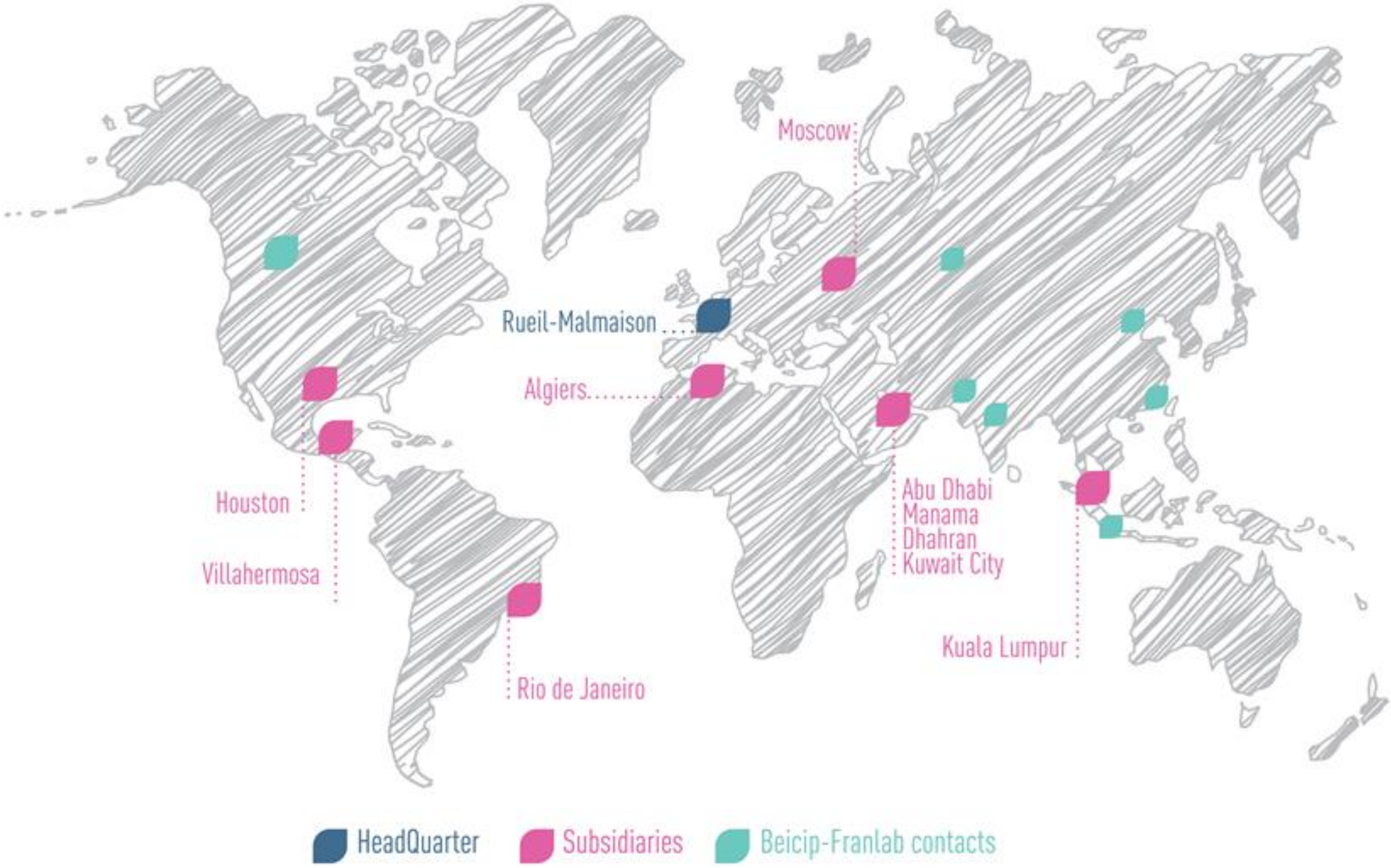

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