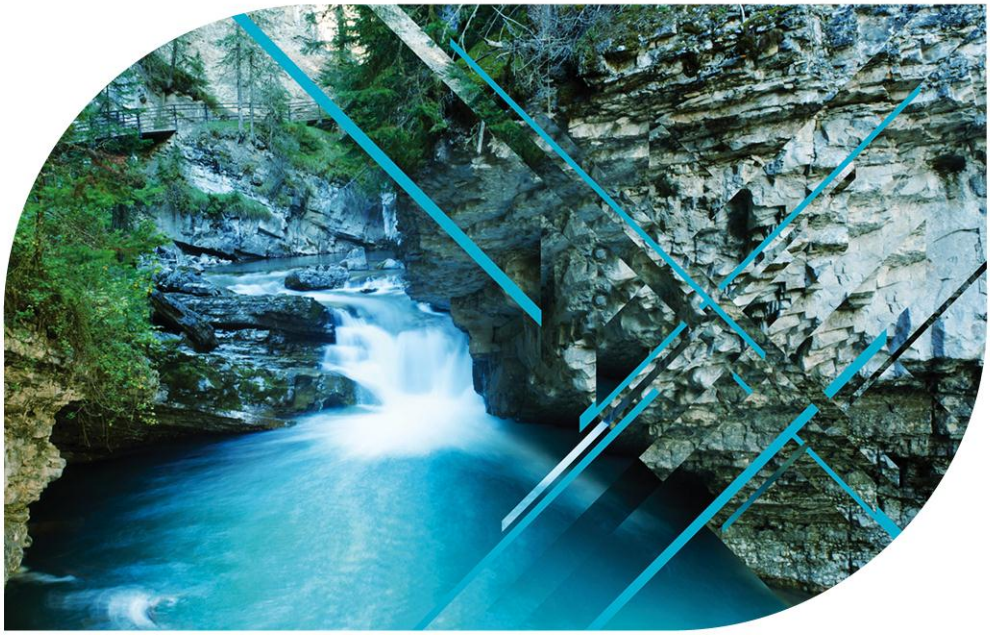
TightFlow™



IFPen and Beicip-Franlab Consortium

to address the

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 FracaFlowTM and PumaFlowTM.

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.

The TightFlow Project is managed as a consortium of Oil and Gas Companies, Contractors and R&D organizations together with IFPEN and Beicip-Franlab. Sponsors are invited to share knowledge and experience as well as to provide real data cases in order to add value to the software prototypes to be developed.

This document aims at presenting our project. It describes the current approach of IFPEN and Beicip-Franlab for hydraulic fracturing. The current prototype is presented as well as the main guidelines 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 geomecanical 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 gives 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 dependent permeability are available in PumaFlow for better reliability of the simulations.

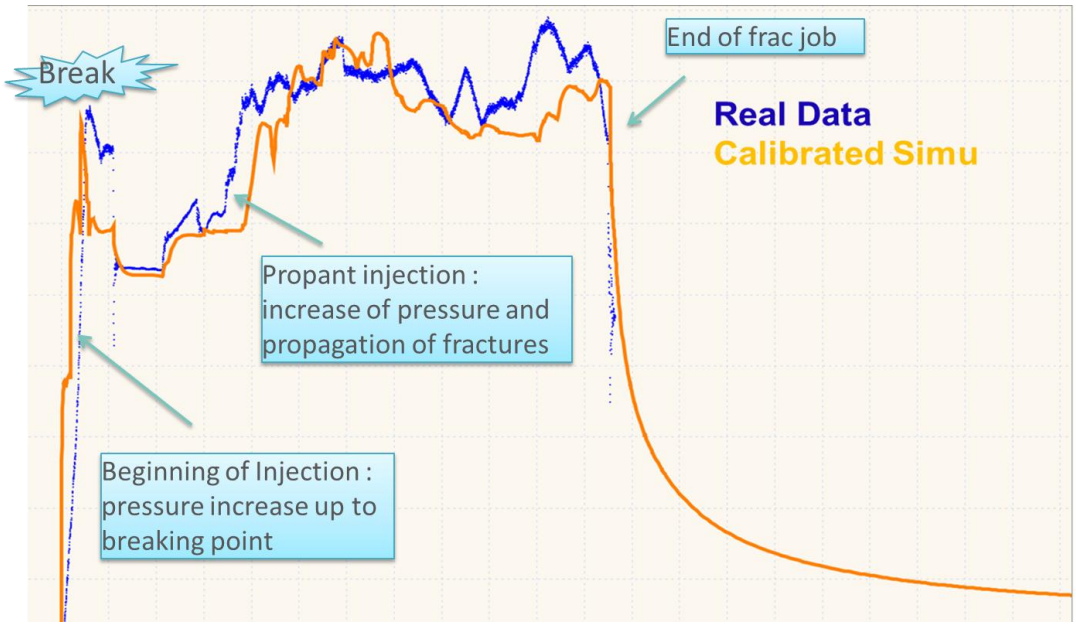
3 WHAT IFPEN/BEICIP-FRANLAB HAS DONE SO FAR

IFPen and Beicip-Franlab worked with an operating company providing a complete set of data that allows building a prototype 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.

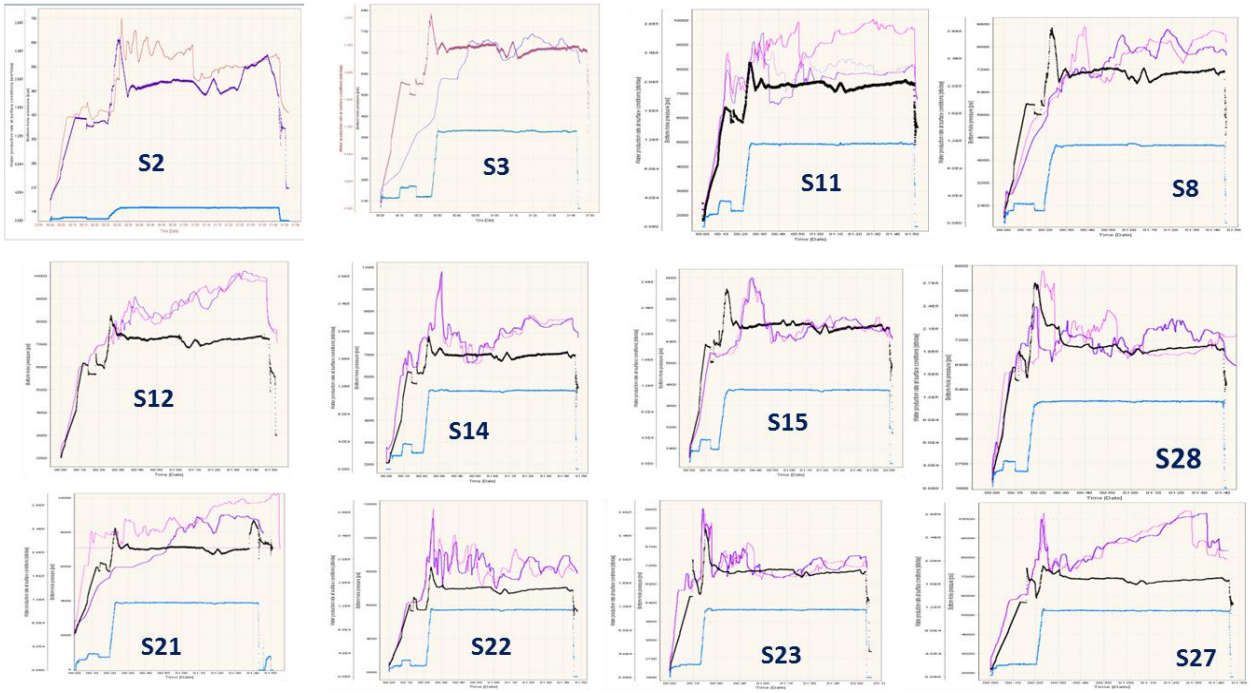
Hydro mechanical parameters, static and dynamic characteristics of fractures, stress orientation are used as matching parameters to reproduce BHP and microseismic envelop. A methodology has been experimented to achieve a good match following a sequential tuning of parameters on specific parts of the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

They're still challenges in this simulation to be able to reproduce Oil or Gas production. Water production including flowback is still difficult to match. Nevertheless, 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.

4 WHERE DO WE STAND

Today we have good simulation response on the use case treated. However, we have identified possible improvements in the current prototype. One of them is the variation of the stress during a frac job, the second is the proppant effect and transportation.

Also, we want to comfort our solution on more real cases to cover different geological context and practices.

5 WHY A CONSORTIUM

The TightFlow project is best described as a technical consortium contributing to the development and validation of new technologies originally developed by IFPEN into a fit-for-purpose software prototype thanks to the guidance and contribution of the participating sponsors to the research program. The objectives are as follows:

- Technical exchanges and validation of selected technologies and workflows fulfilling the research program described in detail in article 3,
- Steering of the prototype products and of future developments,
- Testing and validation of the prototype on some selected datasets,
- Early and exclusive access to prototypes allowing the members to apply the workflows on their own datasets,
- Collaboration through specific project studies (Price not included in the participation fees of the present Proposal),
- Sharing of know-how and experience.

The TightFlow research program is open to Oil & Gas companies, contractors and R&D organizations.

6 TENTATIVE CONTENT

In order to model the effects of hydraulic stimulation and fracturing on low/very low permeability media, TightFlow will propose the specific following developments:

- **Elastic and plastic deformation of the natural (pre-existing) fractures due to pressure increase.** Elastic-plastic laws are used to predict the evolution of fracture aperture and conductivity as a function of

pressure, fracture orientation and stress, those being considered constant along the whole fracture plane. Two families of fractures with different mechanical responses are considered: natural fractures undergoing elastic deformation before reaching plastic deformation, and hydraulically induced fractures (initially not open), upon reaching a stress criteria, undergoing plastic deformation (created).

- **Development of hydraulic fractures.** Hydraulic fracture planes are a priori generated before the stimulation takes place, in a stochastic or deterministic way. This is due to the fact that prediction of where and how the rock will initially break and propagate (geometrical complexity) is a difficult task. This issue, more directly tackled by geomechanics is approached here through the use of concepts such as brittleness using seismic attributes and mechanical properties derived from well logs, leak-off tests, minifrac etc. Those initial hydraulic fractures are positioned along perforation shots. Information from third party software such as *FracPro*, *Gohfer* or *MFrac* could be integrated.

- **Changes in stress field.** The stress field is currently considered to be constant through time and space, which means that local interferences between fractures cannot be taken into account, nor predict change of stress due to a previous fracture stage. We will go beyond this first simplification during the research program and will discuss and develop algorithms and methodologies to model the stress field variation in space and be at least updated after each stage. Real-time stress update is also an objective of the research program.

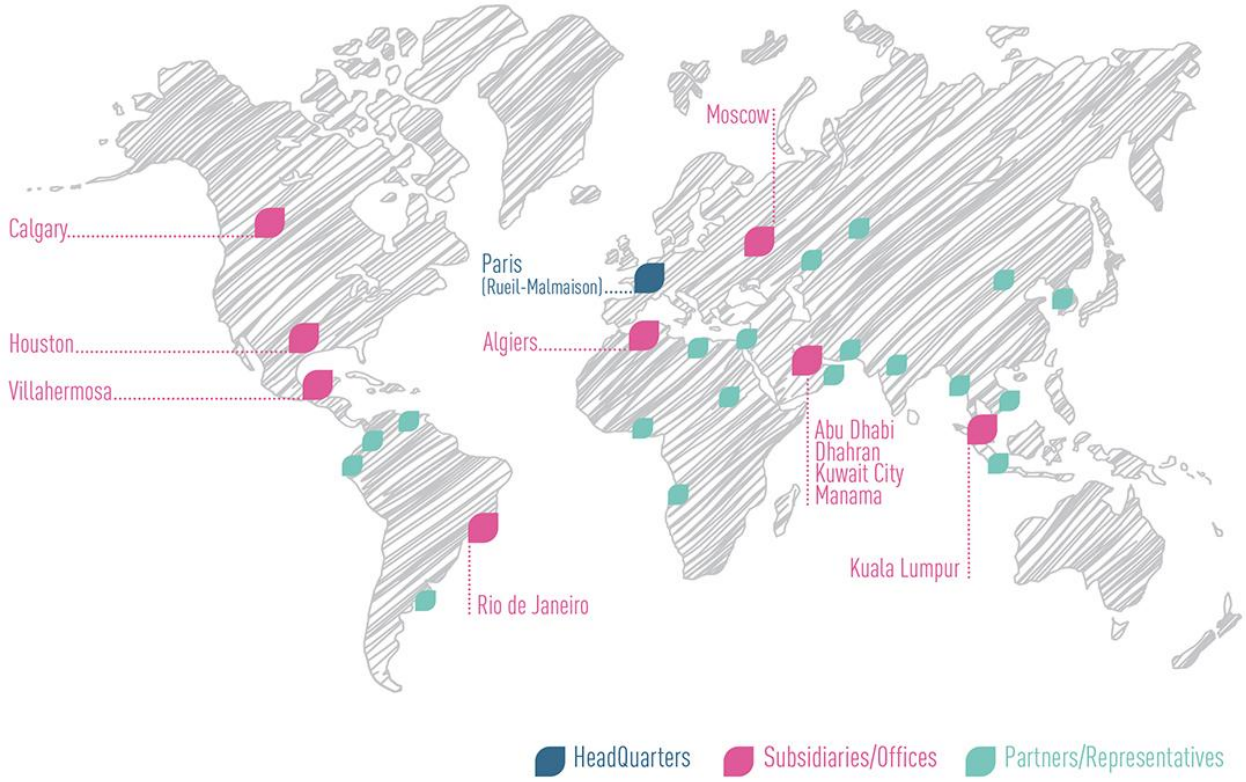
- **Effect of Injected agents** (gel, proppant or acid…) is currently not explicitly modeled. Its macroscopic effect can be assessed through a change of the equivalent injected fluid viscosity through time. The effect on aperture is accounted through the definition of a post-closure minimum aperture (irreversible). Thus the model approximates observed agents effects during stimulation and production. During the duration of the project we will look at ways to improve the above model at local scales (eg. proppant or acid placement during time within the DFN and/or degree of aperture closure) using partners experience in these domains. A simple transport model will be developed. Its validation will require calibration data at both lab-scale (kinetics) and well scale (pressure / flow rates relationships). This approach will of course add complexity to the model and may impact computational performances. Therefore a compromise must be found and based on the first results that will be discussed with partners.

- **Modeling of hydrocarbon production in stimulated shale or tight reservoirs.** Because of very low permeability of tight rocks, the reservoir may be in a long transient state, thus breaking down the traditional Warren & Root double porosity model. Therefore the WR model may carry errors when handling the fluid-flow matrix fracture interactions. The specific TightFlow™ dual discretization explicitly accounts for the fracture geometry, allowing a matrix refinement function of heterogeneities. New matrix nodes volumes approximations will be studied during the research program regarding specific properties of the produced fluids. Given the fact that we are treating many fractures, the numerical optimization is very important. At the same time accounting for stress and fluid geometry fronts is just as important. Thus we aim to reach a compromise between these two goals during the 3 years of the research program.

7 HOW TO REGISTER INTEREST

If your company is interested in joining this consortium, please let us know by contacting your account manager or by sending an email to *software@beicip.com*. We will get back to you shortly with additional details on participation conditions and budget.

Contact us



BeicipFranlab

Beicip Franlab Headquarters

232, avenue Napoleon Bonaparte - BP 231

92502 Rueil Malmaison Cedex - France

Phone: + 33 1 47 08 80 00 - Fax : +33 1 47 08 41 85

e-mail : *info@beicip.com - www.beicip.com*

For further information, please contact your regional office or visit www.beicip.com

Europe / Africa / Asia	Middle East	CIS / Russia	South America	North America	Mexico
Head Office, Paris	info.bahrain@beicip.com	*info.moscow@beicip.com*	*info.rio@beicip.com*	info@beicip-inc.com	*info.mexico@beicip.com*
info@beicip.com	Tel: + 973 17 21 11 50	Tel: + 495 937 70 98	Tel: +55 21 8254 9756	Tel: +1 281 293 85 50	Tel: +52 9931 46 10 63
Tel: +33 1 47 08 80 00					