Fracture-matrix flow partitioning & cross flow:

Numerical modeling of laboratory fractured core flood

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COMSOL CONFERENCE EUROPE 2012

Excerpt from the Proceedings of the 2012 COMSOL Conference in Milan

Presentation layout

- Introduction
- Problem description
- Darcy Law interface
- Free & porous media interface
- Cross flow investigations
- Concluding remarks

Introduction

- Fracture : different permeabilities
- Fracture-Matrix Flow partitioning
- In-situ Stress regime

- Reservoir characterization
- Wellbore stability
- Completion design
- EOR

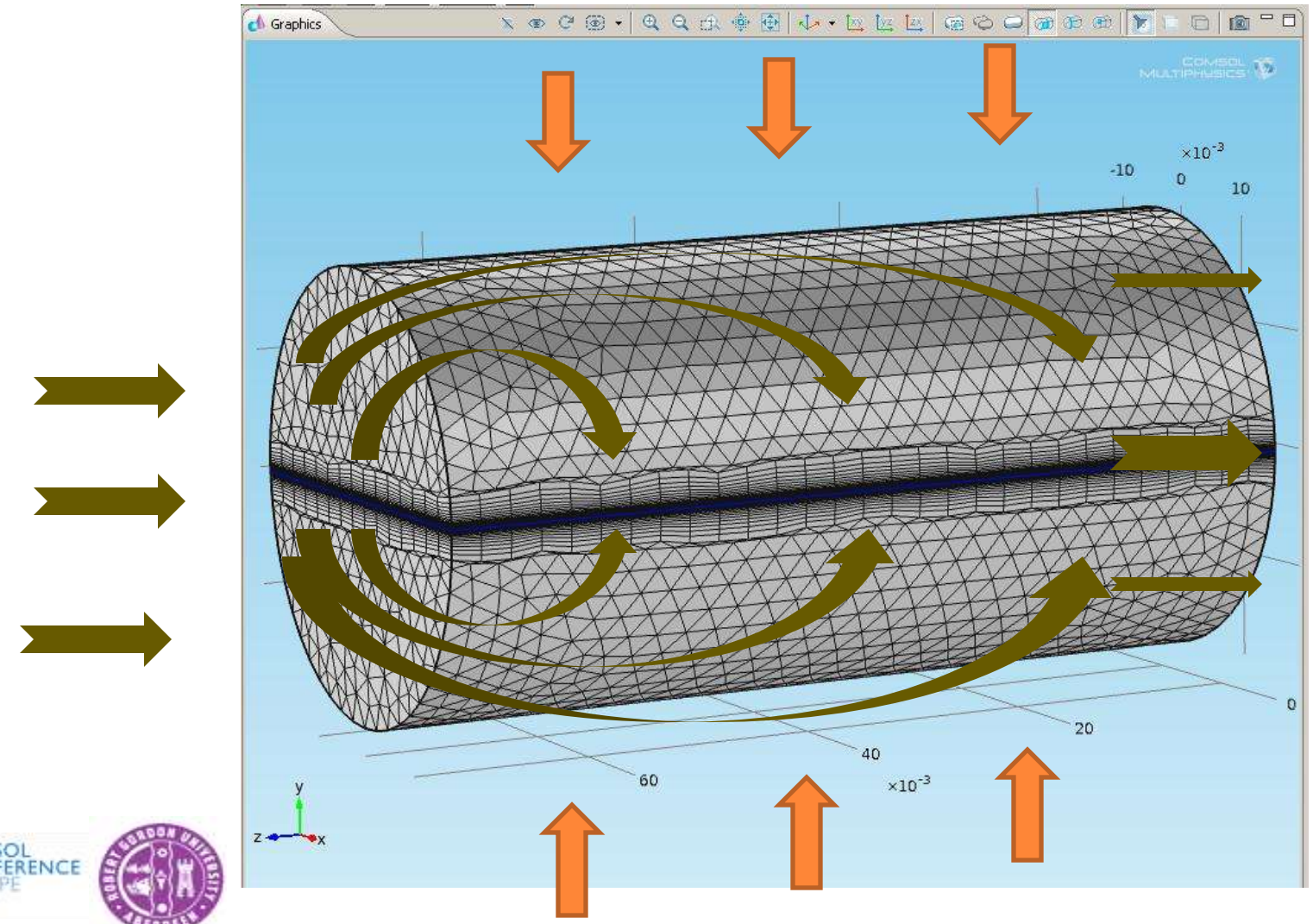
PROBLEM DESCRIPTION

- Brine flooding of a longitudinally fractured core (Stalker et. al., 2009)

Table 1: Core flooding experimental data

Core diameter	*3.79 cm*
Core length	*7.54 cm*
Matrix porosity	*0.154*
Matrix permeability	*315 mD*
Brine viscosity	*1 cp*
Brine Density	*850 kgm^{-3}*

PROBLEM DESCRIPTION



DARCY LAW INTERFACE

- Darcy + Continuity in Matrix (Comsol dl interface theory)

$$\frac{\partial}{\partial t}(\rho\varphi) + \nabla.\rho\left[-\frac{k}{\mu}(\nabla P + \rho g \nabla D)\right] = Q_m$$

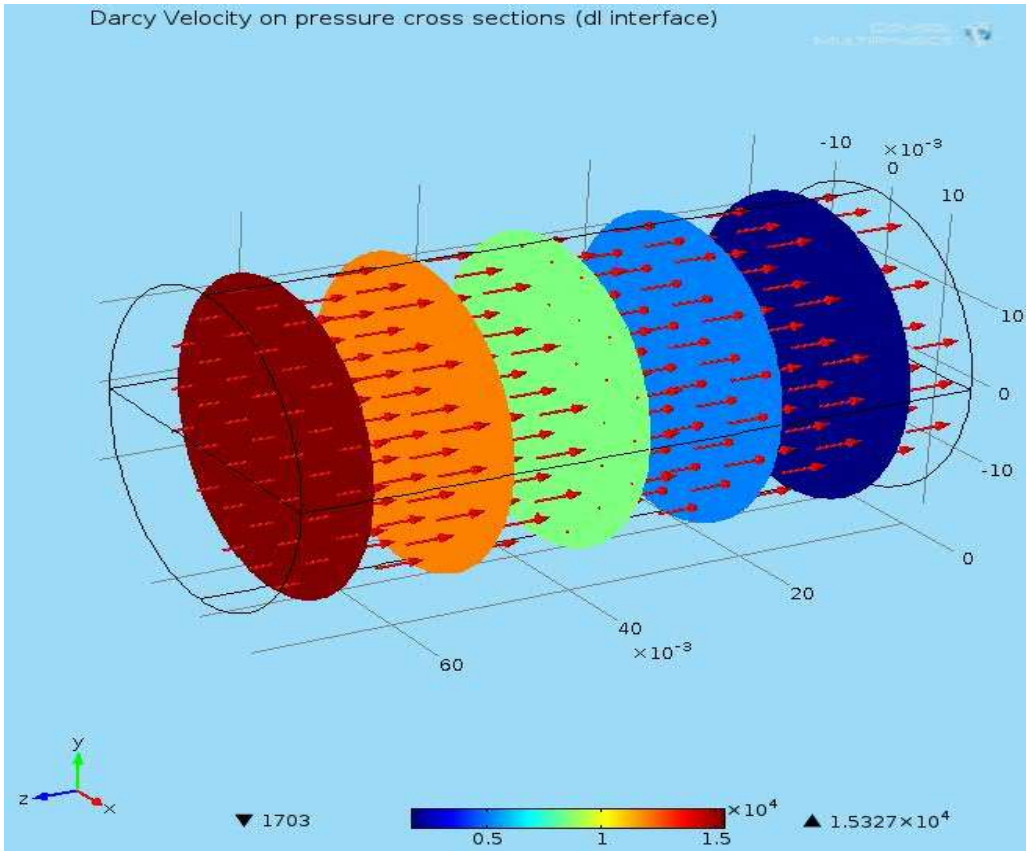
- Tangential form of Darcy Law + Continuity in Fracture (Comsol dl interface theory)

$$q_f = -\frac{k_f}{\mu} d_f (\nabla_T P + \rho g \nabla_T D) \qquad d_f \frac{\partial}{\partial t}(\varphi_f \rho) + \nabla_T.(\rho q_f) = d_f Q_m$$

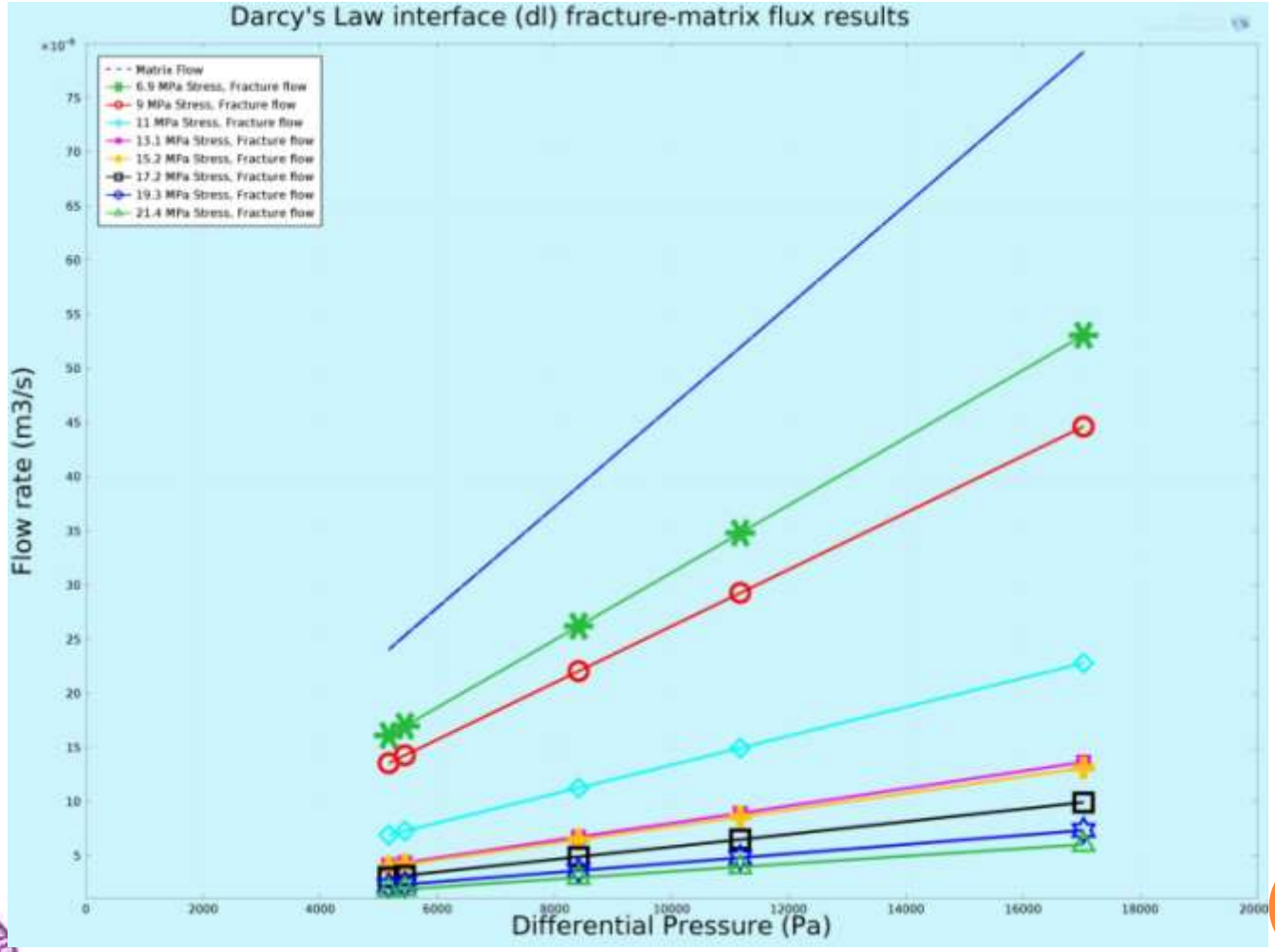
- K_f : Schechter correlation based on d_f (Stalker et. al., 2009)
- Φ_f :slide fracture model concept (Van Golf-Racht, 1982)

DARCY LAW INTERFACE

- Memory-efficient, straightforward mesh, No detectable change in flow path



DARCY LAW INTERFACE



DARCY LAW INTERFACE

1. Fracture flow partitions are less than matrix for all overburden stresses!
2. Fracture-matrix cross flow and its change due to stress cannot be investigated 

Free & Porous media interface 

FREE & POROUS MEDIA INTERFACE

- Brinkman equation for steady state flow for the matrix fracture transition zone (Martys and Hagedom, 2002):

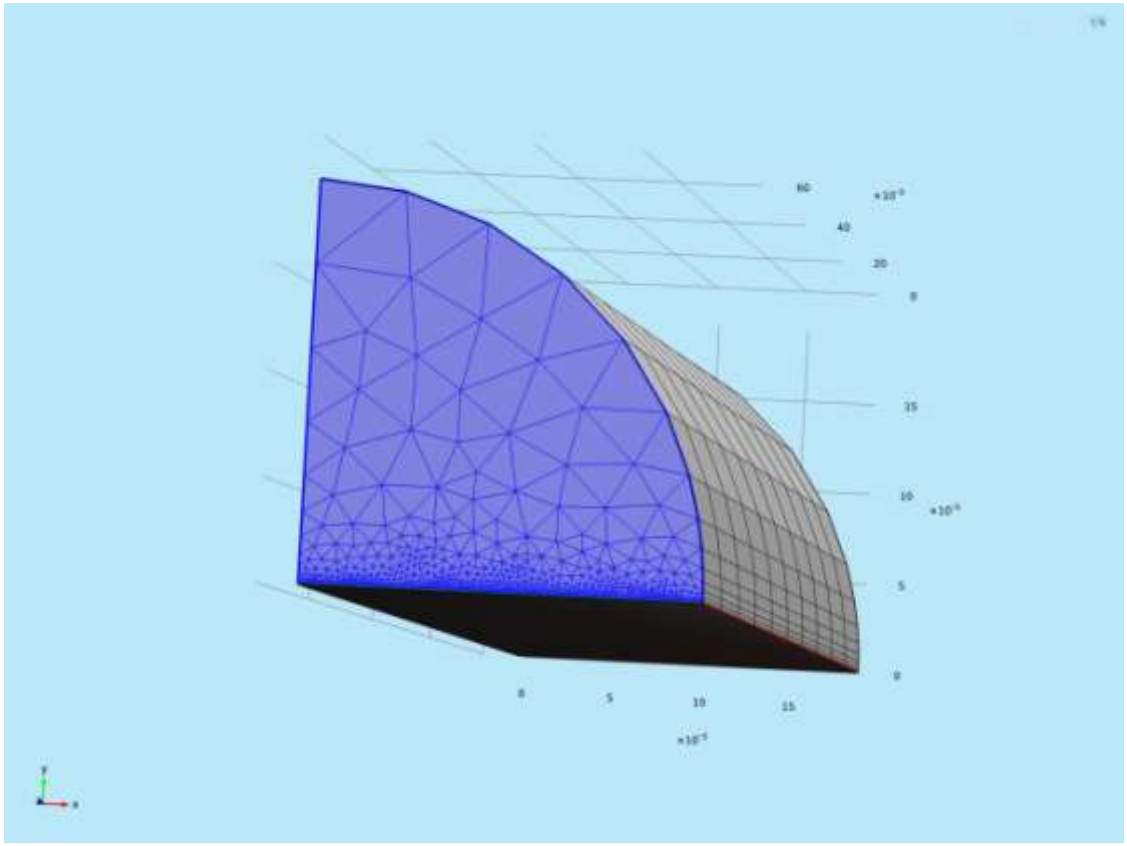
$$\nabla P = -\frac{\mu}{k}u + \mu_e \nabla^2(u)$$

- Laminar form of Navier-Stokes flow in the fracture (Comsol fp interface theory):

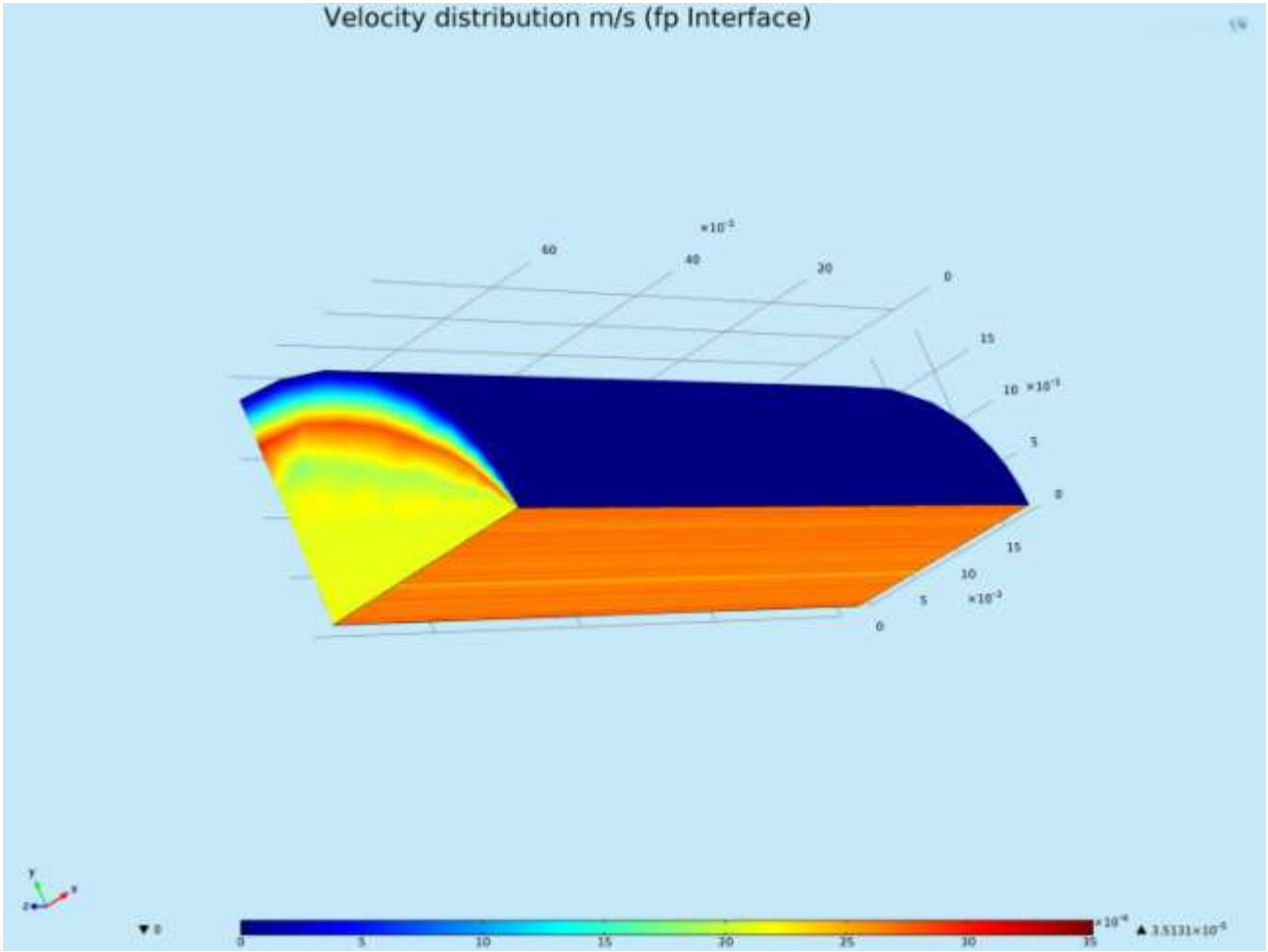
$$\nabla P = -\rho\frac{Du}{Dt} + \rho g + \mu\nabla^2 u$$

Free & porous media interface

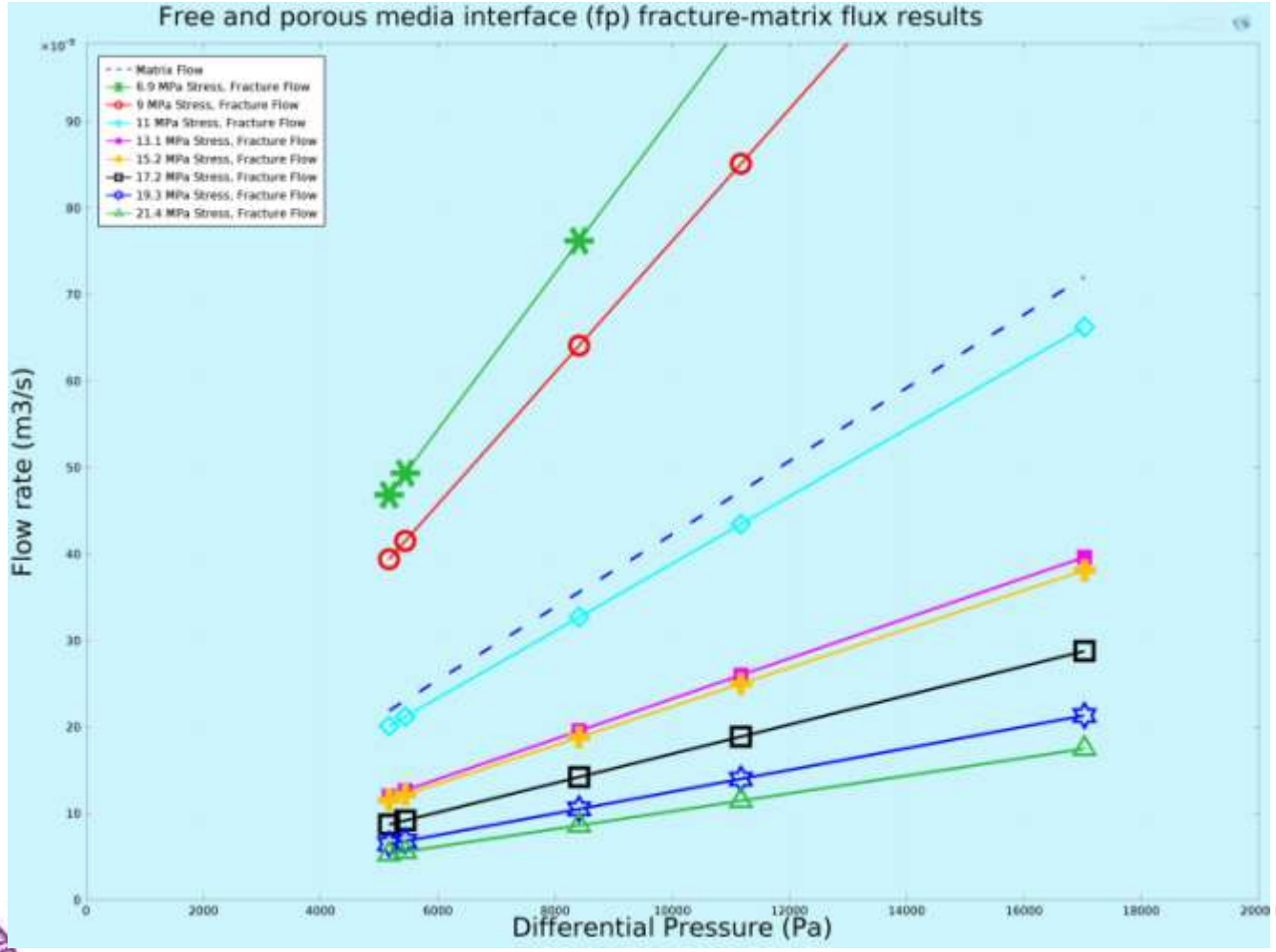
1. Fracture as a volume in geometry
2. Complex mesh and excessive runtime



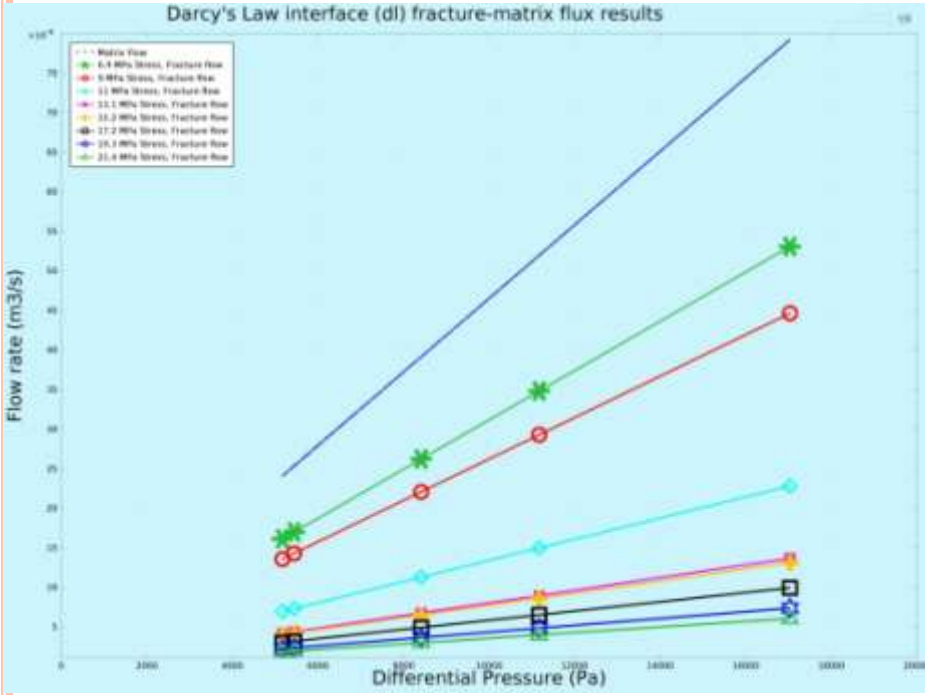
Free & porous media interface

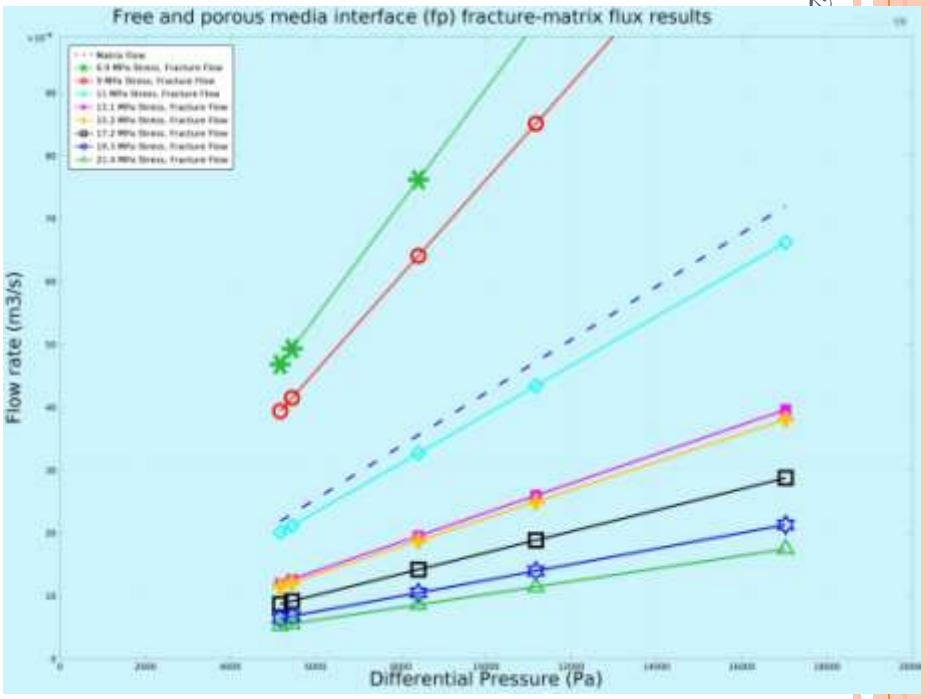


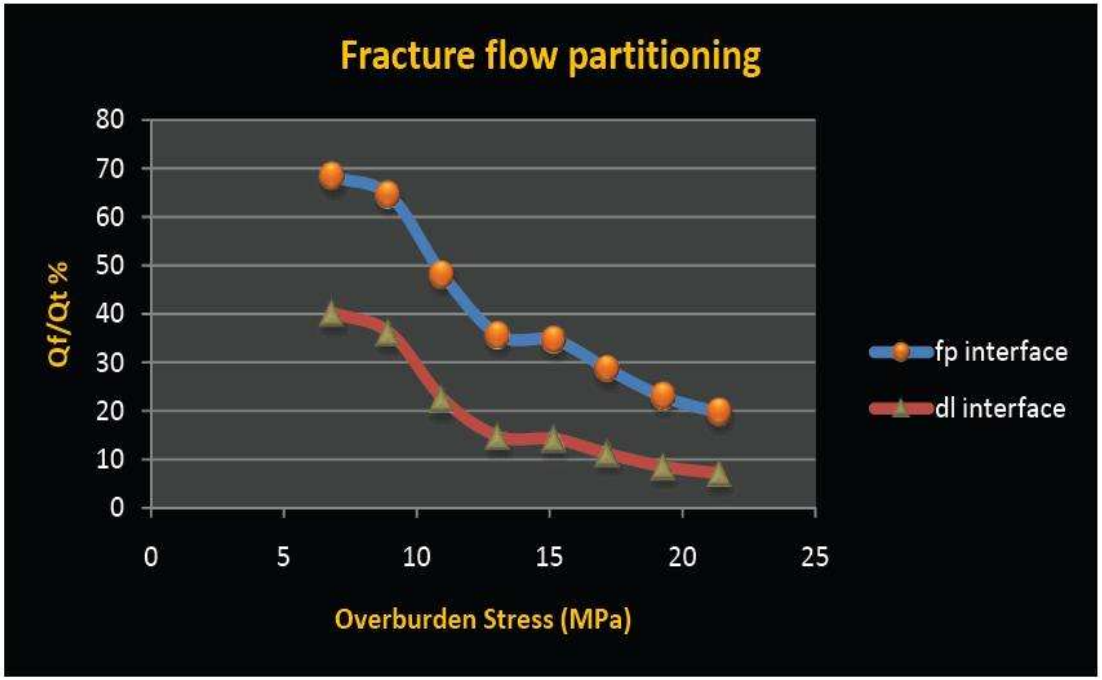
Free & porous media interface

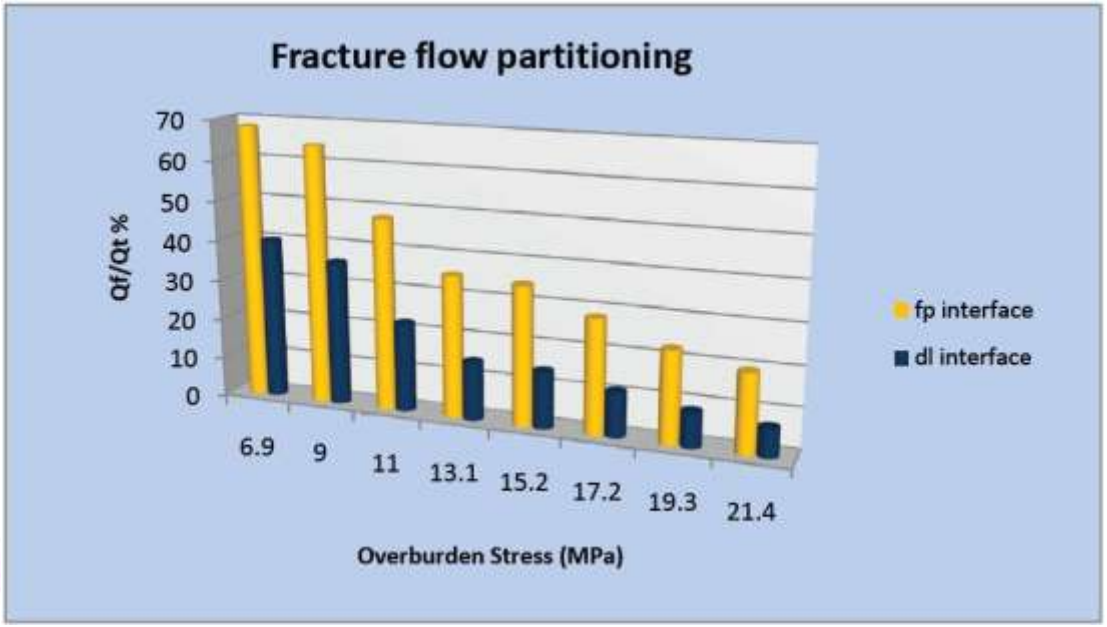


DL VS. FP


Darcy's Law interface (dl) fracture-matrix flux results
Flow rate (m3/s)
Differential Pressure (Pa)


Free and porous media interface (fp) fracture-matrix flux results
Flow rate (m3/s)
Differential Pressure (Pa)


Fracture flow partitioning
Qf/Qt %
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
Overburden Stress (MPa)
fp interface
dl interface


Fracture flow partitioning
Qf/Qt %
70
60
50
40
30
20
10
0
6.9
9
11
13.1
15.2
17.2
19.3
21.4
Overburden Stress (MPa)
fp interface
dl interface

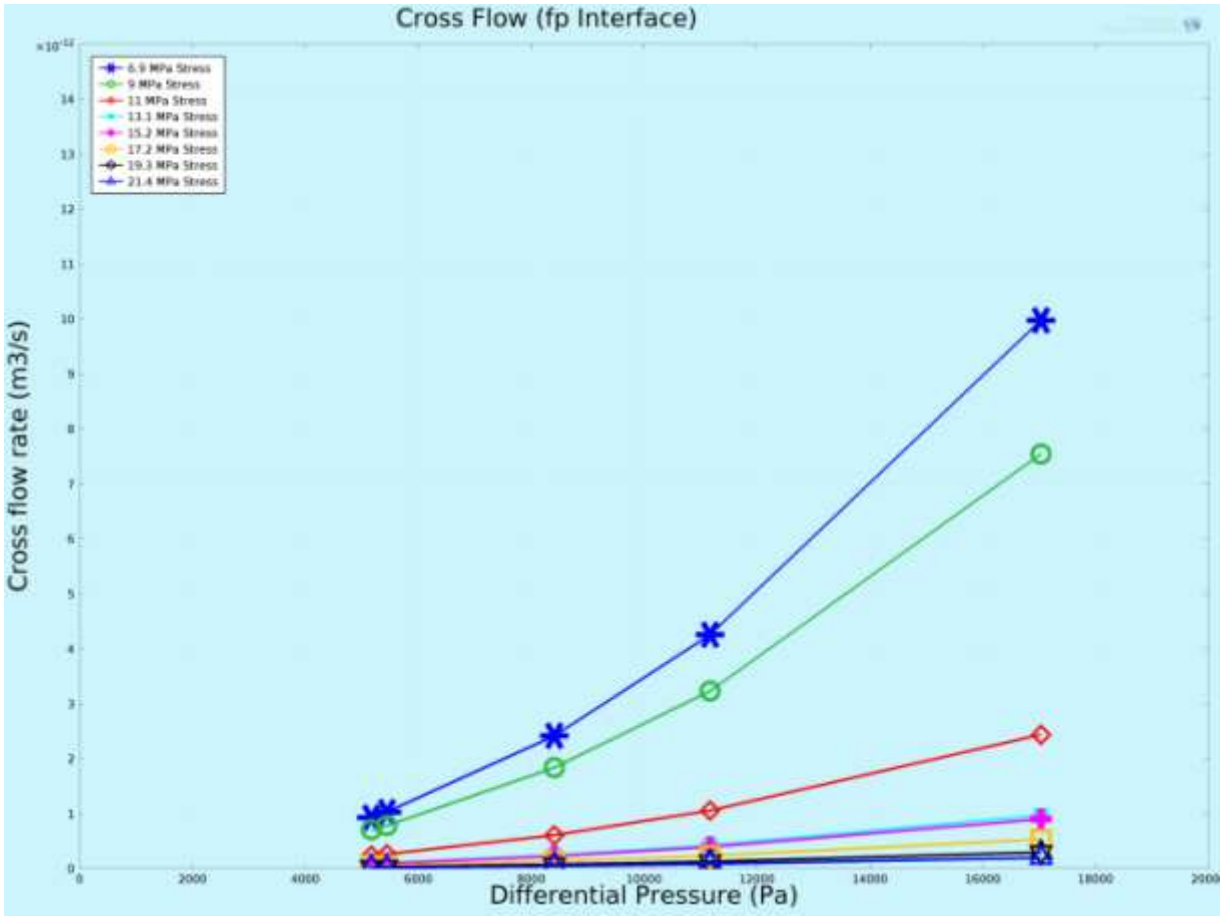
Free & porous media interface

1. Flow rates are higher
2. Fracture flow partitioning magnitudes are higher
3. Identical trends to dl interface
4. Change in flow partitioning for overburden stress>13Mpa
5. There is a shift in the dominant flow path (unlike dl interface)

LABORATORY INVESTIGATION NEEDED

Cross flow

- Cross flow: Vertical flow from matrix to the fracture



Cross flow

1. More pronounced shift in the cross flow
2. Cross flow increases exponentially with pressure drop for low overburden stresses

Concluding remarks

- Fracture flow partitioning results in fp interface are higher and closer to cumulative flux experimental data
- Matrix would be the dominant flow path under increased stress (dl vs. fp)
- A fracture closure threshold can be detected especially in terms of cross flow
- Cross flow decreasing due to increased overburden stress varies significantly beyond the closure threshold

Hmm?

Thank you!