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ite reservoir engineering

Pressure Drop Separation during Aqueous Polymer Flow in Porous Media

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Introduction: Aqueous polymers used for enhanced oil recovery (EOR) application is considered a complex fluid. It can exhibit Newtonian and non-Newtonian behavior depending on the velocity or the stresses that it is submitted during the flooding process. Therefore, the polymer flooding project requires a detailed understanding of chemical and physical process occurred in the porous subsurface reservoir, particularly polymer flow behavior while flowing through the porous media. Due to non-Newtonian flow behavior of polymer solutions, the pressure drop that occurred during polymer flow in porous media can be separated in shear pressure drop and elongation pressure drop.

$$\Delta P_t = \Delta P_{sh} + \Delta P_{el}$$

The main objective of this research is the COMSOL implementation to numerically solve the pressure drop calculation by considering Non-Newtonian flow behavior of aqueous polymer solutions.

Computational Method: Several assumptions were made in the simulator, such as incompressible flow, no oleic phase, adsorption and gravity forces are neglected, steady state flow and homogenous rock properties. A single phase Darcy equation was used to calculate the pressure drop in porous media. In the laboratory experiment, we applied the confining pressure surrounding the core plug to create a linear flow direction. Here, we used no flow boundary equation.

$$u = -\frac{k}{\mu}\nabla P$$

$$-n.\rho u = 0$$

Steady state flow can be defined by using following equation:

$$-n.\rho u = \rho U_0$$

$$-n.\rho u = -\rho U_0$$

We also introduced the term of pressure ratio. This term was proposed by Hincapie and Gaol from Clausthal to establish the relationship between the results from eVROC™ and the results from core flooding experiments. The correlation is based on the geometrical characteristics of the eVROC™ device and Bentheimer core plugs. The correlation can be used to calculate elongation and shear pressure drop.

$$CRp = \frac{\Delta P_{el}}{\Delta P_{sh}}$$

$$CRp_{(c)} = CRp_{(e)} 0.0038c[\eta]^2 - 0.0053c[\eta] + 0.1482$$

References:

1. Gaol, C.L, Investigation of Non-Newtonian Flow Behavior of Commercial EOR Polymers in Sand Packs and Cores, TU-Clausthal, Clausthal-Zellerfeld (2015).
2. Sheng, J., Modern Chemical Enhanced Oil Recovery: Theory and Practice, Elsevier Inc. Burlington, USA (2011)

Results: Simulation results show a good agreement with experimental results indicating a successful implementation of COMSOL to calculate pressure drop that occurred during polymer flow in porous media by taking into account the non-Newtonian behavior of aqueous polymers solutions. The results are presented in figure (4) and (5).

Table 1. Input Parameters

Parameter	Value	Unit
Radius, r	1.5	cm
Length, l	6	cm
Initial Pressure, P_i	1	bar
Porosity, Φ	0.264	-
Permeability, $\boldsymbol{k}$	1	D
Water Saturation, S_w	1	-
Rock density, ρ_r	2650	Kg/m^3
Outlet Pressure, P_o	1	Bar
Max. element size, Δx	1	cm
Min. element size, Δx	0.15	cm
Time step, Δt	1	Min

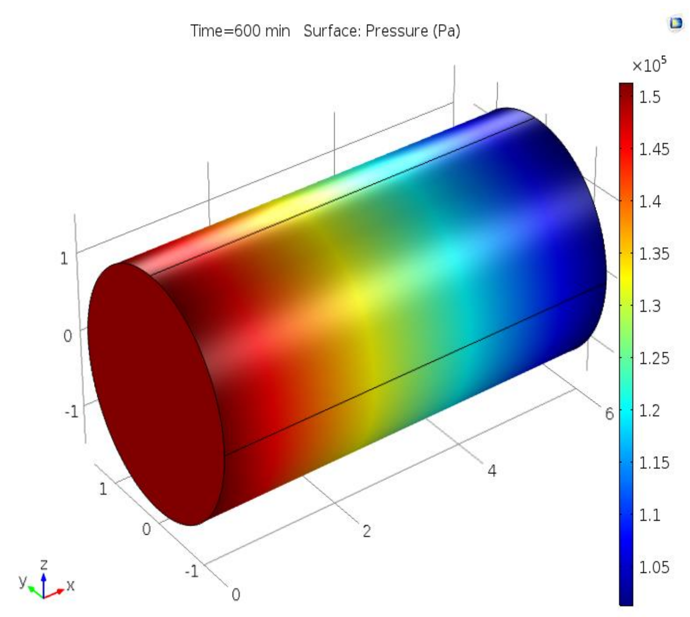

Figure 3. Core Model

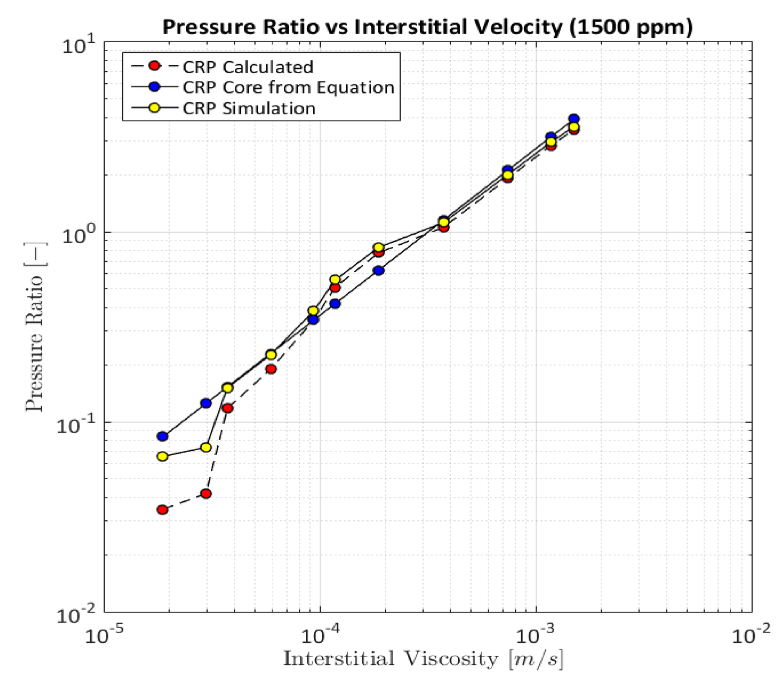

Figure 4. CRP Simulation Results

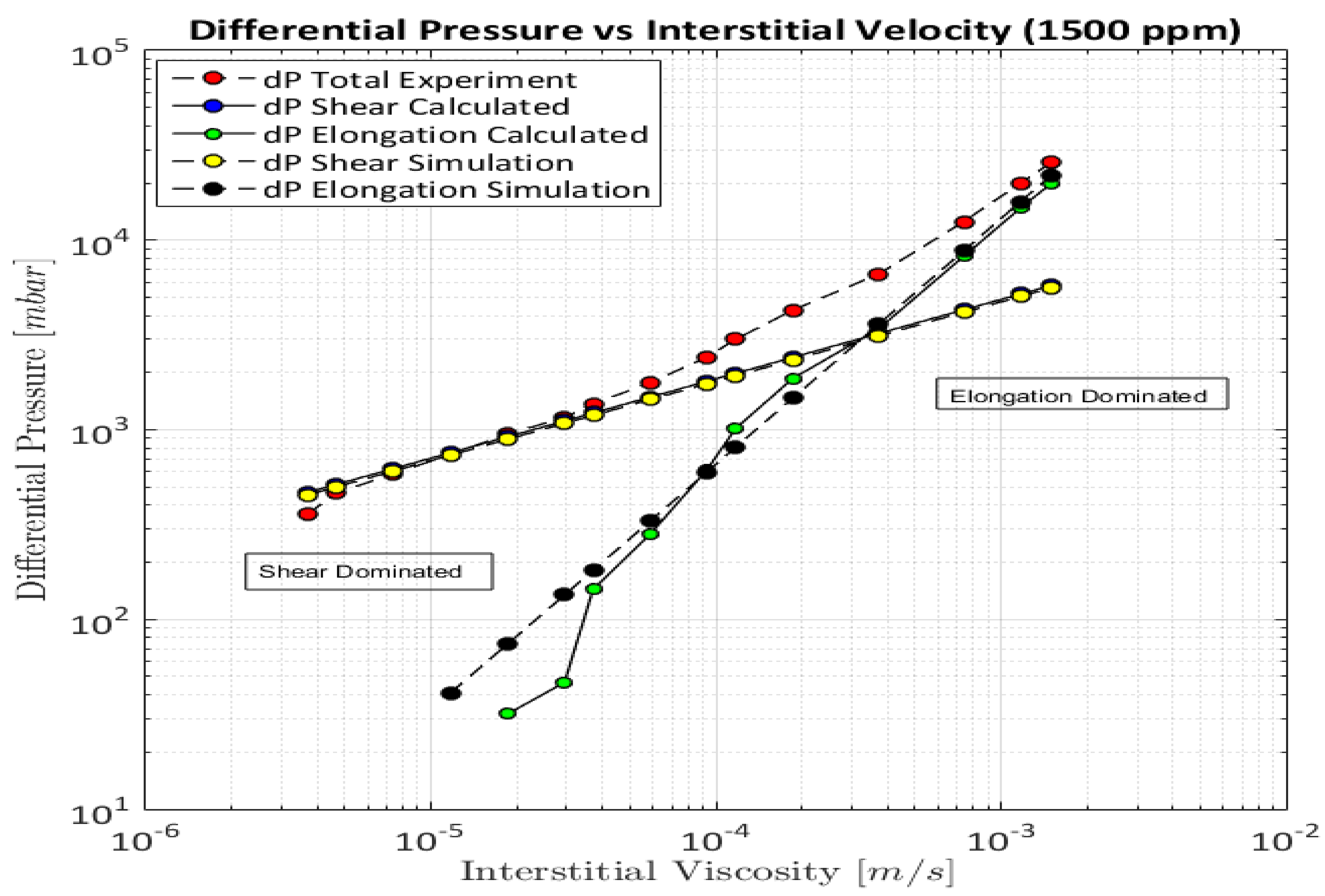

Figure 5. Simulation Results

Conclusions: The results from this research provide us with the new insight of polymer flooding process and can be used to improve the flooding process. Moreover, due to its Multiphysics capabilities and flexible framework to integrate physical and chemical mechanisms during polymer flow in the porous media or enhanced oil recovery (EOR) processes, COMSOL provides an alternative for current reservoir simulators used in the oil and gas industries.

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