EPSRC CDT in Fluid Dynamics across Scales

Project Title: Upscaling Polymer Enhanced Oil Recovery Processes

Introduction

This will be a 4-year postgraduate program consisting of a one year MRes (Master of Research) in Fluid Dynamics, followed by 3 years of PhD research, to be supervised jointly by the university and an industrial partner.

Project Title: Upscaling Polymer Enhanced Oil Recovery Processes

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Description of Project

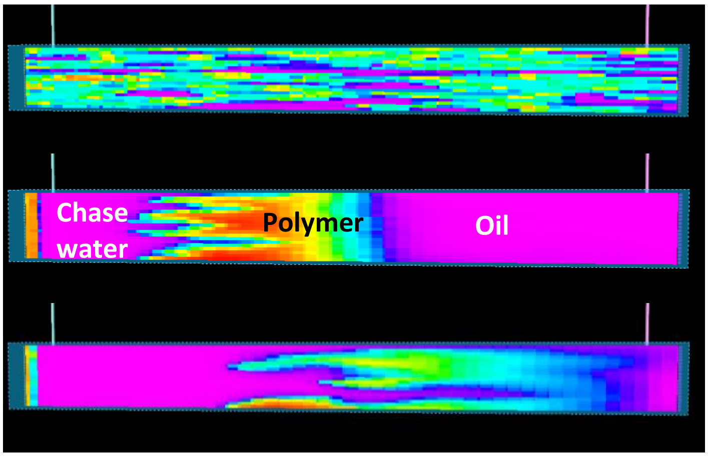
Technical Introduction and Background

Enhanced Oil Recovery (EOR) is of increasing importance in oil production, as operating companies attempt to improve the ultimate recovery from existing reservoirs. Reported experience of EOR projects shows that there are many problems in predicting performance in the oilfield, generally due to practical implementation issues as well as uncertainties in the distribution of rock properties (controlled by geology) in the subsurface.

In a typical EOR project, initial experimental studies are performed in a laboratory using samples of reservoir rock taken from wells, called core plugs. Reservoir engineers use the observed data to build numerical flow models, for predicting the behaviour of EOR processes within the reservoir rock at the field scale, over longer time periods.

Numerical reservoir simulators use the multi-phase extension to Darcy's Law to model flows in porous media, represented on 3D grids, discretized using finite volume techniques. A simulation model can contain millions of grid cells, but, even at the highest resolution, individual cells in a full field grid are generally many times larger than a core plug. Nonetheless geological heterogeneity occurs all length scales from the pore to the km scale and these heterogeneities can have a significant effect on oil recovery. Upscaling reservoir properties from a fine grid to a coarse grid (to represent the average effect of these heterogeneities on reservoir performance) is a challenging problem, particularly for highly heterogeneous reservoirs and for multiphase flows. In Chemical EOR studies, additional upscaling problems are related to physical phenomena, such as adsorption and decay of chemicals, which may need to be modelled at different time and length scales compared to fluid flow behavior.

This PhD program will focus on improving the field scale modelling of polymer injection for EOR. In this process polymers are used to control the mobility of injected water, to prevent early breakthrough of water at production wells and reduce the amount of bypassed oil left in the reservoir. Upscaling is important for polymer simulations, but numerical upscaling of grid cell properties is not sufficient without better understanding of polymer physics in the reservoir. Improvements are needed to develop more accurate models of changes in polymer properties due to mixing and decay over time, shear effects (polymer solutions often exhibit non-Newtonian flow behaviour), mechanical degradation and the impact of polymer adsorption on reservoir rock properties.



Simulation results, showing a cross-section view of viscous fingering into the trailing edge of a polymer slug injected in a heterogeneous reservoir: note that the chase fluid is water, which is less viscous than polymer. The top image shows the reservoir permeability distribution. The lower images show the polymer concentration at two different times. Flow is from left to right.

Objectives and Methodology

The work in this program will focus on the numerical modelling of fluid flows and polymer physics. It does not include experimental laboratory work, but realistic data will be obtained from appropriate sources.

A 5-month MRes project is a required part of this studentship program. This will be an important phase in the student's training, which will be complementary to the PhD research, but the MRes project write-up cannot be included in the final PhD thesis.

For the MRes, we propose a project focused on reservoir simulation upscaling for multi-phase flow of fluids with mobility contrasts. The knowledge gained from the MRes studies will ensure that the student is ready for the PhD research, in which they will develop a deeper understanding of the issues related to polymer physics at different scales.

MRes Project Activities

The proposed project will enable the student to learn about reservoir simulation and numerical aspects of upscaling, by investigating the modelling and analysis of a selection of the following topics:

- Heterogeneity, optimum grid resolution, relative permeabilities
- Viscous fingering
- Numerical and physical dispersion
- Velocity calculations (coarse vs fine grid)
- Use of transport coefficients for modeling flows of aqueous polymer solutions

The student will learn to use reservoir simulation software including Schlumberger's commercial products (Petrel, ECLIPSE and INTERSECT), to build models and simulate flows at different scales, using realistic parameters.

Tasks will include development of algorithms for defining model parameters, definition of calculations for implementation in simulation workflows, and sensitivity tests to compare different approaches. Deliverables from the project will include documented workflows and example data sets, suitable for publication or distribution to reservoir simulation users.

PhD Project Activities

The objective of the PhD research will be to improve understanding of the physics of polymer EOR processes, and develop methodologies for upscaling in time and space.

The student will investigate current knowledge and build simulation models of the multiple phenomena related to the behavior of aqueous polymer solutions at different scales. The results of the simulation studies will be used to make recommendations on the design and implementation of polymer injection schemes, taking into account practical issues such as injectivity, as well as the requirement to optimize oil recovery.

Topics to be considered include adsorption, degradation and non-Newtonian flow. There is particular interest in predicting polymer performance in different regions of the reservoir, e.g. near or distant from the injection well, where shear effects may be highly significant. These investigations may comprise a mixture of mathematical analysis to develop new mathematical models of the physics (e.g. for upscaling in the near well bore region) and scripting or code development.

Deliverables from the PhD project may include definitions of requirements for enhancements to the commercial software tools, for better quality polymer modeling or for better workflows to be used in future studies.

Resources

Reservoir simulation software tools will be provided by Schlumberger, with training and mentoring to enable the student to use the software and associated workflows.

Internship opportunities will be offered for the MRes project and during the PhD research program. The intern projects will be based in Abingdon Technology Center, Schlumberger's center of excellence for reservoir engineering, where world leading experts are developing the latest generation of numerical reservoir simulation products for the oil industry.

Petroleum engineering specialists based in Abingdon specify requirements, ensure product quality, train internal and external users, and provide worldwide product support. A student intern working in the center will gain experience of working in a commercial software development environment, following company quality standards. The results of research and development performed in Abingdon are used by Schlumberger consulting engineers and customers in the oil industry.

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