Simulation of geo-thermal wells with reduced order modelling and data assimilation

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Background

There is a growing interest in exploiting the vast reserves of heat beneath the ground in the UK but especially so in China, whose needs for energy are substantial and who have committed to seek out green, low carbon forms of energy. One difficulty is extracting the energy efficiently. In order to maximise the heat which is drawn from the rock by water, multi-lateral wells (see figures 1 and 2) are being developed by Sinopec (China) and Enteq (UK) for example. These types of well offer massive reservoir contact and, therefore, have a large potential extraction efficiency. Where exactly to drill the bore and laterals, how to decide the optimal path through the reservoir, and the control and management of the well system are the focus of a large grant in AMCG and this PhD would contribute towards this effort.

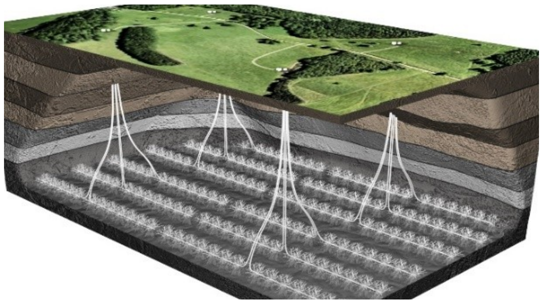

Figure 1: *Schematic of a geothermal multi-lateral well system (for shale gas removal – envisaged by Statoil). A similar approach is proposed for geothermal reservoirs.*

A numerical tool which is fast becoming indispensable, **reduced order modelling** (ROM) works by transforming the discretised governing equations from a high dimensional space to a low dimensional space. Instead of expanding the solution in terms of simple, piecewise, low order polynomials (as done in the Finite Element method for example), ROM seeks global basis functions which contain much information about the behaviour of the system. As a result, many fewer of these global basis functions are required, and so the dimension of the problem reduces to something that is very fast to solve. For example, the governing equations may result in a 1,000,000 by 1,000,000 system, whereas the ROM system is likely to be of the order 100 by 100.

Data assimilation is a technique used widely in weather forecasting, which incorporates physical observations into a computational model to improve the accuracy of the computational model. A somewhat related technique, **uncertainty quantification**, examines the relationship between the uncertainties in the inputs to the model (for example model parameters or initial conditions) with uncertainty in the numerical solution. Data assimilation can be used to reduce uncertainty. Both these techniques require solving the discretised equations many times for different parameter values, boundary or initial conditions. For problems of interest to industry, solving the equations to produce sufficiently high resolution solutions just once is extremely demanding. To solve the equations multiple times in a reasonable time is well beyond today's computing power. Replacing the discretised governing equations with a reduced order model would enable the application of data assimilation and uncertainty quantification to the optimisation of geo-thermal wells.

Project

The aim of the project is to develop a practical tool for data assimilation. A reduced order model will be developed that will run several orders of magnitude faster than a standard, forward model used to solve the governing equations. The computational speed of the ROM will enable the rapid exploration of the sensitivity of the solution to the controls (the initial conditions, and formation properties). To aid in validating the framework, data assimilation techniques will be applied which constrain the solutions to the observations.

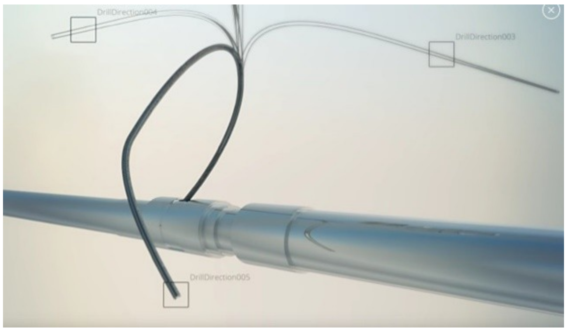

Figure 2: *Enteq's multi-lateral well system having a mother bore and many laterals for increased reservoir contact.*

Candidate

The candidate should have a strong mathematical background, a good degree in an appropriate subject (eg. earth sciences, mathematics, physics, computer science or engineering), and a strong interest in computational modelling and code development. The student will be joining one of the largest research groups at Imperial, namely the NOvel Reservoir and Simulation (NORMS) group, with experience in geo-thermal wells, flooding, multiphase flows, porous media, reservoir modelling. The candidate will have the opportunity to develop their career and profile by presenting at conferences and publishing in high impact journals as well as helping to save the planet.

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