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Prediction of Thermal Conductivity of Oil Sands Based on Particle Size Distribution

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Introduction

Heavy oil and bitumen are of a great interest for Canadian economics. Thermal recovery techniques are widely used across Alberta. To produce heavy oil its viscosity should be significantly decreased. One of the approaches is to heat the reservoir. Effective thermal conductivity of oil sands is an important parameter in reservoir simulation of thermal recovery processes such as steam assisted gravity drainage (SAGD). There are several mixing rules available in the literature, which allow for calculating effective thermal conductivity of porous material based on porosity and thermal conductivities of their components (matrix and fluid). Most of them use a so-called structural approach, which assumes that porous media consist of certain structures for each of which effective thermal conductivity can be calculated analytically. The other class of models uses statistical techniques. In all predictive equations, the overall thermal conductivity of the oil sands is calculated by knowing the individual properties of the fluids and the rock. The fluid properties are measured relatively easy. However, the thermal conductivity of sand is more challenging. When measuring the thermal conductivity of an oil sand sample, the obtained value is not only based on the fluid and solid properties but also on the structure of the pore space. Thus composite oil sand experimental measurements need to be complemented by predictive modeling that addresses the effects of pore structure.

Theory and/or Method

In the approach presented at this paper a systematic construction of the pore space is attempted from the grain size up. There is a wealth of experimental particle size distribution data of unconsolidated sands available. Given a particle size distribution, a virtual porous medium is generated using a special algorithm that simulates a geological deposition process. Compaction techniques are applied in order to maximize the contact area among grains. The porosity and permeability of the virtual porous medium are calculated to confirm that the medium truly represents oil sands. Then the effective thermal conductivity of the dry medium is calculated using computational physics whereby a heat flux across the medium is applied and the temperature profiles are generated at a sub-pore scale. Subsequently the medium is saturated with either bitumen or water and the same calculations are repeated. The temperature dependency of individual thermal conductivities on the effective thermal conductivity of the virtual oil sand is evaluated. The virtual porous medium can be constructed in a way that captures structural heterogeneities at the grain level. Structural heterogeneities at a higher level can be addressed through a scale up algorithm that was presented earlier (Skripkin, Kantzas, & Kryuchkov, 2014).

Conclusions

The results of this work are compared to limited experimental data that became available through a parallel study (Arthur, 2015).

The virtual porous medium results are also compared to a large number of available mixing rules.

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