Development of COMSOL-Based Applications for Heavy Oil Reservoir Modeling

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Abstract

The efficiency and environmental impact of oil production become a principal challenge of energy producing companies. The improvement of existing and development of novel methods are often feasible within either a "new" physical framework (from the viewpoint of oil reservoir applications) or a non-trivial combination of "known" phenomena. Last fifty years the dedicated reservoir simulators have been developed and successfully used to better describe and predict the production from oil reservoirs. Modern reservoir simulators are capable to model many conventional and even unconventional recovery methods, and hence the associated physical mechanisms of oil displacement. However, no one of them is able to take into account the "ordinary" electromagnetic (eg. microwave) heating and so the promising oil recovery applications based on this technique. A new approach is required which will extend the "standard" reservoir simulator capabilities. Therefore it is not so surprising that the coupling software development has already made its own little history.

Generally speaking, the coupling between multiphysics (which may equally offer complex internally coupled models) and reservoir simulators can be done in quite different way. In practice it quickly became clear that the principal difference in underlying numerical methodologies results in main advantages of the idea and its realization. The main objective of our work, i.e. to develop an adequate numerical tool for numerical analysis of the technology based on the radio-frequency (RF) heating [1,2], included finally a number of interesting studies aimed at learning and mastering the coupling paradigm. In particular, we will illustrate how the code coupling based on COMSOL Multiphysics® software can be efficient within considered external coupling framework.

Technically speaking, COMSOL may also be used for fully-integrated models of multiphase flow (cf. [3]) which may be helpful for numerical testing and lab tests modelling. Along with this COMSOL provides complete Java capabilities, making possible the coupling code development within the same programming environment. The developed code launches and keeps in memory both simulators, controls their states, solution results quality and data exchange between them, the computational resources and performance, and the job termination.

One of greatest benefit of such procedure is the easy update of the COMSOL model depending on the porous medium state, i.e. the information coming from the reservoir simulator. Note that a developer may adapt the code functionalities to the specific problem framework. For example,

several functions have been added to the coupling code to compute the heating power per cell or per specific subdomain of the reservoir model and to transmit this information to the reservoir simulator at each coupling time step.

The so-called loose coupling framework [4] offers significant benefits coming mainly from the intrinsic COMSOL features. Mention in passing just few of them: (1) the computational domain dimension and size can be adapted independently of reservoir model; (2) the numerical grid, FEM order and shape should be aimed at the quality of the FE solution only; (3) linear and nonlinear solver parameters can be chosen for best performance according to the equation type and other features of the EM-field model without additional limitations associated to reservoir model.

The results for 2- and 3D reservoir-size models obtained within a reasonable computational time, some examples of numerical analysis information addressing the computational performance, the technical discussion on RF heating modelling advantages and potential of further improvement are provided.

Reference

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