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Reservoir simulation with the MUFITS code: extension for horizontal wells and fractured reservoirs

Andrey Afanasyev[a,*]

[a]*Institute of Mechanics, Moscow State Uniniversity, 1 Michurinkiy prospekt, Moscow 119192, Russia*

Abstract

Two new modelling options developed recently within the MUFITS reservoir simulator are presented. The first wellbore friction option allows a simplified modelling of wellbore hydraulics that often needs to be accounted for in horizontal wells. The second option concerns the modelling of fractured reservoirs using the double porosity, the double permeability and more general multiple interacting continua approaches. Results of the options validation against benchmark problems are presented and internal structures that MUFITS builds in kernel for such reservoir models are demonstrated.

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Keywords: Reservoir simulation; MUFITS; horizontal wells; wellbore friction; fractured reservoirs; double porosity

1. Introduction

Reservoir simulation is required in many processes of subsurface utilization including petroleum or geothermal energy extraction, subsurface CO_2 disposal, and many others. These applications are complicated with multiphase behaviour of the flow in porous medium, phase transitions as well as different space and time scales associated with coupled reservoir-wellbore flows or fluid transport in fractured reservoirs. The software packages for numerical modelling of such flows in geophysical applications, that are called reservoirs simulators, are the only effective tools for prediction and optimization of subsurface processes [1,2]. Development of a reservoir simulator requires

* Corresponding author. Tel.: +7-495-939-5767 .
E-mail address: afanasyev@imec.msu.ru

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comprehensive testing techniques, verification and validation against benchmark problems. Most of such benchmark problems do not allow analytical solution. Therefore, the validation is conducted by means of intercomparison of the simulation results obtained with different simulators. A good agreement between the results magnifies the confidence in accuracy of reservoir simulators.

In this work, two recently developed options available with the free dynamic reservoir simulator MUFITS are presented [3]. This software is designed to provide to a wide scientific community an extended set of complicated modelling options that are more common for applied rather than for academic research. MUFITS includes different fluid properties modules (EOS-modules) for accurate prediction of the properties in different scenarios of subsurface utilization. It can be applied to petroleum reservoirs [4], underground CO_2 storage [5], and non-isothermal flows under sub- and supercritical conditions [6].

The first new extension of the simulator covers pressure loss due to the wellbore friction. This modelling option might be necessary in scenarios that include horizontal wells. The frictional pressure loss can have significant effect on production rates in the case of long perforated wellbore intervals. In order to develop the wellbore friction option, the multi-segment well approach has been introduced in MUFITS where the well is discretized in a sequence of the pipe segments (well segments) connected with the pipe junctions. The second extension of the code covers modelling fractured reservoirs using conventional double porosity, double permeability and multiple interacting continua approaches. The functionality of these options exceeds in some respects the capabilities of many other reservoir simulators. Both new options can be used with any EOS-module.

In the following sections, MUFITS is applied in the benchmark problems that were used for its validation. Both the simulation results and internal representation of the reservoir models in the simulator kernel using 3D graphs are presented. The simulator extension for building such graphs was one of the most time-consuming work with the simulator code when developing the options. Understanding of this internal representation may be useful when applying the simulator to a particular subsurface process.

2. Internal representation of reservoir models

MUFITS converts any reservoir model into a 3D graph when it loads the model into the simulator kernel [4]. The graph consists of a set of primitives. The graph nodes are the primitives corresponding to the reservoir fluid accumulation (accumulation term in the balance equations). The nodes can be the grid blocks, the pipe segments (well segments) or the stock tanks (Fig. 1). The graph edges are the elements associated with the fluid transport between any two connected nodes (transport term in the balance equations). The edges can be the interfaces between the grid blocks, the pipe junctions, the well completions, or the pumping devices. Using these primitives, a reservoir model of arbitrary complexity can be built. MUFITS builds the 3D graph using input data of general form provided by the modeller.

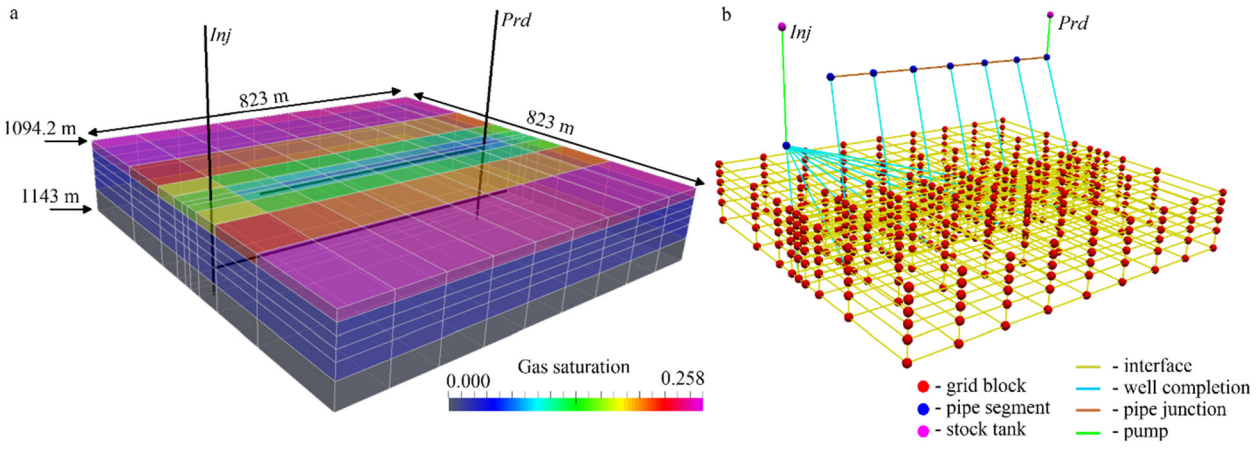

Fig. 1. (a) The gas saturation in the 7th SPE comparative study, case 4b at t=1500 days; (b) 3D graph built in MUFITS for this study.