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New dynamic permeability upscaling method for flow simulation under depletion drive and no-crossflow conditions

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Abstract: The main purpose of upscaling in reservoir simulation is to capture the dynamic behavior of fine scale models at the coarse scale. Traditional static or dynamic methods use assumptions about the boundary conditions to determine the upscaled properties. In this paper, we show that the upscaled properties are strongly dependent on the flow process observed at the fine scale. We use a simple no-crossflow depletion drive process and demonstrate that an upscaled property is not a constant value. Instead, if the goal is to match the performance of the fine scale model, the upscaled permeability changes with time. We provide an analytical solution to determine the upscaled permeability and present the value of upscaled permeability under limiting conditions. Our equation suggests that it is possible that upscaled value can fall outside the range of fine scale values under certain conditions. We show that for pseudo steady state flow, using common averaging methods like arithmetic or even geometric averaging methods can lead to optimistic results. We also show that the no-crossflow solution is significantly different than crossflow solution at late times. We validate our method by comparing the results of the method with flow simulation results in two and multi-layered models.

Key words: Upscaling, permeability, reservoir simulation, no-crossflow, depletion drive

1 Introduction

Reservoir simulation allows an engineer to evaluate various complex scenarios and predict the future reservoir performance. With increasing computer power and better geological and geophysical evaluation, it is possible to obtain more detailed information about reservoirs. Instead of building overly simplistic models only capturing extremely large scale details, geo-modelers can build a very detailed model capturing small scale details which can resolve what can be observed on a core scale. These detailed models contain millions of discrete cells and running flow simulations on these fine models for multiple scenarios is practically impossible. More than that, production data resolution is much coarser than the static data. Because of these two limitations, the static model (or geo-cellular model) needs to be upscaled to a dynamic (coarse simulation) model so that it can serve two purposes: (i) it can reduce the computational effort to conduct simulation; and (ii) it can capture the resolution of dynamic data.

This illustrates the difficulty in upscaling the geo-cellular models. First, upscaling by necessity, would be dependent on the flow process we are trying to mimic. i.e. for petroleum reservoirs, a simple depletion process will require different upscaling than gravity dominated displacement. Second, it would be computationally very expensive to simulate the geo-cellular model under actual flow process conditions to compare it to the dynamic (coarse scale) model.

In this paper, we consider a simple depletion process in a petroleum reservoir to illustrate the difficulty in upscaling reservoir properties using simplified approaches. By using an analytical approach, we propose a method for calculating upscaled permeability for depletion processes.

2 Literature review

While reducing the number of grid blocks in a geo-cellular model to create a dynamic model, we normally go through a two step process: upgridding and upscaling. In the first step, we determine to what extent we can coarsen the geo-cellular model (Kelkar and Sharifi, 2012). For example, if we had five hundred fine scale layers in the geo-cellular model, we determine that reducing those layers to about fifty would retain enough geological details. Then we should determine how to upscale the reservoir properties in the upscaled model. For example, if we combine a certain number of layers into one upscaled layer, we will need to define an effective

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