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Absolute Permeability Upscaling for Superelement Modeling of Petroleum Reservoir

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Abstract—A technique for local upscaling of absolute permeability is proposed intended for the superelement modeling of petroleum reservoir development. The upscaling is performed for every block of an unstructured superelement grid based on solving a series of stationary one-phase flow in reservoir problems on a refined grid with the initial permeability field under various boundary conditions reflecting the characteristic structural variants of the filtrational flow and taking into account the presence or absence of wells inside the block. The resulting components of the effective permeability tensor in each superelement are sought from the solution of the problem on minimizing the deviations of the normal flows through the faces of the superelement averaged on a refined computational grid from those approximated on a coarse superelement grid. The application of the method is demonstrated by examples of the reservoir of the periodic and nonperiodic structure. The method is compared with the traditional techniques for local upscaling.

Keywords: upscaling, absolute permeability, porous medium, petroleum reservoir simulation, superelements

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1. INTRODUCTION

The superelement model of petroleum reservoir enables the fundamental acceleration of the computational process by using a coarse computational grid with the block size of the order of the distance between the wells [1–4]. The equations of this model have the same structure as the ordinary equations of two-phase flow but the functions of absolute permeability (AP) and of the relative phase permeability (RPP) differ from the original ones and result from transferring the properties of the reservoir from the detailed geological grid to the superelement grid. This process is called upscaling and is implemented in most computational and software packages such as Roxar Tempest, Schlumberger Eclipse, and TimeZYX. Earlier, we considered the RPP upscaling in a superelement model [5, 6]. The present study is devoted to the problem of absolute permeability upscaling.

There are many approaches to AP upscaling. Simplified analytical formulas of upscaling are only applicable to a small number of idealized types of heterogeneity. Porous reservoirs of a more complex structure call for different averaging methods. The mathematical averaging apparatus in the problems of flow in porous media theory is described in [7] and allows us to estimate effective flow parameters of the medium. The main results in this direction were obtained for periodically structured media [8–10]. A generalization of the averaging theory to random structures usually prevents the simplification of the initial problem with a small-scale inhomogeneity [11, 12].

The most popular techniques in the computational practice of modeling petroleum reservoir development are numerical methods for determining the AP tensor for each block of the coarse grid. The AP tensor is determined from the condition of the best approximation of the averaged fluid flow (flow-based upscaling) [13]. To this end, both global [14, 15] and more popular local upscaling methods [16, 13] are used. In contrast to the superelement modeling under consideration, in the finite superelement method [17] applied to the description of flows in the reservoir [18], the upscaling function is performed by the procedure of constructing the basis functions in each block of a coarse grid.

Obviously, upscaling should take into account not only the grid geometry but also the computational scheme for solving the problem on a coarse grid. In this paper, we propose a specialized method for the local AP upscaling of the superelement modeling of a petroleum reservoir development. The known tech-