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Title A Fast and Efficient Methodology to Convert Fractured Reservoir Images Into a Dual-Porosity Model
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Abstract

Both characterization and dynamic simulation of naturally-fractured reservoirs benefited by major advances in the recent years. However, the reservoir engineer remains faced with the difficulty of parameterizing the dual-porosity model used to represent such reservoirs. In particular, the equivalent fracture permeabilities and the equivalent matrix block dimensions of such a model cannot be easily derived from the observation of the complex images of natural fracture networks. This paper describes an original and systematic methodology to compute these equivalent parameters. Results of its implementation with a specific software demonstrate its validity and efficiency to deal with field situations A tensor of equivalent fracture permeability is derived from single-phase steady-state flow computations on the actual fracture network using a 3D resistor network method and specific boundary conditions. The equivalent block dimensions in each layer are derived from the fast identification of a geometrical function based on capillary imbibition. The methodology was validated against reference fine-grid simulations with a conventional reservoir simulator. Then, a complex outcrop image of a sandstone formation was processed for demonstration purposes. This innovative tool enables the reservoir engineer to build a dual-porosity model which bestly fits the hydraulic behavior of the actual fractured medium.

Introduction

Modeling naturally-fractured reservoirs remains a difficult reservoir engineering task although a great deal of efforts have recently been made to better characterize the geometry and distribution of fractures within the reservoir and to increase the capabilities of dual-porosity simulators. Actually, the 3D images of fracture networks derived from field fracturing data integration cannot be turned straight into the "sugar lump" conceptual model underlying any dual-porosity simulator. Such a model, introduced in the early sixties by Warren and Root, represents the fractured reservoir as an array of parallelepipedic matrix blocks limited by a set of uniform orthogonal fractures (Fig. 1). Fracture flows are computed within the fracture grid, matrix-fracture transfers are computed at each gridblock position, and block-to-block exchanges are also accounted for in the dual-permeability option of such simulators.

The first difficulty encountered is to parameterize this conceptual model, and especially to find equivalent fracture permeabilities and equivalent parallelepipedic blocks enabling to simulate the reservoir flow dynamics.

A methodology is presented in this paper to compute equivalent permeabilities and equivalent blocks from 3D geological images of the fracture network. Firstly, a general format has been defined to be able to process the 3D images of any fracture characterization model. The methodology itself includes the determination of an equivalent fracture permeability tensor and of an equivalent block section for any layer or stack of layers. It has been validated against reference solutions provided by finely-discretized models. And finally, its implementation with a specifically-developed software is demonstrated for a naturally-fractured outcrop rock volume.

Before detailing our methodology, it is worthwhile making a quick literature review of existing approaches. All published works concern the determination of equivalent permeabilities. No systematic method is reported for determining equivalent block dimensions.

The approaches detailed in Refs. 2 through 6 differ on the geometry of flow considered, the role of matrix medium, the technique of discretization of the fracture network and the method used for computing flows in fractures. Long et al., Cacas et al. and Massonnat et al. developed 3D flow models. Lough et al. developed a 2D fracture flow model including the contribution of 3D matrix flows and based on the boundary element method.

The matrix permeability is taken into account in Massonnat's, Odling's and Lough's models.

The technique used for representing and discretizing the fracture network is probably the main feature giving specificity to each of those models.