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Title **Single Medium Simulation of Reservoirs with Conductive Faults and Fractures**
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Abstract

This paper describes a technique to incorporate conductive faults and -fractures in a reservoir simulation model. The technique is appropriate for reservoirs with significant primary matrix productivity, and a large spacing between fractures (in the order of tens of meters). The single porosity (one grid) formulation is applied. Any fracture geometry can be represented accurately without grid modifications. The key elements of the approach are pseudo relative permeability curves for grid bocks containing fractures. These curves are determined through an analytical procedure, based on the local fracture and matrix properties. The method is applied successfully to a Middle East carbonate reservoir.

Introduction

Conductive faults and -fractures are common features in reservoirs worldwide. Several methods have been proposed to model fluid flow in fractured reservoirs. Well known is the Warren and Root [1] approach, which applies homogenization of the fracture properties and a dual porosity formulation (separate matrix and fracture grids). The homogenization of the fracture properties is possible when the Representative Elementary Volume (REV) [2] of the fracture network is smaller than the reservoir simulation grid.

This paper focuses on fracture patterns that can not be homogenized, because the fracture REV is several times larger that the grid block size. Figure 1 provides an illustration. This figure represents a 10 by 22 kilometer sector of a much larger carbonate reservoir. The displayed fracture pattern is obtained from fracture analysis [3]. It is superimposed on a 250 by 250 meter simulation grid. In this example the conductive fractures are identified as the key contributor to unstable movement of the water injection front. Consequently, the fracture pattern must be incorporated when a simulation model is to be built.

Several methods are available in the literature to integrate conductive fractures in a reservoir simulation model. Some of these methods are described below, with their strengths and weaknesses summarized in Table 1.

Phelps et al [4] apply local grid refinement (LGR) to model conductive fractures explicitly. This approach is thorough in the handling of the physical elements of the displacement process. However, numerical difficulties may be experienced due to a large flow rate in grid blocks with a small pore volume. This is especially the case when a rapidly advancing water tongues develop due to gravity segregation in the fractures. Henn et al [5] extend the LGR technique by applying vertical lumping of the fractured grid blocks, in combination with an analytical treatment of capillary/gravity equilibrium in the fracture. Their method strongly improves numerical performance of the simulation model. The general disadvantage of these

LGR approaches is that they are impractical for complex fracture patterns like the one shown in Figure 1. Cosentino et al [6] apply a dual media (dual permeability dual porosity) formulation to model conductive fractures explicitly. Their approach facilitates the capture of any complex fracture geometry without the need for modifications to the grid geometry. The method is thorough in its treatment of the processes that may take place during water flooding. The numerical challenges, with respect to high flow rates in grid cells with a small pore volume, are comparable to those experienced in the conventional LGR approach. Subsequently, relatively small time steps are required to adhere to stability criteria.