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Compressible Streamline-Based Simulation with Changes in Oil Composition

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Abstract

There are several oil fields offshore Brazil with horizontal oil density variations. API tracking, that is available in some commercial finite difference simulators, can deal with such cases by allowing definition of an initial oil gravity distribution and tracking variations of oil density, due to the movement of oil.

Streamline-based simulators can be much faster than conventional finite difference simulators when applied to large and heterogeneous models. However, this approach is most accurate and efficient when it is assumed that the rock and fluids are incompressible. In previous work (Beraldo *et al*, 2007), we presented an incompressible formulation for streamline simulation with an API Tracking option using two components in the oleic phase.

This paper presents a compressible formulation for streamlines that also considers API tracking. It extends the work of Cheng *et al*. (2006) and Osako and Datta-Gupta (2007) by consistently accounting for flux of mass and volume along streamlines. We describe how mass and volume can be mapped between the underlying grid and streamlines to minimize mass balance errors and how consideration of cumulative volume in a streamline can substitute for time-of-flight.

The method was implemented in a three-dimensional two-phase streamline-based simulator. Tests based on a Brazilian oilfield model and on the SPE10th Comparative Case demonstrate that the implementation can reproduce the results of a conventional simulator, while being substantially faster for finely-resolved models, even when compressibility is significant.

Introduction

Streamline simulation is based on decoupling the pressure solution from the saturation solution, as is done in the conventional IMPES method (**Fig. 1**). The description of the principles of streamline simulation can be found in several papers (Batycky *et al.* 1997; Thiele *et al.* 1997; Thiele 2003; Samier *et al.* 2002). Pollock's method (Pollock 1988) is used to trace streamlines and transport along each streamline is solved independently. The updated masses and saturations at the end of the time step are mapped back to the original grid. Nowadays streamline simulation is used in a range of applications that includes history matching (Emanuel and Milliken 1998; Maschio and Schiozer 2004; Cheng *et al.* 2007; Stenerud *et al.* 2008; Gross *et al.* 2004; Fenwick *et al.* 2005), quantification of uncertainties (Christie *et al.* 2002; Ligero *et al.* 2003), flood surveillance (Batycky *et al*. 2008), CO_2 storage (Qi *et al.* 2007), compositional simulation (Thiele *et al.* 1997; Osako and Datta-Gupta 2007), and dual porosity modeling of fractured reservoirs (Di Donato *et al.* 2004; Kozlova *et al.,* 2006).

Many reservoirs have compositional oil variations in both the vertical and horizontal directions (Behrenbruch *et al.* 1995; Pádua 1997, 1999; Wenger *et al.* 2002; Gibson *et al.* 2006). **Fig. 2** shows a representation of this kind of reservoir. In a previous paper, a 3D incompressible streamline simulator was modified to incorporate an API Tracking option by considering two components in the oleic phase (Beraldo *et al.* 2007). The results showed that API tracking can be used with streamline simulators, with all the advantages of this kind of simulation, including reduced run time, while giving similar results to grid-based codes.

To apply streamline method as a substitute for conventional finite difference simulators, it is necessary to accommodate the effects of compressibility. Despite several studies in this area (Thiele *et al.* 1997; Cheng *et al* 2005; Kozlova *et al.* 2006; Ingebrigtsen *et al.* 1999; Osako and Datta-Gupta, 2007), most present practical applications are still based on the assumption of incompressibility or rate-controlled wells. To extend streamline simulation with oil composition variation to compressible cases, a formulation similar to the one proposed by Cheng *et al.* (2006) and Osako and Datta-Gupta (2007) has been used. As we show later, the overall results were in good agreement with those from a commercial finite difference simulator, while being more computationally efficient for finely-resolved models.