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Computational procedure for determination of minimum miscibility pressure of reservoir oil

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HIGHLIGHTS

- A methodology has been developed for calculating the MMP.
- The displacement of oil by multi-component gas injection has been investigated.
- The PR EoS and random mixing rules are used to determine the phase behavior.
- It is assumed that the MMP is completely independent of the porous media.
- The algorithm is fast and easy to compute.

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ABSTRACT

A methodology has been developed for computing minimum miscibility pressure (MMP) for the displacement of oil by multi-component gas injection (It is focused on multiple contact miscibility mechanism (forward/backward)). The algorithm is presented for the calculation of the minimum miscibility pressure using an equation of state. The Peng–Robinson (PR) equation of state (EoS) along with random mixing rules is used to determine phase behavior of oil and gas. The key assumption of the method is that the MMP is completely independent of the porous media. This algorithm handles vaporizing (forward multiple contact) miscibility mechanisms. The MMP calculations include pressure/temperature flash calculations and oil properties characterization method of Riazi–Daubert. The proposed algorithm is fast and easy to compute.

1. Introduction

Oil companies nowadays spend huge amount of money to obtain optimum oil recovery methods, whereas they tend to recover much more valuable petroleum fluids, in addition to, lower cost. Gas injection processes are among the most effective methods of Enhanced Oil Recovery (EOR). A key parameter in the design of a gas injection project is the minimum miscibility pressure (MMP), the pressure at which surface tension between phases becomes zero and the local displacement efficiency approaches 100%. So far, various approaches have been suggested in the literature for determining the MMP. A review of different approaches has been reported by Wang and Orr [1]. Zick [2] and later Stalkup [3] showed that the MMP could be determined by one-dimensional compositional simulation [4].

There are two common idealizations of the way in which a two-phase gas and liquid system achieves miscibility through multiple contacting [4]: In the vaporizing mechanism, fresh (original) liquid phase is contacted with a vapor phase whose composition is altered by repeated equilibration with the liquid. In the condensing mechanism, the composition of the liquid phase is altered by equilibration with fresh vapor phase. The generally accepted definition of minimum miscibility pressure is that pressure, at a fixed temperature, above which miscibility occurs for a given feed (i.e. liquid of oil) and pressurizing gas solely through the multiple contact equilibrium process [4,5]. The computation of this pressure bound is dependent on the mechanism invoked; the MMP is assumed to

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be the lower of the two bounds [4]. Miscibility between a reservoir fluid and an injection gas is normally developed through a dynamic process of mixing, with component exchange controlled by phase equilibria (*K*-values) and local compositional variation along the path of displacement.

Taking into account the aforementioned considerations, we present a new algorithm for calculating MMP of reservoir oil, which is faster than a 1D simulator and easy to apply. The results for two oil systems are presented and discussed.

2. Algorithm development

The proposed mechanism and algorithm are shown in Figs. 1 and 2. The Peng–Robinson (PR) equation of state (EoS) [6] is used in the calculations. This algorithm relies on the following key point: the MMP is completely independent of the porous media. Like any equilibrium property of a system, the MMP is not influenced by the relative permeability, and capillary pressure. Minimum miscibility pressure is only dependent on the phase behavior of the system. All these points were verified experimentally by the French petroleum company TOTAL SA. In particular, more than 50 MMP were determined with two slim tubes: the first one full of sand and the second one full of glass beads. In all cases, the measured MMPs were exactly the same. Therefore, it should be possible to compute the MMP using a simplified slim tube, i.e., with a cell to cell simulation in which no porous media and very simple flow dynamics are considered [7]. This is the basis of our work.

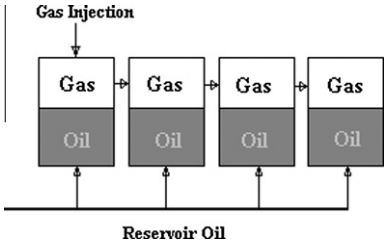

Fig. 1. Forward (vaporizing) multiple contact [5].

The multi-cell technique used in this work and described below is identical to the one developed by Metcalfe et al. [8]. This method may be summarized as follows: In the first step, the program simulates a number of cells of equal volume in a series as shown in Fig. 1. The temperature and the pressure are the same in each cell, and the volume is kept constant. All the cells contain initially the same fluid (the reservoir oil). A specified amount of gas is added to cell 1. It is assumed that perfect mixing takes place and thermodynamic phase equilibrium is reached. This means that the conditions in the cell can be described by a pressure/temperature (P/T) flash calculation, here based on the PR-EoS [6].

When one batch calculation has been completed, a new gas injection into cell 2 can take place and the cell to cell transfer calculation is resumed. To properly model such processes with an equation of state-based compositional simulator, fluid

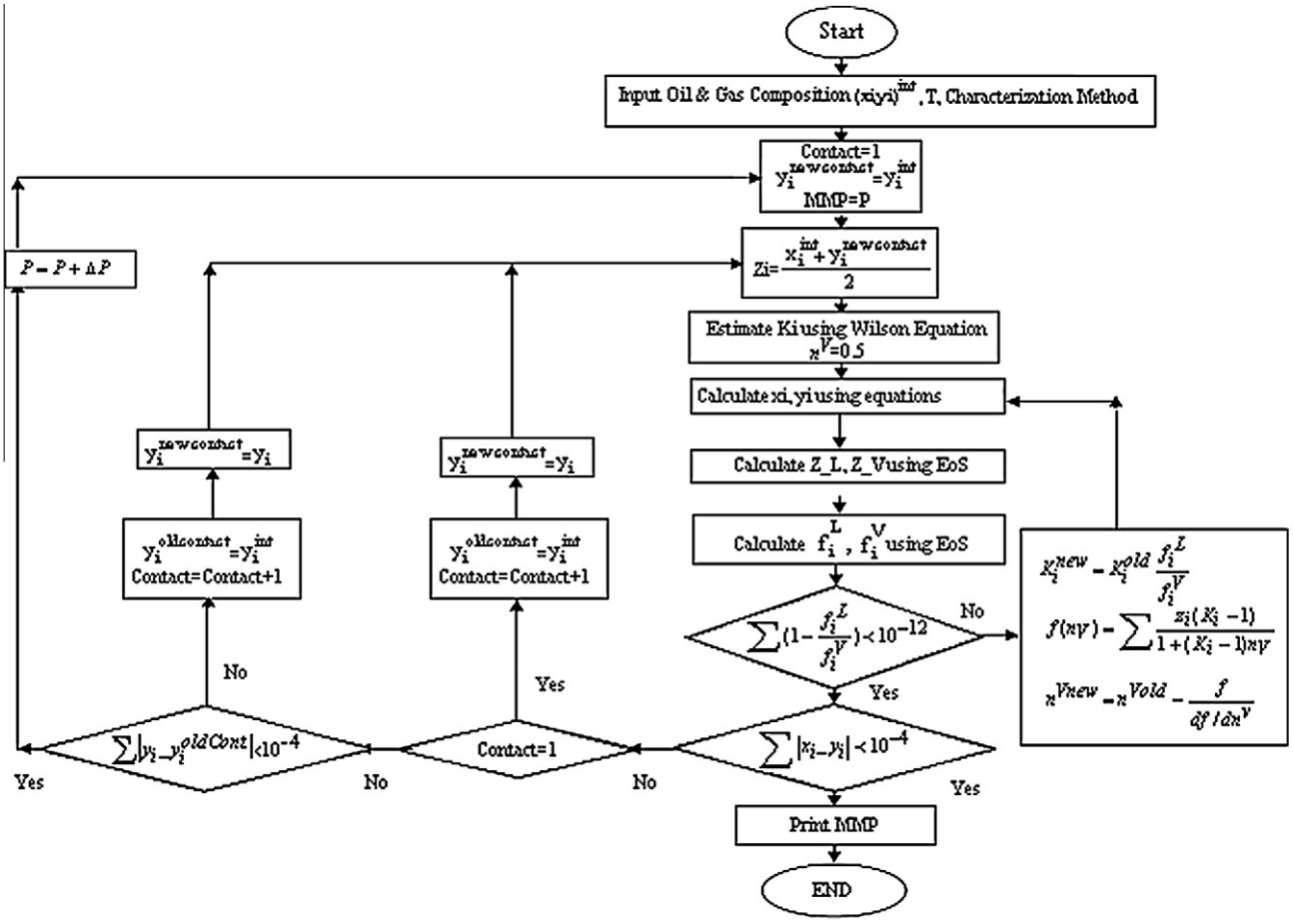

Fig. 2. The algorithm of computing minimum miscibility pressure.