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Title:	*PIMS Tech. Report*
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Submitted to:	
Date:	November 17, 2011
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1 Governing equations

PIMS, parallel immiscible multiphase flow simulator is a simplified version of the PFLOTRAN MPHASE mode in which the dependencies on thermodynamic relations have been removed, since for immiscible systems, the solubility is zero for every component. Then the number of component is the same as the number of phases, and the degree of freedom on every node if isothermal system is consider. This totally immiscible assumption also removes the variable switching strategy used in MPHASE, which may be the most difficult part of PFLOTRAN, and may cause problems for multi-level solvers.

The governing equations solved by PIMS are given by

$$\frac{\partial}{\partial t}\left[\varphi(\rho_i s_i)\right] + \boldsymbol{\nabla}\cdot\left(\rho_i \boldsymbol{q}_i\right) \;=\; Q_i, \tag{1}$$

where φ is porosity, s_i, ρ_i refer to the ith phase saturation and density, q_i is ith phase velocity, and Q_i is the source/sink term. Thus, the number of equations is equal to number of phases. The selection of primary variables are pressure p and $n-1$ independent phase saturation variables $s_i, i = 1, ..., n-1$ with

$$\sum_{i=1}^{n} s_i = 1. \tag{2}$$

Compared to the PFLOTRAN MPHASE mode, PIMS conserves mass instead of molar numbers.

2 PETSc Solver

PIMS is using PETSc SNES nonlinear solver. Note: the pre-conditioner option `-pc_factor_nonzeros_along_diagonal` is needed to reduce the chance of getting zero pivot errors. Since for an incompressible fluid, if the phase saturation is lower than its residual, the mass balance equation for that phase is independent of pressure and its adjacent nodes' saturation.