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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 dependency on thermodynamic relations have been removed, since for immiscible systems the solubility is identically zero for each component. In this case the number of components is equal to the number of phases, or degrees of freedom associated with each node for an isothermal system. The immiscible property removes the variable switching strategy used in MPHASE, which may be the most numerically 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.