Modeling Strategy and Reasoning

Can we really model a dripping and no-dripping condition? How?

- Multiphase Models available and applicable to this multiphase topology:
  - ✓Multiphase Segregated Flow Model (Eulerian – Eulerian)
  - ✓Eulerian Multiphase Mixture Model
  - ✓Volume of Fluid (VOF)

Modeling Strategy and Reasoning

Eulerian Multiphase Mixture Model

Volume Fraction Governing Equation

$$\frac{\partial}{\partial t}\int_V \alpha_i \, dV + \int_A \alpha_i \mathbf{v}_m \cdot d\mathbf{a} = \int_V \left(S_{u_i} - \frac{\alpha_i}{\rho_i}\frac{D\rho_i}{Dt} \right) dV + \underbrace{\int_A \frac{\mu_t}{\sigma_t \rho_m} \nabla \alpha_i \cdot d\mathbf{a}}_{\text{Turbulent Term}} - \underbrace{\int_V \frac{1}{\rho_i} \nabla \cdot (\alpha_i \rho_i \mathbf{v}_{d,i}) dV}_{\text{Slip Velocity Term}}$$

Continuity

$$\frac{\partial}{\partial t}\int_V \rho_m \, dV + \int_A \rho_m \mathbf{v}_m \cdot d\mathbf{a} = \int_V S_u \, dV$$

Momentum

$$\frac{\partial}{\partial t}\int_V \rho_m \mathbf{v}_m \, dV + \int_A \rho_m \mathbf{v}_m \otimes \mathbf{v}_m \cdot d\mathbf{a} = -\int_A p\mathbf{I} \cdot d\mathbf{a} + \int_A \mathbf{T}_m \cdot d\mathbf{a} + \int_V \mathbf{f}_b \, dV + \int_V \mathbf{s}_u \, dV - \underbrace{\sum_i \int_A \alpha_i \rho_i \mathbf{v}_{d,i} \otimes \mathbf{v}_{d,i} \cdot d\mathbf{a}}_{\text{Slip Velocity Term}}$$

Modeling Strategy and Reasoning

Volume of Fluid (VOF)

Volume Fraction Governing Equation

$$\frac{\partial}{\partial t}\int_V \alpha_i dV + \oint_A \alpha_i \mathbf{v}\cdot d\mathbf{a} = \int_V \left(S_{\alpha_i} - \frac{\alpha_i}{\rho_i}\frac{D\rho_i}{Dt}\right) dV - \int_V \frac{1}{\rho_i}\nabla\cdot\left(\alpha_i \rho_i \mathbf{v}_{d,i}\right) dV$$

Continuity

$$\frac{\partial}{\partial t}\left(\int_V \rho dV\right) + \oint_A \rho\mathbf{v}\cdot d\mathbf{a} = \int_V S dV$$

Momentum

$$\frac{\partial}{\partial t}\left(\int_V \rho\mathbf{v} dV\right) + \oint_A \rho\mathbf{v}\otimes\mathbf{v}\cdot d\mathbf{a} = -\oint_A p\mathbf{I}\cdot d\mathbf{a} + \oint_A \mathbf{T}\cdot d\mathbf{a} + \int_V \rho\mathbf{g} dV + \int_V \mathbf{f}_b dV - \sum_i \int_A \alpha_i \rho_i \mathbf{v}_{d,i}\otimes\mathbf{v}_{d,i}\cdot d\mathbf{a}$$

Modeling Strategy and Reasoning

Volume Fraction Governing Equation

$$\frac{\partial}{\partial t}\int_V \alpha_i\, dV + \int_A \alpha_i \mathbf{v}_m \cdot d\mathbf{a} = \int_V \left(S_{u_i} - \frac{\alpha_i}{\rho_i}\frac{D\rho_i}{Dt}\right) dV + \underbrace{\int_A \frac{\mu_t}{\sigma_t \rho_m}\nabla\alpha_i \cdot d\mathbf{a}}_{\text{Turbulent Term}} - \cancel{\underbrace{\int_V \frac{1}{\rho_i}\nabla\cdot\left(\alpha_i\rho_i\mathbf{v}_{d,i}\right)dV}_{\text{Slip Velocity Term}}}$$

Mixture Model

$$\frac{\partial}{\partial t}\int_V \alpha_i dV + \oint_A \alpha_i \mathbf{v}\cdot d\mathbf{a} = \int_V \left(S_{\alpha_i} - \frac{\alpha_i}{\rho_i}\frac{D\rho_i}{Dt}\right) dV - \cancel{\int_V \frac{1}{\rho_i}\nabla\cdot\left(\alpha_i\rho_i\mathbf{v}_{d,i}\right) dV}$$

VOF

Continuity

$$\frac{\partial}{\partial t}\left(\int_V \rho dV\right) + \oint_A \rho\mathbf{v}\cdot d\mathbf{a} = \int_V S dV$$

$$\frac{\partial}{\partial t}\int_V \rho_m dV + \int_A \rho_m \mathbf{v}_m \cdot d\mathbf{a} = \int_V S_u\, dV$$

Momentum

$$\frac{\partial}{\partial t}\int_V \rho_m \mathbf{v}_m\, dV + \int_A \rho_m \mathbf{v}_m \otimes \mathbf{v}_m \cdot d\mathbf{a} = -\int_A p\mathbf{I}\cdot d\mathbf{a} + \int_A \mathbf{T}_m \cdot d\mathbf{a} + \int_V \mathbf{f}_b\, dV + \int_V \mathbf{s}_u\, dV - \cancel{\underbrace{\sum_i \int_A \alpha_i\rho_i\mathbf{v}_{d,i}\otimes\mathbf{v}_{d,i}\cdot d\mathbf{a}}_{\text{Slip Velocity Term}}}$$

Mixture Model

$$\frac{\partial}{\partial t}\left(\int_V \rho\mathbf{v}dV\right) + \oint_A \rho\mathbf{v}\otimes\mathbf{v}\cdot d\mathbf{a} = -\oint_A p\mathbf{I}\cdot d\mathbf{a} + \oint_A \mathbf{T}\cdot d\mathbf{a} + \int_V \rho\mathbf{g}dV + \int_V \mathbf{f}_b dV - \cancel{\sum_i \int_A \alpha_i\rho_i\mathbf{v}_{d,i}\otimes\mathbf{v}_{d,i}\cdot d\mathbf{a}}$$

VOF

Modeling Strategy and Reasoning

Differences between both formulations

- How the convective term is resolved
- ***Source terms***

Source term

Surface tension *"The surface tension force is a tensile force tangential to the interface separating two fluids. It works to keep the fluid molecules at the free surface in contact with the rest of the fluid. The interfacial surface force is modeled as a volumetric force."* StarCCM+ documentation

Modeling Strategy and Reasoning

Momentum

$$\frac{\partial}{\partial t}\int_V \rho_m \mathbf{v}_m \, dV + \int_A \rho_m \mathbf{v}_m \otimes \mathbf{v}_m \cdot d\mathbf{a} = -\int_A p\mathbf{I} \cdot d\mathbf{a} + \int_A \mathbf{T}_m \cdot d\mathbf{a} + \int_V \mathbf{f}_b \, dV + \int_V \mathbf{s}_u \, dV - \underbrace{\sum_i \int_A \alpha_i \rho_i \mathbf{v}_{d,i} \otimes \mathbf{v}_{d,i} \cdot d\mathbf{a}}_{\text{Slip Velocity Term}}$$

Mixture Model

$$\frac{\partial}{\partial t}\left(\int_V \rho \mathbf{v} dV\right) + \oint_A \rho \mathbf{v} \otimes \mathbf{v} \cdot d\mathbf{a} = -\oint_A p\mathbf{I} \cdot d\mathbf{a} + \oint_A \mathbf{T} \cdot d\mathbf{a} + \int_V \rho \mathbf{g} dV + \int_V \mathbf{f}_b dV - \sum_i \int_A \alpha_i \rho_i \mathbf{v}_{d,i} \otimes \mathbf{v}_{d,i} \cdot d\mathbf{a}$$

$$+ \int_V \left(-\sigma \nabla \cdot \left(\frac{\nabla \alpha_i}{|\alpha_i|}\right) \nabla \alpha_i + (\nabla \sigma)_t \, |\nabla \alpha_i|\right) dV$$

VOF