Turbulent Fluid Micromixing of Two-Phase Taylor-Couette Flow

Hyunkyung Lim
Yijie Zhou and James Glimm
Department of Applied Mathematics
Stony Brook University

Valmor F. de Almeida
Oak Ridge National Laboratory

September 25 2014
Outline

1. Motivation
2. Goals
3. Mathematical Model
4. V & V of One-Phase
5. Main Results of Two-Phase
Sketch of the cross section of an annular centrifugal contactor

- Turbulent fluid mixing of two viscous and immiscible liquids in rotating Taylor-Couette flow
- Solvent extraction process in nuclear fuel reprocessing
- Taylor Couette flow consists of a viscous fluid confined in the gap between two rotating cylinders.
- Flow parameters are in the turbulent flow regime.

Source: https://sites.google.com/site/kwardleweb/research/centrifugal-contactor
Chemical reaction rate is critical in solvent extraction process.

- interfacial surface area
- extent of turbulent induced fluid diffusion

The central goal is to promote chemical reaction at the interface, thus the creation of an extensive interfacial area in a two-phase mixing flow.

To develop a sharp interface tracking simulation capability for predicting interaction of droplets in rotating flows.
Incompressible Navier-Stokes equations:

$$\rho \frac{\partial v}{\partial t} + \rho \nabla \cdot (v \otimes v) = \nabla \cdot T + b + f$$

$$\nabla \cdot v = 0$$

$$T = -pI + \mu (\nabla v + \nabla v^T)$$

Hydrodynamic pressure correction for disjoining pressure:

$$v_{dp} = v + \delta v$$

Mixing of two viscous, immiscible liquids with interfacial tension and different mass densities
Re = 8000, Mean angular momentum $< v_\theta r > / U_i R_i$

The most refined mesh agrees with the experimental data and DNS.
Two-phase Turbulent Taylor-Couette Mixing

Taylor-Couette flow:
- RT instability by centrifugal force
- KH instability by shear stress

white: heavy liquid (aqueous)
red: light liquid (organic)

early time with unstable configuration
late transient flow regime
statistically stable flow regime
Challenging Microphysics

- Experiment: Honeycomb microstructure flow regimes near the outer wall of mixing annular gap.

- Microphysics of lubricating thin films
- Hydrodynamic pressure correction: disjoining pressure (repulsive force) of molecular origin
- This correction is essential for obtaining results in qualitative agreement with experimental visualizations (stable dispersion).