CFD Evaluation of Mixing Processes for High-Level Waste

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DOE-FIU Science and Technology Workforce Development Program
Applied Research Center
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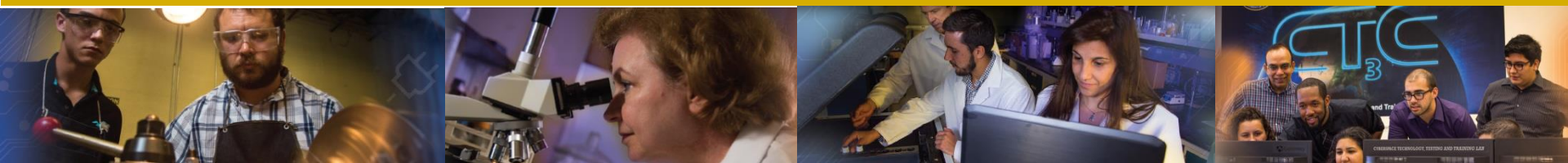

Introduction

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Summer internships:
NETL
Dr. Chris Gunther

The Big Picture

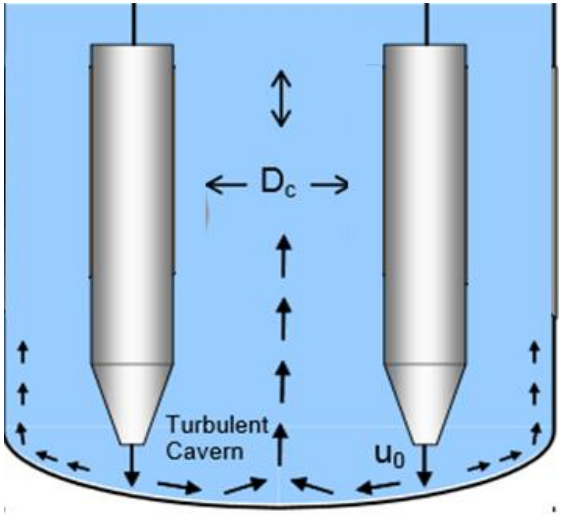
Background

Various mixing processes are required prior to waste transfer. These involve pulse jet mixers and can be used to release the entrained gas in a controlled manner.

14-ft-diameter vessel to test PJMs

Pulse Jet Mixers (PJM)

The PJMs contain pressurized vessels which intake the waste and discharge it back out at high velocity creating radial jets. These jets collide at the center of the vessel creating an up wash and promoting circulating motions.

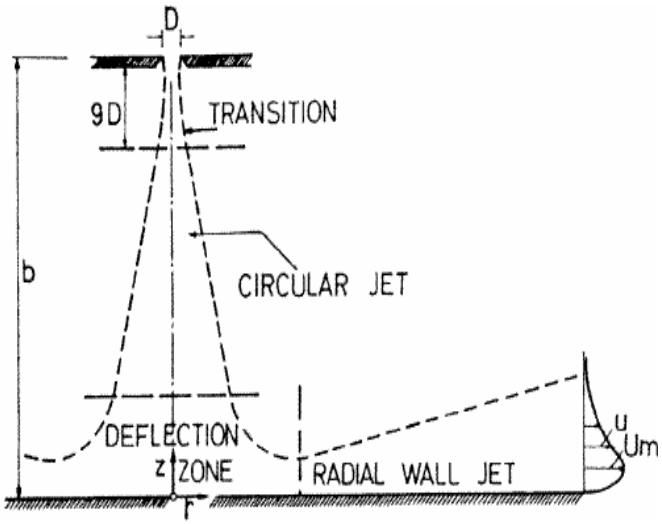


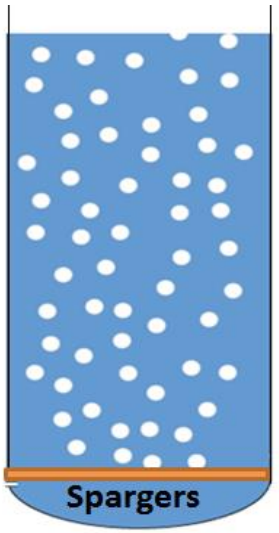
PJM circulation Demonstration

Scope/Objective

Several aspects of the PJM process are uncertain. Through the use of CFD, the objectives are to:

- Investigate the applicability of correlations used to describe the radial wall jet during the PJM process
- Investigate the effects of sparging on mixing for the PJM process





Radial Wall Jet Correlations

$$\delta = b * .098 * \left(\frac{r}{b}\right)^{.9}$$

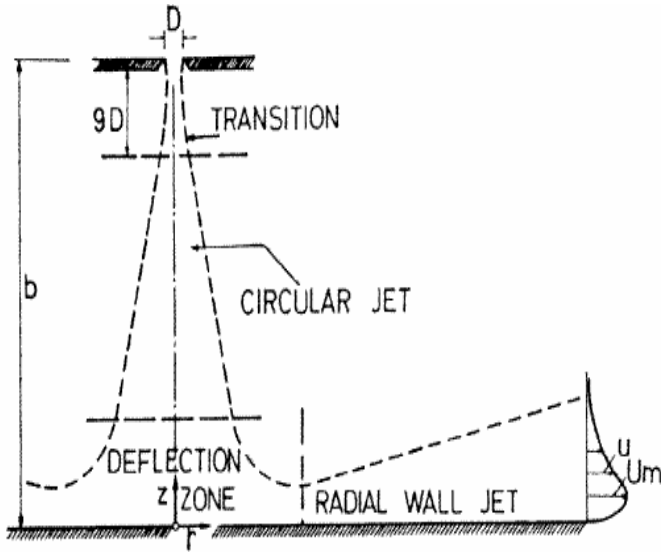
$$U_m = \frac{\sqrt{K}}{b} * 1.32 \left(\frac{r}{b}\right)^{-1.1}$$

δ : Distance at which U/U_m=.5

U_m : Maximum velocity

b : Distance from orifice to impingement wall

- b/D ratio in experimental investigation only went down to 8
- PJM Vessels typically have b/D ratio of 1.5
- Will Poreh's correlations still hold for B/D=1.5 ?



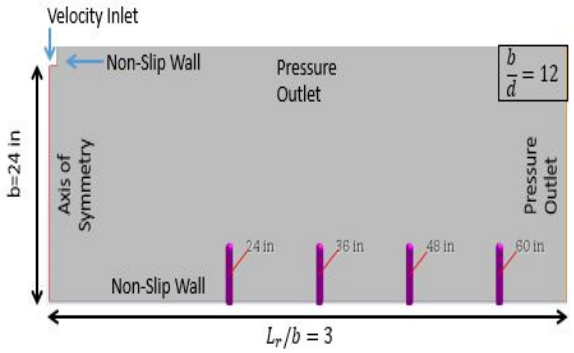
Poreh et al (1963)

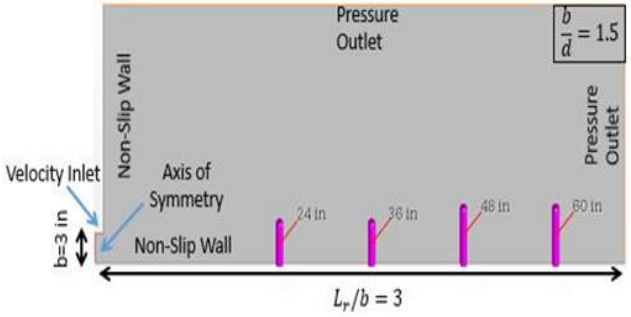
Method / Approach

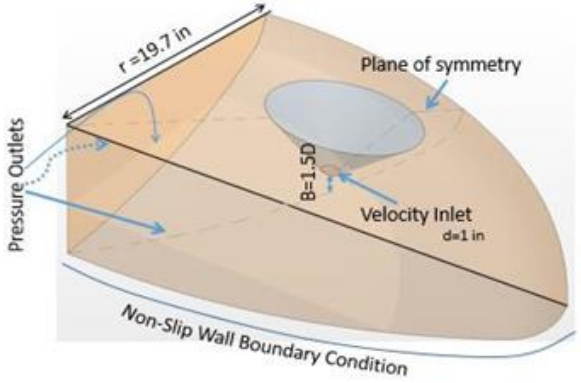
Simulate Poreh's Experiment

Simulate Poreh's experiment with PJM b/D ratio

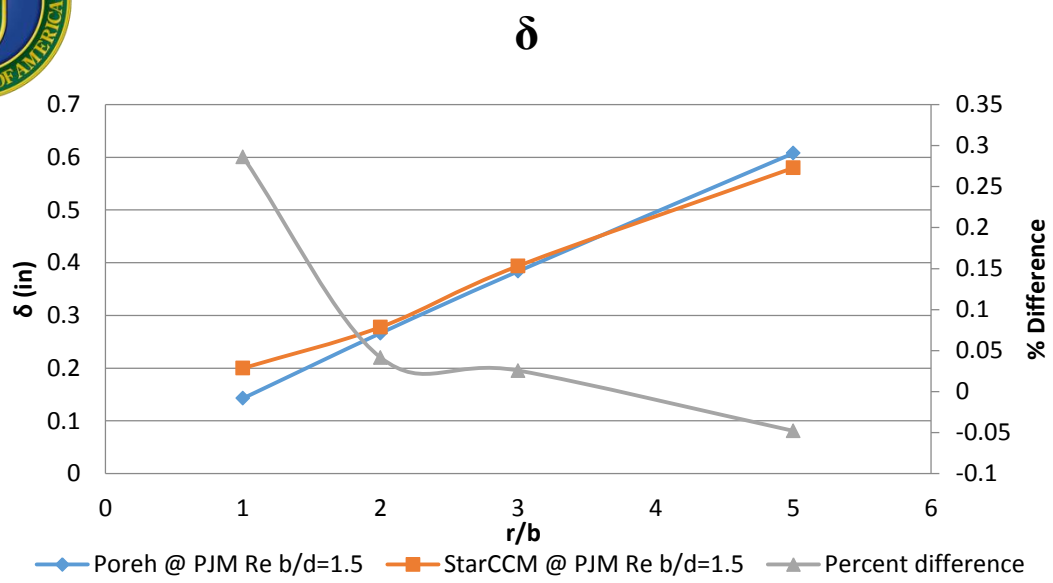
Simulate Poreh's experiment with both PJM b/D ratio & Geometry

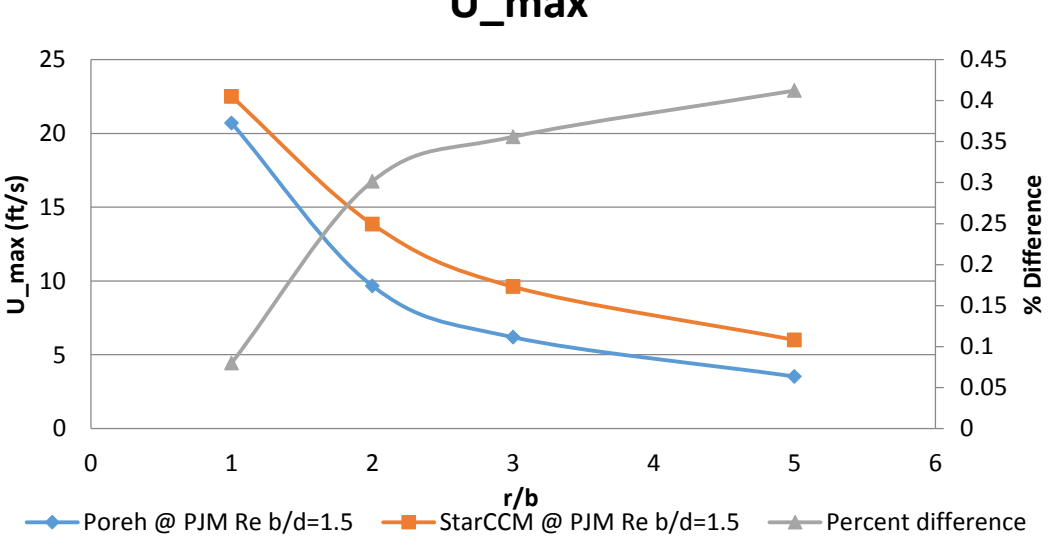






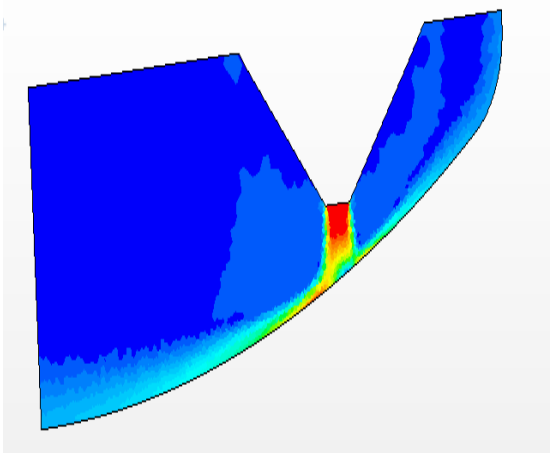
Results/Conclusions





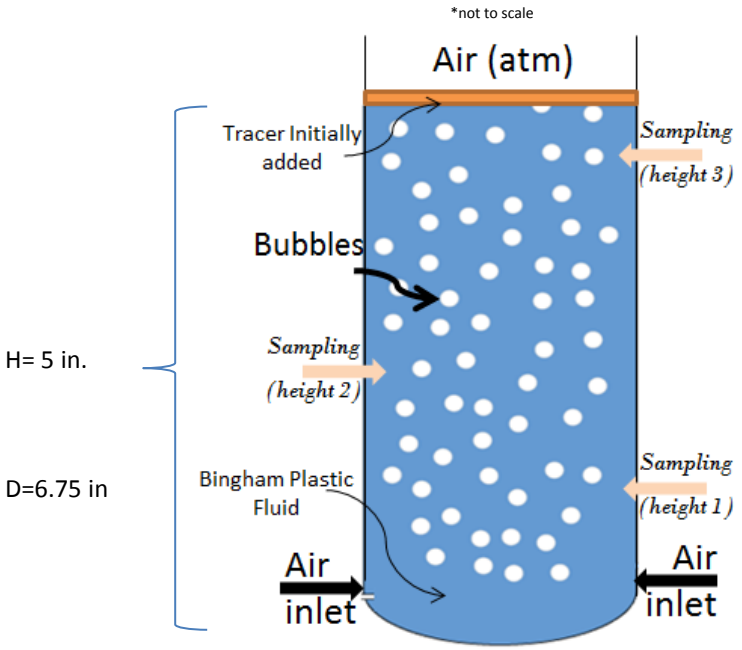
CFD suggests that Low B/d Ratio and curved impingement surface:

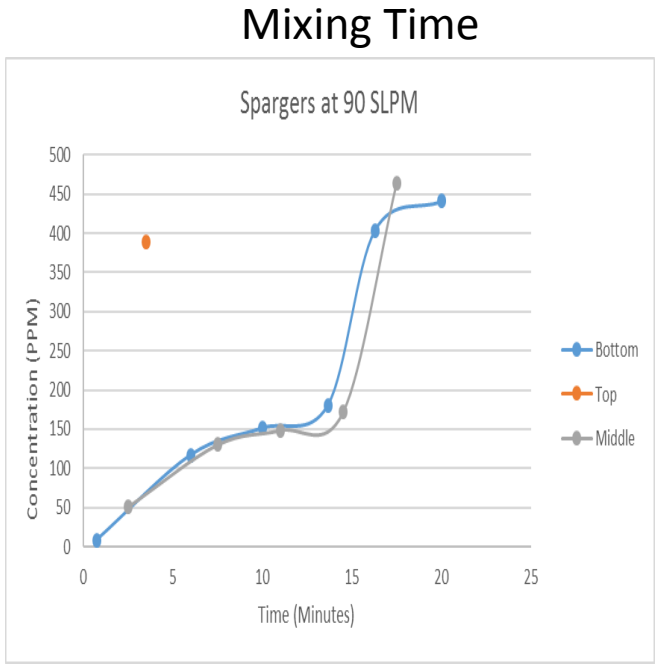
- Have little effect on radial jet thickness
- Under predicts maximum velocity



Effect of sparging on mixing times

- During 2016 summer internship, experimental data on mixing time of a non-Newtonian fluid was gathered





- Investigate mixing times in sparged non-Newtonian vessels through CFD for the application of the PJM's

Method / Approach

- The nuclear waste sludge is classified as a Bingham plastic fluid
- No research has been found on sparging of a Bingham plastic
- Experimental data on sparging of non-Newtonian fluid has been found

Simulate sparging of Newtonian fluid

Simulate sparging of non-Newtonian fluid

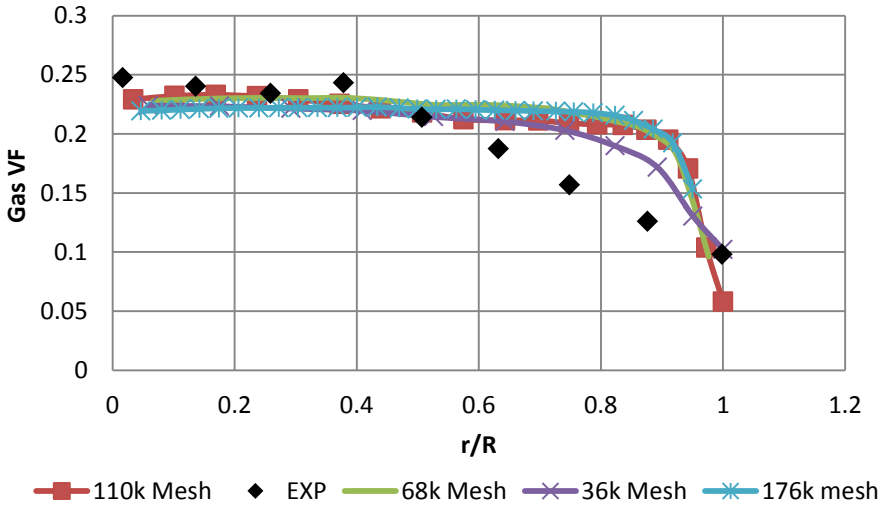
Simulate benchmark Bingham plastic type flows

Create validated simulation and use it to understand mixing times

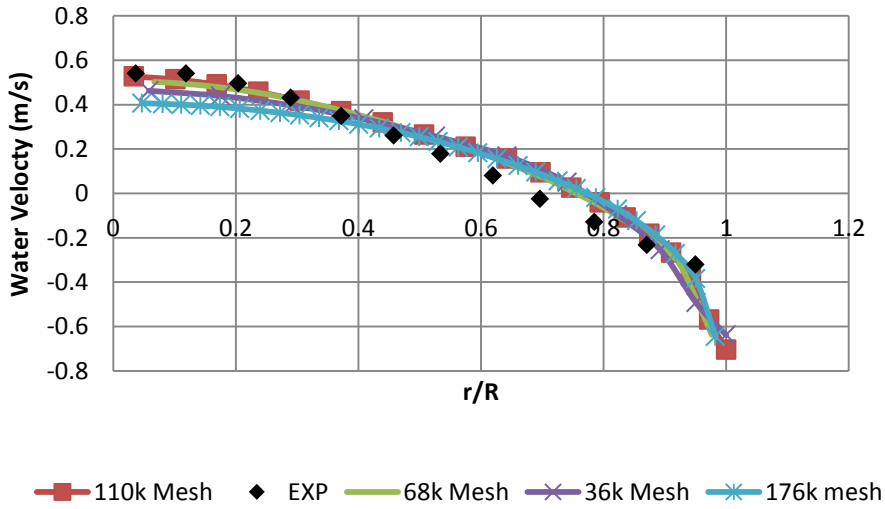
Preliminary Results/Discussion

Newtonian Simulation

Time Average Gas Volume Fraction



Time Average Water Velocity

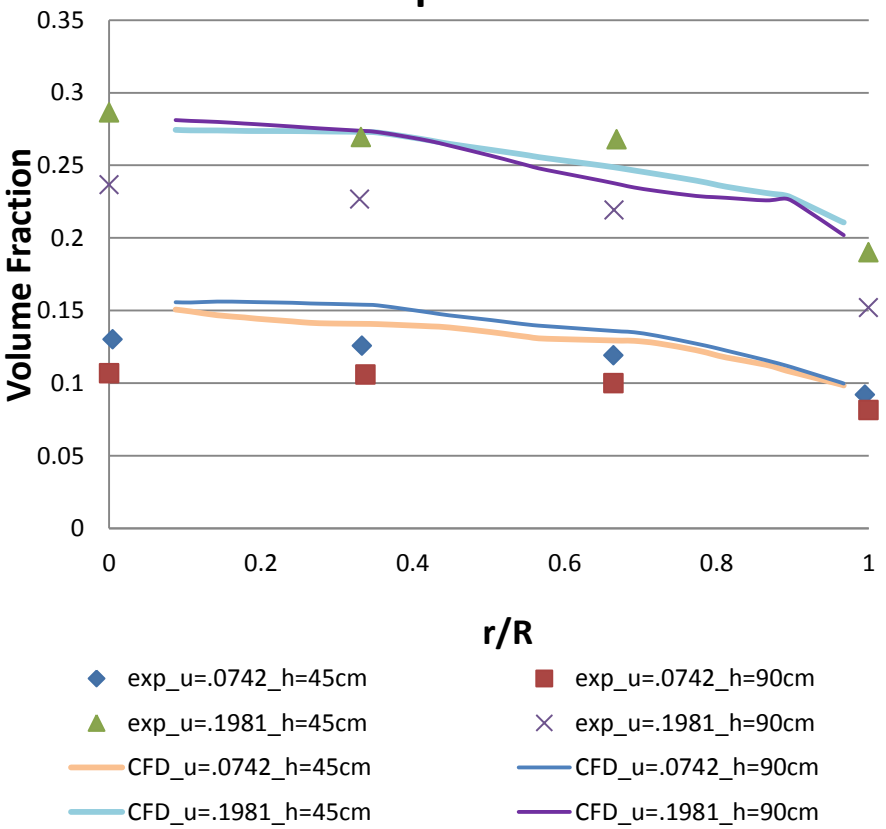


- Physics in sparging of Newtonian fluid is captured
- Mesh independence study shows simulation robustness

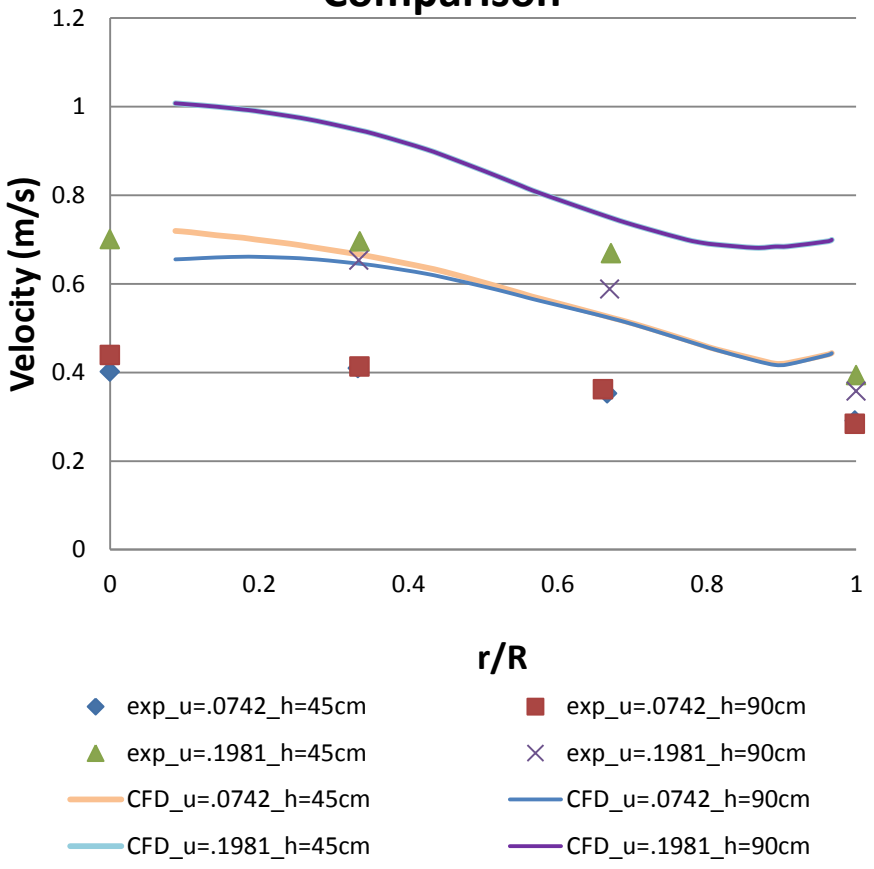
Preliminary Results/Discussion

Non- Newtonian Simulation

Time Averaged Volume Fraction Comparison



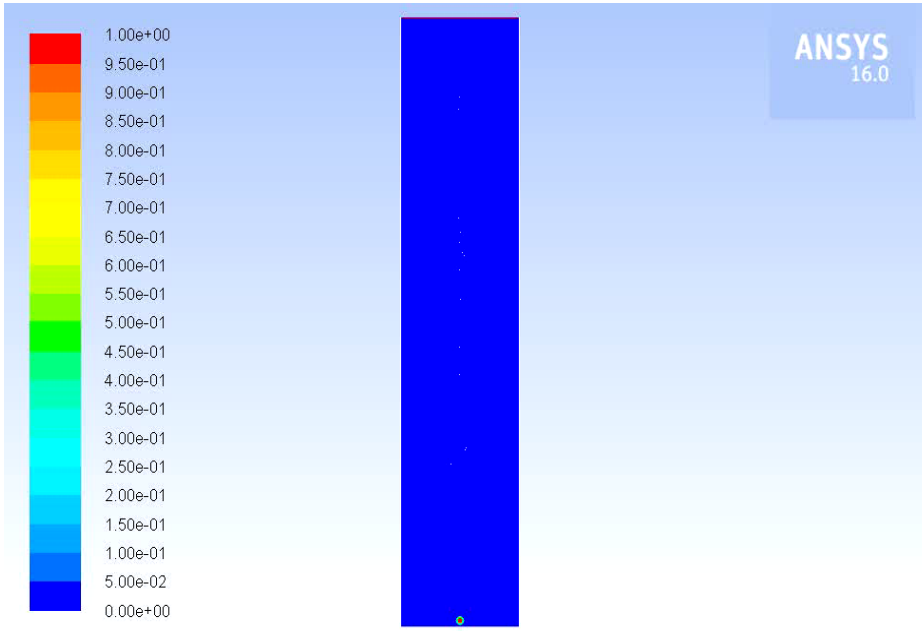
Time Averaged Z Velocity Comparison



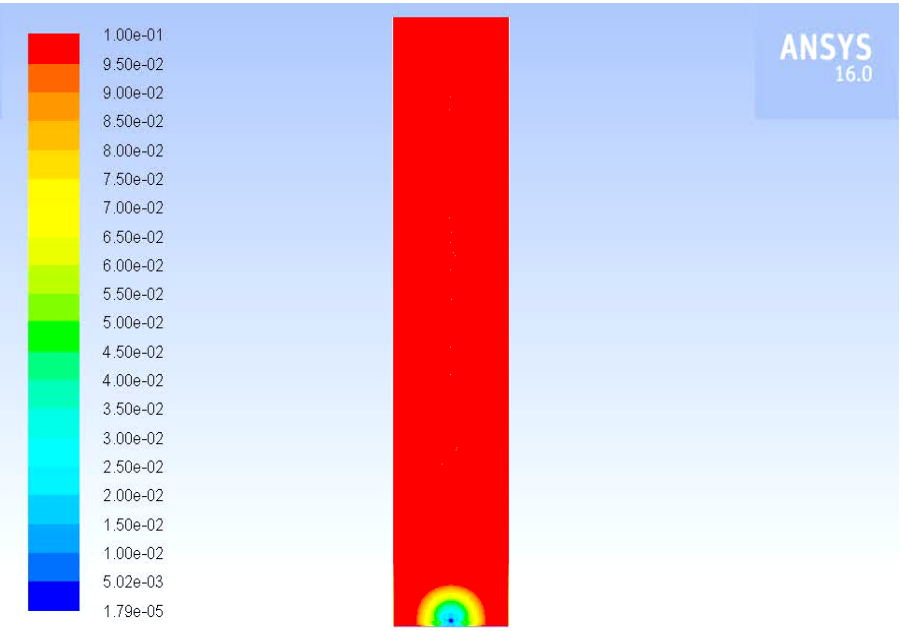
Preliminary Results/Discussion

- **Non- Newtonian Bench mark**

Bubble traveling through non-Newtonian fluid



Contours of Volume fraction (phase-2) (Time=5.0000e-03) Jun 30, 2017
ANSYS Fluent Release 16.0 (2d, dp, pbns, vof, lam, transient)



Contours of Molecular Viscosity (mixture) (kg/m-s) (Time=5.0000e-03) Jun 30, 2017
ANSYS Fluent Release 16.0 (2d, dp, pbns, vof, lam, transient)

Conclusions/Future Work

- Non-Newtonian CFD simulation needs to be improved
- More Bingham plastic benchmark simulations need to be conducted
- Final validated model to gain insight into mixing times will be conducted by introducing a tracer

Acknowledgements

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  - Dr. Rahul Garg
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