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Secondary Flow of Liquid-liquid Two-Phase Fluids in a Pipe Bend

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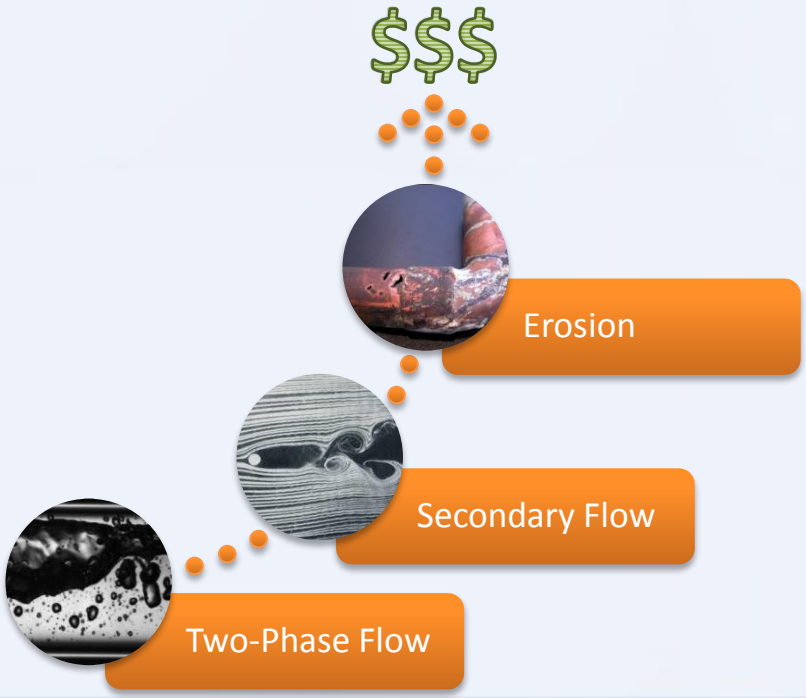
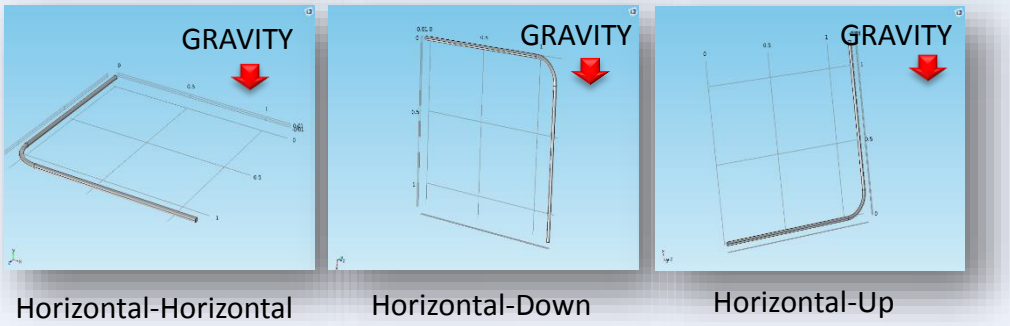
Introduction

- The world is progressively requiring more energy, mainly from the oil company
- Erosion is a phenomena that costs millions of dollars to companies
- Highest erosion rate is most commonly found in bends
- Better understanding of flow behavior would help in the future to minimize erosion



Approach to a solution

- **Physical Model**

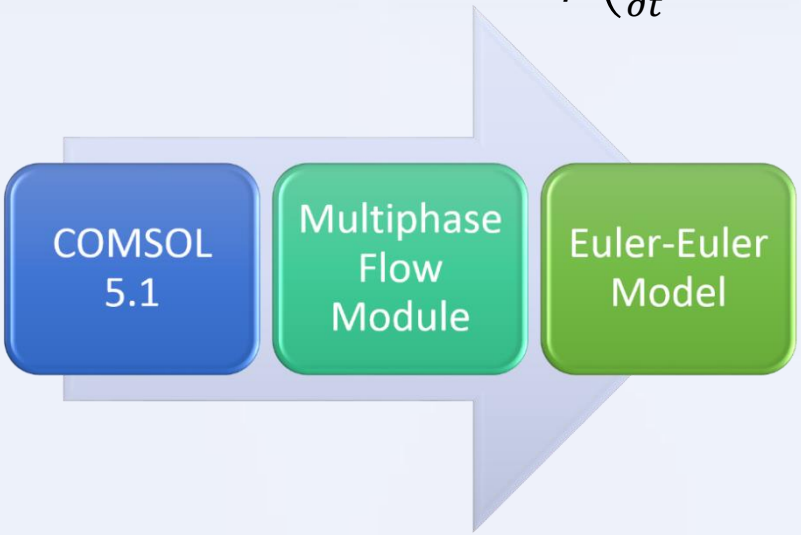


Horizontal-Horizontal Horizontal-Down Horizontal-Up

Reynolds Number	• 100,000 and 10,000
Phases	• Continuous Phase • Dispersed Phase
Fluids	• Water with 20% or 0% of NaCl • Oil
Volume fraction	• 80% Oil – 20% Brine or Water • 20% Oil – 80% Brine or Water

Approach to a solution

- **Numerical Model**



- **2 sets of Navier-Stokes equations**

$$\rho\left(\frac{\partial u}{\partial t} + u.\nabla u\right) = -\nabla p + \nabla.\left(\mu(\nabla u + (\nabla u)^T) - \frac{2}{3}\,\mu(\nabla.u)I\right) + F$$

- **Continuity Equation**

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho u) = 0$$

- **Transport Equation**

$$\nabla \cdot (\phi_d\,\mathbf{ud} + \phi_C\mathbf{uc}) = 0$$

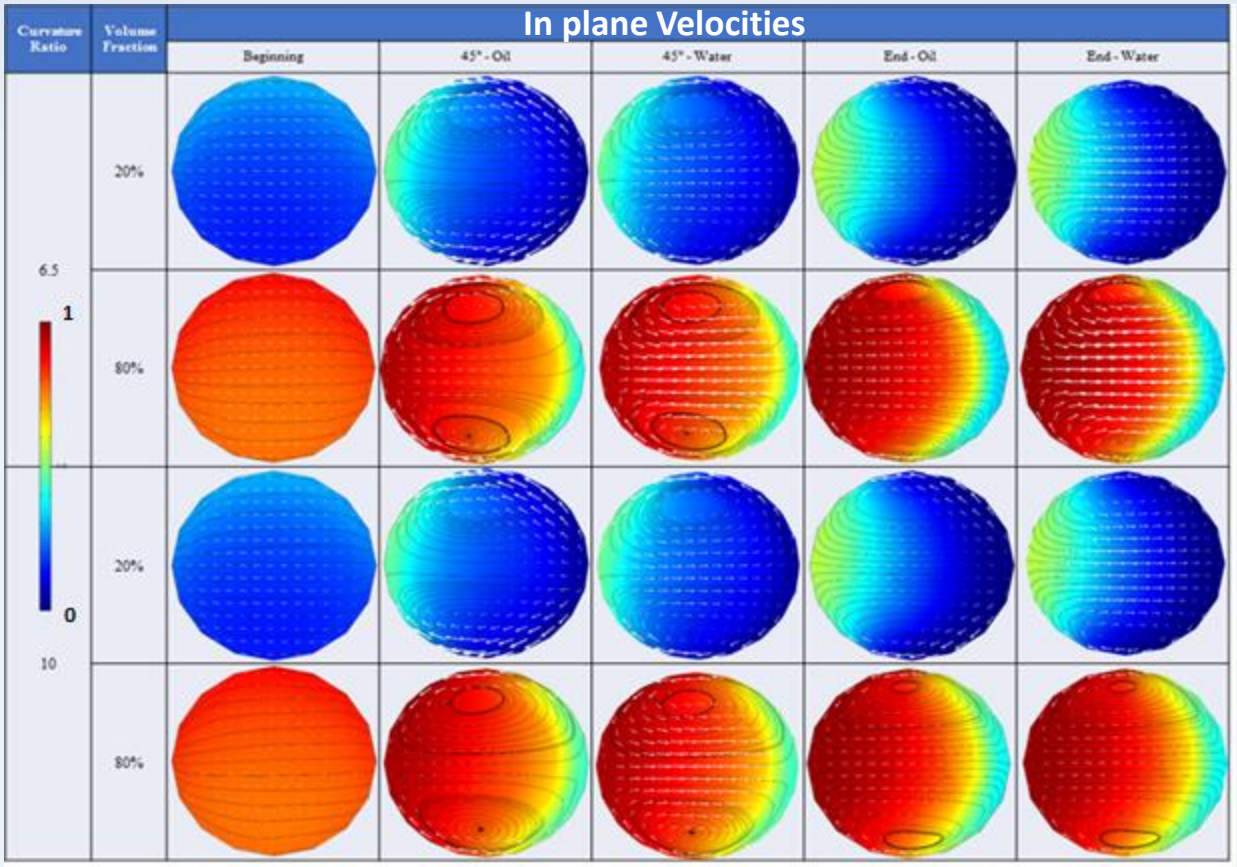
Mesh Sensitivity Analysis

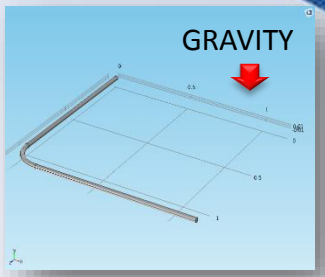
Normal mesh results had 7% difference when compared to finer

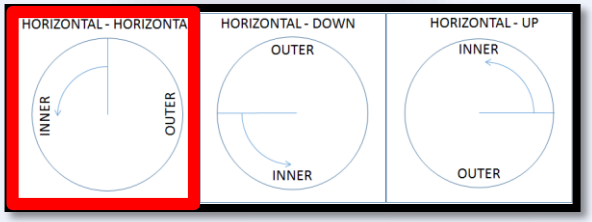
Wall lift-off values were lower than 20 (viscous units)

Results

Reynolds 100,000



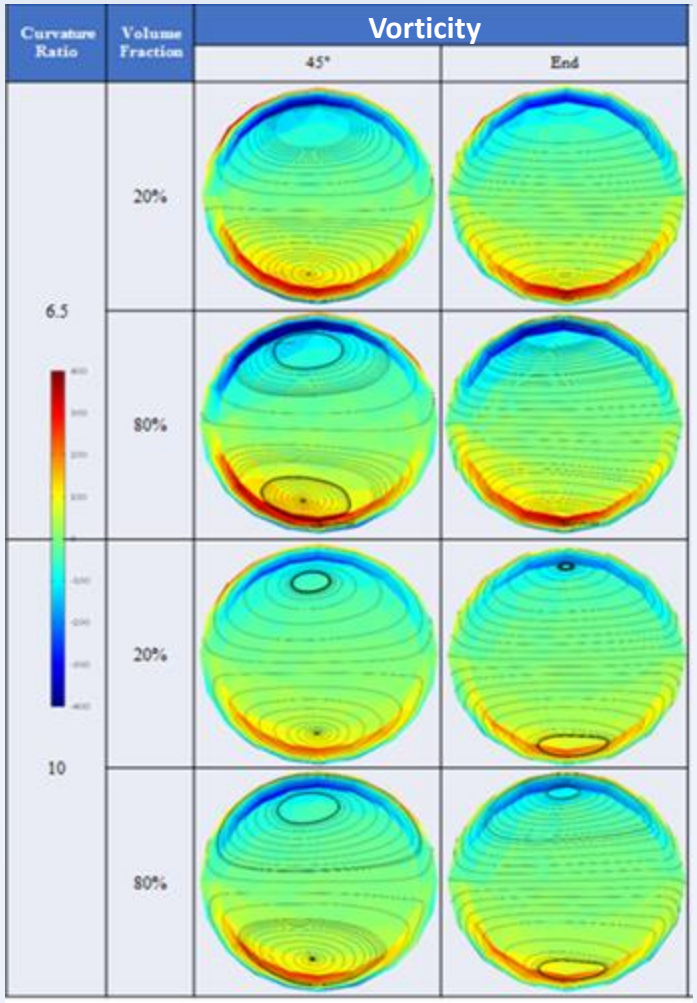


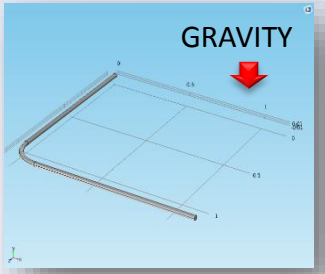


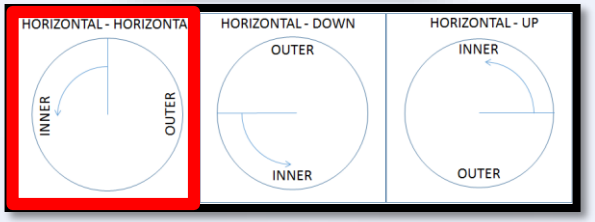
- Vortical Structures follow same behavior as a one phase fluid
- 2 perfectly defined Dean vortices through the whole bend

Results

Reynolds 100,000



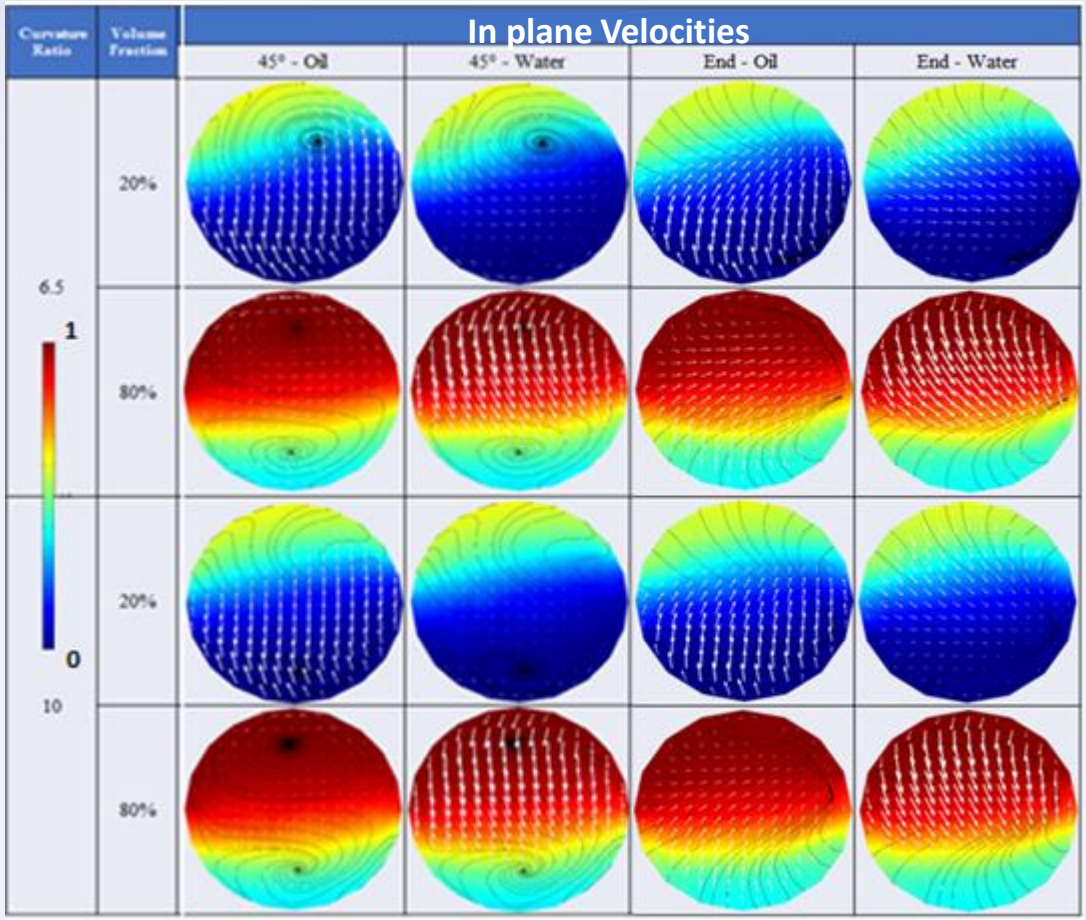


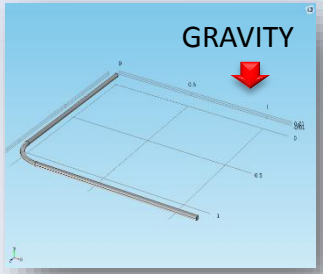


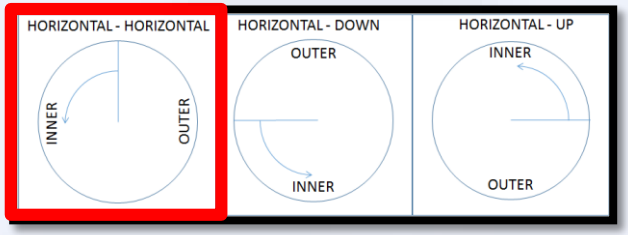
$$a_c \, \alpha \, \frac{u^2}{r}$$

Results

Reynolds 10,000



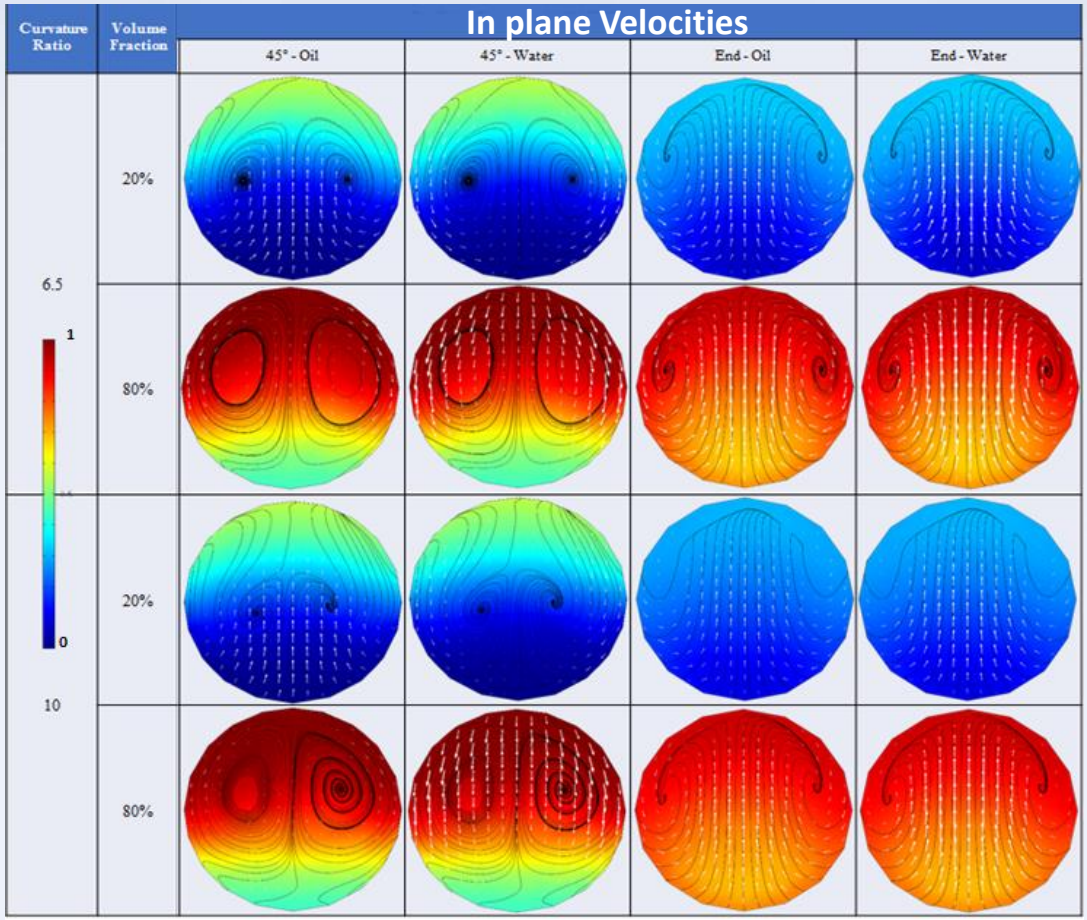


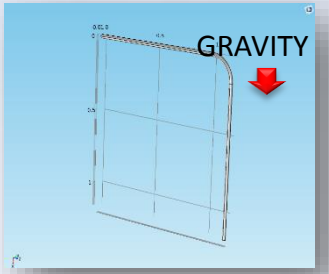


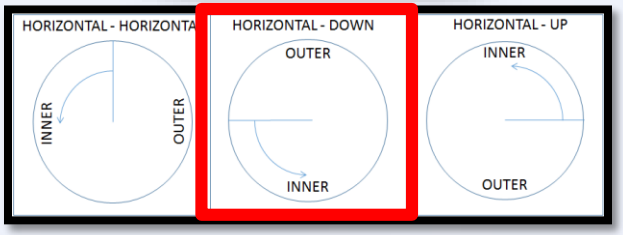
- Slightly diagonal volume fraction stratification
- Strong gravity seems to diminish the vortical structures

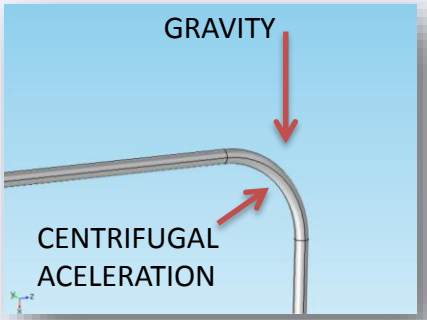
Results

Reynolds 10,000





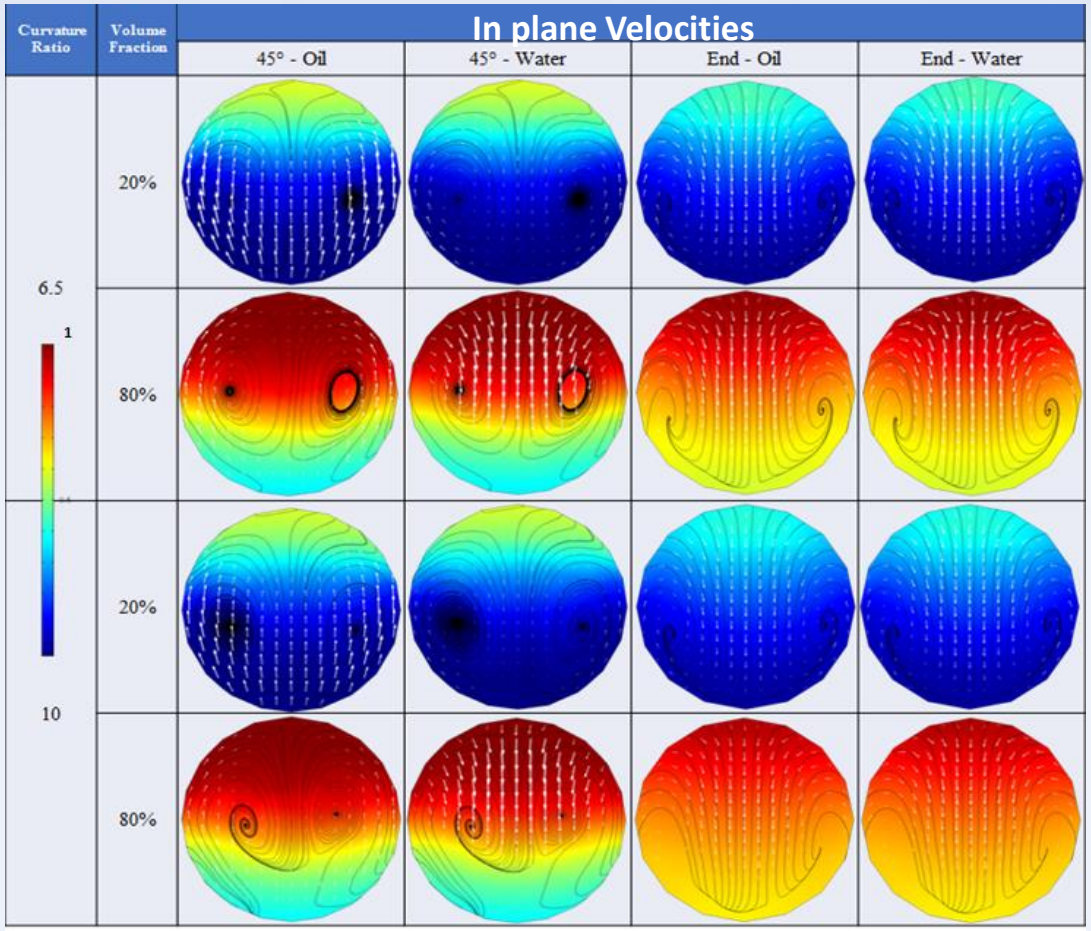


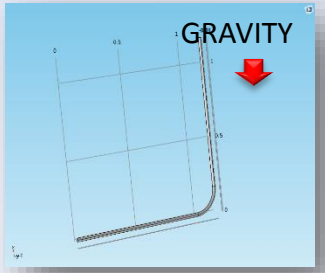


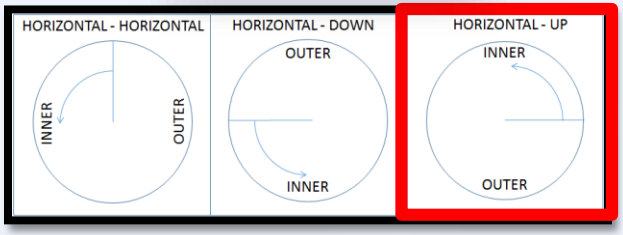
- Gravity does not affect strongly at the end of the bend
- Some vortical structures appear to be close to the center of pipe

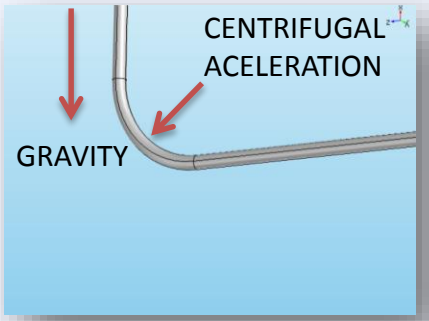
Results

Reynolds 10,000









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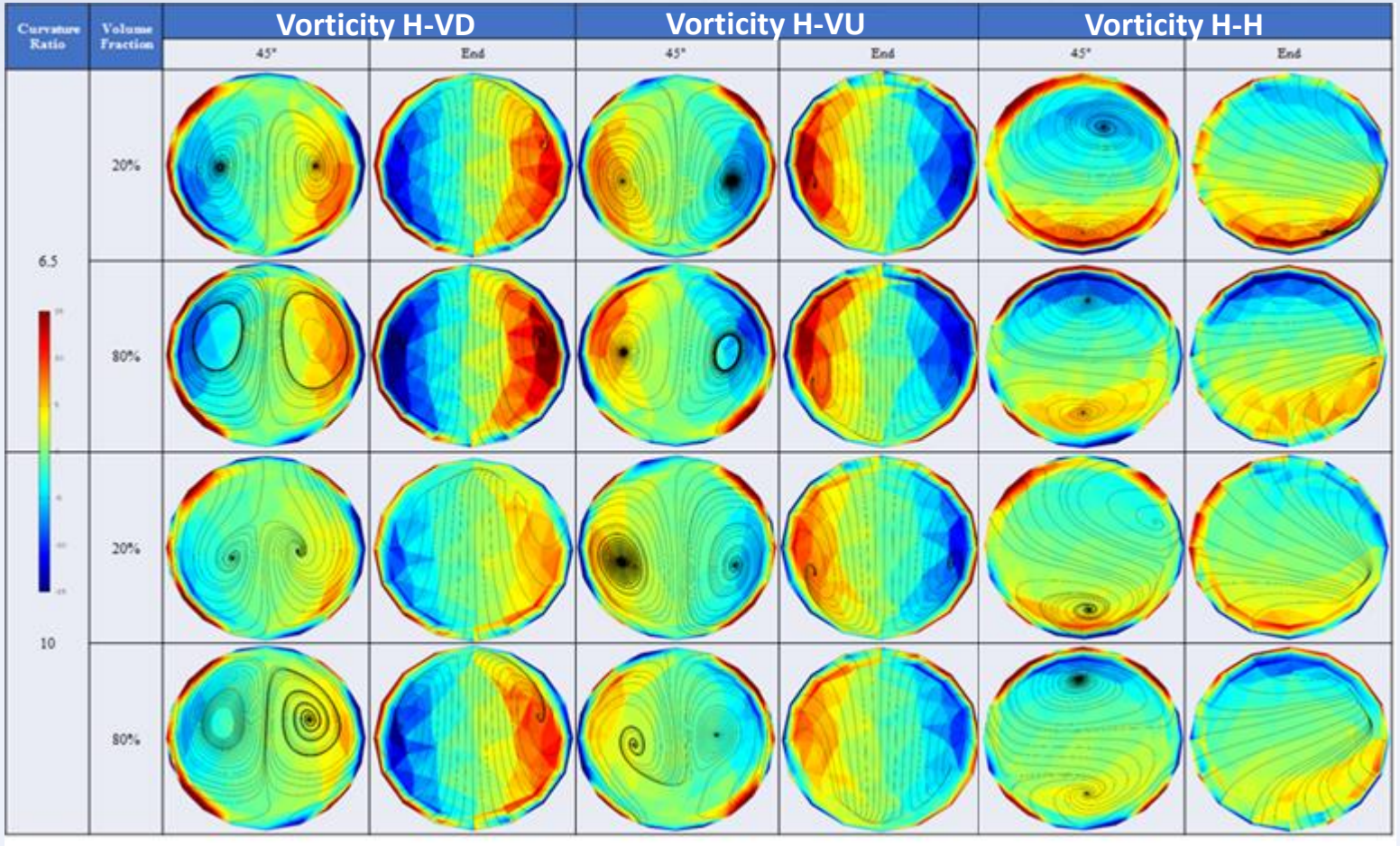

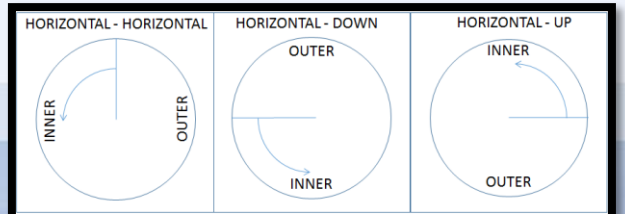

Conclusions

- The flow behavior is strongly related to gravitational and centrifugal force ratio
- Secondary flow appears, in the form of vortical structures
- Salt concentration plays little or no role on the fluid behavior
- Future work is planned to undergo a study of a gravitational-to-centrifugal ratio of 1 and behavior of two-phase Laminar flow in pipe bends

Thank You!