Numerical Study of Secondary flows in a Sinusoidal Pipe

COMSOL CONFERENCE 2016 BOSTON

O. Ayala[1], I. Ahumada[2], L. Renaundin[2]
[1]Engineering Technology Dept, Old Dominion University, Norfolk VA, USA
[2]Brazil Scientific Mobility Program, CAPES, Brasilia DF, Brazil

ODU IDEA FUSION

Introduction: In many industrial settings, secondary flows have been induced to significantly enhance heat transfer and mixing (Yang et. Al., 2000). In contrast, in cases where the fluid contains particles, it could enhance undesired erosion phenomenon. To better understand the impact of this phenomenon it is better to take a step bake and study thoroughly secondary flows in industrial bends. In this research we analyzed the flow behavior through a sinusoidal pipe with a center line following the equation "z=a sin kx". To the best of our knowledge this pipe shape has been used by some authors in their studies but they either have focused on the axial flow of non-Newtonian fluids (Iemoto et. al., 1985-1986; Goplan, 1985), enhanced heat transfer coefficient (Yang et. al., 2000; Yang and Chiang, 2000-2002;), pulsating flows (Inaba and Murata, 1978), or limited Reynolds number and curvatures (Murata et. al., 1976).

Computational Methods: Since the Reynolds number is one of the main parameters that influence secondary flows; in this study 4 were used, in the case of laminar regimes (100 and 1000) and for turbulent (10,000 and 100,000), additionally 6 combinations of pipe amplitude (a) and period (1/k) were applied to the study. In order to compare the sinusoidal pipe with bends which are normally used on the industry, the equations $\theta = \operatorname{atan}(ka)$ and $Rc = \left(\frac{k}{D\pi \sin(\theta)}\right)$ were developed, making a correlation between the sweep angle (θ) and the period (k) times the amplitude (a) and between radius of curvature on the point of inflection (Rc) and the period (k).

28	1.5	6.5	10
Θ (degrees)	22.5	45	

Table 1: Values of Radius of Curvature and Sweep angle

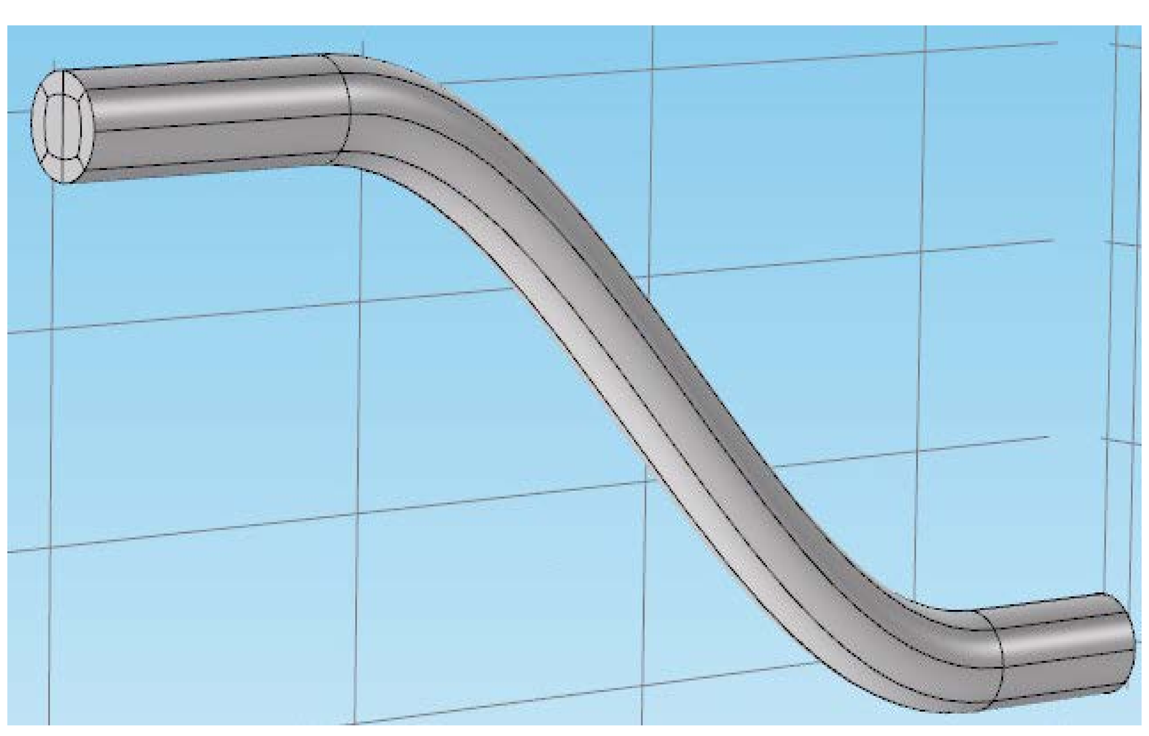

Figure 1: Geometry of Rc=6.5; θ = 45 degrees

For this numerical study the carrier fluid was water following the sinusoidal pipeline for which COMSOL 5.1 was used, using the Single Phase Flow Module with Turbulent K-ϵ Model for turbulent regimes and the Laminar Module in the cases for laminar regimes.

Results:

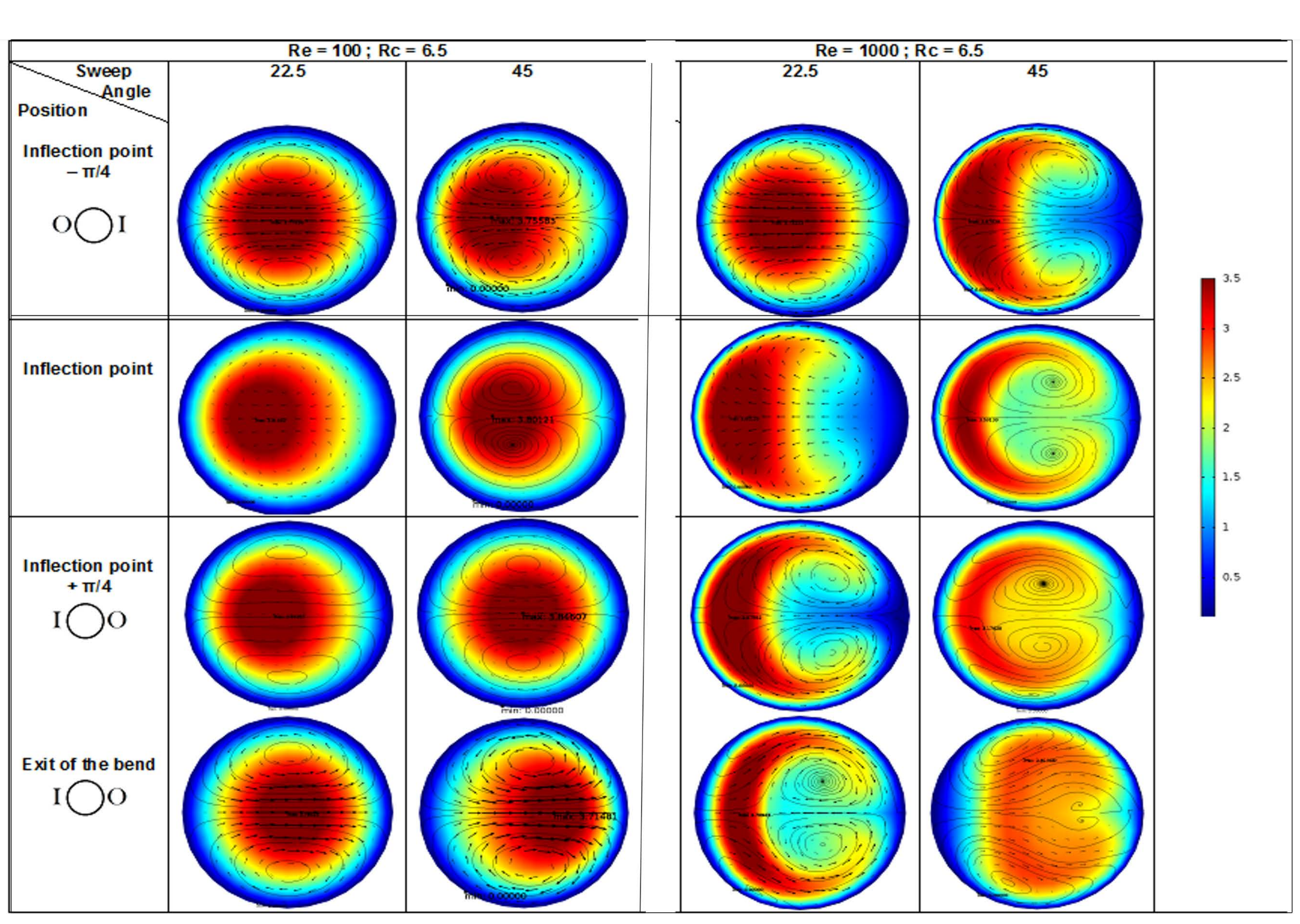

Figure 2: Axial velocity and streamlines for Re= 100;1000 and Rc= 6.5 for all θ

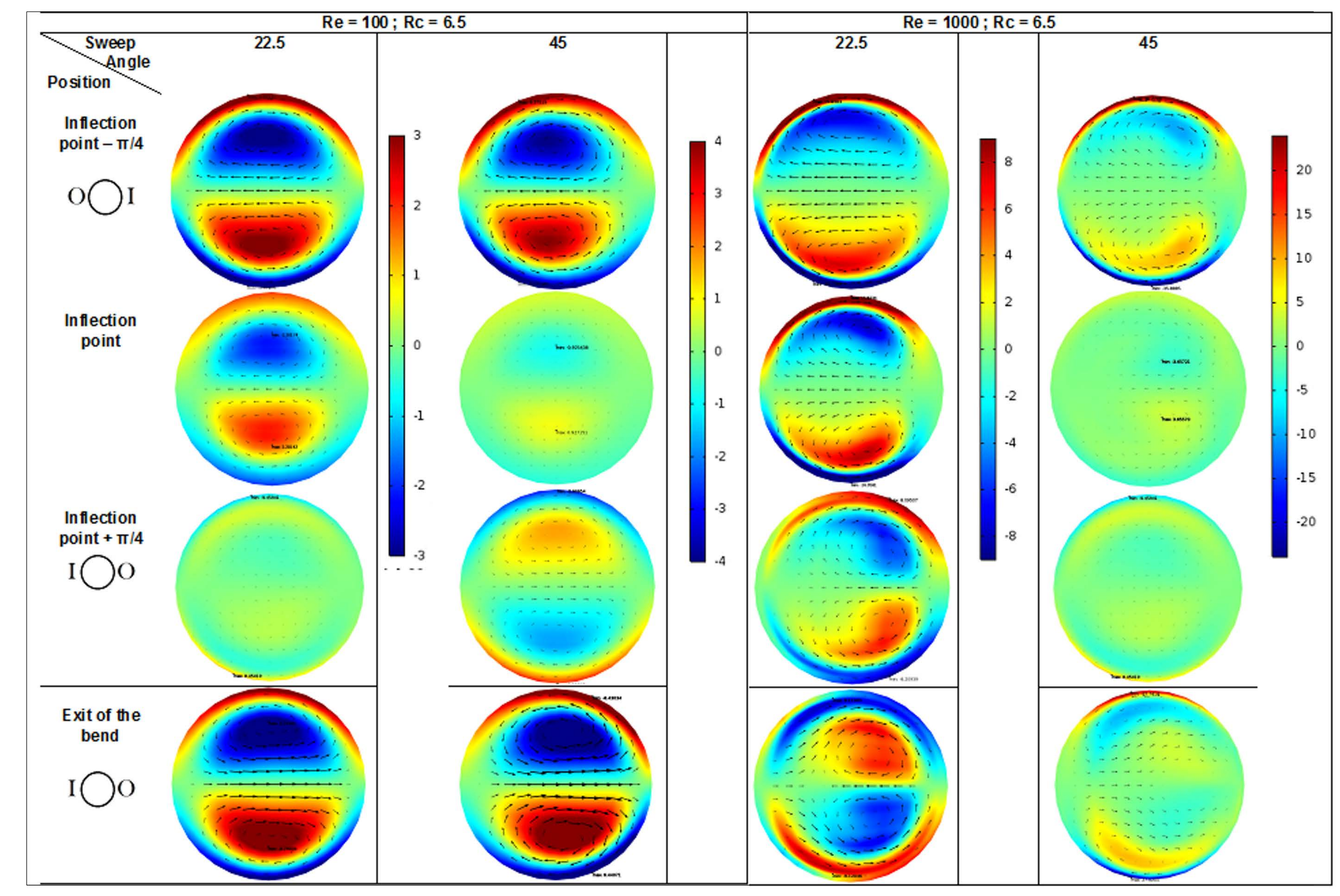

Figure 3. Normalized Vorticity for Re= 100; 1000 and Rc= 6.5 for all θ

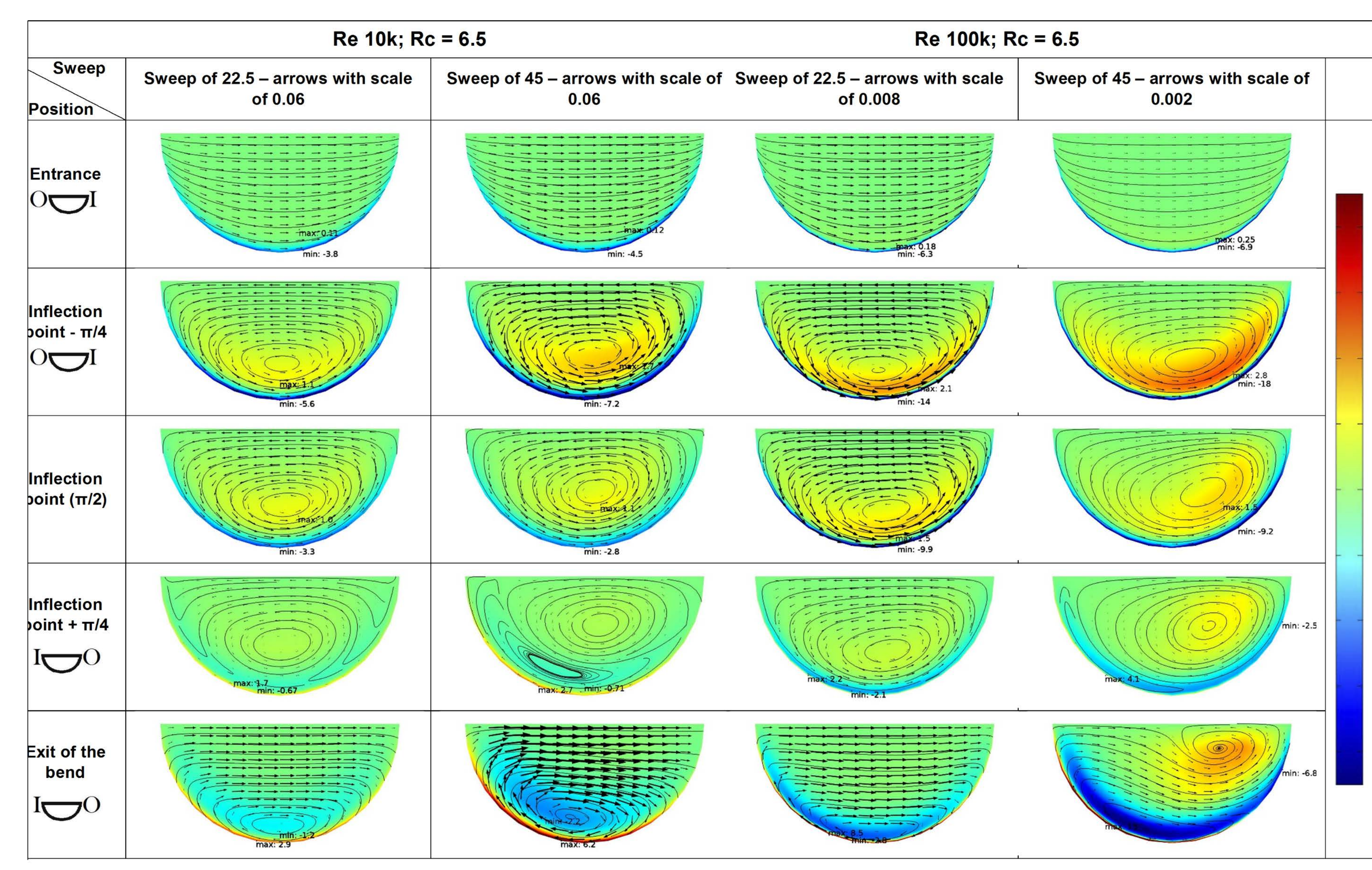

Figure 4. Normalized Vorticity for Re= 10,000; 100,000 and Rc= 6.5 for all θ

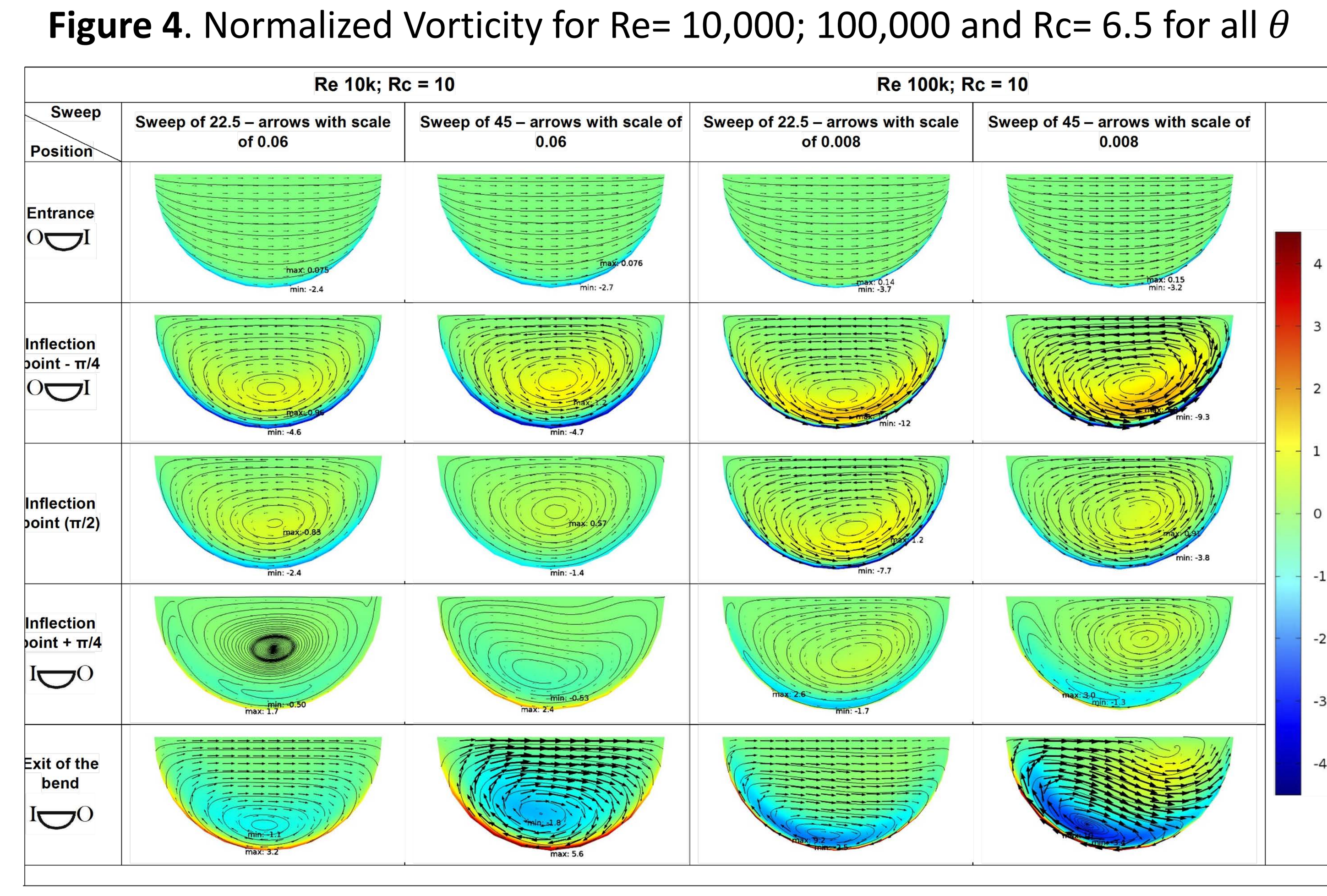

Figure 5. Normalized Vorticity for Re= 10,000; 100,000 and Rc= 10 for all θ

Conclusions:

- The direction of the fluid is strongly related to the Reynolds number; as it increases, so does the centrifugal acceleration which tends to push the axial flow towards the outer side of the pipe
- Secondary flow appear as 2 or 4 vortical structures after the inflection point
- For low Reynolds number, the rotational direction of vortical structures remains unchanged
- The core of the vortical structures get closer to the wall as the Reynolds number increases

References:

1. R. Yang et.al. Flow And Heat Transfer In A Curved Pipe With Periodically Varying Curvature, International Communications Heat Mass Transfer Vol. 27, No. I, pp. 133-143, 2000
2. S. Murata et.al. Laminar flow in a curved pipe with varying curvature, Journal Of Fluid Mechanics vol. 73, part 4, pp. 736-752 ,1976