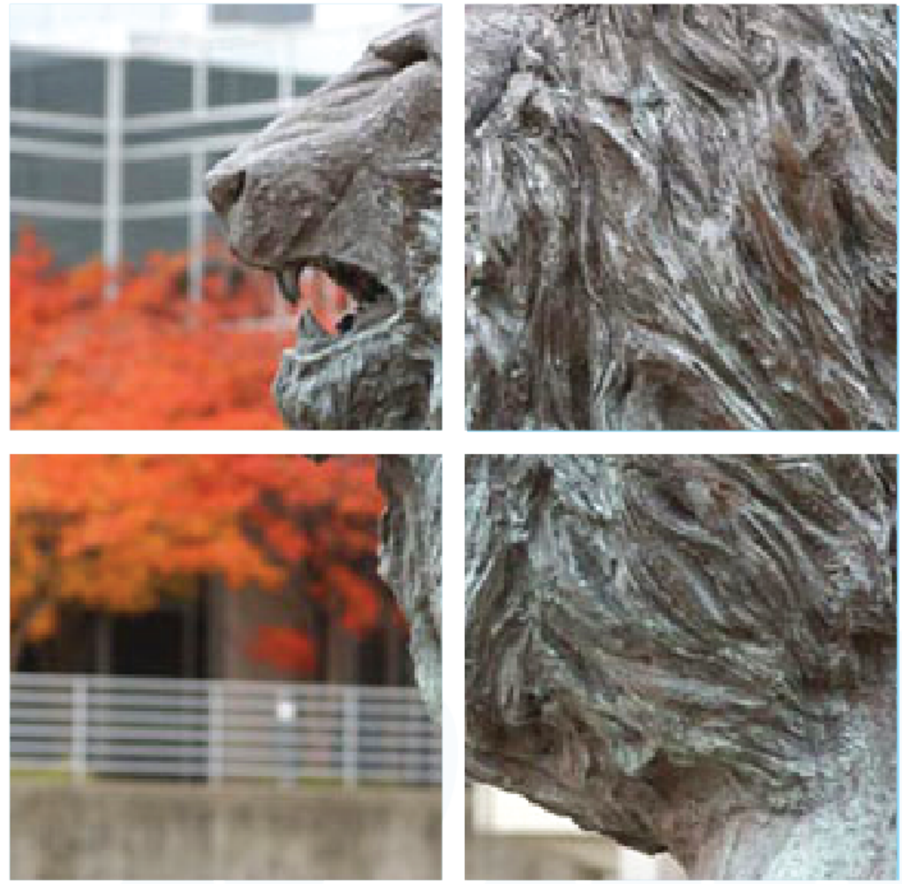
OLD DOMINION UNIVERSITY

IDEA FUSION



Reynolds Number and Geometry Configuration Effect on Secondary Flows in S-Shaped Circular Bends

COMSOL CONFERENCE
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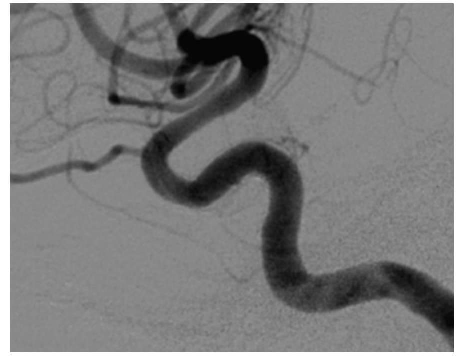
CFD Session

O. Ayala, M.F. Degenring, P. Loures

Introduction



S-shaped bends can be found in industrial pipe layouts and even in arteries!

- Presence of secondary flows
- If particles → erosion might be found

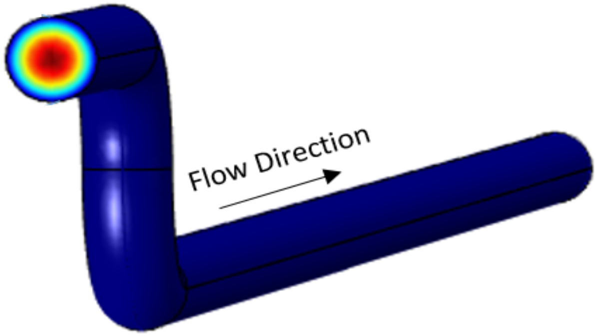
- Most studies on laminar flows
  (Hoogstraten et al.,1996; Johnston and Johnston,2008; Niazmand and Jaghargh, 2010)

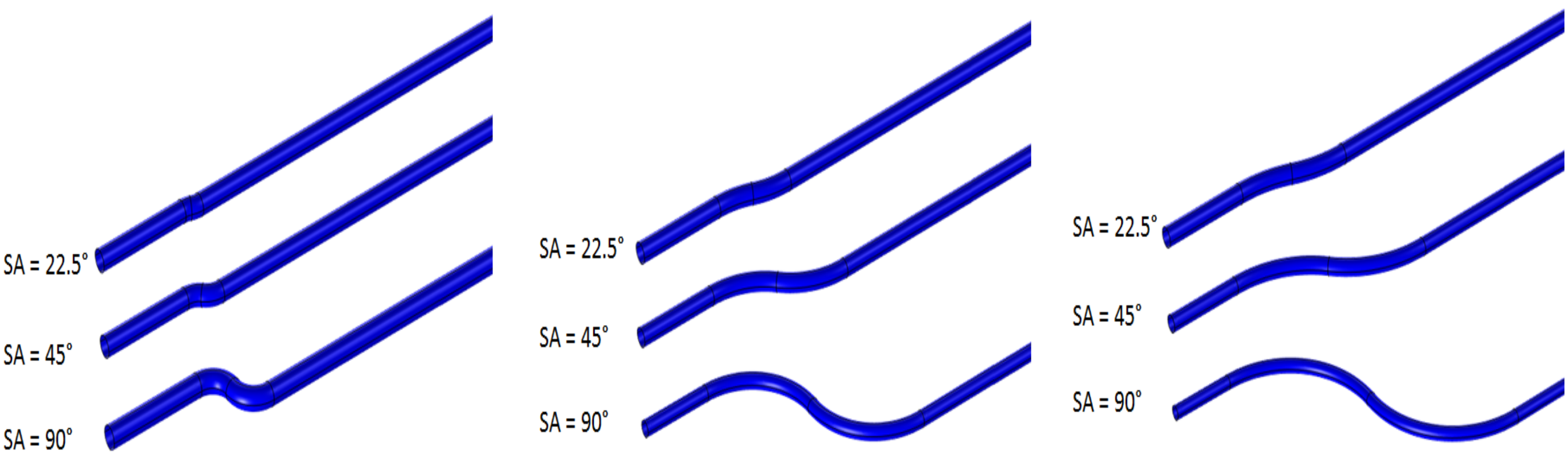
- Few for turbulent flow but:
  - non-circular cross sections (Ng and Birk, 2013; Debnath et al. 2015)
  - primary flow interest only (Mazhar et al., 2014)
  - limited Reynolds numbers (Taylor, 1984)

Physical Model

- Sweep Angle (SA)
- Radius of Curvature (RC)
- Reynolds Number

  100, 1000, 10 000, 100 000





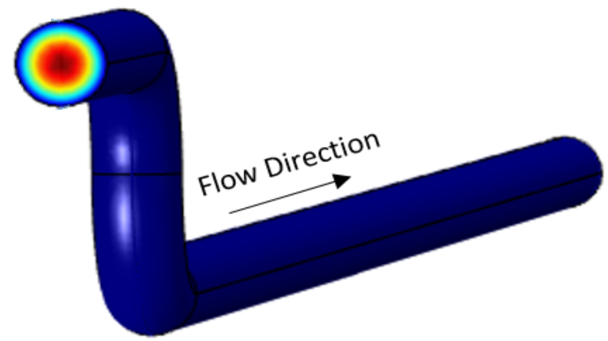
RC = 1.5D RC = 6.5D RC = 10D

Mathematical and Numerical Model

$$\rho\frac{\partial \mathbf{v}}{\partial t} + \rho\mathbf{v}\cdot\nabla\mathbf{v} = \mu\nabla^2\mathbf{v} - \nabla P$$

$$\nabla\cdot\mathbf{v} = 0$$

k-*ε* model



COMSOL

▪ INLET	Velocity profile
▪ OUTLET	Constant pressure
▪ WALL	Non-slip or Wall functions
▪ STRAIGTH PIPES	Long enough (sensitivity)

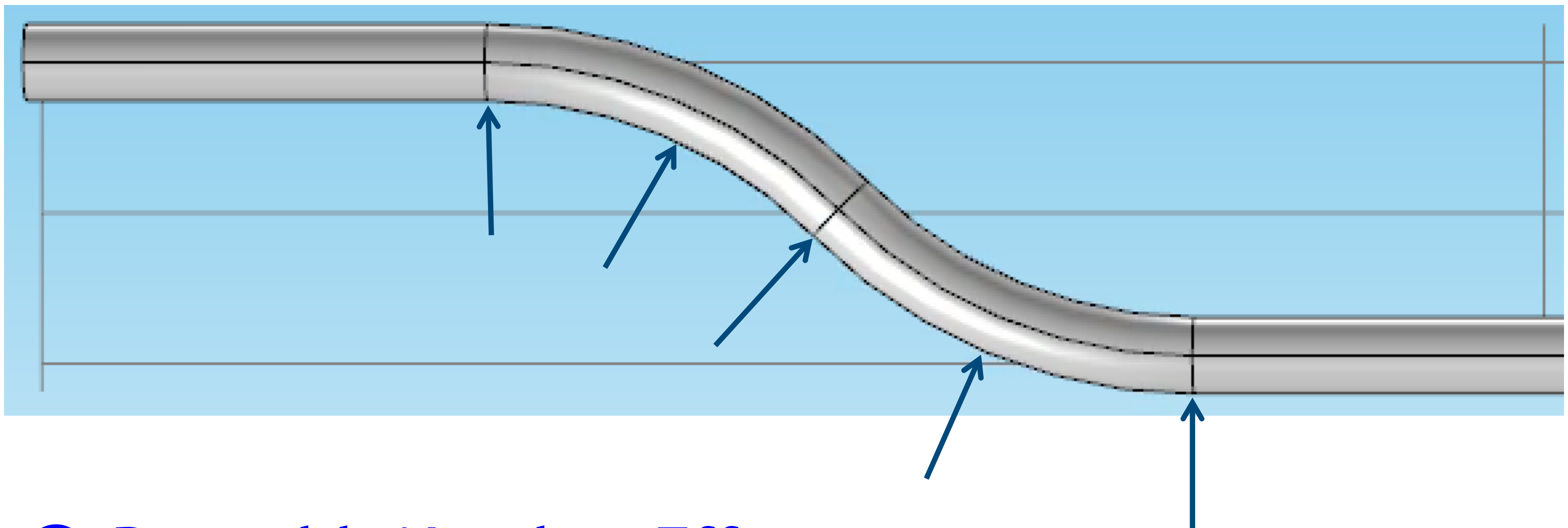
MESH SENSITIVITY

(normal mesh→5% diff, y^+~12)

VALIDATION

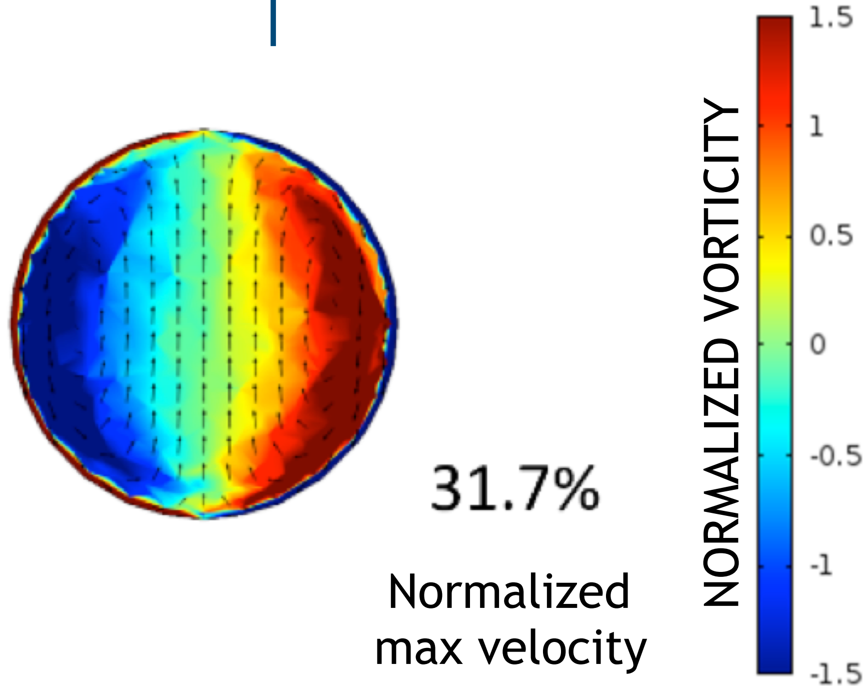
(Niazmand and Jaghargh, 2010)

Results



① Reynolds Number Effect
② Radius of Curvature Effect
③ Sweep Angle Effect

a) Velocity vectors
b) Normalized max velocity
c) Normalized vorticity

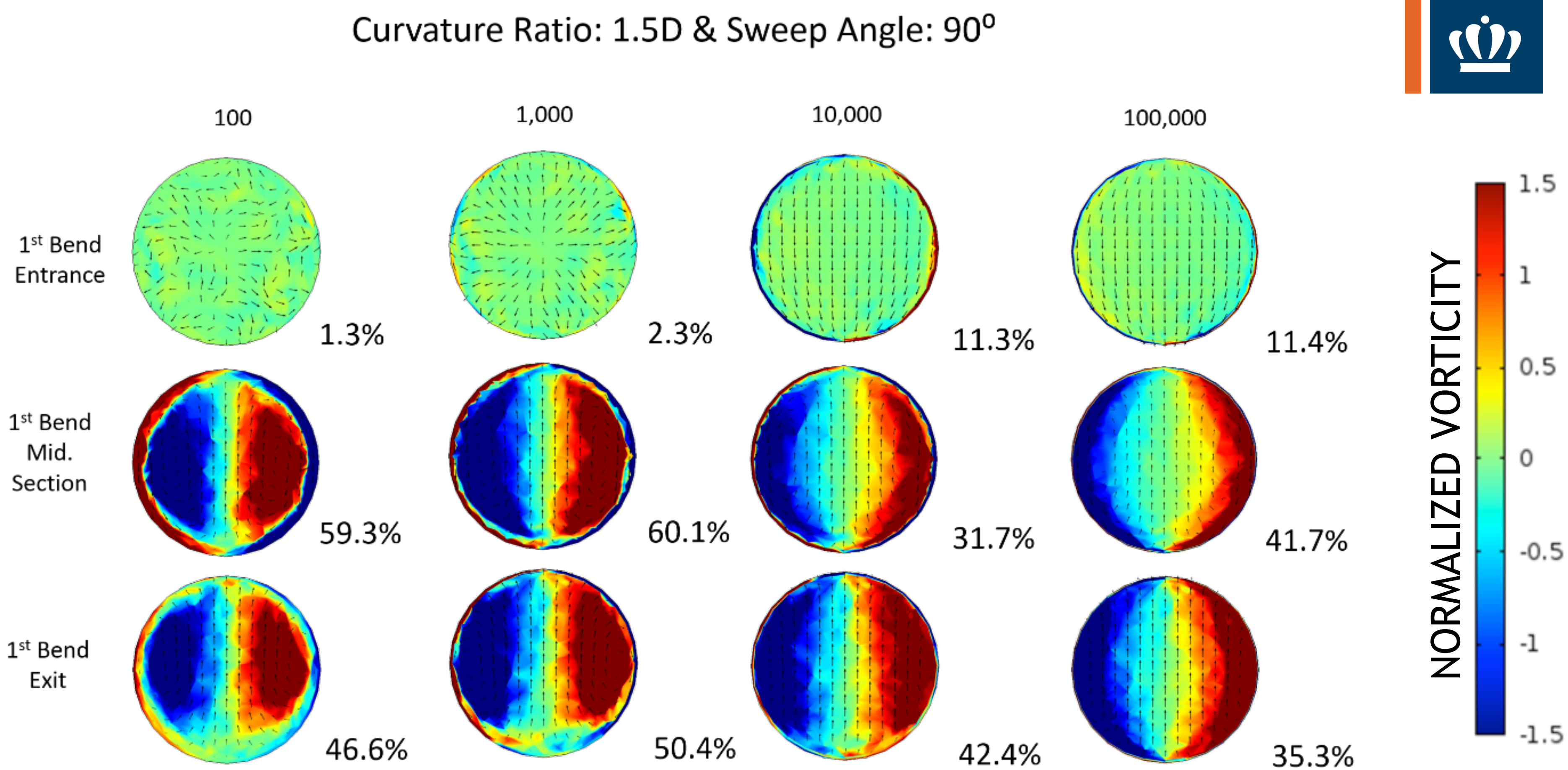


31.7%

Normalized max velocity

Results

Reynolds Number Effect



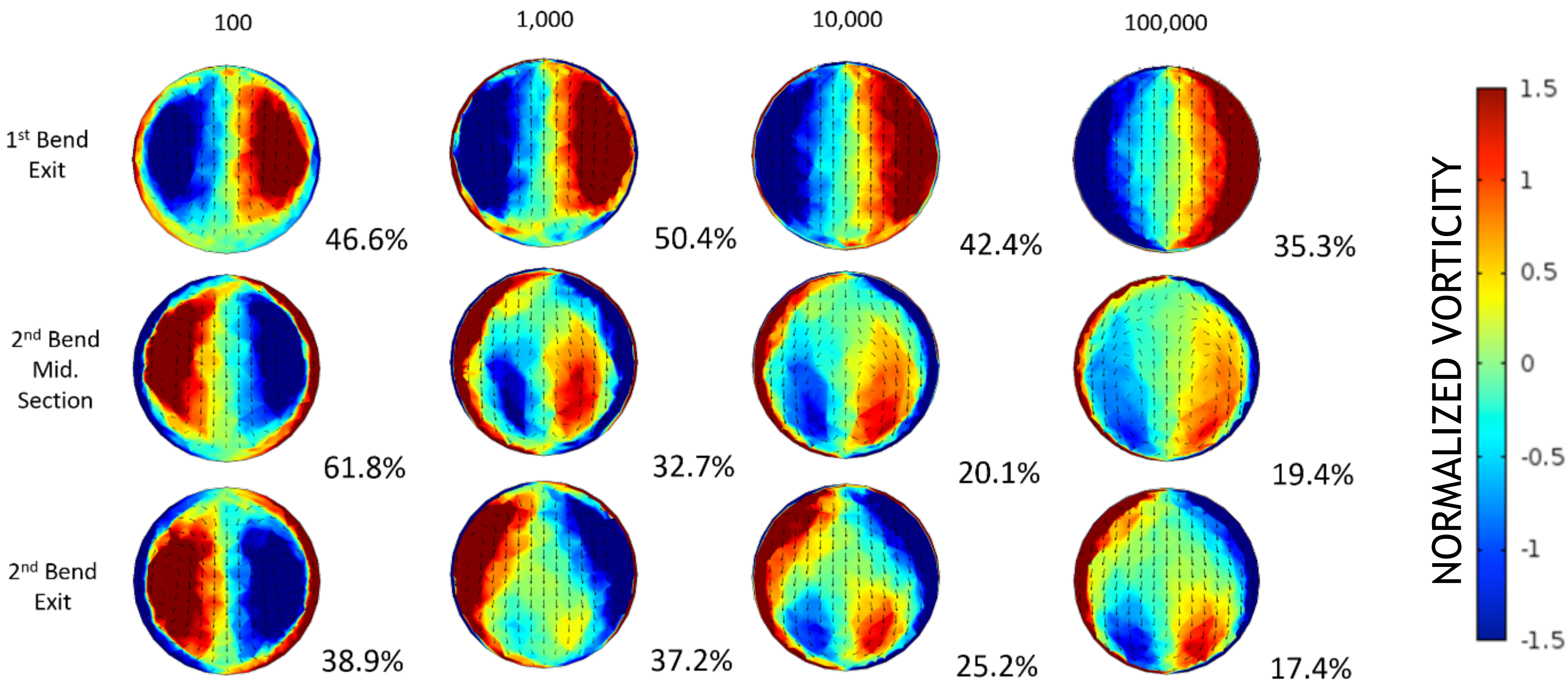
$$a_c \propto \left(\frac{u_{axial}^2}{r} \right)$$

Normalized max velocity

Results

Reynolds Number Effect

Curvature Ratio: 1.5D & Sweep Angle: 90^{o}



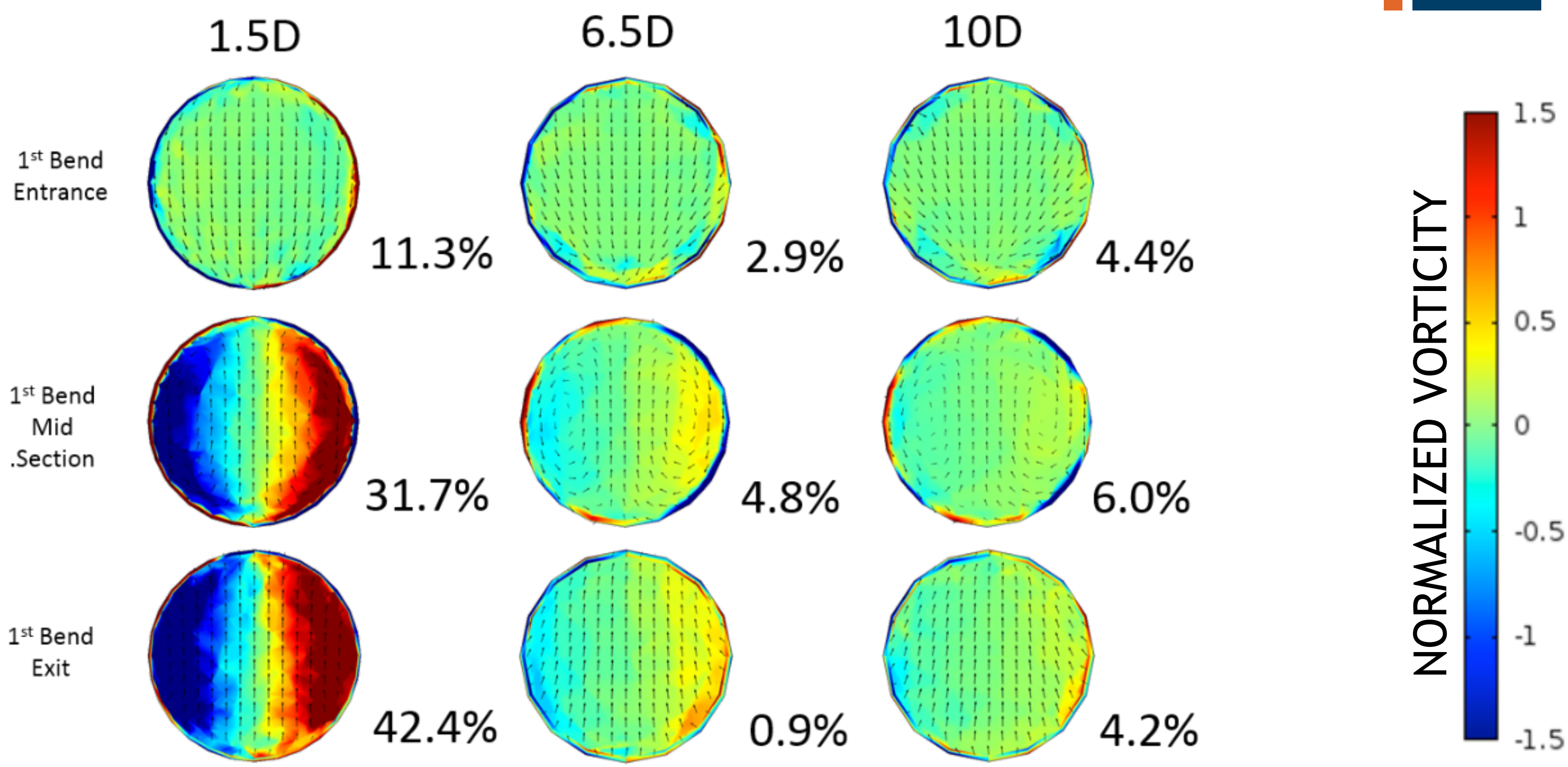
$$a_c \propto \left(\frac{u_{axial}^2}{r} \right)$$

Normalized max velocity

Results

Radius of Curvature Effect

Reynolds Number: 10,000 & Sweep Angle: 90°



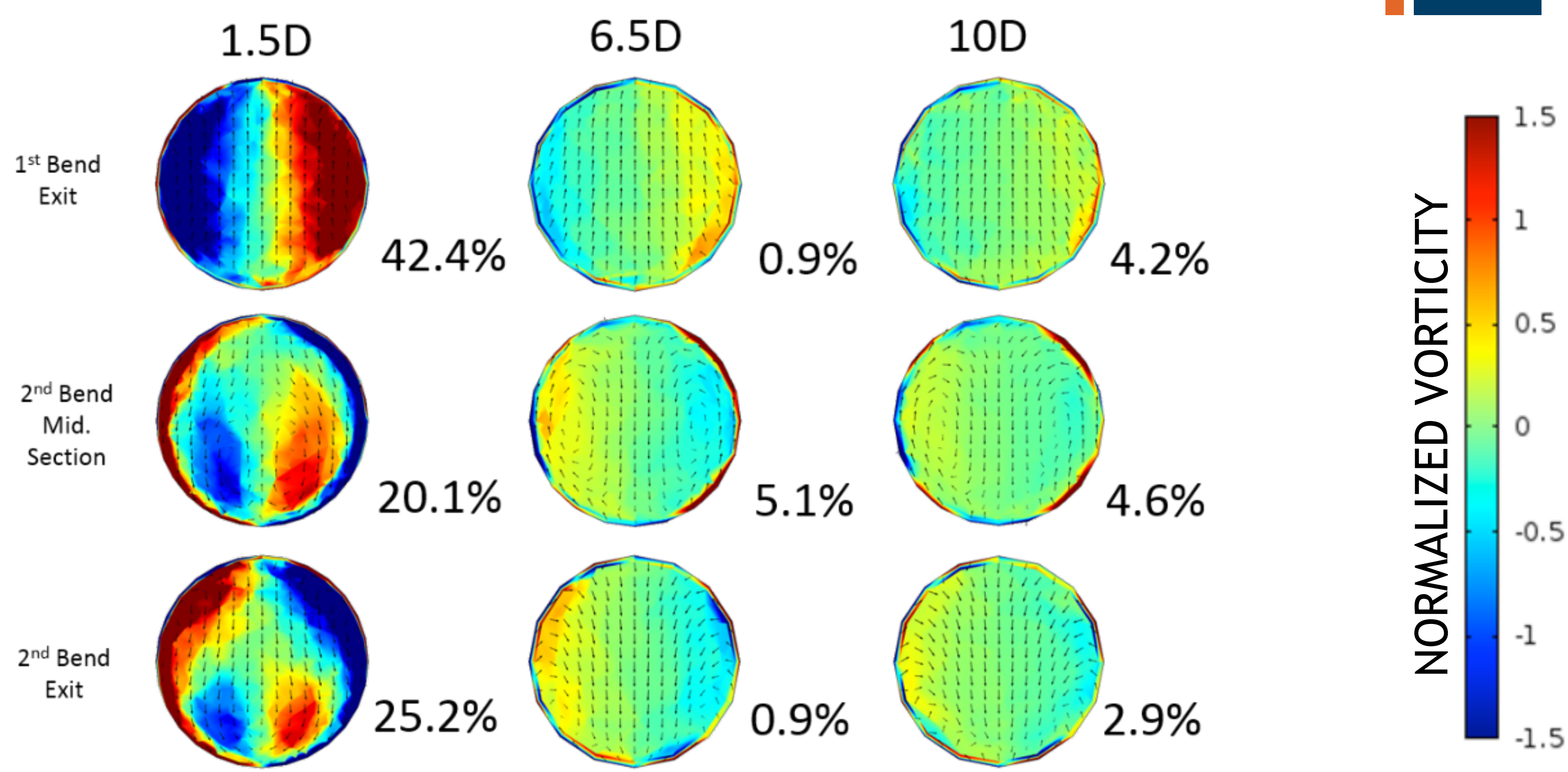
$$a_c \propto \left(\frac{u_{axial}^2}{r} \right)$$

Normalized max velocity

Results

Radius of Curvature Effect

Reynolds Number: 10,000 & Sweep Angle: 90°

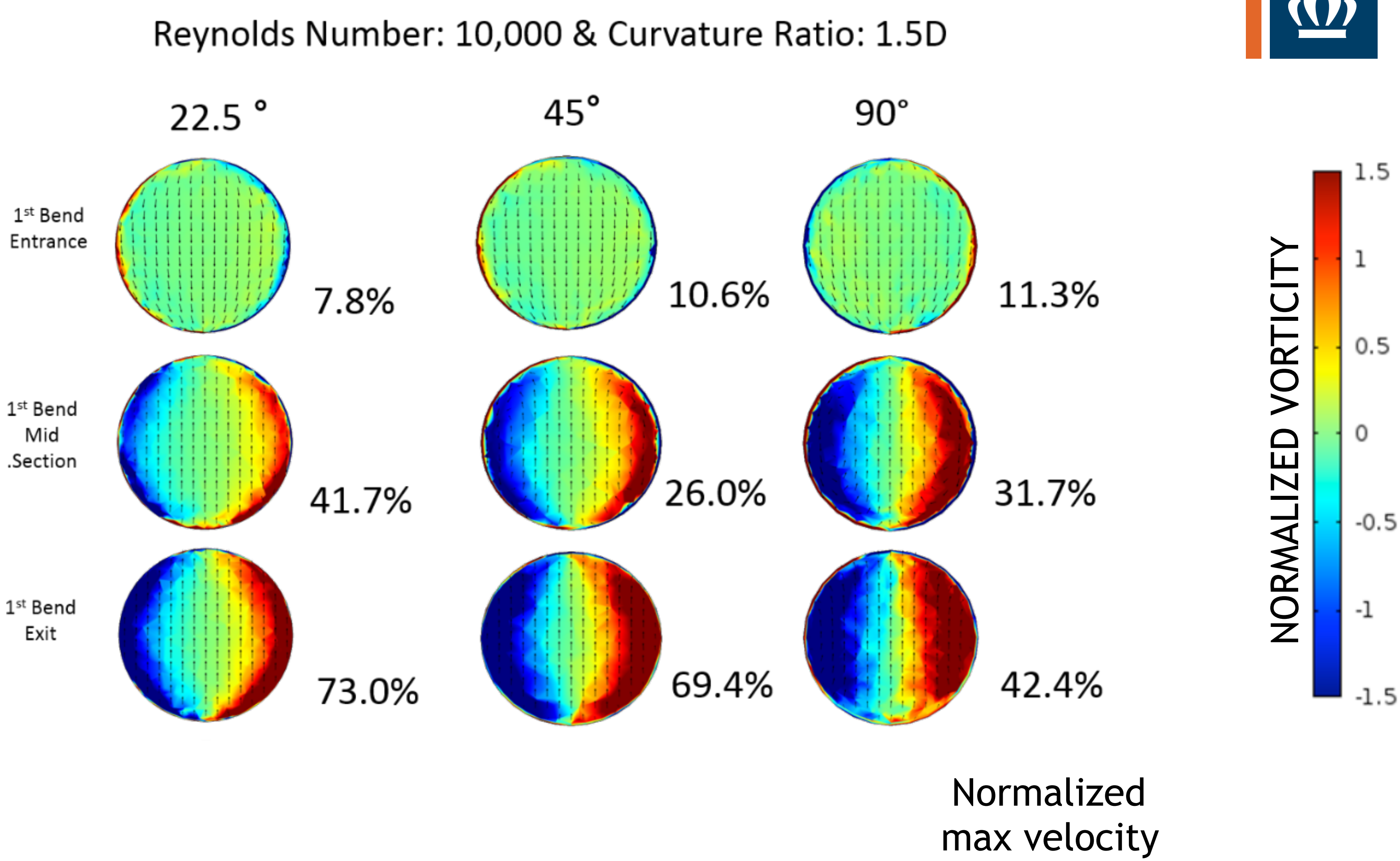


$$a_c \propto \left(\frac{u_{axial}^2}{r}\right)$$

Normalized max velocity

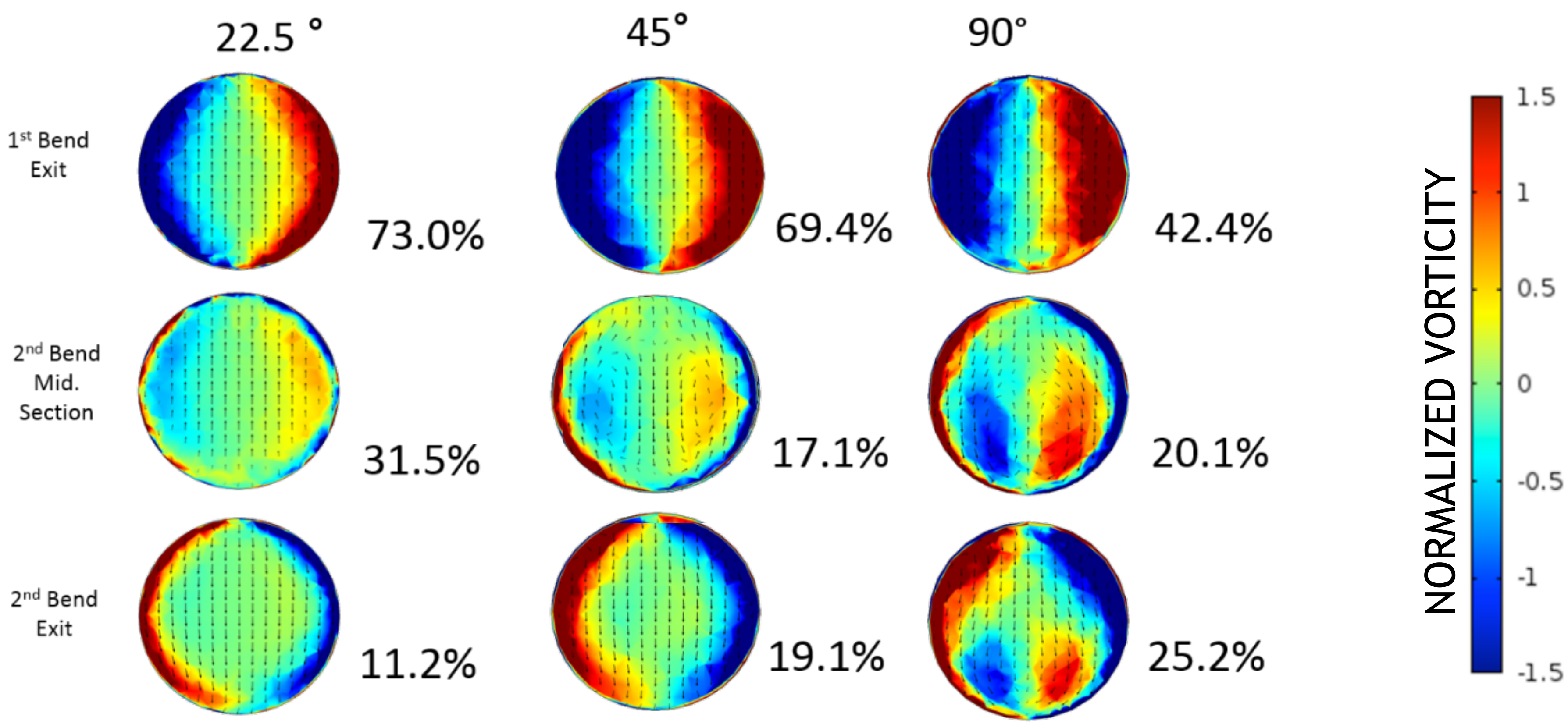
Results

Sweep Angle Effect



Results Sweep Angle Effect

Reynolds Number: 10,000 & Curvature Ratio: 1.5D



Normalized max velocity

Conclusions

- Reynolds Numbers
  - 1st bend: High Re ➔ 1st vorticity pair stays longer & closer to wall
  - 2nd bend: High Re ➔ secondary flow from 1st bend dominates
- Radius of Curvature
  - The smaller it is, the stronger the vorticity magnitude
  - The smaller it is, the harder it takes for 2nd vortical pair to develop
- Sweep Angle
  - The larger it is, the stronger the vorticity magnitude is and the longer it lasts.

OUR NEXT GOAL: Better quantification to develop models