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The Effect of Eccentricity in Fully Developed Annular Pipe Flow on the Convective Heat Transfer and Darcy Friction Factor

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Introduction: Annular flow has different turbulent and boundary layer characteristic than pipe flow. Eccentricity (e) in annular channels contributes to changes in flow properties, imposes complex challenges in the flow, affects the heat transfer process and impacts the performance and integrity of the configuration. Current pipe flow models do not accurately account for the effect of e. The present study models the effect of e in annular channels.

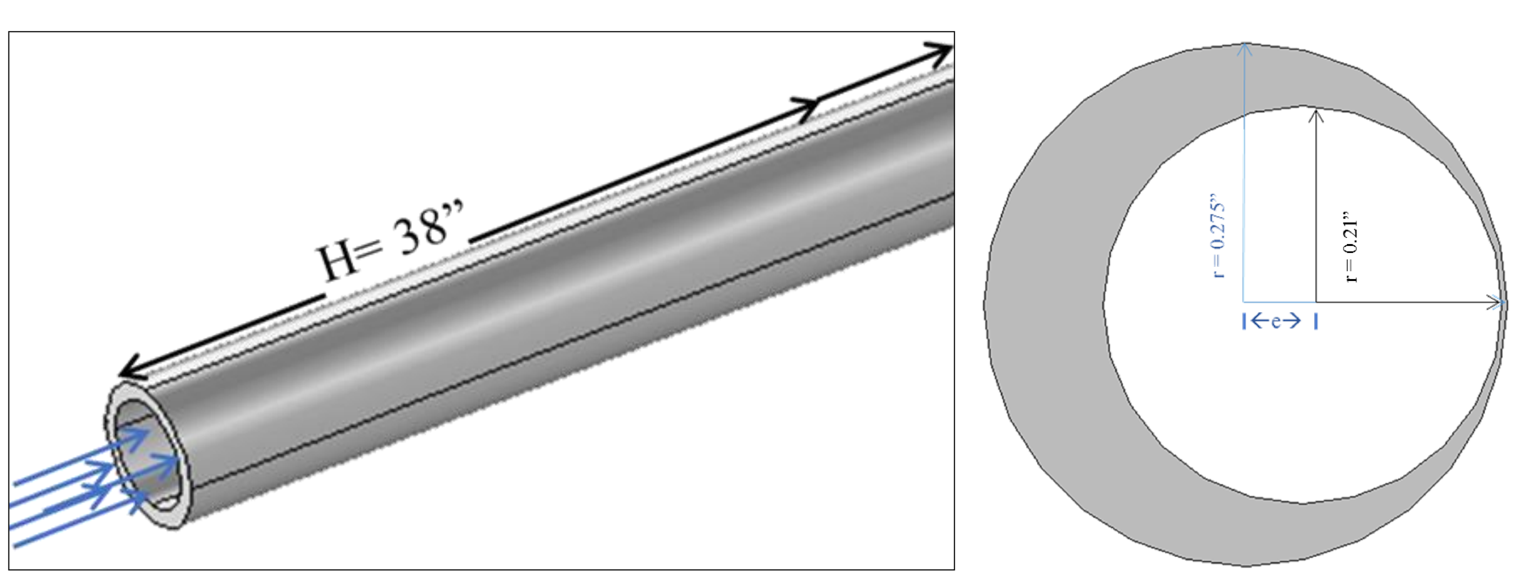

Figure 1: Annular channel with flow direction and dimensions

Computational Methods: The simulation involves a 3D annular channel with Turbulent Flow, k-ε and Heat Transfer in Fluids modules under a stationary study.

•To study the effect of e on heat transfer coefficient and Darcy friction factor

1. $e^* = e / \Delta r$
2. Seven different cases of e* were studied for one Reynolds Number value
3. The two extreme e* cases were simulated for different Reynolds Number values
4. The results were compared to Moody's chart and empirical solutions

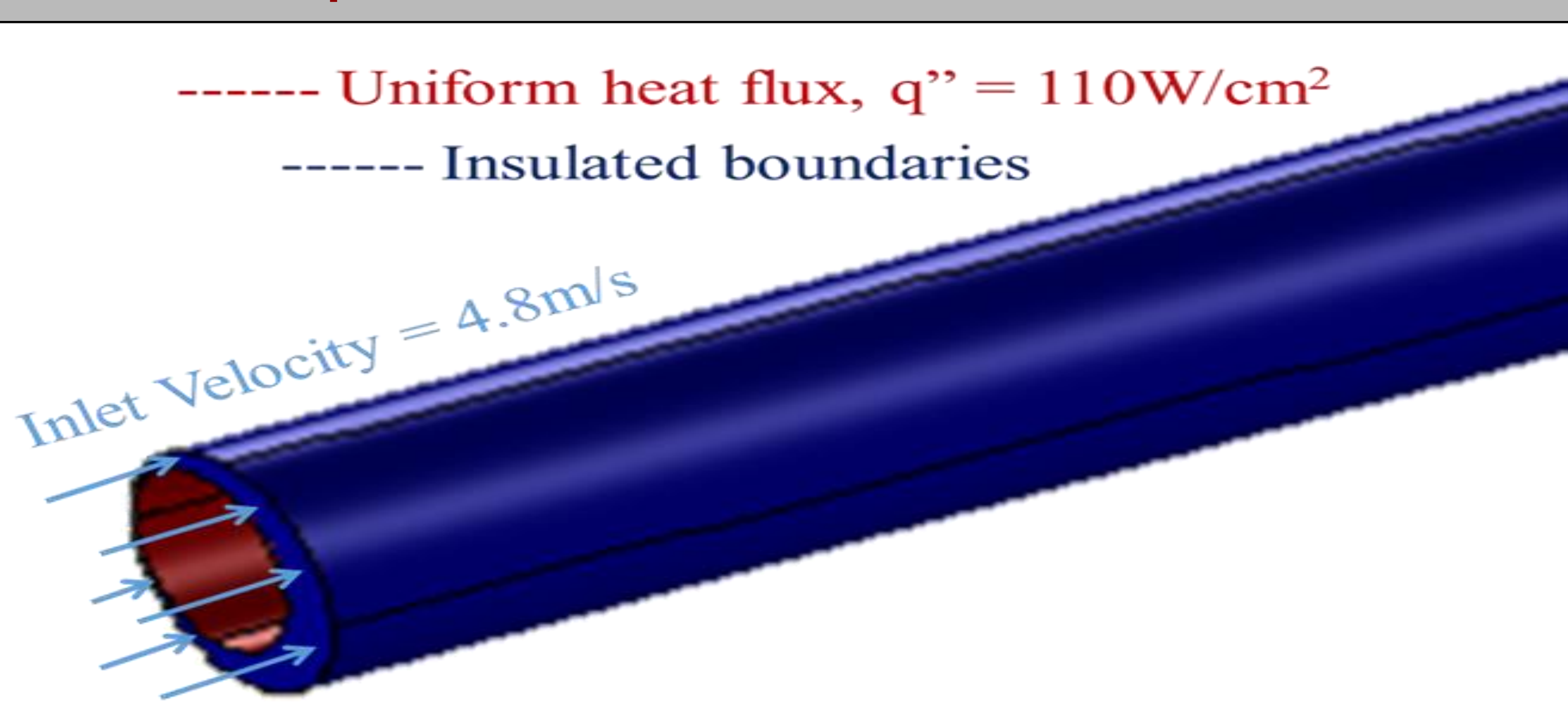

Figure 2: Annular channel with boundary conditions

Results:

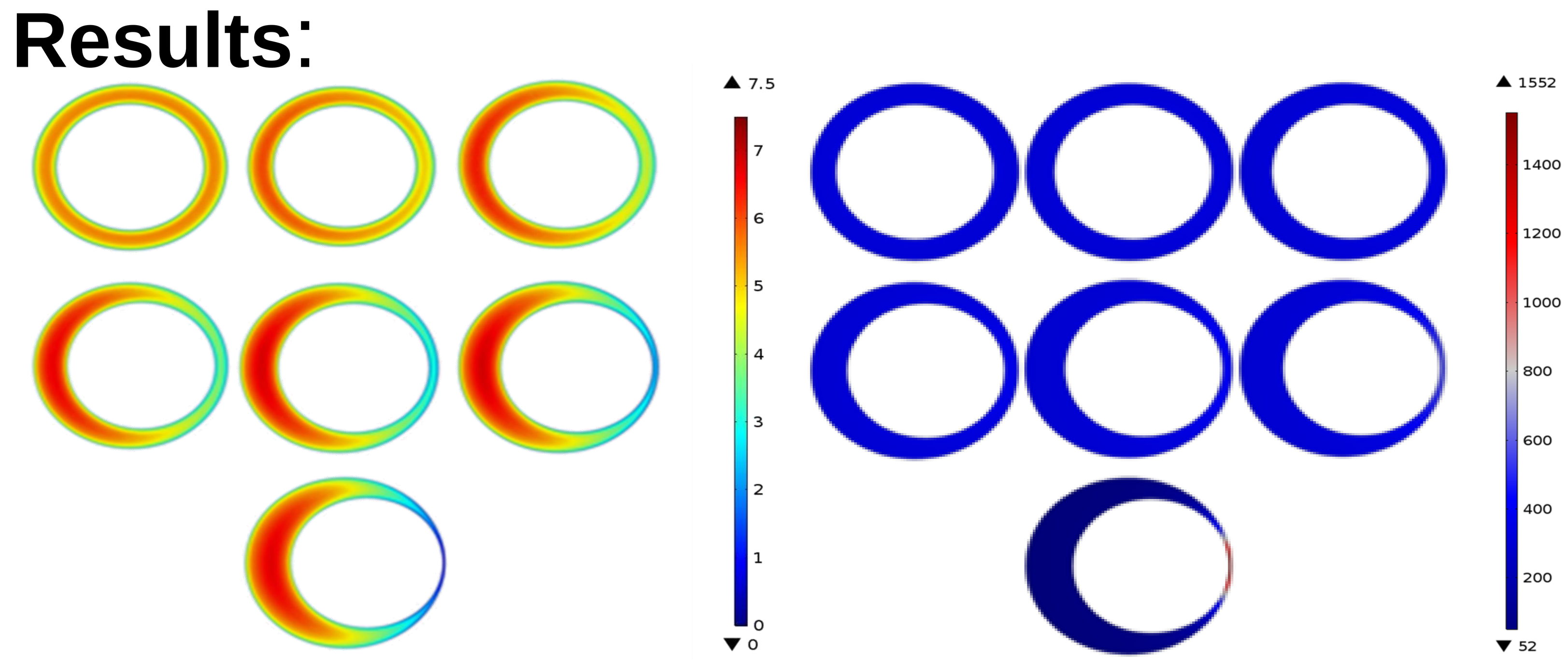

Figure 3: 7 e* cases at outlet. **Left** :Velocity(m/s) **Right**: Temperature (K)

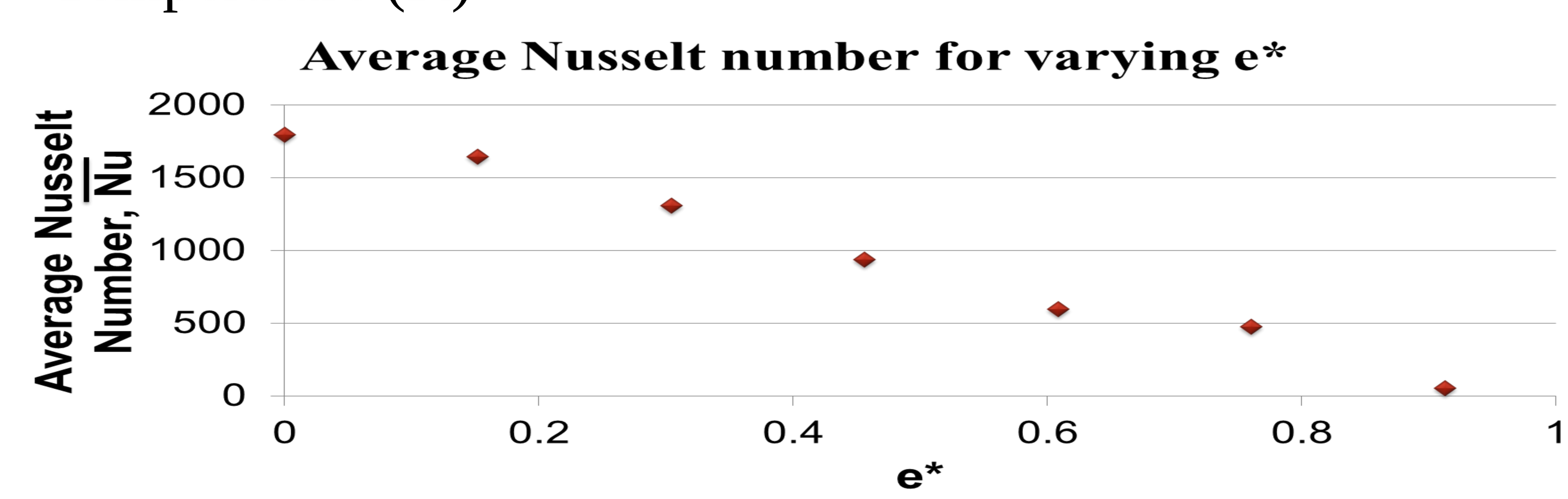

Figure 4: Average Nusselt number for varying e*

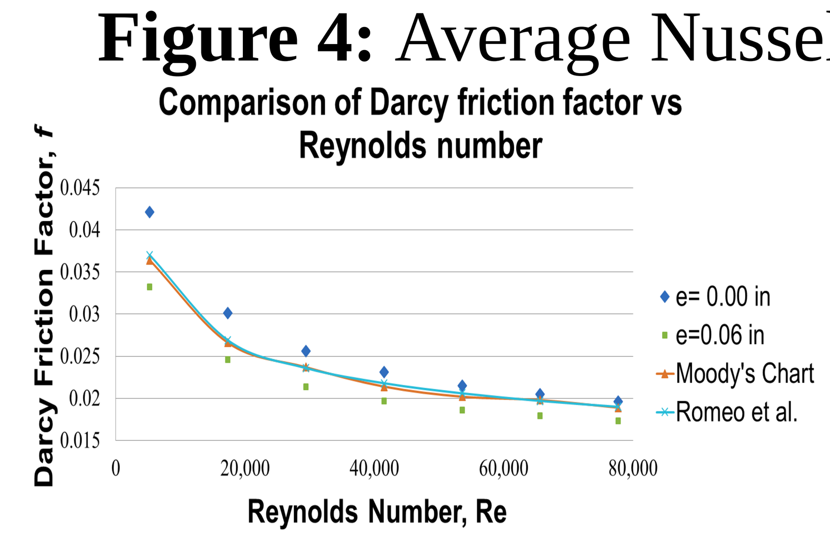

Figure 5: Friction factor comparison of computed and explicit models

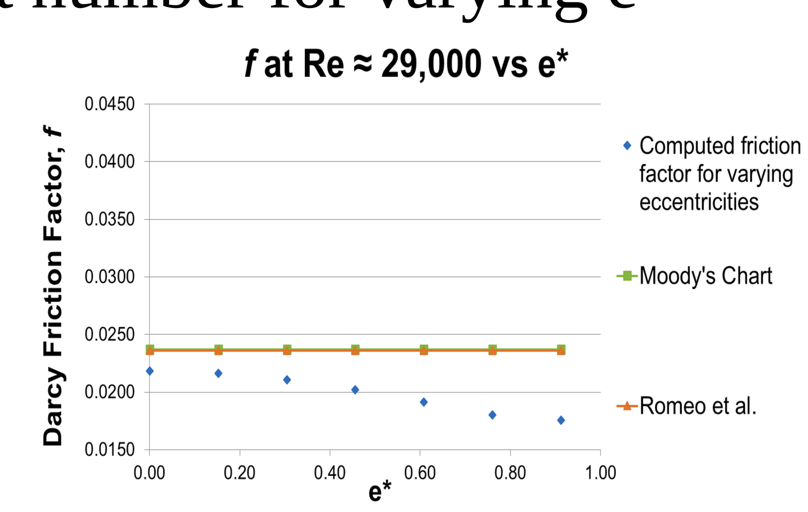

Figure 6: Friction factor comparison for varying eccentricities at Re≈ 29,000

Conclusions:

- Highly eccentric cases result in
  - extreme conditions causing the flow to change states, thus changing the properties and behaviors
  - unfavorable surface temperatures which impose safety hazards and structural failures
- Pipe flow and annular flow have different flow characteristics
- For e*>0.7, analysis is necessary to avoid extreme behaviors and failures

References:

-E. Romeo et al., "Improved explicit equations for estimation of the friction factor in rough and smooth pipes", Chemical Engineering Journal, 2001

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