Comparing Open-Source and Commercial Software Solvers for Hagen-Poiseuille Flow

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Introduction

- There is a large potential for leveraging computational evidence in the regulation of medical devices.
- Computational evidence for regulatory applications must be credible, trustworthy, high quality, reproducible, and transparent.
- It is possible to build credibility into computational models by breaking down complex systems into simpler verifiable models.

Background

Medical Device: An Electronic Drug Delivery System has an inner pipe with an atomizer spanning 1/5th of the pipe.

Simplified System: Hagen-Poiseuille pipe flow (without coils)

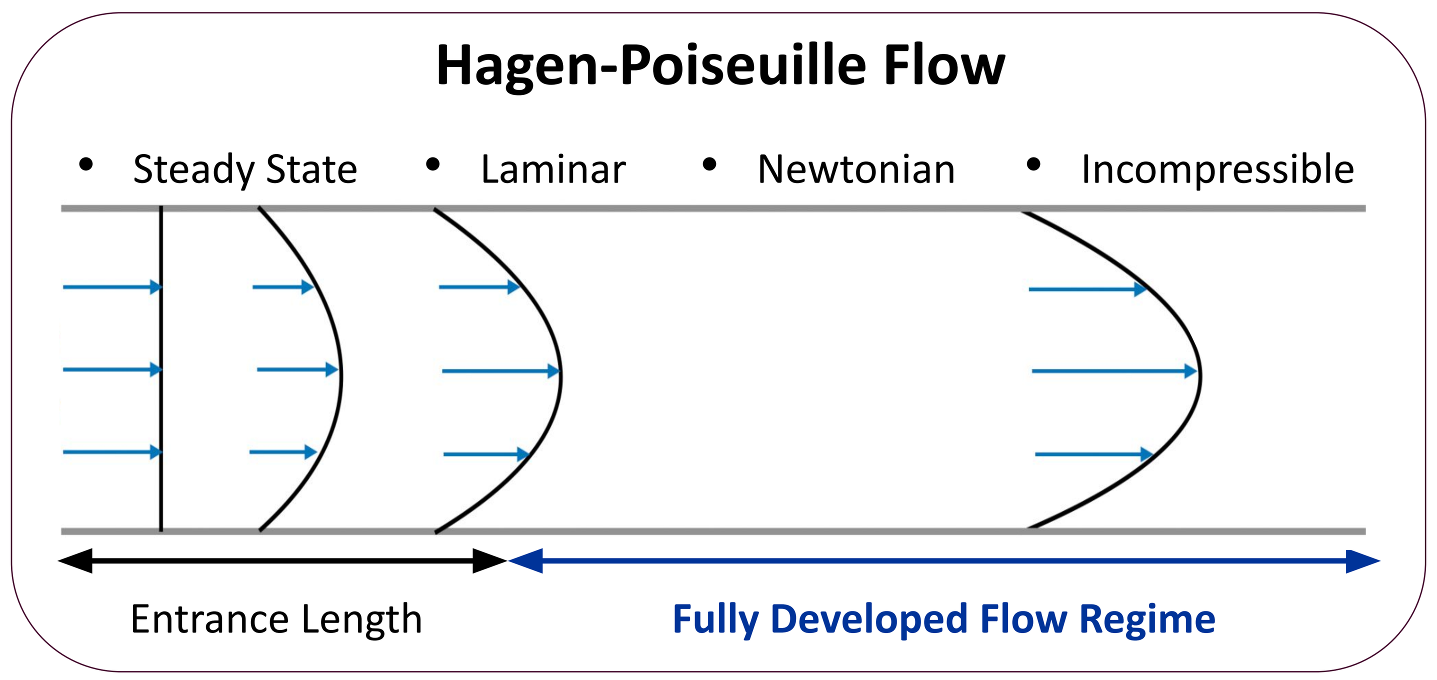
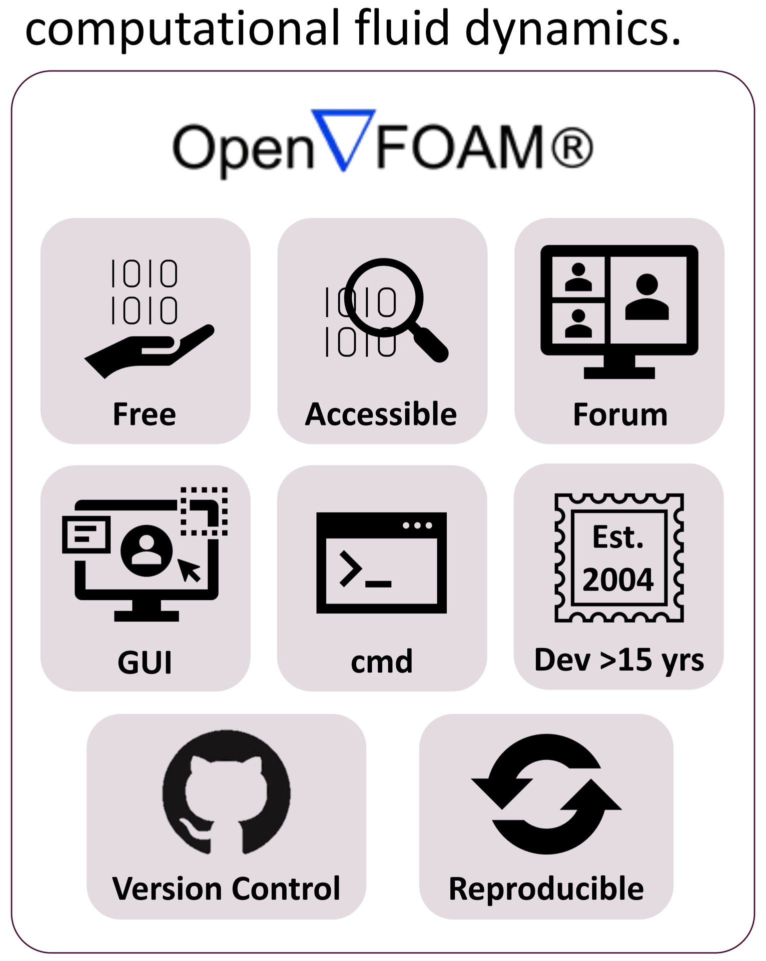
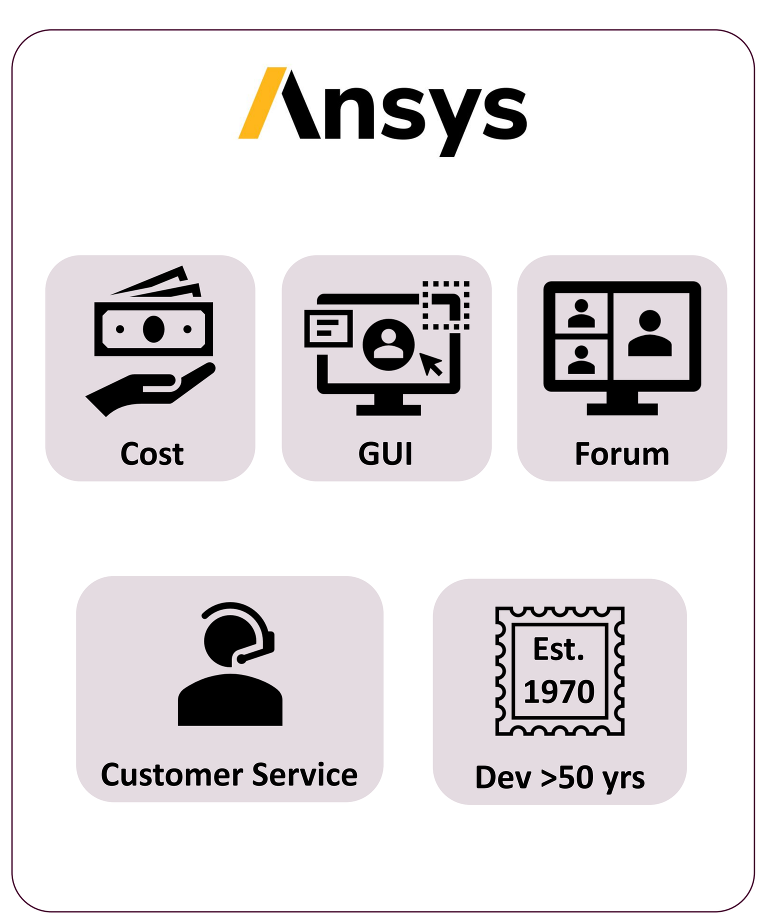


Figure 1: The pipe has a length of 0.12 [m] with a radius of 0.00227 [m]. The uniform inflow velocity is 0.5216 [m/s]. The output velocity is twice the inflow velocity.

Methods

Select a commercial and an open source software that simulate computational fluid dynamics.



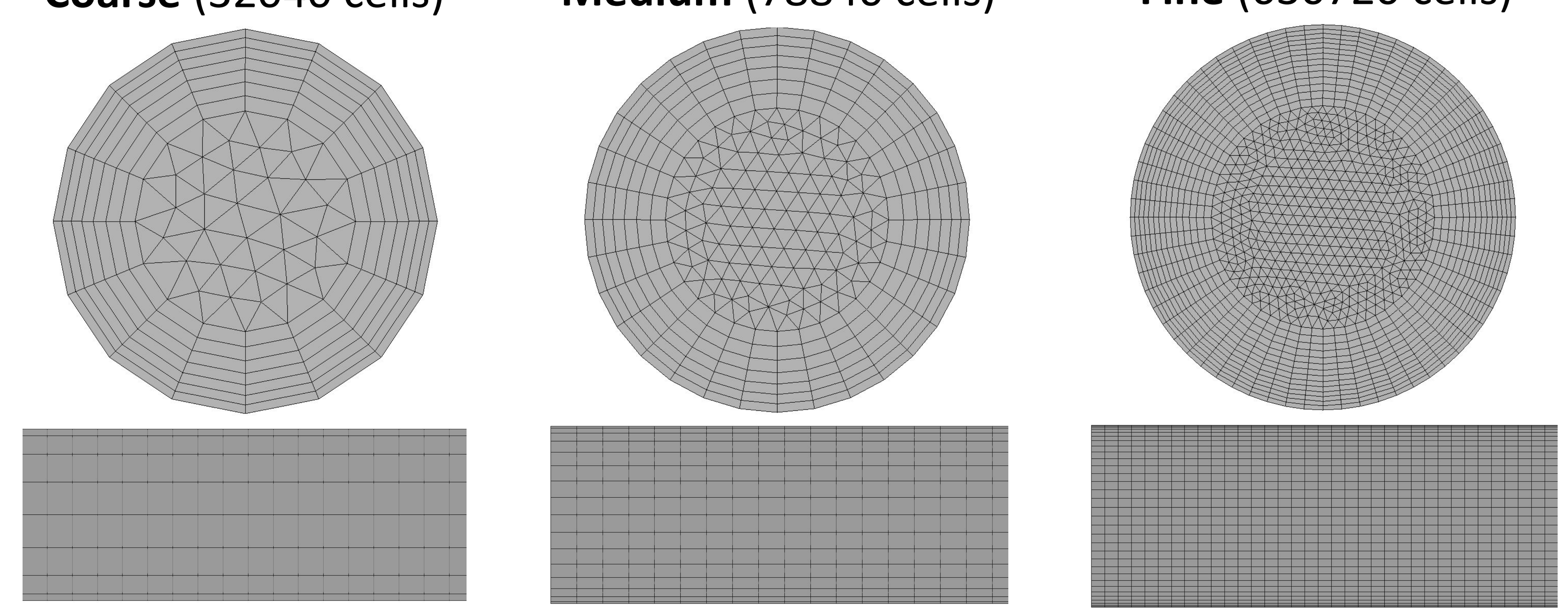


Initiate a reproducibility infrastructure by implementing knowledge management, project management, and version control

Establish the model based on the physics of the Hagen-Poiseuille pipe flow including the geometry, initial conditions, boundary conditions, fluid properties, and flow regime.

Find the best mesh and create three mesh resolutions.

Coarse (32040 cells) **Medium** (78840 cells) **Fine** (630720 cells)



Develop two computational models using the same physics model and spatial discretization: **OpenFOAM** model, **ANSYS** model.

Compare simulation results at the three mesh resolutions with the Hagen-Poiseuille analytic solution.

Results

Both a qualitative and quantitative assessment were conducted in order to compare both the **OpenFOAM** model and the **ANSYS** model.

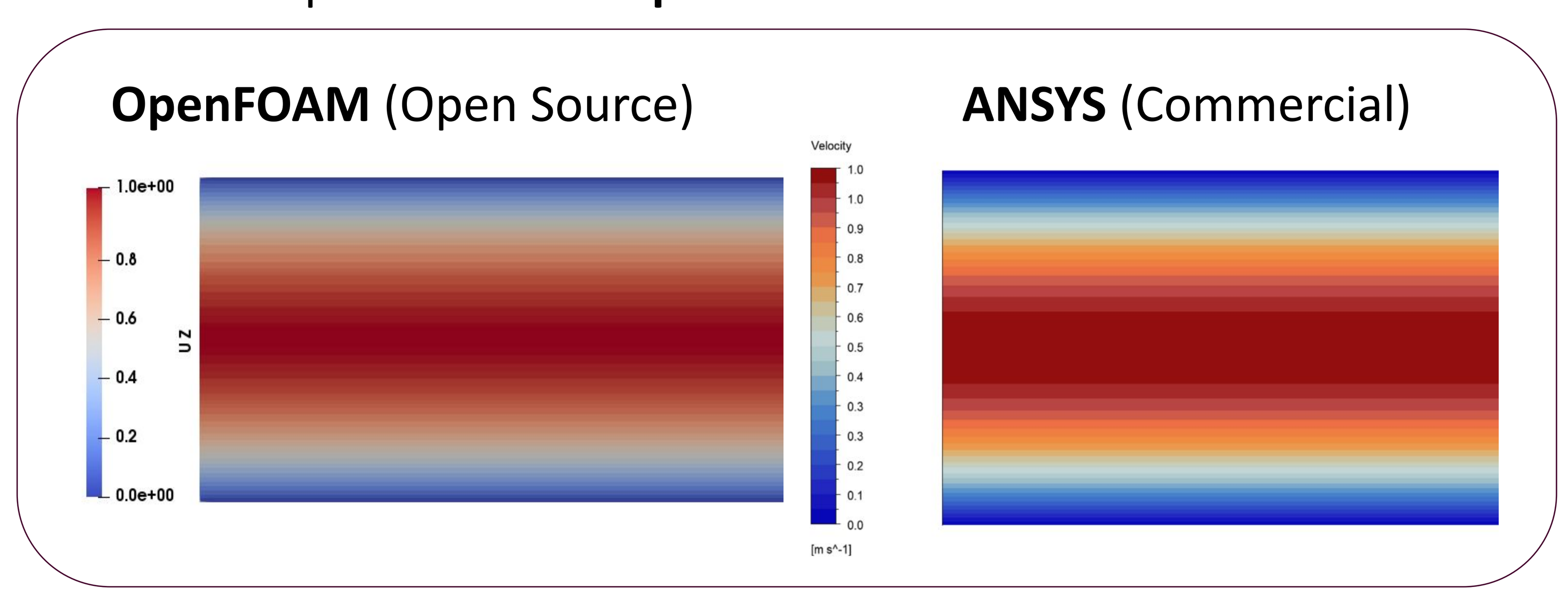


Figure 2: The velocity contours across the YZ plane for the region of fully developed flow demonstrates qualitatively that both software outputs have similar profiles.

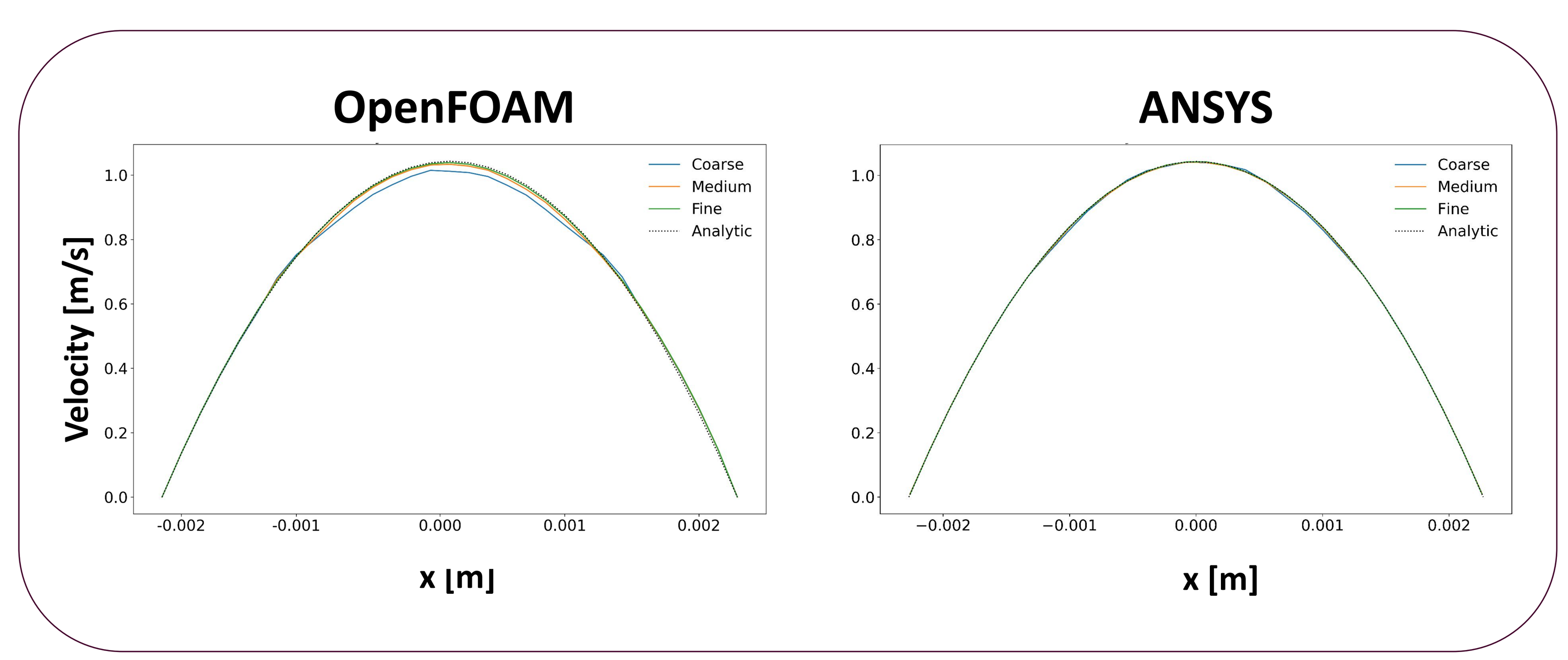


Figure 3: The velocity profiles at z = 0.11 [m] show fully developed flow parabolic profiles with mesh resolution significantly impacting the **OpenFOAM** model.

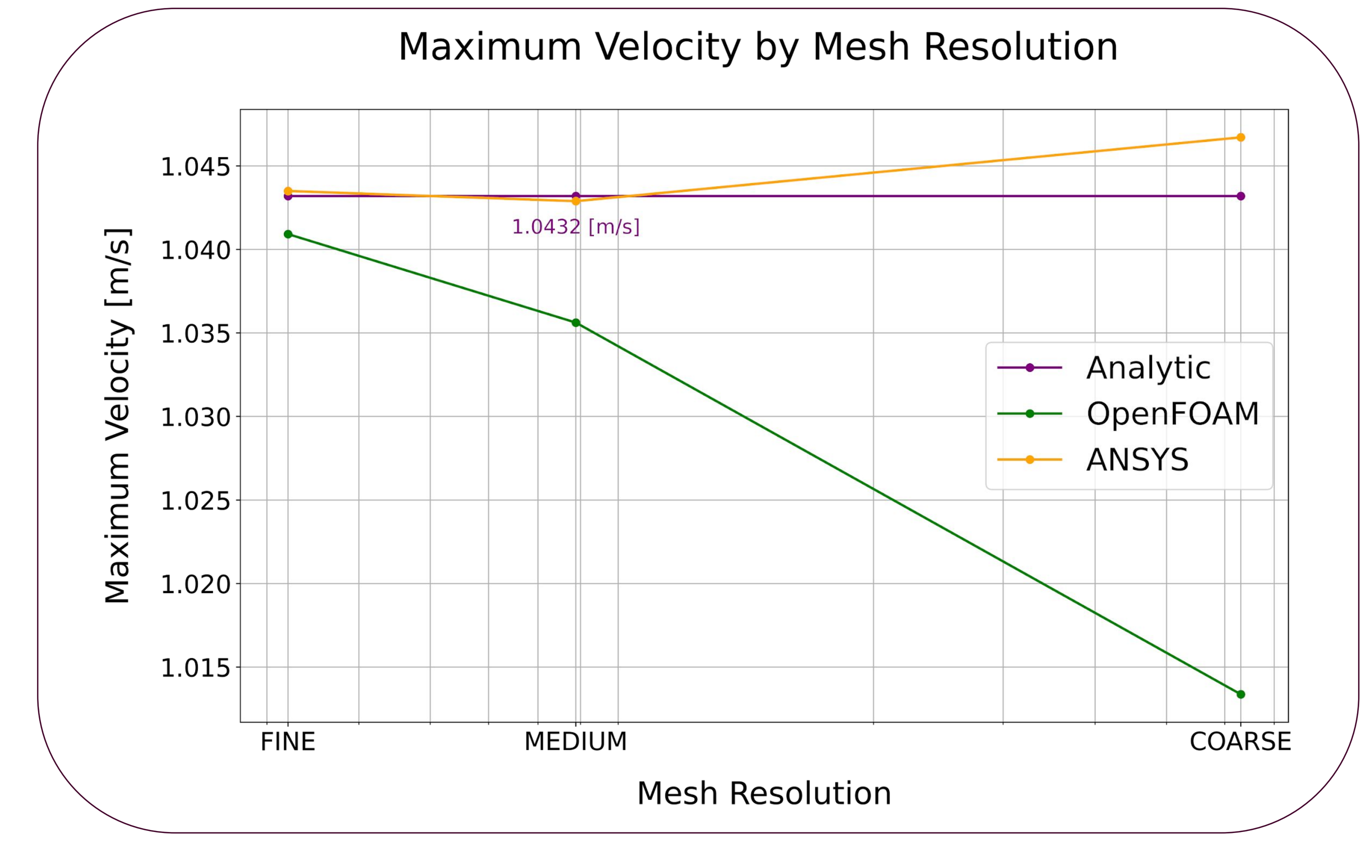


Figure 4: The **OpenFOAM** model requires a higher resolution to improve accuracy.

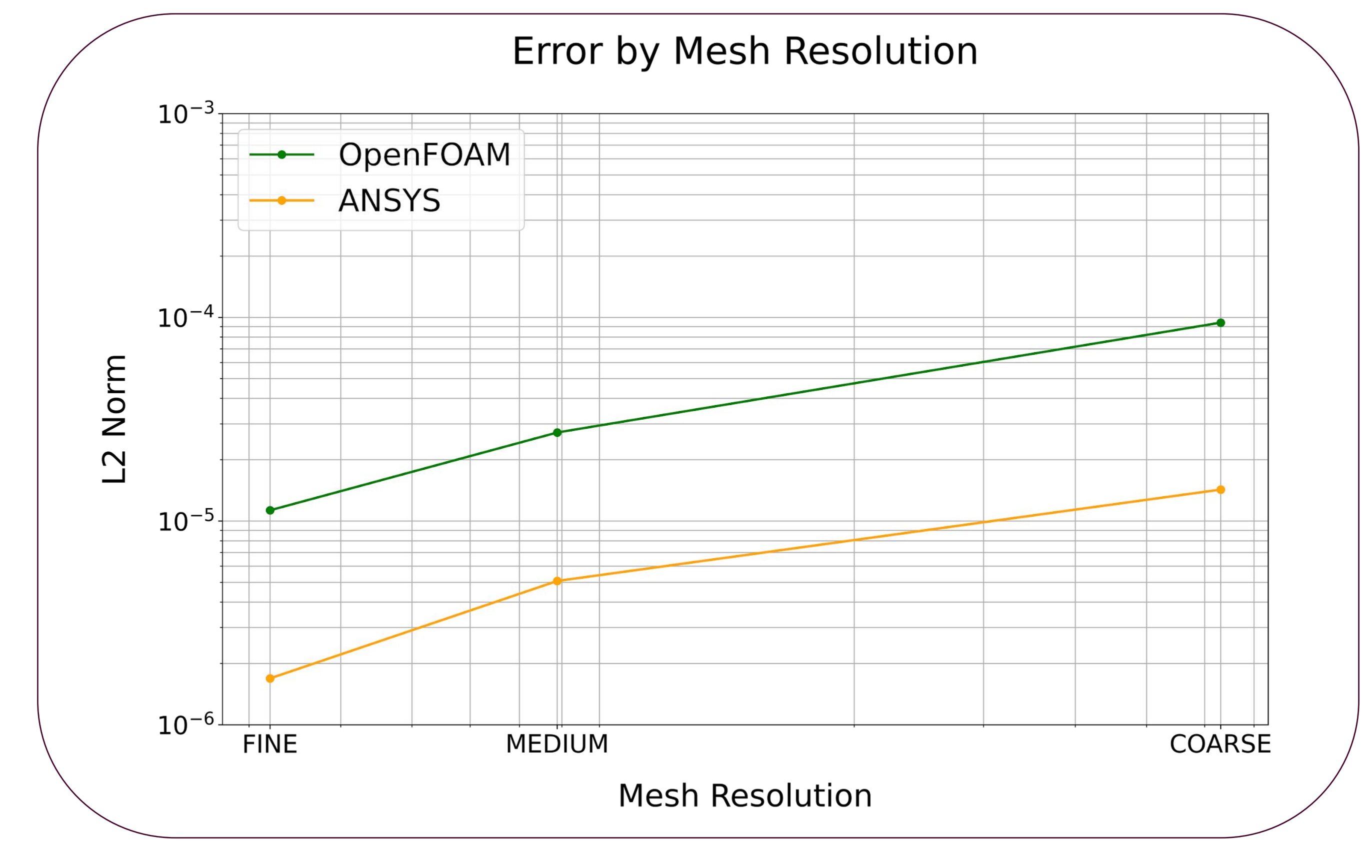


Figure 5: The L2 norm error trends are simliar for both models, but the **ANSYS** model has L2 Norms about an order of magnitude smaller for all mesh resolutions

Discussion

- Overall, the **ANSYS** model generates smaller errors, but for finer meshes both models were comparable.
- The **OpenFOAM** model accuracy is sensitive to mesh resolution.
- Although, the **ANSYS** software produces smaller code errors the financial cost is greater than that of the **OpenFOAM** software.

Future Work

Perform a global sensitivity analysis and conduct uncertainty quantification. Build the complexity of the openFOAM model, repeat the workflow, and conduct validation. Develop regulatory tools.

Acknowledgements

This work was funded by the Department of Energy Computational Science Graduate Fellowship (DE-SC0022158) and supported by the U.S. Food and Drug Administration's Office of Science and Engineering Laboratories (FDA OSEL).