COMSOL CONFERENCE 2017 BOSTON

UNIVERSIDAD SAN FRANCISCO DE QUITO

Air-Water-Foam Mix Chamber for Fire Protection of Fossil Fuel Containers: Modeling and Optimization

Universidad San Francisco de Quito - Ecuador

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Brief History

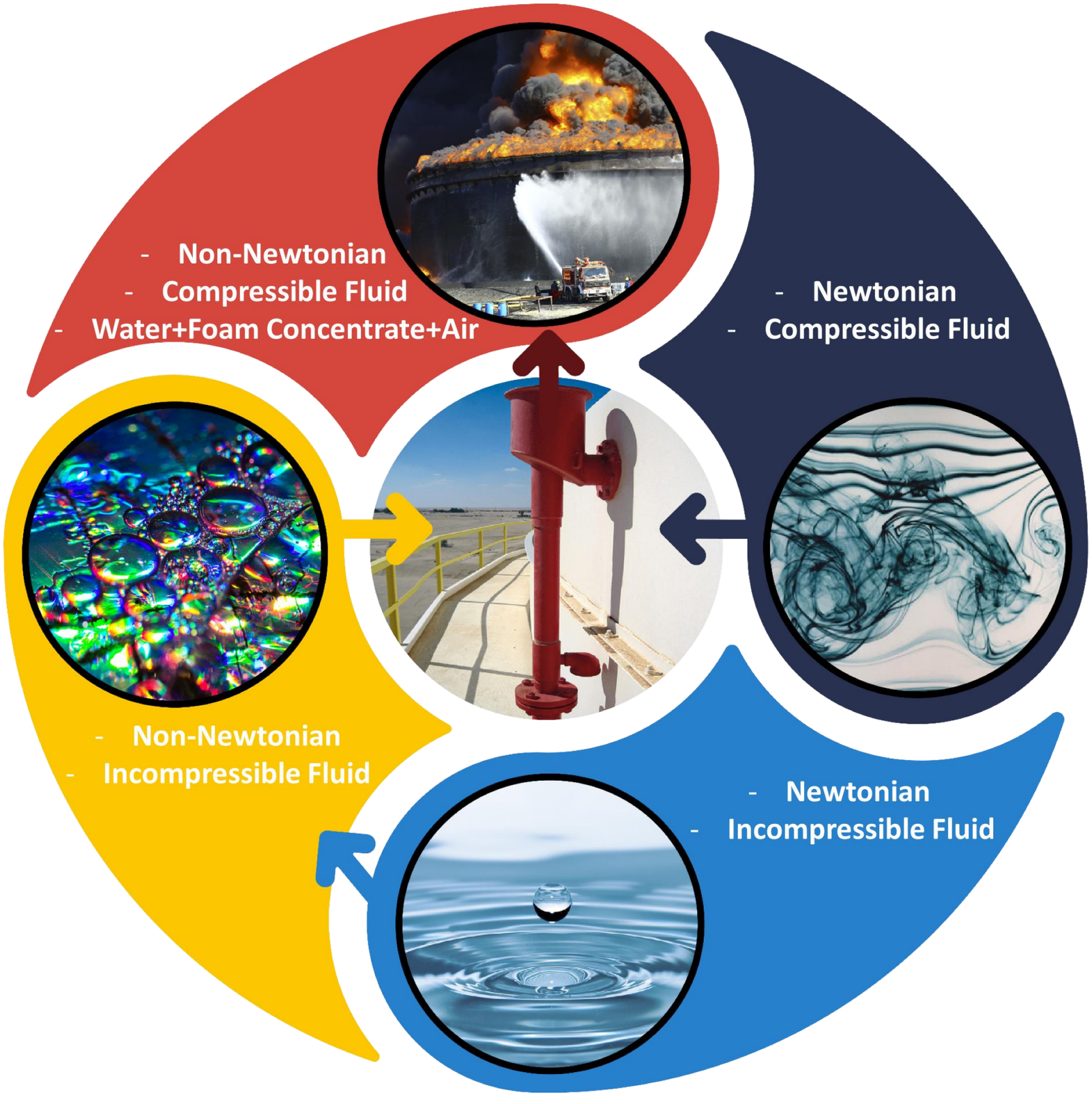
Fire Incidents and Accidents

Fire Protection Methods

Fire Protection Industrial / Field Applications

- Electricity Generators
- Fuel Tanks
- Mining Industry
- Chemical Facilities
- Transfer Fuel Areas

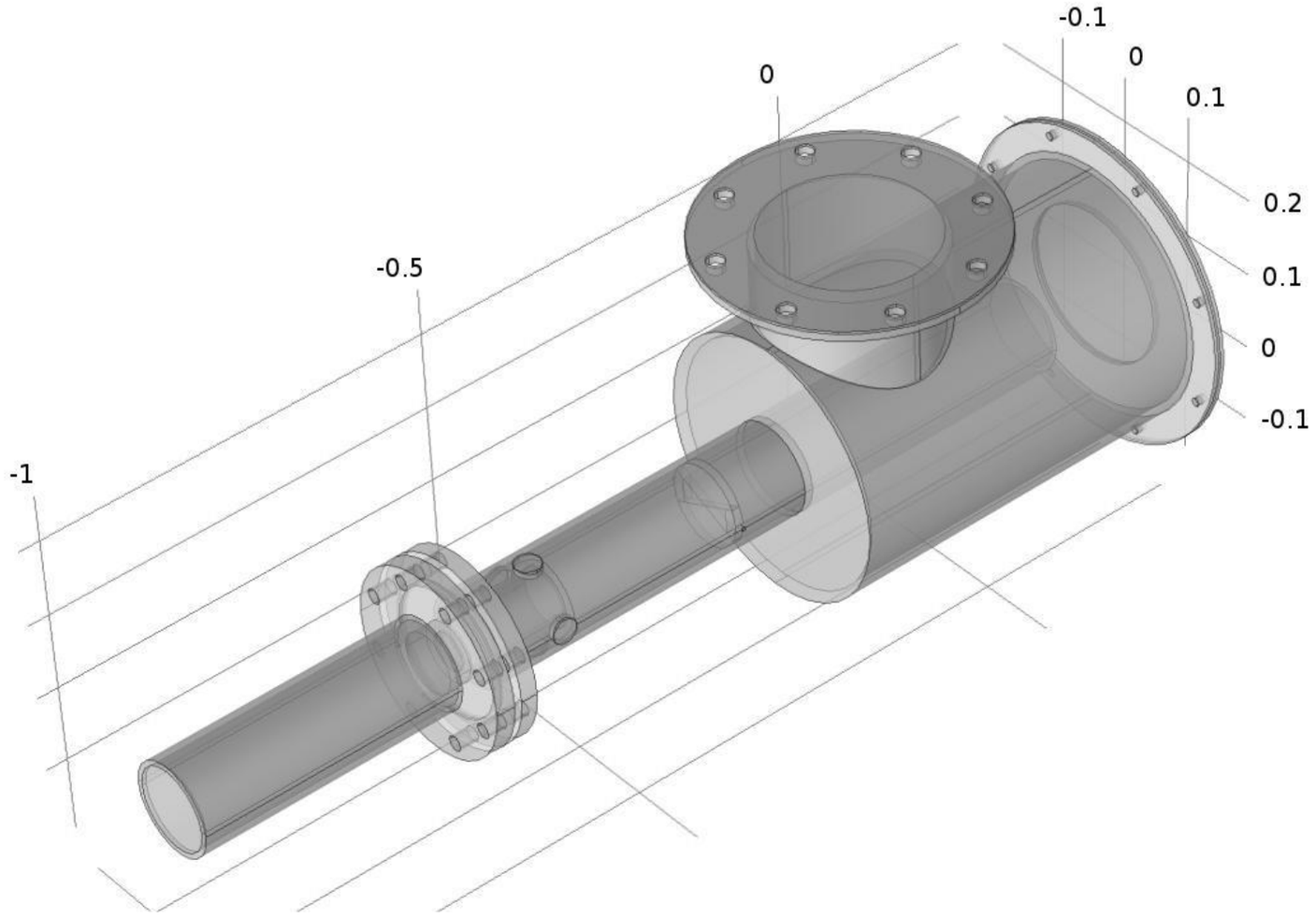
Foam Chamber Mixing Cycle

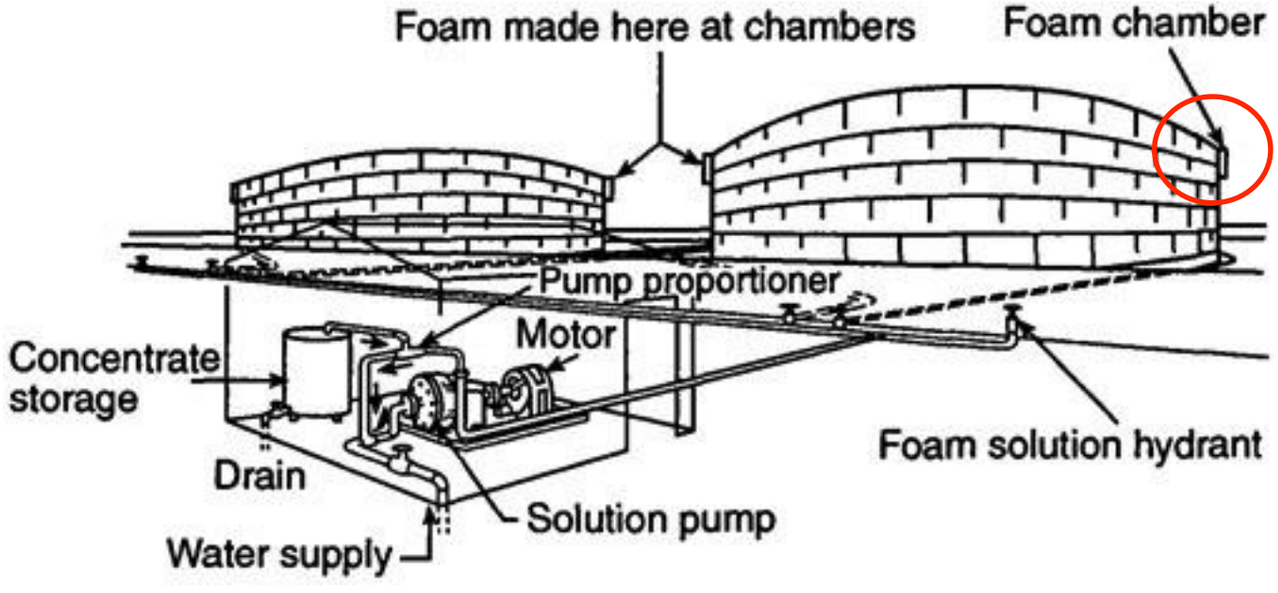


Objectives

1. Generate 3D CAD representation and mesh of the Foam Chamber Geometry.
2. Model and understand the physical interaction between the multi-phase fluid Water-Foam Concentrate-Air mixture and the process in the chamber.
3. Optimize the chamber geometry in order to produce a better mixing process of the final mixture.

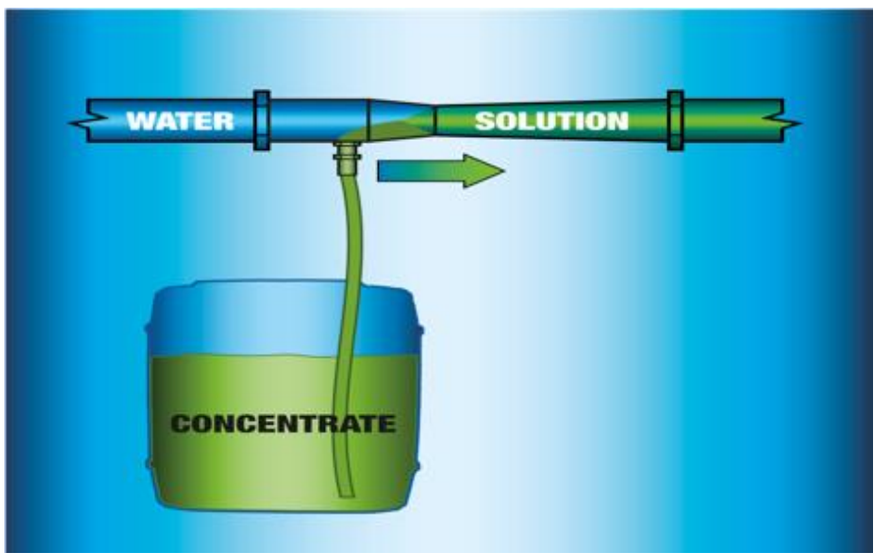
Chamber Geometry

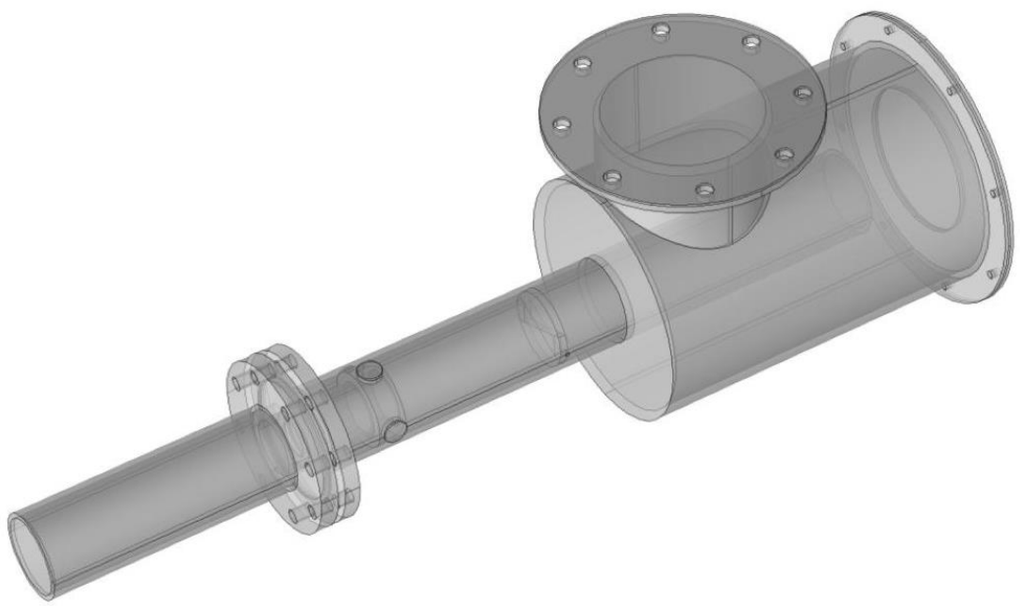


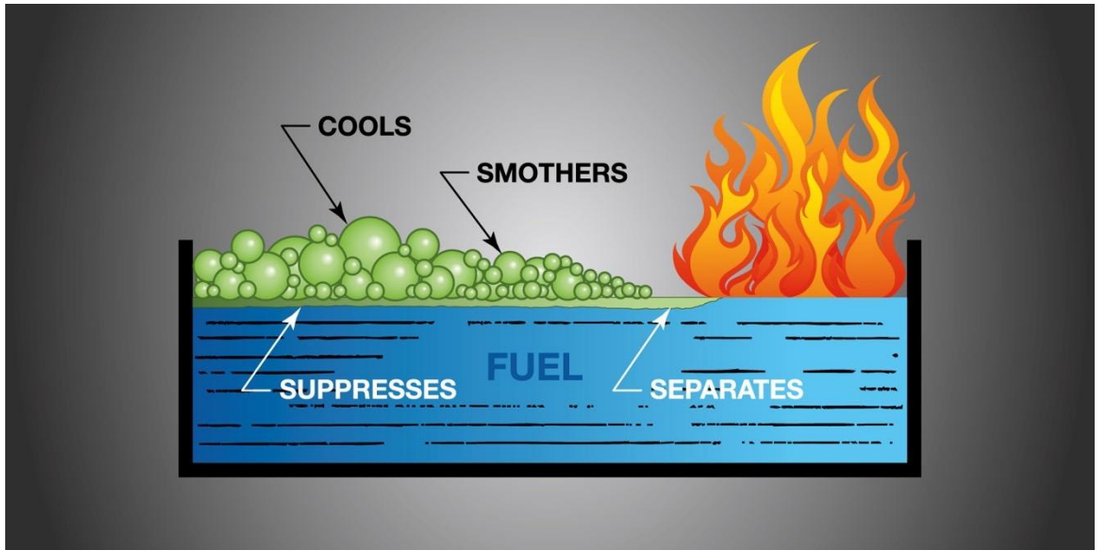


(Taken From NFPA 11)

Fluid Mixing Process





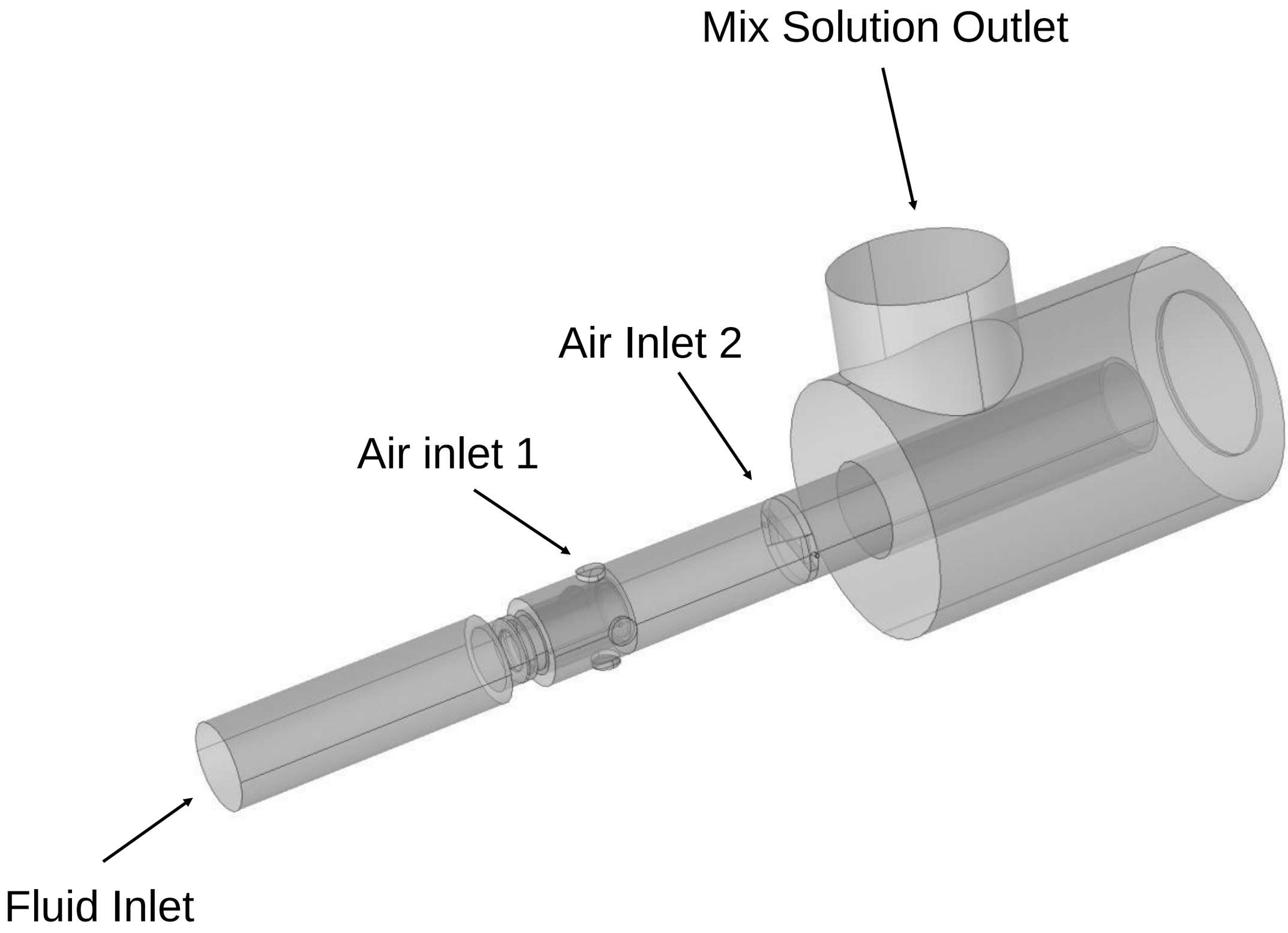


(Taken From Smith, William J. - Solberg)

Research Methodology

1. Create & import the Foam Chamber CAD model to Comsol Multiphysics®.
2. Define material properties: Water, Foam Concentrate and Air.
3. Apply proper physics model for phase-to-phase fluid interactions, i.e., water-foam concentrate-air.
4. Test meshing techniques to find a proper mesh and corresponding multi-phase flow modeling.
5. Optimize chamber geometry in terms of foam-solution mixing rate and volume.

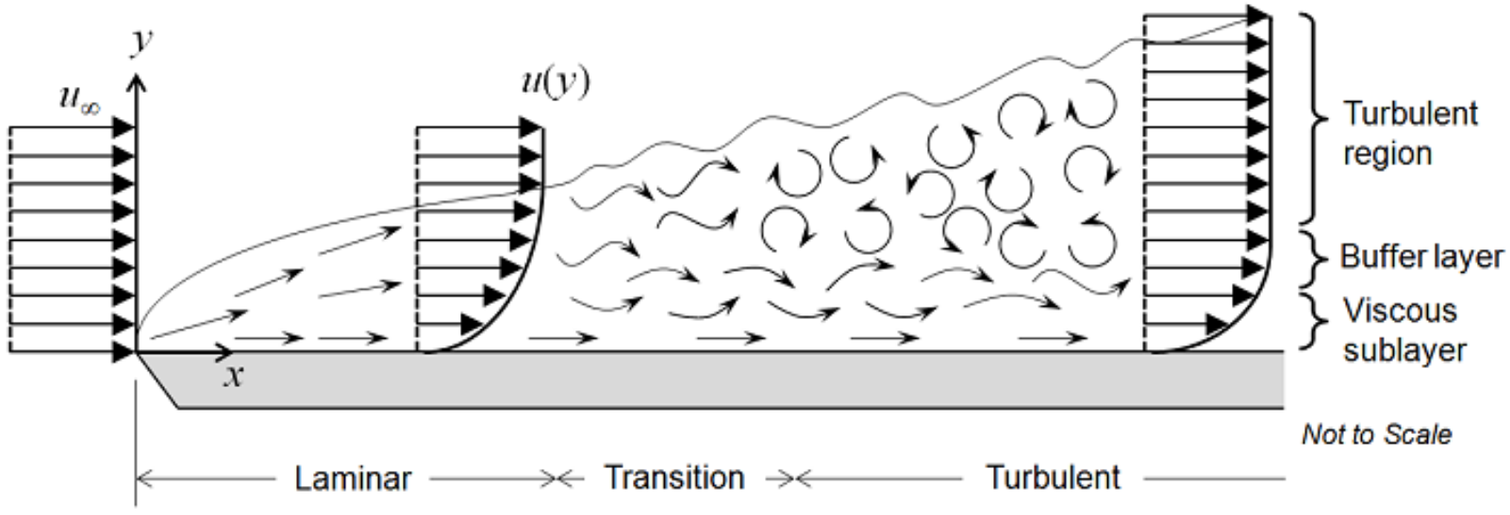
Fluid Domain and Boundary Conditions



Model Set-Up and Input Parameters

- Turbulent flow constitutive model: Algebraic yPlus.
  - Fluid: Water.
  - Tolerance error: 1×10^{-3}
  - Wall Boundary Condition: No Slip.
  - Gravity Included
  - Inlet velocity: $4.5\ m/s$
- Stationary Study
  - With wall distance initialization.

Turbulent Flow-Algebraic Method



$$\rho(\mathbf{u}\cdot\nabla)\mathbf{u} = \nabla\cdot[-\mathbf{pI} + (\mu+\mu_\mathbf{T})(\nabla\mathbf{u} + (\nabla\mathbf{u})^\mathbf{T})] + \mathbf{F} + \rho\mathbf{g}$$

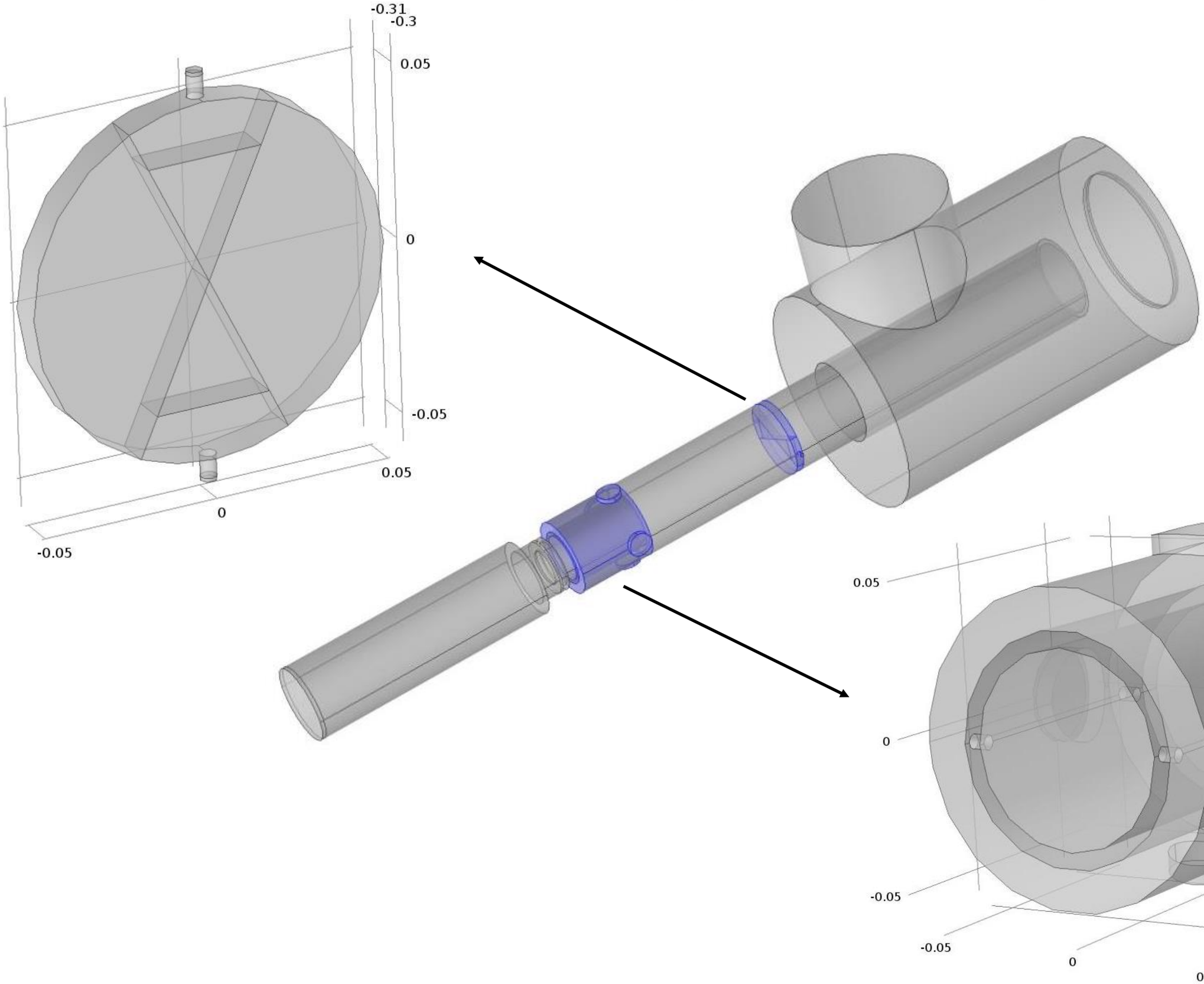
$$\rho\nabla\cdot(\mathbf{u}) = \mathbf{0}$$

$$\mathrm{Re_w} = \frac{\rho l_w|\mathbf{u}|}{\mu} = \frac{|\mathbf{u}|}{\mathrm{u}_\tau}\cdot\frac{\rho \mathrm{u}_\tau l_w}{\mu} = \mathrm{u}^+ l_w^+$$

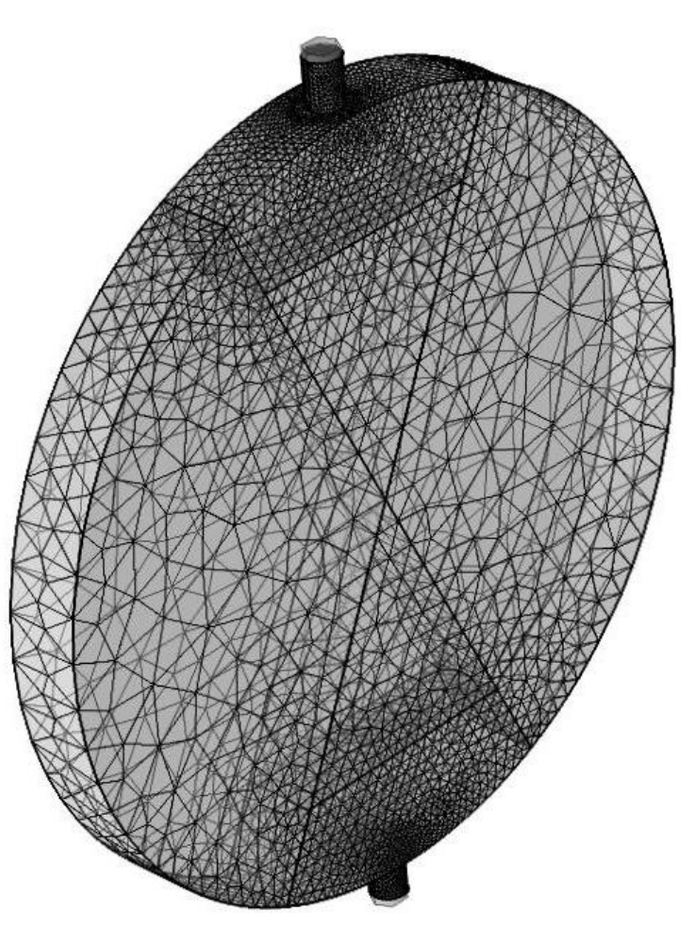
$$\mathrm{u}^+ = f(l_w^+)$$

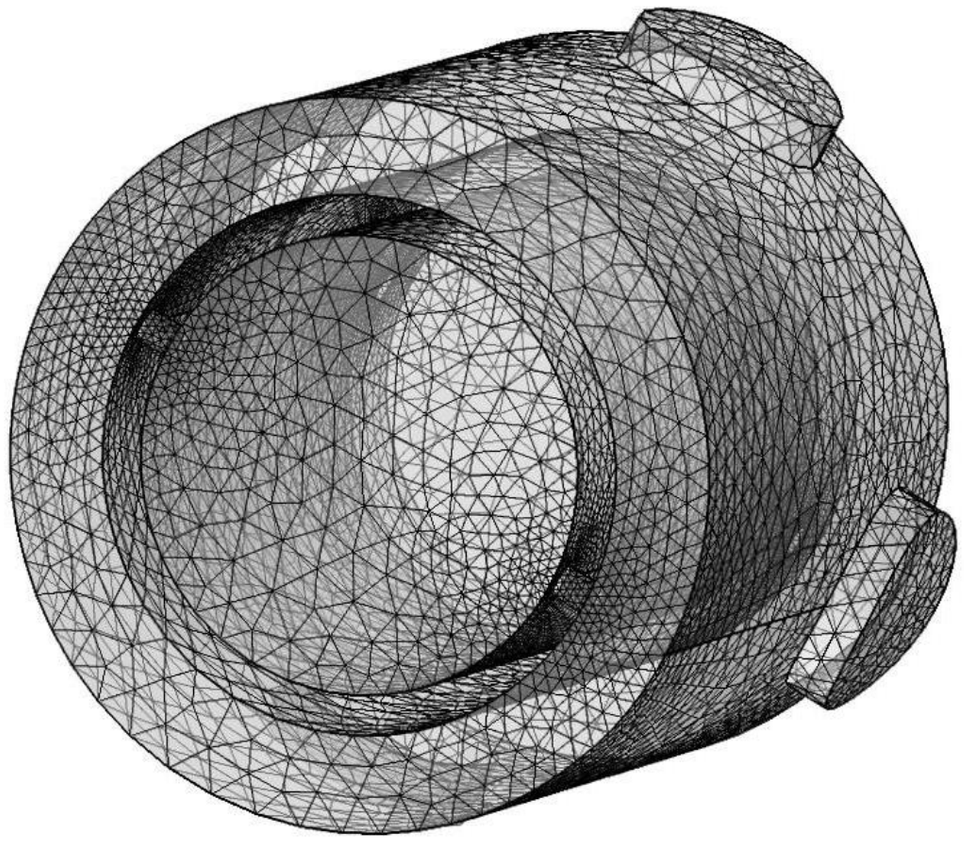
(Taken From Walter, Freig - Comsol Blog)

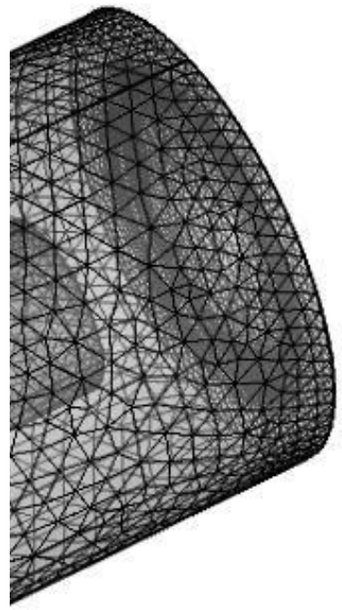
Partitioning Technique

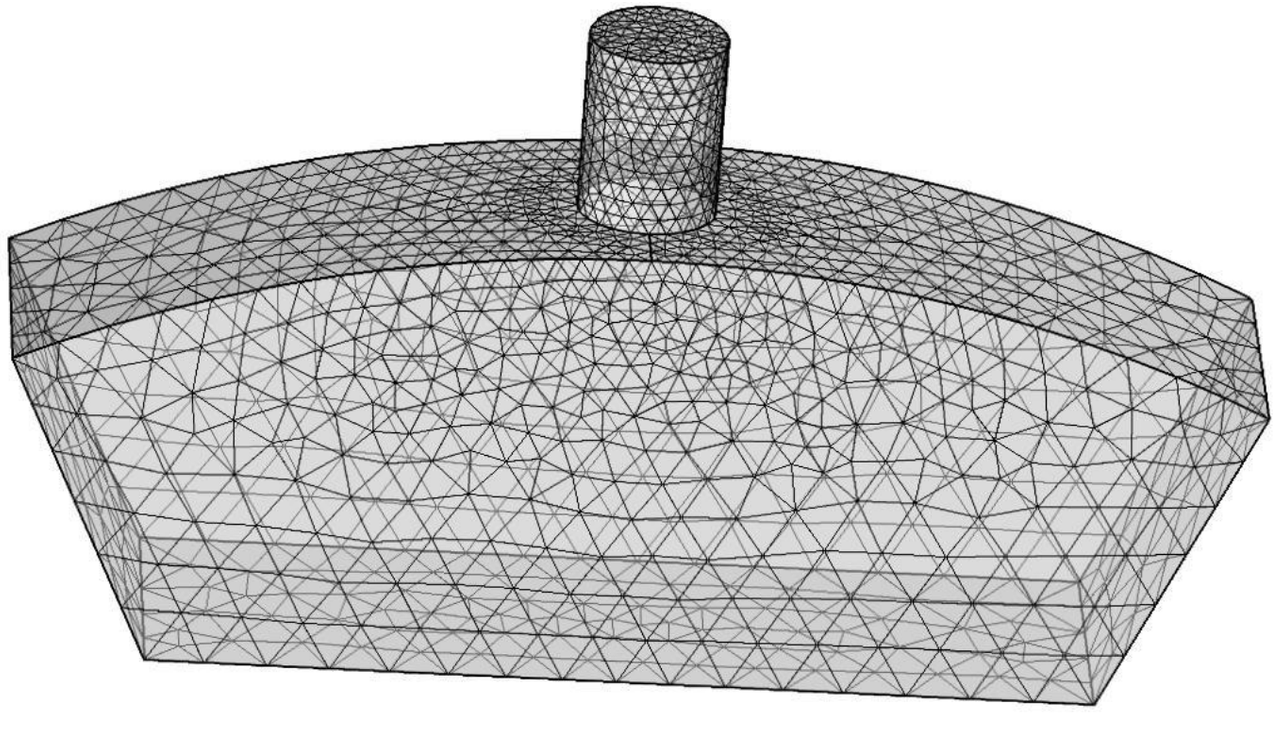


Final Mesh

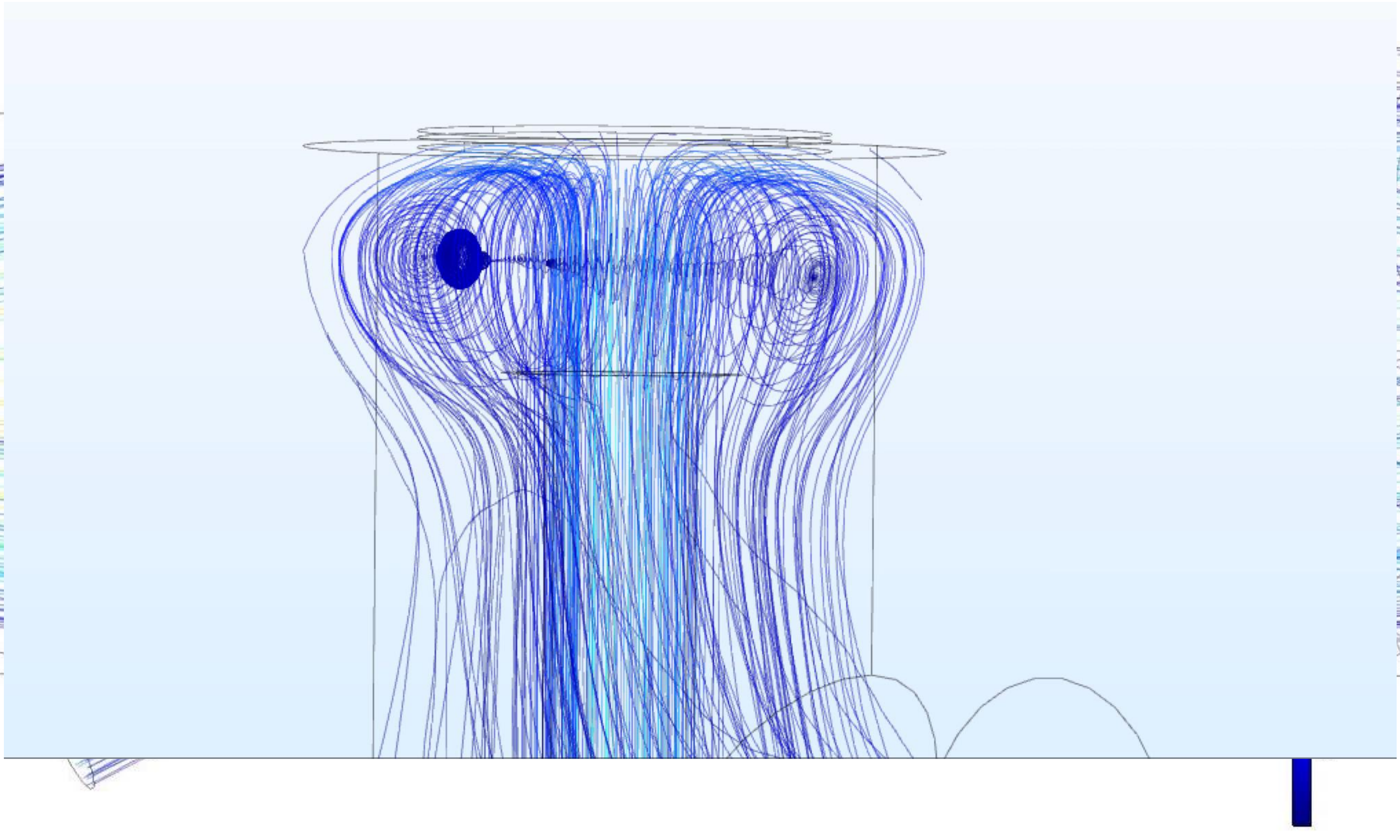




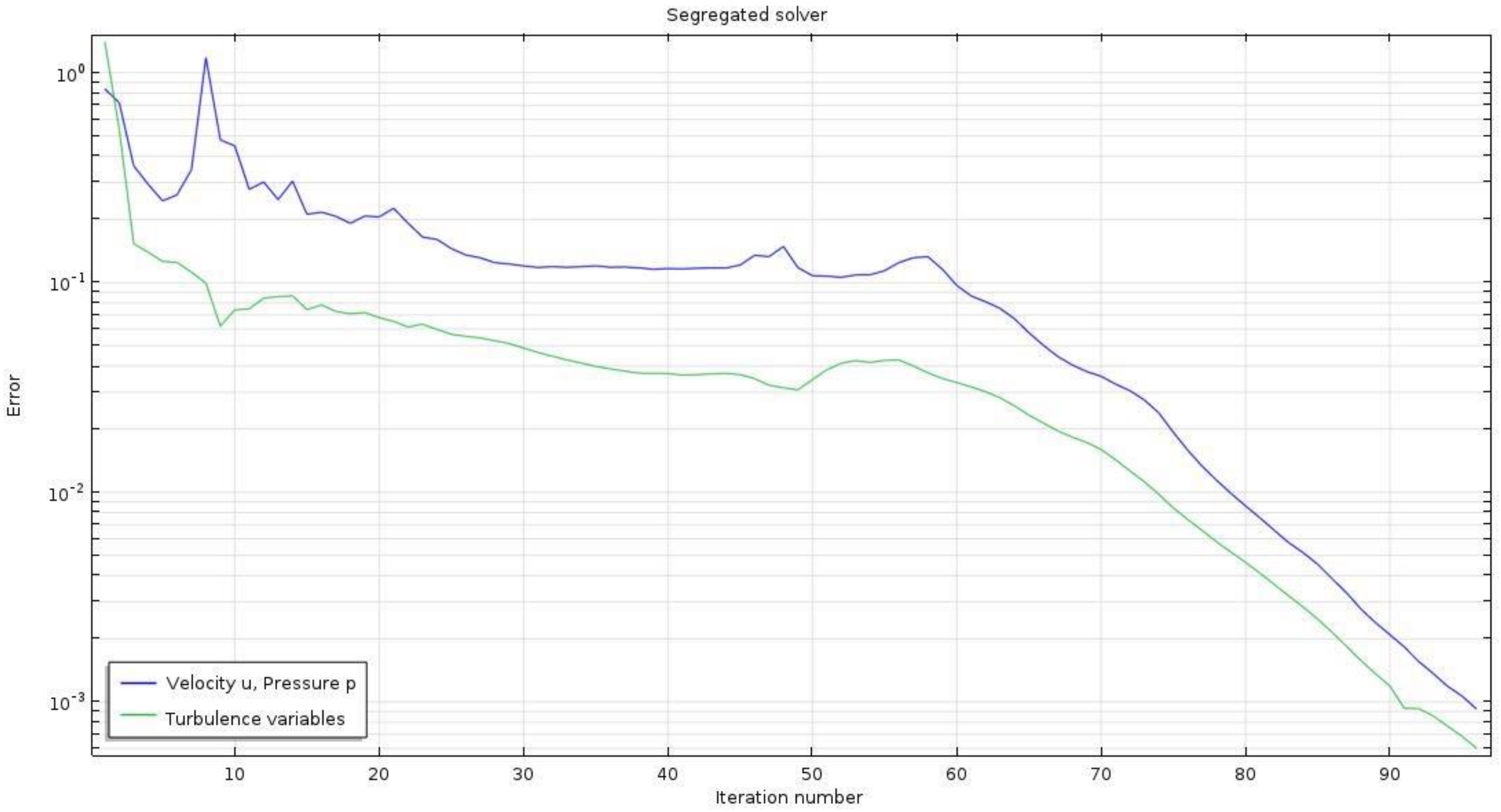




Results



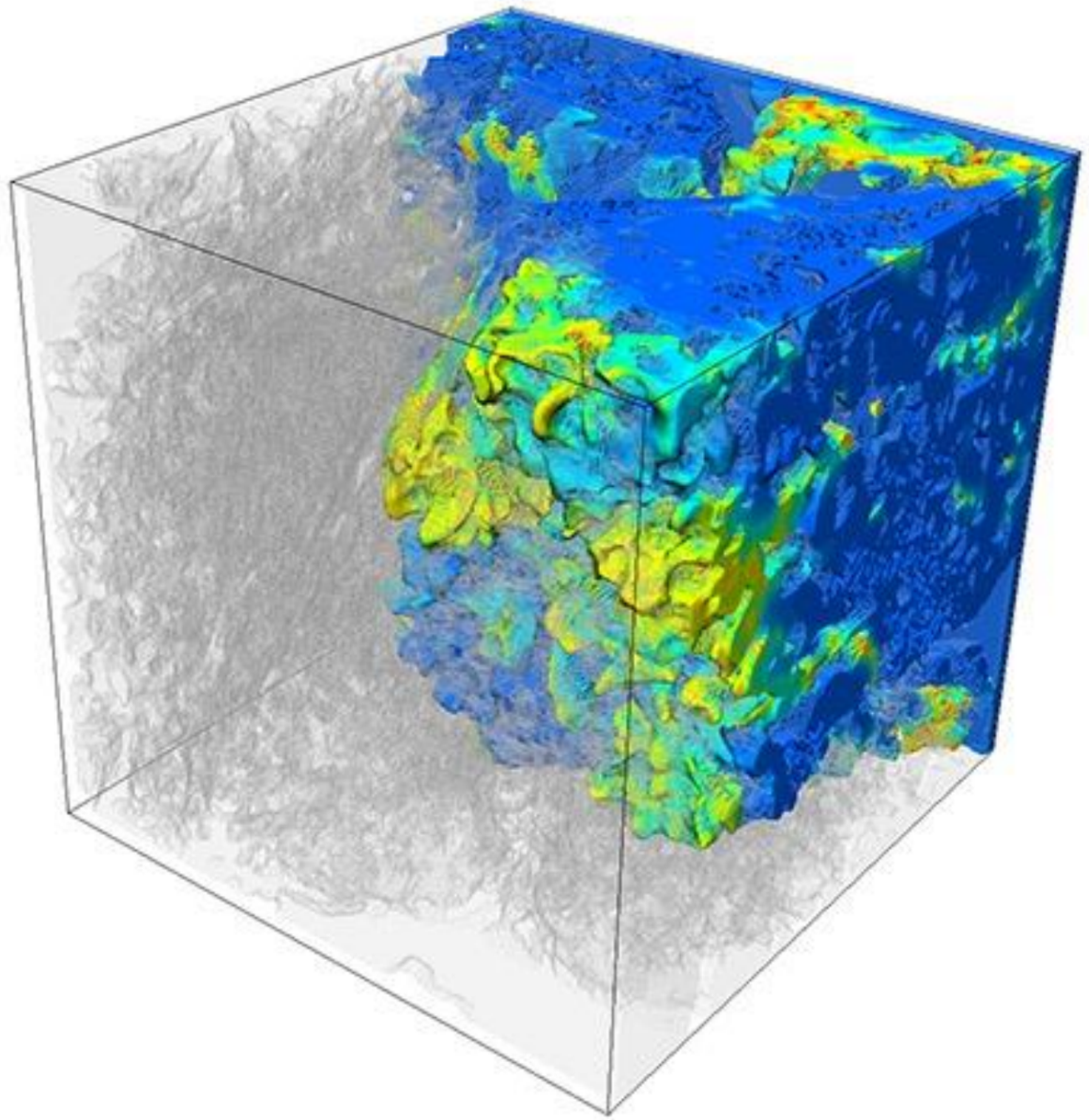
Convergence Plot



Conclusions

- Creating a accurate CAD model is extremely important (complex geometry).
- Developing techniques of domain partitioning determines the mesh quality.
- Creating the proper mesh using different elements and sizes ensures the solution convergence.
- Taking in consideration the previous steps, we saved computational resources and time.
- Using a Mac Pro (Processor with 2.7 GHz 12-Core Intel Xeon E5):
  - It is obtained a computational time of: 43 min 33 s.

What is Next?



(Taken From Fraunhofer Institute for Industrial Mathematics ITWM)

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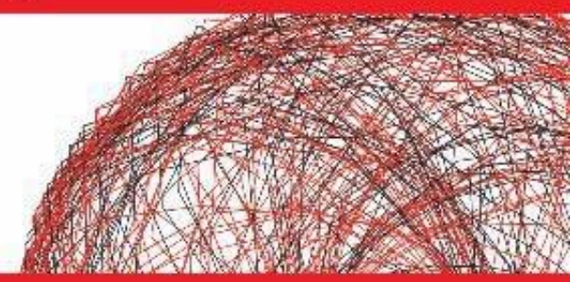

COMMITMENT & PASSION