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Optimizing Tailing Tank Configuration and Processes for Efficient Tailings Management: A Simulation-Based Approach

17 May 2024

OTRO CONGRESO
MENTORIS
EL PODER DE LA PARTICIPACIÓN

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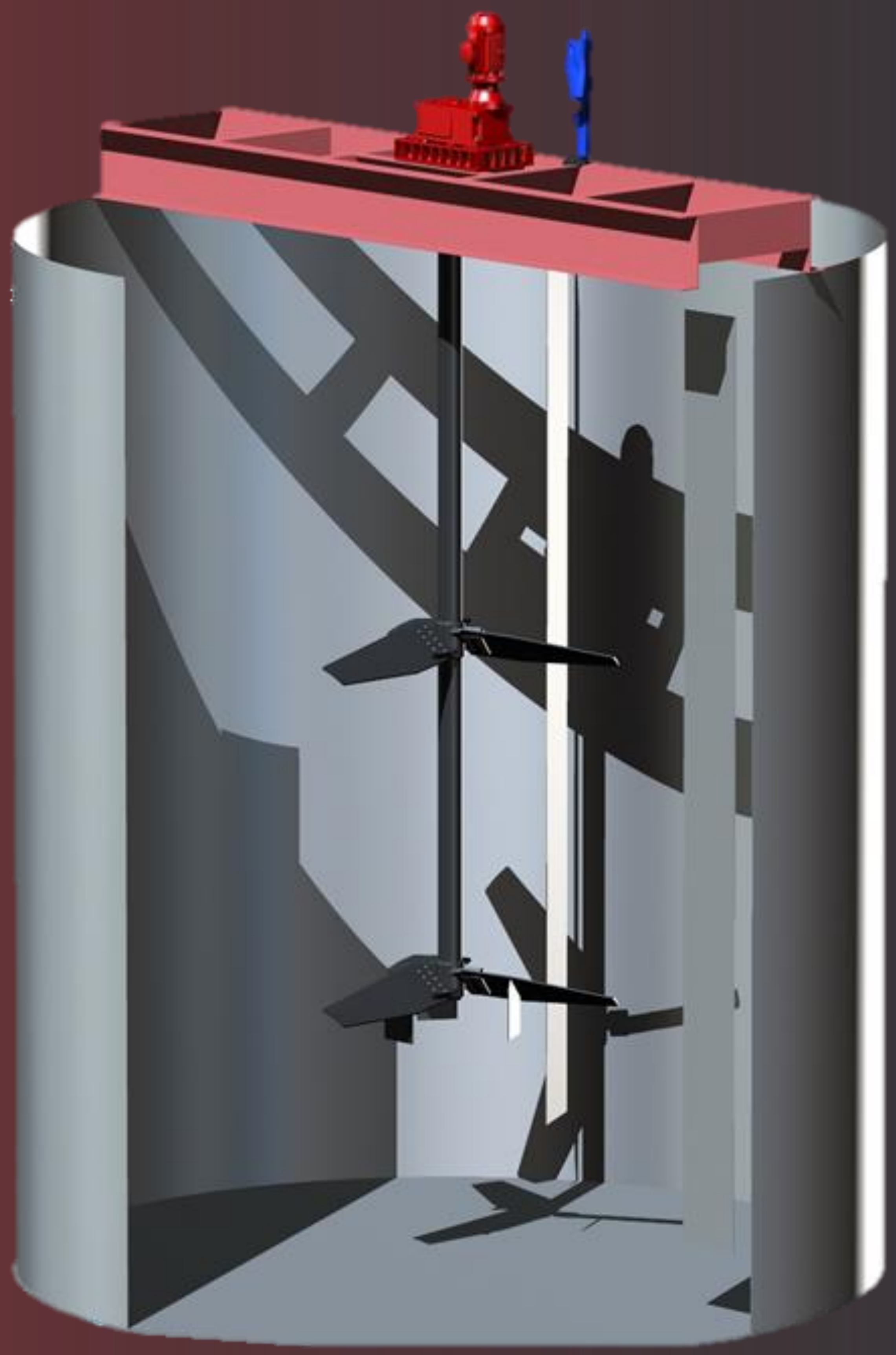
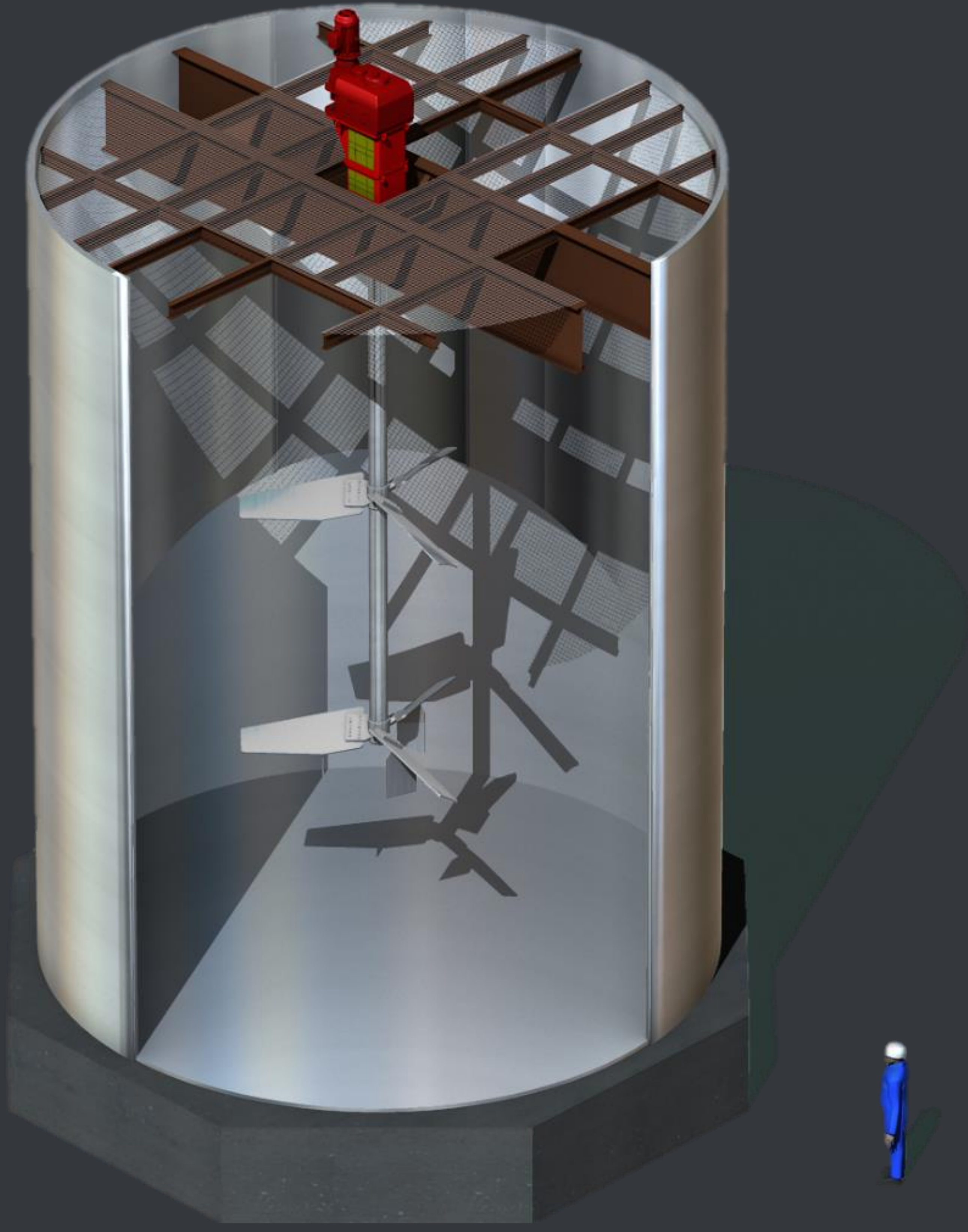
AFX MIXING AND PUMPING TECHNOLOGIES INC.

AFX MIXING AND PUMPING TECHNOLOGIES

AFROMIX

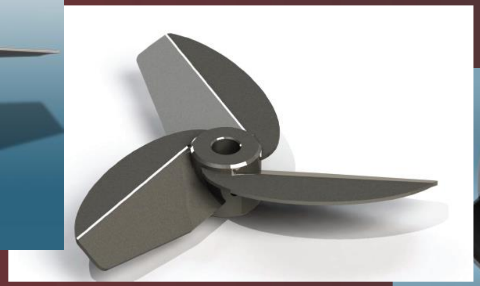
AMX AGITATORS

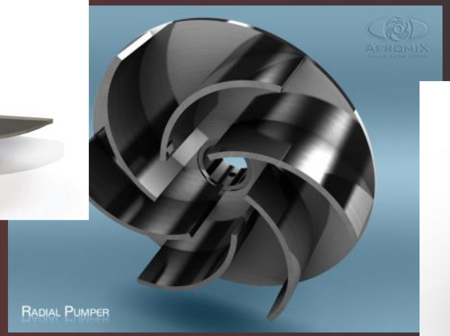


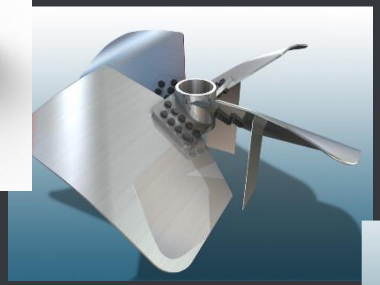


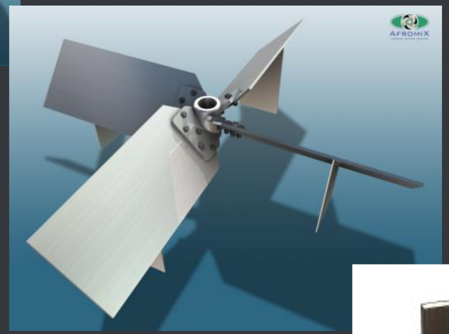
AGITATOR RANGE

IMPELLER TECHNOLOGY

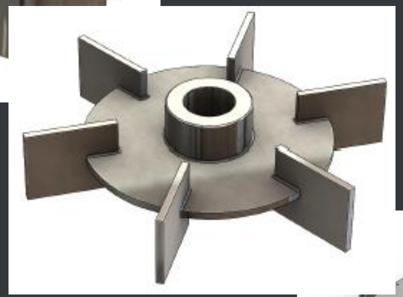




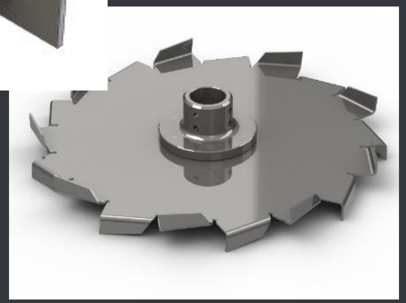




Customized optimization to your process



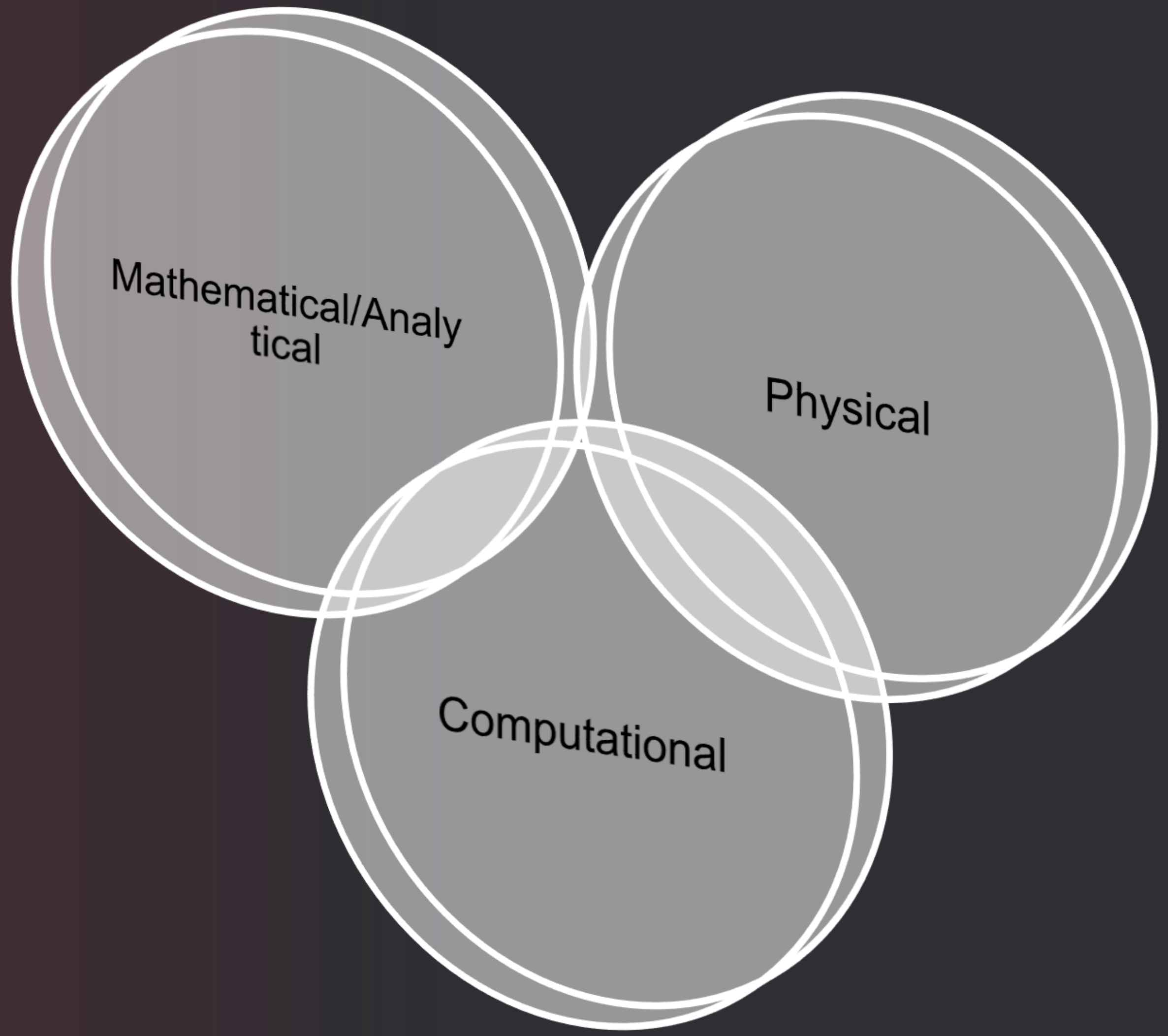
Efficient and effective flow engineering



Highest quality mechanical integrity

Simulation in Tailings Management

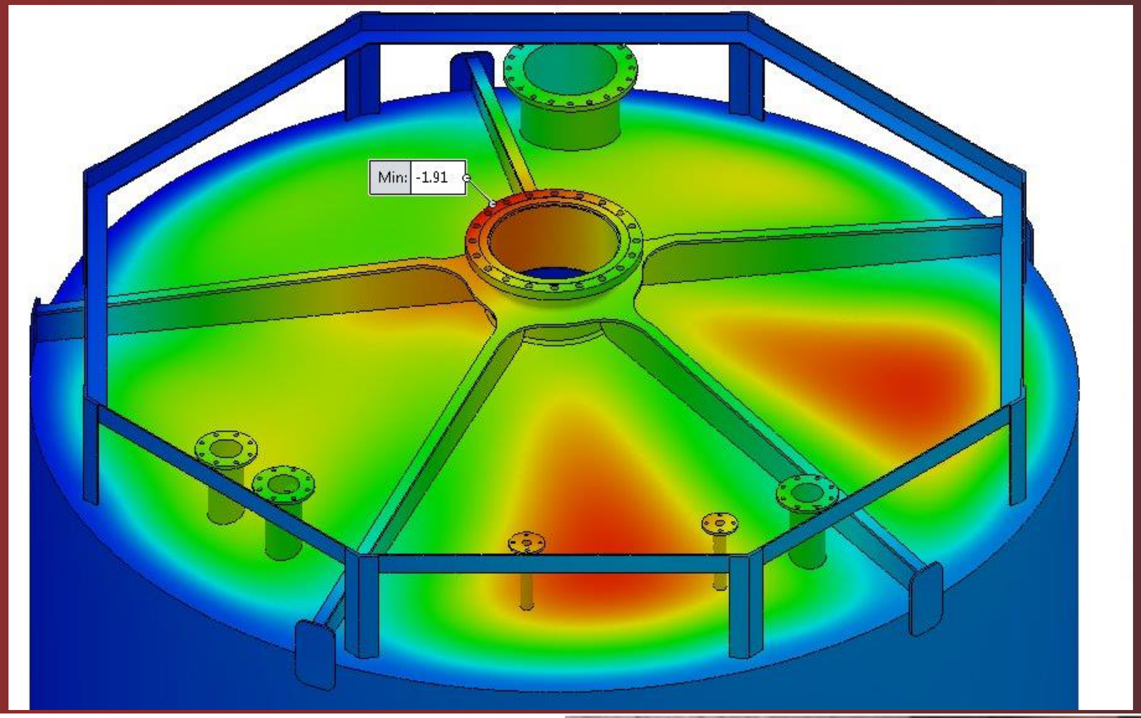
- Cost-Effective Analysis
- Risk Reduction
- Optimization of Designs
- Time Savings
- Insight into Complex Phenomena
- Accessibility to Inaccessible Environments
- Documentation and Visualization
- Support for Innovation and Research
- Regulatory Compliance
- Sustainability

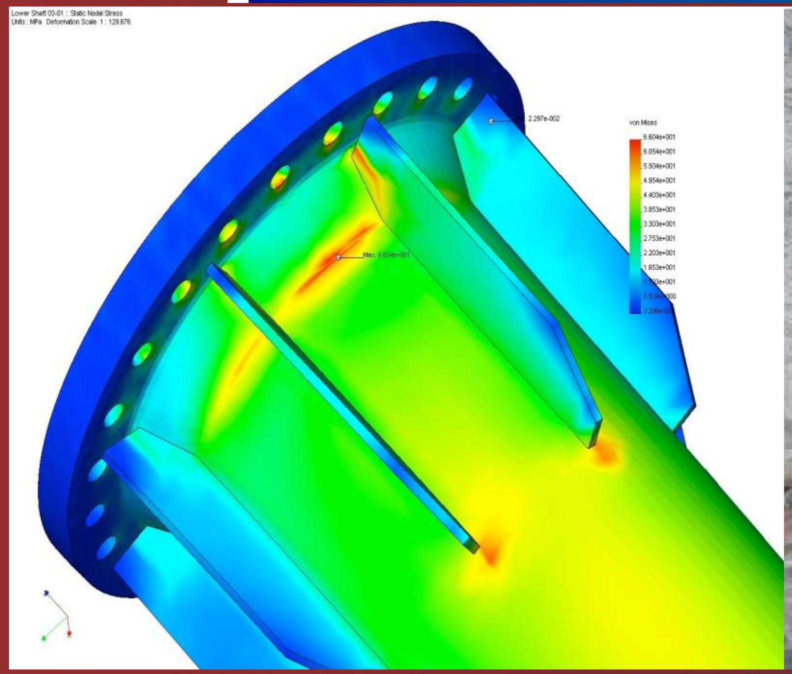


"In real life mistakes are inevitable. Computer simulation however makes it economically possible to make mistakes on purpose. If you are astute therefore, you can learn much more than they cost. Furthermore, if you are at all discreet, no one but you need ever know you made a mistake."
- John McLeod and John Osborn (1966)

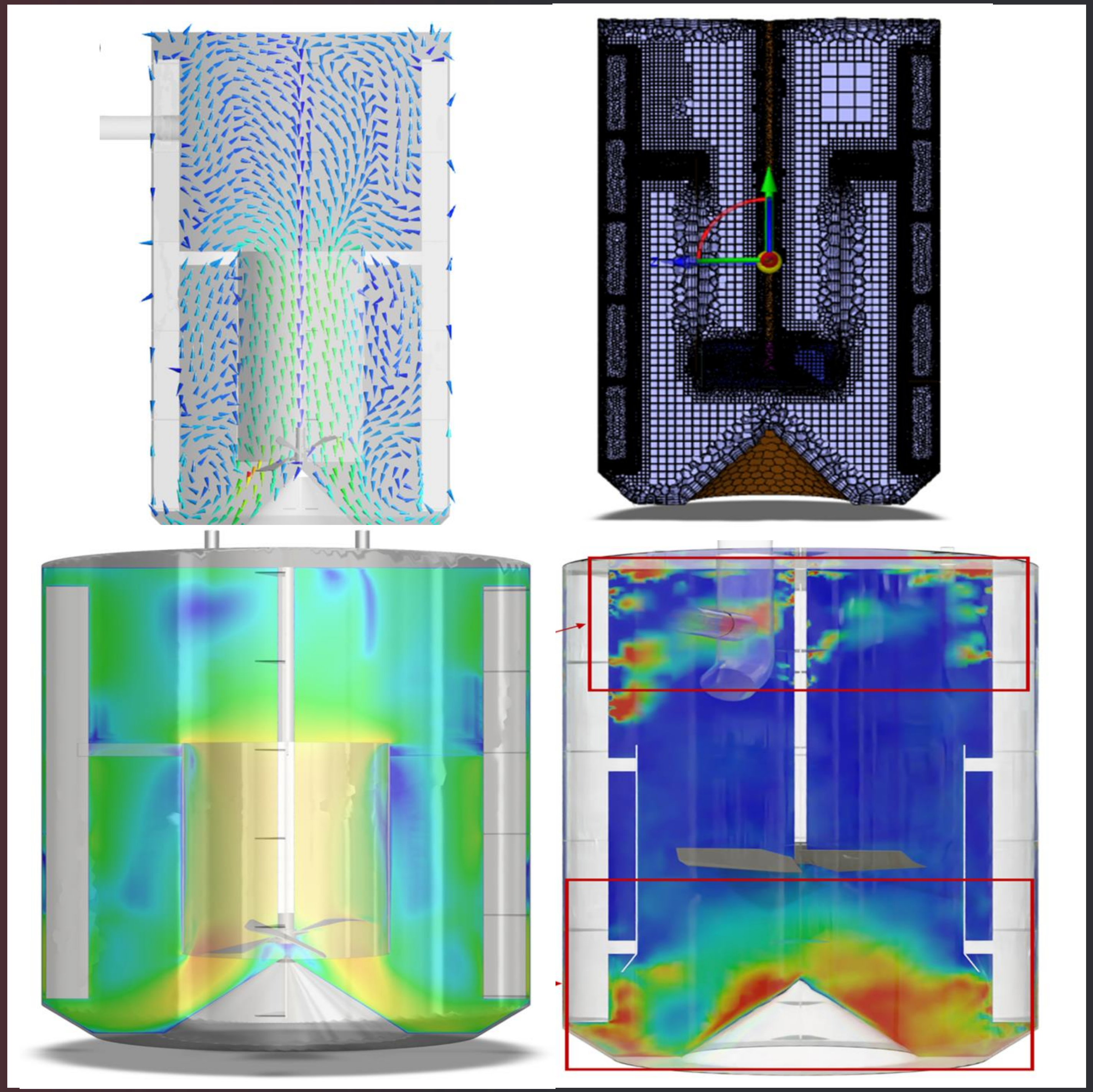
What are the types of simulation?

- Finite Element Analysis - FEA



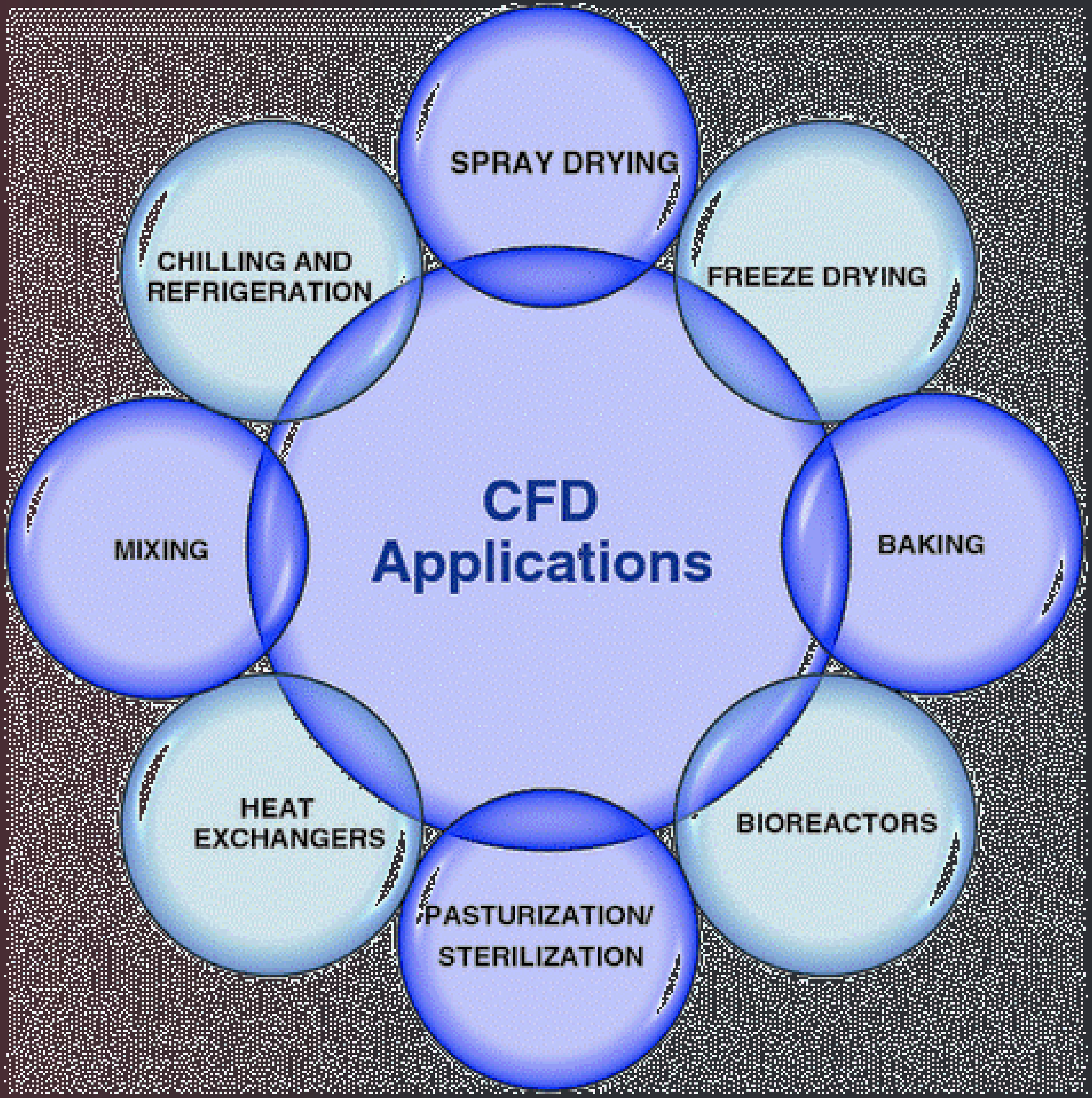


- Computational Fluid Dynamics - CFD



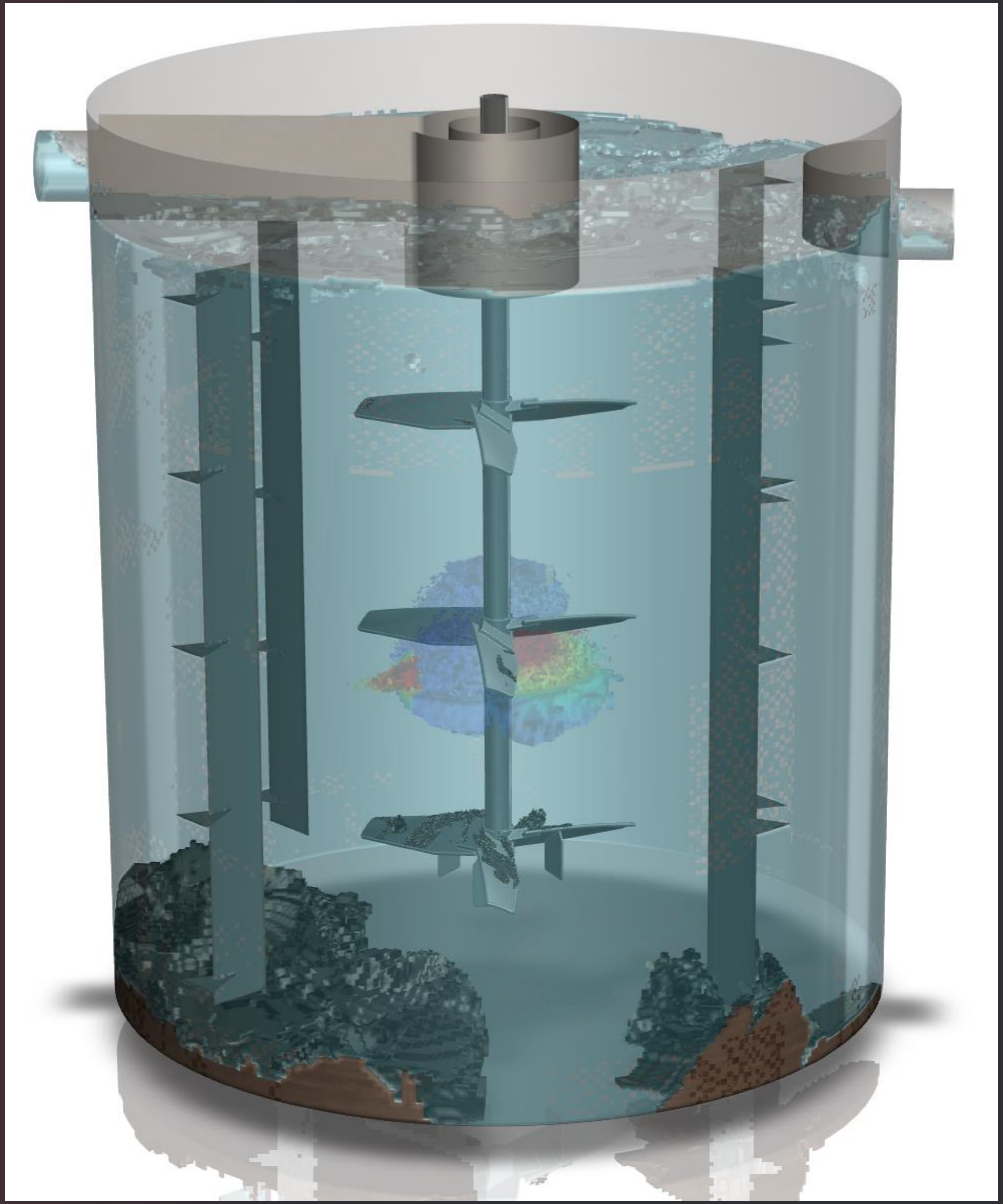
What is CFD?

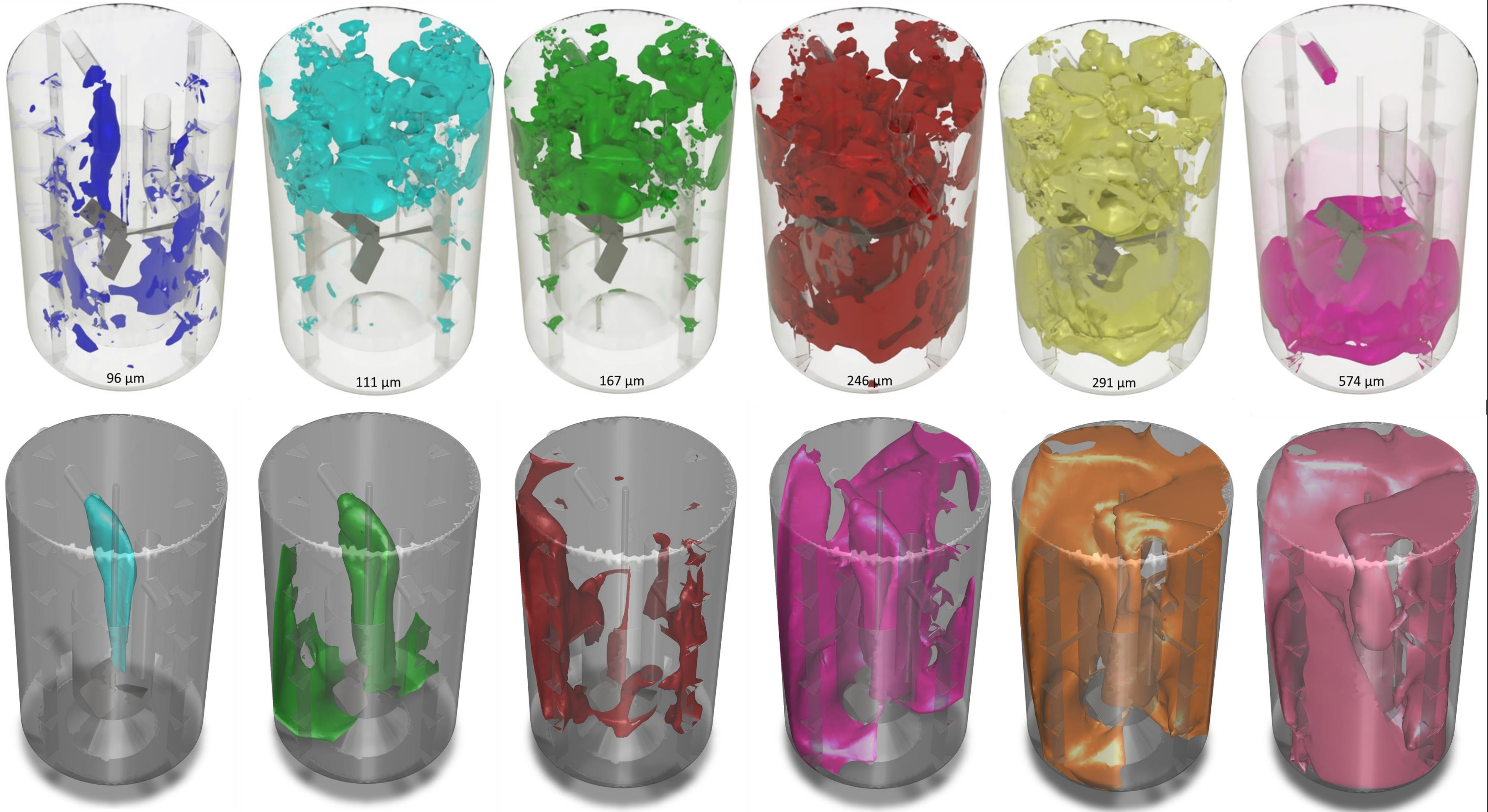
- CFD is a discipline within fluid mechanics that utilizes computational methods to analyze and simulate the behavior of fluids.
- Involves the numerical solution of governing equations that describe fluid flow, heat transfer, and related phenomena.
- Allows engineers to study how fluids (liquids, gases, or plasmas) interact with solids or other fluids in various physical systems.
- By discretizing the domain into a grid and solving mathematical equations iteratively, CFD predicts fluid flow patterns, velocities, pressures, temperatures, and other properties.



What does CFD tell us?

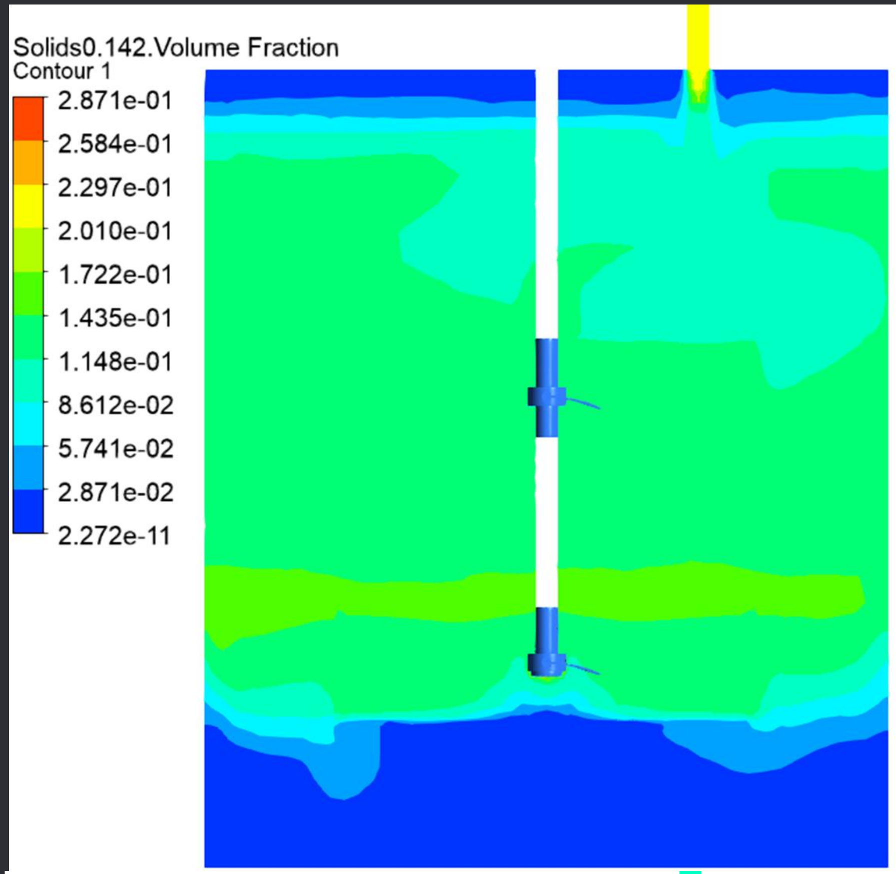
- **Fluid Flow Characteristics**
  (i.e., fluidic behaviors and conditions, flow streamlines, recirculation identification);
- **Mixing/Agitation** of Solids, liquids, and/or gases;
- **Heat and Mass Transfer** capability
  (i.e., Temperature distributions, Heat transfer coefficients, species diffusion, solid settling/suspension);
- **System performance and efficiency**
  (i.e., power consumption, force analysis, and process usage).

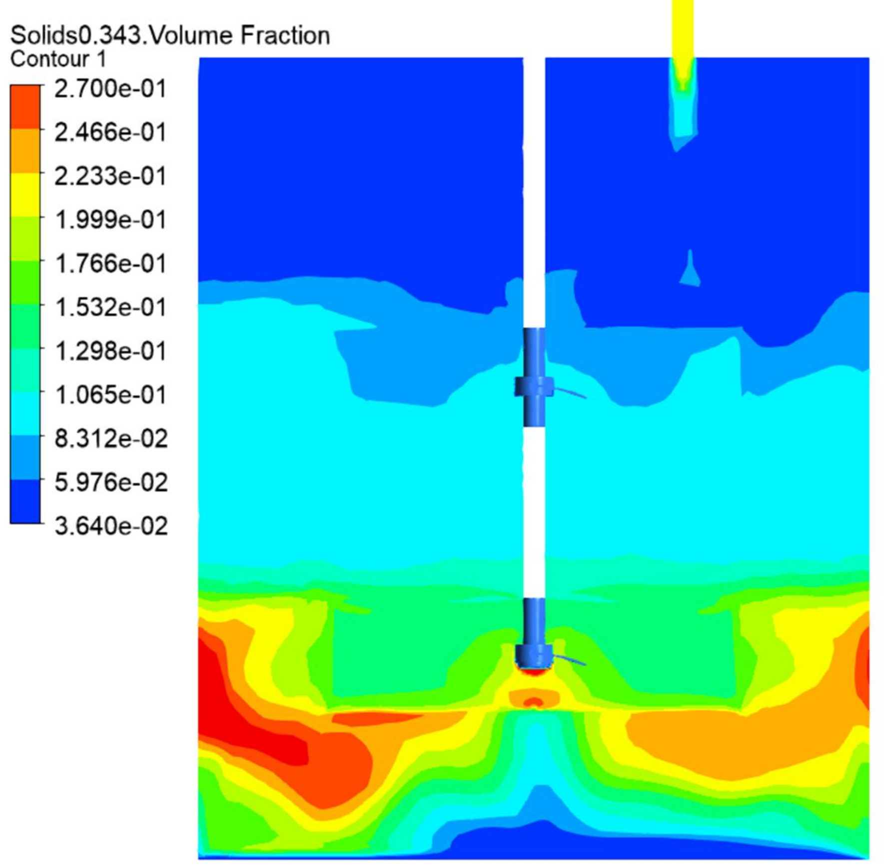


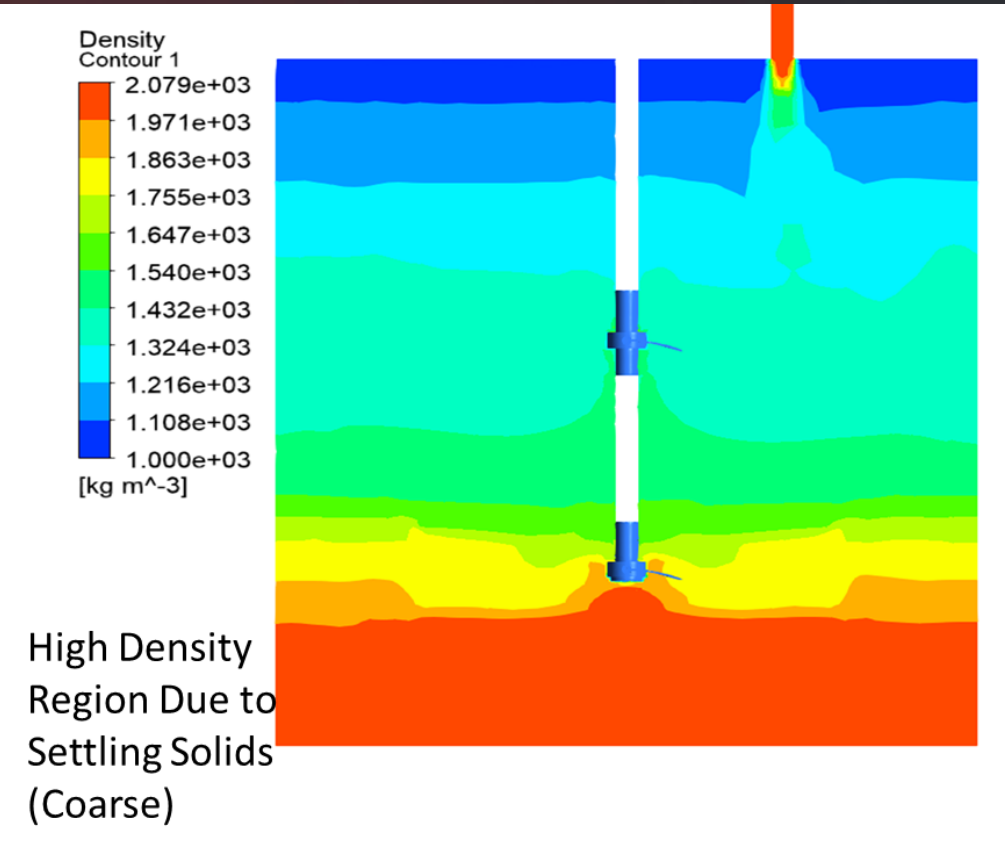

96 µm
111 µm
167 µm
246 µm
291 µm
574 µm

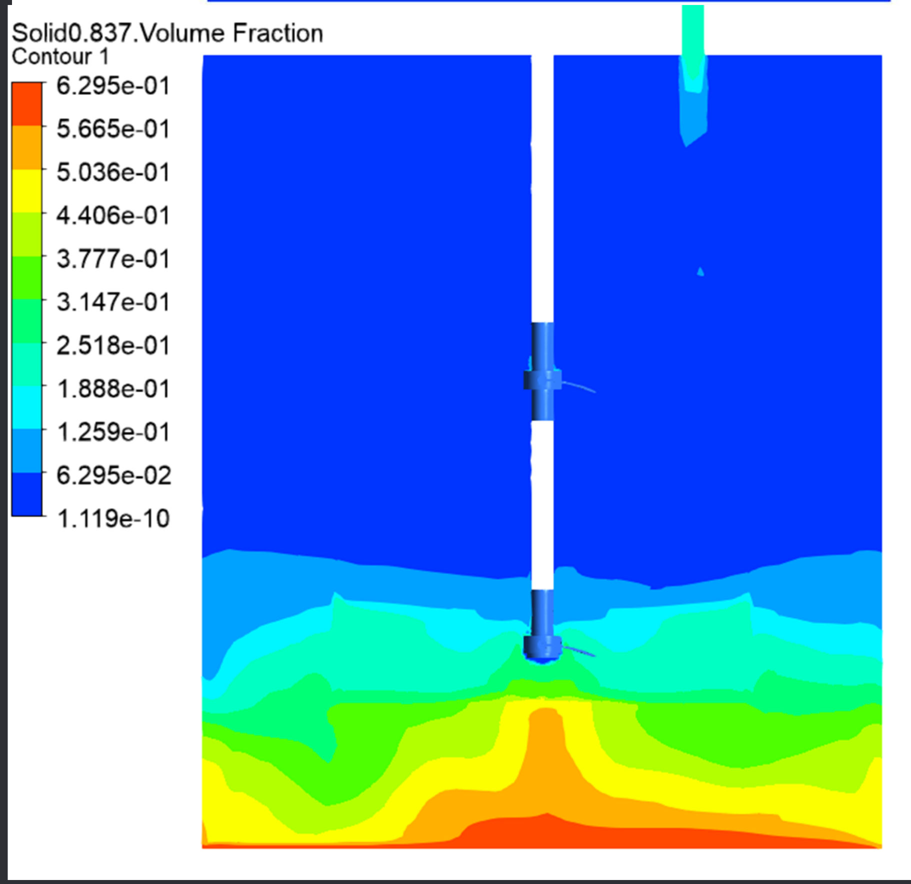
CFD – PROBLEM IDENTIFICATION

- **Sedimentation Analysis**: Predicting solid particle settling patterns and identifying potential build-up areas.
- **Mixing Efficiency**: Evaluating mixing performance and solid suspension to prevent settling and ensure homogeneity.

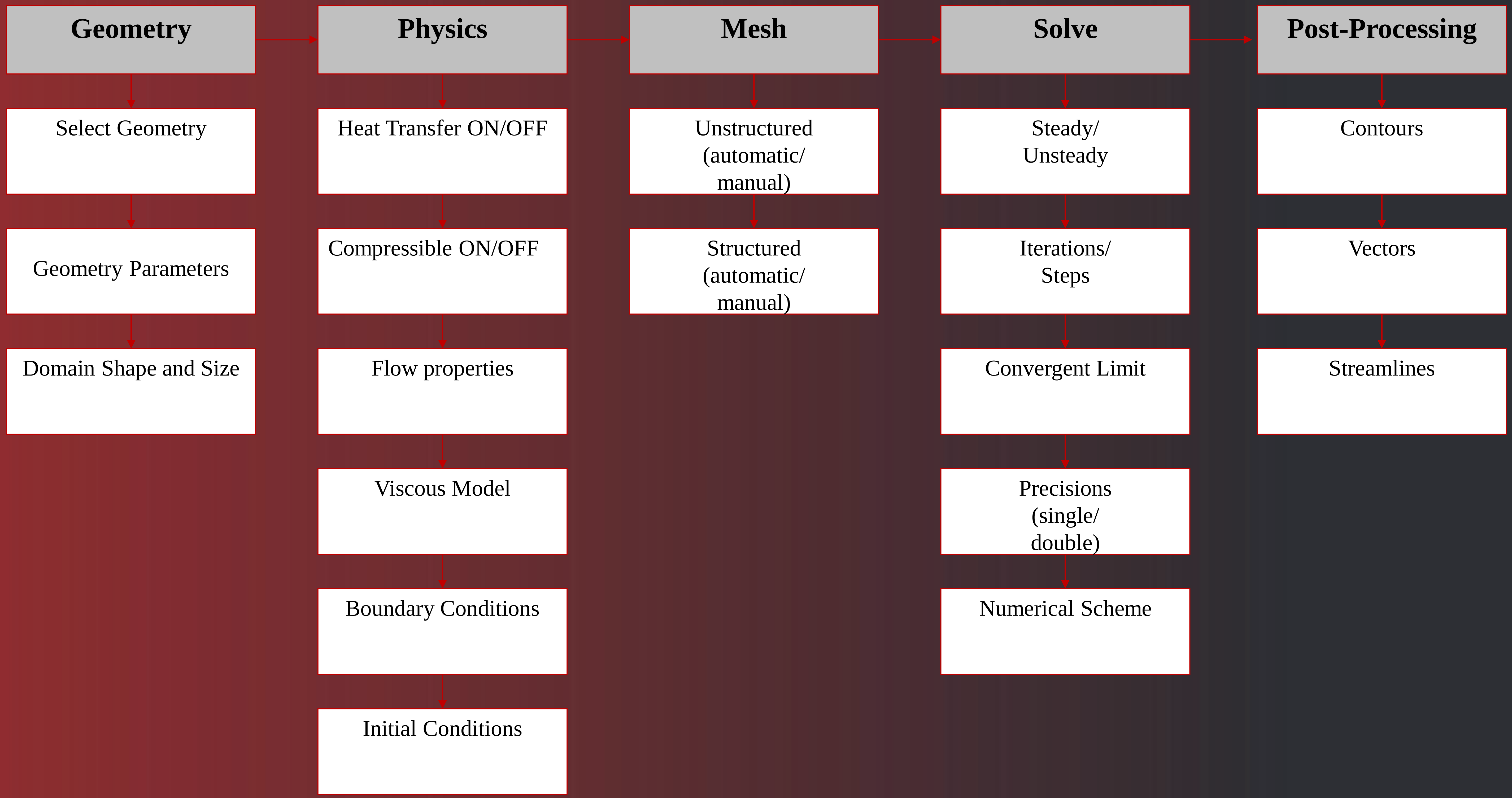








CFD Process


Geometry
Select Geometry
Geometry Parameters
Domain Shape and Size
Physics
Heat Transfer ON/OFF
Compressible ON/OFF
Flow properties
Viscous Model
Boundary Conditions
Initial Conditions
Mesh
Unstructured (automatic/ manual)
Structured (automatic/ manual)
Solve
Steady/ Unsteady
Iterations/ Steps
Convergent Limit
Precisions (single/ double)
Numerical Scheme
Post-Processing
Contours
Vectors
Streamlines

Physics

- Flow conditions and fluid properties variables for research codes.
    1. **Flow conditions**: inviscid, viscous, laminar, or turbulent, etc.
    2. **Fluid properties**: density, viscosity, and thermal conductivity, etc.
    3. **Flow conditions and properties** usually presented in dimensional form in industrial commercial CFD software, whereas in non-dimensional
- **Selection of models**

  Different models usually fixed by codes, options for user to choose
- **Initial and Boundary Conditions**

  Not fixed by codes, user needs specify them for different applications.

- Navier-Stokes Equations (3D)

$$\rho\frac{\partial u}{\partial t}+\rho u\frac{\partial u}{\partial x}+\rho v\frac{\partial u}{\partial y}+\rho w\frac{\partial u}{\partial z}=-\frac{\partial \hat{p}}{\partial x}+\mu\left[\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right]$$

$$\rho\frac{\partial v}{\partial t}+\rho u\frac{\partial v}{\partial x}+\rho v\frac{\partial v}{\partial y}+\rho w\frac{\partial v}{\partial z}=-\frac{\partial \hat{p}}{\partial y}+\mu\left[\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right]$$

$$\rho\frac{\partial w}{\partial t}+\rho u\frac{\partial w}{\partial x}+\rho v\frac{\partial w}{\partial y}+\rho w\frac{\partial w}{\partial z}=-\frac{\partial \hat{p}}{\partial z}+\mu\left[\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right]$$

Local acceleration | Convection | Piezometric pressure gradient | Viscous terms

Continuity equation

$$\frac{\partial \rho}{\partial t}+\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0$$

Equation of state

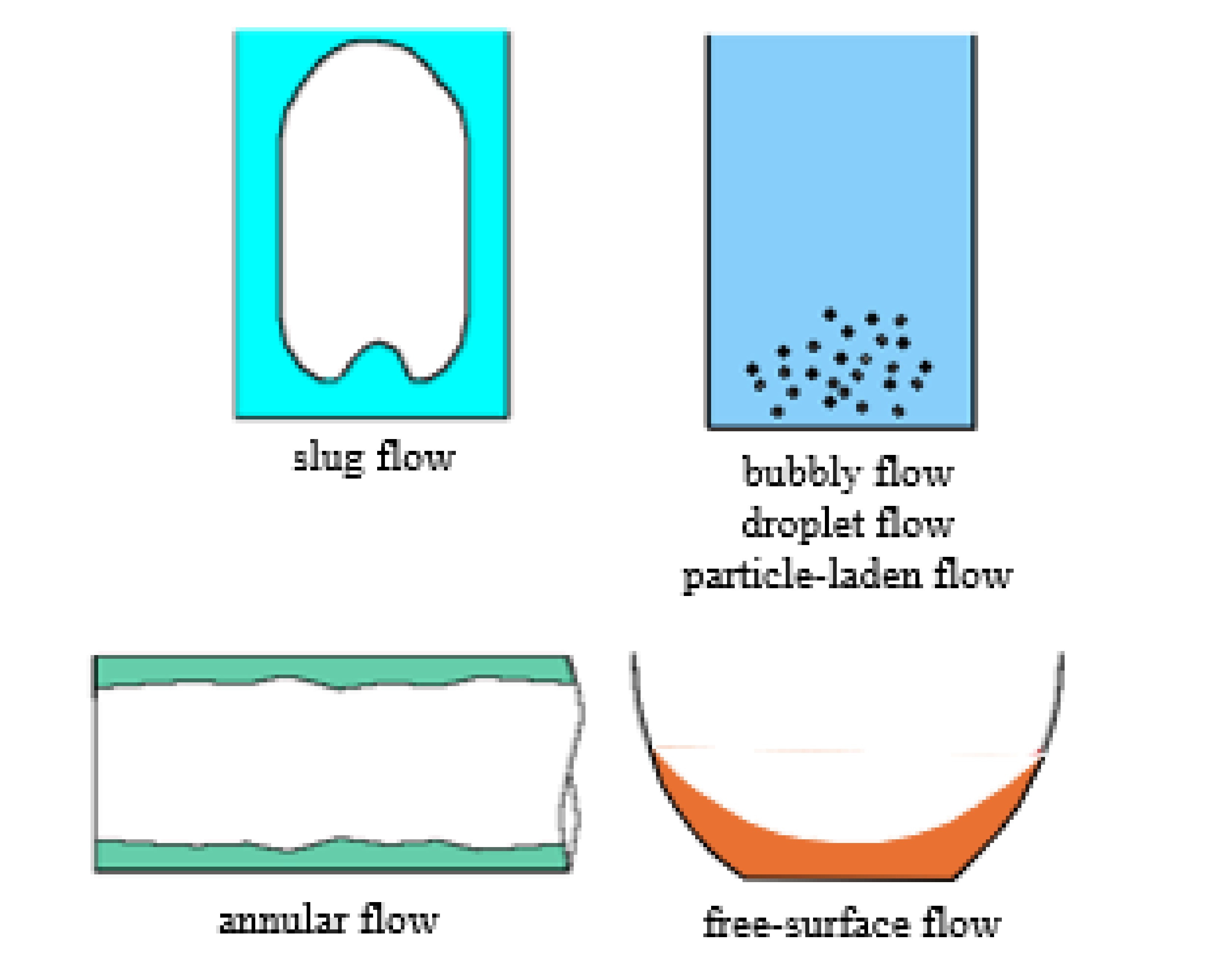
$$p=\rho RT$$

Rayleigh Equation

$$R\frac{D^2R}{Dt^2}+\frac{3}{2}\left(\frac{DR}{Dt}\right)^2=\frac{p_v-p}{\rho_L}$$

Multiphase Flow Regimes

- **Bubbly flow:** discrete gaseous bubbles in a continuous liquid.
- **Droplet flow:** discrete fluid droplets in a continuous gas.
- **Particle-laden flow:** discrete solid particles in a continuous fluid.
- **Slug flow:** large bubbles in a continuous liquid.
- **Annular flow:** continuous liquid along walls, gas in core.
- **Stratified and free-surface flow:** immiscible fluids separated by a clearly-defined interface.



Multiphase Formulation

- Two phases

Fluid

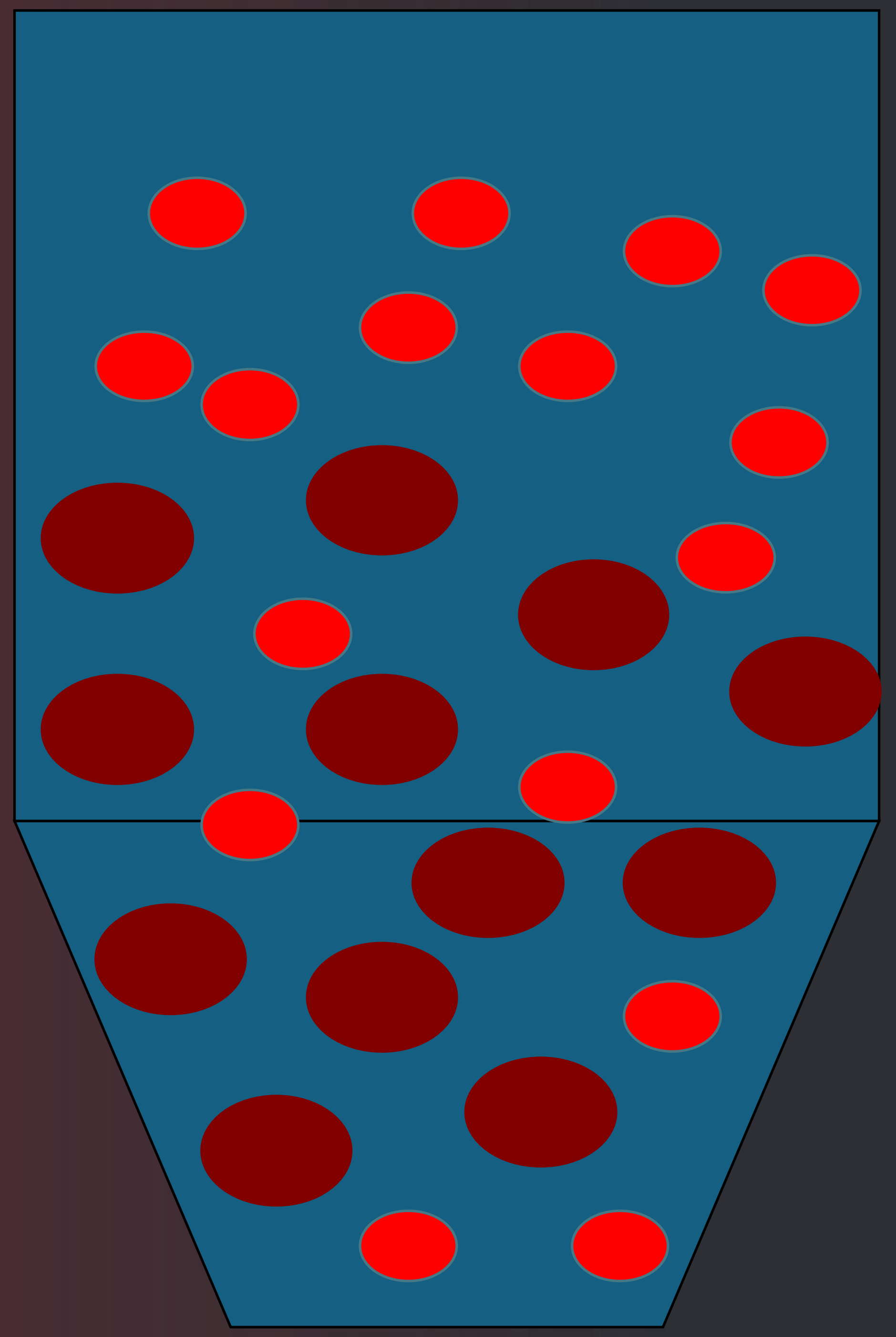
Solids

- Three Phases

Fluid

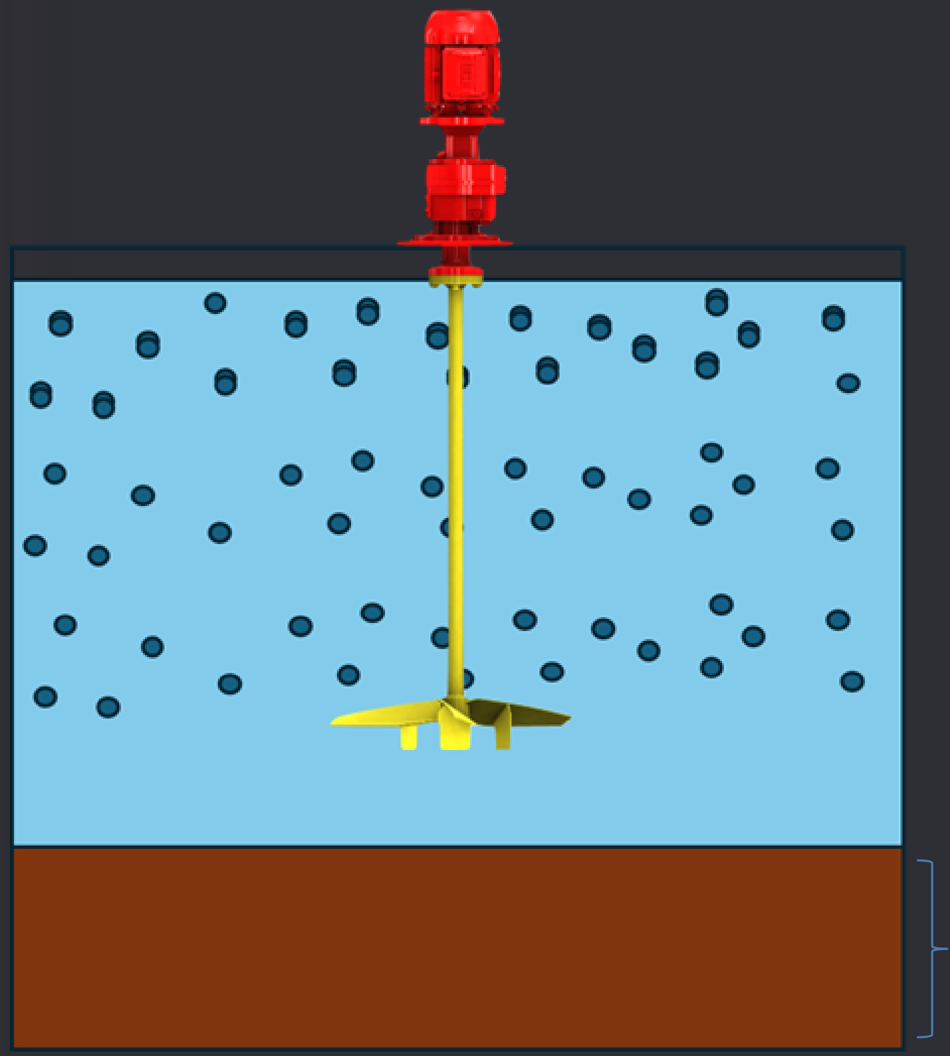
Solids - 1

Solids - 2

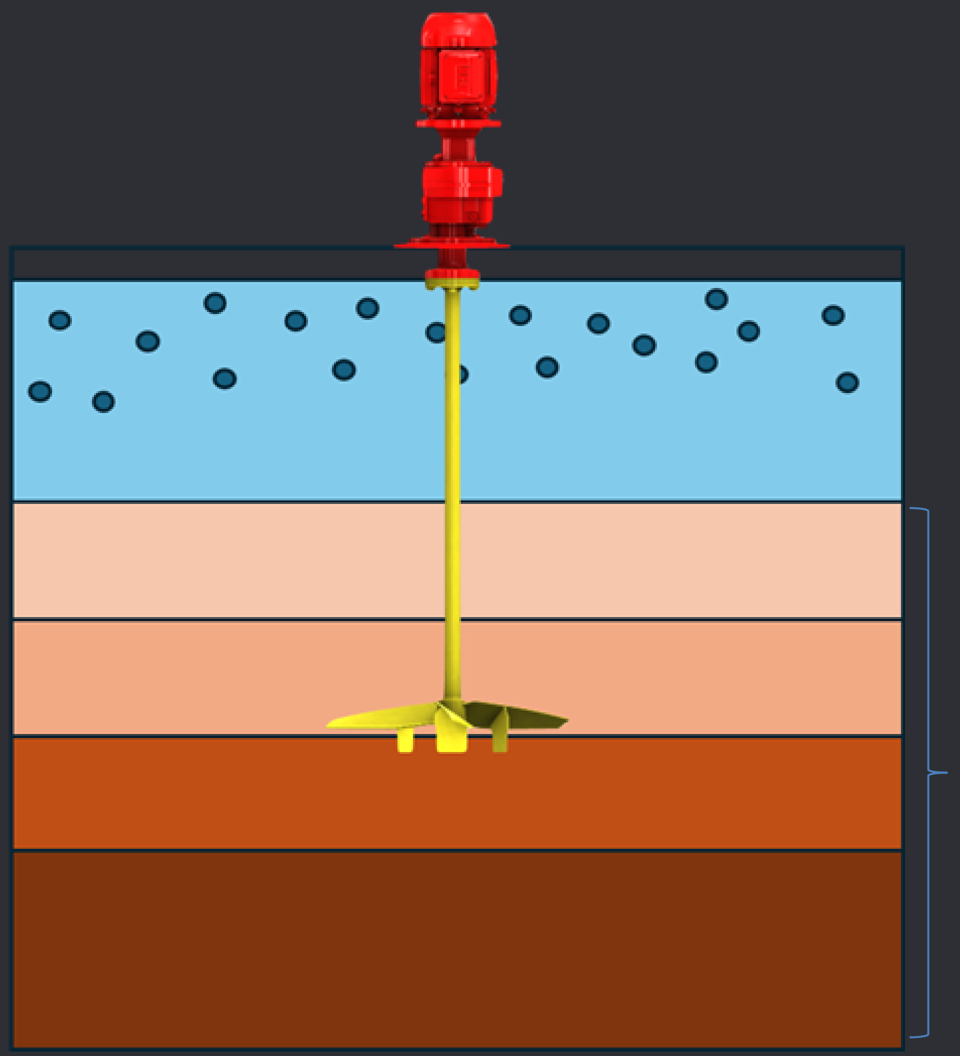


Challenges in Tailings Management

- **Sedimentation and settling:** Solid particles settling at the bottom of tailing ponds.
- **Stratification:** Formation of distinct layers within the tailings.
- **Environmental risks**: Potential for water contamination and ecosystem disruption.



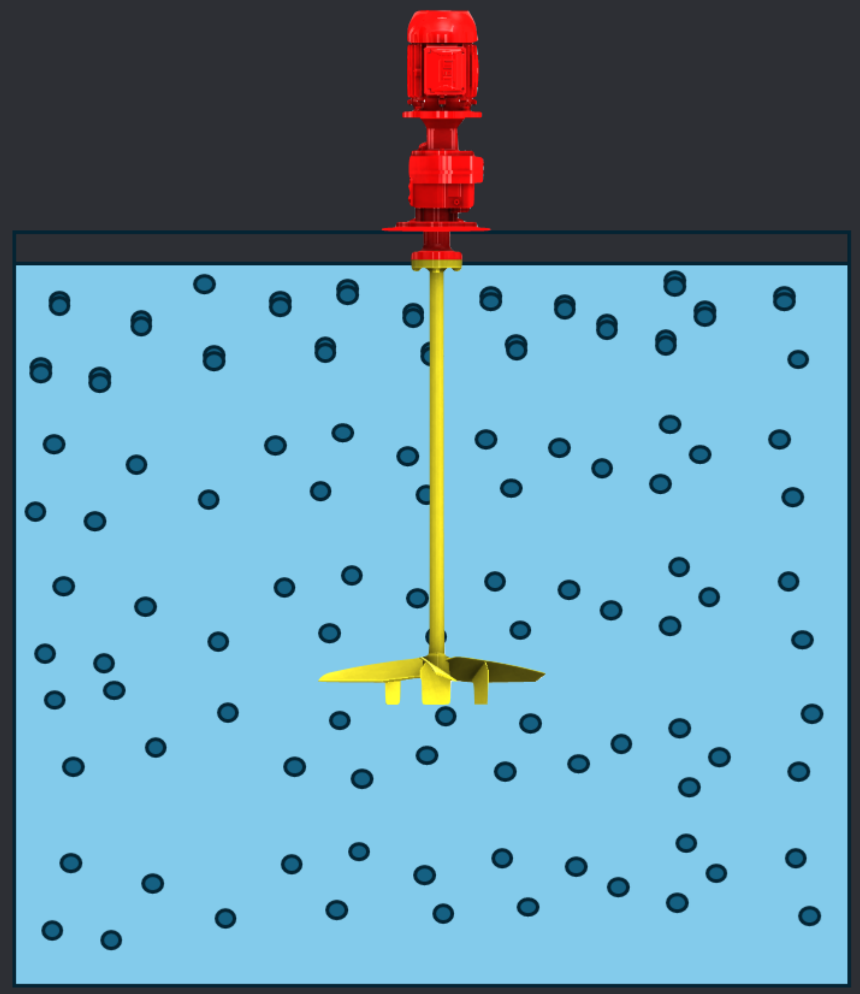
Sedimentation



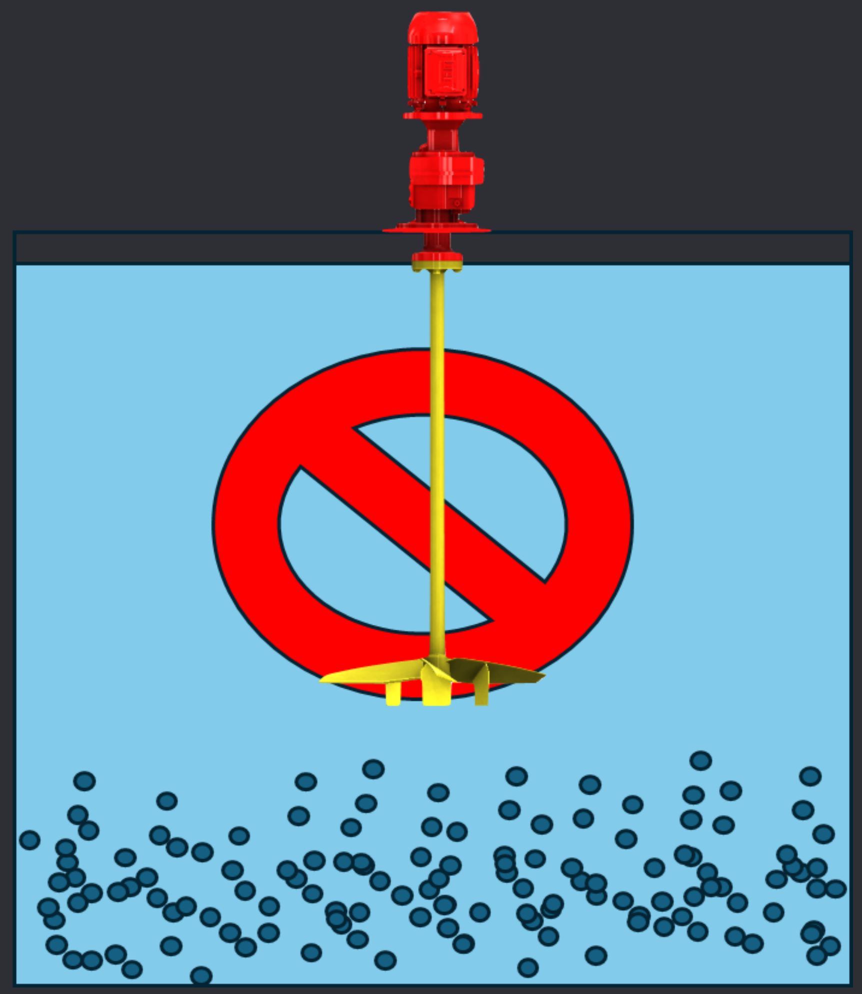
Stratification

Role of Mixers in Tailings Management

- **Homogenization:** Ensuring uniform distribution of solids and chemicals.
- **Suspension:** Preventing settling of solid particles.
- **Chemical reaction enhancement:** Facilitating treatment processes.
- **Temperature control:** Managing heat transfer within the tailing pond.
- **Preventing crust formation:** Maintaining surface integrity.



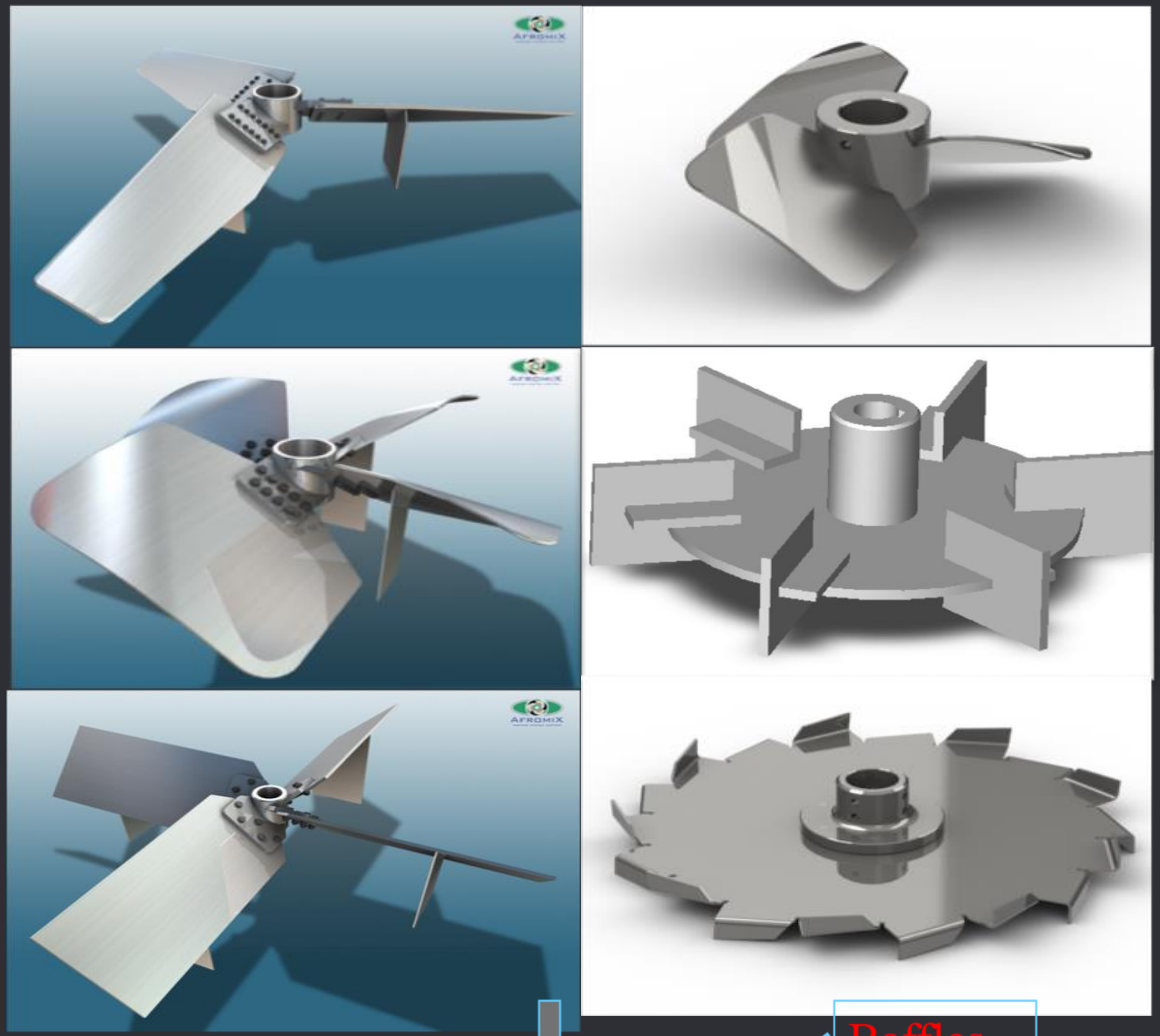
Homogenization

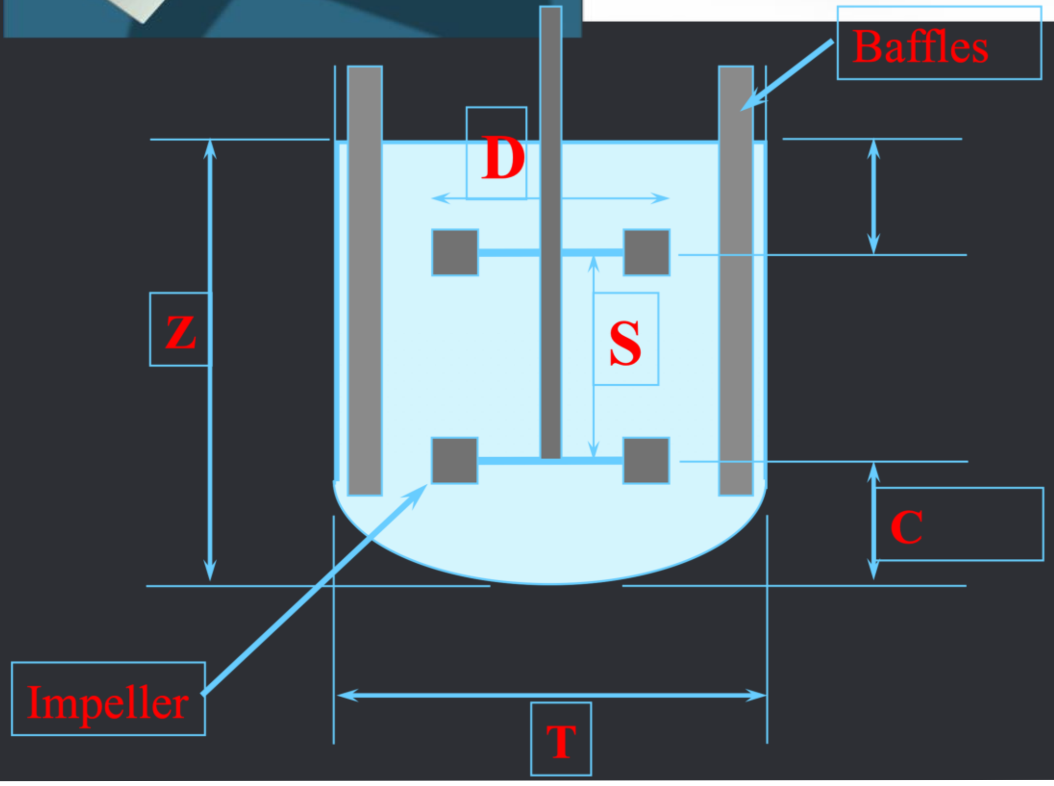


Settling

Mixer Selection Considerations

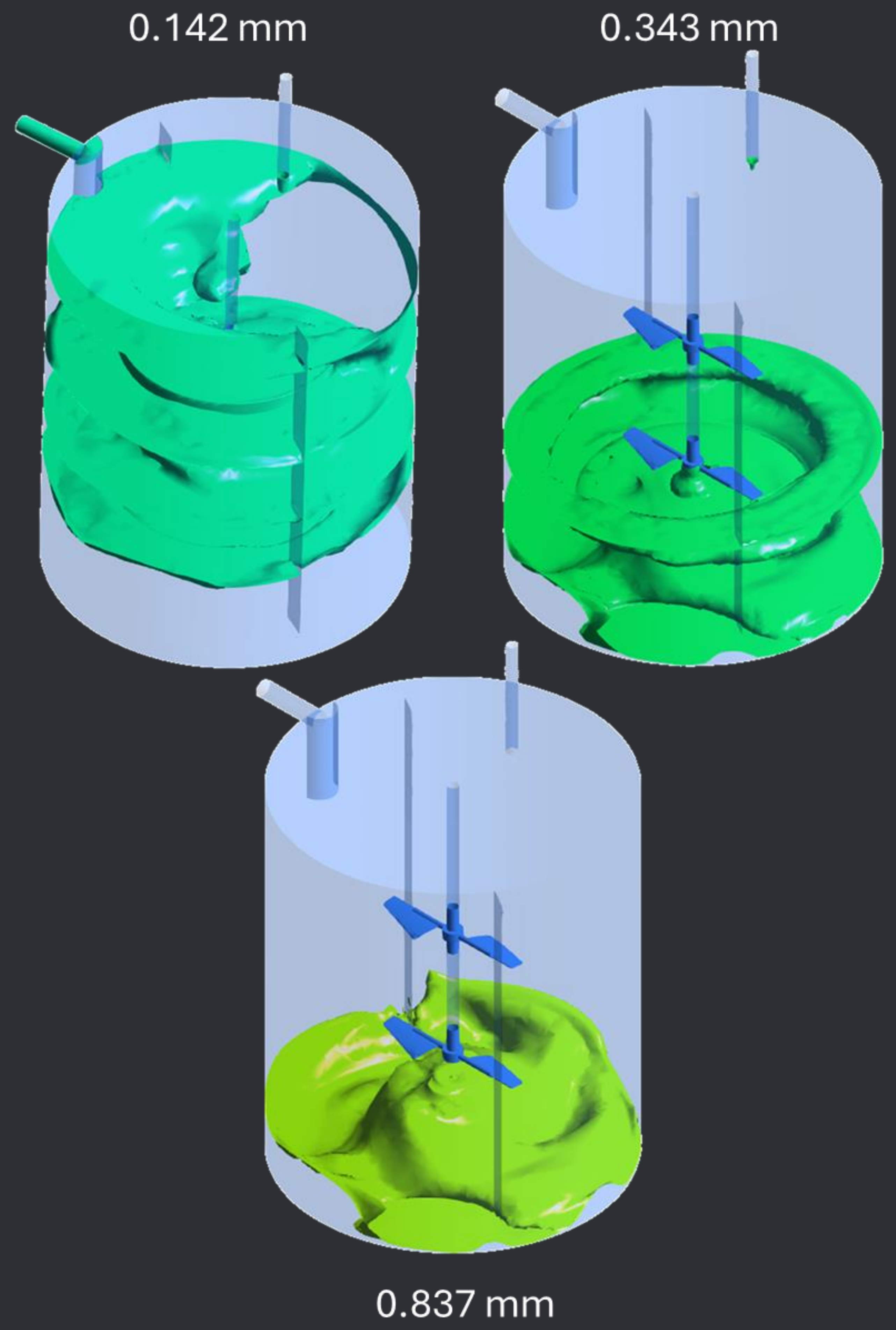
- **Type of mixer:** Agitators, impellers, propellers, etc.
- **Tank geometry and size:** Matching mixer design to tank dimensions.
- **Material compatibility:** Resistance to corrosion and abrasion.
- **Power requirements:** Ensuring sufficient mixing energy.
- **Operational considerations:** Maintenance requirements, reliability, and safety.





Mixing in Tailings

- Slurry Conditioning
- Thickening
- Flocculation
- Transportation
- Tailings Disposal
- Environmental Management

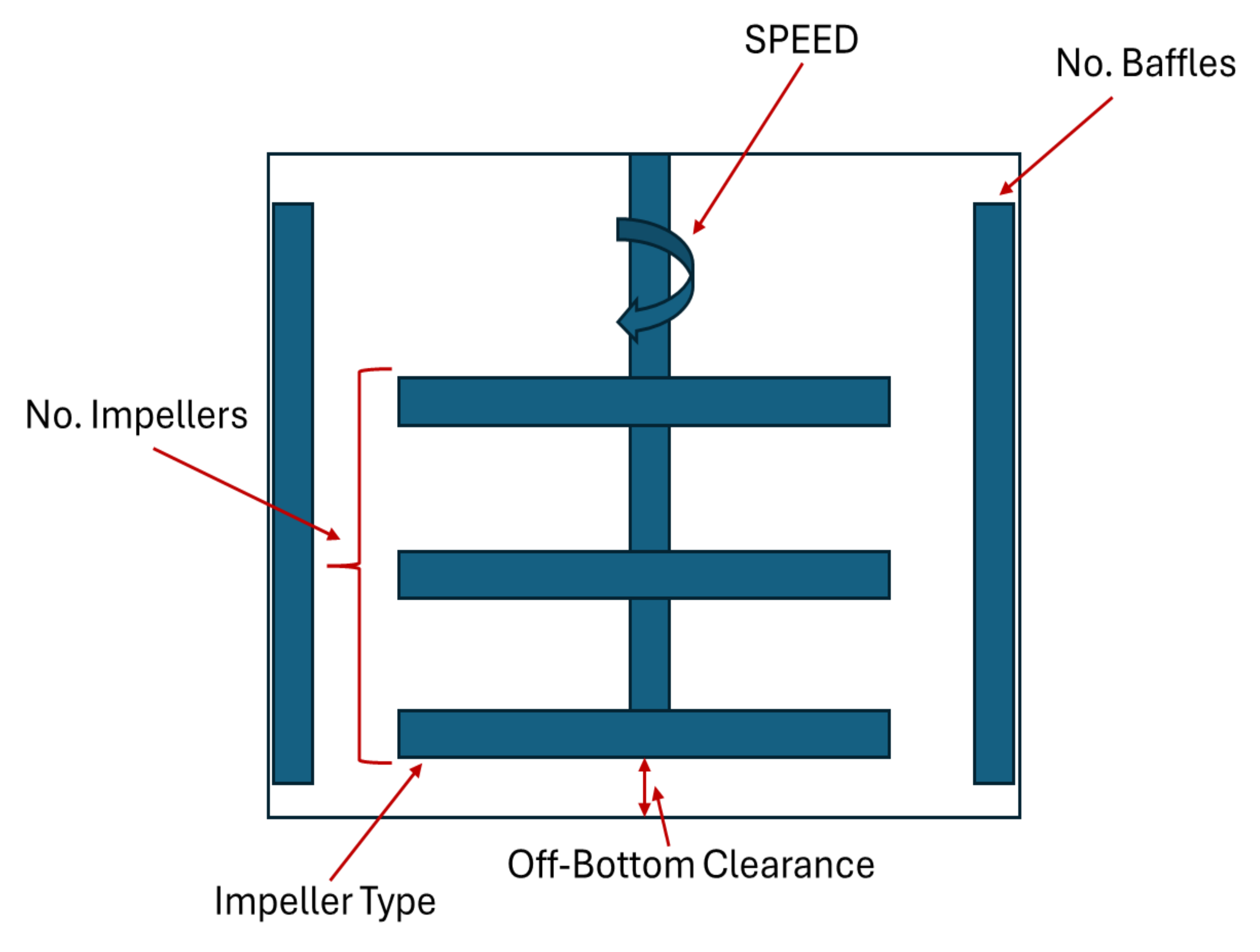


Taguchi Design of Experiments

Taguchi Design of Experiments (DOE) offers a systematic approach to optimizing mixing tanks for tailings management.
By varying factors and analyzing their effects on performance, Taguchi DOE helps identify the most influential parameters for optimal mixing.

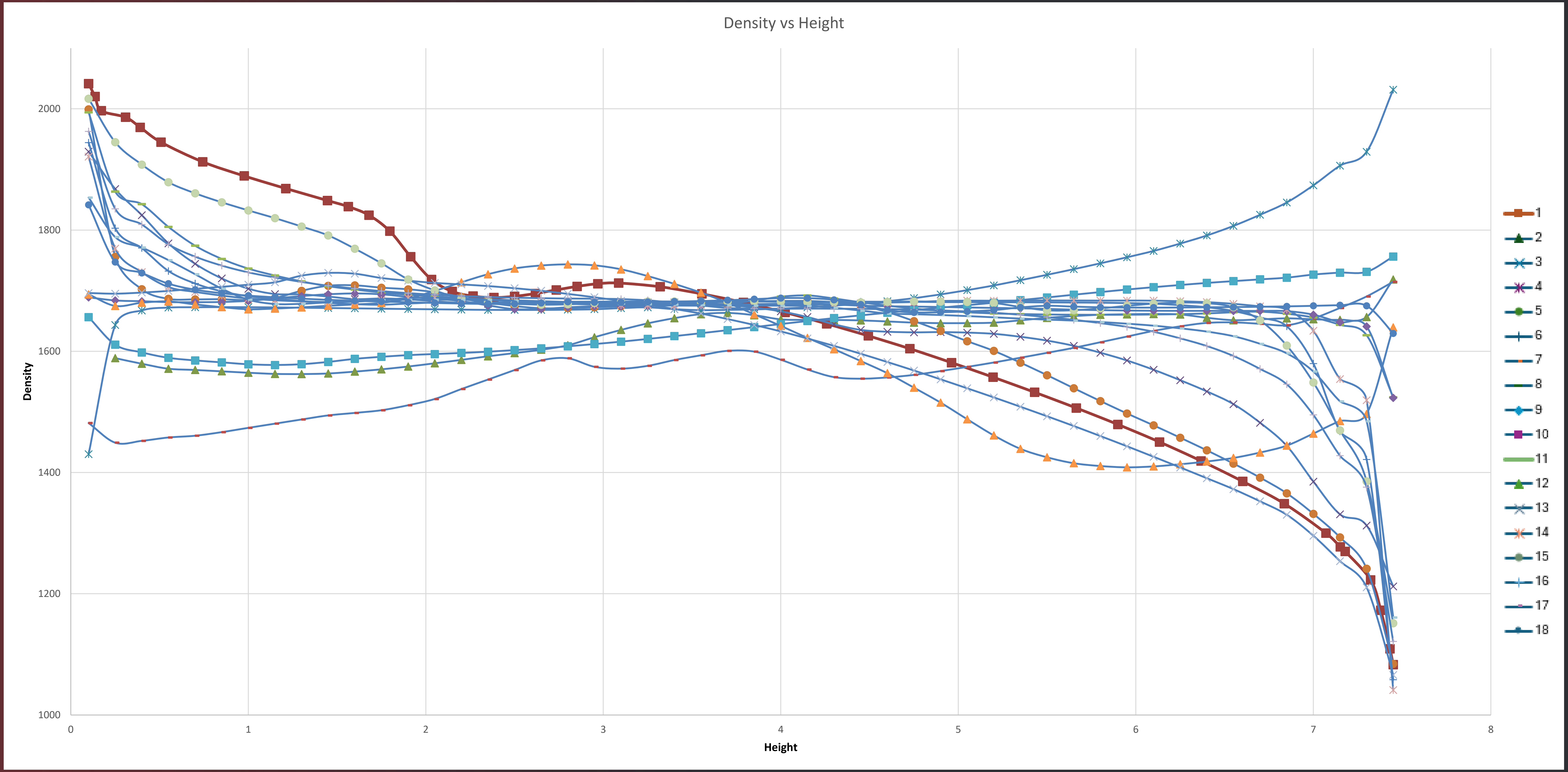
1. **Objective:**
   - The primary objective is to maximize the efficiency and effectiveness of mixing tanks in tailings.
2. **Key Factors:**
   - Factors affecting mixing tank performance include:
     - Impeller type
     - Number of Impellers
     - Number of Baffles
     - Off-Bottom Clearance
     - Agitator Speed
3. **Response Variables:**
   - Response variables include:
     - Homogeneity of the slurry
     - Efficiency of solid suspension
     - Variation in density
4. **Analysis Methods:**
   - Use statistical techniques to analyze experimental data and identify significant factors.
   - Evaluate signal-to-noise ratios to determine optimal parameter settings.
   - Conduct sensitivity analyses to assess the robustness of the optimized settings.

DOE for Optimization in Tailings



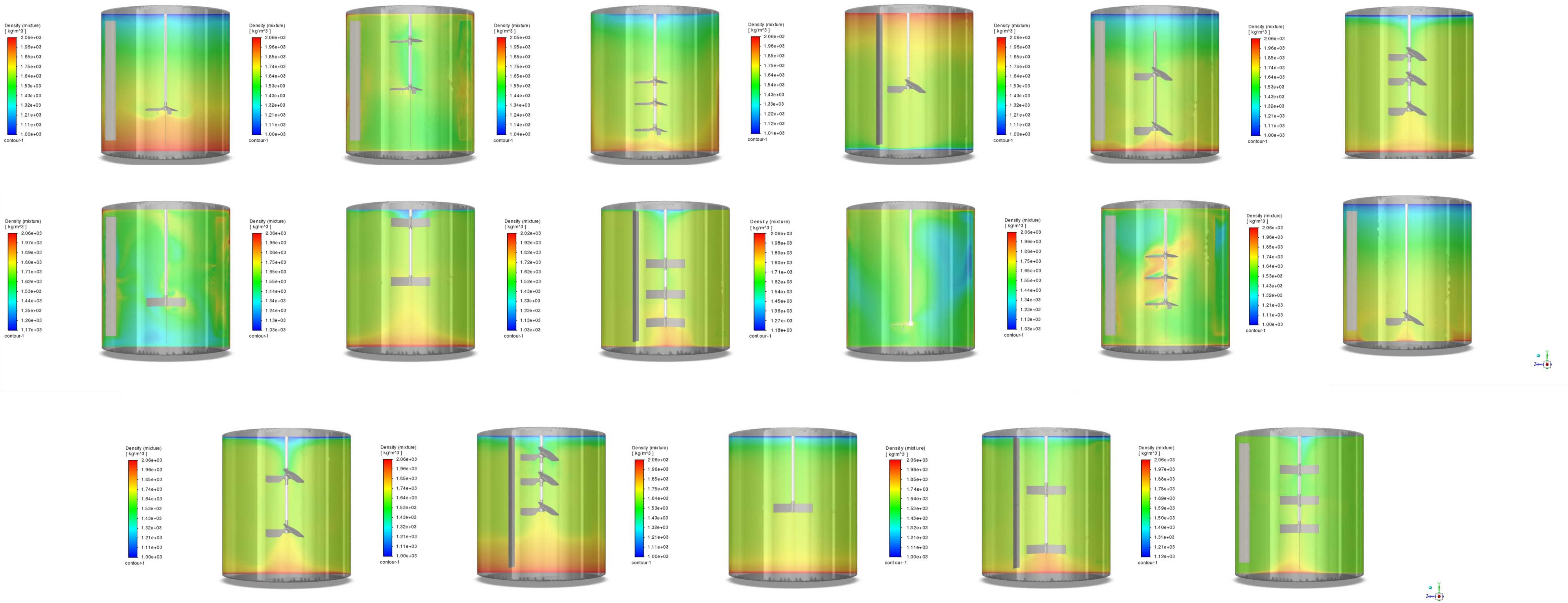
No.	Impeller Type	No. Stages	No. Baffle	Off Bottom (mm)	Speed (RPM)
1	Hydrofoil	1	3	2225	33
2	Hydrofoil	2	4	3337.5	50
3	Hydrofoil	3	0	1112.5	25
4	PBT	1	3	3337.5	50
5	PBT	2	4	1112.5	25
6	PBT	3	0	2225	33
7	Rushton	1	4	2225	25
8	Rushton	2	0	3337.5	33
9	Rushton	3	3	1112.5	50
10	Hydrofoil	1	0	1112.5	50
11	Hydrofoil	2	3	2225	25
12	Hydrofoil	3	4	3337.5	33
13	PBT	1	4	1112.5	33
14	PBT	2	0	2225	50
15	PBT	3	3	3337.5	25
16	Rushton	1	0	3337.5	25
17	Rushton	2	3	1112.5	33
18	Rushton	3	4	2225	50

DOE Results

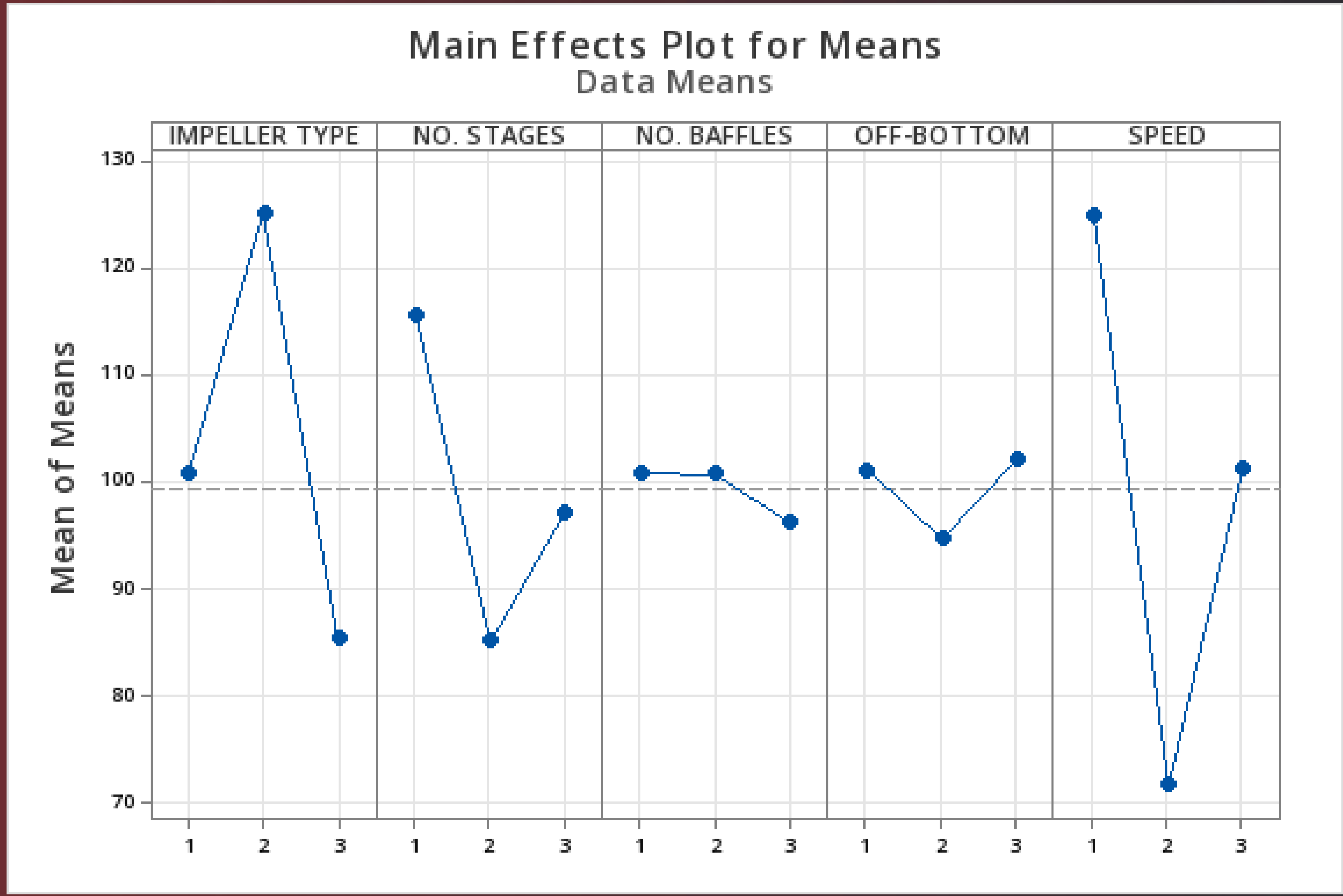


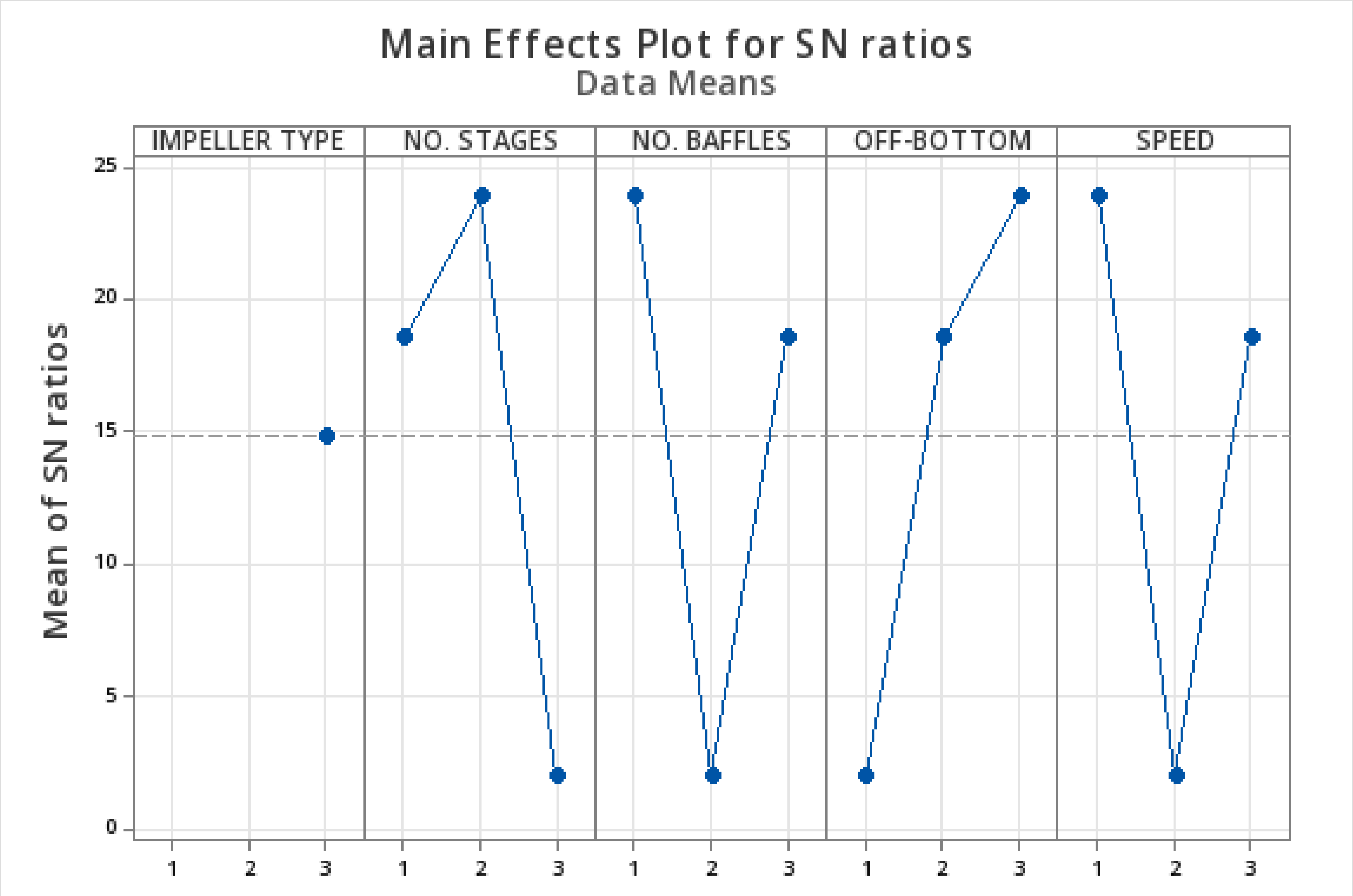
Density vs Height
Density
Height
2000
1800
1600
1400
1200
1000
0
1
2
3
4
5
6
7
8
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

DOE Density Contours



DOE S/N Ratio

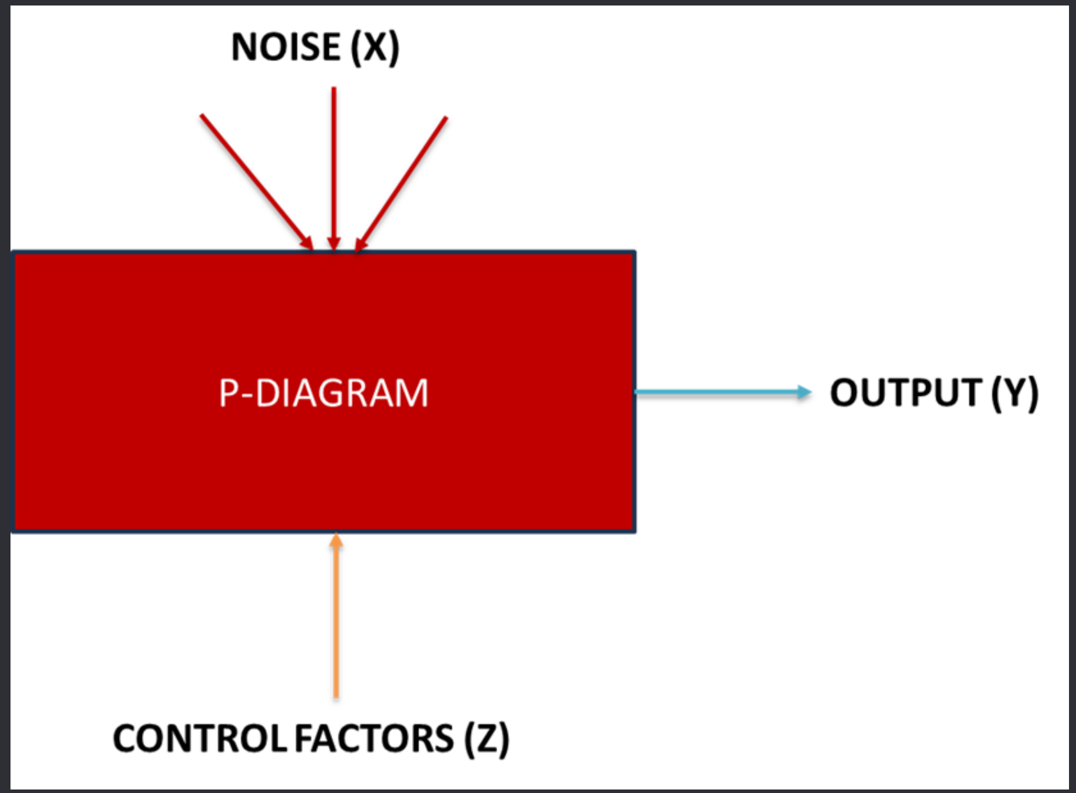




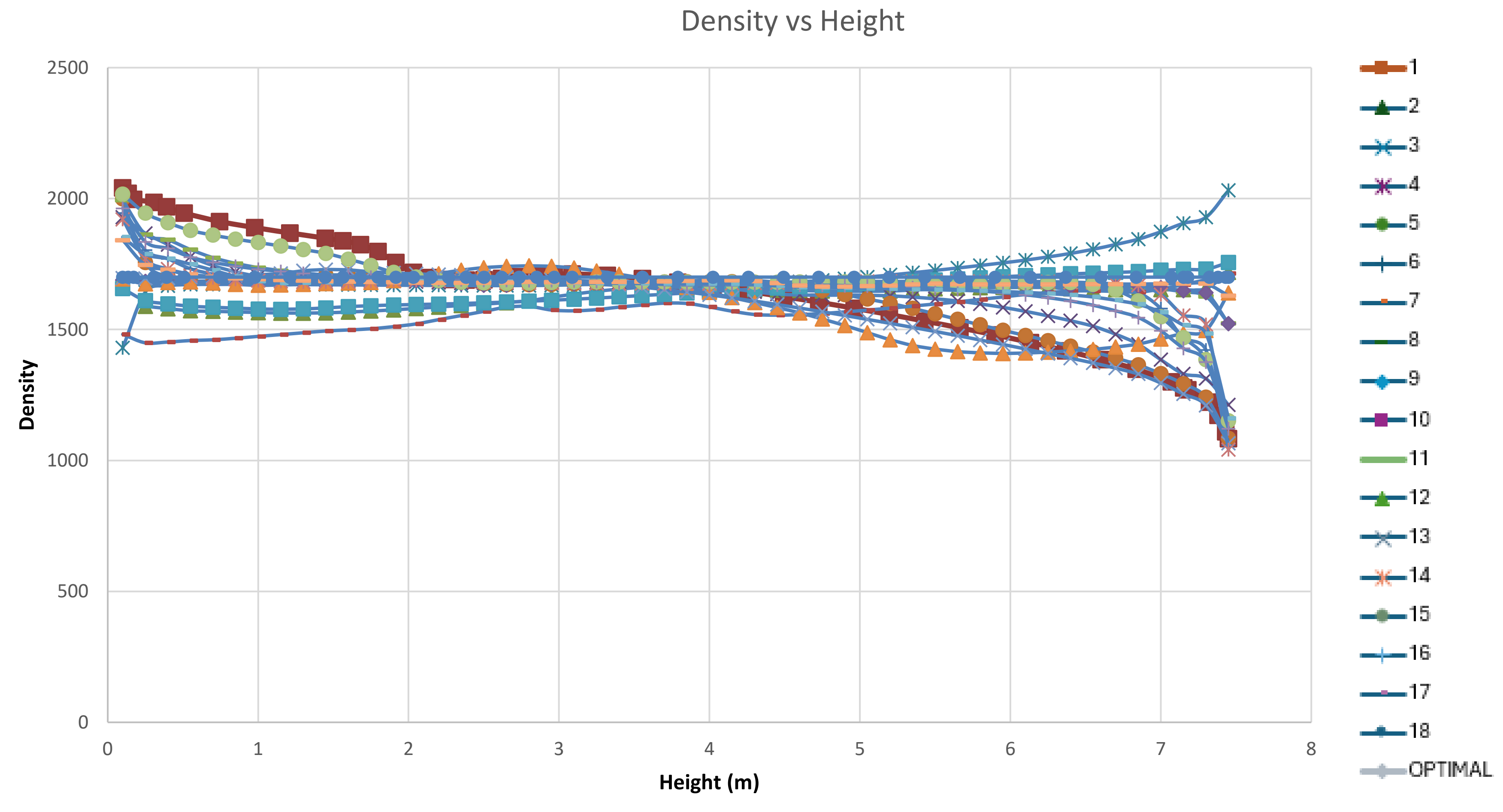
Impeller	
F	1
P	2
R	3
No. Stages	
1	1
2	2
3	3
Baffle	
Yes-3	1
Yes-4	2
No	3
Off Botom	
2225	1
3337.5	2
1112.5	3
Speed	
32.9	1
49.35	2
24.675	3

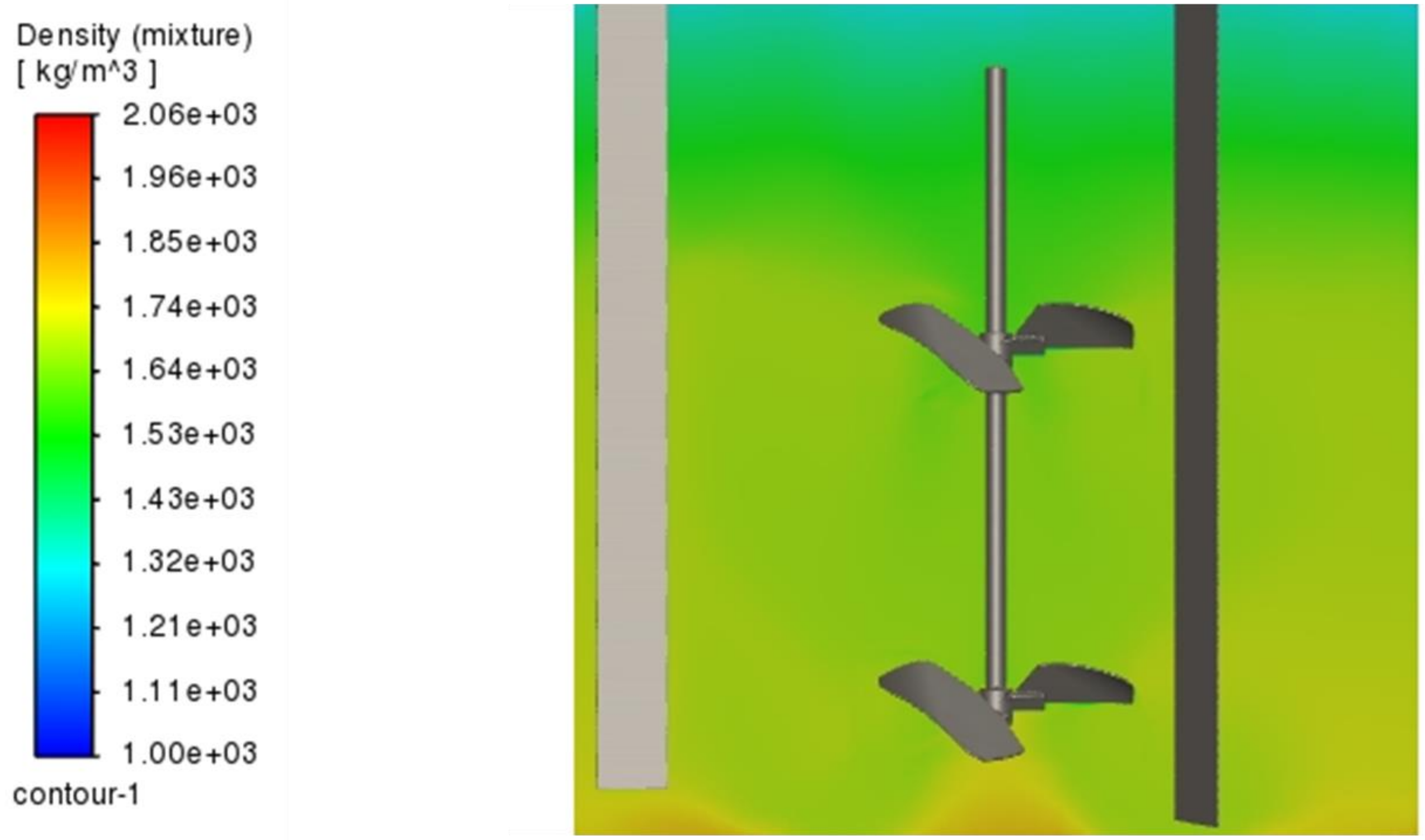
Optimized design based on DOE

Impeller	P-Type
No. Stages	2
Baffles	3
Off-Botom	1112.5
Speed	33

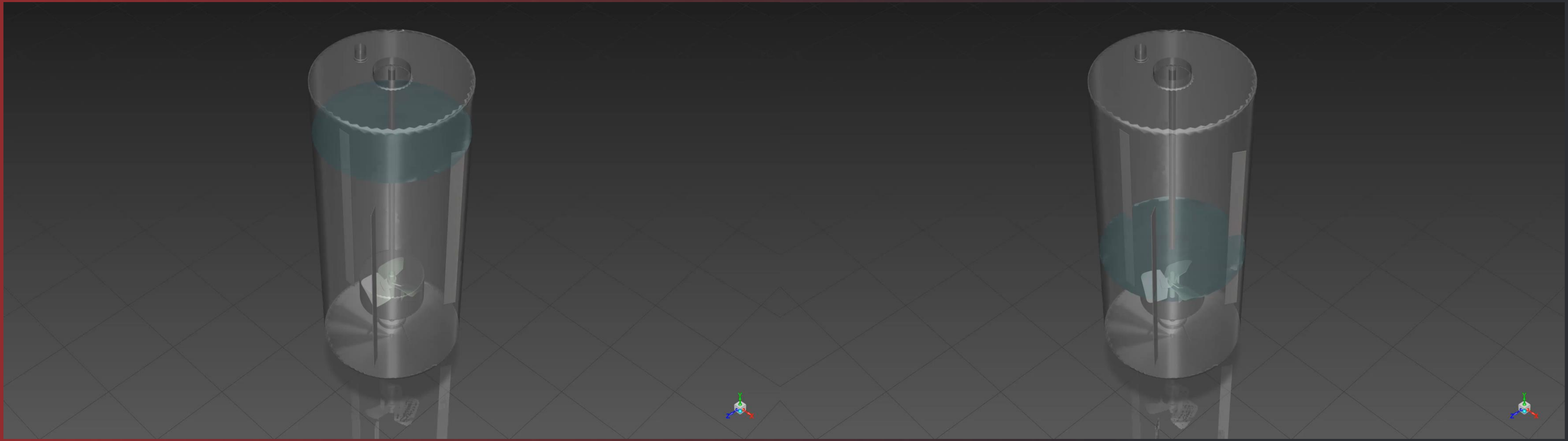


Optimized design based on DOE

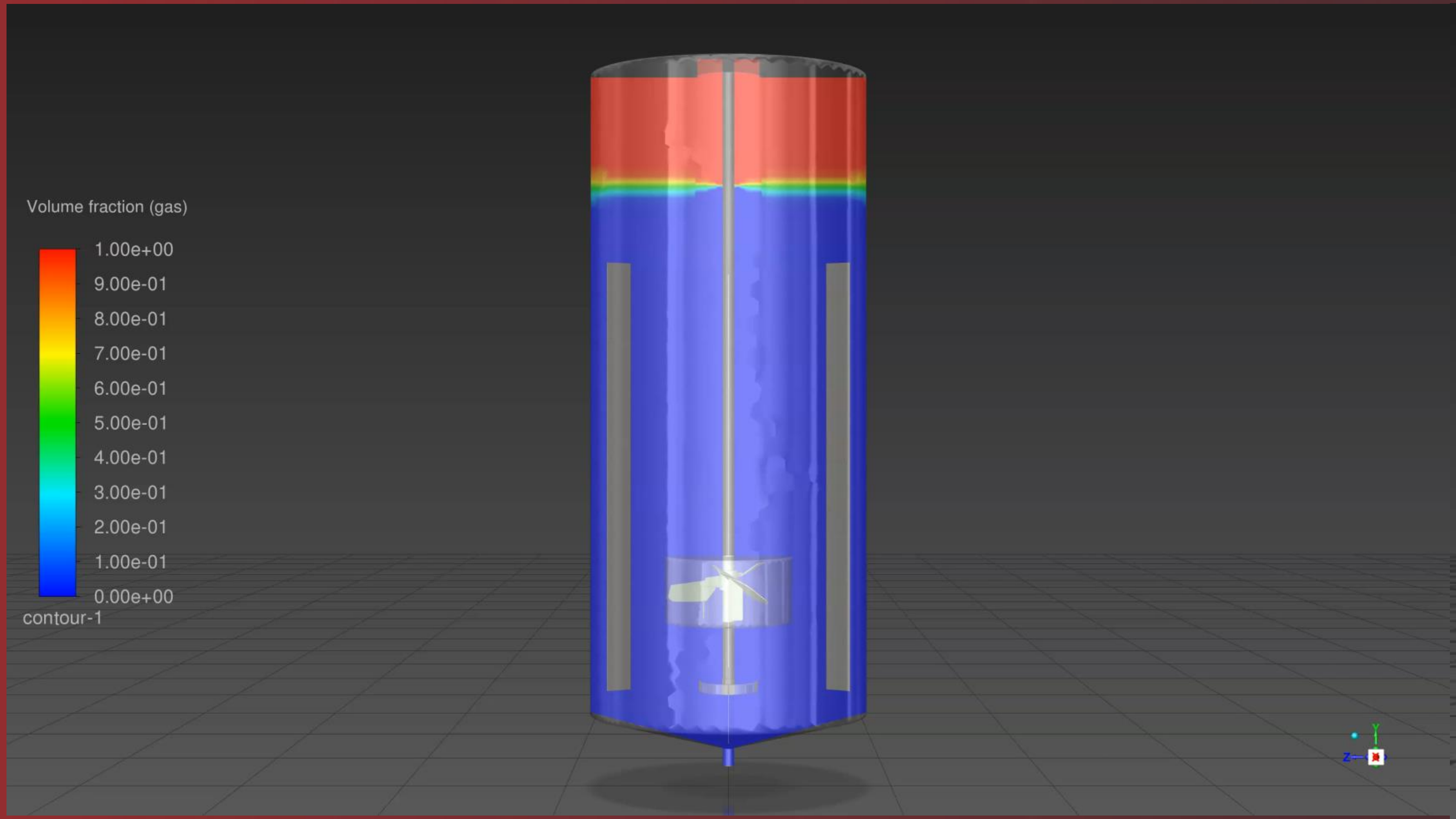


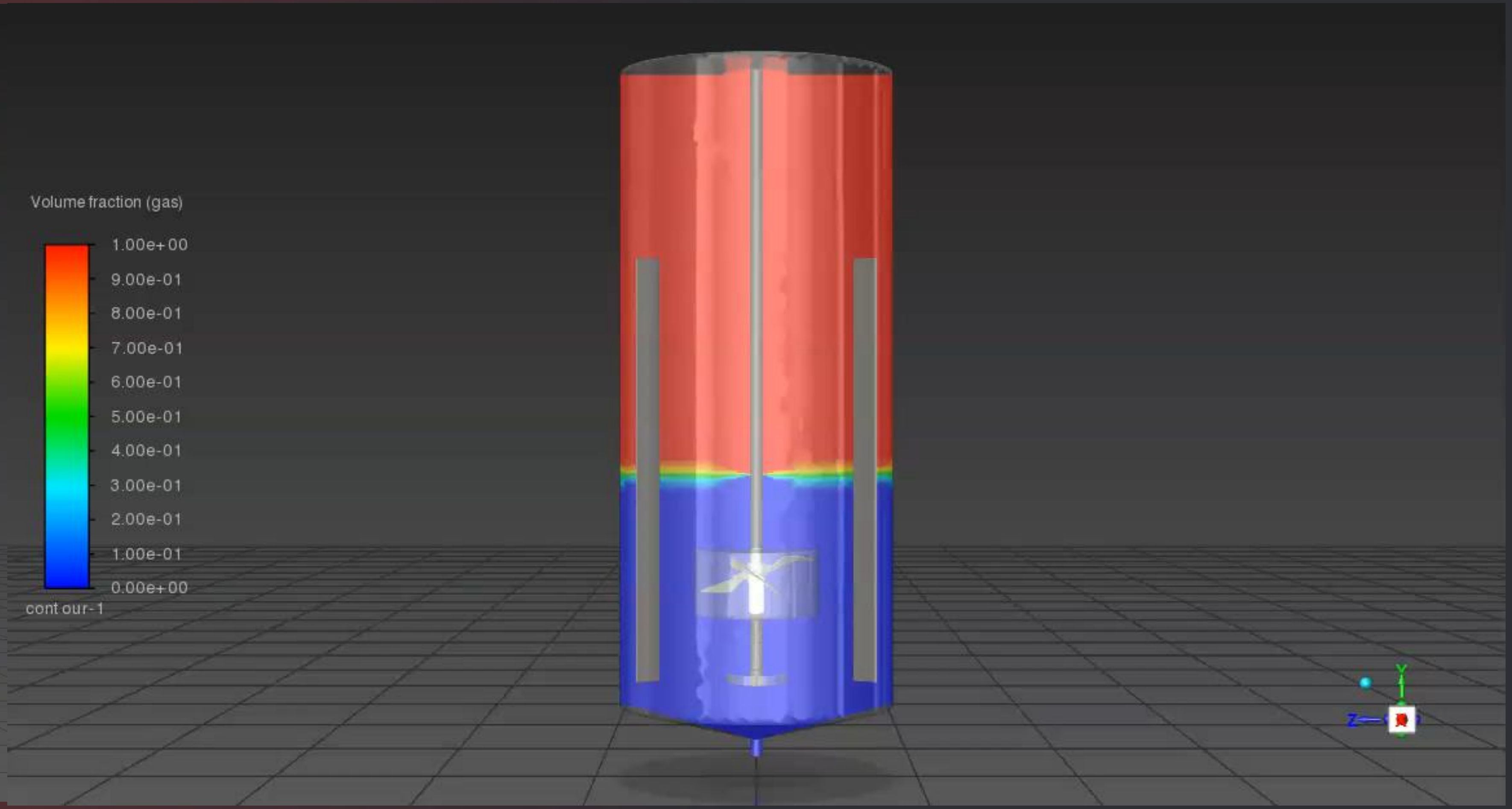


Liquid-Gas Free Surface



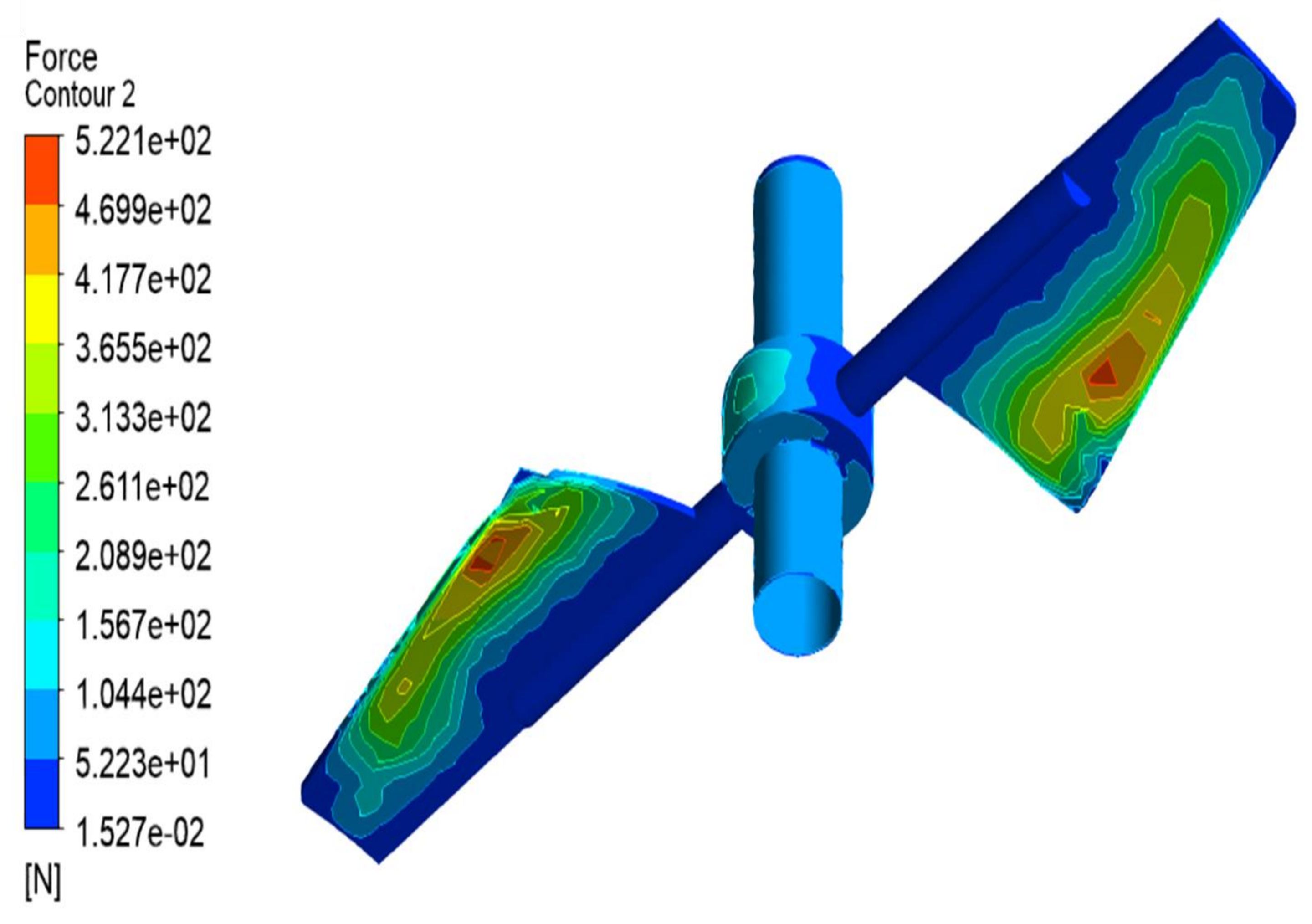
Volume Fraction Gas





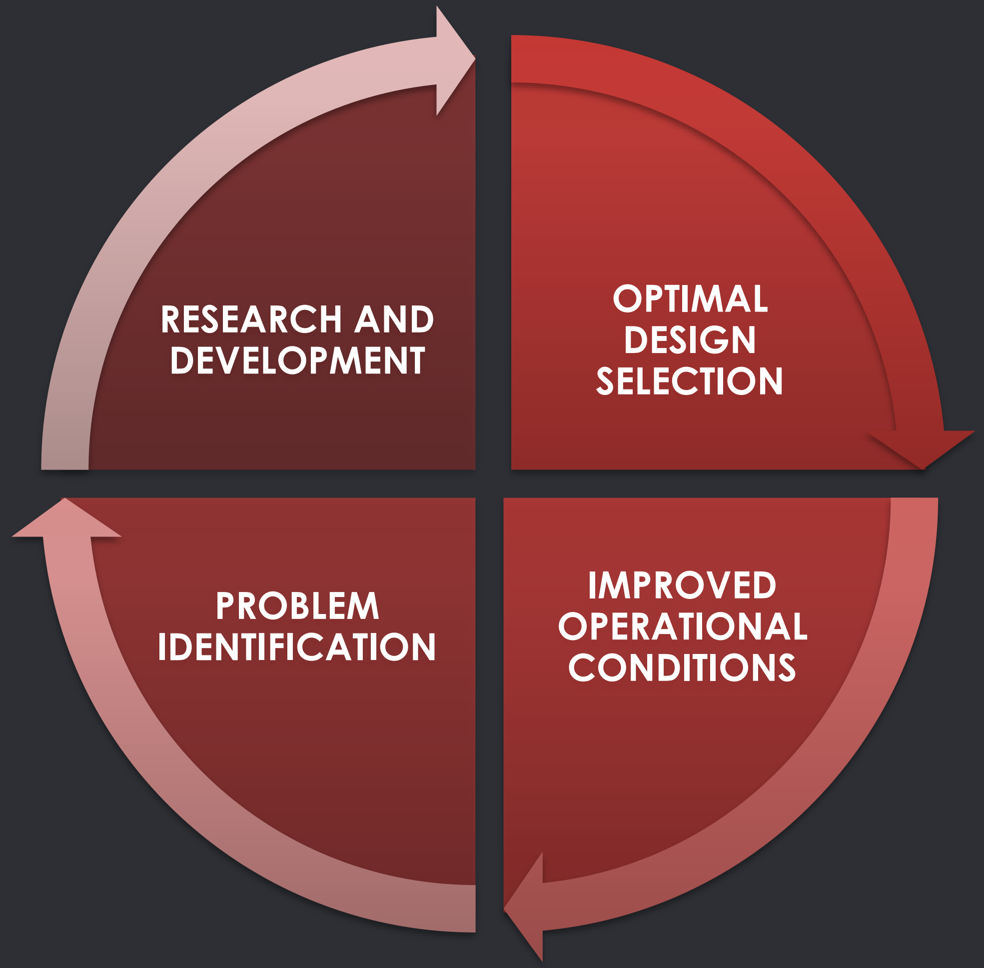
What can CFD offer you?

- CFD studies tailored to your specific process
- Insights into how varying parameters affect your process
- Assurance that your equipment will perform as desired
- Lower cost compared to experimental methods
- Affordable validation for expensive equipment



These parameters ultimately assist with the selection of the Optimal System Design and Configuration for the client's specific application.

This service is also used to identify system problems and provides insight to the best possible solution.



GRACIAS!

Questions?

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