

On the AI driven geometry optimization of a stirred tank CFD model in laminar flow

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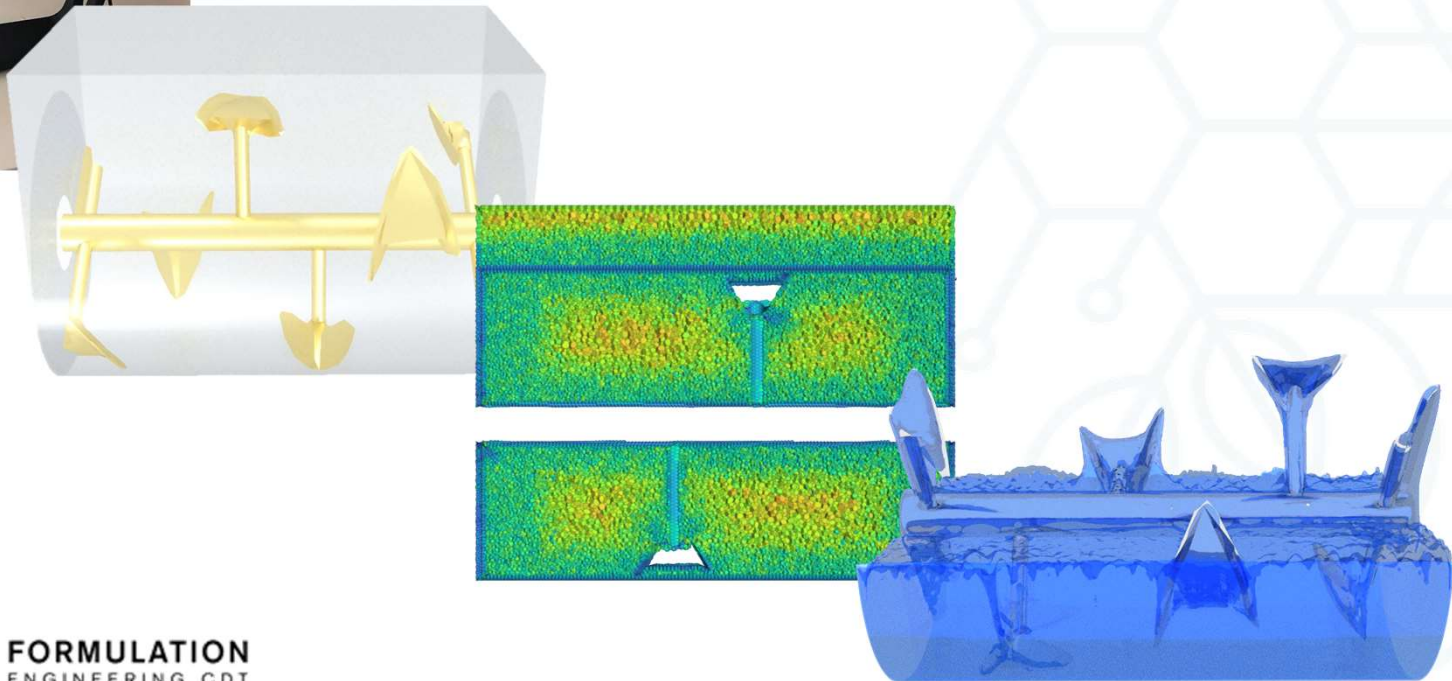
FMP SIG, January 10th, 2024

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[2] Hindustan Unilever R&D, Bangalore.
[3] Unilever R&D, Port Sunlight Laboratory.

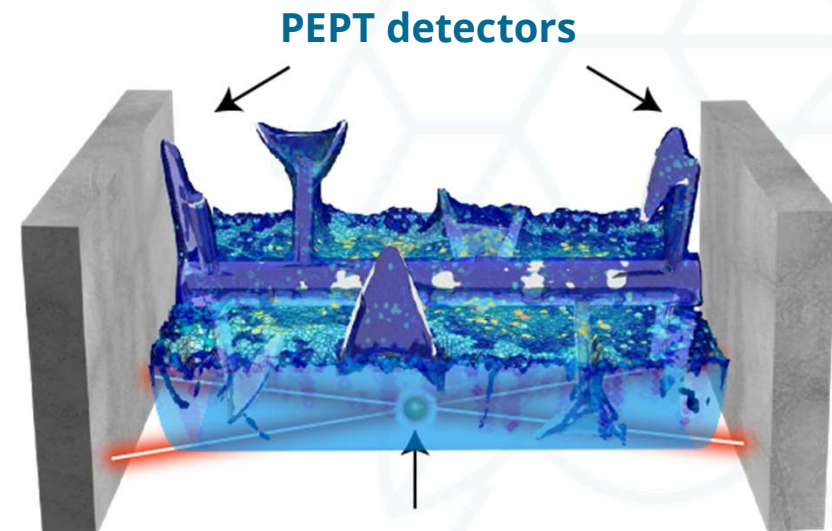
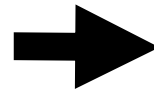
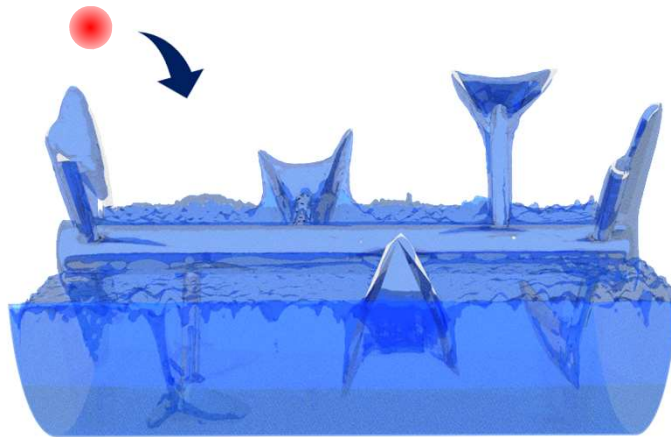
Introduction



What is Positron Emission Particle Tracking (PEPT)?

- Direct tracking of **particle motion in 3D** using gamma rays.
- It allows us to **'see inside' opaque systems**.

e^+
emitter



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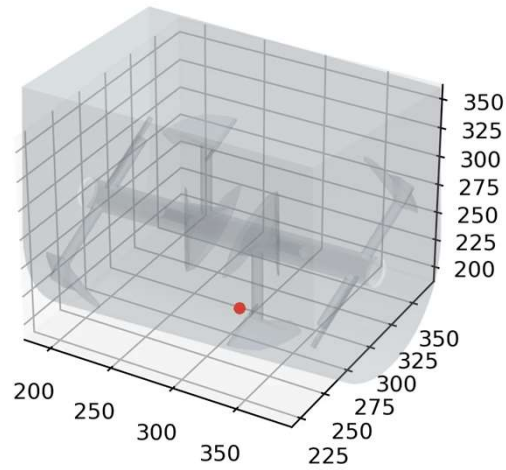


FORMULATION
ENGINEERING CDT

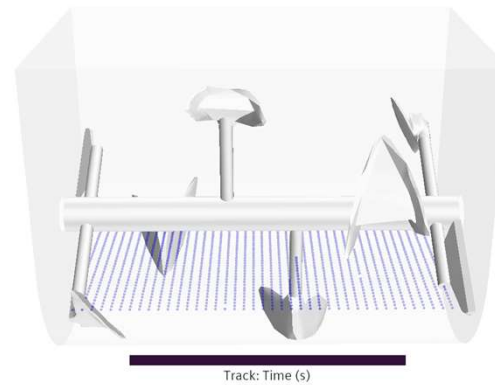
[1] Windows-Yule et al., 2022. *PEPT, a Comprehensive Guide*, IoP eBooks, ISBN 9780750330718

Validation

PEPT Experiment

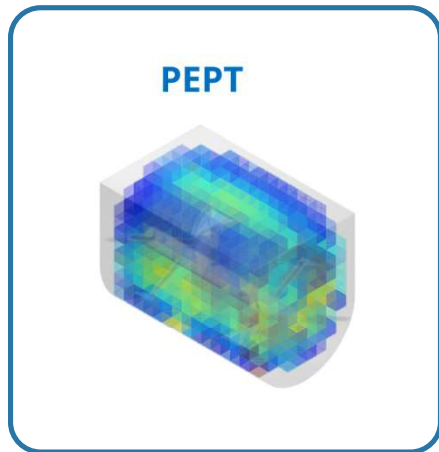


Simulation



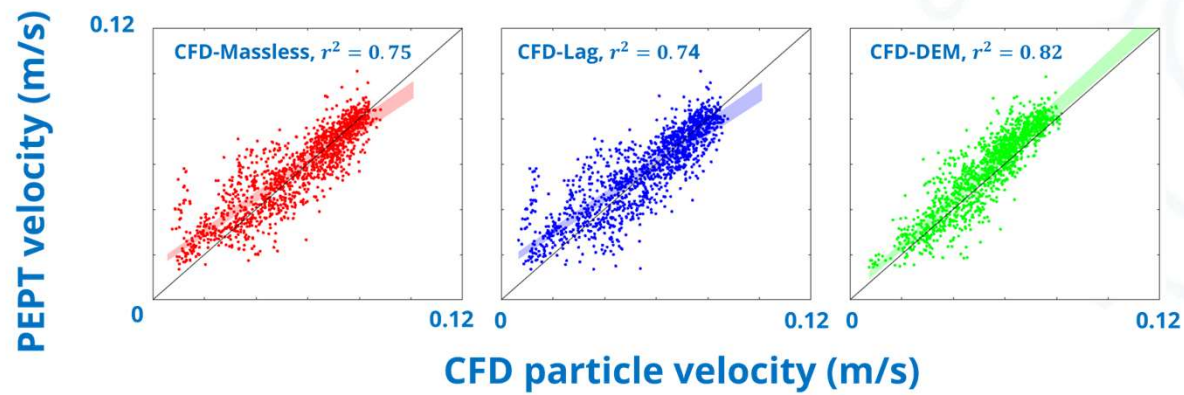
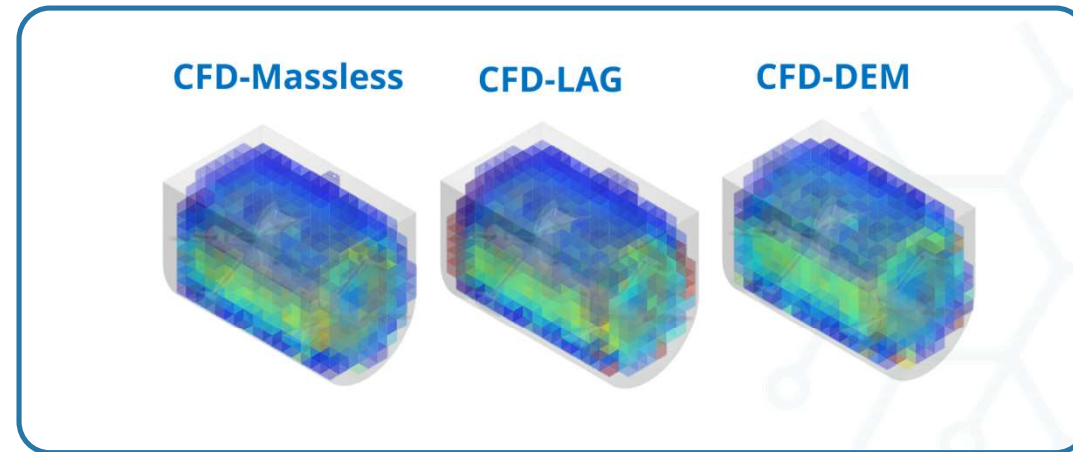
Validation

Experiment

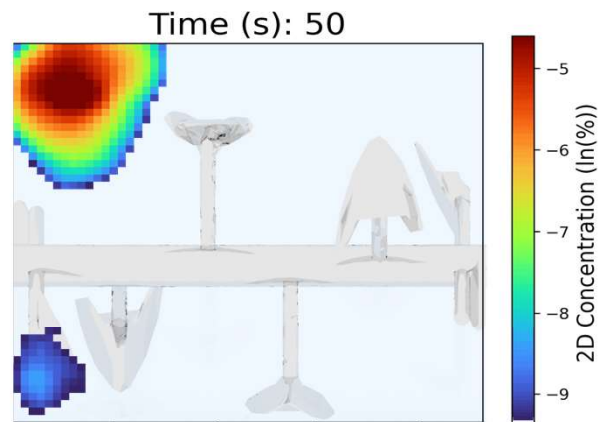


VS

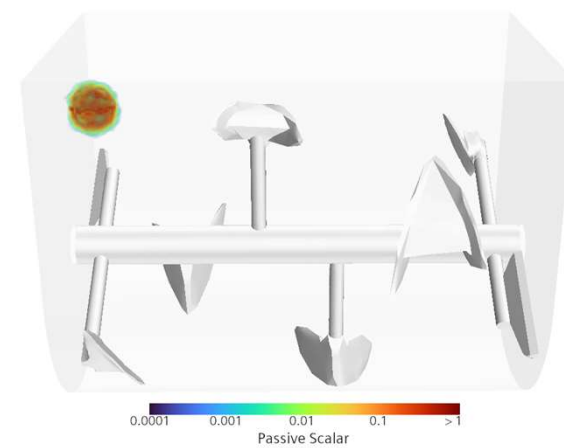
Simulation



Validation



Positron Emission Projection Imaging

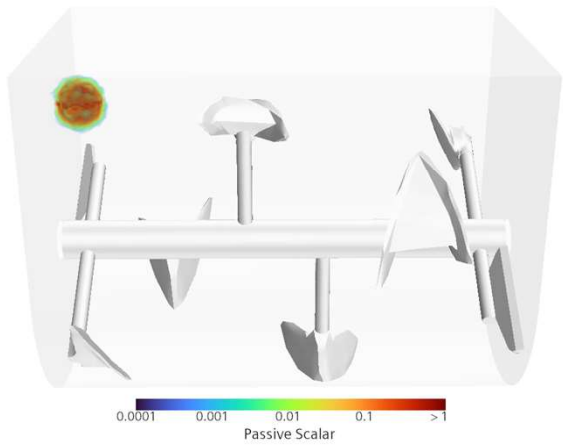


Solution Time 0.02 (s)

Passive scalar CFD

Free parameters

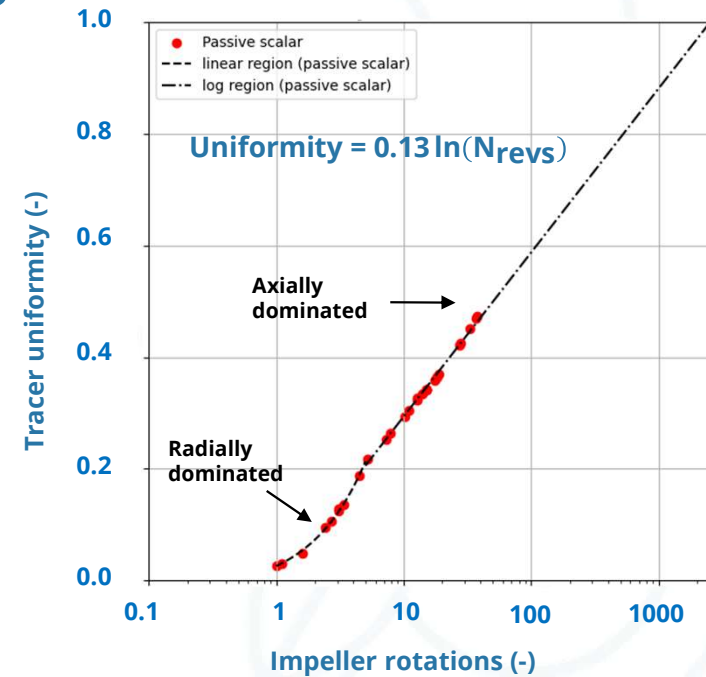
Re
 ρ μ



Evaluate

Rate of
uniformity

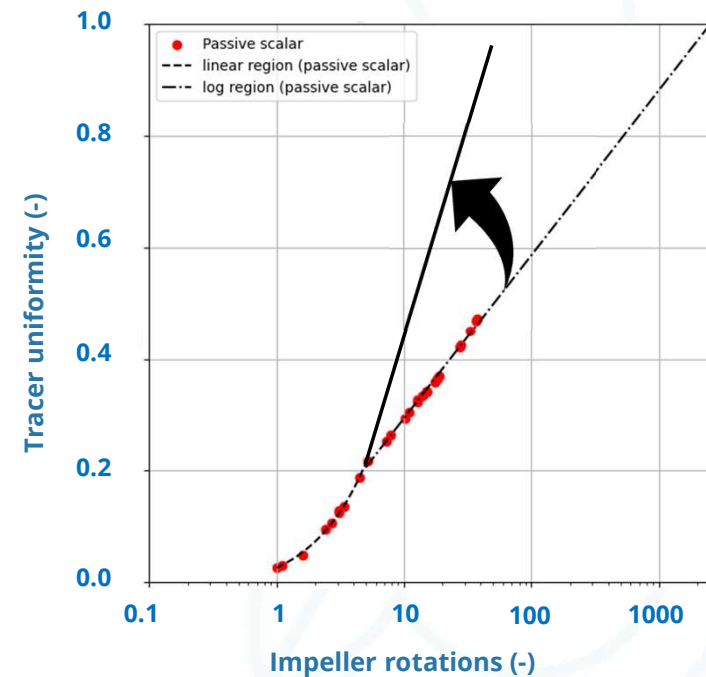
Exploration



Optimisation

Objectives

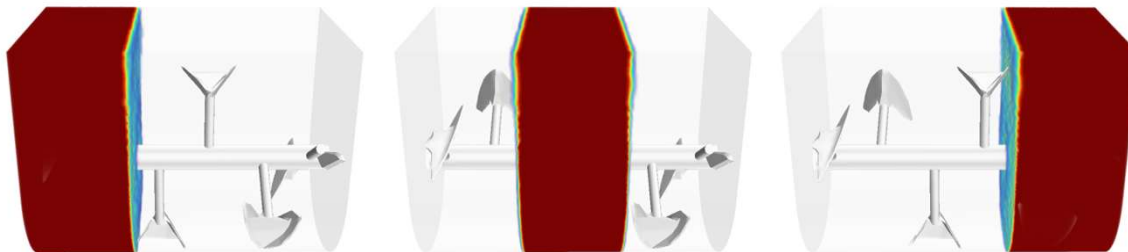
- Maximise axial mixing
- Modify geometry
- Retain plough-like features
- Constrain energy requirements



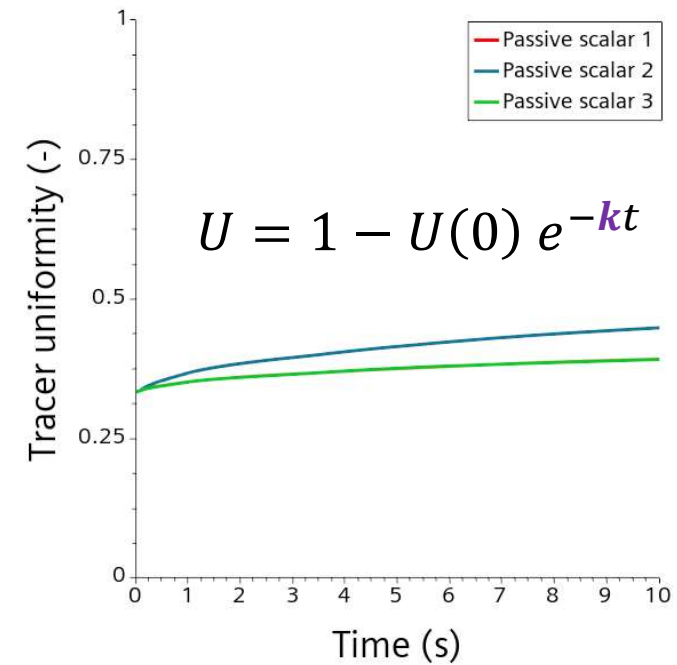
Optimisation

Objectives

- Maximise axial mixing



$$\text{minimise } t_{1/2} = [\ln 2 / k_1, \ln 2 / k_2, \ln 2 / k_3]$$



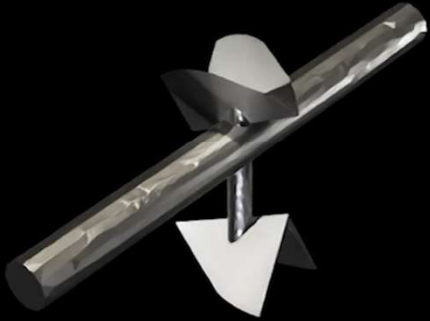
Optimisation

Objectives

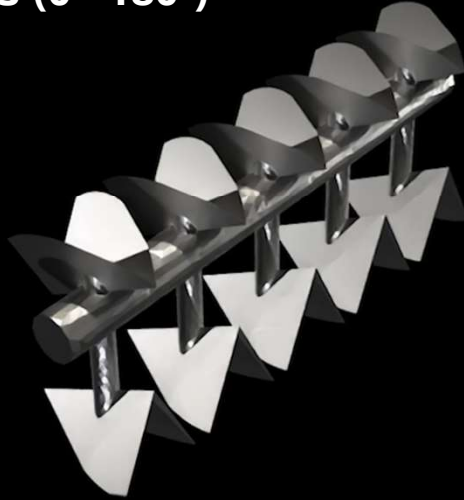
- **Modify geometry (12 free shape parameters)**
- **Retain plough-like features**



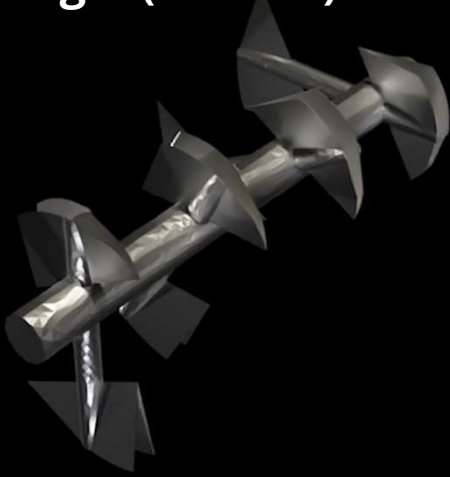
Number of plows (1-12)



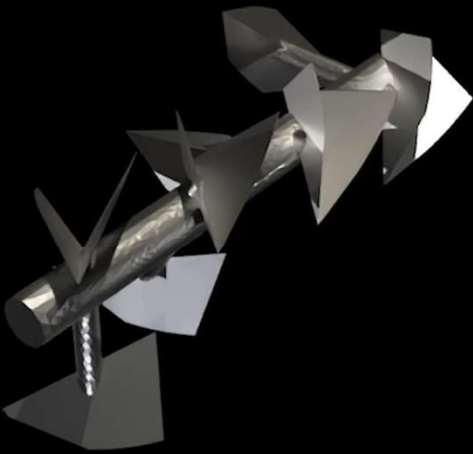
Bias (0 - 180°)



Side angle (-45 - 45°)



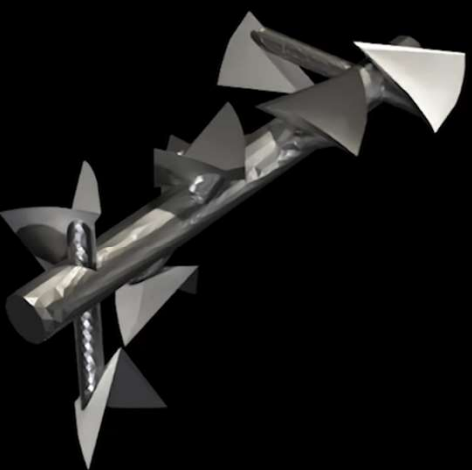
Twist angle (-45 - 45°)



Plough top height (-15 - 50 mm)

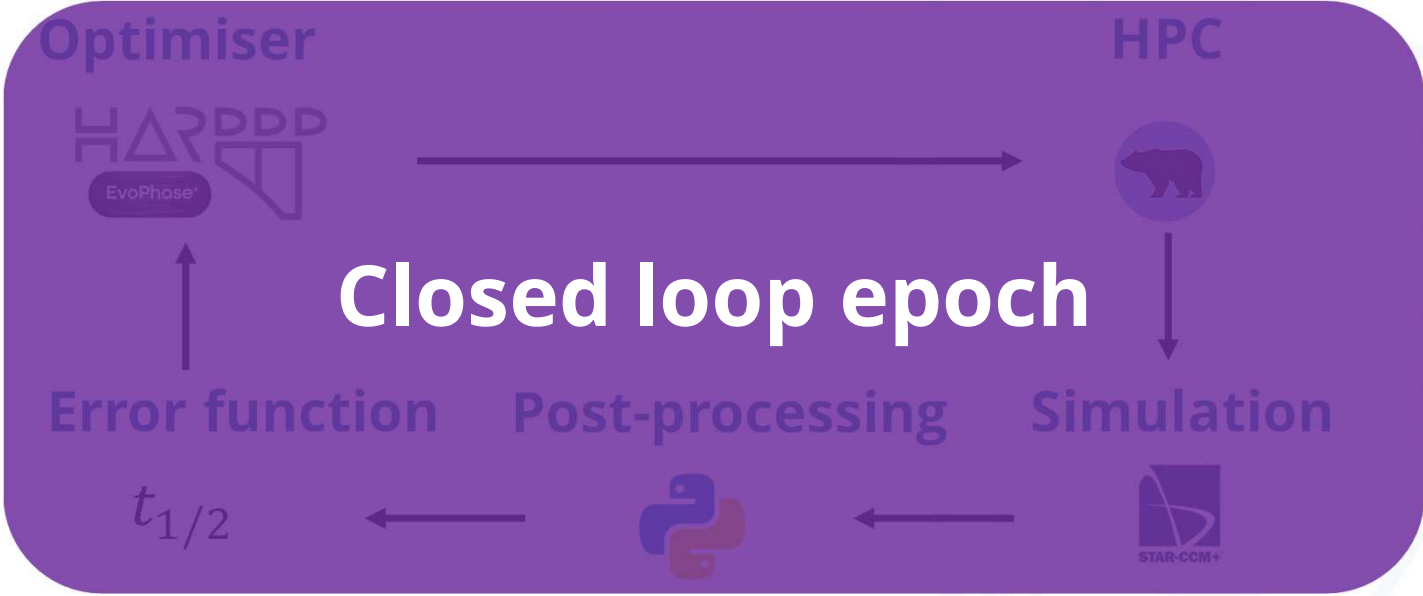


Plough length (15 - 100 mm)

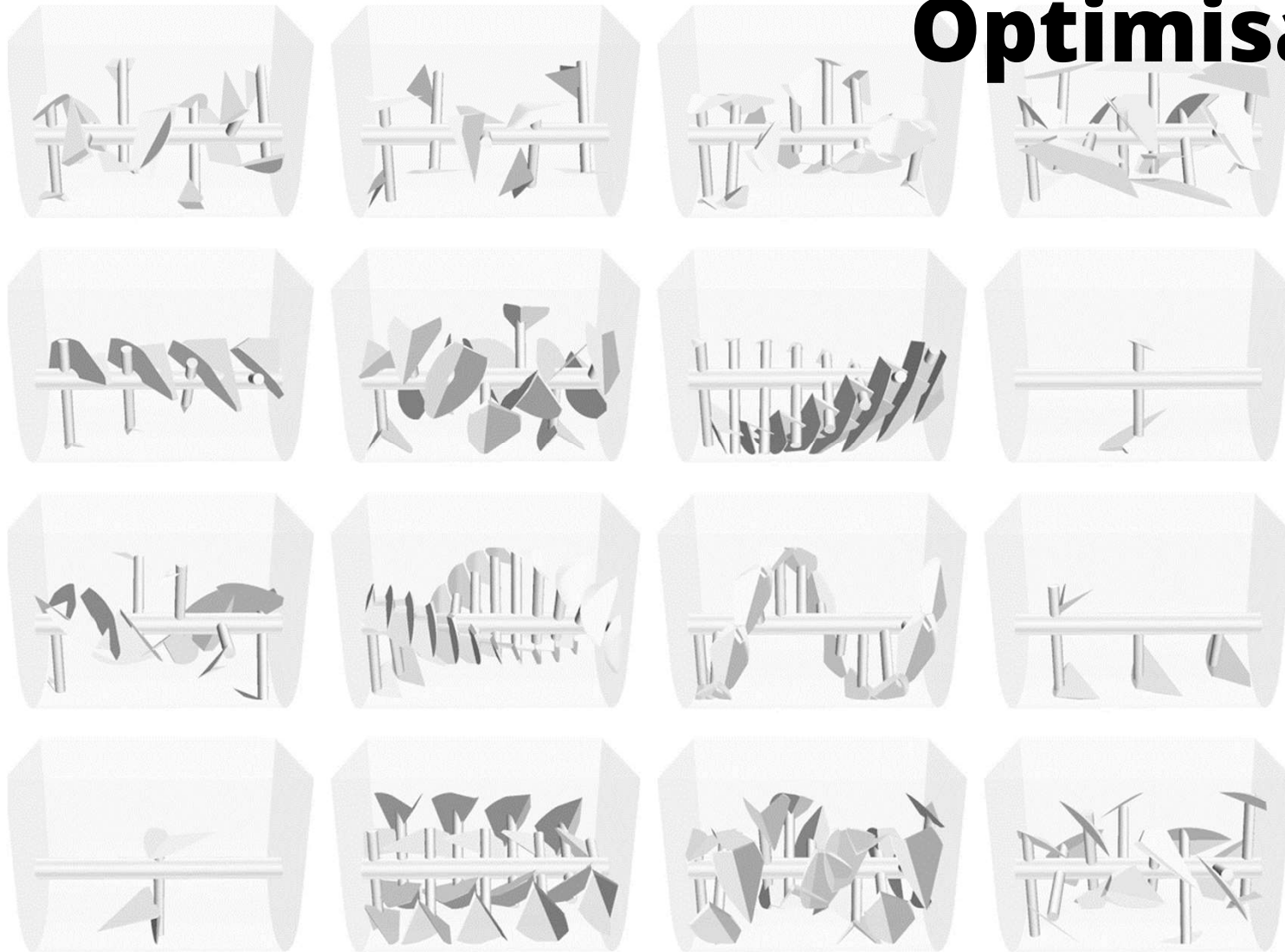


Optimisation

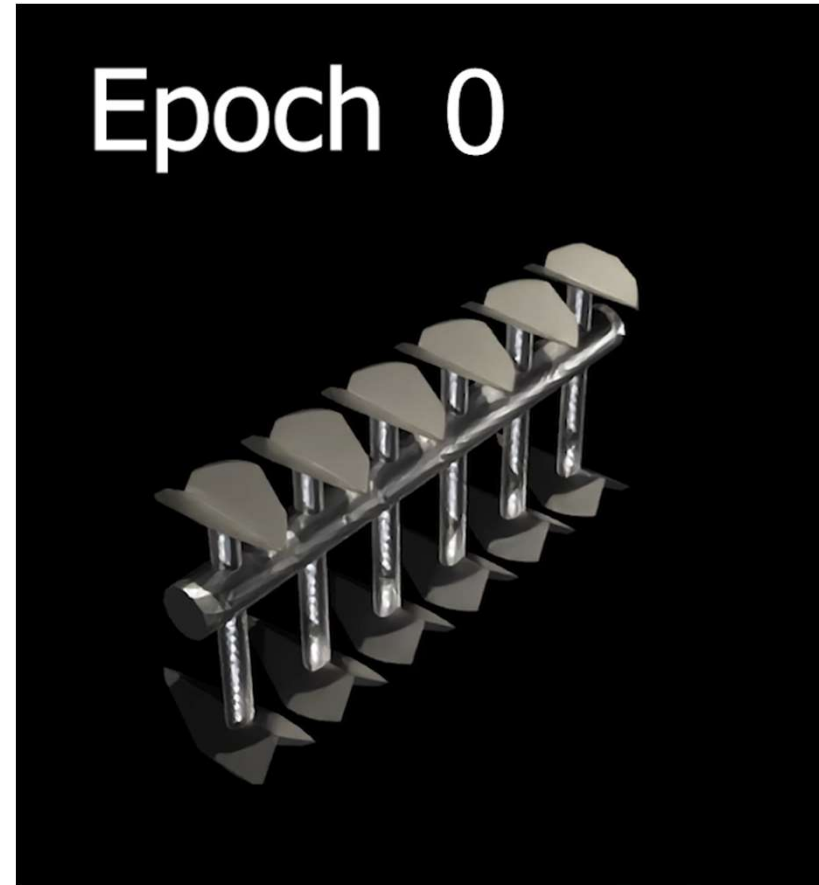
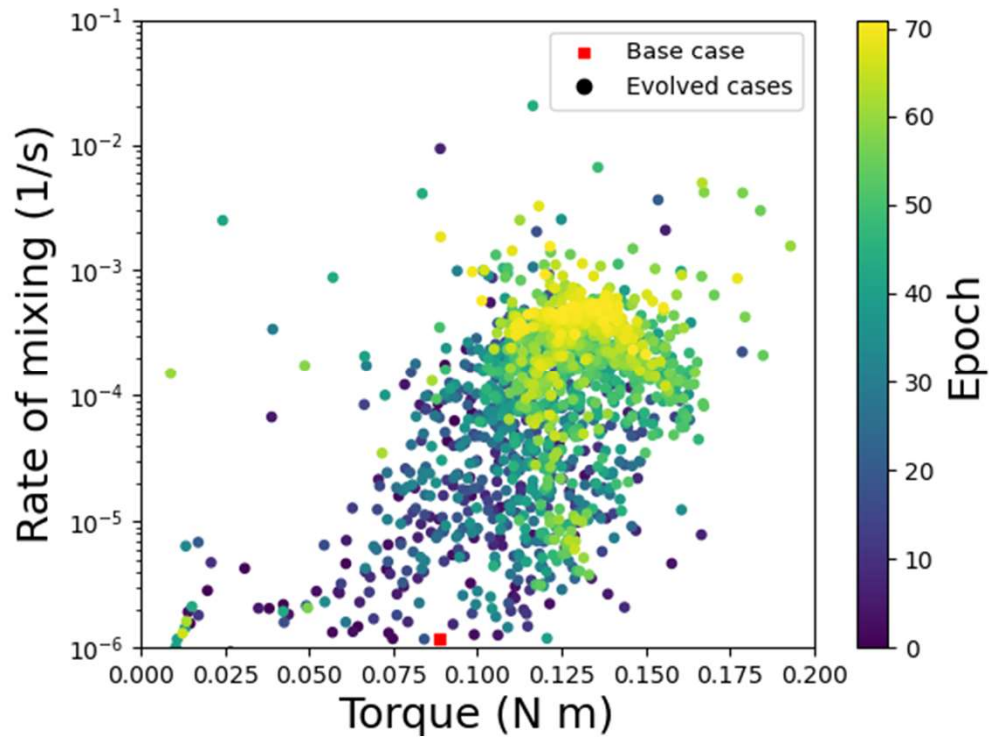
Input parameters



Optimisation

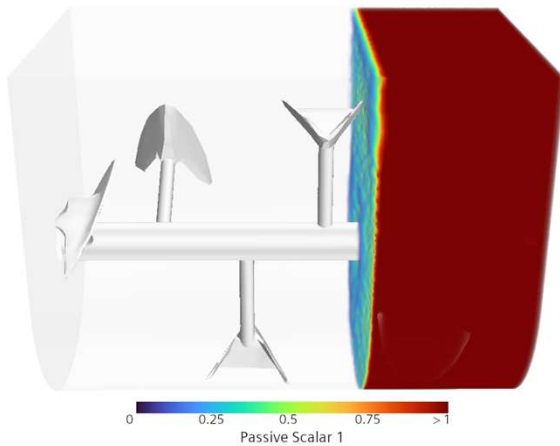


Optimisation



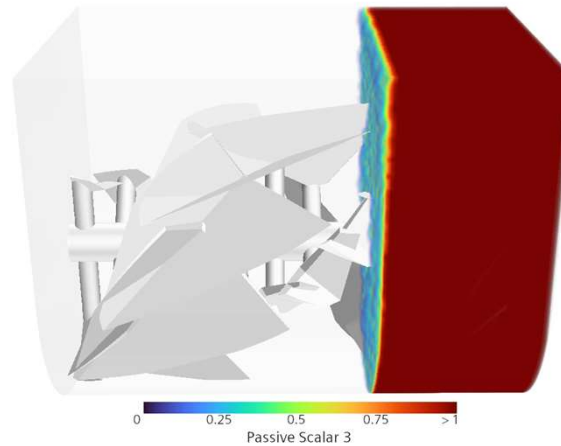
Optimisation

Base case

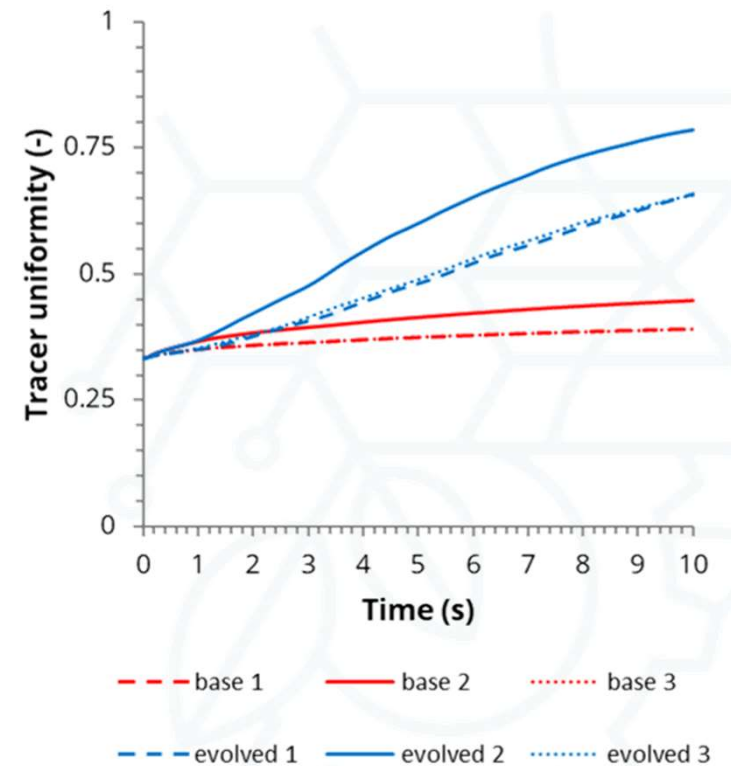


Solution Time 0.04 (s)

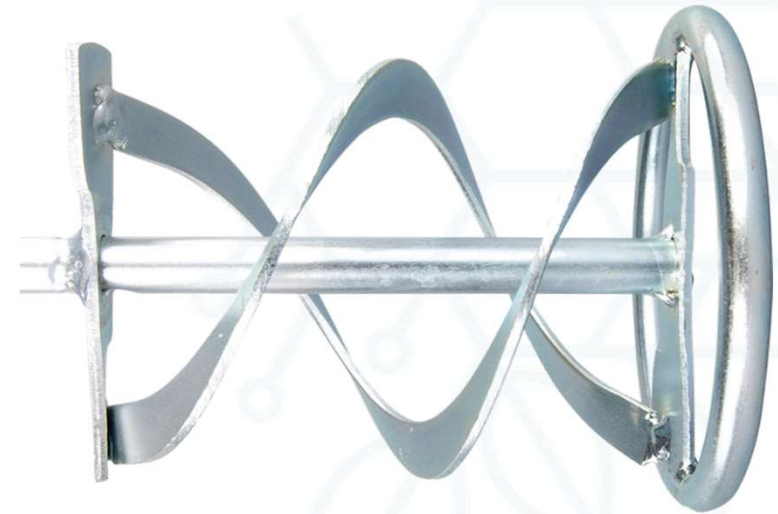
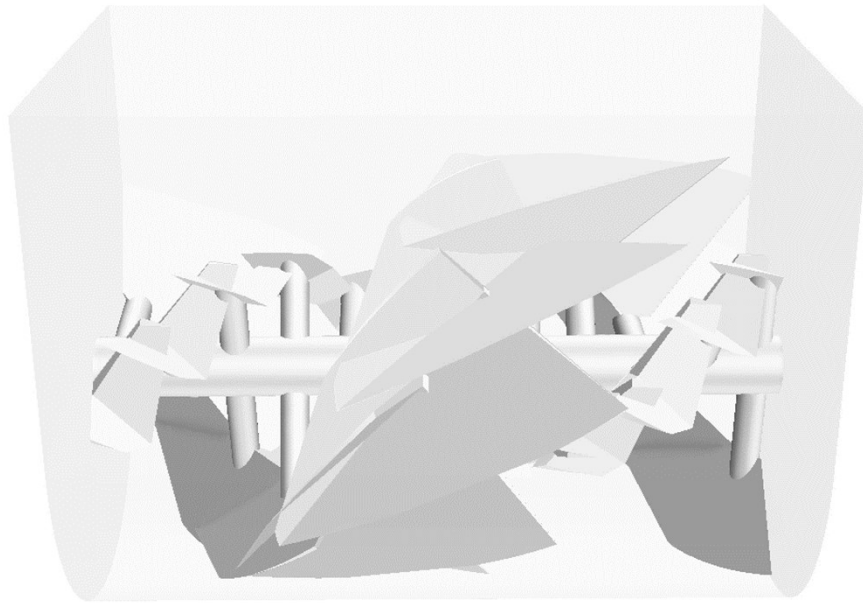
Evolved design



Solution Time 0.04 (s)



Optimisation



Summary

- ~**1000x** improved rate of axial mixing at similar torque.
- Blindly “*rediscovered*” existing optimal designs.
- **General** approach for autonomous geometry optimisation.
- Data driven evolutionary strategy hugely applicable to industrial mixing.



Thanks for your time



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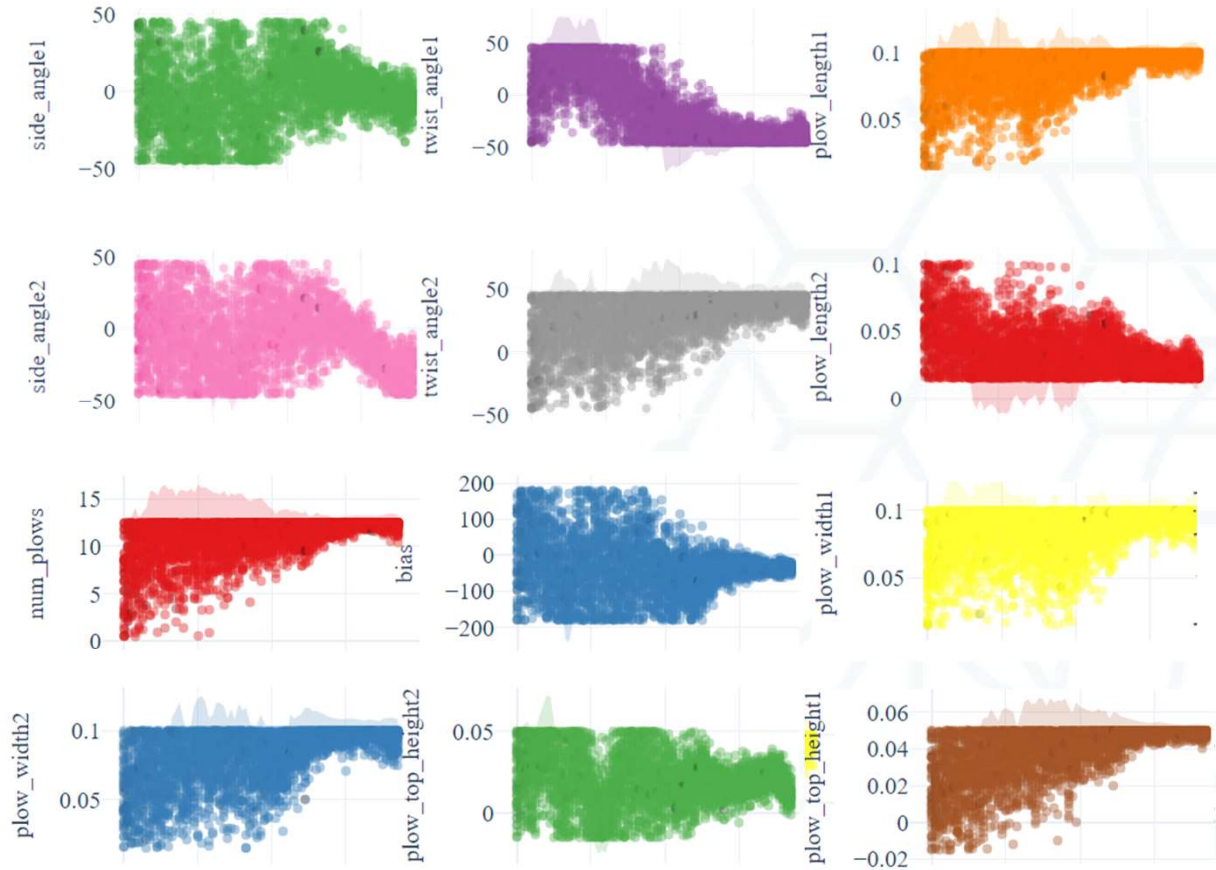
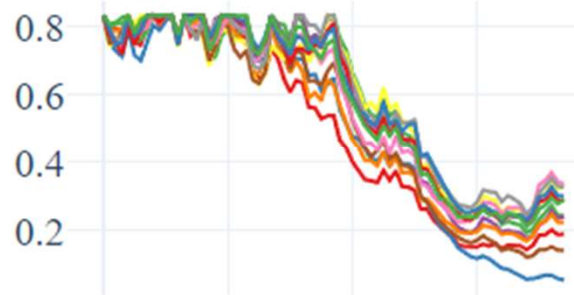
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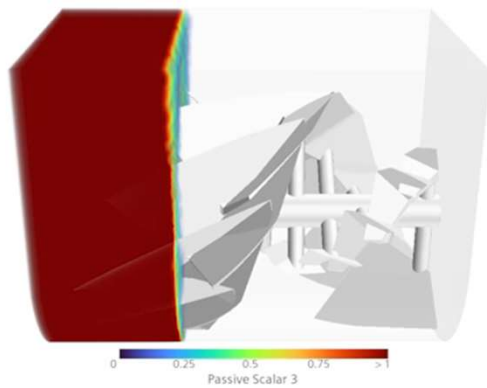
[3] Unilever R&D, Port Sunlight Laboratory.

Convergence

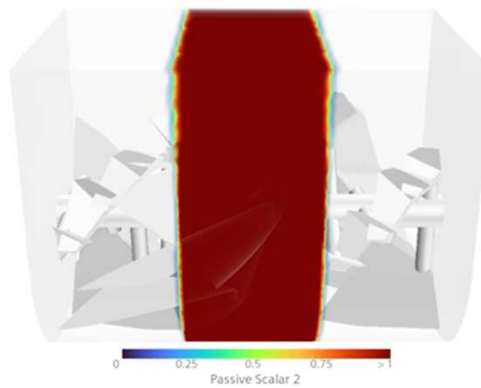
Standard Deviation



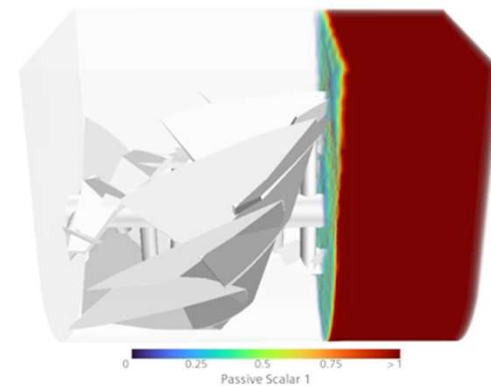
Passive scalar vs Particles



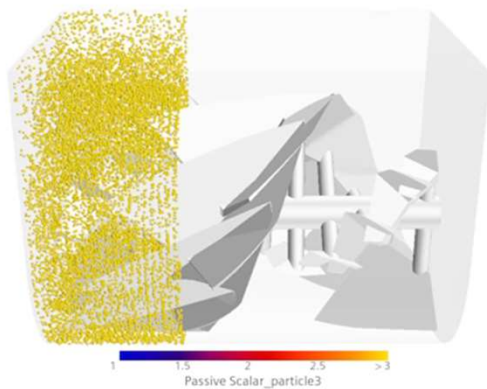
Solution Time 0.04 (s)



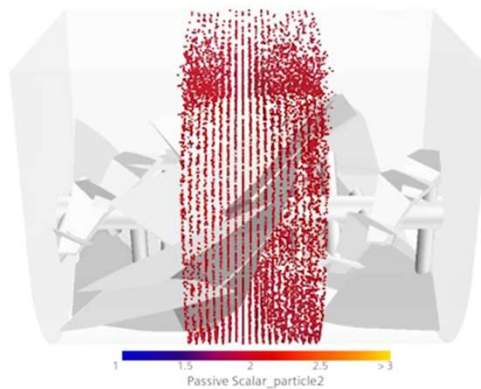
Solution Time 0.04 (s)



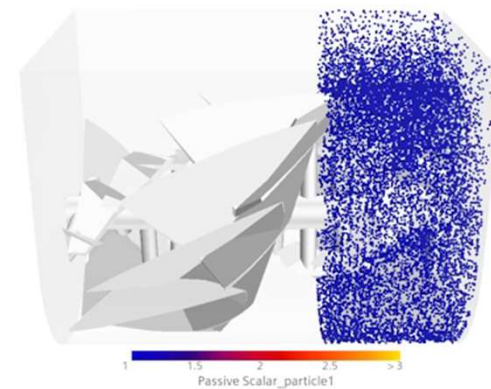
Solution Time 0.04 (s)



Solution Time 0.04 (s)



Solution Time 0.04 (s)



Solution Time 0.04 (s)

Passive scalar vs Particles

