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Simulation of A Dynamic Scraped Surface Heat Exchanger For Non-Newtonian Fluids

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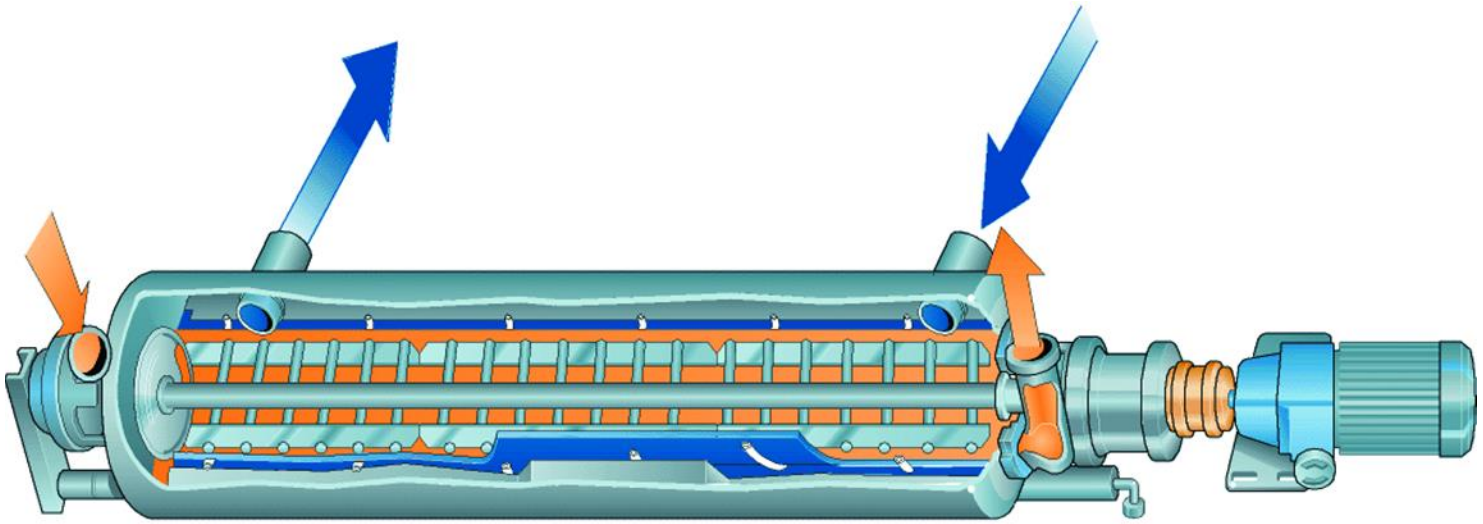
Introduction

- Scraped-surface heat exchangers (SSHE) are widely used in food industry for products
  - viscous, sticky,
  - contain particulate
  - need some degree of crystallization.
- SSHE provides
  - Exceptional thermal efficiency
  - Higher throughput
  - Uniform heat transfer

Operating Principle

- Cold stationary outer cylinder is scraped by the blades to prevent crust formation
- Flow is combination of Poiseuille and Couette



Modeling Rationale

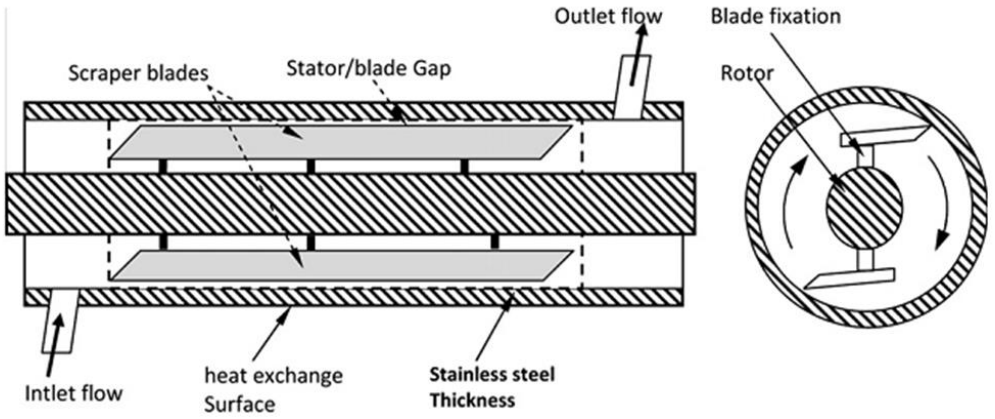
Model can be used to:

- Identify the knowledge gaps in the product-process interactions and enable focus on these bottlenecks.
- Scale-up in one single step from bench-scale equipment to factory scale-equipment, hence enabling a significant reduction in time-to-market
- Fault diagnosis by comparing the actual working of the process with the desired performance.
- Performance improvement

Overview of Problem

3-D Problems in Fluid Dynamics and Heat Transfer:

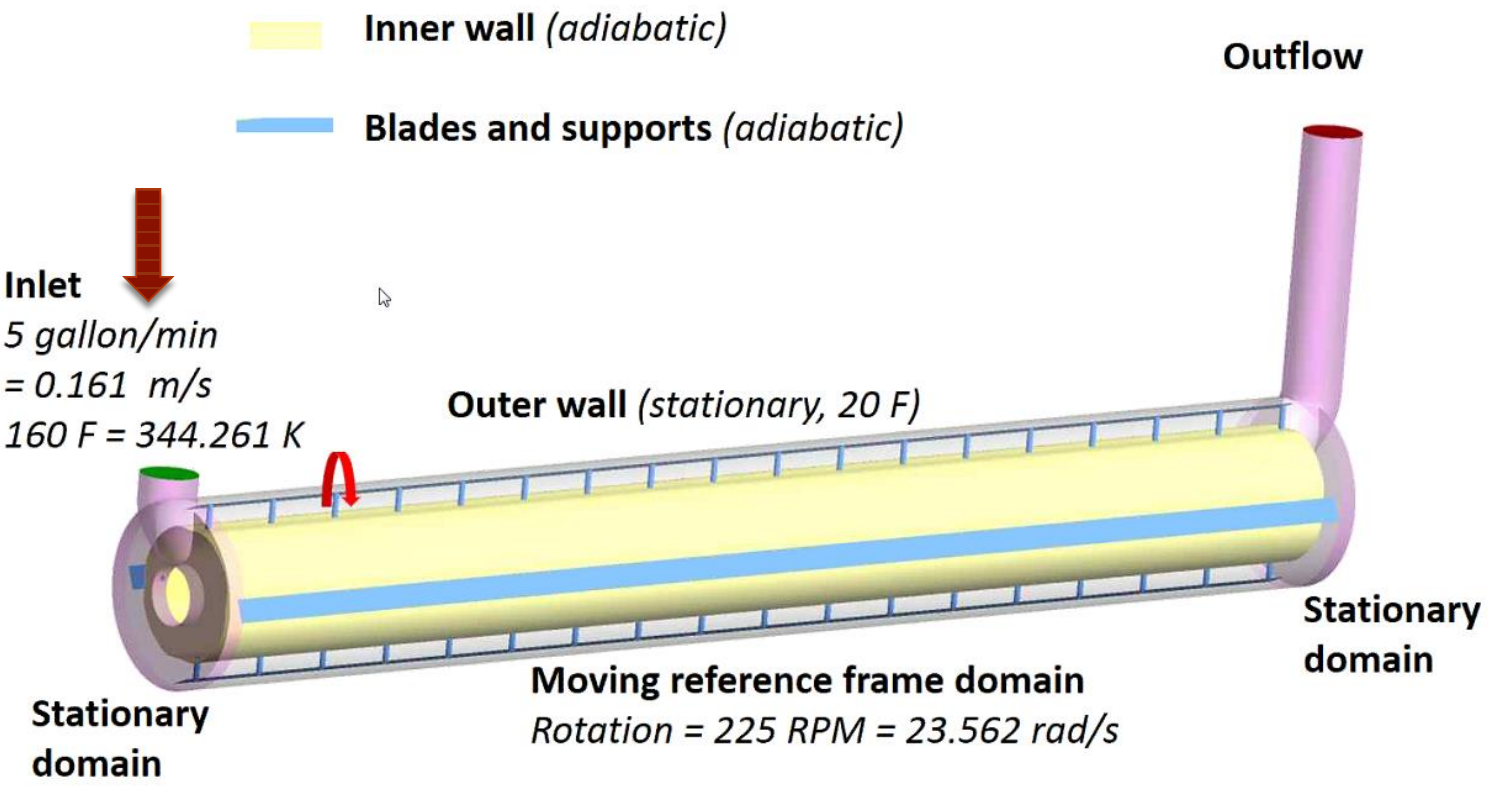
- Conservation
  - Mass
  - Momentum
  - Energy
- Paradigm Problems
  - Channel flow
  - Thin cavity
- Non-Newtonian fluid
  - Power-law shear thinning
  - Heat thinning
- Viscous Dissipation



Material Properties

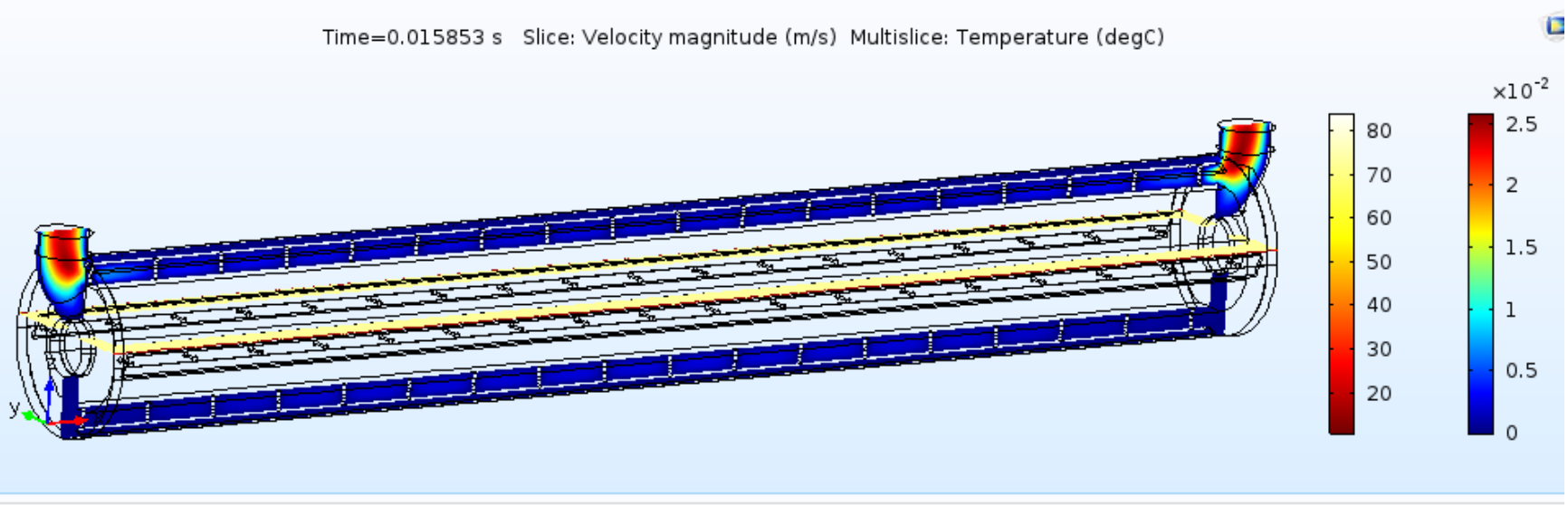
Fluid	2% CMC	Peanut Butter
Viscosity K Pa*s	0.07768 EXP(1888.1/T)	-2.2177+0.0707*T
n	45.15 EXP (-1528.9/T)	1.4563-0.00284*T
Heat capacity J/Kg	4000	2030
Thermal Conductivity W/m/K	0.6	0.21
Density Kg/m^3	1050	1115

Simulation Model Set Up



Pilot plant Scraped Heat Exchanger

Built model from COMSOL non-isothermal 2-d model library

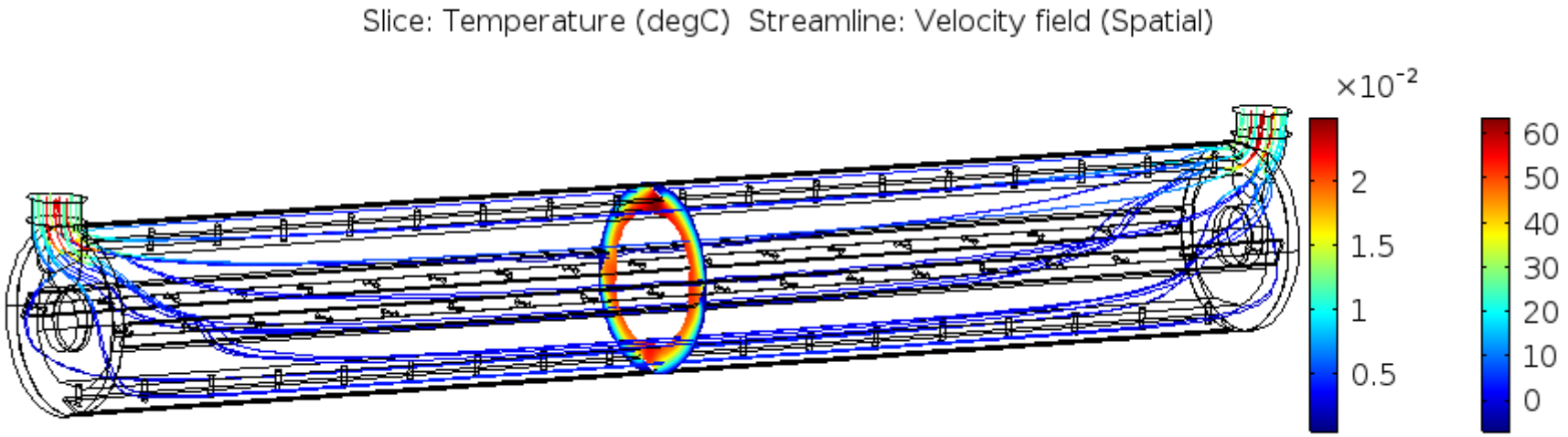


Lesson Learnt : Start from frozen rotator study

Velocity Streamline

Cooling of CMC flowing @ 4lbs/min

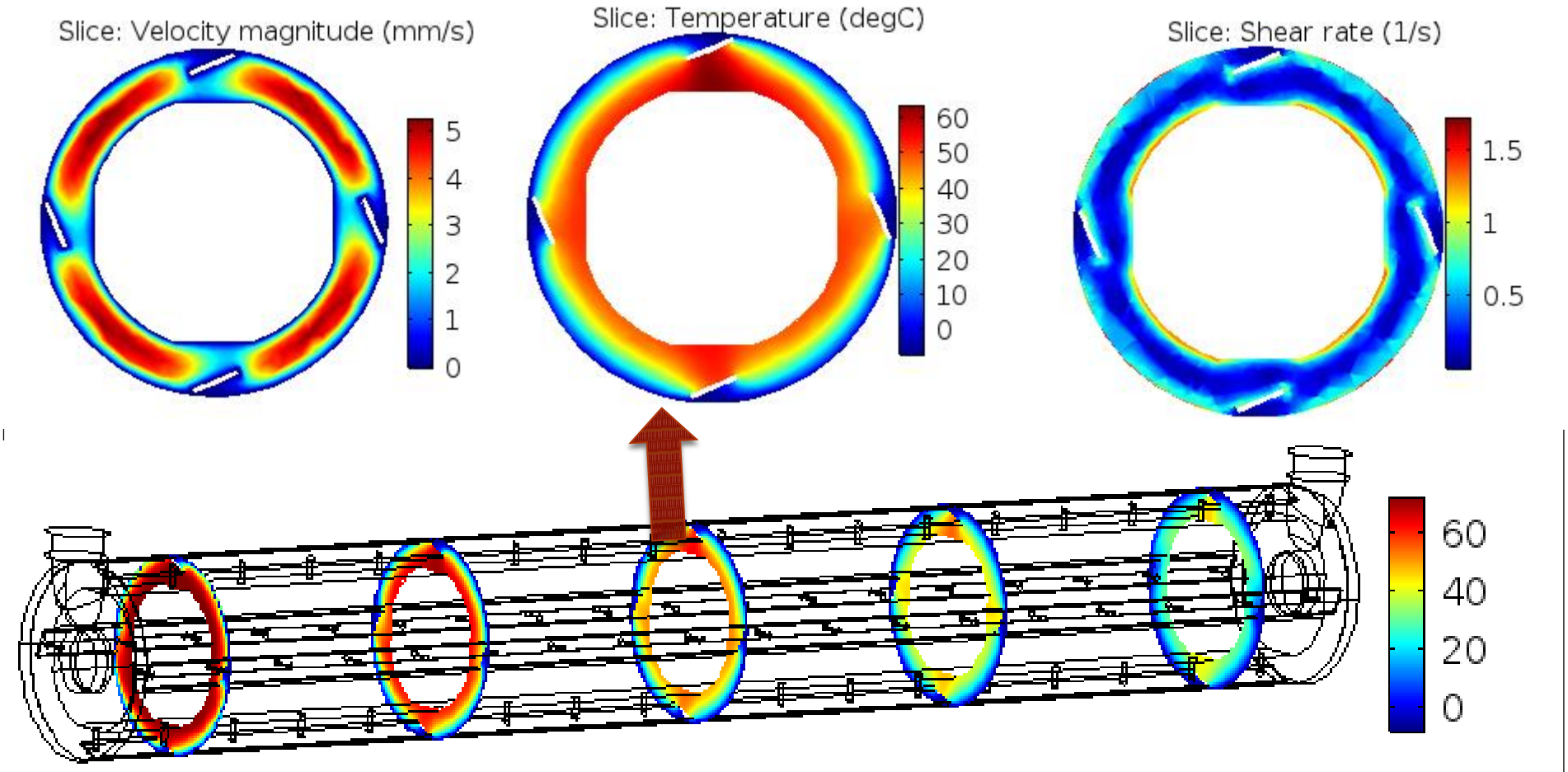
Frozen rotor solver used



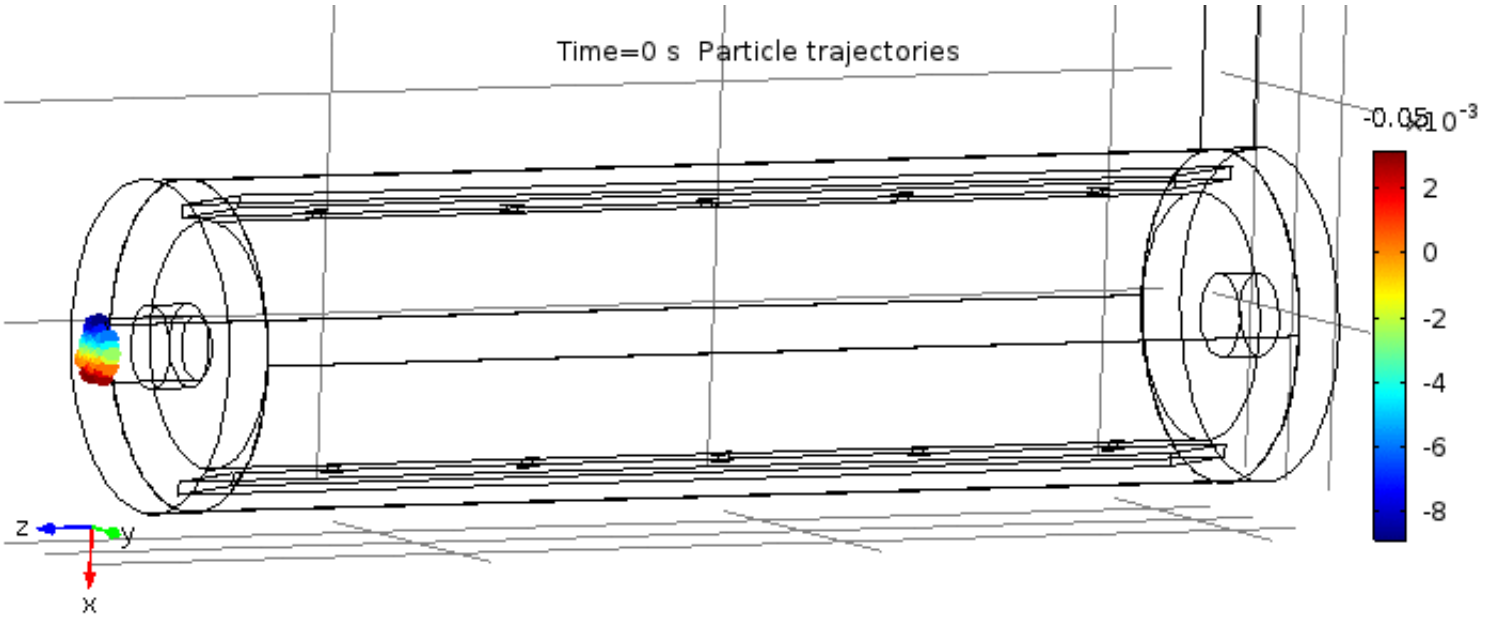
Velocity profile does not make sense

Slice Plot –Frozen Rotor Solver

Cooling of CMC flowing @ 4lbs/min

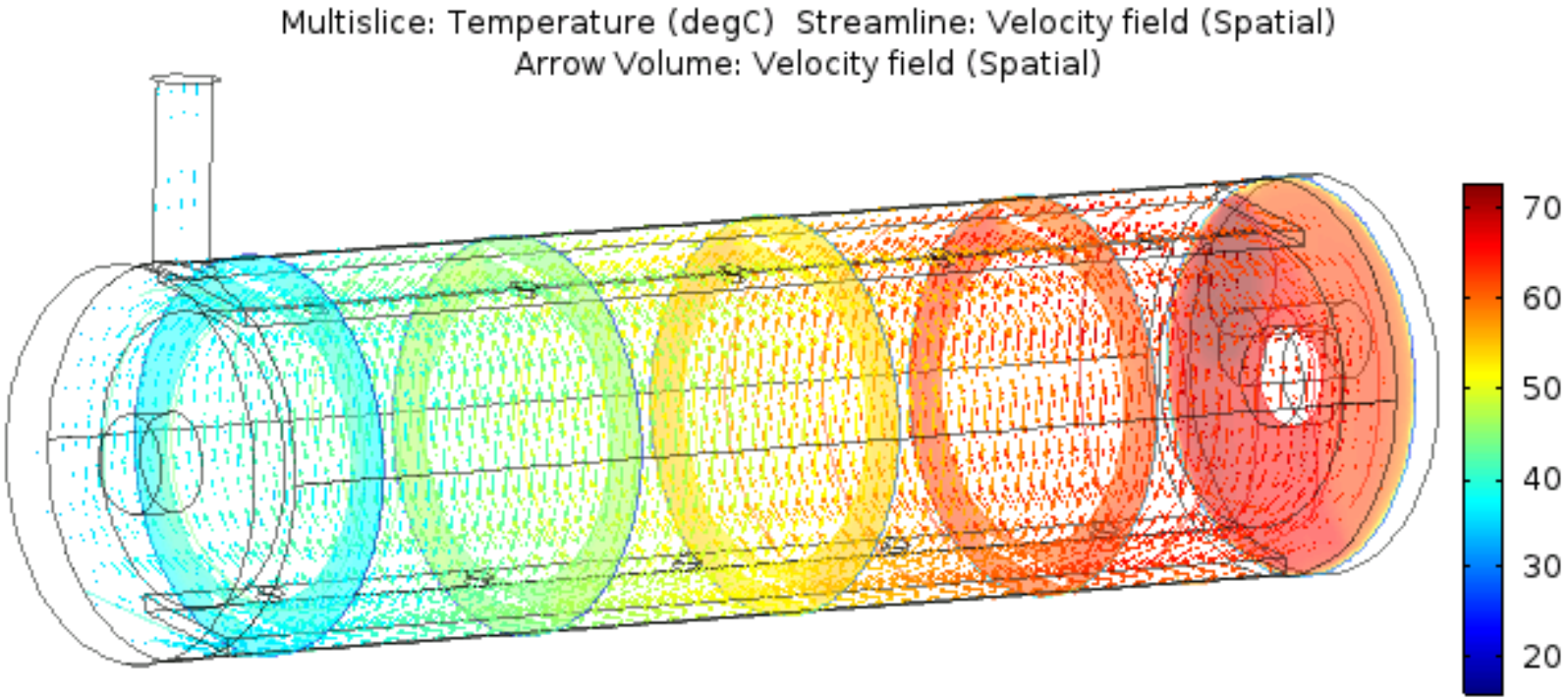


Particle trajectory in Lab Scale SSHE



Lesson Learnt from mistake :
Do not put step function in frozen rotor study

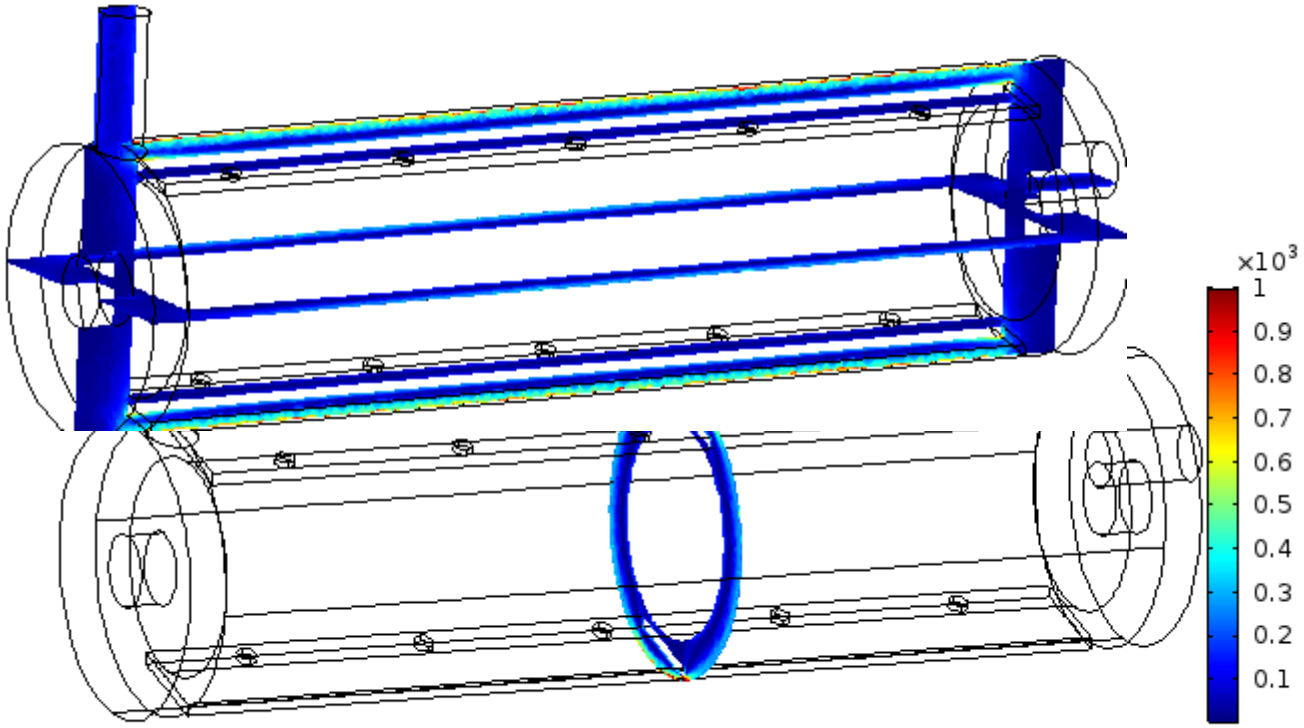
Lab Scale SSHE



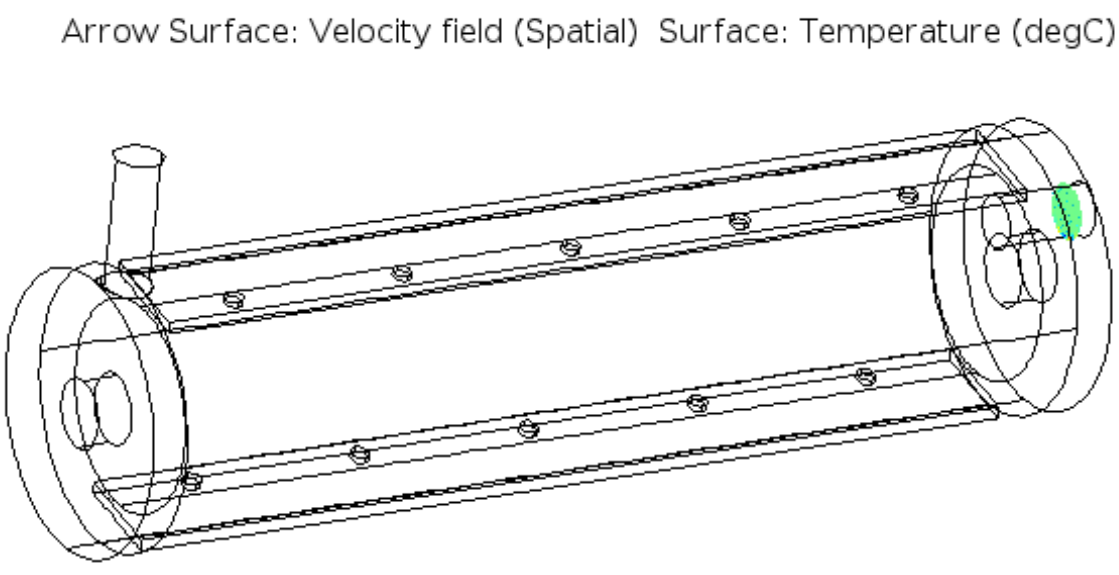
Stationary Solver Solution time: 9 hours, 30 minutes

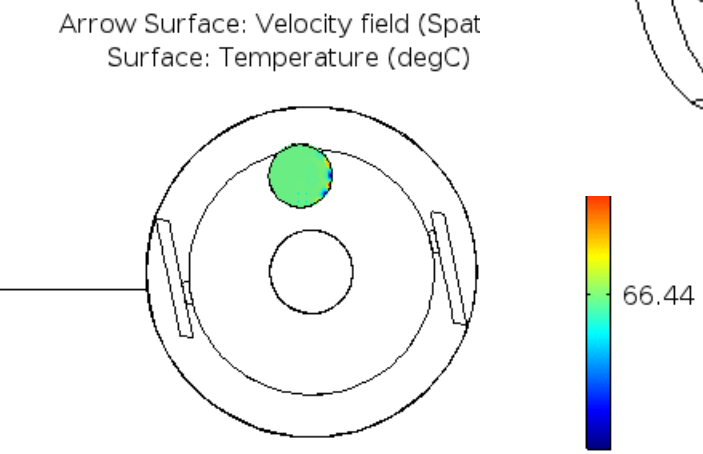
Physical memory: 65.43 GB Virtual memory: 74.56 GB

Shear Rate

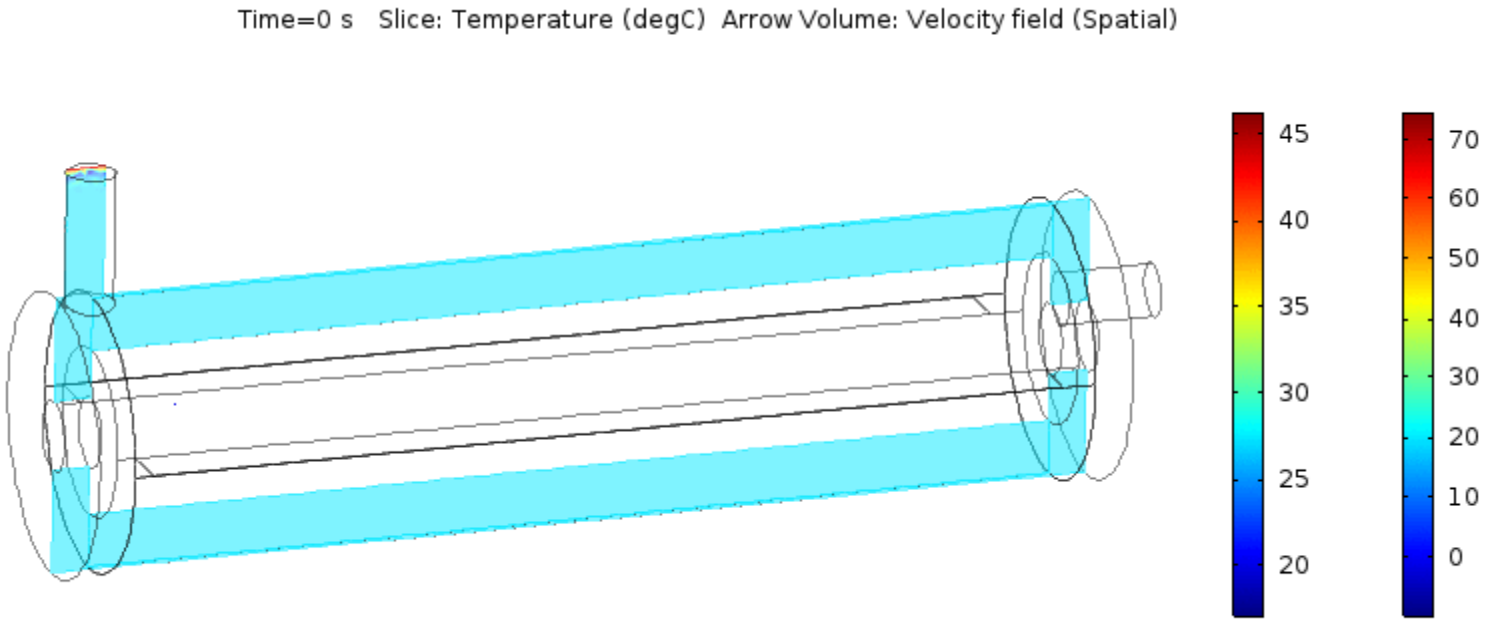


Post-processing





Transient Solver



321 2.0219 0.0050163 1624 1166 2426 2 1 32 1.9e-011 2.1e-015
322 2.0269 0.0050163 1628 1169 2432 2 1 32 2.1e-011 3.4e-015StoppedTime-Dependent Solver 1 in Study 3/Solution 3 (sol3): Solution time: 877955 s **(10 days, 3 hours,** 52 minutes, 35 seconds)
Physical memory: 51.85 GB Virtual memory: 58.56 GB

Summary

- Rotating machinery non-isothermal flow module used for heat transfer
- Frozen rotor solver is only plausible. Time dependent solver takes days
- Solve for particle tracing to visualize the mixing during heat transfer in non-Newtonian fluid