DRD TECHNOLOGY

Simulating Liquid Sprays: Applications Across Industries

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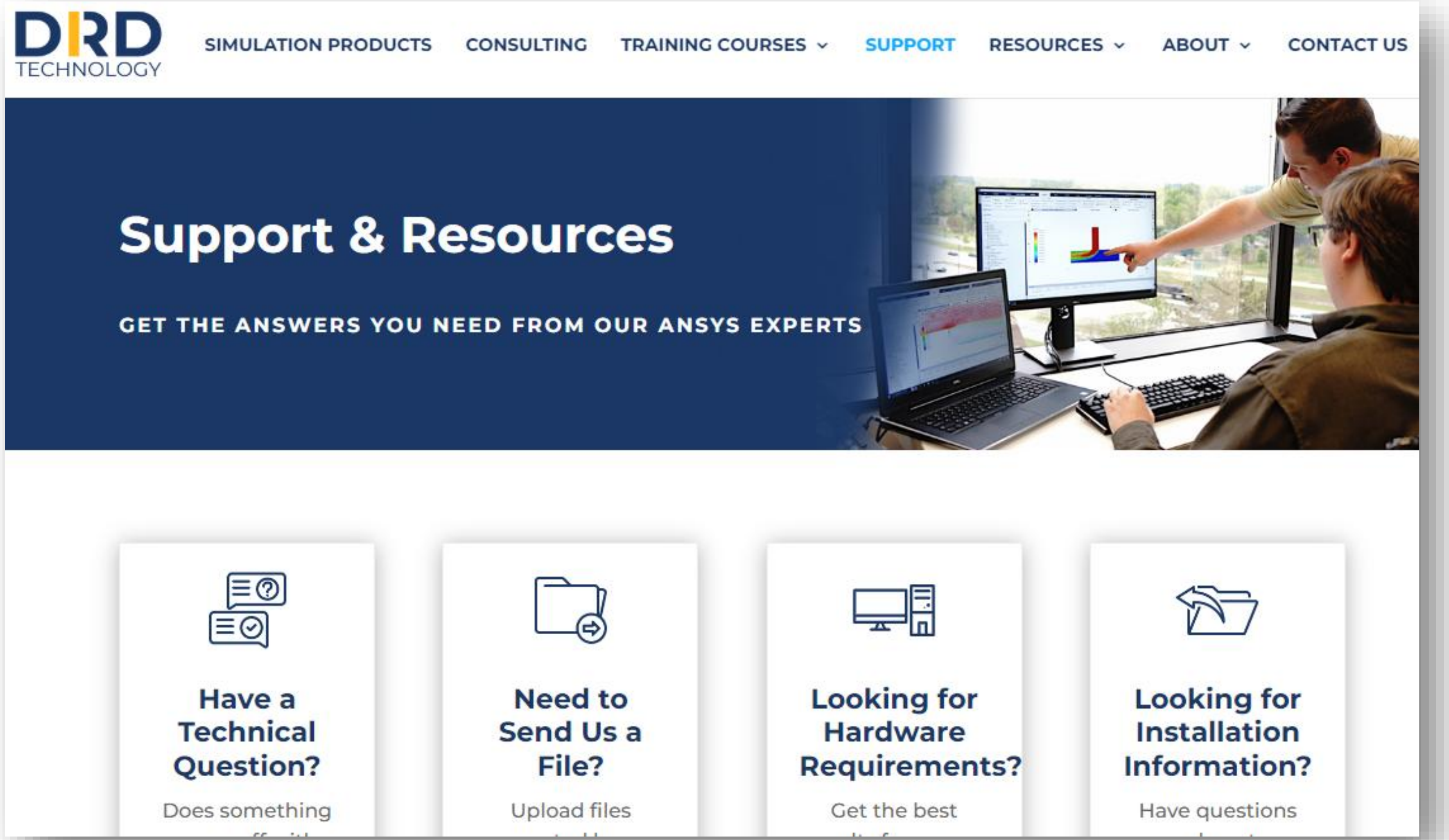
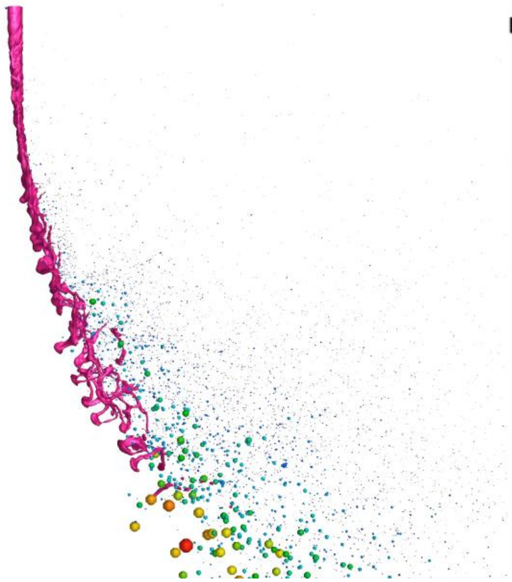


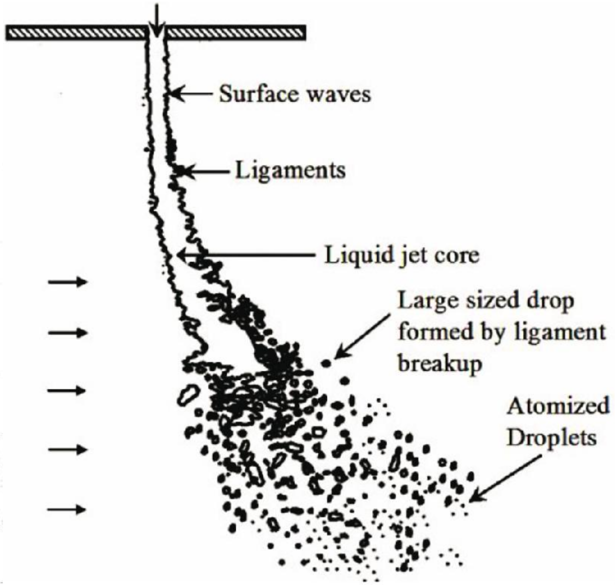
I have had over 40 years of experience working with DRD Technology and have been very satisfied with them through the years.

- *David Stribling, P.E.*
Owner, Buffalo Hump Solutions

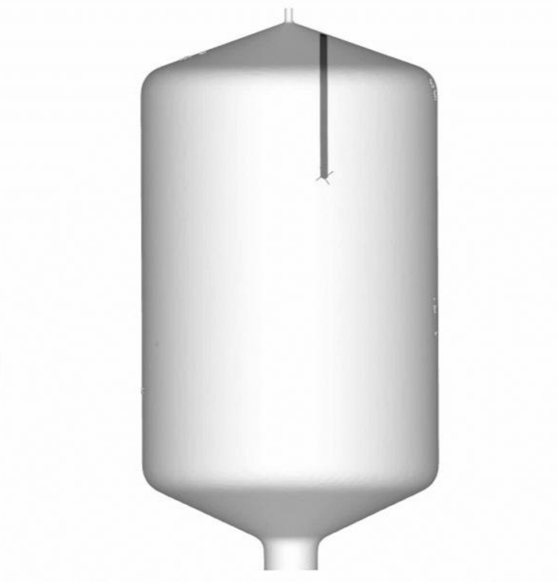
Introduction

- What are “sprays” in this context?
- Liquid sprays are common yet complex phenomenon
- Application specific outcomes are more difficult to predict
- How can we model sprays with Fluent CFD?

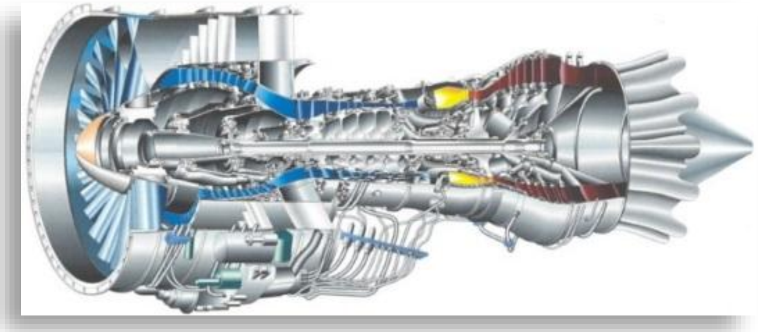




Osta, Anu. (2022). Imaging Diagnostics for Jet Breakup into Droplets: A Review. 10.5772/intechopen.107370.



Applications



Automotive and Aerospace Engineering
- Fuel injection systems
- De-icing fluid sprays
- Windshield washer/wiper optimization

Industrial Processes
- Spray painting and coatings
- Cooling systems
- Spray drying

Agriculture
- Pesticide and herbicide spray drift
- Irrigation spray distribution efficiency

Consumer Products
- Perfume and deodorant dispersion
- Cleaning product coverage and surface interaction

Environmental Engineering
- Odor control spray dispersion in waste treatment
- Dust suppression in mining and construction sites

Fire Safety and Suppression
- Water spray patterns from sprinkler systems
- Fine mist and aerosol fire extinguishing systems

Medical and Pharmaceutical Applications
- Aerosol delivery from inhalers
- Nasal spray for drug delivery
- Tablet coating during manufacturing

Ansys Fluent Spray Modeling Methods

Accurate spray specification is the key for successful modeling of spray dependent applications!

Eulerian Multiphase Approach	Eulerian Wall Film (EWF)	Volume of Fluid (VOF)	Discrete Phase Model (DPM)	VOF-to-DPM
Phases treated as mixture with averaged density	Two-dimensional film model for wall surfaces	Resolves all scales of liquid structures directly	Calibrate droplet properties from measurements	Intact liquid core and ligaments use VOF
Able to handle large droplet counts	Interactions with VOF and DPM easy to define	VERY computationally expensive	Use droplet data as input for the simulation	Droplets use Lagrangian tracking

VOF-DPM Hybrid Modeling for Sprays

Volume of Fluid

- Captures aerodynamic/ hydrodynamic instabilities and large structures
- Primary breakup

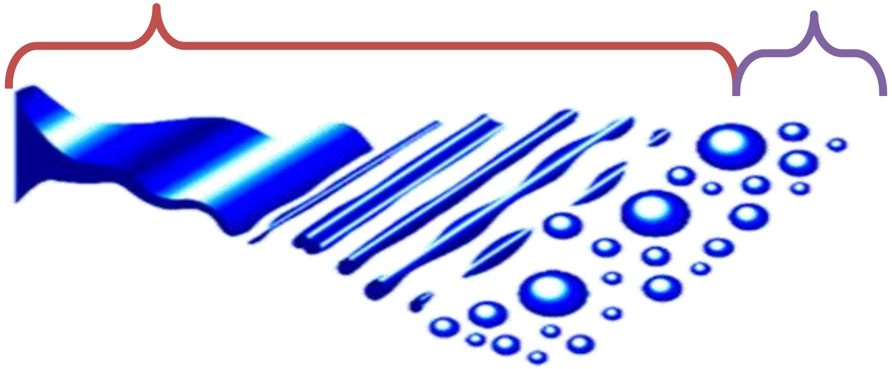
VOF-DPM Transition Tool

- Detached lumps are considered for model transition
- Transition criterions: Equivalent diameter, Asphericity

Discrete Phase Model

- Secondary break-up
- Heating and cooling
- Mass transfer (Evaporation, etc.)
- Coalescence

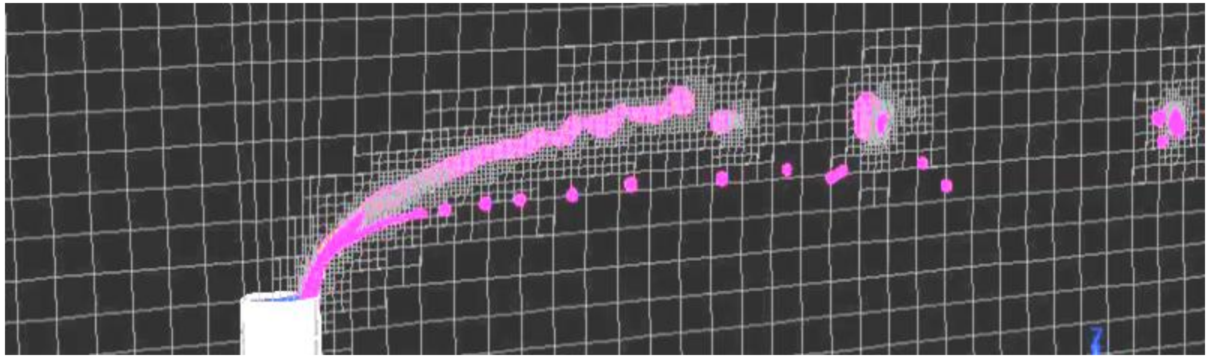
Interface tracking → Model Transition → Lagrangian Tracking



Dynamic Mesh Adaption

Mesh Refinement

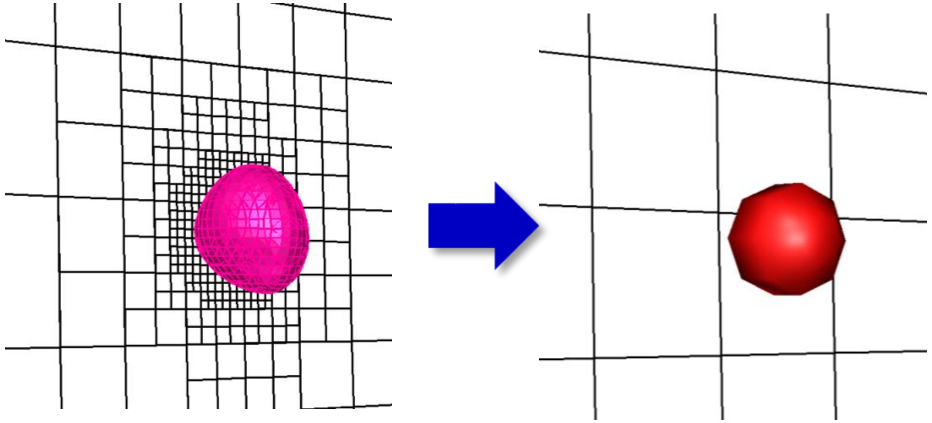
- Resolves gas-liquid interface
- Travels with the interface



Mesh continuously refined with moving interface

Mesh Coarsening

- Resolved liquid drops transition to DPM
- Removes unnecessary refinement

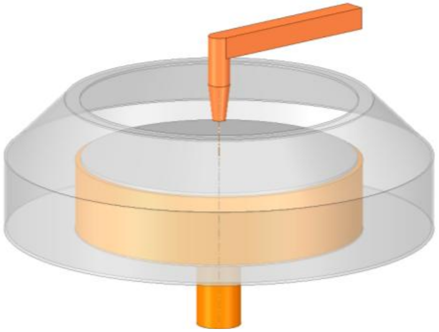


Mesh coarsened after interface advected away from mesh cell, or conversion of VOF to DPM

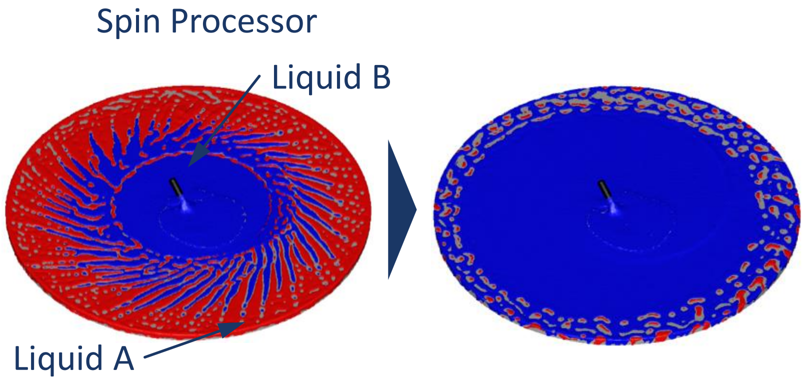
Dynamic Mesh Adaption has preset configurations for VOF simulations but can also be configured for any other field variables that require high refinement for local gradients.

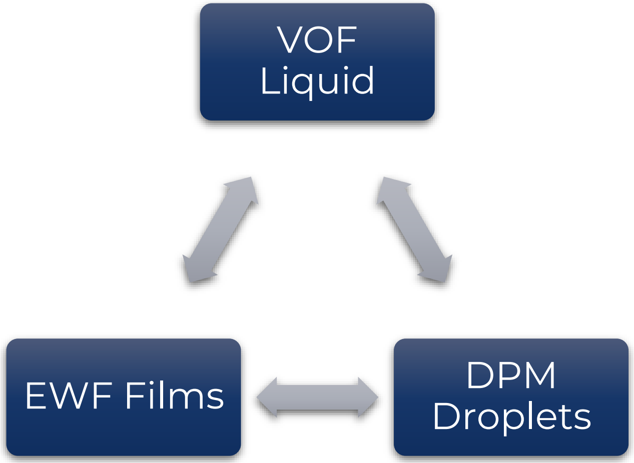
Eulerian Wall Film (EWF)

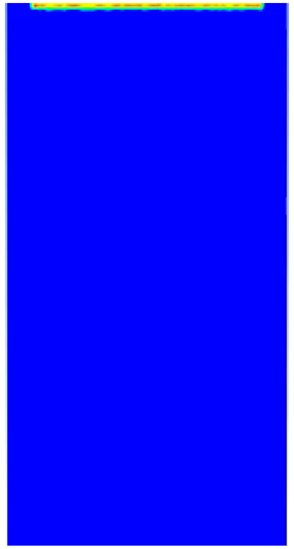
- Lightweight model for thin liquid flows
- Treats the liquid as a 2D surface film with thickness
- Can be paired with other models to model different regimes in different regions of a simulation



Wet type spin processor

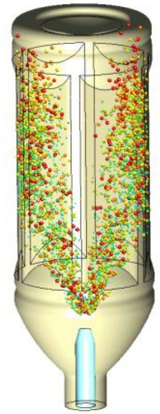






Color Indicates Film Thickness

Bottling line cleaning process

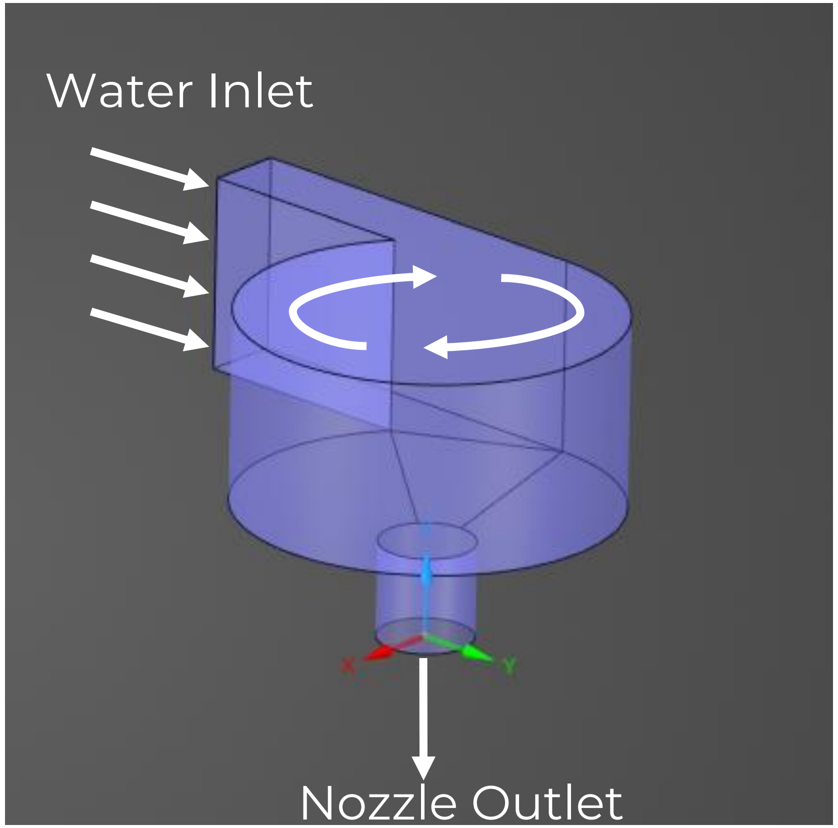


Injected water (DPM)

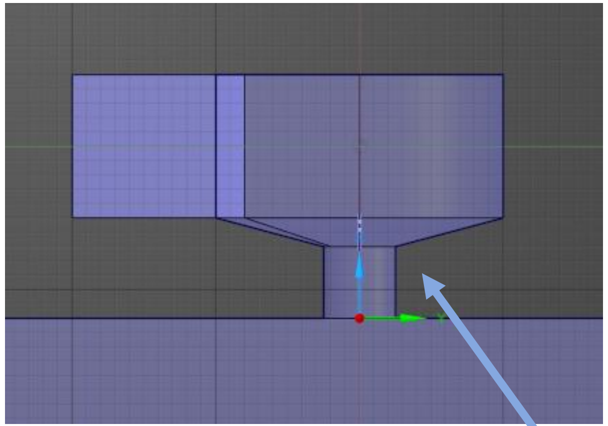
Film Thickness (EWF)

Pressure Swirl Atomizer Case Comparison

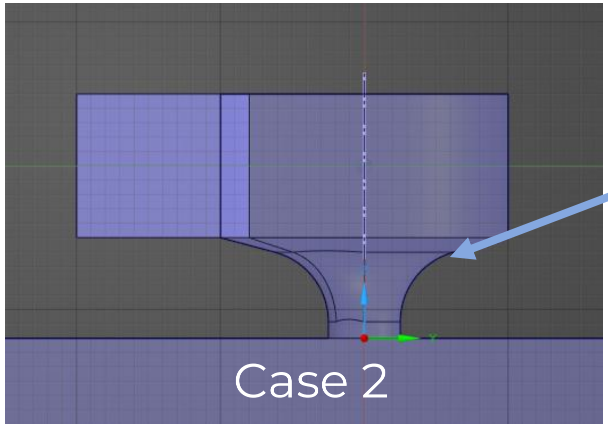
- Comparing spray patterns for two nozzle geometries
- Nozzles spray into 300mm cube of air
- All other settings identical



Case 1 – Straight



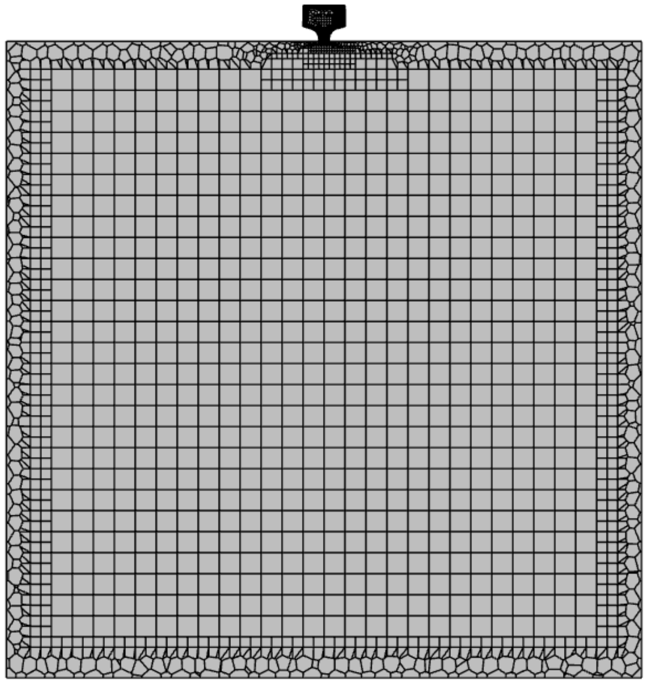
Case 2 – Rounded



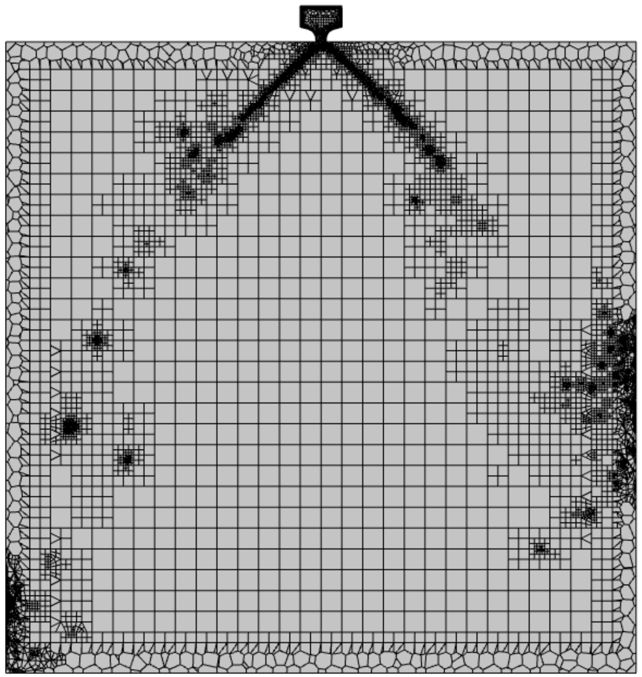
Nozzle modified here

Dynamic Meshing

- Polyhedral-hexahedral with dynamic Mesh Adaption to capture interfaces accurately
- Reduces computational load by only refining mesh only where interfaces exist
- Dynamic adaption has customizable refinement and coarsening criteria for multiphase flows



Initial Mesh

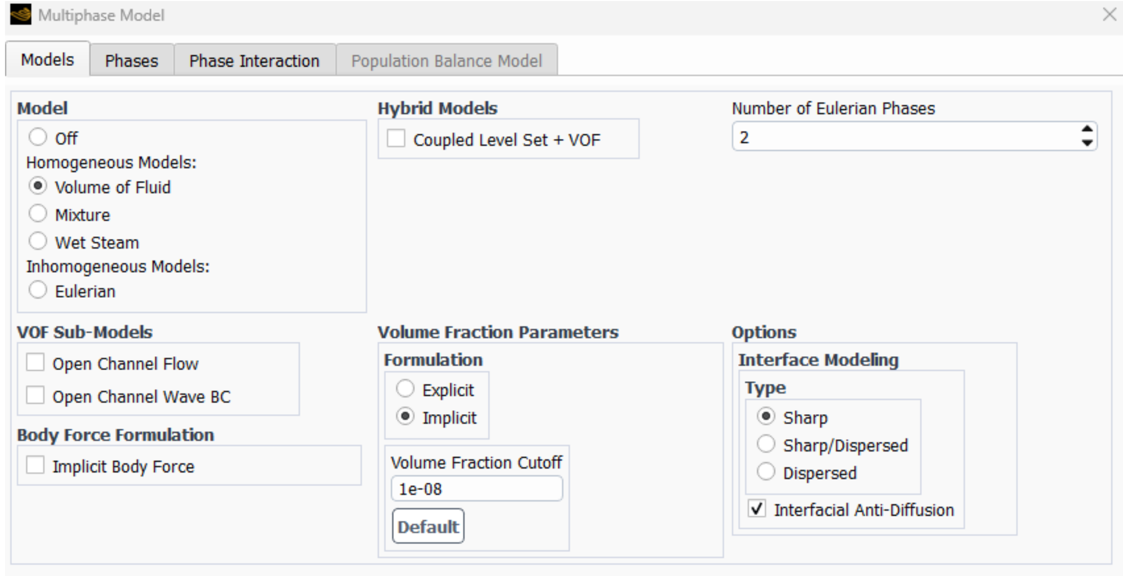


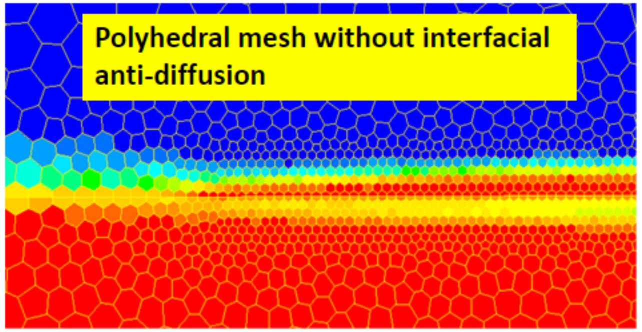
Dynamically refined mesh

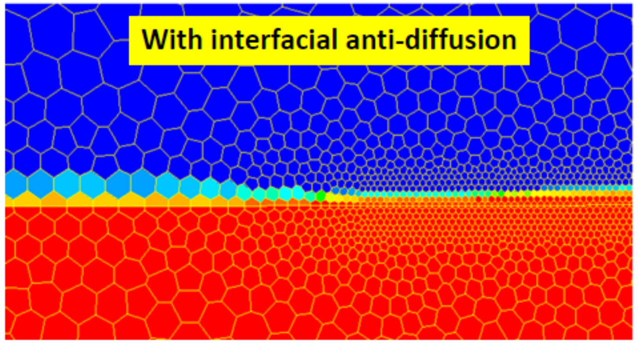
DIRD

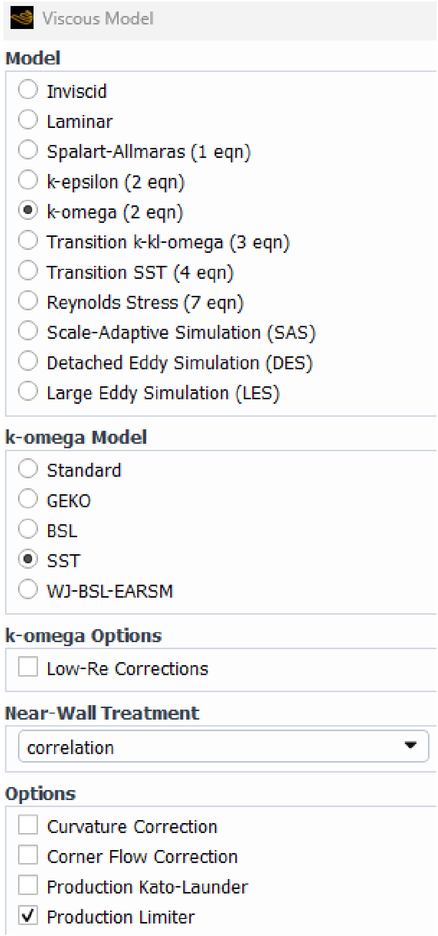
Simulation Configuration

- Volume of Fluid (VOF) Model – for free interface flows
- Implicit formulation to allow larger timestep size
- K-Omega turbulence model, various application-specific models available
- Compressive Scheme with Interfacial anti-diffusion
- CSF Surface tension model



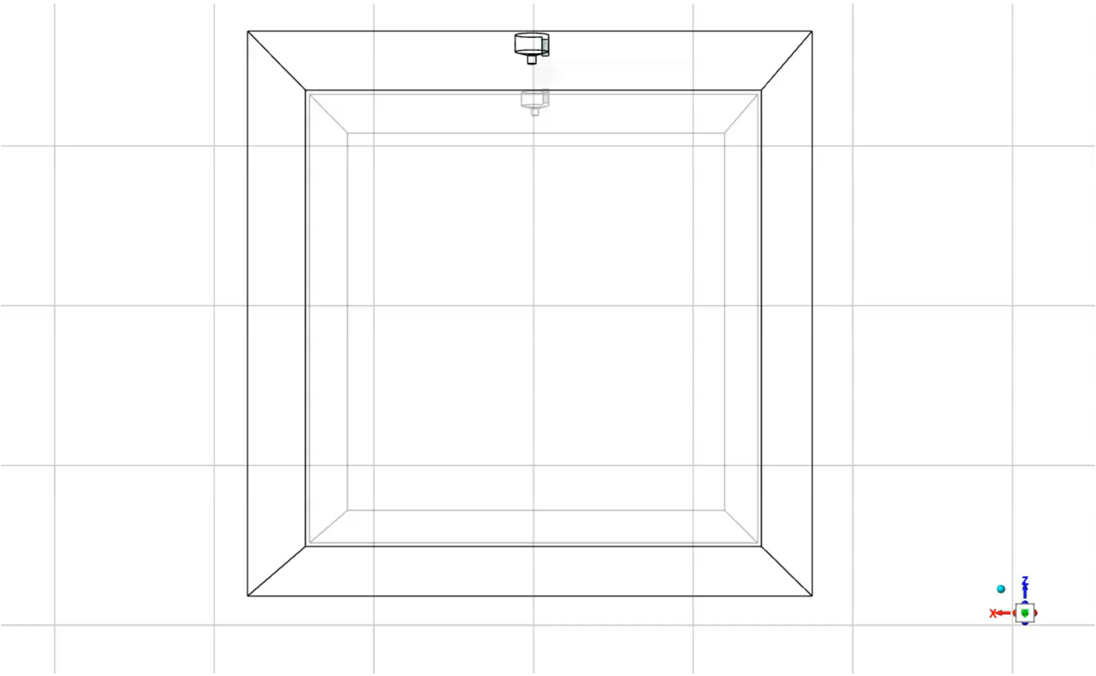




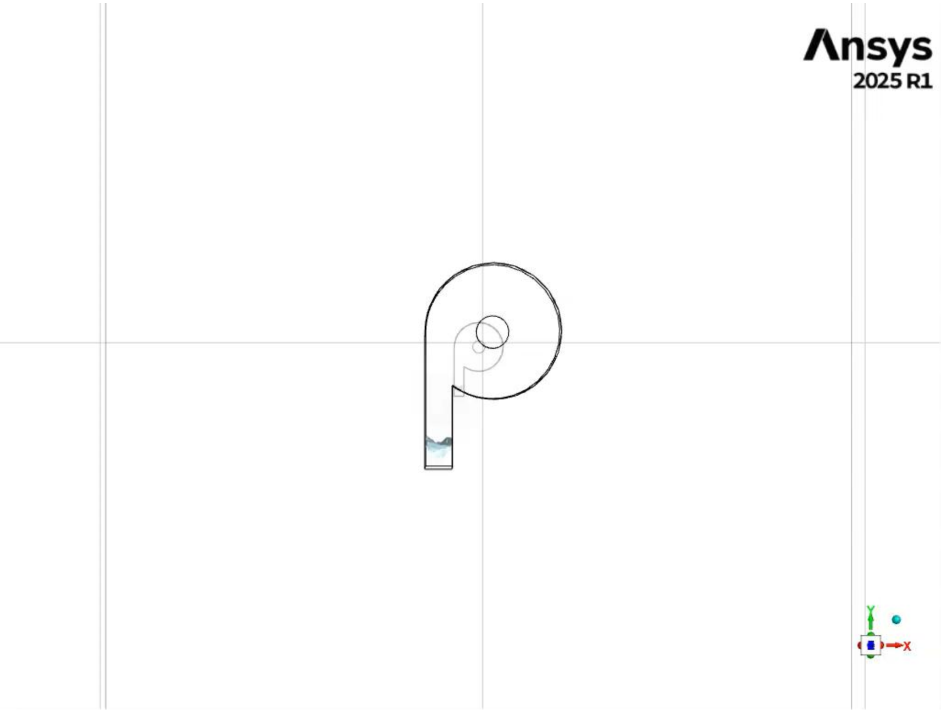


Pressure Swirl Atomizer Animations

- Comparing spray patterns for two nozzle geometries with identical settings
- Simulation durations of 0.25 seconds



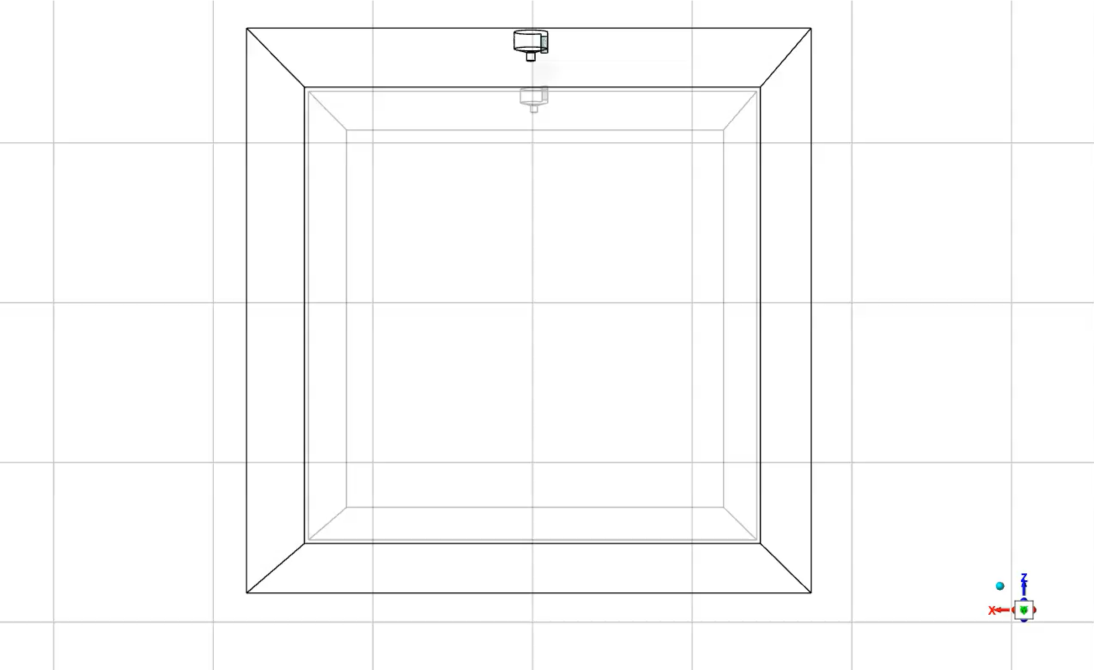
Front View

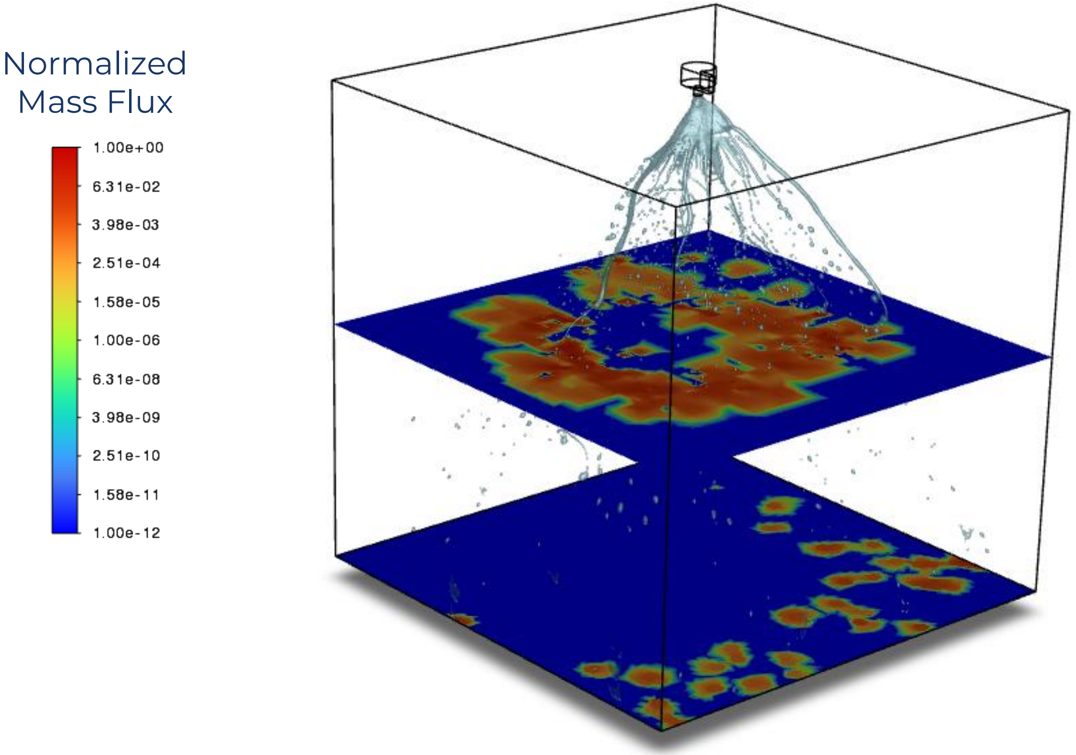


Top-down View

Pressure Swirl Atomizer Post-Processing

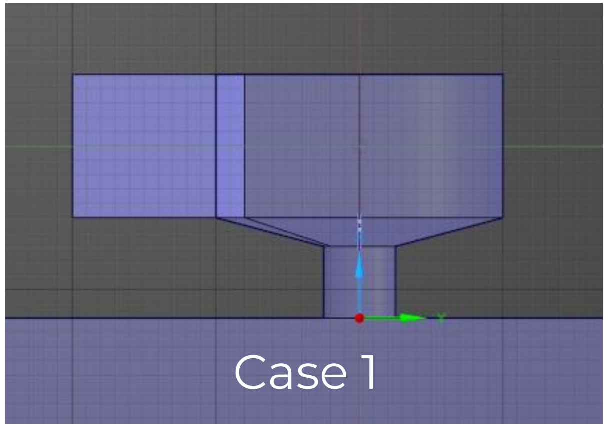
- Spray pattern outputs can be visualized as an animation or surface/volume rendering
- Ligament formation and primary breakup can be observed

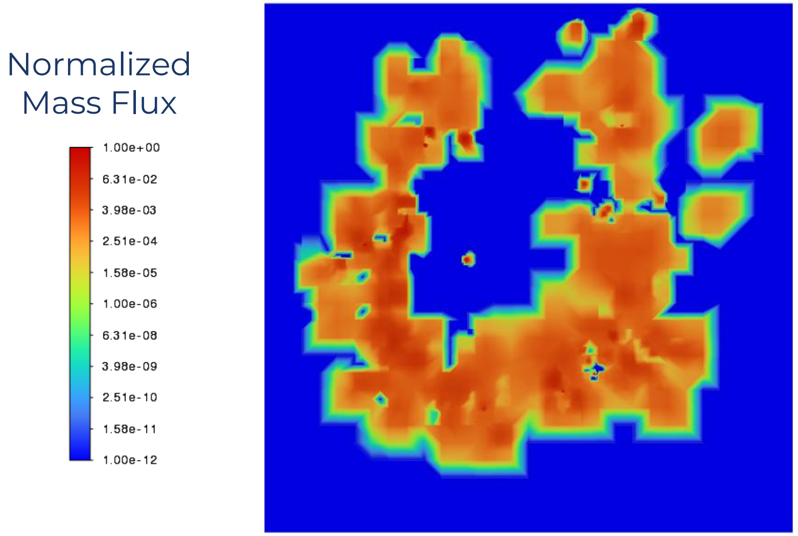


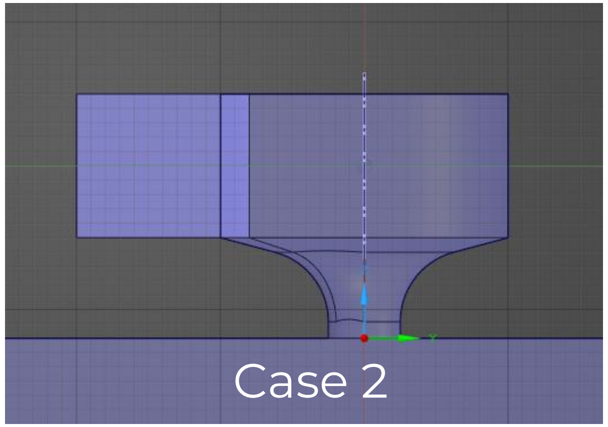


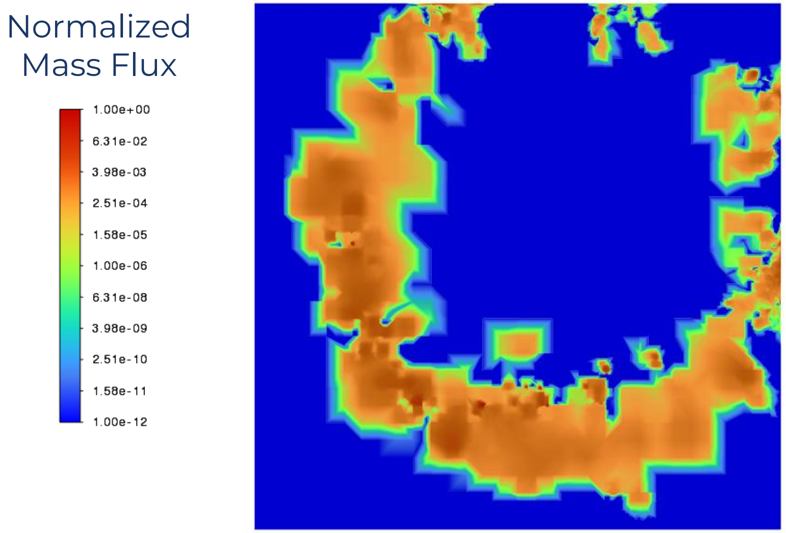
Pressure Swirl Atomizer Results

- Spray pattern outputs at midplane for each case:

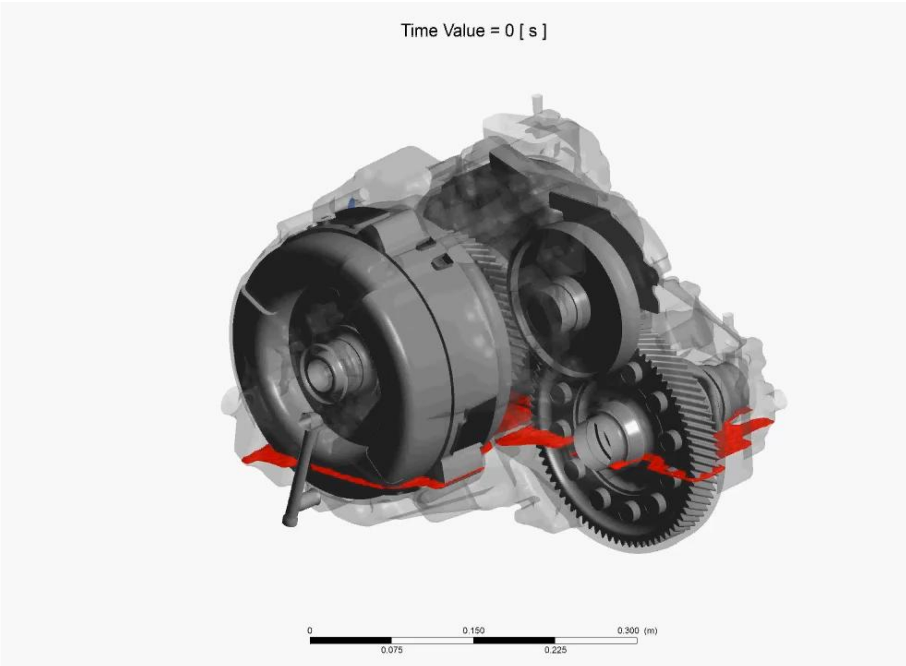


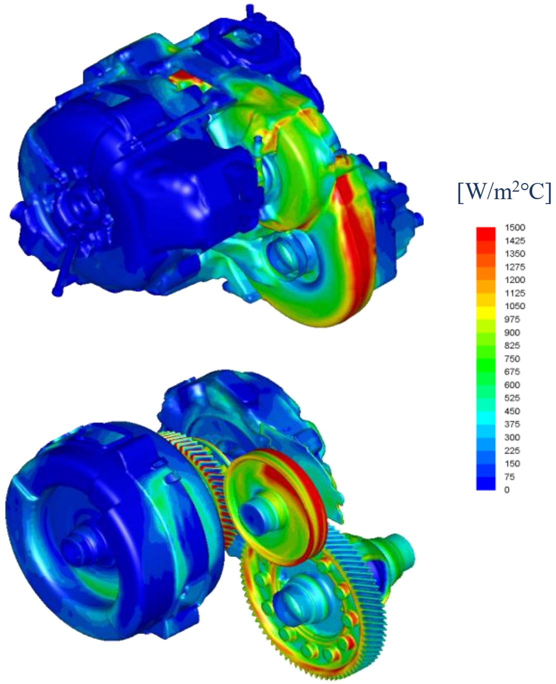


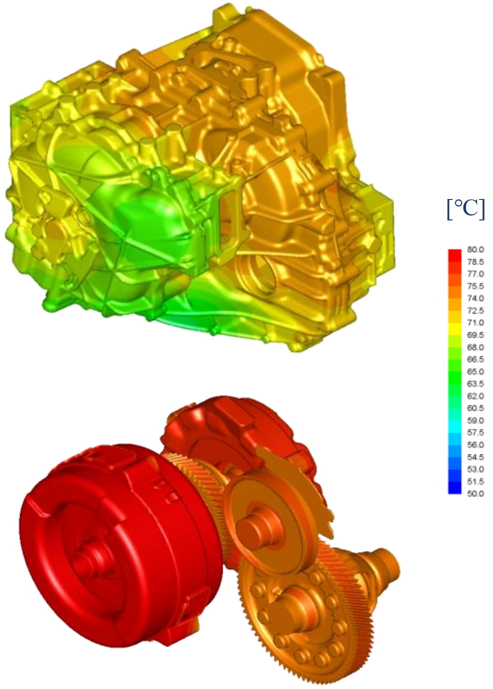




Post Processing Outputs







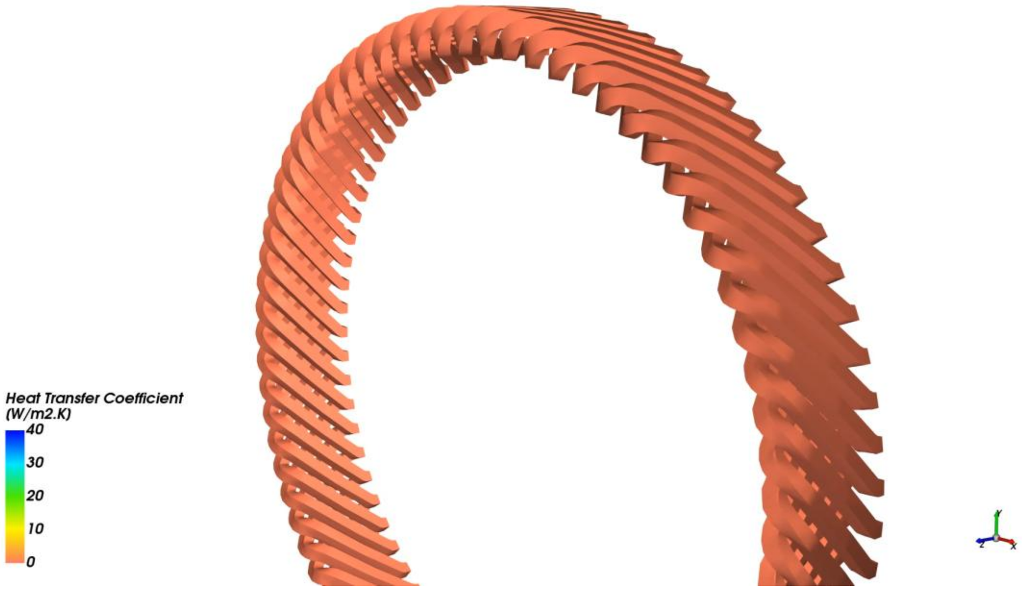
Oil distribution
(Transient)

Heat transfer
coefficient
(Time averaged)

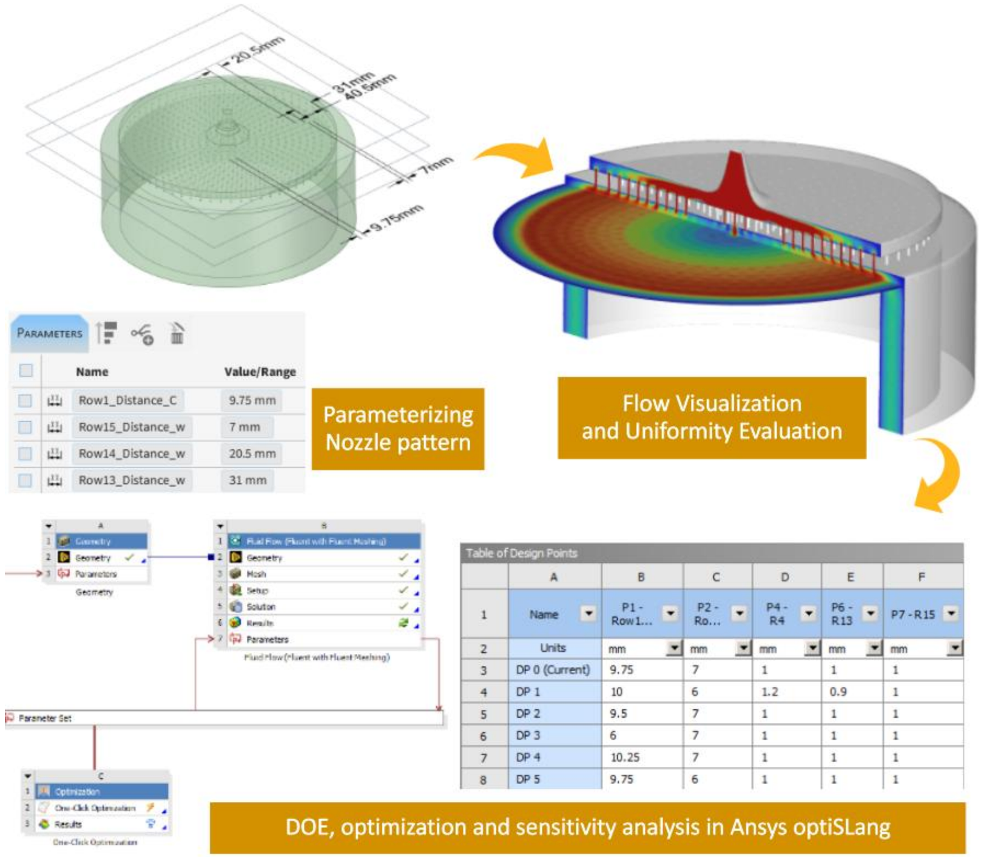
Temperature
(Steady)

Parametric Analysis Options

- Operating conditions such as inlet pressure or velocity can be easily varied and compared
- Comparisons for Heat Transfer Coefficients, Lubrication, etc.
- Geometric changes possible via Ansys Workbench



Note: This animation is for illustration purposes of HTC prediction was created with SPH simulation, not via the VOF model presented earlier.



DRD

Summary

- Primary breakup can be modeled effectively by models available in Ansys Fluent
- Volume of Fluid method can effectively analyze changes in spray patterns due to nozzle geometries
- More information on multiphase flows is available from DRD as well as Ansys Learning Hub

Any questions from the audience?