Case Study: Simulation

Measurement meets Simulation –
Real Bubble Data for Better Model Confidence

In cooperation with

ENGINSOFT

Particleworks™
Particle-based simulation software for CAE

Application:
Gearbox Aeration

Environment:
Testing & Simulation Workflow

Focus:
Model Confidence

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Case Study at a Glance

A complementary engineering workflow combines real bubble measurement with simulation insight.

Challenge

Air-in-oil behavior is dynamic, multi-scale and difficult to understand through simulation or measurement alone.

Approach

EnginSoft / Particleworks simulation and Smart Bubble System optical measurement were combined as complementary engineering perspectives.

Result

Real bubble data can support simulation calibration, trend validation and model interpretation.

Impact

The joint workflow creates deeper system understanding and increases confidence in development, testing and validation decisions.

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Measurement Approach

A complementary workflow connects simulation and optical measurement.

Simulation perspective

- Visualizes oil-air flow behavior inside the gearbox
- Identifies flow paths, recirculation zones and aeration hotspots
- Explains where and why air is entrained or transported

Measurement perspective

- Measures bubble behavior under real operating conditions
- Captures air volume fraction, bubble size distribution and trends
- Adds temperature, operating-state and system-dynamics context

Define → Measure → Simulate → Map KPIs → Correlate → Generate Insights

The strength of the approach lies in complementarity, not equivalence.

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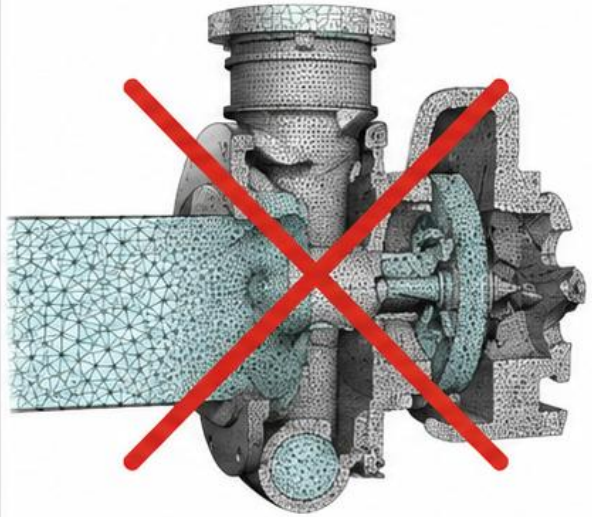
Particleworks: No Mesh, Many Benefits

Conventional mesh-based CFD

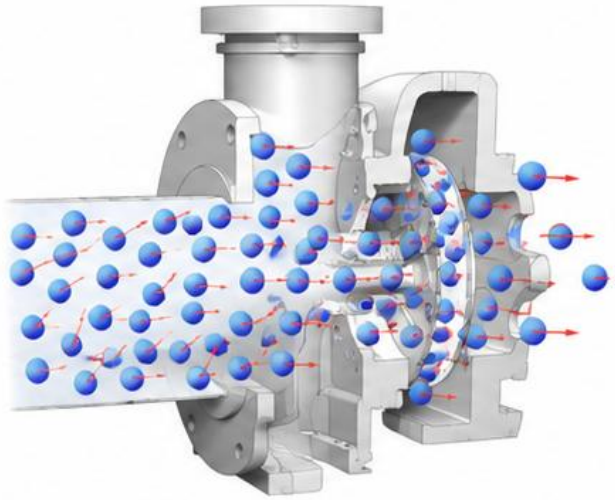


Mesh-dependent

Grid creation and mesh adaptation increase setup effort and complexity.

Particleworks MPS

Mesh-free MPS approach



No mesh required

Particles carry flow information (velocity, pressure, temperature) and move based on the simulation result.

Key Benefits

- Faster setup
- Less meshing effort
- Better handling of complex fluid motion
- Easier scenario iteration
- More flexible analysis of moving fluid behavior

Particleworks MPS delivers accurate fluid analyses without the limitations of meshing.

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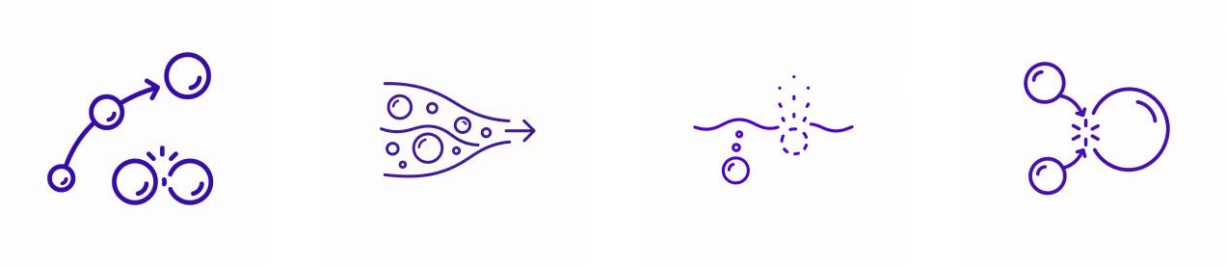
Particleworks™ Particle-based simulation software for CAE

Capabilities of Particleworks

Dedicated aeration module.

It includes a set of **numerical models** to predict:

- Bubbles **generation** (multiple diameters)
- Bubbles **transportation**
- Bubbles **disappearance** (lifetime model)
- Bubbles **coalescence**



Generation | Transportation | Disappearance | Coalescence

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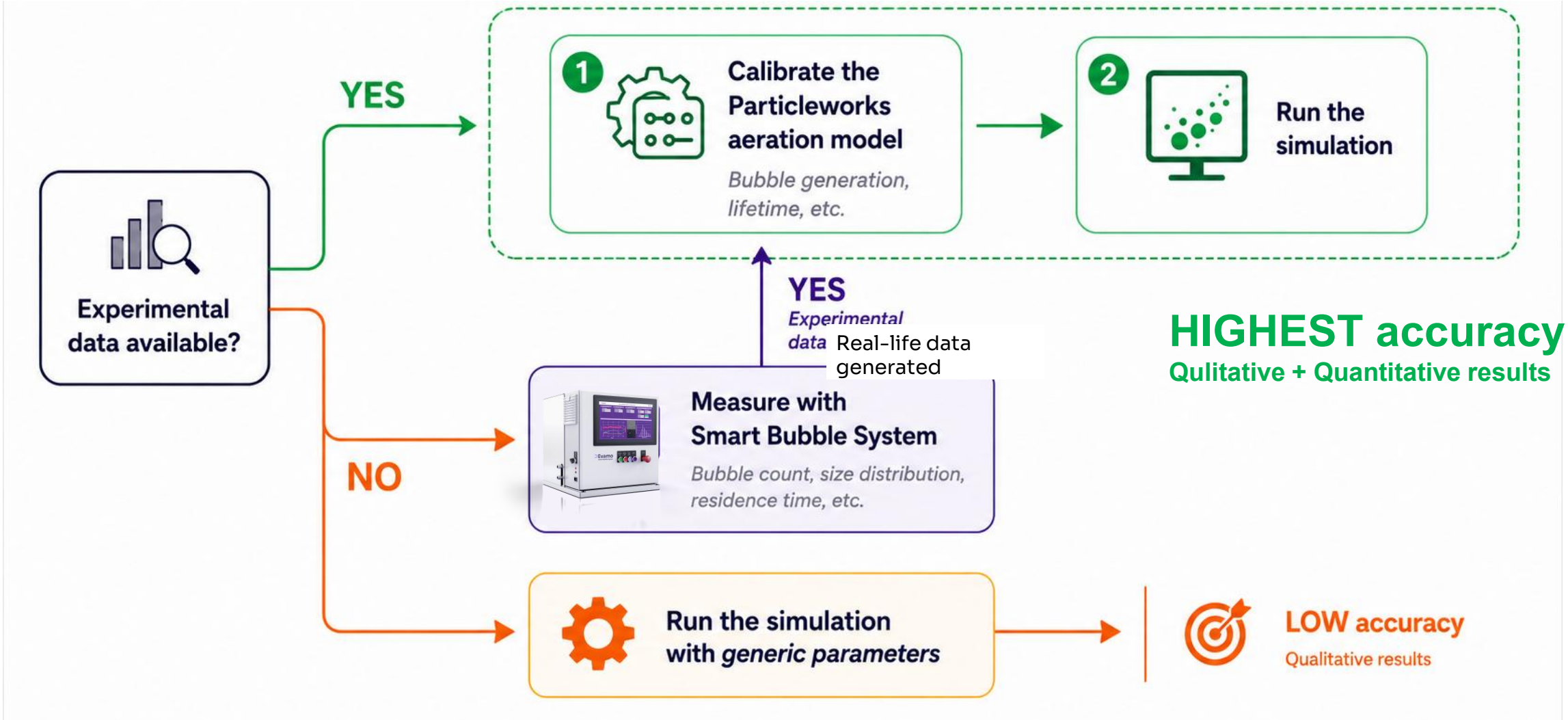
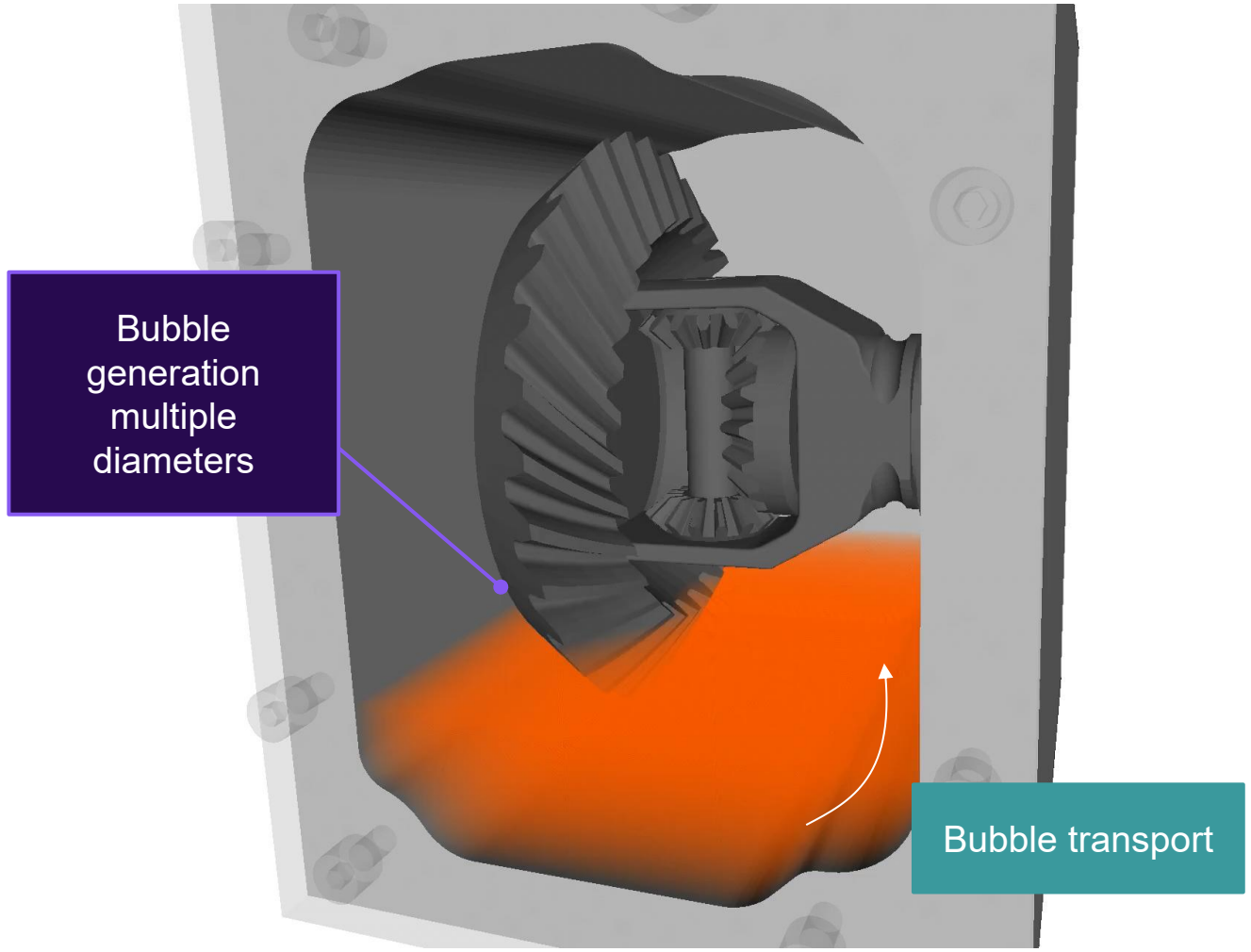
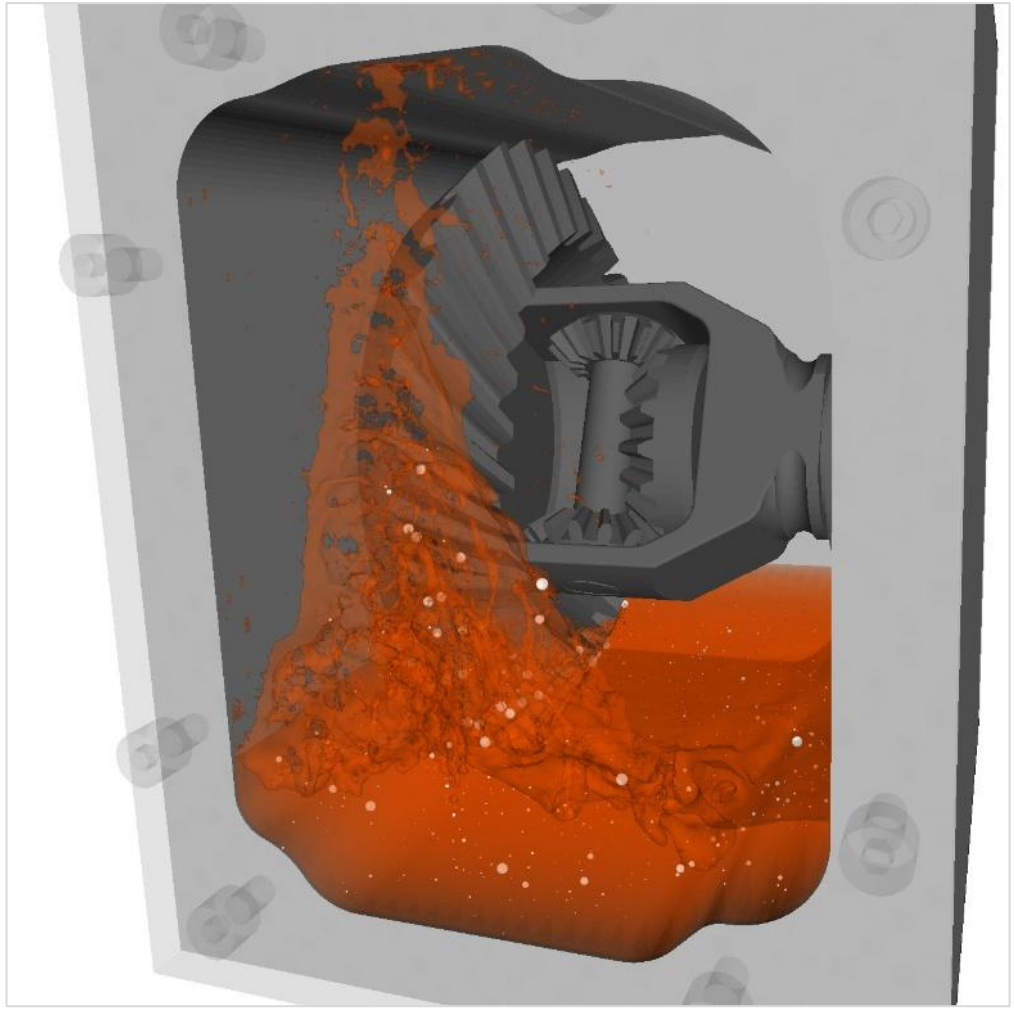
Workflow: Particleworks Aeration Module & deepfluid Measurement

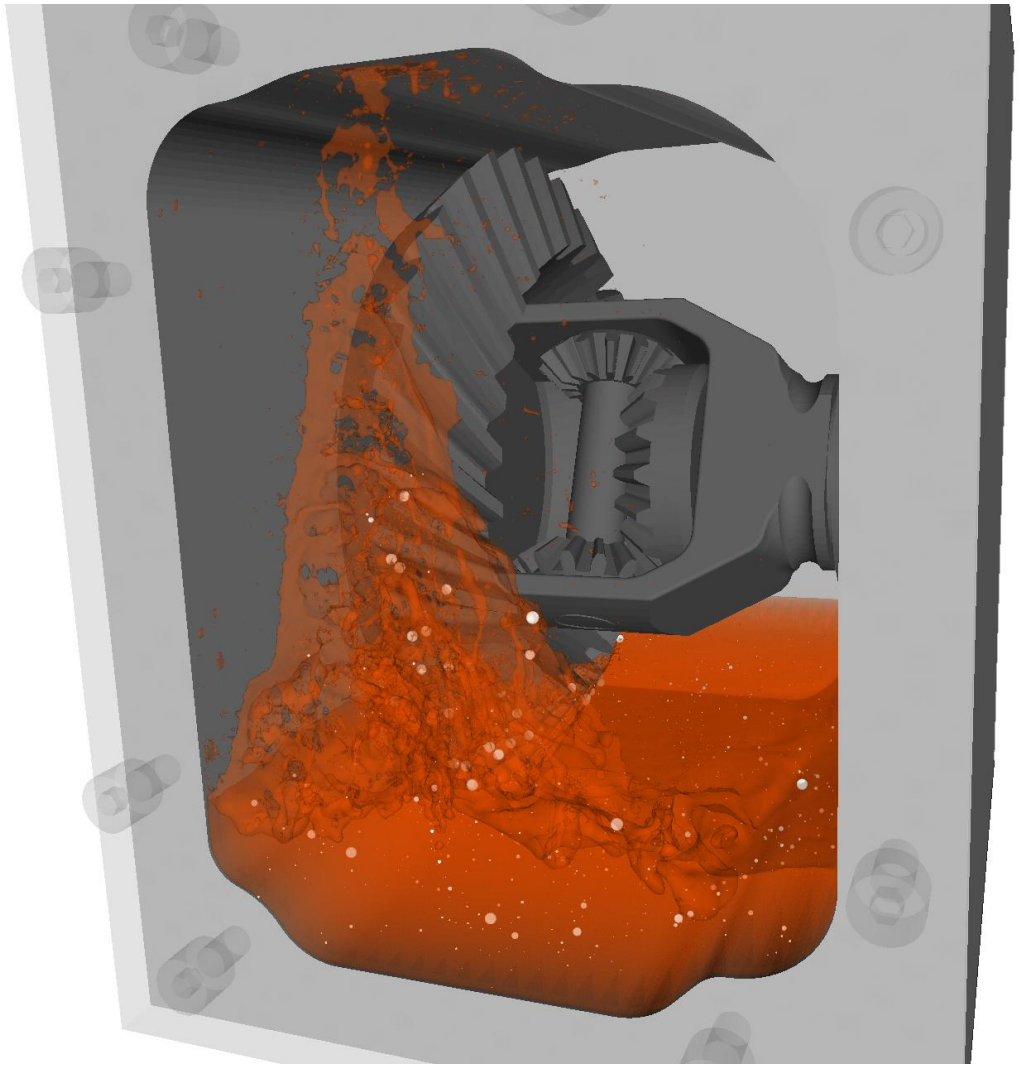


Particleworks Aeration Module

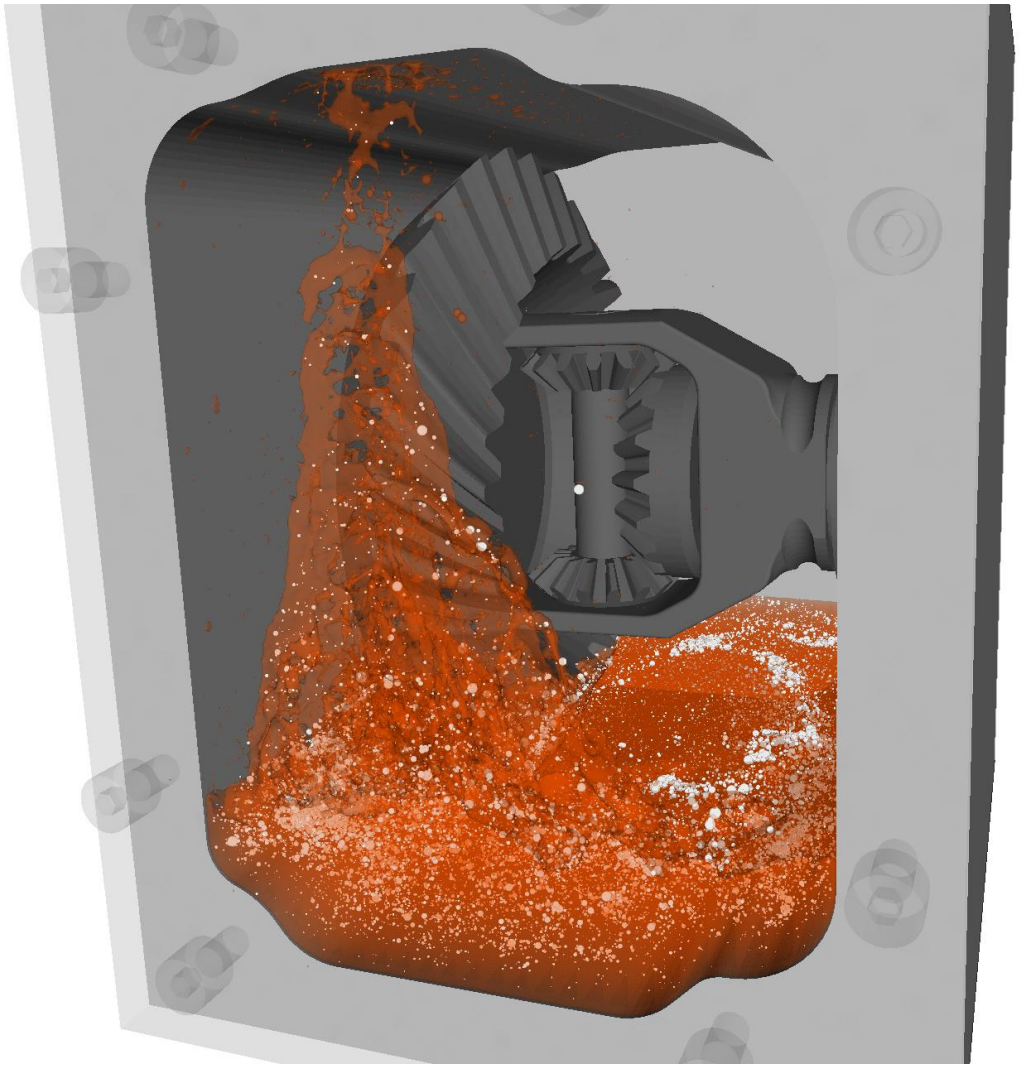




Before Calibration

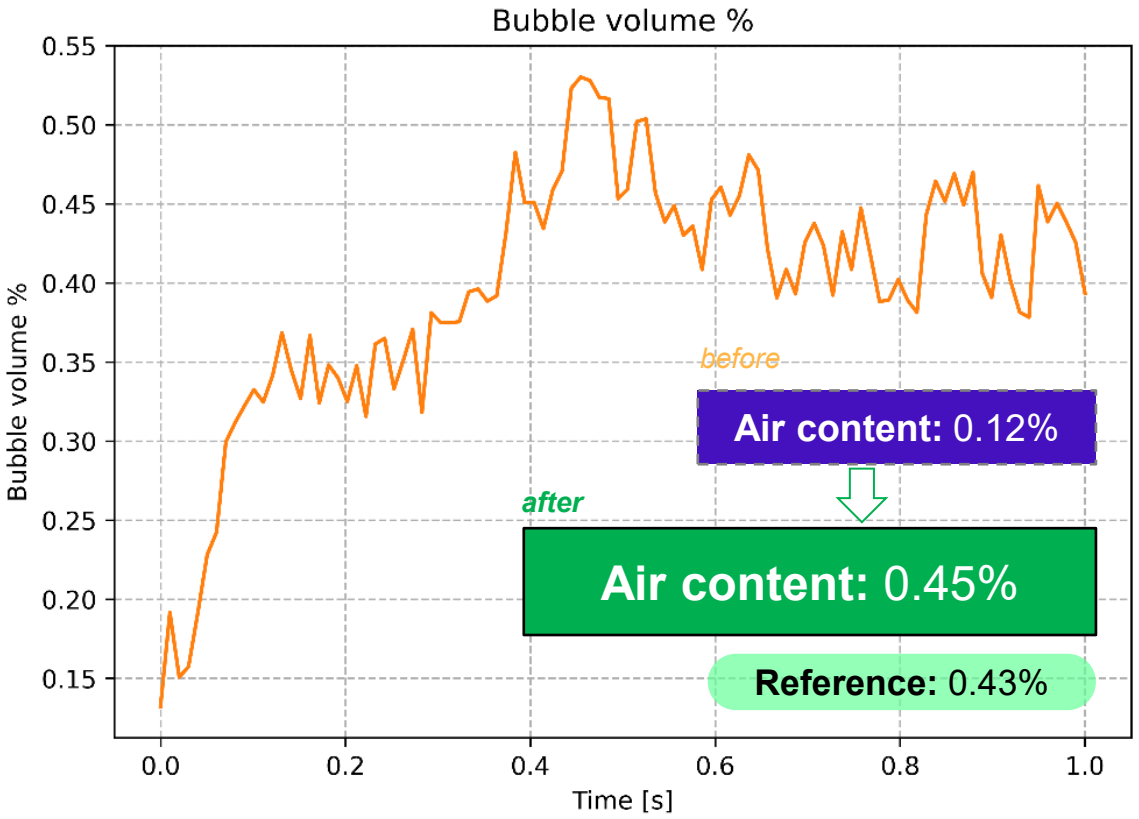


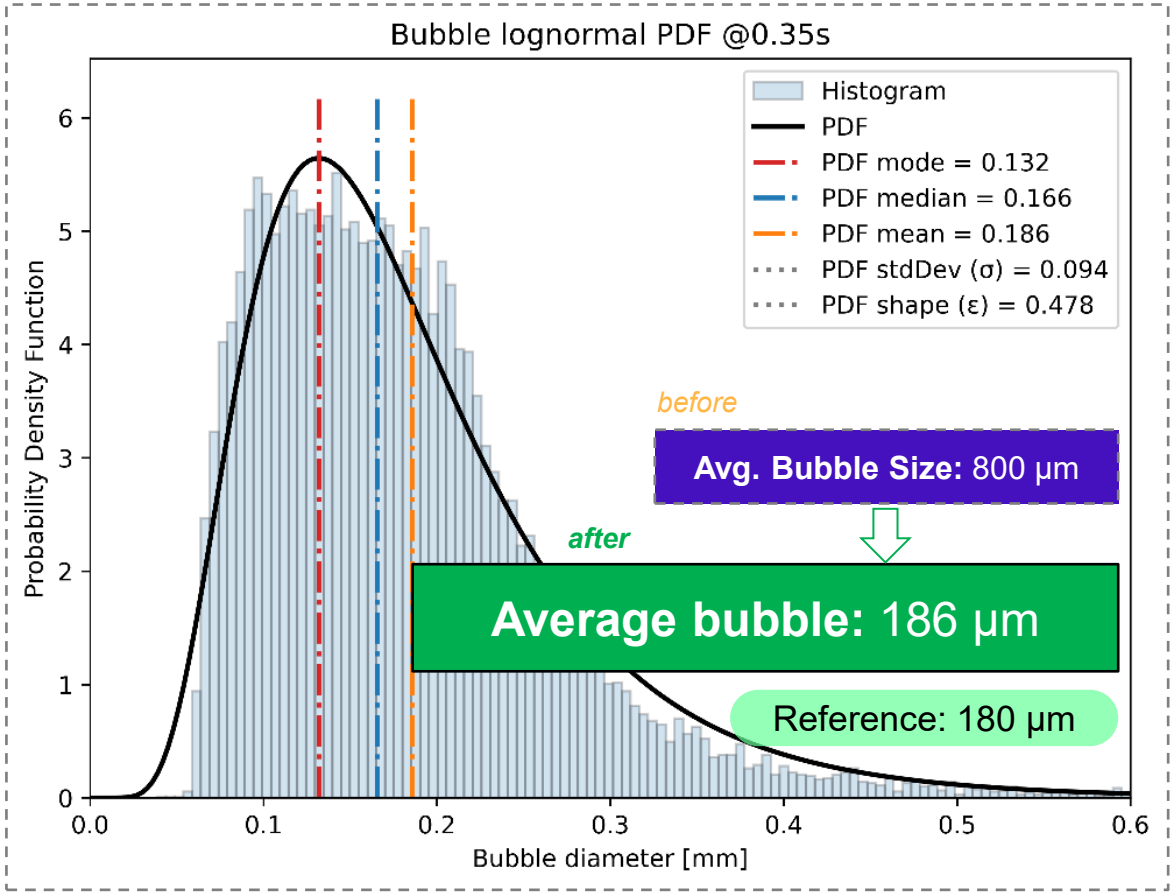
After Calibration with SBS



Simulation meets Measurement: Quantative Comparison

Charts of **air content** and **bubble size distribution** can be retrieved from the simulation.





Measured Metrics & Data Basis

Real bubble behavior becomes simulation-relevant data.

The measurement transforms optical bubble behavior into structured metrics that can be mapped against simulation outputs.

Metric	What it shows	Why it matters for simulation
Air volume fraction	Amount of air dispersed in the oil	Provides a measured reference for aeration level
Bubble size distribution	Size range and distribution of bubbles	Supports comparison with expected dispersion behavior
Bubble count	Number of detected bubbles over time	Helps characterize aeration intensity
Bubble dynamics	Movement, persistence and trend behavior	Connects measurement to operating transitions
Operating context	Temperature, speed, load, oil level and boundary conditions	Aligns measurement and simulation cases
Time-based trends	Development across operating points	Enables comparison of patterns instead of isolated values

Data Value

Real bubble data does not replace simulation. It creates an additional validation layer that can support calibration, improve interpretation and increase confidence in simulation results.

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Engineering Interpretation & Impact

Measurement and simulation create stronger engineering confidence together.

What the data indicates

- Measured air-in-oil behavior creates a real reference for the model
- Simulation helps investigate internal aeration mechanisms and hotspots
- Trend similarities and deviations become visible
- Boundary conditions can be aligned across testing and simulation
- Real data supports calibration and improves interpretation confidence

Impact

System understanding	Connects internal mechanisms with measurable outcomes
Development efficiency	Reduces uncertainty in design and validation decisions
Testing & validation	Links test bench data with simulation outputs
Critical operating regimes	Helps identify aeration- and cavitation-relevant conditions
Product robustness	Supports optimized gearbox design, lubrication concepts and operating strategies
Scalability	Creates a transferable workflow for other gearboxes, fluids and operating profiles

Measurement and simulation are not competing approaches — together, they connect internal mechanisms with real measurable outcomes.