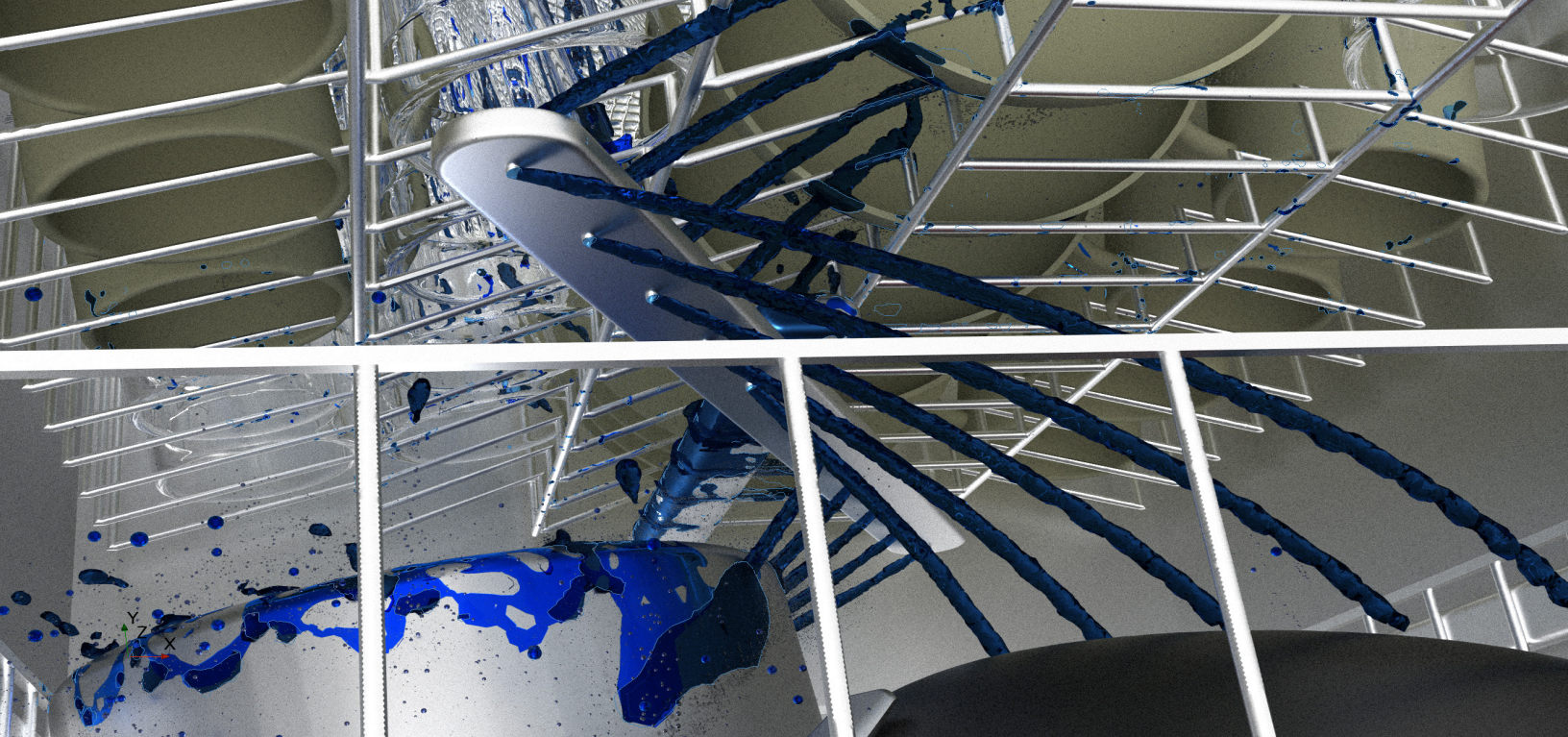




DIGITAL INDUSTRIES SOFTWARE

Simcenter STAR-CCM+ multiphase CFD simulation

Accurately model complex industrial multiphase applications with confidence

Benefits

- Model complex industrial multiphase systems without extensive geometry simplification
- Simulate multiphase applications with a high degree of fidelity
- Get accurate results using optimal multiphase modeling techniques based on available resources

Summary

In the highly competitive race toward a sustainable future, environmental concerns must be factored into new product design. To maximize performance, the scope of your simulations must extend to the digital twin at the system level. As a result, applications are more likely to be multiphase in nature. For example, a pump may be a single-phase application, but its system might not be.

In addition to being multiphase, larger problems likely contain multiple flow regimes such as mixtures, free surfaces, sprays or fluid films. This is a challenge for classical multiphase models, which were designed for a single flow regime and no longer meet the computational fluid dynamics (CFD) simulation needs for many applications. Without a new approach, we are constrained to simulating part of the problem or accepting an inaccurate approach that operates beyond its range of applicability. How do we close this gap?

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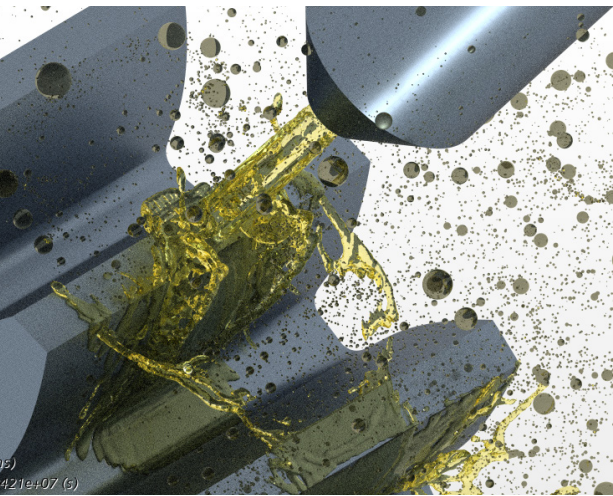


Figure 1. VOF to LMP resolved multiphase simulation of an oil jet hitting a rotating gear.

Simcenter STAR-CCM+ offers the solutions

With its innovative, industry leading, hybrid and multiple regime multiphase technologies, Simcenter™ STAR-CCM+™ software enables you to go faster by providing new insight into your design. You can model the complexity of an entire system without simplification, which unlocks your potential to improve performance. Simcenter STAR-CCM+ is a part of the Siemens Xcelerator business platform of software, hardware and services.

Simcenter STAR-CCM+ provides:

- A comprehensive ecosystem of multiphase models that can be used in a hybrid manner. This allows the solution to adapt locally, on the fly, to any regime
- Multiple regime modeling capabilities, which enable mixtures and free surfaces to coexist
- Complementary technologies to accelerate your solution, including adaptive mesh refinement (AMR) and adaptive time stepping

The multiphase models

The ecosystem of multiphase models in Simcenter STAR-CCM+ caters to every regime in industrial multiphase flows:

- *Volume of fluid (VOF)*: Captures free surfaces and highly resolved details such as individual droplets and bubbles. Applications include marine vessel simulations and automotive applications such as water management and powertrain lubrication
- *Mixture multiphase (MMP)*: Models mixtures with a smaller difference in velocity (slip) between phases. Applications include multiphase pumps and powertrain lubrication
- *Eulerian multiphase (EMP)*: Models mixtures that allow the phases to behave more independently with significant levels of slip. This is suited for oil and gas, nuclear and chemical/process applications
- *Dispersed multiphase (DMP)*: Models dispersed phases with low-volume fractions. Useful for applications such as aircraft icing
- *Fluid film*: Models liquid wall films that develop where droplets impinge on 2D surfaces (the thickness is not resolved). Applications include spray painting, coating, aircraft icing and vehicle water management
- *Lagrangian multiphase (LMP)*: Models dilute discrete phases such as sprays of droplets or particle flows. This is most suitable for ballistic droplets in sprays that cannot be represented as a mixture
- *Discrete element method (DEM)*: Models particle flows that place importance on particle shape and particle-particle contact. Applications include excavation, drilling, agriculture and food and materials handling

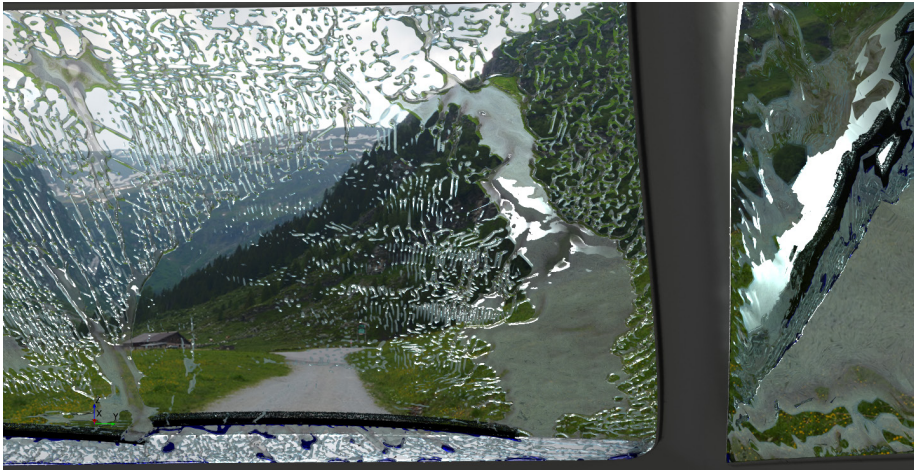


Figure 2. Vehicle water management (LMP-VOF-film).

- *Smoothed-Particle Hydrodynamics (SPH)*: Models liquid flows with complex geometry and motion. This is suitable for applications involving highly dynamic free surface flows such as drivetrain lubrication, sloshing and liquid run-off applications

Each of these models meet a need. However, they reach their full potential when used together.

Hybrid multiphase – multiple model approach

In Simcenter STAR-CCM+, Siemens has pioneered an innovative hybrid approach that allows multiple multiphase models to seamlessly work together. This enables each model to be used in the flow regime it is designed for without being pushed beyond its applicability range.

A common hybrid multiphase strategy is to extend the VOF model by using it alongside the fluid film and LMP models for smaller scale multiphase features. Resolving these features with VOF is computationally expensive, but the hybrid multiphase strategy can prevent errors.

In this approach, small droplets are modeled using LMP and thin films are modeled using fluid film. VOF only needs to capture the large-scale flow features. This allows you to simulate previously impractical applications with a high degree of fidelity and confidence.

Applications include vehicle water management, fuel spray breakup, e-motor cooling and household appliance fluid management. The hybrid multiphase approach is built around several key phase interactions:

- *Hybrid VOF-film (resolved film)*: Model fluid films of varying thickness that can transition seamlessly into VOF when the mesh is fine enough or the amount of fluid becomes great enough (and back again when it is not). Include the effects of key physics such as surface tension across the transition
- *VOF-Lagrangian resolved transition*: Capture important physics such as jet breakup with VOF while using the cheaper Lagrangian model for the resultant droplets
- *LMP-film impingement and stripping*: Models Lagrangian droplets impinging into and stripping from fluid film, which includes effects of splashing

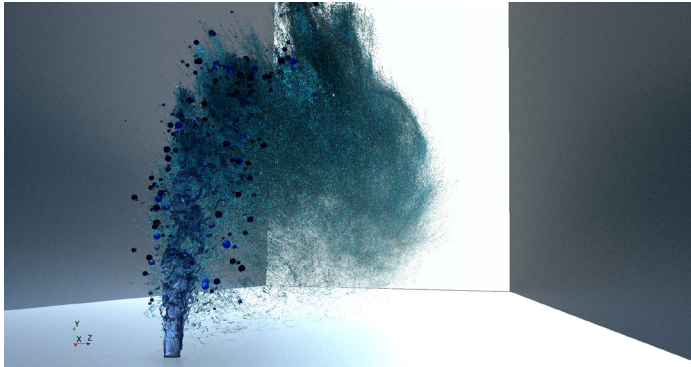


Figure 3. Jet breakup (VOF-LMP).

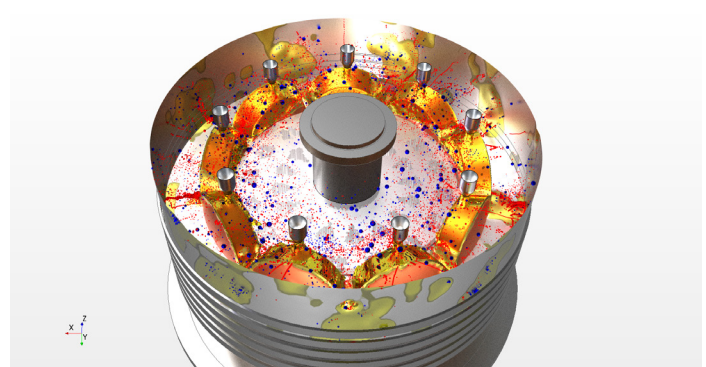


Figure 4. E-motor cooling (VOF-film-LMP).

Along with these interactions, you can include more complex physics, such as boiling, cavitation and reactions and cater to a range of droplet or bubble sizes with advanced population balance models.

Multiple regime modeling

Alongside hybrid multiphase modeling, Simcenter STAR-CCM+ offers the ability to handle different regimes in the bulk fluid. Two phases will interact differently depending on the nature of the fluids, amount of mixing and resolution of the simulations. Phases can meet at a resolved free surface or form a mixture.

Many multiphase problems cover a range of regimes with free surfaces and mixtures coexisting. This is a challenge for traditional multiphase models since they are only suited for one regime. Using these models for such problems leads to excessive computational cost from resolving small details or errors from failing to capture important physics.



Figure 5. Fluid management in dishwasher (VOF-film-LMP).

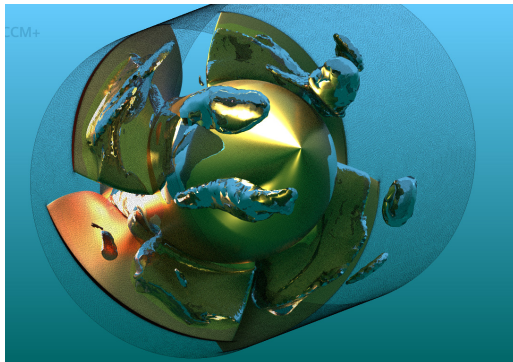


Figure 6. Multiphase pump showing separation of a mixture.

Simcenter STAR-CCM+ provides innovative multiphase modeling that can bridge this gap:

- **Large-scale interface (LSI) model:** Allows free surfaces and mixtures to coexist and is available for EMP and MMP models. When used with MMP, it provides a single model with the benefits of VOF for free surfaces and MMP for mixtures. It allows you to rapidly run simulations previously tackled with VOF and eliminates the need to resolve every detail
- **Multiple regime model:** Models what happens when two phases meet at a sharp free surface using the LSI model or a mixed regime, which enables a regime to transition through phase inversion

Smoothed-particle hydrodynamics (SPH)

Simcenter STAR-CCM+ includes a powerful smoothed-particle hydrodynamics (SPH) solver, offering a volume mesh-free approach to modeling complex fluid dynamics. Based on a Lagrangian, particle-based method, SPH is ideally suited for highly dynamic free surface flows with liquid jets and splashes, such as drivetrain lubrication, sloshing, liquid run-off. For targeted applications, SPH significantly reduces setup and solving times, while

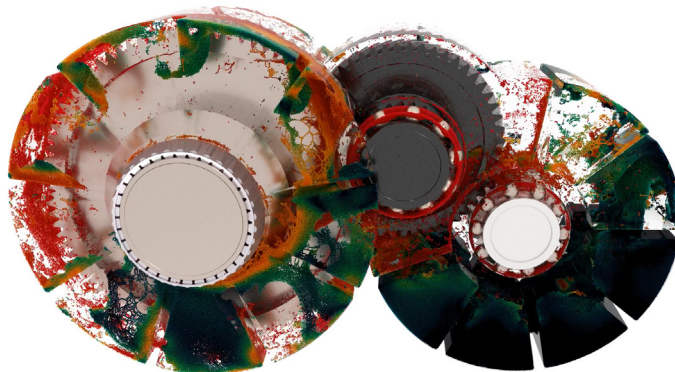


Figure 7. Partially resolved gear lubrication.

enabling accurate simulation of flows with moving boundaries. Integrated within the Simcenter STAR-CCM+ environment, the SPH solver supports high-performance computing and GPUs, making it a robust and rapid choice for transient, high-fidelity CFD applications.

Complementary technologies

Simulating multiple regime flows requires support for different scales from the small bubble or droplet or thin fluid film, to large resolved free surfaces. These varying scales can make simulation expensive. Simcenter STAR-CCM+ provides several tools to achieve an order of magnitude speed up:

- **Model based AMR:** A free surface-based refinement provides an automatic tool to keep free surfaces sharp and only use mesh where needed. This model does not require user input to automatically produce the mesh needed from a coarse initial mesh
- **Model based adaptive time step:** A free surface-based adaptive time step predicts and adjusts the time step needed to capture any small details that may develop, while allowing a larger time step to be used when the flow is calmer

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