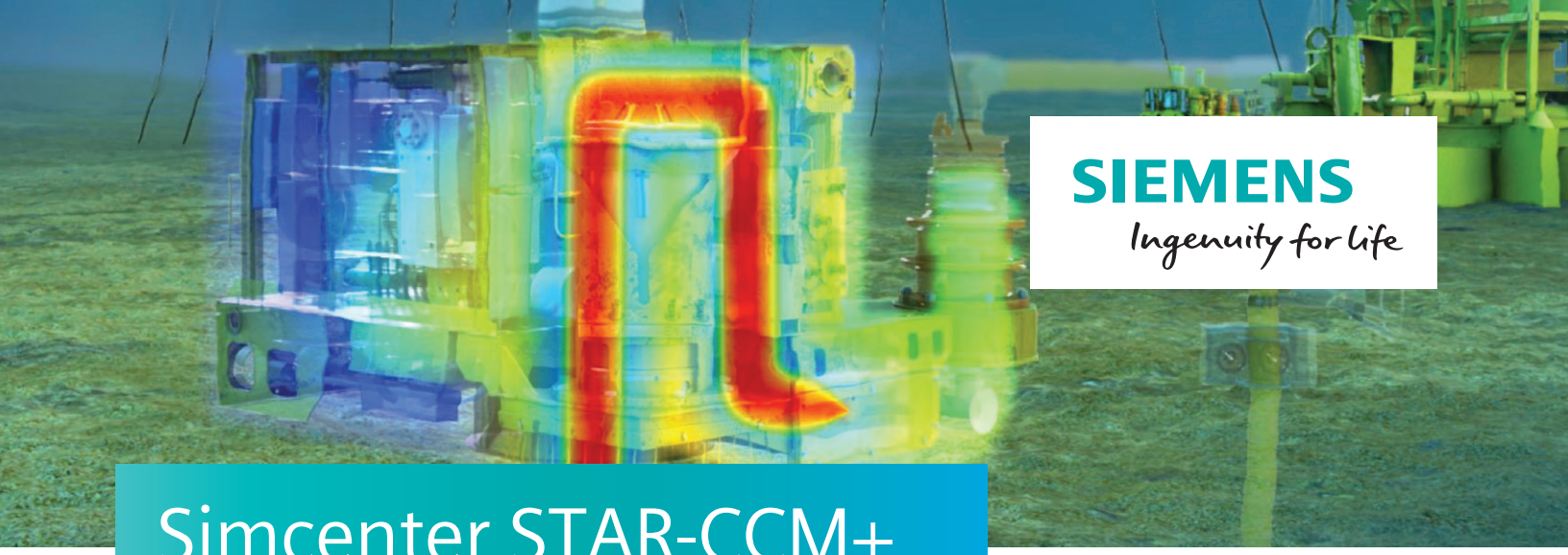

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Ingenuity for life

Simcenter STAR-CCM+ multiphysics solutions

Enabling the prediction of real-world performance earlier in the design process

Benefits

- Enables users to predict real-world performance earlier in the design cycle
- Reduces time-to-market and costly failures
- Improves realism and accuracy by providing a wide range of physics in a seamless, single integrated user interface

Summary
Multiphysics engineering simulation can accurately capture all the relevant physics that influence the performance of increasingly sophisticated products. Simcenter™ STAR-CCM+™ software enables users to minimize the level of approximation and assumption by providing a comprehensive, accurate and efficient array of multiphysics solutions, providing confidence the predicted performance of designs will match the real-world product.

Multiphysics simulations you can trust
Simcenter STAR-CCM+ delivers accurate and efficient multidisciplinary technologies in a single integrated user interface (UI). This enables the study of sophisticated industrial problems with complex physical phenomena in a fully coupled manner. Users benefit from increased accuracy and the ability to discover better designs faster. Comprehensive multiphysics include fluid dynamics, solid mechanics, multiphase and particle flow, acoustics, heat transfer, reacting flow, electromagnetics, electrochemistry and rheology.

Fluid dynamics
Simcenter STAR-CCM+ offers powerful flow solvers that are easy to set up and are robust, accurate and deliver excellent scalability. This allows users to quickly transition from single point simulations to exploring the entire design space. It enables you to:

- Cover a full range of applications from subsonic to hypersonic with robust and easy-to-use coupled and segregated flow/energy solvers
- Get to solutions quickly using the most efficient solver for the application, with steady and unsteady implicit and explicit formulations, including Pressure-Implicit with Splitting of Operators (PISO)
- Account for turbulence on any scale with a wide range of turbulence models, from Reynolds-Averaged Navier Stokes (RANS) to detached/large eddy simulation (DES/LES)
- Represent unresolved devices and components and their effect on the flow-field with porous media. Includes the ability to account for heat transfer with unresolved solid components. Fan and heat exchanger models allow such components to be accurately characterized

Simcenter STAR-CCM+ multiphysics solutions

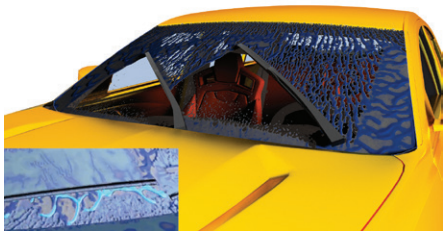
Heat transfer
Simcenter STAR-CCM+ can be used to rapidly solve conjugate heat transfer (CHT) problems by solving on a separate timescale in fluid and solid regions within a single simulation:

- Includes all modes of heat transfer, including the effects of radiation between surfaces and participating fluids
- Saves meshing and computational time by replacing thin solid components with zero-thickness shells

Applications include vehicle thermal management, headlamps, electronics cooling, gas turbine cooling and combustion.

Conjugate heat transfer of a cooled turbine blade.

Hybrid multiphase
Real-world multiphase problems span every industry and application. They cover more than one regime, including mixtures of one phase containing bubbles or droplets of another, free surfaces between immiscible fluids, mixed regimes in which no phase dominates, and thin fluid films and sprays of droplets with dimensions too small to resolve. Traditional multiphase models can cover only one of these regimes, forcing the user to make assumptions and accept the associated error, or to face not carrying out a simulation due to computational cost.



Vehicle water management using hybrid multiphase switching between fluid film and VOF.

Simcenter STAR-CCM+ offers an unrivaled set of hybrid and multiple regime multiphase capabilities to automatically transition between different regimes based on local flow conditions and modeling budget in a single simulation. This unique approach ensures the most efficient and appropriate modeling strategy is used without compromising physical accuracy.

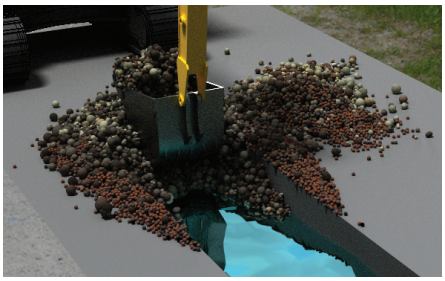
- Hybrid multiphase is built around a family of multiphase models that collectively can cover any regime, including but not limited to the volume of fluid (VOF) model for free surfaces, fluid film for thin unresolved films on walls and Lagrangian Multiphase (LMP) for discrete droplets
- Alongside these models, Simcenter STAR-CCM+ provides a set of phase interaction models to allow them to work collectively in a hybrid fashion, intelligently switching between models based on local needs to capitalize on each model's strengths and avoid its weaknesses. These models provide a large array of physics, including boiling, droplet-wall impingement and surface tension.

Applications include: marine hydrodynamics, tank sloshing, vehicle water management, aircraft icing, e-motor cooling, selective catalytic reduction (SCR) and fuel cells.

As an alternative to the hybrid multimodel approach, Simcenter STAR-CCM+ also provides the multiple regime model, extending the comprehensive Eulerian Multiphase (EMP) model that enables the user to solve real-world problems that are not limited to a single regime. This allows sharp free surfaces and mixed regimes to coexist alongside traditional continuous/dispersed regimes.

Applications include bubble columns, fluidized beds and mixing vessels.

Particle flows
Multiphase applications are not restricted to gas and liquid flows but can also involve the processing of solid granular materials. Simcenter STAR-CCM+ provides a comprehensive set of solutions including the discrete element method (DEM), which allows users to accurately model solid particle flows in which particle collisions and shape are important.

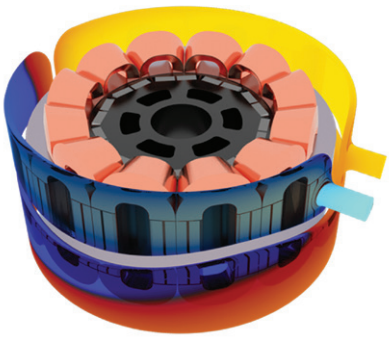


An excavator digging rocks/soil modeled using DEM particles in a flooded trench (VOF).

You can efficiently model any particle shape with spherical, coarse grain, composite, clumped, cylindrical, capsule and polyhedral particles. It allows the user to model complex systems in a single software package, coupling fluid flow and motion with the dynamic fluid-body-interaction (DFBI) for six degrees of freedom (6DOF) solver, avoiding complex multi-code coupling.

Applications include fluidized bed reactors, blast furnaces, tablet coating, construction equipment, agricultural machines and bulk material handling equipment.

Electromagnetics
Environmental considerations are driving an increase in electrification and alternative propulsion methods. A key aspect of multiphysics simulations in the design of such new technologies is electromagnetism.



E-machine cooling simulation.

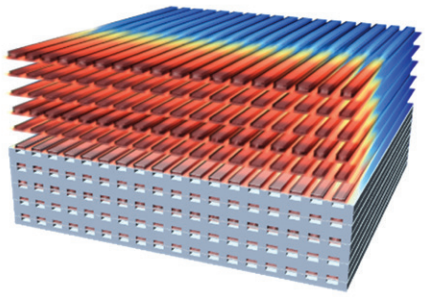
Simcenter STAR-CCM+ offers a set of low frequency electromagnetics solvers that can easily be coupled with flow and thermal analyses for the thermal management of electric machines.

Simcenter STAR-CCM+ enables the user to solve in either a time or single-frequency domain to produce results quickly on large industrial meshes with a highly scalable finite element (FE) iterative solver.

Applications include electric machines, magnetohydrodynamics, plasma arcs and induction heating.

Electrochemistry
Simcenter STAR-CCM+ electromagnetic capabilities are complemented by electrochemistry models that allow the user to predict and understand real-world behavior in complex electrochemically driven processes coupled with the flow, thermal and electromagnetic fields:

- Electrochemical and bulk ion reactions allow the user to resolve ion distributions and the resultant voltages in devices
- Complex plasma phenomenon can be modeled with the coupled plasma electron model



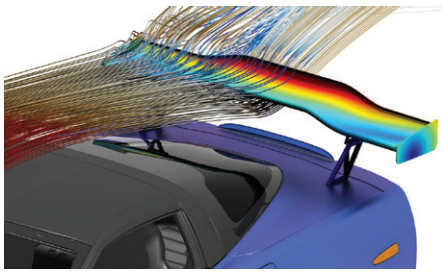
Water management in a SOFC fuel cell.

Applications include proton exchange membrane (PEM) fuel cells, circuit breakers and other plasma applications and electroplating.

Solid mechanics
Solve fluid-structure interaction (FSI) and fluid-thermal-stress problems quickly in Simcenter STAR-CCM+ with an expansive nonlinear FE-based solid mechanics capability.

- Reduce time to solution with the direct parallel solver, and increase thermal problem size with the iterative solver for solid energy
- Handle a wide range of material types, including elastic, hyper-elastic and elastic-plastic materials
- Include the effects of loads and constraints on surfaces, lines or points

Applications include heat exchangers, fuel rods, stents, marine propellers and hydrofoils.

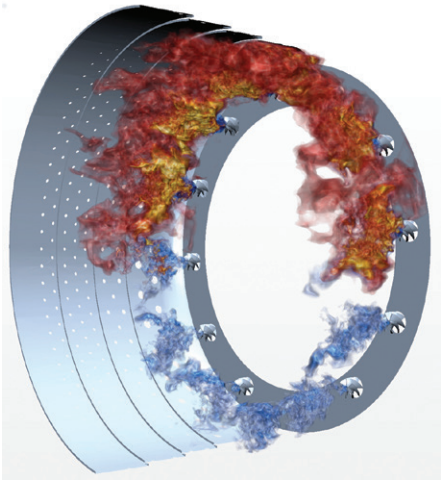


FSI simulation of a car rear wing.

Reacting flows
Tightened emissions controls are driving a move to alternative fuels and novel combustion methods. To be successful, much greater control of (and insight into) the reacting flow-field is required. Simulation tools must give detailed and accurate results quickly. Simcenter STAR-CCM+ provides a comprehensive suite of reaction and emission models to give insight into real-world behavior in reacting flows. A wide range of methods are provided to balance compute time and accuracy.

You can determine the yield of processes by accurately predicting species concentrations with complex chemistry.

- Determine flame location and dynamics with flamelet models
- Predict emissions of nitrogen oxide (NOx), soot, carbon monoxide (CO) and other pollutants with specialized emission models
- Simulate reactions between fluids with multiphase reactions for VOF, Lagrangian and DEM models



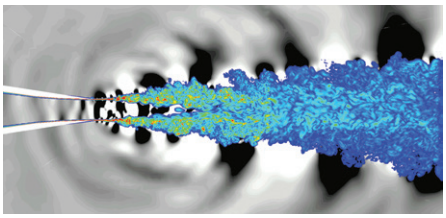
Aero gas turbine ignition.

Applications include gas turbines, internal combustion engines, after-treatment systems, polymerization reactors, chemical vapor deposition and coal furnaces.

Acoustics

Wherever there is flow, there is the potential for unwanted noise, which is increasingly recognized as a form of pollution to be minimized. To accurately predict the sources of noise and propagation to the environment or users of equipment, Simcenter STAR-CCM+ provides an extensive library of aeroacoustics models:

- Quickly identify sources of noise in a RANS simulation with steady-state models and estimate mesh cutoff frequencies for mesh refinement
- Accurately model sources of noise with computational aeroacoustics using DES or LES, including prediction of convective turbulence and methods for propagating noise in the near field



Sound waves propagating from a nozzle.

- Model the propagation of aero-acoustic noise sources to the far field using in-built Ffowcs Williams-Hawkings time domain methods
- Improve accuracy and reduce spurious noise with the hybrid acoustic perturbation equation (APE) solver
- For subsequent acoustic/vibroacoustic propagation analysis in Simcenter 3D, Simcenter STAR-CCM+ can also export computational fluid dynamics (CFD) data representing sound sources

Applications include heating, ventilation and air conditioning (HVAC), external aerodynamics, engine powertrain, aircraft noise and fan cooling.

Rheology

In industries such as chemical processing and food production, engineering extends beyond devices to the fluids themselves, which are designed to exhibit highly viscous, non-Newtonian behavior. Simcenter STAR-CCM+ enables the study of such complex rheological materials by providing a finite element rheology solver.

- Accurately model complex viscoelastic materials using one of four standard viscoelastic constitutive equations (Oldroyd-B, Giesekus-Leonov, Phan Thien-Tanner and extended Pom-Pom)
- Model thixotropic fluids with the Rolie-Poly model, and other non-Newtonian fluids with the generalized Newtonian models

Applications include mixing of non-Newtonian materials such as foodstuffs or paint and extruding parts such as door seals and material processing.

Extruded parts.

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