

Introduction of COMSOL Multiphysics® and Release Highlights of Version 5.3

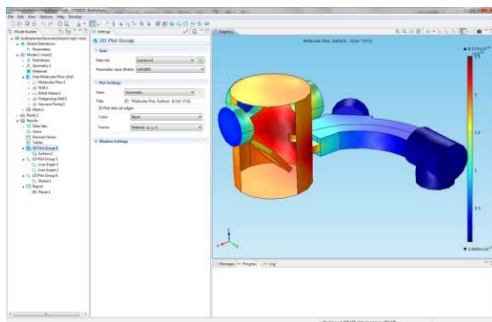
Lizhu TONG, Ph.D.

Keisoku Engineering System Co., Ltd., Japan

November 9, 2017

Keisoku Engineering System Co., Ltd., 1-9-5 Uchikanda, Chiyoda-ku, Tokyo 101-0047, Japan. TEL:+81-3-5282-7040 FAX:+81-3-5282-0808 <http://www.kesco.co.jp/>

Why COMSOL?

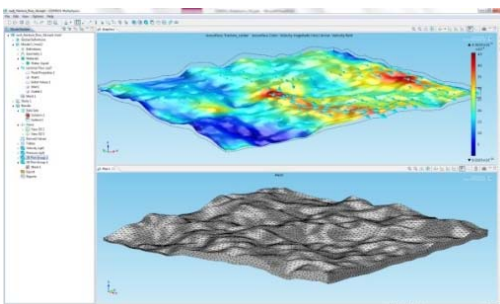


- COMSOL is the leading provider of multiphysics simulation and analysis software

- A large company with decades of experience in simulation

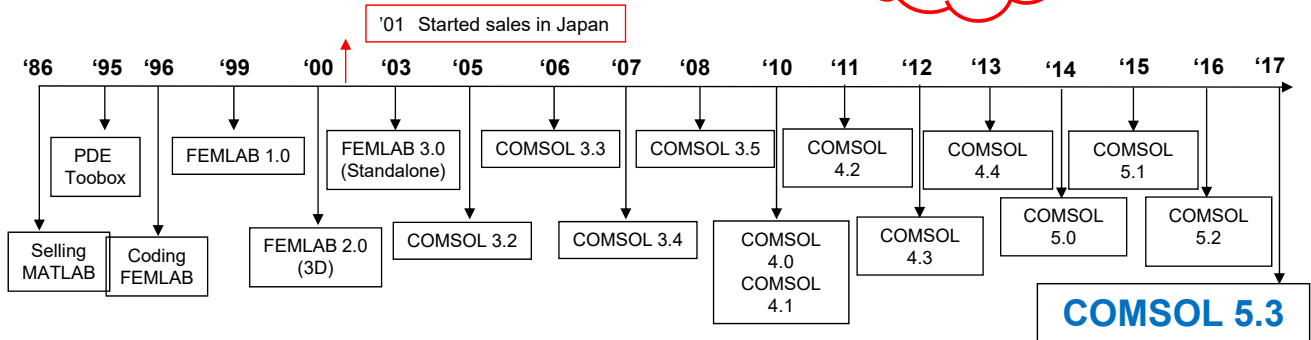
<https://www.linkedin.com/company/comsol-inc-/>

- The Multiphysics advantage:
Easy and simple to set up coupled simulations such as coupling thermal effects into a model and then including a detailed convective heat transfer model that solves for the fluid flow.



COMSOL, Inc.

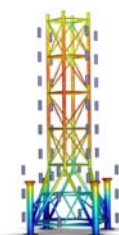
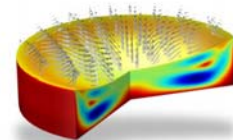
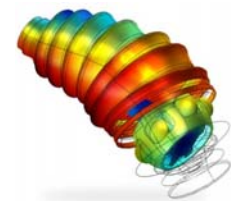
- Founded: 1986 (Stockholm, Sweden)
- Employee: more than 450 people
- Offices: 21+, Agencies: 13
 - USA: Boston (Headquarters/sales office)
 - Sweden: Stockholm (Development center)
 - North America, South America, Europe, and Asia
- Number of users : 120,000+



General agency in Japan: *Keisoku Engineering System Co., Ltd. (KESCO)*

Multiphysics and Single-Physics Simulation Platform

- Mechanical, Fluid, Electrical, and Chemical Simulations
- Multiphysics - Coupled Phenomena
 - Two or more physics phenomena that affect each other with *no limitation* on
 - which combinations
 - how many combinations
- Single Physics
 - One integrated environment – different physics and applications
 - One day you work on Heat Transfer, next day Structural Analysis, then Fluid Flow, and so on
 - Same workflow for any type of modeling
- Enables cross-disciplinary product development and a unified simulation platform



Highly Customizable and Adaptable

- Create your own multiphysics couplings
- Customize material properties and boundary conditions
 - Type in mathematical expressions, combine with look-up tables and function calls
- User-interfaces for differential and algebraic equations
- Parameterize on material properties, boundary conditions, geometric dimensions, and more
- High-Performance Computing (HPC)
 - Multicore & Multiprocessor: Included with any license type
 - Clusters & Cloud: With floating network licenses



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Multiphysics: Multiple Interacting Phenomena

Could be simple:

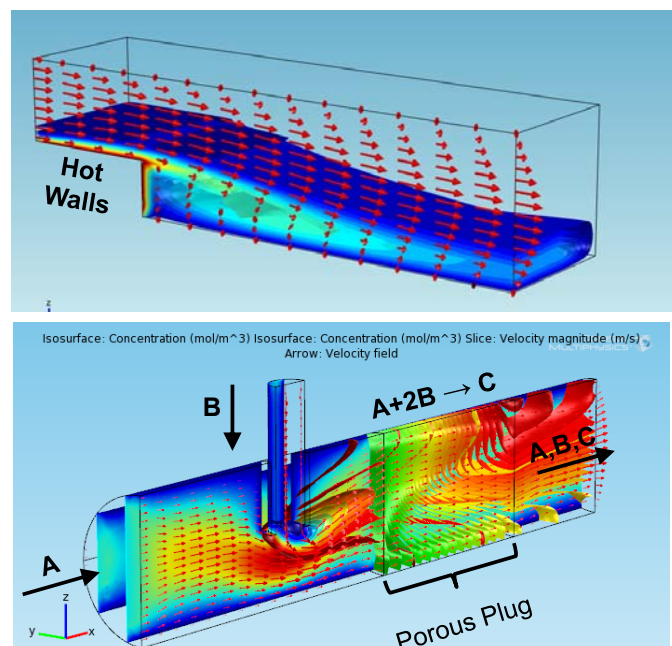
- Heat convected by flow

Could be complex:

- Navier-Stokes in tubes
- Porous flow in plug

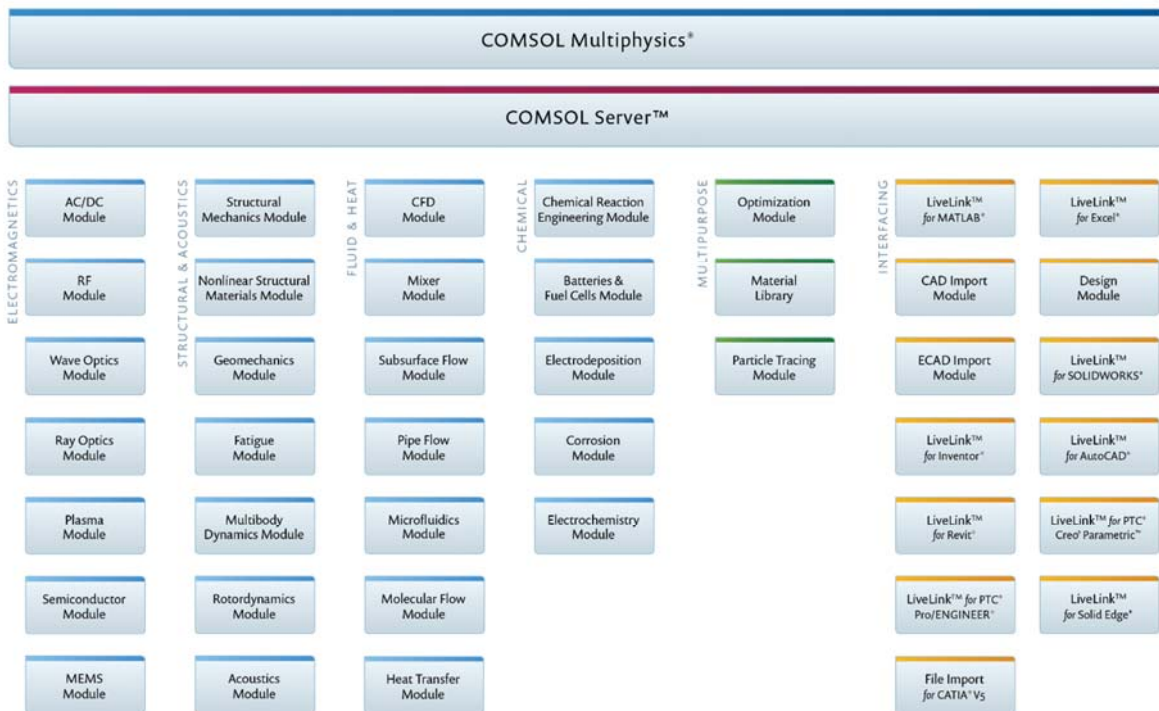
- Mass transport of A,B & C
- Reacting: $A+2B \rightarrow C$

- Reaction is exothermic
- Reaction rate is temperature dependant



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The COMSOL Product Suite



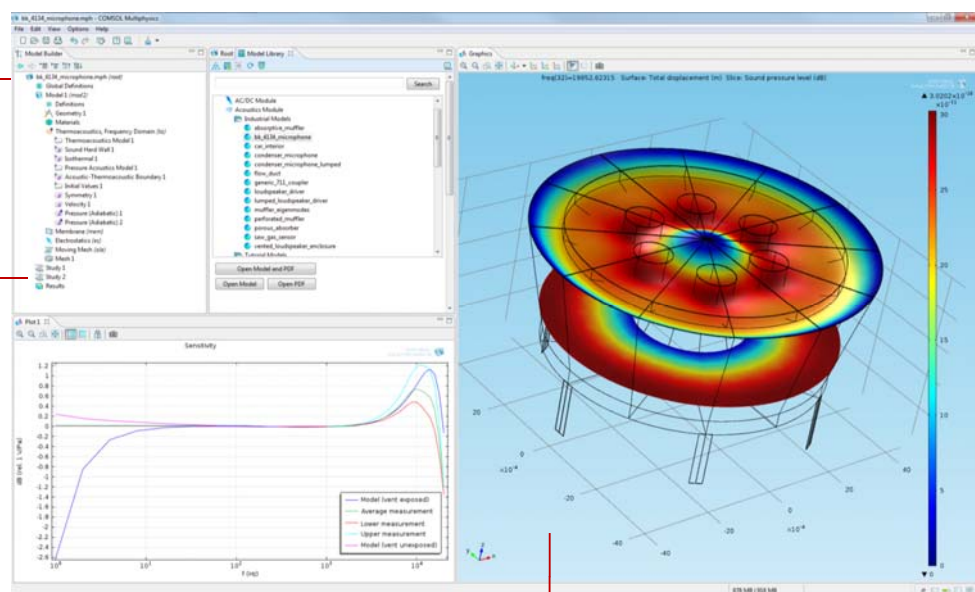
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All Inclusive Interactive Modeling Environment

COMSOL Desktop—
Straightforward to use, it gives full insight and control over the modeling process

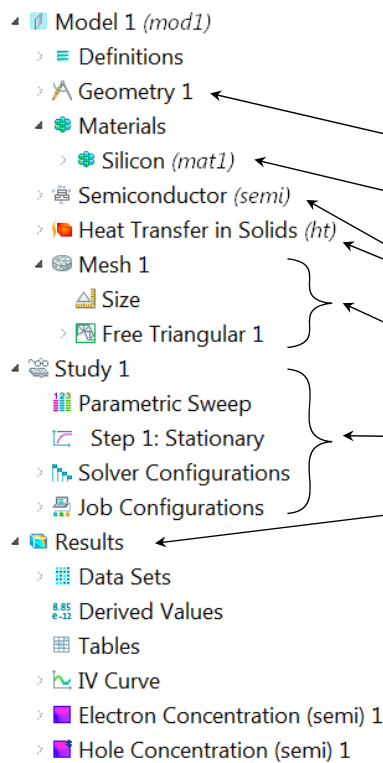
Model Builder
Provides instant access to any part of the model settings

- CAD/Geometry
- Materials
- Physics
- Mesh
- Solve
- Results



Graphics
Ultrafast graphic presentation, stunning visualization, and multiple plots

COMSOL is a Fully Integrated Software Suite



All modeling steps are available from a single unified environment. The model tree (shown on the left) provides quick and easy access to all the settings:

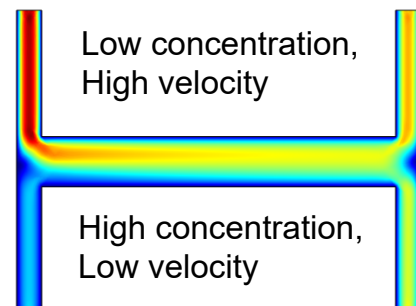
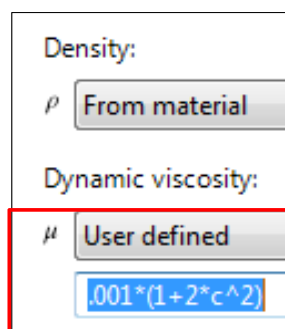
- Geometry setup / CAD /ECAD Import
- User defined and built in material libraries
- Simple and intuitive Multiphysics Problem setup
- Meshing
- Solving
- Visualization + Postprocessing
- Data Import/Export

COMSOL is designed from the bottom up for arbitrary combinations of physical equations and easy user customization

Anywhere you can type a number ... you can type an equation

- Or an interpolation function ...
- And it can depend on anything known in your problem
- Example: Concentration-dependant viscosity:

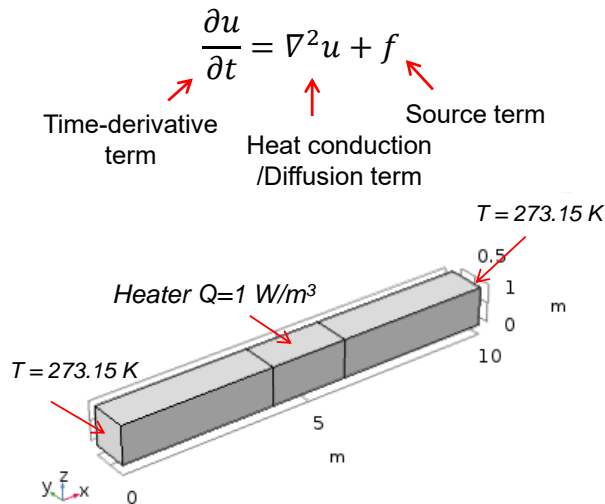
$$\mu = 0.001 \times (1 + 2c^2)$$



PDE-based COMSOL modeling, Demo

■ PDE modeling

Heat-conduction/Diffusion Equation



COMSOL MULTIPHYSICS

Equation

Show equation assuming:

Study 1, Time Dependent

$$e_a \frac{\partial^2 T}{\partial t^2} + d_a \frac{\partial T}{\partial t} + \nabla \cdot (-c \nabla T - \alpha T + \gamma) + \beta \cdot \nabla T + a T = f$$

$$\nabla = \left[\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z} \right]$$


$$\begin{aligned} e_a &= 0 & \gamma &= 0 \\ d_a &= 1 & \beta &= 0 \\ c &= 1 & a &= 0 \\ \alpha &= 0 & f &= 1 \end{aligned}$$

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PDE-based COMSOL modeling, Demo

Select Physics

Search

- AC/DC
- Acoustics
- Chemical Species Transport
- Electrochemistry
- Fluid Flow
- Heat Transfer
- Optics
- Plasma
- Radio Frequency
- Semiconductor
- Structural Mechanics
- Mathematics
 - PDE Interfaces
 - Coefficient Form PDE (c)
 - General Form PDE (g)
 - Wave Form PDE (wahw)
 - Weak Form PDE (w)
 - PDE, Boundary Elements (pdebe)
 - Lower Dimensions
 - ODE and DAE Interfaces
 - Optimization and Sensitivity

Add

Added physics interfaces:

- Coefficient Form PDE (c)

Review Physics Interface

Coefficient Form PDE (c)

Dependent Variables

Field name:

T

Number of dependent variables:

1

Dependent variables:

T

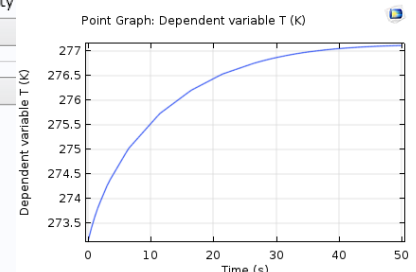
Units

Dependent variable quantity

Temperature (K)

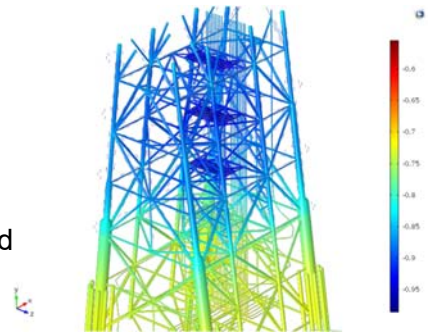
Source term quantity

Heat source (W/m³)



General News in Version 5.3

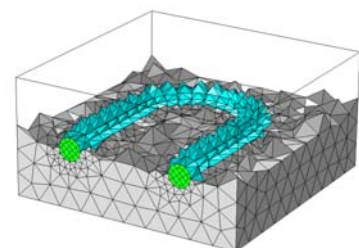
- Performance improvements
 - For handling of large models
 - Faster load and save of model MPH files
- Electromagnetics and corrosion
 - Boundary element method for electrostatics and corrosion
- Structural Mechanics
 - Easier modeling with automatic constraints of rigid body motions
- Fluid Flow and Heat Transfer
 - New user friendly and efficient CFD solver
- COMSOL Server™
 - Administrator cluster settings and log file for application usage
- Model Builder
 - Model methods for automating modeling tasks in the Model Builder
- Application Builder
 - Interactive graphics objects



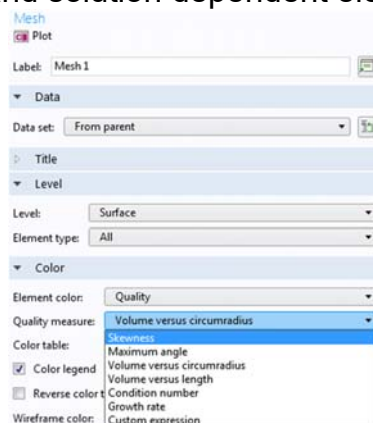
The electrochemical potential on an offshore jacket structure submerged in seawater, calculated with the boundary element method.

Meshing

- Performance improvements
- Automatically combine swept and tet meshes
 - Pyramidal element transitions between hex, prism, and tet meshes
- New mesh quality measures
- Coordinate and solution dependent element size expressions



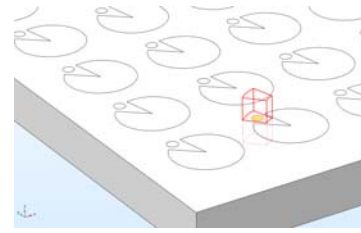
Pyramidal elements in the transition layer between a hexahedral and tetrahedral mesh.



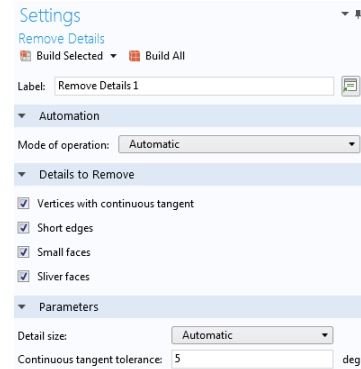
Different mesh quality measures lets you assess the quality of the mesh before solving. Better quality measures can often give faster convergence. Different mesh quality measures are suitable for different types of physics

Geometry

- Performance improvements for geometry operations
- Undo/redo for geometry operations
- New option for automatic removal of geometric details
 - You can edit the automatically generated sequence of virtual geometry operations
- Associative line segments between geometry vertices
- Cylinder selections extended with sector angles and minor/major radii
- Use coordinate systems defined by work planes in primitives
 - Block, array, copy, mirror etc.
- New types of Coordinate Systems: Combined and From Geometry
 - Use for material definitions in physics
- Geometry part variants
- Extrude in both directions and extrude to vertex



Cylinder selections with sector angle and radii makes it easier to create selections of individual objects that are arranged in arrays.

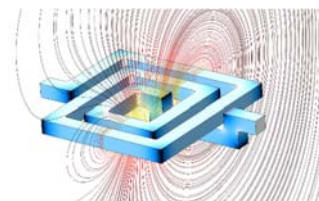


Optional automatic removal of geometry details before meshing.

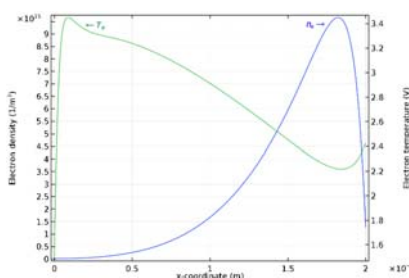
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Visualization & Results

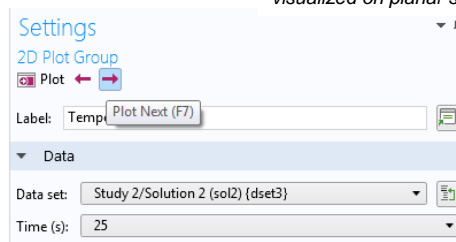
- Dual y-axes
 - Plot two different quantities simultaneously on the y-axes
- Quick selection filters for plots
 - Right-click to add a Selection node and select which parts should be included
- Streamline and fluxline plots on 3D planar surfaces
- Step between different solutions with toolbar buttons
- Geometry length units in the graphics window
- Units for color legends



Magnetic flux lines can now be visualized on planar sections.



A new feature allows for two different quantities to be represented simultaneously on the y axes.



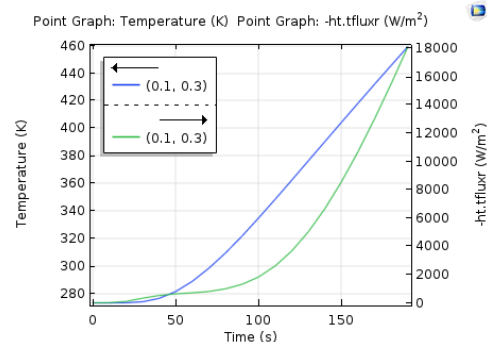
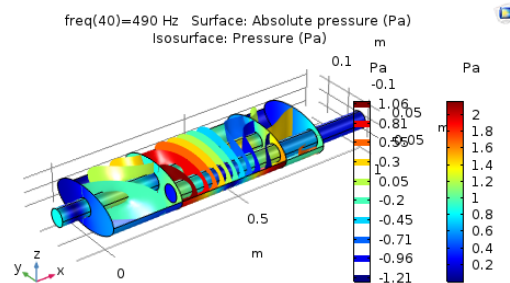
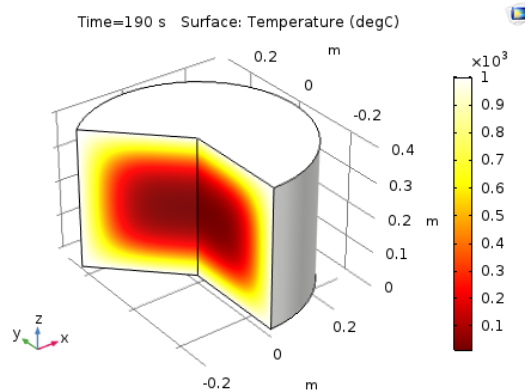
Step between different solutions with toolbar buttons.

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Visualization & Results, Demo

- COMSOL Multiphysics>Heat Transfer> heat_transient_axi.mph
acoustics> automotive_muffler.mph

- Dual y-axes
- Step between solutions
- Quick selection filters for plots
- Units in the graphics window
 - ✓ Length units, and physics units in legend

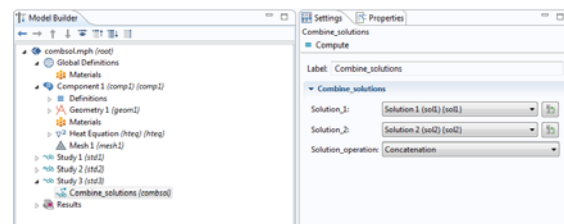


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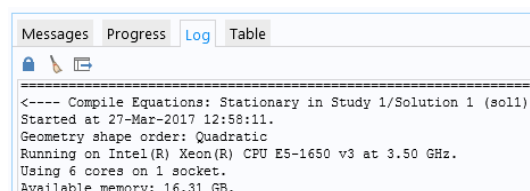
Physics and Modeling News in Version 5.3

Studies and Modeling Tools

- Direct and iterative solver suggestions
- New algebraic multigrid (AMG) solver for fluid flow
- Combining solutions
 - Example: concatenation of two time dependent solutions
- Adaptive meshing integrated with mesh sequences
- More detailed solver log
 - Contact problems, rotating machinery, transport problems, FSI
- The projection coupling operators now support all element types



The Combine Solutions feature allows for combining two time-dependent solutions into one for easier postprocessing.

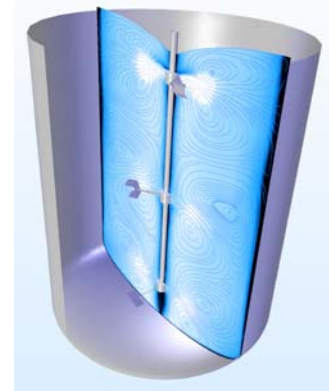


System (hardware) information in the solver log.

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Fluid Flow

- New algebraic multigrid (AMG) solver
 - The new default solver for fluid flow and transport
 - Robust alternative that minimizes user interaction
 - Works also on imported meshes
- V2-f turbulence model
 - Useful for flow inside turbines and cyclones
 - Covers cases where the turbulent behavior has strong directional dependence
- New automatic wall treatment for turbulent flow
 - Automatically blends low-Reynolds treatment and wall functions
- Automatically generate new turbulent flow interfaces from existing interfaces
 - Makes it easy to “upgrade” or “downgrade” the fidelity of your flow models
- Streamlines on planar cross-sections in 3D

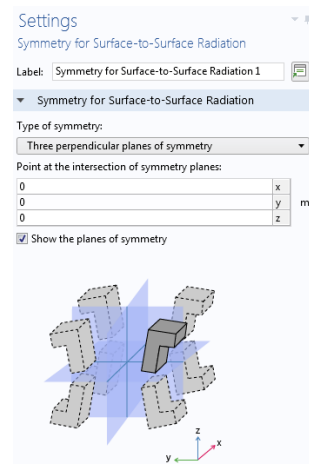


Streamlines can now be visualized on planar sections.

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Heat Transfer

- Heat and Moisture Transport in Air
 - Turbulent mixing by eddy diffusivity in turbulent moisture convection
 - Evaporation and condensation on boundaries
 - Combines with heat and moisture transport in building materials
- Diffuse and direct solar radiation for surface-to-surface radiation
 - Contribution from solar radiation scattered by the atmosphere
- Part library for heat sinks
- Building material library with 12 common material types
- Symmetry planes for radiation
 - Visualization of planes
 - Three perpendicular symmetry planes
- Heat transfer perturbation analysis in the frequency domain
- More efficient serendipity elements for heat transfer

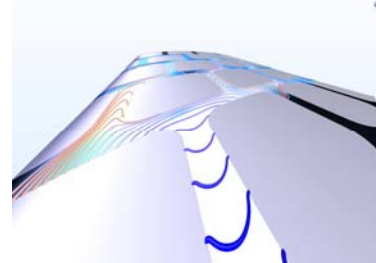


Symmetry planes for surface-to-surface radiation.

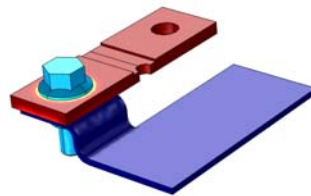
- Building
 - Cellular concrete
 - Wood (pine)
 - Gypsum board
 - Glass wool board
 - Cellulose board
 - Glass wool batt
 - Cellulose batt
 - Cellulose (loose)
 - Lime silica brick
 - Plastic coated paper
 - Expanded polystyrene board (EPS)
 - Extruded polystyrene board (XPS)

Chemical and Electrochemical

- New interfaces
 - Reacting Flow in Porous Media
 - Transport in Porous Media with Fractures
 - Electrophoretic Transport
 - Current Distribution, Shell
 - Current Distribution, Boundary Elements
- New modeling tools for
 - Ion-exchange membranes
 - Charge transport models for tertiary currents
 - Thin electrode and electrolyte layers
 - Charge-discharge cycling for electrochemical cells



Transport of diluted species in fractures.

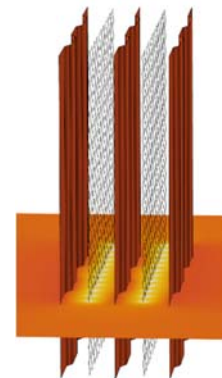


A corrosion simulation visualizing the potential distribution on mechanical parts.

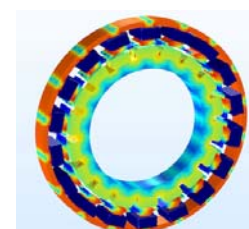
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AC/DC

- Electrostatics with the boundary element method (BEM)
 - Advantages:
 - Easy modeling of infinite domains
 - Allows for combinations of wires/beams, surfaces, and solids in the same model
 - Only a surface mesh is required
 - Can easily be combined with the previous finite-element based electrostatics interface via a standard multiphysics coupling
 - New user interface concept for “unmeshed domains”: voids and infinite void
- New study type Source Sweep
 - For accelerated port sweeps
- New permanent magnet motor example model



The electric potential around wire electrodes and ground plates in an electrostatic precipitation filter solved with the boundary element method.

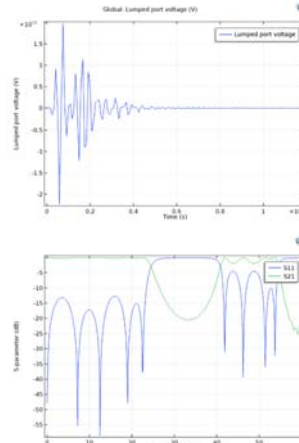


New permanent magnet motor example model.

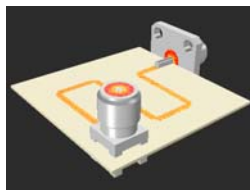
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RF and Optics

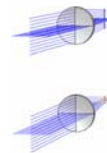
- S-parameters from transient simulations
 - Equivalent surface current magnetic density
 - Gives easier model setup for electric dipoles
- RF component part library
 - 36 Rectangular waveguides
 - 22 Surface mount device footprint
 - 3 SMA connectors
- Ray termination
- Photometric data import for Ray Optics
- Part variants for all lenses in the Part Library



S-parameters from a transient simulation.



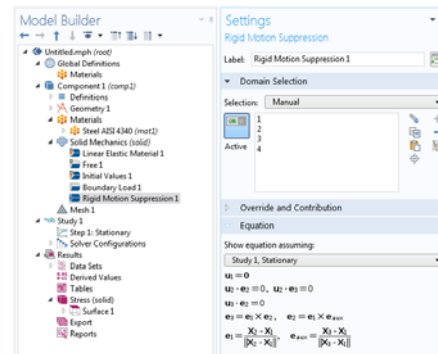
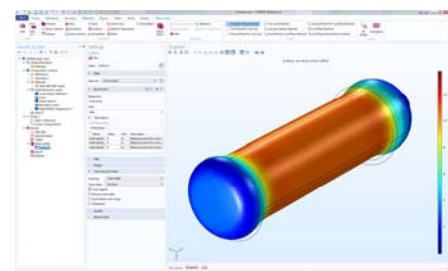
RF component part library



Intensity-based ray termination

Structural Mechanics

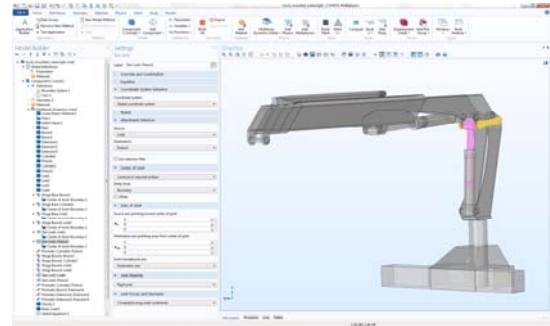
- Results variables for safety factor post-processing
 - Safety factor, margin of safety, damage index, and failure index
- Rigid Motion Suppression for static models with “self-balancing” loads
 - Also available without a Structural Mechanics Module license
- Frequency shifts caused by thermal expansion
- Stress linearization for pressure vessels
 - Compute membrane, bending, and peak stresses in thin solids
- Frequency-response analysis on prestressed models with structural contact
- Mode analysis
 - Non-destructive evaluation and acoustic-structural evaluation
- Additional modeling tools for bolts



The new Rigid Motion Suppression functionality.

Structural Mechanics Module Add-Ons

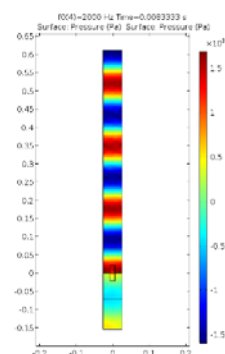
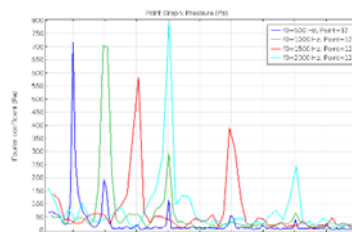
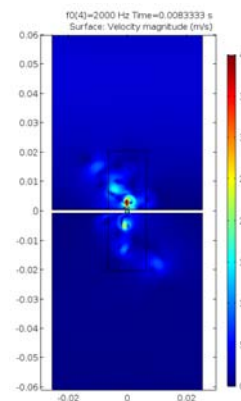
- Nonlinear Structural Materials Module
 - Hyperelastic materials with
 - ✓ Anisotropic thermal expansion
 - ✓ Anisotropic hygroscopic swelling
 - Chaboche and Perzyna viscoplasticity
 - Porous plasticity modeling of metal powders
- Fatigue Module
 - Fatigue on frequency-response results
- Multibody Dynamics Module
 - Joint highlighting
- Rotordynamics Module
 - Inlet and outlet for hydrodynamic bearings
 - Rotor Bearing System Simulator app



Highlighting of joints in the Multibody Dynamics Module.

Acoustics

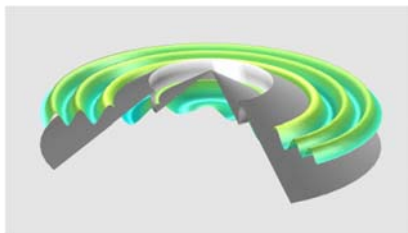
- Predefined iterative solver options
- Automatic calculation of beam width with far field plots
- Discontinuous Galerkin method updates
 - Axially symmetric Convected Wave Equation interface
 - Solver performance improvements
 - Enabled for cluster computations
- Perfectly matched layers (PMLs) for pressure acoustics in the time-domain (finite element formulation)
- Transient thermoviscous acoustics
- New tutorials
- And more



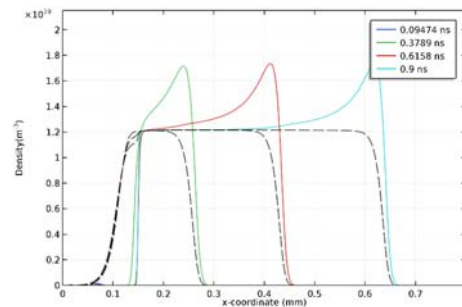
Sound generation from vortex shedding.

Plasma and Semiconductor

- Plasma Module
 - Global modeling is available in the Plasma interface
 - Makes it easier to debug complex chemistries
 - Local field approximation
 - Simplified form of the energy equation which is more stable at high pressures
 - Automatic Calculation of Electron Mobility
- Schrodinger Equation interface in the Semiconductor Module



Decay of a quasi bound state in a quantum wire.

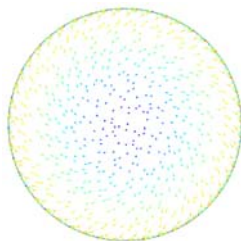


Plasma simulation using the new global modeling approach.

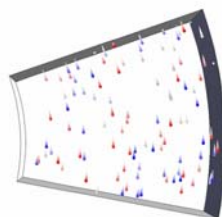
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Particle Tracing

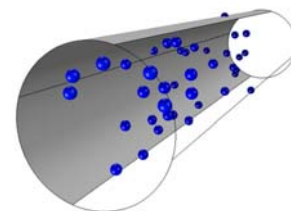
- Periodic boundary conditions
- Rotating frames
- Random initial positions
- Tutorial for wall induced lift force and inertial focusing



Rotating frames.



Periodic conditions.

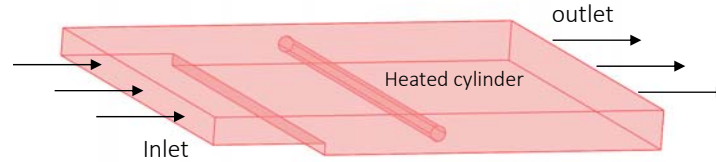


Random release.

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Thermal Decomposition, Demo

■ Simulation of Thermal Decomposition



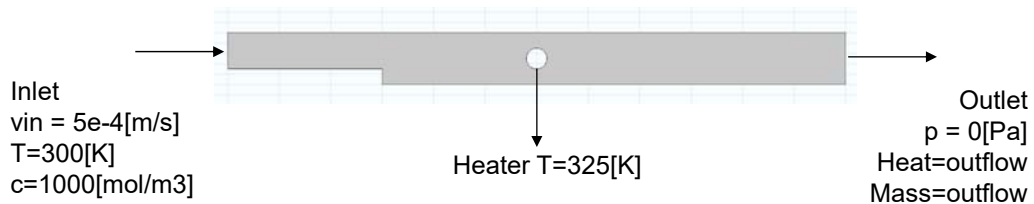
• Coupled transport of heat, mass and momentum

- Fluid heated by cylinder, fluid properties depends on temperature
 - Transport of chemical species and heat, depends on fluid flow
 - Decomposition rate of a chemical species, depends on temperature and conc. Product is a non reacting solid.
 - Exothermic chemical reaction, heat source depending on concentration
- Shows the Chemistry interface
 - How to plug in the Chemistry feature in other interfaces.
 - Shows staged coupling by Multiphysics node
 - Simple->Complex coupling
 - Couples momentum, heat and chemistry in an exothermic temperature dependent reaction.

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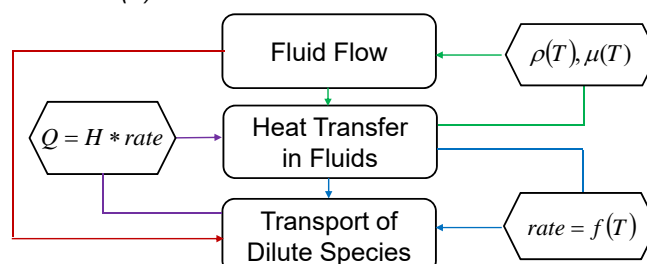
Thermal Decomposition, Demo

■ Simulation of Thermal Decomposition



Reaction Kinetics (Exothermic)

Rate of energy expelled = $H \cdot \text{rate}$
 (where H is the heat of reaction (100 kJ/mol))
 $\text{rate} = k \cdot cA$
 $k = f(T)$



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Online News in Version 5.3

- Release highlight page

<https://www.comsol.com/release/5.3>

- Blog on new app

<https://www.comsol.com/blogs>

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Thank you for your attention !



Questions & Comments ?

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