SIEMENS
Ingenuity for life

Siemens Digital Industries Software

Simcenter 3D for composites simulation

Enhancing the development of robust, lightweight structures

Solution benefits

- Achieve weight reduction targets while providing safe and durable structures

- Capture and identify the behavior of composite components, reducing overdesign

- Control and reduce development costs of composite structures

- Mitigate risk by controlling processes up front with a collaborative workbench

- Simulate manufacturing process phenomena for designing as manufactured

- Consider manufacturing defects at the early stage of your design process like the springback after a curing cycle

Simcenter™ 3D software from Siemens Digital Industries Software provides a complete set of features and digital workflows that allow you to predict classical first-ply failure, stress, thermal and thermomechanical co-simulation, including manufacturing simulation with curing. This solution can support design with continuous fiber like unidirectional ply, sandwich, woven type of material and with fiber reinforced plastic.

Scalable solution for composites simulation

Simcenter 3D supports native composite material as well as other types of advanced materials like lattice structure or plastic material. It provides an efficient workbench for composites with a large set of tools to extract mid plane or modify the geometry on the fly. Simcenter 3D allows you to manage large assemblies with label management, including defining the dedicated physical properties of composite or fiber reinforced plastic materials.

siemens.com/simcenter3d

Simcenter 3D for composites simulation

Powerful modeling tools

Simcenter 3D Laminate Composites software is a modular simulation toolset for laminate composite structures (continuous fiber). Easy-to-use ply and laminate definition tools enable you to quickly create finite element (FE) models in 2D and 3D representing your design, and helps you optimize and validate composite structures using your preferred solver. There is also a complete set of features to validate your draping simulation.

The environment provides capabilities to model highly nonlinear effects like progressive damage with dedicated meshing method for cohesive element generation.

Reduce laminate model creation time

Simcenter 3D Laminate Composites allows you to reduce laminate model creation time by choosing between zone-based modeling, ply-based modeling or a mixture of both approaches. Draping data like fiber orientation and material definition can also be imported form specific composite design tools. For instance, it's possible to use the Fibersim™ portfolio, which is bi-directional, for ply exchange to communicate with composites designers. Plies can be imported directly from a Simcenter 3D .prt file, or via an HDF5 file. You can also exchange zone and laminate definitions via the zone interfaces.

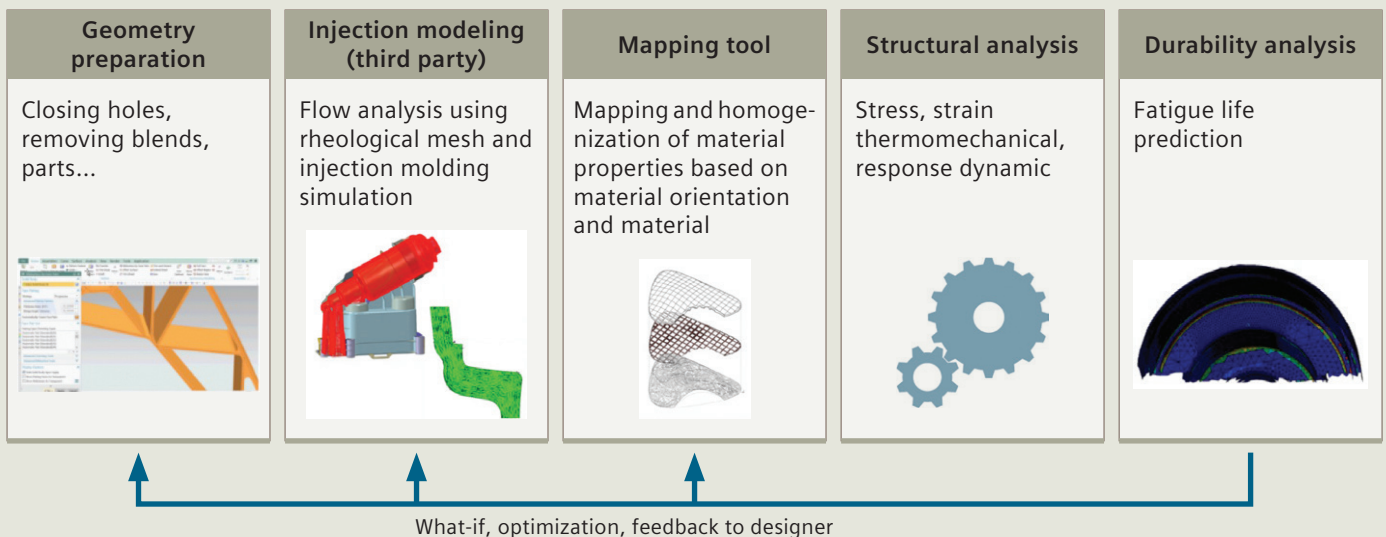## Improve composite modeling accuracy

Simcenter 3D Laminate Composites draping algorithms can be used to predict the fiber orientations and shear of unidirectional and woven plies as they drape around doubly curved or undevelopable surfaces. Simcenter 3D enables you to specify a draping start point and direction, or to pick a seed curve. You can then coarsen or refine the drape mesh size and view the ply flat pattern.

Simcenter 3D for composites extends the boundaries of the classic FEA method so you can study the structural and highly nonlinear behavior of composite materials, but also complex phenomena like curing of thermosets. Composites simulation can also be performed using the multidisciplinary capabilities of Simcenter 3D like motion, thermal and durability.

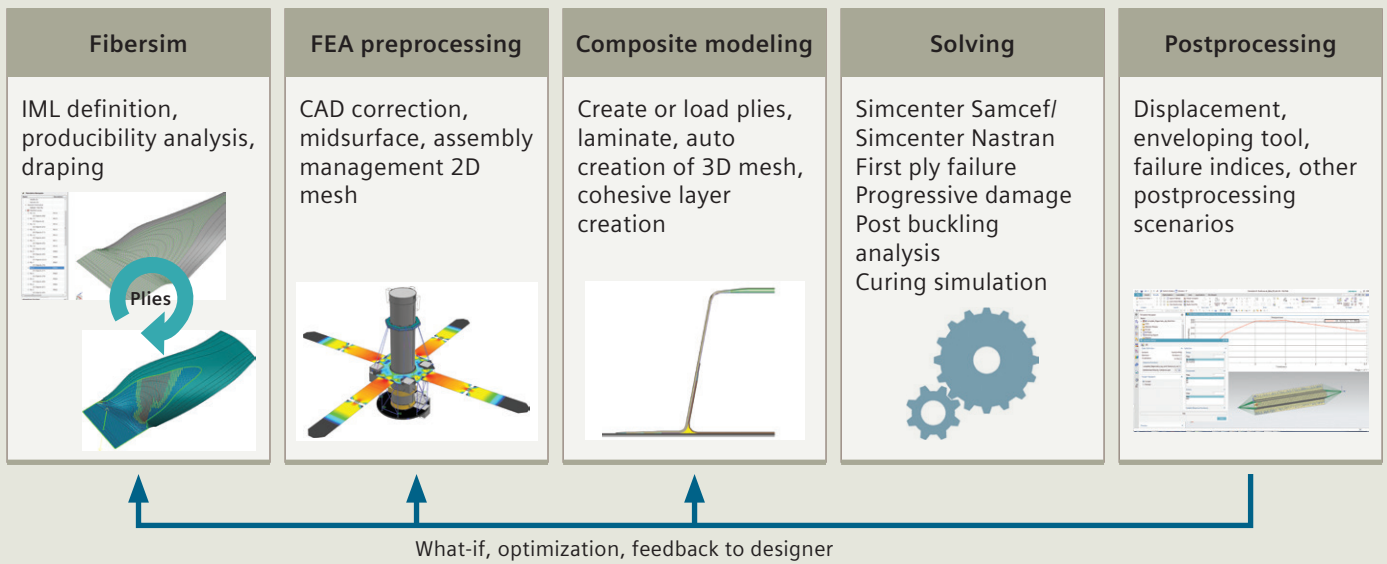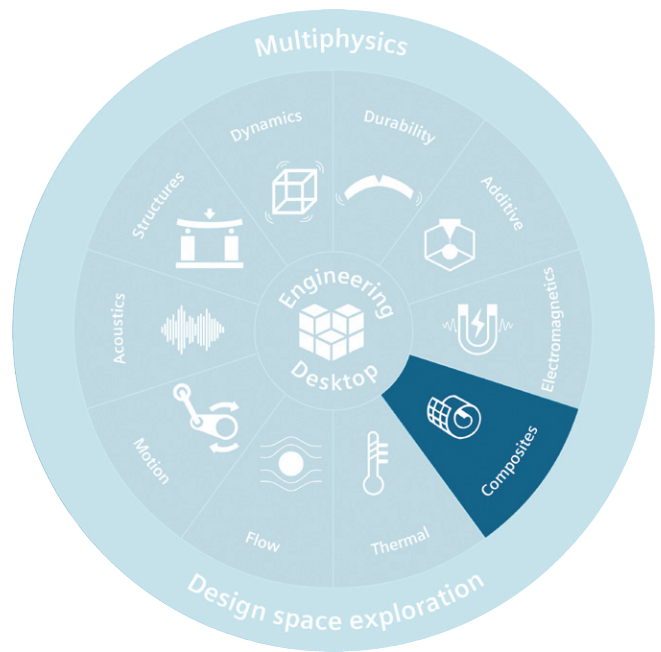## Efficiently create 3D layup inflation

The Simcenter 3D Laminate Composites 3D inflation tool enables you to automatically create detailed, solid laminate models that were previously too tedious to attempt.

You can extrude normal to a 2D mesh or by filling the volume between 2D dependent meshes. You can taper core or filler plies. A dedicated sandwich panel capability allows the automatic generation of 2D or 3D facesheet plies along with a user-defined number of solid element layers for the core. Cohesive elements can be introduced between selected plies by using Simcenter Samcef® software for assessing delamination.

Geometry preparation	Injection modeling (third party)	Mapping tool	Structural analysis	Durability analysis
Closing holes, removing blends, parts...	Flow analysis using rheological mesh and injection molding simulation	Mapping and homogenization of material properties based on material orientation and material	Stress, strain thermomechanical, response dynamic	Fatigue life prediction

What-if, optimization, feedback to designer

Providing a platform for multidiscipline simulation

The Simcenter 3D composites solution is part of a larger, integrated multidiscipline simulation environment with the Simcenter 3D Engineering Desktop at the core for centralized pre-/postprocessing for all Simcenter 3D solutions. This integrated environment helps you to achieve faster computer-aided engineering (CAE) processes and streamline multidiscipline simulations such as motion analysis and/or the noise, vibration and harshness (NVH) analysis of composites components. You can also validate your composite structure fatigue life using Simcenter 3D durability modules and validate your FE model with test results using correlation and model updating tools.

Fibersim	FEA preprocessing	Composite modeling	Solving	Postprocessing
IML definition, producibility analysis, draping	CAD correction, midsurface, assembly management 2D mesh	Create or load plies, laminate, auto creation of 3D mesh, cohesive layer creation	Simcenter Samcef/ Simcenter Nastran First ply failure Progressive damage Post buckling analysis Curing simulation	Displacement, enveloping tool, failure indices, other postprocessing scenarios

What-if, optimization, feedback to designer

Short and long fiber reinforced composites CAE workflow.

Industry applications

Simcenter 3D composite simulation capabilities are used by many industries, although aerospace has always been a driver for this type of application thanks to its never-ending quest for reducing weight. These applications include:

Aerospace and defense

- Composites airplane frame – Stiffness, frame durability, nodal frequency

- Composite wings – Stiffness, skin buckling, modal frequency

- Satellite – Lightweight design

- Launch vehicles – Thermal stress, maneuver loads, payload bracket loads, lightweight design

- Aero engines fans – Rotating loads, distortion, composites

- Aero engines casing – Bearing loads, maneuver loads, lightweight design

- Manufacturing tools – Curing simulation

- Unmanned aerial vehicle (UAV) primary flight structures, tie rods, compression struts, high-altitude telescope structures, cooling tubes, shuttle actuator mounts and turbine fan blades

### Automotive and transportation

- Body – Roof crush, panel strength, stiffness, frame durability, lightweight design

- Chassis – Harshness loads, suspension deflections

- Manufacturing tools – Curing simulation

- Drive shafts, suspension control arms, structural braces, crash structures and seat structures

Marine

- Ships, yacht, sport boats –Stiffness, deformation, strength, lightweight design

- Hulls – Skin rupture

- Bulkheads – Structural strength

- Boat hulls, decks and superstructures

Electronics

- Hand-held equipment made of composites – Drop simulation, plastic component stress

Composites modeling

Linear/nonlinear

Response dynamics

Damage growth

Manufacturing process
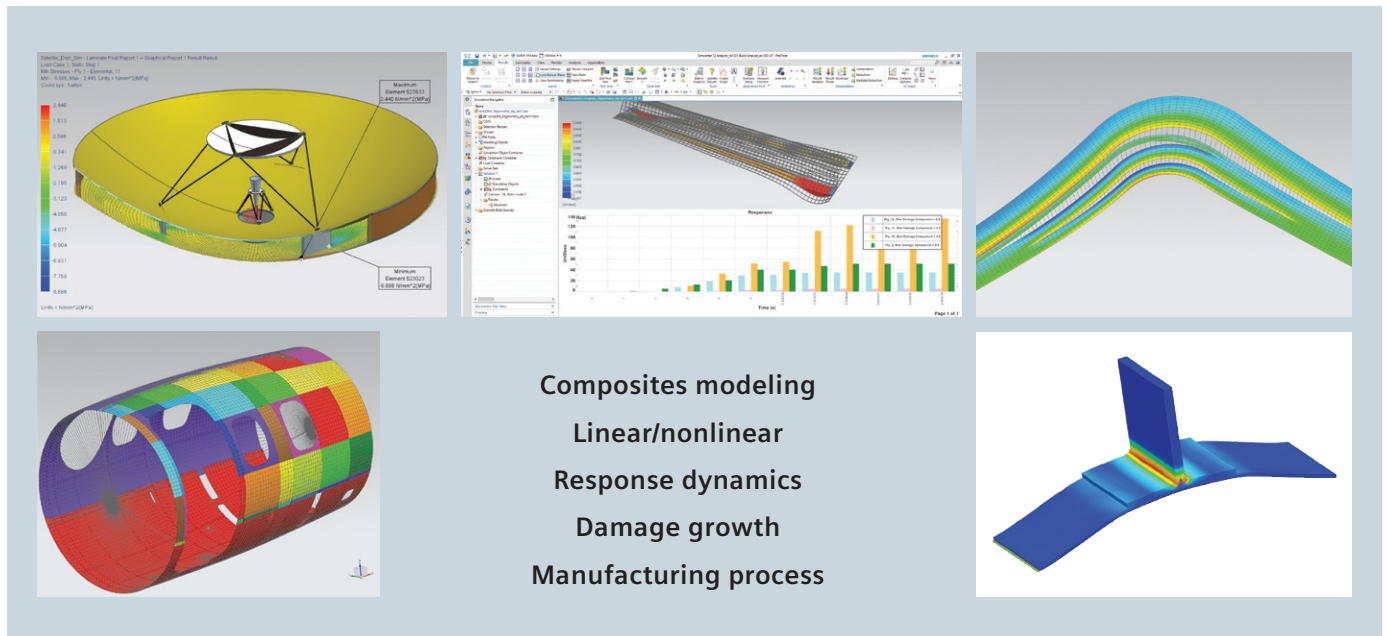
Simcenter 3D Laminate Composites

Easy-to-use ply and laminate definition tools in Simcenter 3D Laminate Composites enable you to quickly create finite element models of structures. Simcenter 3D Laminate Composites helps you create, optimize and validate composite structures using Simcenter Nastran® software, Simcenter Samcef, MSC Nastran, ANSYS, Abaqus or LS-DYNA as your solver. Laminate post reporting generates graphical and spreadsheet ply results from shell stress results and envelopes of ply stresses, strains and failure metrics on elements over multiple load cases.
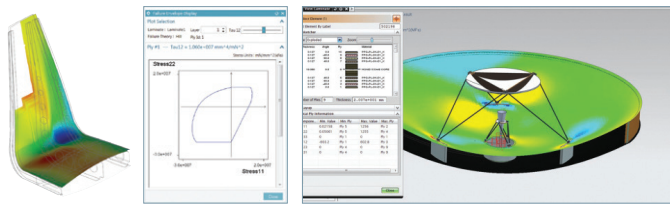
Module benefits

- Reduce laminate model creation time by choosing between zone-based modeling, ply-based modeling or a mixture of both approaches

- Leverage the open solver architecture of Simcenter 3D to perform state-of-the-art dynamic, nonlinear, progressive failure and delamination simulations

Key features

- Keep your model up-to-date with the latest design using geometry associativity

- Interact with computer-aided design (CAD) based composites definitions from Fibersim, CATIA and others

- Use Simcenter standard materials, or create ply materials from the constituent fiber and matrix material properties, to simulate plies made of woven, unidirectional, randomly oriented short fibers and particulates and to represent cores

- Conveniently assign laminates and plies to your choice of geometry, meshes and/or elements

- Improve finite element modeling accuracy by accounting for distorted fiber orientations

- Postprocessing tools allow you to quickly identify critical plies and load cases using classical and user-defined failure theories and create reports

Simcenter Samcef

Simcenter Samcef is used as a solver to simulate components made of composite materials. It facilitates not only classical linear and nonlinear analysis, but can be used to predict defects, including intra- and interlaminate defects, as they grow. This includes delamination and complex scenarios in which both defect types grow together in a fully coupled way.

Curing of thermoset materials induces undesirable deformations that require iterations in the manufacturing process. By combining robust thermal and structural analysis technologies, Simcenter Samcef offers thermal, chemical and mechanical capabilities to predict the residual strain from the curing cycle. This allows you to optimize your process, comparing manufacturing options for the curing cycle and the design, and applying mold compensation techniques to minimize springback effects at demolding. It is then possible to simulate as-built composite component rather than as-designed.

Module benefits

- Achieve weight reduction targets and provide safe, durable structures
- Design as manufactured and for manufacturability
- Capture and identify the behavior of layered composite components, reducing safety concerns
- Identify and optimize unexpected deformation during the curing cycle

Key features

- Static/dynamic/thermal analysis of composite models including material and geometrical nonlinear behaviors
- Comprehensive finite element library for 2D shell or 3D solids, cohesive zone modeling
- Orthotropic, anisotropic, bilinear, accurate progressive damage prediction including intra- and interlaminar damage with coupling of the corresponding damage
- Failure indices, strength ratios, usual finite element outputs
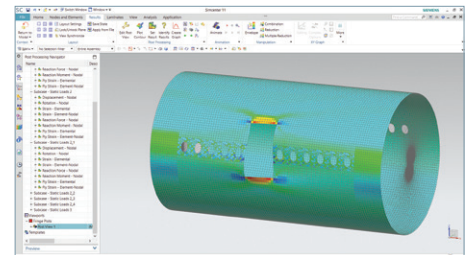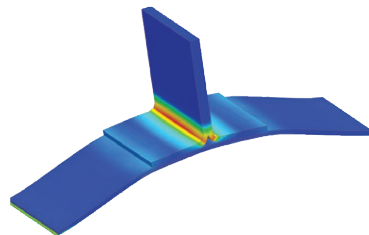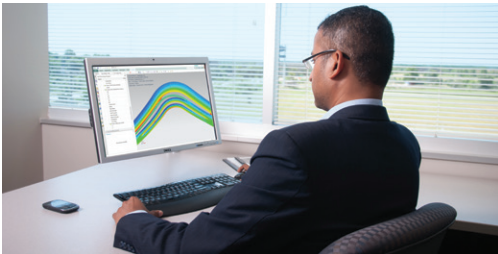
Capabilities chart

General capabilities	Specific capabilities	Simcenter 3D Laminate Composites	Simcenter Samcef solver
Composite types			
Unidirectional ply		•	•
Woven ply		•	•
Sandwich		•	•
Filament winding			○
Fiber reinforced plastic			•
Analysis			
Linear statics with several load cases			•
Modal analysis			•
Buckling analysis (form linear statics analysis) with several load cases			•
Nonlinear static analysis with several subcases	Large displacement effect		•
	Large strain effect		•
Standalone bucking			•
Thermal analysis (steady state or transient)			•
Mapping of temperature field/glass temperature/degree of cure			•
Superelement generation, recovery on superelement			•
Cyclic symmetry recombination			•
Laminate modeling			
Laminate modeling and validation	Ply-based modeling	•	•
	Zone-based modeling	•	•
	2D laminates (layered shell)	•	•
	3D laminates (layered 3D solids) including automatic 3D inflation	•	•
	Automatic generation of cohesive layers	•	•
	Drop off element		•
	Anisotropic behavior of sheared woven plies	•	•
	ABDS matrices and equivalent properties	•	
	Fiber orientation displays	•	
	Ply section displays	•	
	View laminate core sampling	•	

General capabilities	Specific capabilities	Simcenter 3D Laminate Composites	Simcenter Samcef solver
CAD Interfaces	Fibersim	•	
	CATIA/laminate tools	•	
Postprocessing and reporting	Graphical and spreadsheet reporting	•	
	Enveloping by ply and load case	•	•
	Management of post reports and prerequisite solutions	•	
	Classical and user-defined failure theories	•	
	Multiple failure theories in single report	•	•
	Ply failure indices, strength ratios and margins of safety	•	•
	Dynamic base excitation metasolutions	•	
	Harmonic with phase-consistent failure metrics	•	
	Random with confidence-based peak failure metrics	•	
Materials			
Isotropic			•
Temperature dependent			•
Orthotropic			•
Temperature dependent			•
Anisotropic			•
Temperature dependent			•
Hyperelastic	Moony-Rivlin		•
	Arruda- Boyce		○
	Ogden		•
	Foam		•
	Hart-Smith		○
	Alexander		○
	Marlow		○
	Test based		○
	Mullins effect		•
	Viscoelastic effect		○
Nonlinear elastic			•

Siemens Digital Industries Software

General capabilities	Specific capabilities	Simcenter 3D Laminate Composites	Simcenter Samcef solver
Gasket			○
Visco-elastic			●
Plasticity	Temperature dependence		●
	Bilinear		●
	Multilinear		●
	Rupture		●
	Isotropic hardening		●
	Kinematic hardening		●
	Mixed hardening		●
	Cyclic plasticity		
	Strain rate effect		○
Creep	Bailey Norton model		●
	Strain hardening power model		●
	Norton model		○
	Garafolo model		○
	Temperature dependent		●
Visco-plastic			●
User defined			○
Composite			
Shell elements (mono and multilayers)			●
Solid elements (mono and multilayers)			●
Failure indices			●
Strength ratios			●
Cohesive delamination			●
Progressive failure			●
Non-local laws			●
Curing simulation			●
Elements			
3D solids			●
2D solids	Axisymmetric		●
	Plane stress		●
	Plane strain		●
	Generalized plane strain		○
Shell			●
Thickness output			●
Membrane			●
Solid shell			●

General capabilities	Specific capabilities	Simcenter 3D Laminate Composites	Simcenter Samcef solver
Beam			●
Nonlinear effects			●
Springs			●
Nonlinear force displacement			●
Rods			●
Rigid	Large rotation effect		●
	Stiff rigid (RBE2)		●
	Constraint rigid (RBE3)		●
U-P formulations			●
Potential fluid			○
Add/remove			●
Algorithms			
Static solution (implicit)			●
Transient solution (implicit)			●
Thermomechanical co-simulation			○
Modal			●
Complex modal			○
Buckling			●
Multistep			●
Arc length			●
Auto-time stepping			●
Shared memory parallel (SMP)			●
Distributed memory parallel (DMP)			●
Superelements			●
Recovery including stresses			●
Cyclic symmetry modes			●
Multi-stage cyclic symmetry			●
Harmonic modes			○
Restart			●

General capabilities	Specific capabilities	Simcenter 3D Laminate Composites	Simcenter Samcef solver
Connections			
Glue	Sliding glue		•
	Large displacement		•
Bolted joints	1D		•
	2D		•
	3D		•
	Bolt sequencing by steps		•
	Bolt force output		•
Multipoint constraint (MPC)			•
Contact	Coulomb friction		•
	Other friction models		•
	No separation contact		•
	Fluid pressure penetration contact		•
	Temperature dependence		•
	Separation distance output		•
	Slip/slide distance output		•
	Pressure output		•
	Change by steps		o
	Node-to-face contact		•
	Node-to-node contact		•
Kinematic joints			o

General capabilities	Specific capabilities	Simcenter 3D Laminate Composites	Simcenter Samcef solver
Loads and boundary conditions			
Gravity			•
Force/ moment			•
Pressure			•
Distributed force			•
Temperature	3D (spatial variation)		•
	4D (spatial and temporal variation)		•
	Temperature loads from external file		•
Enforced motion			•
Initial stress/strain	Unbalanced		•
	Balanced		
Initial damage for composite			•
Restraints			•
Change by steps			•
Geometry imperfections			•

Legend:
- • = supported in solver and environment
- o = supported in solver but limited in environment

Note: Simcenter 3D Engineering Desktop is a minimum prerequisite for all Simcenter 3D products. Other dependency or prerequisites may apply for individual products.

Siemens Digital Industries Software
plm.automation.siemens.com

Americas   +1 314 264 8499
Europe   +44 (0) 1276 413200
Asia-Pacific +852 2230 3333

Siemens Digital Industries Software