



SIEMENS

Ingenuity for life

Siemens Digital Industries Software

Simcenter 3D for durability simulation

Enabling in-depth fatigue and life analysis

Solution benefits

- Explore multiple design options and optimize your design for strength and fatigue performance
- Perform fatigue life prediction analyses quickly and accurately accounting for realistic loading conditions
- Get insightful and rapid feedback on critical durability areas
- Simulate realistically the durability performance of complex connections and welded joints
- Predict component loads and optimize system level fatigue performance through load-transfer path approach
- Take advantage of the new materials and manufacturing processes using accurate fatigue methods

Simcenter™ 3D software offers a distinctive suite of tools to support fatigue design in all stages of development. This includes easy-to-use wizards for strength and fatigue in the design phase, fatigue information on the current simulated part, detailed analysis of complex load scenarios, including weldments and connections, and new materials and manufacturing processes.

The best way to predict a product's strength and durability

Shorter development cycles and ever-increasing quality requirements have stretched the test-based durability approach to the limits. Evaluating and refining the durability performance by simulation methods is the only valid alternative. The durability modules of Siemens Digital Industries Software's Simcenter 3D give you access to state-of-the-art analysis methods, enabling engineers to interactively assign loads to a model. The solution permits efficient analysis of seam and spot welds as well as new methodologies for composite materials.

Simcenter 3D for durability simulation

Eliminate over- or under-designed components

Analyze loads acting on the critical regions and improve the load flow from the application points that have the greatest influence on the critical areas, which is much better than just reinforcing around the critical area.

Enabling a more efficient and safe physical validation

Virtual test rig experiments facilitate the analysis of the impact of individual load events on component damage. Such analysis also permits the flexibility to define your specific load scenarios for each of the components, thereby saving testing time.

Include manufacturing and assembly aspects in durability analysis

New materials and manufacturing processes often have an important influence on fatigue behavior. With Simcenter 3D, one can take into account such manufacturing defects while performing durability analysis.

Design right the first time

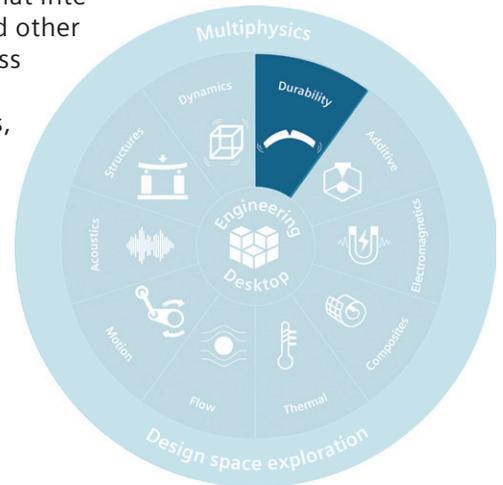
To perform fatigue analysis in an efficient way, durability modules provide access to:

- Test data such as load data, test schedule definitions, etc.

- Simulation data, such as multibody results and finite element simulations of the digital twin
- State-of-the-art fatigue simulation methods
- Fatigue-specific postprocessing

Providing a platform for multidiscipline simulation

The Simcenter 3D durability 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 CAE processes and streamline multidiscipline simulations that integrate durability and other disciplines like stress and strain from structural solutions, load prediction using motion solution and short or long-fiber composites nonlinear behavior prediction up to tight integration for damage tolerant design.



Loads

Measure

Simulate

Create digital twin of test

Stress calculation

Load events Duty cycles

| Case# | CaseName | Order | Order# | Subcase | Subcase# | SubcaseName |
|-------|----------|-------|--------|----------|----------|-------------|
| 1 | Stress-1 | 1 | 1 | Stress-1 | 1 | Stress-1 |
| 2 | Stress-2 | 2 | 2 | Stress-2 | 2 | Stress-2 |
| 3 | Stress-3 | 3 | 3 | Stress-3 | 3 | Stress-3 |
| 4 | Stress-4 | 4 | 4 | Stress-4 | 4 | Stress-4 |

Simulate test

Apply material

Apply methods and parameters with one click

- Stress Life
- Predefined Stress Life
- Preconfigured Stress Life
- Strain Life
- Interlaminar
- Van Paasgegem
- Short Fiber Master SN Curve
- Nominal Stress Seam Weld
- Notch Stress Seam Weld
- Force Based Spot Weld
- Stress Based Spot Weld
- Hy Stress Life

In depth analysis

If and where fatigue occur

Why and when they occur

Industry applications

Aerospace and defense

Simcenter 3D is used to predict mechanical system fatigue life for landing gears, control mechanisms, slat tracks and other critical assemblies. Local stress concentrations are identified based on all possible combinations of local load conditions to address durability problems long before prototypes are built. A wide range of methods can localize weak spots and assess fatigue life.

Automotive and transportation

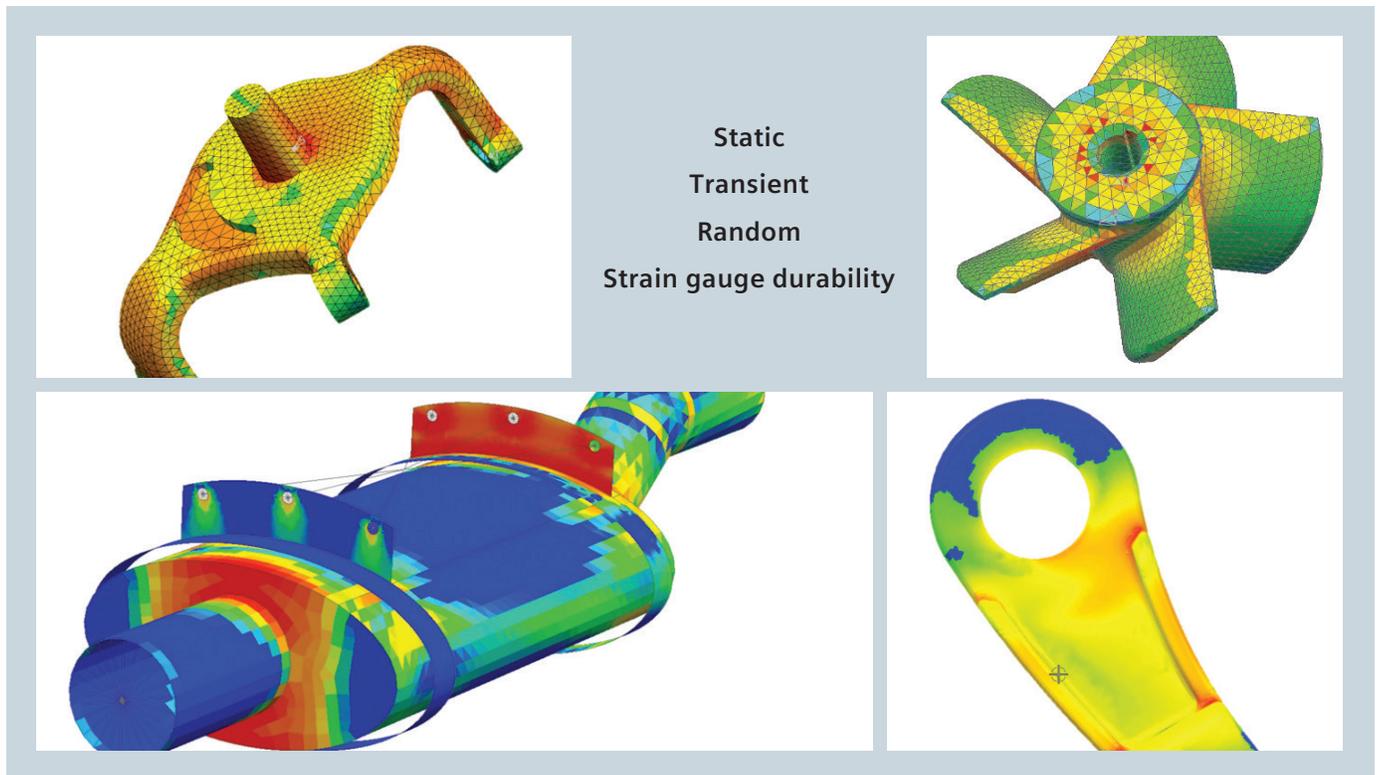
Simcenter 3D is used to execute fatigue-life assessments on body frames, panels, cross-members and door systems as well as on sunroofs, latches and locking systems. The Simcenter 3D Durability module also enables a high degree of accuracy for specific seam and spot weld analyses. Advanced numerical durability predictions can be applied to engines, powertrain parts, engine brackets, gear box chain heels and exhaust lines.

Industrial machinery

In industrial applications, achieving cost efficiencies depends on critical parts that are typically subjected to large dynamic multiaxial load cases. Any metal component subjected to dynamic loading cycles can be efficiently optimized. Simcenter 3D Durability can be used to determine rotor base fatigue life in large rotating machines.

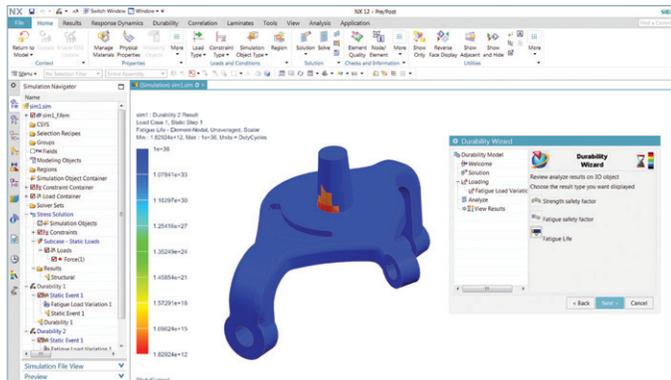
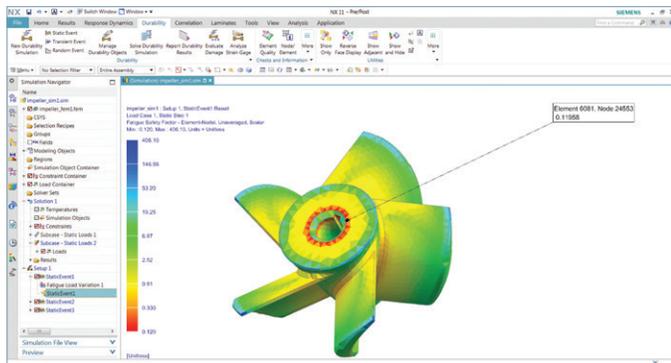
Marine

Simcenter 3D Specialist Durability connection modeling allows you to have a digital twin for kilometers of welds performed in ship structures. For high-end yachts with lots of composite materials, the Simcenter 3D Specialist Durability Composite Fatigue module facilitates state-of-the-art analysis.



Simcenter 3D Durability wizard

Simcenter 3D Durability wizard is a simulation wizard for calculating the fatigue life of mechanical components subjected to cycles of loading. This solution is performed after users have calculated a stress state from static loading using a finite element (FE) solver. The durability algorithms in the wizard are based on the crack initiation method for fatigue analysis.



Module benefits

- Improves robustness by predicting the life of product designs and determining which design features are over- or under designed
- Reduces physical testing costs by allowing you to analyze product life in a virtual environment
- Accelerates product design by allowing designers to quickly perform what-if reanalysis of new designs
- Understand the impact of changes to product durability

Key features

- Use linear stress or strain results in static solutions with NX™ software stress wizard, Simcenter Nastran® software, MSC Nastran, Abaqus and ANSYS
- Define the cyclic loadings that define the duty cycle of the part over its lifetime
- Compute static safety factors, fatigue safety factors and fatigue life
- Available fatigue criterion: Smith-Watson-Topper, strain or stress life
- Display contour plots for strength safety factor, fatigue safety factor or fatigue life
- Prepare a technical durability report

| Worksheet: Durability - Information - Microsoft Excel | | | |
|---|---------------------------------------|--------------------------------------|---------------------------------|
| E10 | A | B | C |
| 1 | Durability 2 | | |
| 2 | | | |
| 3 | Fatigue Load Variations | Number of Cycles | Scaling Factor |
| 4 | Load Variation | | Scaling Function |
| 5 | Fatigue Load Variation 1 | 7000 | 7.000000 Full Unit Cycle |
| 6 | | | |
| 7 | Fatigue Analysis Options | | |
| 8 | Evaluation Type | Options | |
| 9 | Stress Safety Factors | Ultimate | |
| 10 | Fatigue Safety Factors | Von_Mises | |
| 11 | Fatigue Life | Number of Fatigue Duty Cycles: 1e+20 | |
| 12 | | Fatigue Strength Factor: 1 | |
| 13 | | Smith_Watson_Topper | |
| 14 | Results | | |
| 15 | Coordinate System | Absolute Rectangular | |
| 16 | Number of LoadCases: | 1 | |
| 17 | Load Case 1: Number of Iterations = 1 | | |
| 18 | Iteration 1 | Strength Safety Factor(Unitless) | Fatigue Safety Factor(Unitless) |
| 19 | Max | 1.18E+05 | 4.96E+03 |
| 20 | Min | 1.60E+01 | 2.09E-01 |
| 21 | | | Fatigue Life(DutyCycles) |
| 21 | | | 1.00E+16 |
| 21 | | | 1.45E+14 |
| Durability Report | | | |

Simcenter 3D Advanced Durability

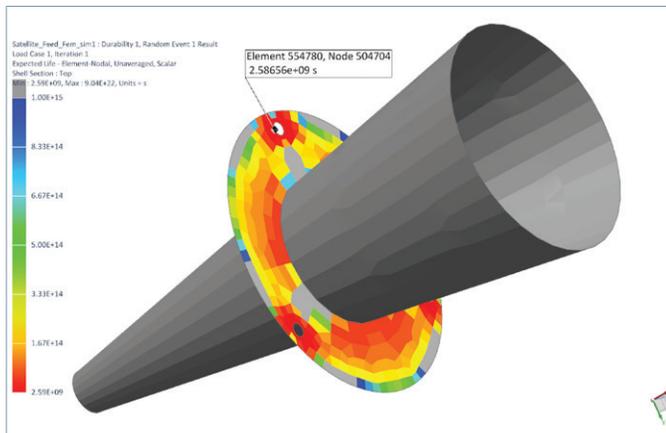
Simcenter 3D Advanced Durability software helps to validate product's structural integrity over its lifecycle under either simple or complex loading conditions. Expert analysts use this solution to perform in-depth fatigue analysis and life calculations to help them determine product durability based on Simcenter Nastran, Simcenter 3D Response Dynamics, MSC Nastran, ANSYS and Abaqus solutions. Based on the crack initiation method for fatigue calculation, the user has a choice of multiple life criteria and can account for mean stress effects, notch effects, hardening effects and biaxial stress effects. Fatigue and strength safety factors, fatigue life and damage results are viewable as contour plots.

Module benefits

- Save time with what-if redesigns
- Improves product design robustness by determining the life of product designs
- Reduces physical testing costs by enabling you to analyze product life in a virtual environment

Key features

- Simcenter 3D integration leverages geometry associativity to quickly evaluate the impact of changing geometrical features on durability
- Industry standard life criteria, stress direction approaches, mean stress effects, notch effects, cyclic stress-strain relations and rainflow cycle counting
- Static, transient (including flexible body) and random events
- Strain gauge durability



Simcenter 3D Specialist Durability Modeling

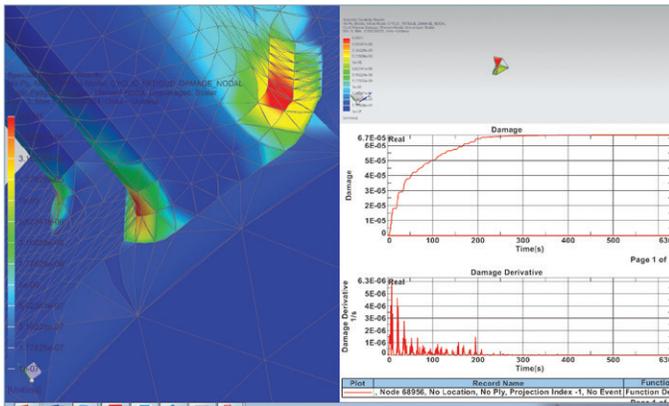
Simcenter 3D Specialist Durability Modeling provides a rich and intuitive tool set to prepare solutions, send them to the solver and postprocess durability results. It enables the setup of complex durability scenarios with many finite element and load history cases. Durability solutions may be configured using the provided parameters or configured to follow the standard procedures of the user.

Module benefits

- Intuitive and flexible parameter-based setup
- Quickly isolate fatigue-critical locations and load cases under complex duty cycles
- Understand the cause of fatigue problems

Key features

- Parameter-driven analysis types, solver profiles and durability simulation objects
- Direct component-load importing from prototype measurements or Simcenter 3D multibody simulation and third-party, time-data formats
- Integration with Simcenter Testlab™ software load-data processing tools for durability load-case selection
- Assign complex duty cycles to assemblies and their connections, including seam and spot welds
- Dedicated 2D and 3D postprocessing scenarios



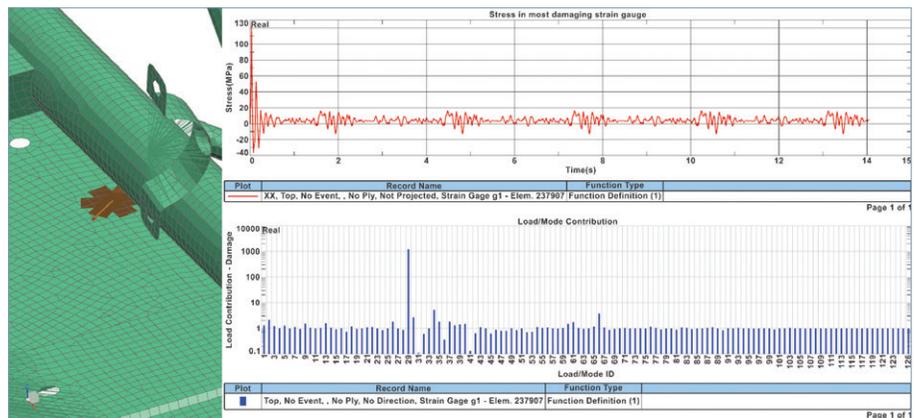
Load Events

- Block Load Event
- Superposition Event
- Transient Event
- Duty Cycle
- Flexible Body Event
- Manage Events

Specialist Solution

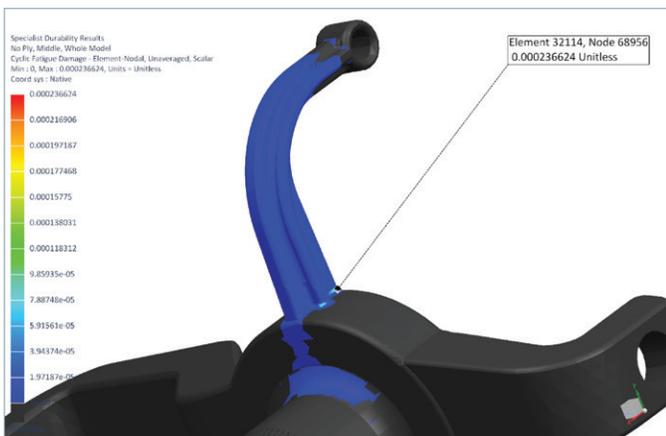
- Durability Solution
- Local Definition
- Function Definition
- Simulation Objects
- Strain Gage
- Solve Model
- Check
- More

| Index | Load History | Data Source | Subcase |
|-------|--------------|-------------|--|
| 1 | WHEEL@+X | MBS_Forces | 1 DURABILITY KNUCKLE CONTROL ARM STEER+X |
| 2 | WHEEL@+Y | MBS_Forces | 2 DURABILITY KNUCKLE CONTROL ARM STEER+Y |
| 3 | WHEEL@+Z | MBS_Forces | 3 DURABILITY KNUCKLE CONTROL ARM STEER+Z |
| 4 | WHEEL@+RX | MBS_Forces | 4 DURABILITY KNUCKLE CONTROL ARM ICA+X |
| 5 | WHEEL@+RY | MBS_Forces | 5 DURABILITY KNUCKLE CONTROL ARM ICA+Y |
| 6 | UCA@+X | MBS_Forces | 6 DURABILITY KNUCKLE CONTROL ARM ICA+Z |
| 7 | UCA@+Y | MBS_Forces | 7 DURABILITY KNUCKLE CONTROL ARM UCA+X |
| 8 | UCA@+Z | MBS_Forces | 8 DURABILITY KNUCKLE CONTROL ARM UCA+Y |
| 9 | STEER@+X | MBS_Forces | 9 DURABILITY KNUCKLE CONTROL ARM UCA+Z |
| 10 | STEER@+Y | MBS_Forces | |



Simcenter 3D Specialist Durability solver

Using Simcenter 3D Specialist Durability solver is the basic solver for specialist fatigue analysis. It may be run on the same computer or independently in batch mode. It provides all standard durability methodologies but may easily be extended with any fatigue methodology due to unique openness via user-defined fatigue methods.

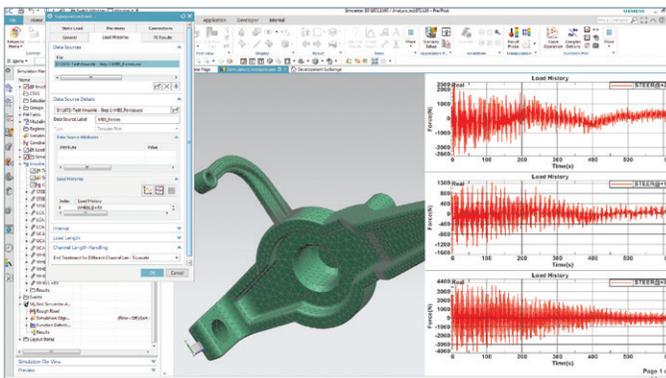


Module benefits

- Reduce fatigue analysis time
- Quick and accurate fatigue-life predictions based on realistic loading conditions
- Explore multiple design options and optimize the design for fatigue performance

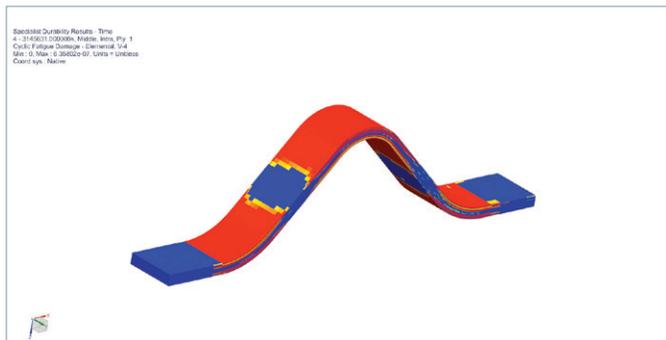
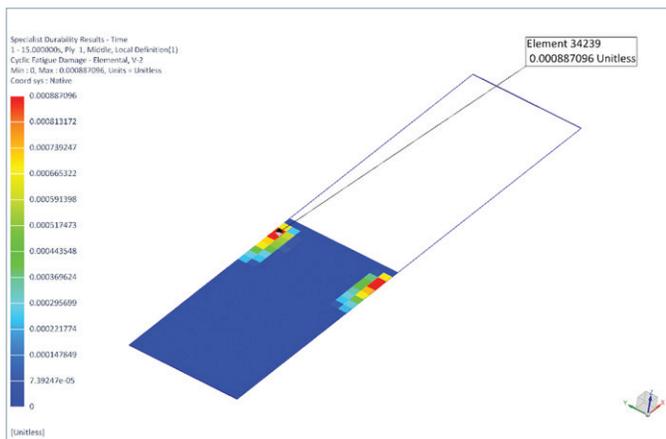
Key features

- Industry standard fatigue-life solver with proven accuracy and speed
- Parallel processing enabled with the standard license
- All industry standard methods
- New and unique user defined methods interface
- Batch processing



Simcenter 3D Specialist Durability Composite Fatigue

Simcenter 3D Specialist Durability Composite Fatigue provides a unique methodology for analyzing short and continuous-fiber composites. It can incorporate stiffness reduction and stress redistribution during the fatigue life of composites under complex load situations. New technologies reduce the effort it takes to test for parametrization of the methods.



Module benefits

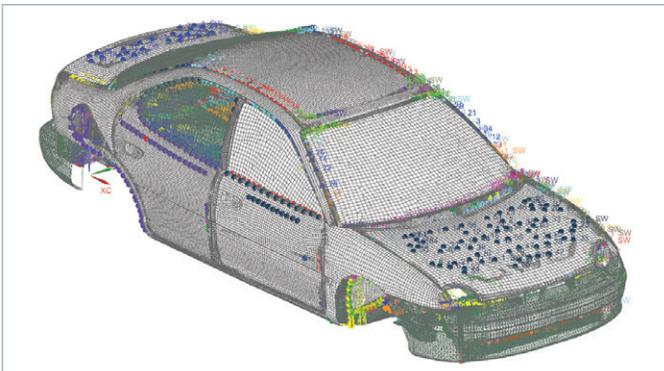
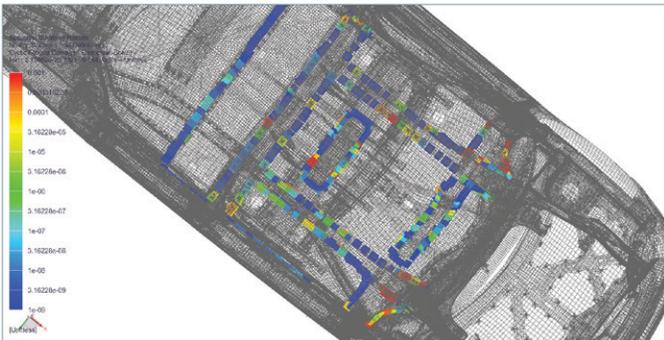
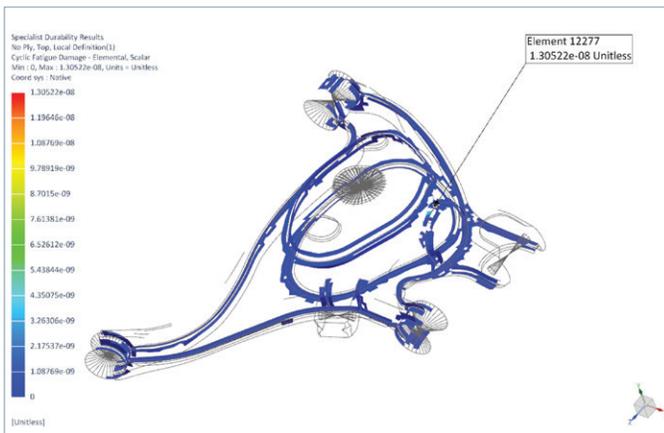
- Know the real progressive damage behavior of your composite material
- Allows damage-tolerant design
- Ability to predict fatigue damage to composite material
- Defined parameter identification processes available

Key features

- Unique workflow that enables stiffness reduction and stress redistribution
- Variable amplitude and multiaxial loads
- Ply-based fatigue behavior modeled with no tests on full stacking needed
- Master SN-curve approach for arbitrary short-fiber orientations
- Intra- and Interlaminar methods for continuous-fiber composites
- Integrated with continuous damage models and analysis with Simcenter Samcef® software solvers
- User-defined methods, including stiffness reduction and stress redistribution

Simcenter 3D Specialist Durability for Connections

Simcenter 3D Specialist Durability for connections allows you to set up and conduct special spot weld and seam weld analysis runs. Welds are taken from connections modeled in Simcenter 3D, defined in the xMCF format, or detected in existing meshes. The load setup and analysis are conducted with the same tools from Simcenter 3D Specialist Durability Modeling and may even be mixed in one analysis case.



Module benefits

- Comprehensive software to predict fatigue of seam and spot welds under arbitrary loading conditions
- Provides most accurate prediction of seam welds fatigue life without remodeling
- Increases engineers' throughput by enabling automatic detection of weld topologies
- Powerful software to handle welded assemblies irrespective of size and number of welds
- Efficiently handles both traditional approaches and most accurate approaches on the same model
- Validate more weld variants and its fatigue life within shorter development cycles
- Understand and improve fatigue testing for seam-welded assemblies

Key features

- Innovatively designed algorithms: Automatic detection of welds and weld geometry from FE models and groups based on joint types, penetration grade and sheet thickness
- Support industry typical FE connection modeling for seam and spot welds
- Handles all load cases: transient, random, harmonic, proportional and non-proportional and schedules
- Special tools for seam welds: Mesh independent notch stress method (R1MS, R03MS, R005MS), including notch effects (effective notch stress method) using the microstructural length ρ^*
- User-defined methodologies can access all weld data

Capabilities chart

| General capabilities | Specific capabilities | Simcenter 3D Durability Wizard | Simcenter3D Advanced Durability | Simcenter 3D Specialist Durability Modeling | Simcenter 3D Specialist Durability solver | Simcenter 3D Specialist Durability Composite Fatigue | Simcenter 3D Specialist Durability for Connections |
|--|---|--------------------------------|---------------------------------|---|---|--|--|
| Loads and stresses | Loads from Simcenter Testlab | | | • | • | • | • |
| | Loads from industry test formats (IST, MSC, EDAS,...) | | | • | • | • | • |
| | Loads from Simcenter 3D Motion | | • | • | • | • | • |
| | Finite element results (Simcenter Nastran, Simcenter Samcef, ABAQUS, ANSYS, universal format) | • | • | • | • | • | • |
| | Block load events | • | • | • | • | • | • |
| | Superposition events (unlimited number of loadcases, automatic matching) | | | • | • | • | • |
| | Transient events (editor to select increments, change order, invert ordering) | | • | • | • | • | • |
| | Pre-stress and static load cases | | • | • | • | • | • |
| | Flexible event (directly analyse Simcenter3D Motion Flexible Body) | | | • | • | • | • |
| | Duty cycle events | | | • | • | • | • |
| | Duty cycles from spreadsheets | | | • | | | |
| | Random vibration loads | | • | • | • | | • |
| Materials | Simcenter3D material database | • | • | • | • | • | • |
| | Generation of material set based on existing material data (UML, universal slope, ...) | | | • | | | |
| | Material individually assigned to selection and groups | • | • | • | | | |
| | Weld standard data (IIW, Eurocode, BS, ...) | | • | • | | | |
| | Durability databases | | • | • | | | |
| Setup | Directly from finite element calculation | • | • | • | | | |
| | Inherit or overwrite materials | • | • | • | | | |
| | Parameter databases | | | • | | | |
| | User defined analysis types - define methods and parameters in one selection | | | • | | | |
| Fatigue methods and solver | High cycle fatigue – stress-life | • | • | • | • | | |
| | Low cycle fatigue – strain-life | • | • | • | • | | |
| | Infinite life – safety factor / margin of safety | • | • | • | • | | |
| | User defined fatigue methods | | | • | • | | |
| | Structural stress seam weld analysis | | • | | | | • |
| | Notch stress seam weld analysis (incl notch severity) | | | | | | • |
| | Stress based spot weld analysis | | | | | | • |
| | Force based spot weld analysis | | | | | | • |
| | User defined weld methods | | | | | | • |
| | Multiple mean stress influence methods | | • | • | • | • | • |
| | Multiaxial fatigue | | • | • | • | • | • |
| | Notch/size effects – stress gradient correction | | • | • | • | • | • |
| | Localized parameters (material/parameter map) | | | • | • | | |
| | Fatigue below surface method | | | • | • | | |
| | Use material data for user defined probability of survival | | | • | • | | • |
| | Multiple damage accumulation rules (linear) | | • | • | • | • | |
| Short-fiber reinforced composites (master SN-curve approach) | | | | | • | | |

| General capabilities | Specific capabilities | Simcenter 3D Durability Wizard | Simcenter3D Advanced Durability | Simcenter 3D Specialist Durability Modeling | Simcenter 3D Specialist Durability solver | Simcenter 3D Specialist Durability Composite Fatigue | Simcenter 3D Specialist Durability for Connections | |
|--|--|--------------------------------|---------------------------------|---|---|--|--|---|
| Fatigue methods and solver (continued) | Intra-ply fatigue of endless-fiber composites (unidirectional/woven. etc) | | • | | | • | | |
| | Inter-ply fatigue of endless-fiber composites (unidirectional/woven. etc) | | | | | • | | |
| | Automatic iteration of FE runs to account for global stiffness changes | | | | | | • | |
| | Arbitrary damage accumulation | | | | | | • | |
| | User defined damage rules for composites | | | | | | • | |
| | Parallel processing (local and on external machines) | | | | • | • | • | • |
| | Different methods (e.g. stress-life and weld) on different locations(groups) in one analysis | | | • | • | • | • | • |
| | Different methods (e.g.different parameters) on one group in one analysis | | | | • | • | • | • |
| Postprocessing | Damage/lifetime | • | • | • | • | • | • | |
| | Detailed analysis of stress (max/min/max amplitude, mean) | | • | • | • | • | • | |
| | Mileage/Real lifetime | | | | • | • | • | |
| | Design life factors | | | | • | • | • | |
| | Safety factors | | • | • | • | • | • | |
| | Individual for groups | | | • | • | | | |
| | Individual for events of duty cycles | | | | • | | | |
| | For intermediate time steps | | | | • | | • | |
| | Hot spot detection | | | | • | | | |
| | Detailed function analysis on strain gauge and individual nodes/elements | | | • | • | | | |
| | Function analysis on all critical planes | | | | • | | | |
| | Damage accumulation time histories | | | | • | | | |
| | Load contribution analysis | | | | • | | | |

Legend:

• = included in module

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

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