



fe-safe® DATA SHEET

*DURABILITY ANALYSIS SOFTWARE
FOR FINITE ELEMENT MODELS*



KEY FEATURES

- Calculates fatigue lives at every point on a model, producing contour plots to reveal fatigue lives and crack sites
- Determines how much the stresses must be changed in order to achieve a target design life, showing clearly where the component is under strength or where material and weight can be saved
- Estimates warranty claim curves based on probabilities of failure
- Identifies which parts of a duty cycle are most damaging. In prototype testing this could mean shorter tests with fewer actuators
- Manufacturing effects such as residual stresses from a stamped or formed part, or the material variation effects in castings and forgings can be included
- Automatic detection of contact using contact fatigue algorithms
- No special meshing is required. fe-safe works from a standard free tet mesh. Solid and shell elements can be combined on the same model
- Unique calculation of the fatigue life of welded joints using the Verity Structural Stress Method
- Unique calculation of composite materials using the physics-based Multi-Continuum Technology (MCT) methods available in fe-safe/Composites™
- Unique methods for fatigue of elastomers using patented elastomer-specific algorithms in fe-safe/Rubber™
- Unique solution providing strain correlated FEA load calculations using the technology available in fe-safe/True Load™ - turns complex components into multi-channel load cells
- New method of fatigue analysis from PSDs of loads. Combines a unique method of superimposing multi-axial PSDs with critical plane analysis

KEY BENEFITS

Fast

- Assemblies of different parts, surface finishes and materials can be analyzed in a single run—fe-safe automatically changes the method of analysis as it moves from one material to another. Contour plots showing the fatigue life at each node, the factor of strength, and probabilities of survival can all be calculated in the same run
- Highly efficient coding plus parallel and distributed processing allow fe-safe to analyse large FE models and report results quickly

Accurate

- Advanced multiaxial algorithms are the core of fe-safe
- Unique nodal elimination methods ensure no trade-off between speed and accuracy
- Users consistently report excellent correlation with test results. Continuous development ensures fe-safe maintains its position as the technology leader

Users consistently report that fe-safe gives accurate, reliable fatigue life predictions that correlate well with test data.

KEY CAPABILITIES

Fatigue of welded joints

fe-safe includes the BS7608 analysis as standard. Other S-N curves can be added. fe-safe also has an exclusive license to the Verity® Structural Stress Method developed by Battelle. Developed under a Joint Industry Panel and validated against more than 3500 fatigue tests, Verity is bringing new levels of accuracy to the analysis of structural welds, seam welds and spot welds.

Vibration fatigue

fe-safe includes powerful features for the analysis of flexible components and structures that have dynamic responses to applied loading. Steady state modal analysis, random transient analysis and a unique approach to PSDs of loads are among the analysis methods included.

Test program validation

fe-safe allows the user to create accelerated test fatigue programs. These can be validated in fe-safe to ensure that the fatigue-critical areas are the same as those obtained from the full service loading. Fatigue lives and fatigue damage distributions can also be correlated.

Critical distance—will cracks propagate?

Critical distance methods use subsurface stresses from the FEA to allow for the effects of stress gradient. The data is read from the FE model by fe-safe, and the methods can be applied to single nodes, fatigue hot-spots or any other chosen areas, including the whole model.

Easy To Use

- fe-safe has many default settings and automatically selects the most appropriate algorithm based on the selected material
- Standard analyses can be saved making it ideal for the non-specialist fatigue analyst
- fe-safe is highly configurable for the advanced user
- Direct interfaces to leading FEA suites such as Abaqus, ANSYS, I-deas, Nastran (MSC, NEi, NX) and Pro/Mechanica are driven from an intuitive, single screen, Windows-based GUI

Property mapping

Results from casting or forging simulations can be used to vary the fatigue properties at each FE node. Each node will then be analyzed with different material data. Temperature variations in service, multiaxial stress states and other effects such as residual stresses can also be included.

Vector plots

Vector plots show the direction of the critical plane at each node in a hot-spot, or for the whole model. The length and color of each vector indicates the fatigue damage.

Warranty curve

fe-safe combines variations in material fatigue strengths and variability in loading to calculate the probability of survival over a range of service lives.

The effect of design variables on product reliability can be explored easily from a single user interface.

Damage per block

Complex loading histories can be created from multiple blocks of measured or simulated load-time histories, dynamic response analyses, block loading programs and design load spectra. Repeat counts for each block can be specified. fe-safe also exports the fatigue damage for each 'block' of loading (for example, from each road surface on a vehicle proving ground, or for each wind state on a wind turbine). This shows clearly which parts of the duty cycle are contributing the most fatigue damage. Re-design can focus on this duty cycle, and accelerated fatigue test programs can be generated and validated.

CAPABILITIES OVERVIEW

Material database

A material database is supplied with fe-safe. Users can add their own material data and create new databases. Material data can be plotted and tabulated. Effects of temperature, strain rate, etc., can be seen graphically. Equivalent specifications allow searching on US, European, Japanese and Chinese standards.

Automatic hot-spot formation

fe-safe automatically forms fatigue hot-spots based on user-defined or default criteria. Hot-spots can be used for rapid design change studies and design sensitivity analysis.

Manufacturing effects

Results from an elastic-plastic FEA of a forming or assembly process or from surface treatments such as cold rolling or shot peening can be read into fe-safe and the effects included in the fatigue analysis. Estimated residual stresses can also be defined for areas of a model for a rapid 'sensitivity' analysis.

Surface detection

fe-safe automatically detects the surfaces of components. The user can select to analyze only the surface, or the whole model. Subsurface crack initiation can be detected and the effects of surface treatments allowed for.

Surface contact

Surface contact is automatically detected. Special algorithms analyze the effects of contact stresses. This capability has been used for bearing design and for the analysis of railway wheel/rail contact.

Virtual strain gauges

Virtual strain gauges (single gauges and rosettes) can be specified in fe-safe to correlate with measured data. fe-safe exports the calculated time history of strains for the applied loading. FE models can be validated by comparison with measured data.

Parallel processing

Parallel processing functionality is included as standard—no extra licenses are required.

Distributed processing

Distributed processing over a network or cluster is available, offering linear scalability. Mixed networks of Windows, Linux and Unix applications are supported. Fail-safe methods if nodes go offline and auto load balancing are included.

Signal processing

Signal processing, load history manipulation, fatigue from strain gauges, and generation of accelerated testing signals are among the many features included as standard.

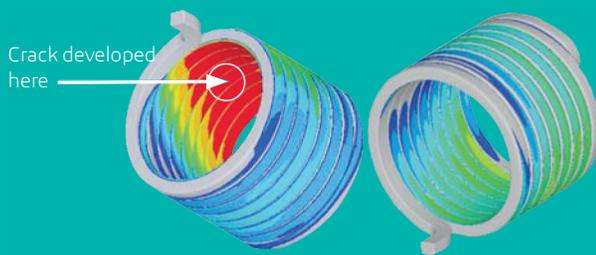
Structural optimization

fe-safe integrates seamlessly into Isight and Tosca from SIMULIA, ANSYS Workbench, and Optistruct from Altair to allow the full fe-safe capabilities to form an integral part of a design optimization process.

fe-safe Custom Module Framework™

Allows users to create new fatigue analysis methods without rebuilding fe-safe. User's own confidential algorithms can be added to those supplied with fe-safe to operate seamlessly within the fe-safe environment. Algorithms can be created in Python, FORTRAN, C++ and other languages. fe-safe interfaces to the FEA files and uses its own powerful fatigue loading capabilities to assemble the tensor time history for each node, which is passed to the user's algorithm. User-defined results and other information are exported through fe-safe. New user-defined material properties can be added to the material database. A user interface (GUI) can be generated automatically by fe-safe. Batch operation and distributed processing are also supported.

This is not a complete list of features in fe-safe. To discuss your particular requirements, please contact Dassault Systèmes SIMULIA or your local fe-safe representative.



fe-safe fatigue life contour plot

CASE STUDY

Fatigue analysis of a supercharger torsion isolator spring

Test results to crack initiation: **60,000 cycles**

fe-safe fatigue life prediction to crack initiation: **67,500 cycles**

"fe-safe - invaluable and indispensable for predictive fatigue analysis"

Eaton Corporation, Vehicle Group, USA

OPTIONAL ADD-ON MODULES FOR FE-SAFE

Fatigue of composites

fe-safe/Composites[®], combines the extensive capabilities of fe-safe[®] with leading edge composite technology exclusively licensed from Autodesk (formerly Firehole Composites) to create a unique and unparalleled commercial solution for the fatigue of composite materials. Both composite and metal materials can be analyzed in a single operation and displayed as a single fatigue life contour plot.

Fatigue of welded joints

Verity[®] in fe-safe is a revolutionary new mesh-insensitive Structural Stress Method developed by and exclusively licensed from Battelle that allows engineers to predict failure locations and calculate fatigue lives for welded joints and welded structures. As an add-on module to fe-safe it enables both welded and non-welded areas to be analyzed in a single operation and displayed as a single fatigue life contour plot.

Thermo-mechanical fatigue

fe-safe/TMF[™] provides a full thermo-mechanical fatigue analysis using instantaneous temperature and strain rates, bulk stress relaxation and effects of strain ageing from an elastic Finite Element model. fe-safe/TMF has been successfully used for pistons, exhaust manifolds and cylinder heads.

Creep-fatigue

fe-safe/TURBOLife[™] has been developed in partnership with AMEC (formerly Serco Assurance) to assess creep damage, fatigue damage and creep-fatigue interactions. It was developed in collaboration with the nuclear power industry using the R5 design code and has been extended to include multiaxial fatigue and complex loading histories. fe-safe/TURBOLife includes several methods for estimating high temperature material properties so that it can be used with sparse material data sets. fe-safe/TURBOLife creep-fatigue algorithms have been successfully applied to gas turbine blades, steam turbine components, exhaust components and turbocharger impellers.

Fatigue of rubber

fe-safe/Rubber[™], developed in partnership with Endurica LLC calculates the fatigue life of elastomer components. It includes a patented critical plane algorithm for finite straining, features a Rainflow counting procedure, provides a selection of nonlinear material models and provides a database of ready-to-use properties for a number of popular elastomer types.

In-situ load management

fe-safe/True-Load[™], developed in partnership with Wolf Star Technologies brings to market a unique solution to provide strain correlated FEA load calculations. fe-safe/True-Load turns complex components into multi-channel load cells and optimizes the location of strain gauge placements in order to provide in-situ load measurement and increase the users' knowledge of the true loading on a structure. This provides the best foundation for accurate fatigue analysis calculations.

safe4fatigue[™]

The proven signal processing suite **safe4fatigue** is included as standard in fe-safe. Capabilities include amplitude analysis, rainflow cycle counting, PSDs and transfer functions, signal cleaning, digital filters, uniaxial and multiaxial fatigue from strain gauges, generation of test command signals with optional cycle omission criteria, and macro recording.

FOR MORE INFORMATION VISIT

www.3ds.com/simulia and www.3ds.com/fe-safe

Our 3DEXPERIENCE[®] Platform powers our brand applications, serving 12 industries, and provides a rich portfolio of industry solution experiences.

Dassault Systèmes, the 3DEXPERIENCE Company, provides business and people with virtual universes to imagine sustainable innovations. Its world-leading solutions transform the way products are designed, produced, and supported. Dassault Systèmes' collaborative solutions foster social innovation, expanding possibilities for the virtual world to improve the real world. The group brings value to over 170,000 customers of all sizes in all industries in more than 140 countries. For more information, visit www.3ds.com.

