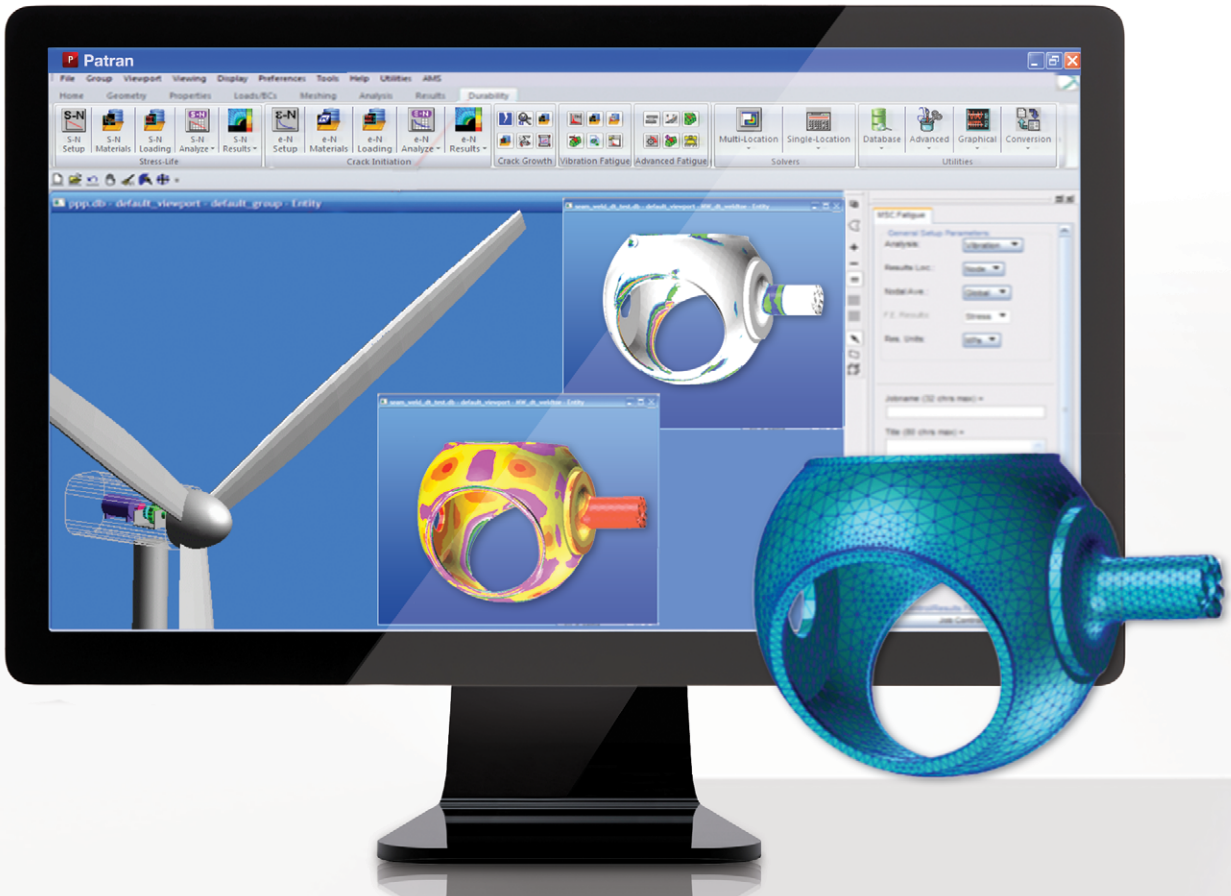
MSC Fatigue®

Fatigue Simulation for Comprehensive Durability Analysis



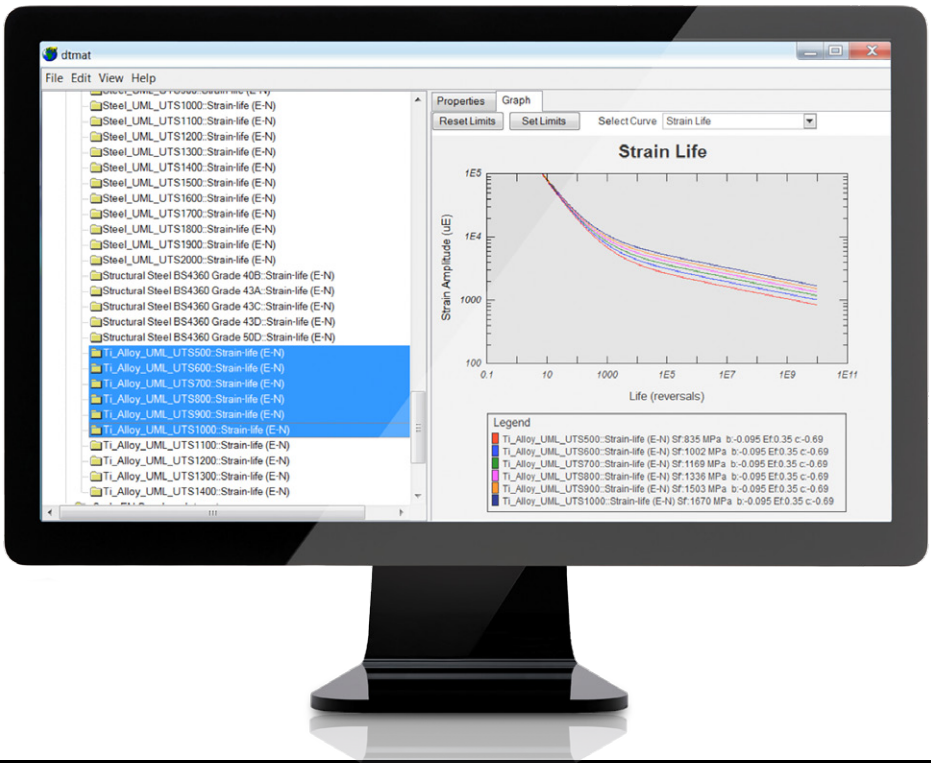
MSC Software®

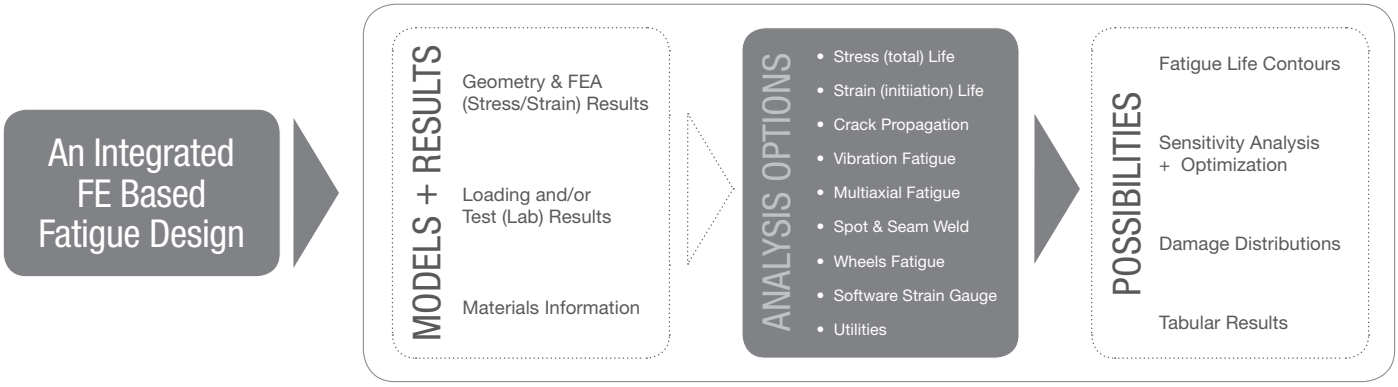
MSC Software, the world leader in simulation technology presents

MSC Fatigue®

From aircrafts to cell phones, this state-of-the-art FE based Fatigue & Damage Tolerance solver for CAE enables the quick and accurate prediction of how long products will last under any combination of time-dependent or frequency-dependent loading conditions.

MSC Fatigue® is an advanced, full featured durability solution available in the marketplace. Its advanced fatigue life estimation program allows users to perform comprehensive fatigue analysis with the same FE results that are used for stress analysis. The environment seamlessly enables CAE, dynamic analysis and durability to be managed in one user friendly interface. It includes advanced modules developed by MSC Software over a 20 year period as well as more recent modules developed as part of the nCode DesignLife suite of programs.





Design Instead of Test

Tools inside MSC Fatigue® can simulate fatigue response of full body systems, offering the possibility for test cycle reductions and the associated cost savings.

Get It Right the First Time

Fatigue failures in the field result in costly retrofits. With MSC Fatigue®, the effectiveness of proposed redesigns can be established in advance.

Manage Fatigue & Durability Data

The durability process includes laboratory and field testing, and Mechanical Computer-Aided Engineering (MCAE) data handling in addition to fatigue analysis.

MSC Fatigue® has the ability to store and seamlessly manage all aspects of the durability process.

Understand Fatigue Behavior

Reliability failures often result from an inadequate understanding of the fatigue process. MSC Fatigue® a highly intuitive tool to provide insights into the key drivers that affect fatigue life.

Auditable and Repeatable Processes

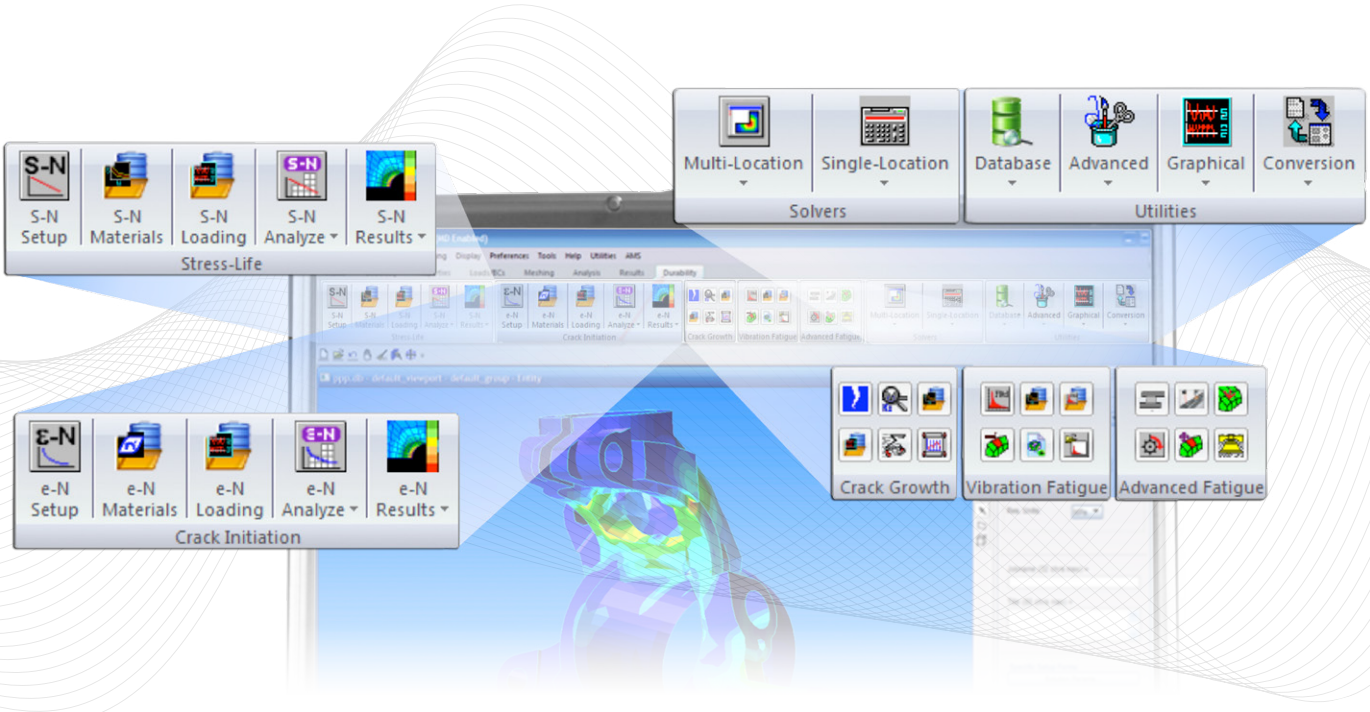
MSC Fatigue is configured to run in a similar way to Nastran using an editable text batch file (cf BDF file). This leaves a useful auditable trail as well as a convenient means to run in batch mode.

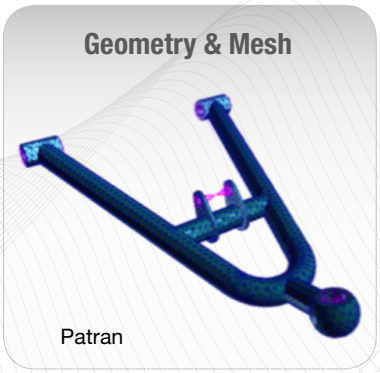
Incorporate More Reliable Material Properties

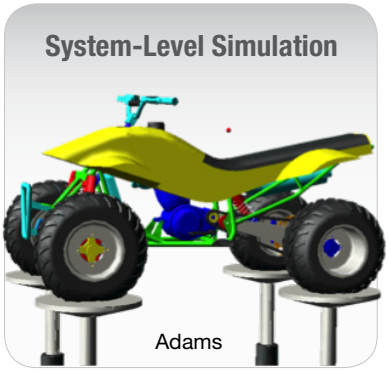
Because reliable materials data is an essential part of any fatigue and durability process, MSC Software offers a comprehensive materials testing service.

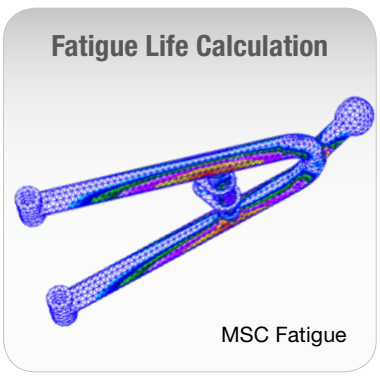
Comprehensive Solution

MSC Software offers a complete solution including advanced fatigue software (MSC Fatigue®), advance materials testing facilities, and new with this release, a comprehensive engineering analysis (for fatigue) consulting service.









Improve Productivity

MSC Fatigue® offers the best-integrated durability solver for the MCAE market. It is the only durability solver that seamlessly links to MSC Nastran™, Adams™ and Patran™. It is also the only solver that can directly read Marc's® non-linear results.

Using MSC Fatigue® early in the design process reduces the high cost of testing and prototyping to get your products to market faster with reliable warranties.

MSC Fatigue® is easy to learn and use. Resources include the Quick Start Guide, on-line help, MSC Software's® excellent technical support and extensive documentation.

Capabilities

- HCF, LCF & Crack Growth
- FE Results support (Static, Transient, Modal, FRF, PSD)
  - MSC Nastran™
  - Adams™
  - Marc®
  - ABAQUS
  - ANSYS
- Advanced Analysis Modules (Multiaxial Fatigue), Vibration Fatigue, Shaker Fatigue, Welding (Spot & Seam), Software Strain Gauge, Wheels, Utilities, Fracture
- Unique Optimization Capability
  - Load Scale Factor
  - Materials
  - Surface Finish/Treatments
  - Certainty of Survival
- Test/Analysis Correlation
- Duty Cycle (Multiple Analysis)
  - Aero-spectrum loading definition

MSC Fatigue Packages

Life and Durability Analysis

Base MSC Fatigue Packages

MSC Fatigue Basic Solver Package

Includes Stress-Life, Strain-Life (401), and Strain Gauge (406)

MSC Fatigue Complete Solver Package

Includes Basic and Advanced Solver Packages (20033 + 20269)

Optional MSC Fatigue Advanced Modules

MSC Fatigue Fracture

MSC Fatigue Vibration

MSC Fatigue Multiaxial

MSC Fatigue Wheels

MSC Fatigue Welds

Includes Spot Weld (408) and Seam Weld (10503)

MSC Fatigue Utilities

Optional Bundles

MSC Fatigue Advanced Solver Package

Includes Fracture, Vibration, Muliaxial, Wheels, Welds and Utilities

Optional GUI Product

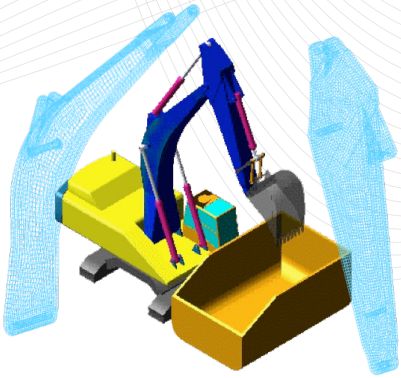
Patran for MSC Fatigue

Includes only the Patran license feature

No CAD Import or FEA Solver Preferences Available

3 Major Principles of Fatigue Life Estimation

MSC Fatigue® incorporates the three major principles of Fatigue Life Estimation: Stress-Life, Strain-Life and Crack Growth.



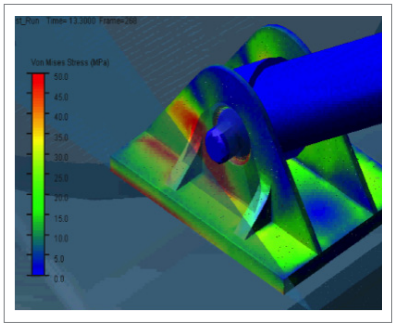
"The results of the durability analysis showed good correlation with our physical test results on an initial prototype, giving us the confidence to predict service lives based on the virtual prototype simulation.

As a result...we only need one physical prototype and are on track to completing the design in only one year."

Terry Ewanochko, Product Engineer
John Deere Welland

Stress-Life

This is the traditional Stress Life, or S-N method, used for High Cycle Fatigue applications (HCF - low load - long life) that makes no distinction between initiation or growth of a crack, but rather, predicts the total life to failure.



Strain-Life

This method is generally used for high load-low life applications (Low Cycle Fatigue - LCF), where material yield due to the application of high loads is taken into account. Sophisticated Strain-Life (e-N) modeling provides a method for estimating the life of a part to a user-defined limit - generally the initiation of an engineering crack.

Crack Growth

Linear Elastic Fracture Mechanics (LEFM) is used to predict the progress of a crack through a component to the point where rapid fracture causes failure. The method is widely used in the Aerospace industry where demonstration of damage tolerance is a design criterion.

Advanced Application Modules

MSC Fatigue® predicts fatigue life from finite element (FE) models. MSC Fatigue® is fully modularized, enabling customization to suit your needs, and includes:

"We evaluated MSC Fatigue against several commercial competitive alternatives. We chose MSC Fatigue was because of its wide range of analysis capabilities and also because it has a strong pedigree."

MSC Fatigue® Basic

Stress-life, Strain-Life, multi-axial assessment, and safety factor analysis based on linear elastic FEA.

MSC Fatigue® Vibration

Frequency based (vibration) and time domain (Modal Participation Factor) methods are available for single and multi input loading systems.

MSC Fatigue® Shaker

Sine sweep and PSD analysis of single input loading systems.

MSC Fatigue® Seam Weld

Stress-Life, Strain-Life and safety factor analysis based on linear elastic FEA.

MSC Fatigue® Spot Weld

Stress-life, Strain-Life, multi-axial assessment, and safety factor analysis based on linear elastic FEA.

MSC Fatigue® Fracture

Crack growth analysis based on linear elastic fracture mechanics including an interface to NASA/FLAGRO.

MSC Fatigue® Strain Gauge

Virtual strain gauges pasted on an FE model for fatigue test/analysis correlation.

MSC Fatigue® Utilities

A number of advanced fatigue utilities for load manipulation, graphical display, and single shot fatigue analysis.

MSC Fatigue® Wheels

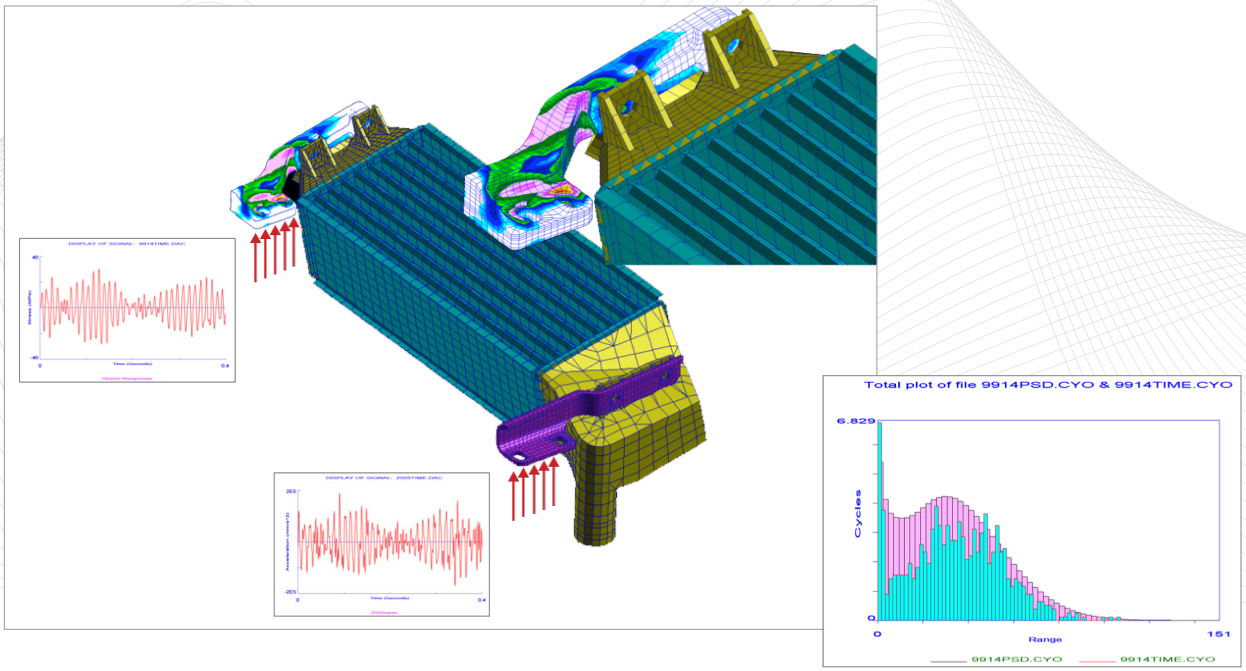
A tool for managing rotating FE system stress fields in order to compute fatigue life.

MSC Fatigue® Multiaxial

Crack initiation and safety factor analysis of components with multiaxial stress states.

MSC Fatigue® Pre&Post

Pre & Post processor for setting up, managing and displaying fatigue analysis for non Patran™ customers. (This module is not required for Patran™ customers.)



Post-Processing Functions

Various listing and post-processing functions are also provided for investigating critical locations and producing tables, and 2D and 3D plots. This includes the ability for rapid re-analysis of critical nodes or elements to investigate the effects of material or loading changes or fatigue parameters without re-solving the complete model.

Stress and strain component time histories can be exported for correlation and further analysis. A 'Fast Analysis' option is provided to more quickly identify critical locations prior to a complete analysis. This option utilizes a peak-valley slicing method to shorten the loading time histories and creates a set of most damaged locations for subsequent analysis.

MSC Fatigue® can directly use modal, transient time history stress/strain data or use static load cases (up to 500 with scaling and offset features) in combination with loading functions and perform the required stress/strain superposition. Multiple events and usage profiles can be analyzed with relative ease with the Duty Cycle Analyzer. Multiple materials and surface finishes can be assigned to different parts of the model by defining groups.

- Modifiable Loads Database with standard time histories and capability for adding time histories from ASCII file import, XY point specification, Graphical Interaction, and Waveform & Block definitions.
- Modifiable Materials Database that has an extensive library of S-N, E-N, Cyclic and Component curves with import capability from MSC Mvision.
- Material searches based on design life.

Results & "What If" Analysis

Results data is reported both in tabular form and in results files for graphical display in the results postprocessor. A single location analyzer can be used for "what if" studies after a global analysis has identified critical locations.

Results data include:

- Damage (reported in linear and log form)
- Life (reported in linear and log form)
- Life reported in user defined units
- Multiaxial assessment parameters:
- Factor of safety
- Stress history output
- Cycle and damage histogram plots

Back calculations based on design life of:

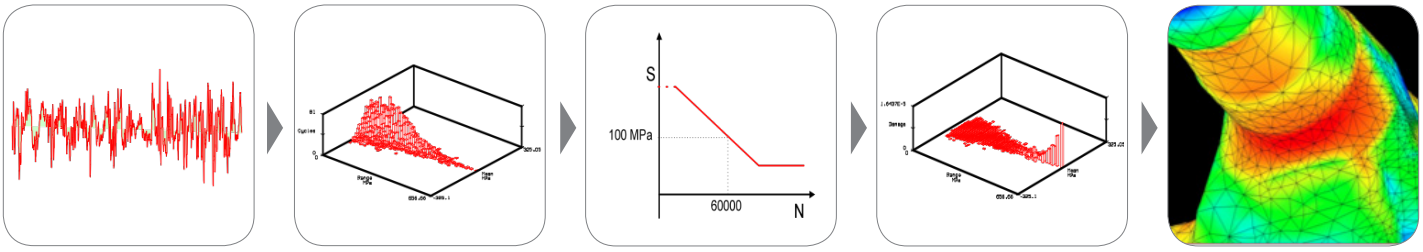
- Scale factor (stress concentration)
- Residual stress
- Probability of failure (design criterion)

Sensitivity studies of:

- Multiple scale factors (stress concentrations)
- Multiple residual stress values
- Multiple probabilities of failures (design criteria)
- Surface finish/treatment
- Mean stress correction methods
- Change materials or surface finish/ treatment

MSC Fatigue® Basic

MSC Fatigue® uses stress or strain results from finite element (FE) models, variations in loading, and cycling material properties to estimate life-to-failure.



Time History | Rainflow Cycle Counting | Damage Counting | Damage Histogram | Fatigue Life

Both the traditional Stress-Life (S-N or total life) and Strain-Life (E-N, local strain or Crack Initiation) methods are available. With minimal knowledge of fatigue analysis, users can perform such evaluations directly in their familiar FE modeling environment. The intuitive interface and the speed at which the fatigue analysis is performed enables durability concerns to be moved up front in the product development cycle, thus avoiding costs due to re-designs, prototyping and testing.

Features Pertaining to both the Stress-Life and Strain-Life methods

- Rainflow cycle counting
- Statistical confidence parameters
- surface finish/treatment corrections
- Palmgren-Miner linear damage summation including Flexible Miner's sum (>0, default = 1.0)
- User-defined life units
- Multi-axial stress state assessments
- Factor of safety analysis
- Stress/Strain tensor combination/ resolution - any individual component, Maximum absolute principal, Signed von Mises, Signed Tresca/Shear
- Critical Plane Analysis
- Scale Factors (stress concentration definitions)
- Offsets - Static load cases
- Results transformations - Global system and Surface Resolved
- Up to 500 simultaneously applied load case

Stress-Life features include:

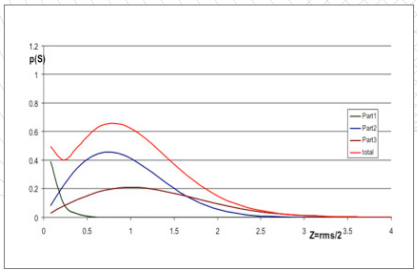
- Goodman, Gerber (tension only), Interpolation-type mean stress correction (Multi-Mean and Multi R-Ratio Curve, Haigh Diagram, Bastonaire)
- Welded Structure Analysis to BS7608
- Material and Component S-N Curves; Interpolation-type S-N curves
- FKM mean stress correction

Strain-Life features include:

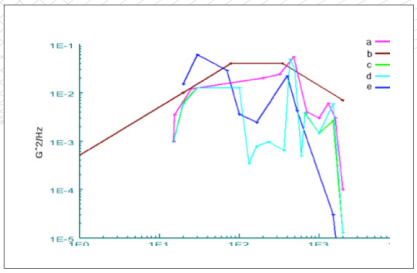
- Neuber and Hoffmann Seeger elastic-plastic correction
- Cyclic stress-strain tracking using Masing's hypothesis and material memory modeling
- Smith-Watson-Topper, Morrow, and Interpolation-type mean stress correction (Multi-Mean and Multi R-Ratio Curve)
- Advanced biaxial corrections (for non-proportional loading) based on Parameter Modification of Hoffman-Seeger

MSC Fatigue® Vibration

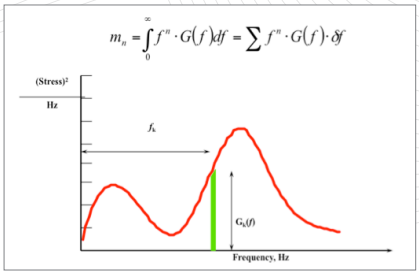
MSC Fatigue® Vibration predicts the fatigue life of structures subjected to multiple input random vibration loads.



Dirlik solution



Typical vibration acceleration specifications



Moments from a PSD

It is important for designers to estimate response at resonance for structures subjected to random input loads and this analysis is best performed in the frequency domain using (PSD's) of input loading and stress response. The Vibration Fatigue module can perform fatigue analysis using either direct external response PSD's (where the stress solver is used to calculate the PSD's) or PSD's calculated within the Vibration module using, as input, the loading PSD's and system transfer funcions. Transfer functions can be computed for various stress scalar values including Principal Stresses.

The Vibration Fatigue Module

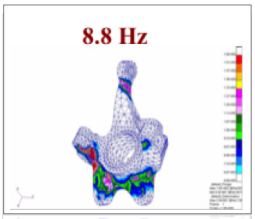
The Vibraton Fatigue module uses the S-N method to predict life (there is also an indirect route using Strain-Life) and a single shot analyzer that accepts a measured or analytically determined stress response PSD.

Specific Features include:

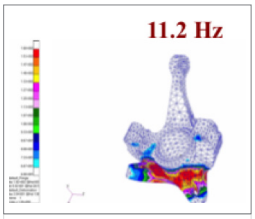
- Welded structure analysis to BS7608
- Goodman and Gerber Mean stress corrections
- Probability Density Functions of Rainflow cycles (various matrix (bin) sizes (32,64,128)
- Stress/Strain Tensor combination/ resolution - Individual Components, Max abs Principal, Signed Von Mises, Signed Tresca/Shear
- FE Results transformations
- Computation of Principal Stress response PSDs at any locaton from transfer functions and input loading PSD's
- Palmgren-Miner linear damage summation including flexible Miner's sum (>0, default=1.0)
- Multiaxial Stress state assessments (stress tensor mobility & biaxiality checks)
- Surface Finish/Treatment Corrections
- Twenty FE load cases with associated input load PSDs can be applied simultaneously. A loading database is also supplied to facilitate creation and storage of these PSD's
- PSD creation from time series data, ASCII file import, graphical or XY point specification, wave form definitions (sine, triangular, square)
- Data transformations
- Plots of PSD's and Rainflow data

Multiple Analysis Methods

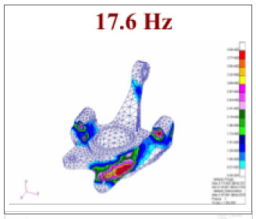
- Dirlik
- Narrow Band
- Steinberg
- Tunna
- Wirsching
- Hancock
- Kam & Do



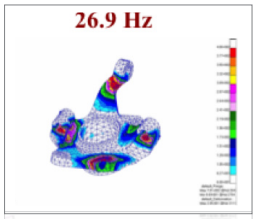
Mode 1



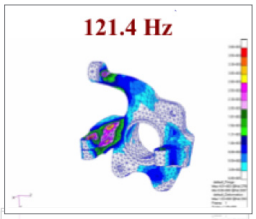
Mode 2



Mode 3



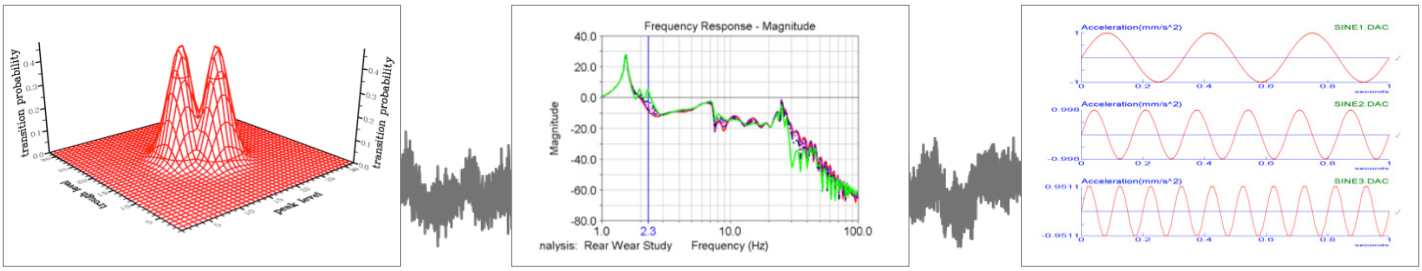
Mode 4



Mode 5

MSC Fatigue® Shaker

MSC Fatigue® Shaker predicts the fatigue life of components subjected to a single input random vibration load.



"The MSC Fatigue Vibration module enabled us to design our components more accurately (with less conservatism) than the traditional Narrow Band or Steinberg approaches"

Shaker table tests are widely specified and are routinely used to "proof test" components before sign-off. Typical input loads could be displacement, velocity or accelerations PSD's.

Fatigue analysis is then performed in the frequency domain rather than the traditional time-based domain approach. Both the input loads characterization and the damage analysis are performed in the frequency domain using Power Spectral Densities (PSD's).

The Shaker Fatigue Module

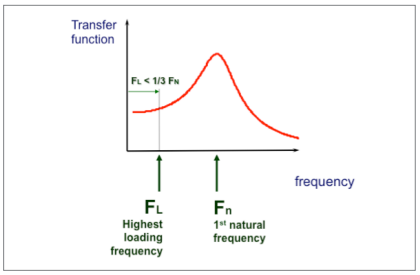
The Shaker Fatigue module can perform fatigue analysis using either direct external response PSD's (where the stress solver is used to calculate the PSD's) or PSD's calculated within the Shaker module using the input loading PSDs and system transfer functions. Transfer functions can be computed for various stress scalar values including Principal stresses.

Multiple Analysis Methods

- Dirlik
- Narrow Bank
- Steinberg
- Lalanne

New Sine Sweep Capability

- Multiaxial Stress state assessments (stress tensor mobility & biaxiality checks)
- Surface Finish/Treatment Corrections



Is the highest possible frequency of loading greater than one third of the 1st natural frequency?

- Twenty FE load cases with associated input load PSDs can be applied simultaneously. A loading database is also supplied to facilitate the management of these PSDs.
- PSD creation from time series data, ASCII file import, graphical or XY point specification, wave form definitions (sine, triangular, square)
- Data transformations
- Rainflow cycle counting and Damage histograms, Stress PSD CSV output

MSC Fatigue® Spot Weld

MSC Fatigue® Spot Weld is a module for predicting the fatigue life of spot-welded sheet connections using static or dynamic FE results from MSC Nastran™ or Adams™ with the S-N (total life) method.

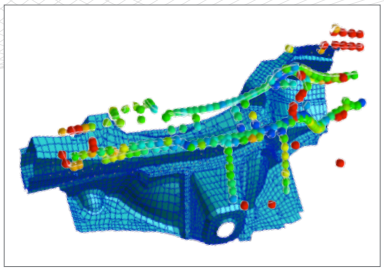
Analysis of spot welds using MSC Fatigue® Spot Weld can help you produce optimized designs and reduce prototyping and testing costs.

The MSC Fatigue® Spot Weld Module

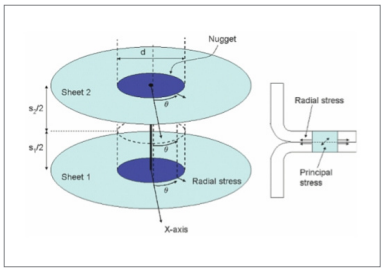
Modern automotive structures can have 4000-6000 spot welds & approximately 80% of automotive body durability problems are associated with spot welds. Tooling costs for spot welds are high & the need for rapid & accurate predictions of fatigue life on spot welds early in the design stage is very important. Besides the structural importance, durability of spot welds can also have an important effect of perceived quality of a part or component.

MSC Fatigue® Spot Weld supports results from 3 commonly used modeling methods & uses the Rupp, Storzel & Grubisic algorithm for computing stresses in each spot-weld nugget & in adjacent sheets.

- Spot welds modeled as stiff beams. The method requires attention to align the spot weld nodes on each flange but is suitable for application to large models as local mesh refinement around the spot weld is not required.
- MSC Nastran™ CWELD elements. The power & modeling flexibility afforded by CWELD element is utilized. The CWELD allows users to model spot welds between dissimilar flange meshes of any refinement. CWELD results are used directly by MSC Fatigue® Spot Weld.
- Spot welds modeled using CHEX/MPC. This method also allows users to model spot welds between dissimilar flange meshes. MSC Fatigue® computes “equivalent” bar forces automatically and posts fatigue results on the faces of the CHEX elements.

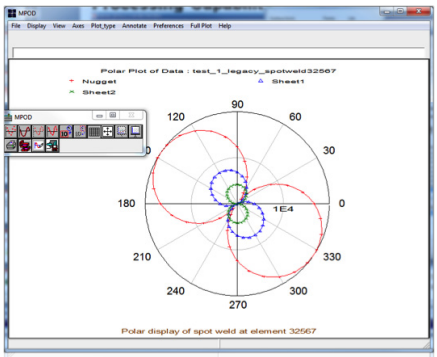


- Automatic extraction of Spot Weld Analysis Groups
  - By flange thickness pairs
  - Weld diameter extracted automatically
- 150 analysis groups
- No limit on spot welds per group
- 500 load channels



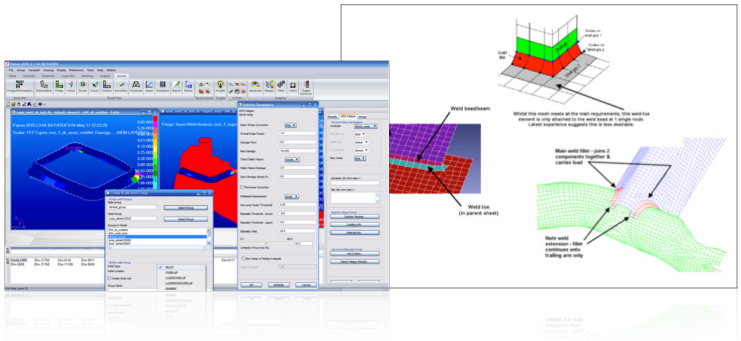
Capabilities of the Spot Weld Analyzer

- Analysis of welds joining two metal sheets
- Three sheet correction
- Weld nugget & sheet fatigue life – user configurable number of fatigue calculations performed per spot weld.
- Rainflow cycle counting - various matrix (bin) sizes (32, 64, 128)
- Statistical Confidence parameters
- Palmgren-Miner linear damage summation
- Flexible Miner’s sum (>0, default=1.0)
- Spot weld S-N curves - Includes Generic Spot Weld (S-N curves for nugget & sheet)
- Add, create or modify materials data
- Graphical & tabular reports of Life & Damage in linear & log form
- User Defined Units for Life reporting
- Polar plots of life/damage for nugget & sheets
- Polar plots of stress for nugget & sheets
- Stress Time history output
- Damage & cycle histogram plotsFailure location – nugget, top or bottom sheet



MSC Fatigue® Seam Weld

MSC Fatigue® includes, as standard, the traditional weld classification approach (BS5400/ BS7608 etc.) for the fatigue design of weldment details as well as the more modern structural stress approach.



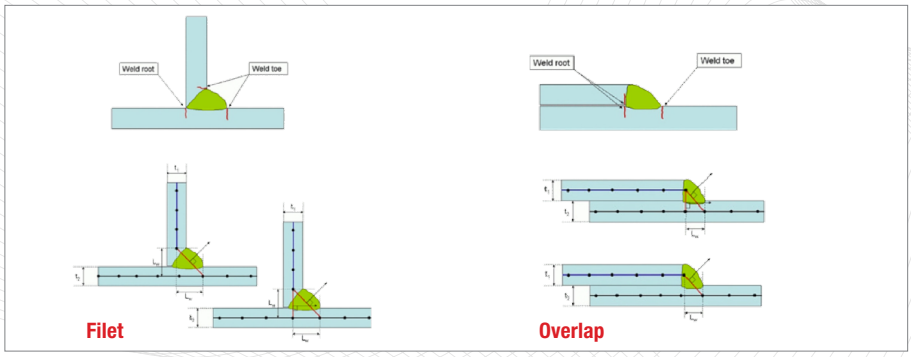
"Where a welded configuration used to take one week to analyze it, now takes just four hours."

The Weld Classification Approach

Using this type of approach, there is no requirement to model the weld detail. Instead, "component" S-N curves are used, which have the weld classification detail (loading and geometry) built into the S-N detail. This approach can, however, be awkward and time consuming to implement for thin sheet styles commonly used for automotive manufacturing because the level of integration with FE is minimal.

To overcome these limitations, MSC Fatigue uses a method developed by Fermer et al. (Ref: SAE 982311) to compute equivalent structural stress in the weld.

- Weld root and weld throat failure prediction
- Additional weld types for brazing and lazer welds
- Interpolation between bending and tension S-N curves rather than just using one or the other
- Users can define the bending ratio threshold to effect the start of the interpolation
- Faster solver also capable of multi-threading (parallel processing)
- Native 64 bit solver (on 64 bit machines)
- Seam weld solver benefits from expanded duty-cycle capability



Available Weld Configurations

MSC Fatigue® Fracture

Crack Growth Analysis

MSC Fatigue® Fracture uses stress results from finite element (FE) models, variations in loading & cyclic material properties to estimate crack propagation rates & times. Traditional linear elastic fracture mechanics (LEFM) is used to determine crack growth.

Crack Growth Modeling

MSC Fatigue® Fracture provides sophisticated crack growth modeling for estimating life to grow a crack through a structure. Features include:

- Kitagawa minimum crack sizing
- Fracture toughness failure criterion
- Mean stress correction
- Rain flow cycle counting with cycle re-ordering
- Initial and final crack length specifications
- Plane stress correction
- Notch effects modeling
- Retardation and closure effects modeling
- Modified Paris law modeling based on effective stress intensity range
- User-defined life units
- Fracture mechanics triangle solutions (stress – stress intensity – crack length)
- Graphical interface to NASA/FLAGRO (via Patran™ or MSC Fatigue® Pre & Post)
- Stress tensor combination/resolution

Models and results can be imported in a variety of ways: Patran™ neutral and external (nod, ele, els) results file MSC Nastran™ OP2 and XDB file Marc®, ABAQUS, ANSYS and SDRC results files

Fracture analysis is performed using stress results from FE models that define the nominal or far field stress, which can be defined as a single location or averaged from an area on the model. Manual input is also possible with no reliance on an FE model. Results access features include FE results data from:

- Patran™ database (linear static and transient results)
- MSC Nastran™, ANSYS, ABAQUS, Marc®, and any other Patran™ supported analysis code

Multiple FE load cases with associated time variations can be defined and applied simultaneously. A time history database is supplied to facilitate creation and storage of these files.

A materials database manager stores and manipulates a library of cyclic material properties. Features include:

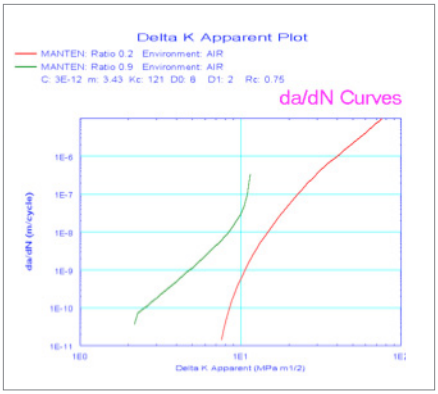
- Approximately 200 materials (metals) supplied
- Add, create, or modify your own or supplied materials data (Imperial & SI units supported)

Graphical display of:

- Apparent stress intensity (DK)
- Effective stress intensity (DK)
- Threshold ratio DK plots

Possible Results

- Interactive XY plot of crack growth during the analysis
- Final crack length versus life curve
- Final crack growth rate curve
- Life interpolation due to different initial and final crack sizes
- Stress history output
- Tabular listing of life:
  - crack size,
  - growth rate
  - stress range
  - Apparent DK
  - Effective DK
  - Current overload K
  - Residual K



Compliance Function Library

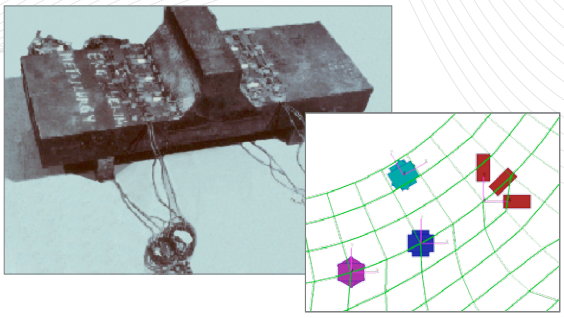
Various crack geometries are supported for determining the K-solution which include:

- Standard specimens
  - Single edge crack in tension
  - Single edge crack in pure bending
  - Double edge crack in tension
  - Center cracked plate in tension
  - Center cracked square plate in tension
  - Three-point bend specimen
  - Compact tension specimen
  - Round compact tension specimen
  - Wedge opening load specimen
  - Quarter circular corner crack tension specimen
- Cracks at holes
  - Single crack at a hole in tension
  - Double crack at a hole in tension
  - Surface crack at a hole in tension
- Elliptical, semi-elliptical cracks in plates
  - Surface cracks in tension
  - Surface cracks in bending
  - Embedded cracks in tension
  - Embedded cracks in bending
  - Surface and embedded cracks in combined loading
- Cracks at corners
  - Quarter elliptical corner crack in tension
  - Quarter elliptical corner crack at a hole in tension
  - Cracks in solid cylinders
  - Circumferential crack in tension
  - Straight crack in tension
  - Semi-circular crack in tension
  - Crack at thread in tension
  - Straight crack in bending
  - Semi-circular crack in bending
- Cracks in hollow cylinders
  - Internal surface crack under a hoop stress
  - Circumferential crack in thin-walled tube in tension
- Cracks in welded plate joints
  - Weld toe surface cracks in tension
  - Weld toe surface cracks in bending
  - Weld toe embedded cracks in tensionWeld toe embedded cracks in bending
  - Surface cracks in combined tension and bending
- Cracks in welded tubular joints
- Cracks at spot welds in tension
- User parametric definitions

MSC Fatigue® Strain-Gauge

Virtual Strain Gauges

MSC Fatigue® Strain Gauge allows the creation of virtual Software Strain Gauges within an MSC Nastran™ finite element (FE) model. These gauges can be used to produce analytical response time histories from the FE model under the effect of multiple time varying applying loads.



Software Strain Gauges

Strain Gauge Definitions

The Software Strain Gauges are defined as FE groups, each containing from one to three elements. All standard strain gauge definitions are supported in both planar and stacked formulations. User defined gauges may also be created, with definitions stored in a gauge definition file.

The virtual strain gauges are positioned on the FE model surface, with the gauge aligned in any orientation and the gauge positioned independently of existing finite elements. The results obtained from the Software Strain Gauge are averaged results from the underlying finite elements, modeling the same geometric averaging obtained with actual instrumentation from a physical prototype. Results are transformed to the coordinate system, and alignment of the software strain gauge and results must be surface resolved.

The MSC Fatigue® Strain Gauge

Stress and strain time histories may be extracted at any point on the FE model surface, based on either standard or user-defined strain gauge definitions. The results obtained from the Software Strain Gauge may be based on static, transient, or quasi-static FE loading.

Use of the MSC Fatigue® Strain Gauge allows the FE analyst to correlate theoretical structural integrity calculations with experimentally determined results. This tool permits the engineering analyst greater confidence in the FE model of the real-world structure. Analysis using MSC Fatigue® significantly reduces costs associated with prototyping and testing by simulating fatigue life early in the design phase, thus shortening time-to-market and improving product reliability, customer confidence, and reducing costly recalls or other undesirable consequences of premature product failure. Usage of MSC Fatigue® brings fatigue analysis up front in the design-to-manufacturing process and creates an MCAE environment for integrated durability management.

Capabilities of the Software Strain Gauge

The Software Strain Gauge can extract FE results and combine them with loading time variations to create response time history for the following strain gauges,

- Uniaxial Gauges
- T Gauges
- Delta and Rectangular Gauges
- Stacked and Planar Gauges
- User Specified Gauge Definitions
- Up to 200 simultaneous Software Strain Gauges

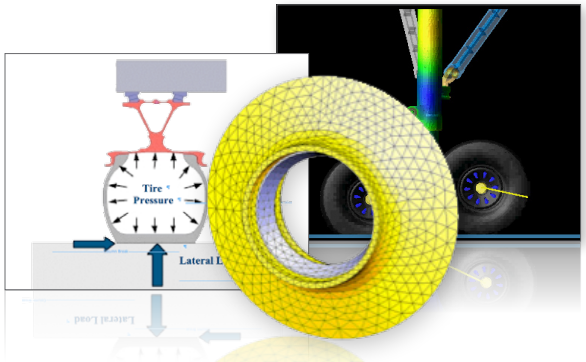
The full range of Stress-Life, Strain-Life and Critical Plane analysis methods can be applied to calculated Strain Gauge results.

The Software Strain Gauge is also of benefit to the analyst performing MSC Fatigue® weld durability calculations in accordance with British Standard 7608. The Gauge tool allows ready access to strain time histories at the weld toe, providing important information for weld durability calculations.

MSC Fatigue® Wheels

MSC Fatigue® Wheels provides a fatigue analysis tool to predict the long-term effects of such cyclic loading.

Fatigue Damage Contour Plot



Predicting Wheel Life

Aircraft wheels play a major role in the takeoffs and landings of an aircraft, whether its a 747 loaded with 568 passengers, the Space Shuttle, or an F-16 Fighting Falcon. Repetitive landings, takeoffs and associated taxi runs subjects the wheels to a considerable spectrum of operational loads that the wheels must withstand time and again. Ensuring that a wheel meets stress and load criteria over time is an important part of the product development process and typically is accomplished by testing physical prototypes. However building and testing a prototype is expensive and time consuming and wheel development programs often require several prototypes be evaluated before the production design is finalized.

MSC Fatigue® Wheels provides a fatigue analysis tool to predict the long-term effects of such cyclic loading. Predicting wheel life for a spectrum of load conditions through simulation using MSC Fatigue® involves determining stress-time histories at nodes in the model for each load condition and determining the critical plane for each node on which the stress-time histories produce the greatest amount of fatigue damage for all load conditions in the spectrum.

MSC Fatigue® Wheels extracts the stress-time histories at each node from the defined FEA solution sets for each load condition, with stress-time histories developed for each user-defined angular increment about each node for every load condition. Mean stress, stress range, and subsequent fatigue damage for each angular increment is calculated. The plane of critical fatigue damage is calculated by summing the fatigue damages obtained for each angular increment.

Aircraft wheels are designed to meet the fatigue life requirements specified by an aircraft manufacturer (OEM). Fatigue life requirements consist of a spectrum of ground load conditions containing combinations of vertical and lateral loads. Each load condition is applied to the wheel for a portion of the required life of the wheel, which is specified in distance (miles or kilometers).

The ground load conditions are specified at the tire to ground interface and actually apply loads to the tire as shown above. The tire in turn imparts a distributed contact pressure on the wheel rim. Since the tire is not included as part of the wheel FEA model, the tire loading of the wheel rim must be determined. The tire contact pressures must be obtained from either experimental measures or from the tire FEA analysis performed by tire manufacturer.

A full FEA transient analysis to obtain the wheel stress fluctuations for each load condition is not feasible. The alternate, but reasonably accurate approach is to perform several linear static FEA for each loading condition. Each incremental static FEA for particular loading condition represents an incremental rotation of the wheel, so all of them together represents the state of stress/strain at any point on the wheel versus time (in terms of wheel rotation angle).

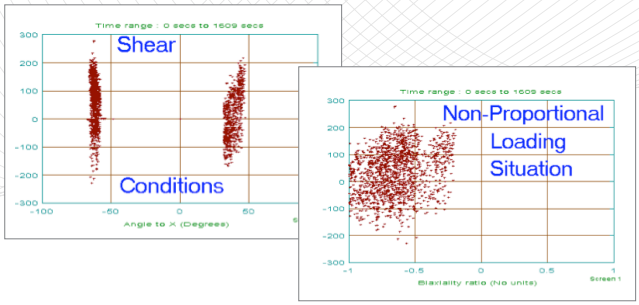
Wheel Rotation

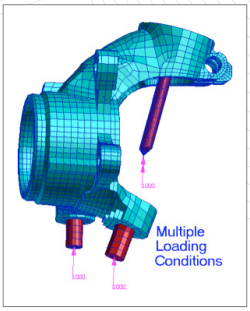
The wheel rotation is represented by rotation of the loads and boundary conditions acting on the wheel. Once the stress/strain “histories” are obtained by performing several linear static FEA for each loading condition, fatigue damage and life are calculated for each loading condition, and the total fatigue damage can be approximated as the sum of damages from all loading conditions.

The total fatigue damage, for each node/element of the wheel model, can be graphically represented as a damage contour plot in the usual way, visually showing the user where the fatigue-critical areas are located. the areas with maximum damage can be further analyzed as required.

MSC Fatigue® Multiaxial

MSC Fatigue® Multiaxial uses stress or strain results from finite element (FE) models, variations in loading, and cyclic material properties to estimate life to failure.



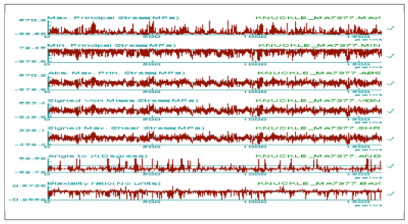


A non-proportional, multiaxial stress state is assumed as opposed to the usual uniaxial or proportional loading states.

The Strain-Life and Stress-Life methods are used in the life prediction and safety factor analyses respectively.

Safety Factor Analysis

Safety factor analysis can be performed over the entire FE model or on a portion thereof. Analysis methods for multiaxial stress states include the Dang Van and McDiarmid methods.



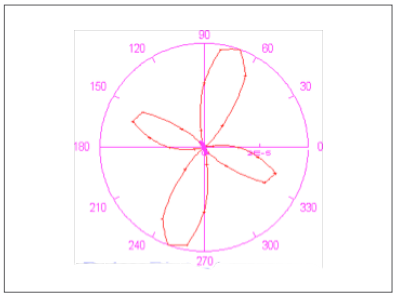
Sophisticated strain-life (crack initiation - e-N) modeling provides a method for estimating life to the “initiation” of an engineering crack from a multiaxial stress state. Six (6) local strain critical plane methods are available. Features include:

- Normal Strain
- Shear Strain
- SWT-Bannantine
- Fatemi-Socie
- Wang-Brown - with and without mean stress correction
- Or all methods at once

Methods of Calculation

These methods include the multiaxial non-proportional notch correction procedure, incorporating an energy-based notch rule based on Neuber’s rule and a Mroz-Garud cyclic plasticity model.

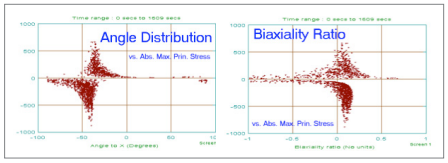
A single shot multiaxial analyzer accepts elastic-plastic rosette stress or strain time histories directly. This input data can be from FE derived histories or measured data.



Polar Plot of Critical Plane Analysis

Methods of calculation include:

- Normal Strain
- Shear Strain
- SWT-Bannantine
- Fatemi-Socie
- Wang-Brown - with and without mean stress correction
- Or all methods at once



Fatigue analysis is performed using stress or strain results from FE models. Results access features include linear static and transient (stresses) FE results data from all Patran™ supported databases:

No limit on number of node or element calculation points

Multiple FE load cases with associated time variations can be defined and applied simultaneously. A time history database is supplied to facilitate creation and storage of these files.

A materials database manager stores and manipulates a library of cyclic material properties.

MSC Fatigue® Pre&Post

MSC Fatigue® Pre&Post provides the required graphical interface to efficiently and easily set up, run and post process an MSC Fatigue® analysis.

MSC Fatigue® Pre&Post uses stress or strain results from finite element (FE) models, variations in loading, and cyclic material properties to estimate life to failure of structures and components.

Features & Functions

MSC Fatigue® Pre&Post gives direct and easy access to all features and functions of the MSC Fatigue® product line including,

- Stress-Life Fatigue
- Strain-Life Fatigue
- Crack Propagation
- Multi Input Vibration Fatigue
- Single Input Shaker Table Fatigue
- Seam Weld Fatigue
- Spot Weld Fatigue
- Multi Axial Fatigue
- Wheels Fatigue
- Fatigue Utilities

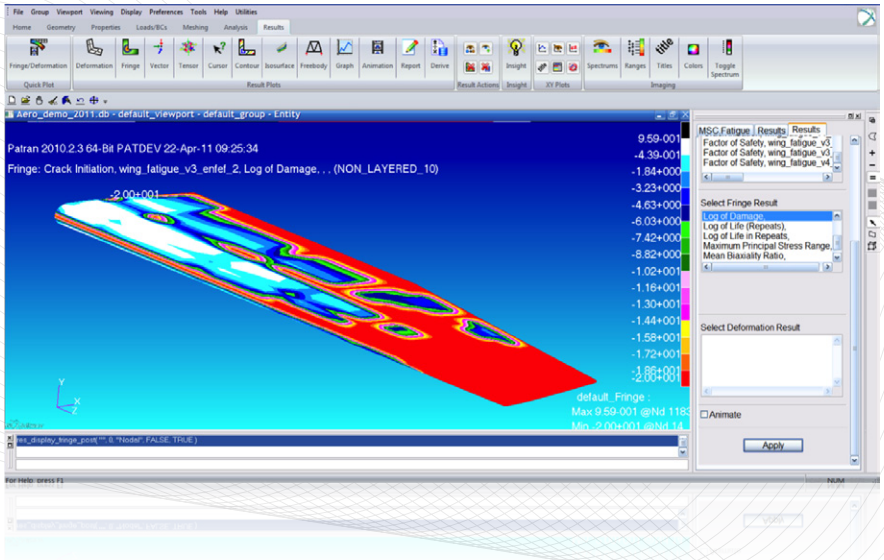
The Pre&Post Environment

The Pre&Post environment is intended for the user who doesn't need the full processing power of Patran™ to run MSC Fatigue® or perhaps has an alternative pre & post for routine day to day pre & post processing work. The Pre&Post environment can easily be modifed to determine sensitivities and optimize designs for durability.

MSC Fatigue® Pre&Post gives access to FE information. Models and results can be imported in a variety of ways: Results access features include linear static and transient (stresses and strains) FE results data from all Patran™ supported databases:

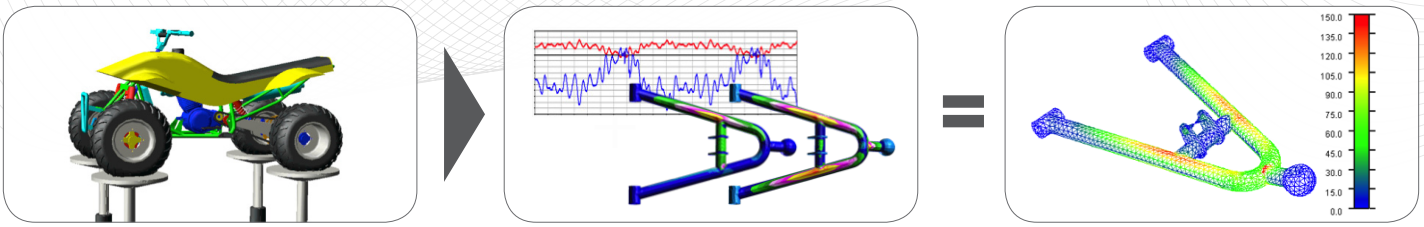
General capabilities exist for easy viewing and manipulation of the model:

- Groups - break the model up into various sections for application of different material and surface finish/treatment combinations
- Model manipulation - rotate, pan and zoom
- Multiple graphic viewports
- Various rendering styles (wireframe, hidden line, shaded) and display properties
- General utilities for coordinate frame creation, node and element attributes
- Associate time or frequency varying loads to FE load cases
- Easily set up fatigue analysis parameters



MSC Fatigue® Utilities

MSC Fatigue® Utilities contains advanced and practical applications to help the MSC Fatigue® user who has a need to collect, analyze and post process measured data, such as stress or strain time histories, or to process such data to prepare for a subsequent MSC Fatigue® analysis.



System Simulation | Modal Coordinates + Stress Shapes | Stress in Component

Advanced Loading Manipulation

Arithmetic Manipulation (MART) is a module which arithmetically manipulates standard loading data files.

Multi-Channel Editor (MCOE) is an interactive alphanumeric editor that allows both the creation of new and the editing of existing time series data files.

Rainflow Cycle Counter (MCYC) is used to process a time series signal by extracting fatigue cycles according to the Rainflow cycle counting algorithm.

Formula Processor (MFRM) is an arithmetic and logical module which can be used to process formulae of varying complexity.

File Cut and Paste (MLEN) is used to extract a portion of data from one file or several files, and load the extracted portions into a new output file.

Multi-File Manipulation (MMFM) is an arithmetic and logical module which can be used to process formulae of varying complexity.

Peak-Valley Extraction (MPVXMUL) extracts turning points from single parameter files such as dac and RPC multiple data - channel files.

Simultaneous Values Analysis DAC/RPC (MSIMMAX) performs simultaneous values analysis on either multi channels in a single RPC file or multiple DAC files from the same test.

Amplitude Distribution (MADA) calculates the probability density distribution and other function of a time signal.

Auto Spectral Density (MASD) performs a frequency analysis of a time signal to determine frequency content.

Fast Fourier Filter (MFFF) creates a finite impulse response (FIR), filter by using the window method.

Butterworth Filtration (MBFL) takes a signal file and passes it through a Butterworth filter to produce an output signal file.

Frequency Response Analysis (MFRA) analyses the response of a single input, single output linear system.

Statistical Analysis (MRSTAT) analyses a time signal and produces a number of statistics about that signal.

Header/Footer Manipulation (MFILMNP) allows both header and extra details manipulation.

Advanced Fatigue Utilities

Single Location S-N Analysis (MSLF) estimates fatigue life using test results using the Stress-Life approach.

Single Location Strain-Life Analysis (MCLF) is the equivalent of MSC Fatigue's Strain-Life module, FEFAT, but in the testing world where the input is a measured strain history from a single location.

Cycle and Damage Analysis (MCDA) calculates and displays cycles and damage distributions so that different test conditions may be compared and the reasons for variations in fatigue damage may be determined.

Time Correlated Damage (MTCD) is a fatigue analyzer that can be used to pin-point fatigue damage within a loading history.

Single Location Vibration Fatigue (MFLF) is a single location, stress-based fatigue analysis module that accepts stress response PSDs as input.

Multi-Axial Life Analysis (MMLF) is a single location multiaxial fatigue analyzer based on the Strain-Life approach.

Crack Growth Data Analysis (MFCG) calculates the Paris Law coefficient and exponent from actual raw test data obtained under constant amplitude loading conditions.

Kt/Kf Evaluation (MKTAN) stores and retrieves values for stress concentration factor (Kt) solutions for geometric details, and calculates Kt and Kf.

Graphical Display & Conversion Utilities

Graphical Editing (MGED) is the multi-channel interactive graphical editor for time series data allowing online manipulation of a signal.

Multi-File Display (MMFD) displays single parameter data files.

Quick Look Display (MQLD) displays single channel data files.

Two Parameter Display (MTPD) and Polar Display (MPOD) display pared (X-Y) data files.

Three Dimensional Display (MP3D) is the histogram and waterfall display module.

Binary/ASCII Convertor (MDTA/MATD) converts a single parameter, X-Y, or histogram binary file into ASCII format.

Signal Regeneration (MREGEN) can regenerate a single parameter signal files from a three parameter range-mean cycles histogram file (cyg type), a three parameter maximum-minimum cycles histogram file (cyh type), a three parameter Markov Matrix (mkh type), and generate a Gaussian series from a user supplied irregularity factor and save it as a dac file.

RPC to DAC - DAC to RPC - (MREMDAC/ MDACREM) extracts channels of data from MTS RPC remote parameter (RPC) files, and creates a single dac file for each channel of the RPC file.

Cross-Platform Conversion (MCONFIL) is a binary to binary file conversion program for transfer of files across multiple platforms.

Waterfall File Create (MWFLCRE) creates a three parameter waterfall file from multiple single parameter files.

MSC Products

Simulating Reality, Delivering Certainty

Integrated Solutions

Adams
Multibody Dynamics Simulation

Actran
Powerful Acoustic Simulation Software

Digimat
Advanced Materials

Easy5
Advanced Controls Simulation

Marc
Advanced Nonlinear & Multiphysics

SimXpert
Multidiscipline Simulation

Solver Solutions

MSC Nastran
Multidisciplinary Structural Analysis

Dytran
Explicit Nonlinear & Fluid Structure Interaction

MSC Fatigue
Fatigue Life Prediction

Sinda
Advanced Thermal

Mid-Sized Business Solutions

MSC Nastran Desktop
Multidiscipline Simulation for the Desktop

SimDesigner
CAD-Embedded Multidiscipline Simulation

Modeling Solutions

Patran
FE Modeling and Pre/Post Processing

SimXpert
Multidiscipline Simulation Environment

Engineering Lifecycle Management

SimManager
Simulation Process & Data Management

MaterialCenter
Materials Lifecycle Management

Our products, services & people are used by 900 of the top 1000 manufacturers in the world, including:

- Aerospace & Defense
- Automotive & Transportation
- Agricultural Equipment
- Heavy Machinery
- Medical Devices
- Oil and Gas
- Nuclear
- Renewable Energy
- Consumer Products
- Packaging
- Electronics

About MSC Software

Simulating Reality, Delivering Certainty

MSC Software is one of the ten original software companies and the worldwide leader in multidiscipline simulation. As a trusted partner, MSC Software helps companies improve quality, save time and reduce costs associated with design and test of manufactured products. Academic institutions, researchers, and students employ MSC technology to expand individual knowledge as well as expand the horizon of simulation.

MSC Software's engineering simulation technology is used by leading manufacturers for linear and nonlinear finite element analysis (FEA), acoustics, CFD, multi-physics, optimization, fatigue and durability, multi-body dynamics, and control systems simulation. The company's products accurately and reliably predict how products will behave in the real world to help engineers design more innovative products - quickly and cost effectively.

Company Profile

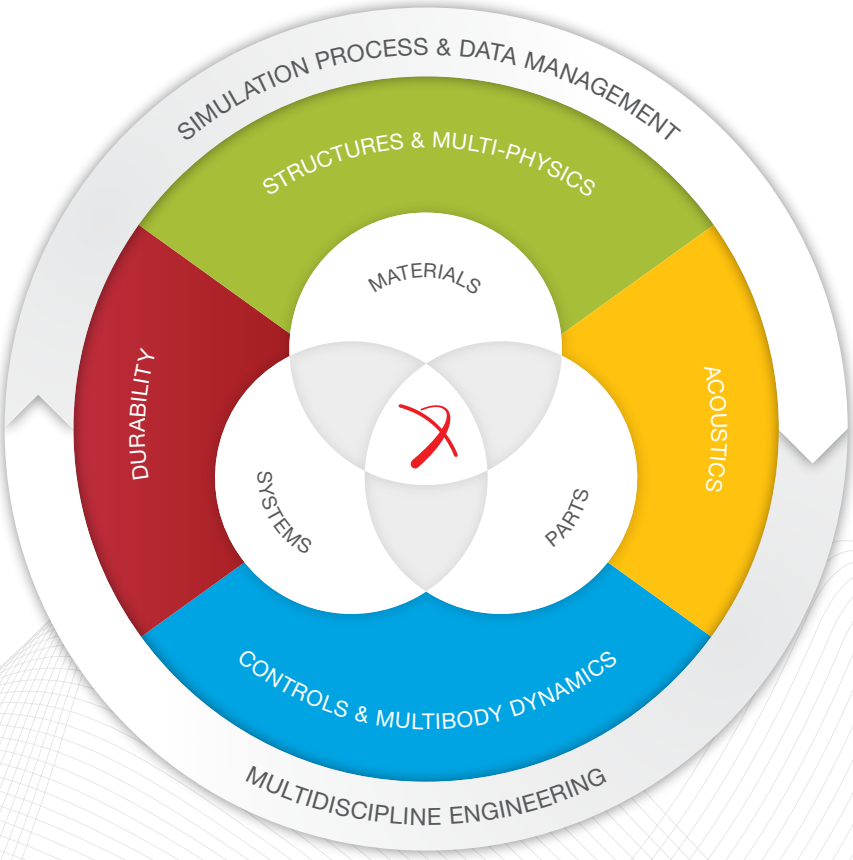
MSC Software Corporation was formed over 50 years ago and was awarded the original contract from NASA to commercialize the finite element analysis (FEA) software known as Nastran (NASA Structural Analysis). MSC pioneered many of the technologies that are now relied upon by industry to analyze and predict stress and strain, vibration & dynamics, acoustics, and thermal analysis in our flagship product, MSC Nastran.

Over our rich history, MSC has developed or acquired many other well known CAE applications including Patran, Adams, Marc, Dytran, Fatigue, SimXpert, SimDesigner, SimManager, Easy5, Sinda, and Actran. We are committed to the continued development of new CAE technology that integrates disciplines and technologies from standalone CAE tools into unified multi-discipline solvers and user environments. These "next generation" products enable engineers to improve the reliability and accuracy of their virtual prototypes by including multi-physics and multi-discipline interactions.

MSC is also the CAE industry's leader in extending simulation to the engineering enterprise. Our customers recognize the need to scale the benefits of virtual prototyping and testing from pockets of experts to mainstream engineering and product development, and MSC offers the only Simulation Data and Process Management platform in the world that has been successfully deployed in industries including automotive, aerospace, shipbuilding, electronics, and more MSC Software employs 1,000 professionals in 20 countries.

MSC Software Products

MSC Software makes products that enable engineers to validate and optimize their designs using virtual prototypes. Customers in almost every part of manufacturing use our software to complement, and in some cases even replace the physical prototype “build and test” process that has traditionally been used in product design.



MSC Fatigue®

Predict Fatigue Life from Finite Element (FE) Models Fully Modularized and Customized to Suit Your Needs

MSC Software is one of the ten original software companies and the worldwide leader in multidiscipline simulation. As a trusted partner, MSC Software helps companies improve quality, save time and reduce costs associated with design and test of manufactured products. Academic institutions, researchers, and students employ MSC technology to expand individual knowledge as well as expand the horizon of simulation. MSC Software employs professionals in 20 countries.

For additional information about MSC Software's products and services, please visit: **www.mscsoftware.com.**

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