



3DEXPERIENCE

**fe-safe<sup>®</sup>**  
DURABILITY ANALYSIS SOFTWARE  
FOR FINITE ELEMENT MODELS



# FE-SAFE

## OVERVIEW

fe-safe® is the technical leader in fatigue analysis software for Finite Element models. It offers its users the most accurate and advanced fatigue analysis technology for real-world industrial applications.

fe-safe is used by leading companies in automotive, heavy truck, off-highway, marine, defense, offshore, power generation, wind energy, medical engineering and many other industries.

fe-safe has been developed continuously since the early 1990's in collaboration with industry to ensure that it continues to set the benchmark for fatigue analysis software.

fe-safe was the first commercially available fatigue analysis software to focus on modern multiaxial strain based fatigue methods.

fe-safe provides unique capabilities for thermomechanical fatigue and creep-fatigue, the fatigue analysis of composite materials, the fatigue analysis of elastomers and the Verity® Structural Stress Method for welded joints.

fe-safe is renowned for its accuracy, speed, comprehensive capabilities and ease of use.

Regardless of the complexity of your fatigue analysis, fe-safe fits smoothly into your design process, enabling you to develop products that are designed for durability.



## INTRODUCTION

Industry is putting increasing pressure on manufacturers to use less material to deliver lightweight but stronger components, lower warranty and recall costs and all in less time.

Many companies use advanced Finite Element Analysis to calculate design stresses, but the fatigue analysis is often still done by manually picking stress points for spread-sheet analysis. This is time-consuming and unreliable because it is easy to miss failure locations.

Component validation by fatigue testing a prototype design in the test lab is time-consuming. If the prototype fails prematurely, a costly, open-ended cycle of design-test-redesign may be required. Project time-scales slip and delivery is late.

## KEY BENEFITS

With fe-safe as an integrated part of your design process, you have the ability to:

- Optimize designs to use less material
- Reduce product recalls and warranty costs
- Optimize and validate design and test programs
- Improve correlation between test and analysis within a single user interface
- Reduce prototype test times
- Speed up analysis times, thereby reducing man-time hours
- Increase confidence that your product designs pass their test schedules as "right first time"

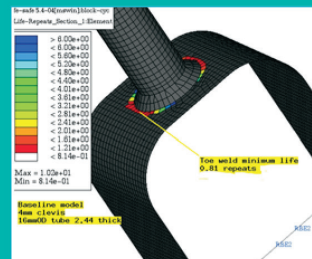
## Durability by design—advanced multiaxial algorithms are the core of fe-safe

### CASE STUDY

#### Weld fatigue analysis of a prototype rear trailing arm link

Test results to crack initiation: **0.83 repeats of block cycle test**  
fe-safe fatigue life prediction to crack initiation: **0.81 repeats**

Ford Motor Company



# WORKFLOW

## LOADINGS

**fe-safe can predict fatigue lives from a range of loading types:**

- Single load time history applied to a linear elastic Finite Element model
- Multiple time histories of loading superimposed in fe-safe (more than 4000 load histories can be applied)
- Sequence of FEA stresses (elastic or elastic-plastic, linear or non-linear)
- Superimposition of steady state modal solutions
- Superimposition of transient dynamic modal solutions
- PSD loading, block loading test programmes, rainflow cycle matrices
- Effects of forming or assembly stresses can be included

fe-safe includes a powerful, simple-to-use batch command system, with on-line parametric variation for 'sensitivity' studies.

Standard analyses can be set up and saved for re-use.



## ANALYSIS METHODS

**fe-safe includes a wide range of analysis methods, all of which are included in the standard package:**

- Strain-based multiaxial fatigue algorithms—axial strain, shear strain, Brown-Miller with a multiaxial Neuber's rule and cyclic plasticity model
- S-N curve analysis including multiaxial fatigue using axial stress or a new Brown-Miller analysis formulated for use with S-N curves
- Dang Van multiaxial fatigue for high cycle design
- Plots of material data including the effect of temperature, strain rate etc.
- Advanced analysis methods for fatigue of cast irons
- Analysis of welded joints
- High temperature fatigue
- Analysis from elastic and elastic-plastic FEA stresses, linear and non-linear analysis
- Automatic detection of surfaces
- Automatic detection of fatigue hot-spots
- Comprehensive element/node group management
- Stress gradient corrections
- Critical distance algorithms
- Critical plane methods for random vibration fatigue
- Analysis of rotating parts

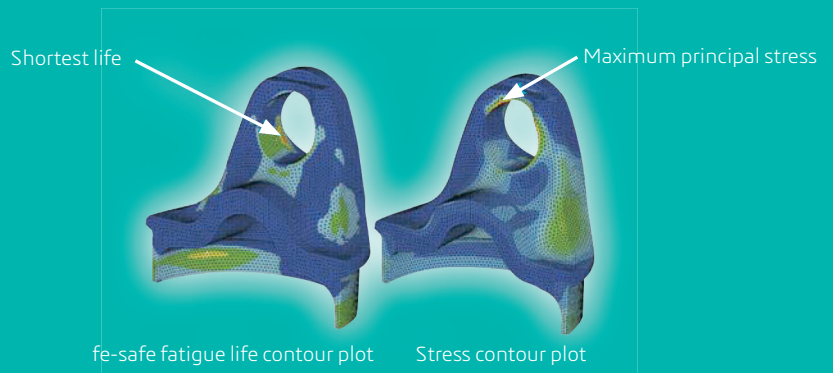
## Cracks may not occur at the locations of maximum stress

### CASE STUDY

**Fatigue analysis of a tube yoke suspension component**

"fe-safe results were confirmed by lab tests on actual loaded specimens"

Dana Automotive Systems Group, LLC

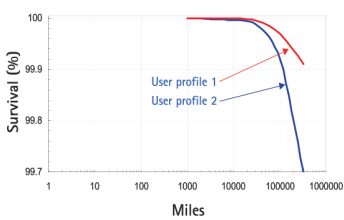
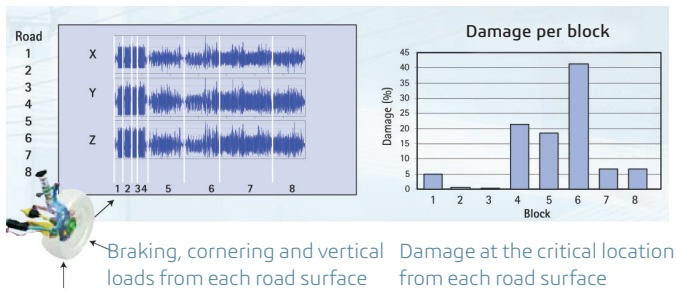




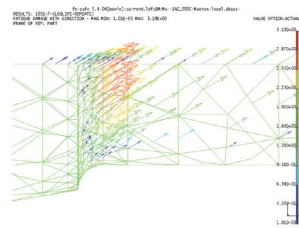
## OUTPUT

**fe-safe outputs a wide range of results, in a single run:**

- Contours of fatigue life show crack initiation site
- Contours of stress-based factors of strength for a specified design life—to show how much the stresses must be changed to prevent failure or to reduce material
- Probability of survival for specified lives (the 'warranty curve')
- Which loads need to be included in a test program
- Contour plots of maximum stress during loading
- Detailed results – time histories of stresses and strain, Haigh and Smith diagrams, Dang Van plots and many more in order to explain the rationale behind the life prediction
- Damage at the critical location from each loading block—for example each road surface on a test track
- Vector plots identifying critical damage planes



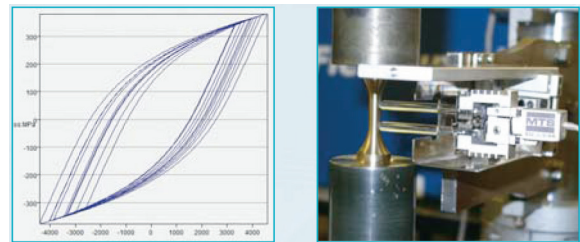
Estimated 'warranty curve' for two user profiles, combines material variability and load variability



Vector plot identifying the orientation of critical damage planes

## Material database

- Comprehensive material database of strain-life and S-N curve properties, fully validated and cross-referenced to international standards
- Equivalent specifications allow searching on US, European, Japanese and Chinese standards
- Users can add their own materials and material parameters
- Strain-life and S-N data is included
- Data has been reanalyzed and correlated with different international standards
- Chemical composition and heat treatment data
- Trace-back to original references



## Testing services

A wide range of testing services are available to support fe-safe, for example, multiaxial fatigue, thermo-mechanical and creep-fatigue, welded joints and composites testing. Material testing includes both S-N and strain-life tests under different loading and temperature regimes. Test results are analyzed and provided in reports and in formats that allow users to add material data to the fe-safe material database.

## Critical plane multiaxial stress-life & strain life methods are included as standard

### CASE STUDY

**fe-safe fatigue life contour plot**

**"fe-safe results were confirmed by lab tests"**

**Raufoss Technology**



## KEY QUESTIONS

fe-safe helps you answer these questions:

### What is the fatigue life of this component?

fe-safe uses advanced critical plane multi-axial fatigue with in-built plasticity modelling to post-process results from an elastic FEA. Results can be displayed as contour plots showing crack locations and fatigue lives.

### Will cracks propagate?

fe-safe uses critical distance methods to check whether cracks will propagate. Allowing cracks to initiate but not propagate to failure may allow higher working stresses and lighter and more efficient designs.

### Where can material be saved? Where must extra material be added?

fe-safe calculates the allowable stresses or loads to achieve a specified service life. This is the factor of strength (FOS).

fe-safe fully accounts for any changes in plasticity that may be caused by changes to loads or stresses.

fe-safe shows how much the design is over-strength or under-strength at each node. Results are displayed as contour plots.



### How reliable is this design?

The 'warranty claim' calculation combines variability in material strength and variability in loading to estimate the proportion of components un-cracked after any period of time in service. This can be used to achieve uniform reliability over different parts of an assembly.

Factor of Strength (FOS) and Probability of Survival calculations can be combined with the initial fatigue life calculation in a single run. Together they show the interaction between design stress margins and component reliability.

### Which loads are causing fatigue damage?

fe-safe performs a load sensitivity analysis to show the effect of each applied load. This can be used to refine the design and to design and validate an accelerated fatigue test.

Once the critical and non-critical loads have been identified, test programs can be optimized and validated by removing unrepresentative tests.

### What is causing fatigue cracking?

fe-safe can provide detailed results for hot-spot areas or individual elements or nodes, time histories of calculated stresses and strains, fatigue cycle and damage histograms, Haigh and Smith plots and many other graphs to explain why the fatigue life is what it is.

## Different parts of an assembly may need different design stress margins to achieve the same level of reliability

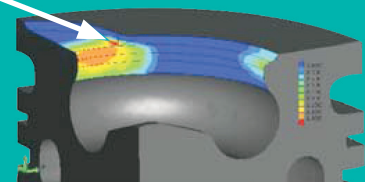
### CASE STUDY

#### Fatigue cracking of a diesel piston

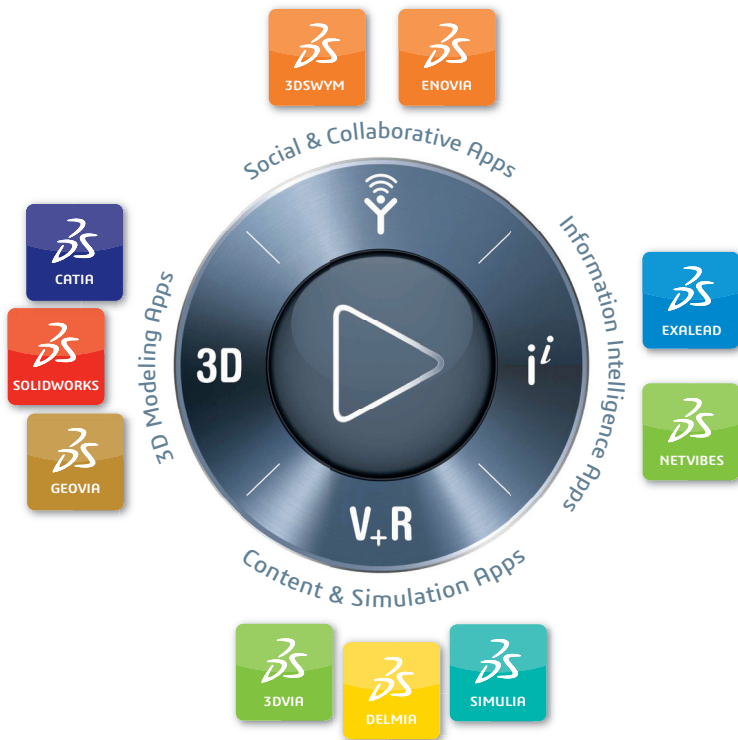
"fe-safe accurately predicted the location and time to crack initiation"

Federal Mogul Technology, USA

Crack initiation site



fe-safe fatigue life contour plot



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