DASSAULT SYSTEMES

SIMULIA

3DEXPERIENCE

VERITY MODULE IN fe-safe®

WELD FATIGUE AND DURABILITY ANALYSIS SOFTWARE FOR FINITE ELEMENT MODELS

INDUSTRY CHALLENGES

Industry is putting increasing pressure on manufacturers to use less material to deliver lightweight but stronger components, less warranty and recall costs and all in less time. Traditional methods of over-engineering components and expensive, open-ended test-redesign-test programs are not meeting the needs of the modern engineering company.

For welded joints and welded structures, the prediction of failure locations and the calculation of fatigue lives are notoriously complex and difficult tasks, which can often result in poor correlation with test data.

SOLUTION

Released in 2005, the Verity® Module in fe-safe®, from the SIMULIA brand of Dassault Systèmes, is the first commercially available and the only patented Structural Stress Method for the fatigue analysis of welded joints. It is a highly validated method, the accuracy of which has been assessed using more than 3500 physical fatigue tests results for welded joints. The Verity mesh-insensitive Structural Stress Method was originally developed and patented by Battelle. It is recognized as a major breakthrough in the fatigue analysis of welded joints for Finite Element models.

The Verity Module in fe-safe combines Verity for the fatigue of welded structures with the advanced features of fe-safe for fatigue analysis for Finite Element models. It allows companies to reduce or avoid the expense of testing to validate the integrity of designs and avoid the common practice of over-engineering due to the uncertainty of fatigue life.

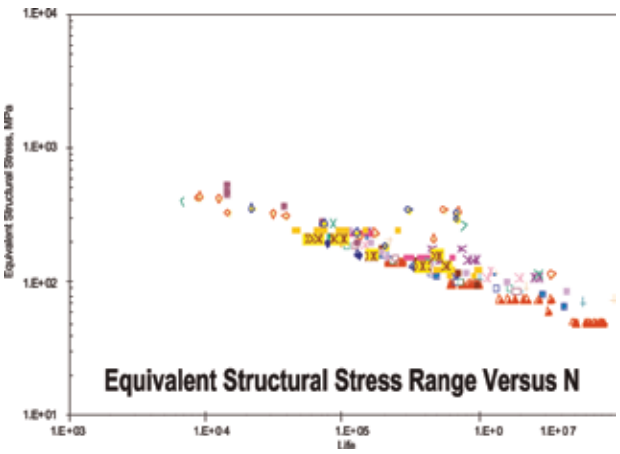
SUMMARY

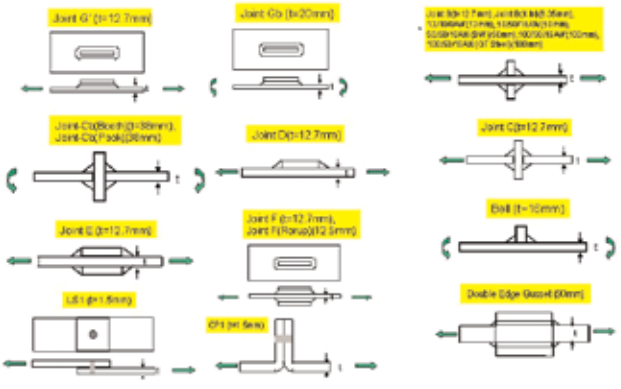
- Offers new levels of accuracy and reliability
- Is mesh-insensitive
- Can be applied to all types of welds and all types of loading
- Removes the subjectivity from welded joint fatigue
- Is not just for the fatigue of welded joints. It can also be applied to other sharp notches such as thread roots
- Is easy to use and automate

KEY BENEFITS

- Welded joints and non-welded areas can be analyzed in a single run and the results displayed on the same contour plot, thereby speeding up whole model analyses
- Significant reductions in CAE and FEA modeling time
- Lower development costs as a result of minimizing the need for physical validation testing
- Inspecting and testing components against fatigue criteria can lower "classification" or regulatory compliance costs
- Optimized designs and lighter structures as a result of less reliance on over-designing to account for uncertainty
- Direct interfaces to leading FEA suites such as Abaqus, ANSYS, I-deas and Nastran (MSC, NEi, NX) are driven from an intuitive, single screen, Windows-based GUI
- The Automatic Weld Finder improves usability by simplifying and accelerating weld configuration
- Spot welded joints are automatically detected, thereby minimizing the need for user input and accelerating the analysis process
- Increased automation removes subjective decisions by the user, thereby increasing reliability and accuracy

Removes subjectivity from welded fatigue analysis





VALIDATION

Verity has been validated for applications ranging from the automotive to offshore/marine industries through collaboration with leading engineering companies who are members of Battelle's Joint Industry Project (JIP). The effectiveness of the method has been demonstrated by collapsing into a single curve many thousands of fatigue tests from lab specimens and full-scale components, obtained and verified from open literature. This is the 'master S-N curve'.

Verity has received many prestigious awards including: TIME Magazine's Math Innovators (2005), Aviation Week and Space Technology's 2004 Laurels Award; and SAE's Henry Ford II Distinguished Award for Excellence in Automotive Engineering (2003). Business Week dubbed Verity as "A Bolt of Genius in Welding" (2004).

ASME & API Codes Standards

Verity is cited as an approved method in:

- ASME Section VIII, Division 2, Part 5 Design By Analysis
- API 579-1/ASME FFS-1 Fitness-For-Service

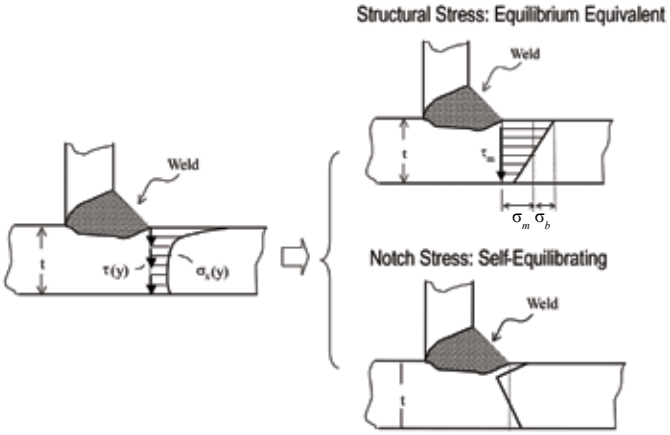
Industry experts estimate that the demonstrated effectiveness of Verity will save hundreds of millions – if not billions – of dollars in engineering, testing and manufacturing costs.

TECHNOLOGY OVERVIEW

The complex stress distribution at the weld toe is separated into two components. A structural stress is calculated from the nodal forces at the weld. This provides the far-field stress that controls most of the crack growth at the weld. It allows for the effects of axial and bending forces. The local notch effect at the weld is calculated using fracture mechanics. The effects of changes in stiffness as the crack propagates are also included.

This method of combining far-field stress, local notch stress and changes in compliance, together with the mesh insensitivity that results from using nodal forces, is unique to the Verity method. It is covered by a number of patents.

The Verity Structural Stress Definition



Validated by Blue Chip engineering companies as part of Battelle's Joint Industry Project

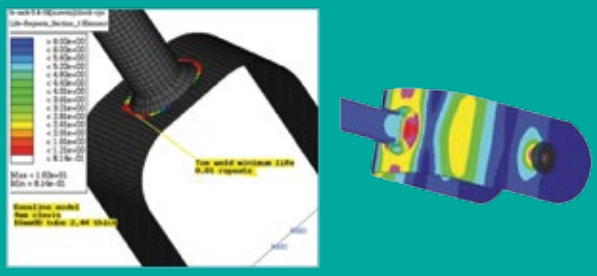
Case Study

Weld Fatigue Analysis of a Prototype Rear Trailing Arm Link

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

"Verity Module in fe-safe enables Ford to run quick iterations/DOE with higher confidence than other methods."

–Ford Motor Company



KEY FEATURES

- Verity is based on nodal forces at the weld toe – not some subjective distance from the weld toe
- Nodal forces are much less sensitive to mesh density than standard FEA stresses. An analysis based on nodal forces, and therefore Verity, is mesh-insensitive
- A single master S-N curve can be used for all welds, be they structural welds, seam welds, spot welds, solder joints... for all thicknesses of sheet and plate and for all types of loading

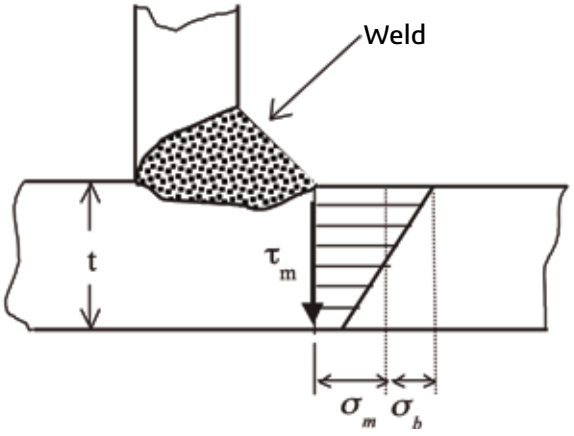
Therefore there are no subjective decisions to be made by the user

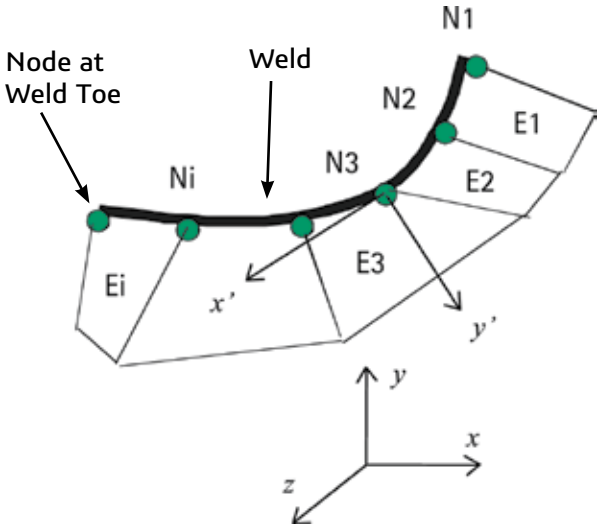
- Offers consistent Structural Stress calculations regardless of mesh size, element types, or the FE software used - a critical step to realizing Six Sigma in CAE applications
- Can be used with coarse meshes of solid or shell elements
- Allows the option of further improving the accuracy of fatigue life predictions by allowing the user to formulate their own custom master S-N curve based on proprietary data
- Is available as an add-on module in fe-safe - enabling users to include the effects of complex loading histories, multiaxial fatigue and other advanced capabilities
- Is supported by tools from SIMULIA and also third-party tools from Altair, ANSYS and BETA CAE Systems for simplifying the definition of weld domains
- Automatic Weld Finder automatically detects seam welds
- Toe, root and throat crack planes are automatically identified
- Fatigue lives for all potential modes are calculated

Fatigue of spot welds

- Supports spot welds modeled with Abaqus, Nastran and ANSYS
- Welds may join 2, 3 or 4 sheets – automatically detected
- Sheet thicknesses are automatically detected
- Nugget size may be specified or defaulted
- Calculates if failure is in the sheet or the nugget
- This methodology is unique to Verity Module in fe-safe

Structural Stress: equilibrium equivalent





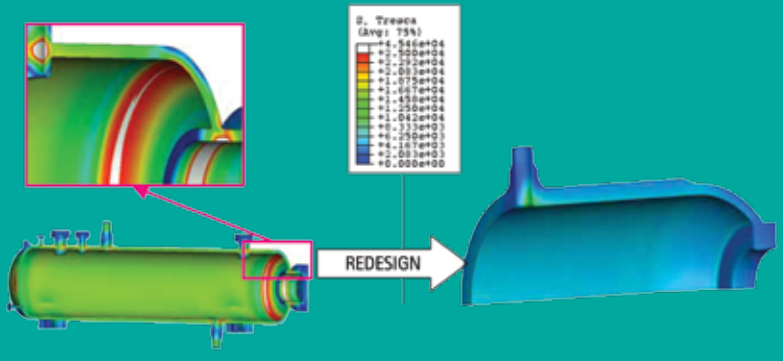
A single S-N curve can be used for all types of welds

Case Study

Redesign of a Critical Component for Higher Fatigue Life

"Verity Module in fe-safe allows our clients to effectively manage the reliability of their cyclic equipment, which ultimately leads to improved safety and considerable economic advantages."

–Robert Brown, Director of Consulting, Equity Engineering Group



CAPABILITIES OVERVIEW

FEA models

- Inputs are usually nodal forces from elastic FEA, so that the results can be scaled and superimposed
- Analysis of solid and shell elements can be mixed in the same model. No in-built limit to the number of elements in the model or the file size. 64-bit file readers allow large files to be analyzed
- Temperature data can be accessed for high temperature analysis
- FEA results from several files can be concatenated
- Interfaces to ABAQUS (.fil and .odb), ANSYS (.rst), MSC. Nastran (.op2 & .f06), NX Nastran (.op2 & .f06), NEiNastran (.op2 & .f06), I-deas (.unv), Altair Hypermesh & Optistruct, PATRAN, FEMSYS, BEASY, CADFIX, ANSA and others. All interfaces included as standard
- Intelligent pre-scanning and load case selection, meaning that the whole model file need not be read into fe-safe

Component loading

fe-safe can analyze very complex load conditions.

- A time history of component loading can be applied to the results of a 'unit load' linear elastic FEA analysis
- Time histories of multi-axis loading can be superimposed to produce a time history of the stress tensor at each location on the model (fe-safe supports superimposition of over 4000 load histories of unlimited length)
- A sequence of FEA stresses can be analyzed. For example, the results of a transient analysis; the analysis of several rotations of an engine crankshaft; or models of several discrete loading conditions
- Sequences with hundreds of thousands of data points are supported
- Mode shapes from steady state dynamics can be superimposed to calculate fatigue life
- PSDs of loading and FEA results from steady state and random vibration analysis can be analyzed
- Block loading programs can be produced and analyzed
- Complex test programs and 'proving ground' sequences can be produced easily
- High and low frequency loading can be superimposed with automatic sample rate matching by interpolation. An example is a thermal cycle with superimposed high frequency loading
- Supported file formats include .DAC, single and multi-channel ASCII, Safe Technology .amc file, RPCIII, Servotest, Snap-master and other files. All file formats are read directly, without file converters

These load conditions can be combined and superimposed with great flexibility. PSDs, dynamics, rainflow matrices and other capabilities are included.

Materials data

- Verity master S-N curves for steel and aluminum alloy welds are provided, for various probabilities of survival
- Users can add their own master S-N curves

Analysis

- Cycle-by-cycle fatigue damage calculation
- Long complex time histories of loading can be analyzed
- Welds can be modeled using solid or shell elements
- For double-sided welds both sides can be analyzed at the same time
- Weld toe, weld throat and weld root fatigue can be analyzed
- ASME Structural Stress Method (ASME Section VIII, Division 2)

Output

All contour plots can be generated in a single analysis run.

- Fatigue lives at each node or element (3D contour plot) in user-defined units, e.g. miles, flights, hours
- Maximum stress at each node during the fatigue loading, and max stress/yield stress, max stress/tensile strength (all 3D contour plots)
- Load sensitivity shows the effect of each load history on the total fatigue damage
- For complex block loading sequences, the fatigue damage from each block can be output
- Time histories of nodal forces and stresses at selected nodes or elements
- A text file of user inputs, analysis type and a results summary is produced for QA trace-back

Signal processing and analysis

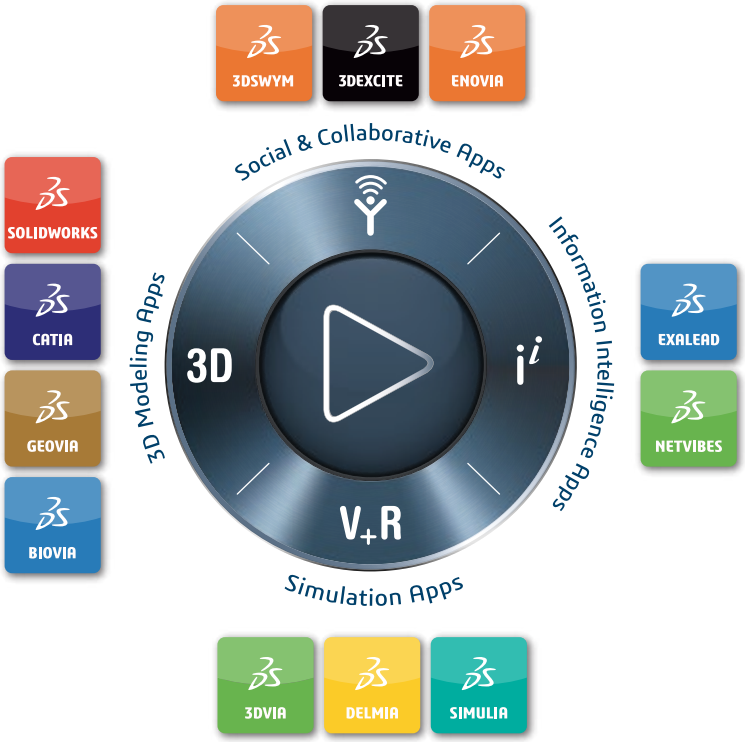
Verity Module in fe-safe includes all the safe4fatigue™ features for signal processing and fatigue analysis from measured data.

- Digital filters, spike removal and noise shaping
- Interactive multi-channel editing with immediate graphics display
- Single and multi-channel peak/valley time-slicing with cycle omission
- Manipulation and powerful re-scale/combine functions for signals, cycle matrices and load spectra
- Full suite of amplitude and frequency analysis, including rainflow cycle counting, PSDs, transfer functions
- Comprehensive fatigue analysis from strain gauges, including a new multiaxial fatigue analysis suite
- Fully featured graphics display and hard copy

Licensing

- Networked license manager/controller (including mixed LINUX and Windows networks)
- Parallel processing comes as standard
- Distributed processing - rapid analysis using multiple licenses for distributed processing across a network.

This is not a complete list of features in the Verity Module in fe-safe.



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