GUIDE TO WELD CERTIFICATION

INTRODUCTION

Welded assemblies are widely used across industrial sectors. The design processes in rail, construction, marine, heavy machinery, pressure vessel construction, and many other industries rely heavily on regulations, codes, and norms such as FKM, DVS-1612, and Eurocode-3. Fatigue strength analysis of welded joints can simulate and evaluate weldment performance against common design codes using results from finite element analysis (FEA).

Weld lines and spotwelds are used in many products and need to be verified during the product development process. Usually these verifications are done based on static and/or fatigue requirements. But the verification process in various industries is characterized by diverse sets of input data that are required to perform the complex calculations. Weld constructions have a vast number of weld lines to consider and during the verification process the critical weld lines need to be identified easily. This makes weld verification to be a repetitive and time-consuming process which includes a substantial amount of manual work.

Virtual Weld Certification

Learn how a process for partially automated mathematical verification of the weld seams can improve outcomes for those in the railroad industry, mechanical engineering, shipbuilding, and vehicle construction who want to make the evaluation and certification of welded constructions more efficient and reliable to exploit optimization potentials.

The rapid identification of low-risk weld seams saves production costs. The use of structural optimization for weld seam utilization to enable significant weight savings can be realized to meet sustainability goals.

IDENTIFYING ISSUES IN THE WELD CERTIFICATION PROCESS

Weld lines are key for structural integrity, product durability, and more, so weld line certification is mandatory for many products with relevant regulations. But the analysis and certification of weld structures can fail due to many different problems.

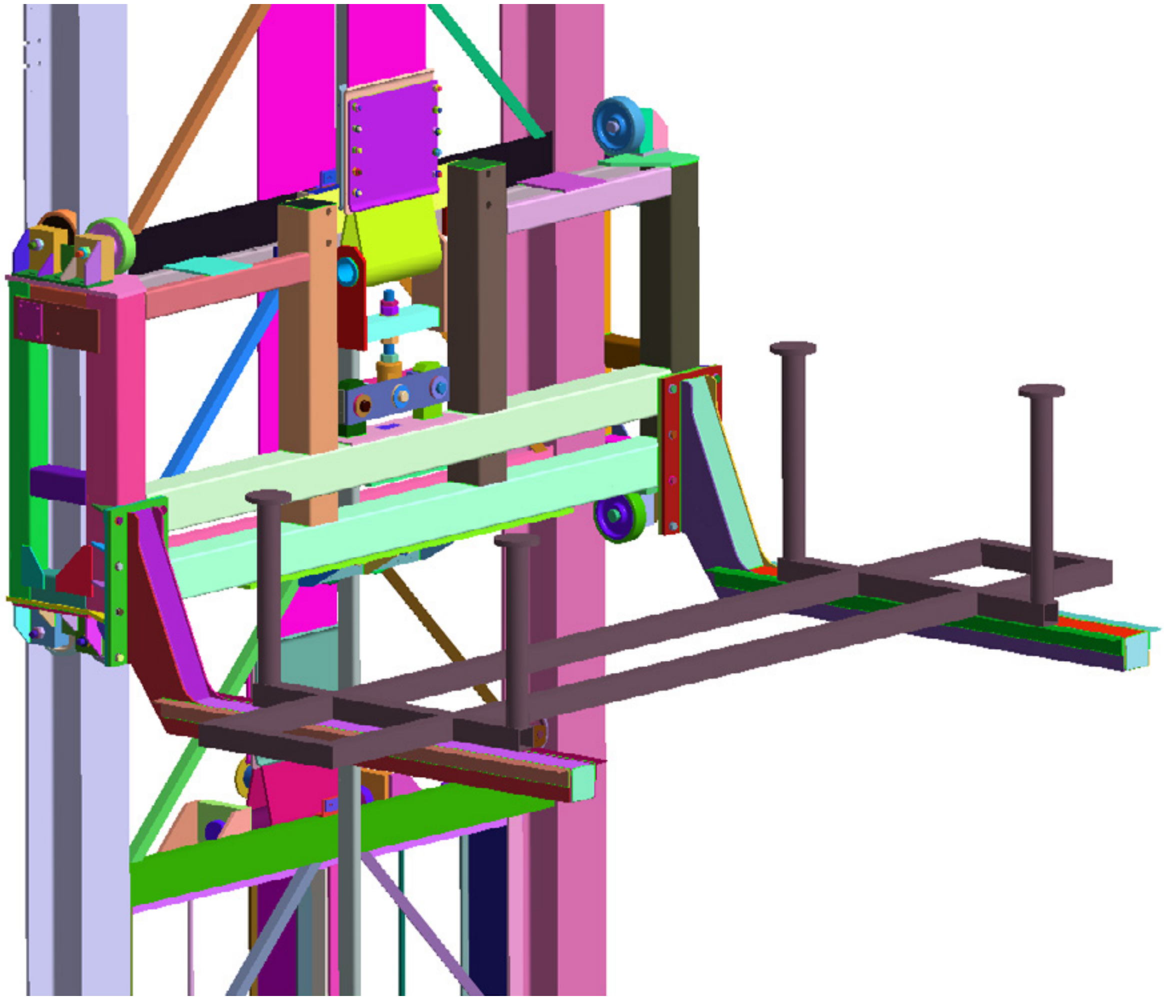
Consider this list to reveal what may slow down your weld certification:

- CAD tool and CAE simulation practice do not model the weld lines consistently
- Non-conventional fatigue evaluation methods for regulations are not understood by all contributors to the process
- Commercial products don't meet individual needs for custom methods
- Standard process and platform cannot handle the changing product configurations
- Effort in modeling and validation of welds due to the large number of welds delays the development
- Validation against various methods and standards results in inconsistent processes

"Avoid costly rework or repairs in later life...

Run traditional weld fatigue calculations, and also evaluate welds to specific standards and regulations such as FKM, EC3, and DVS1612."
Stephen White, Technical Support Manager, Altair

Watch Fatigue Design for Welded Structures Webinar



The choice of weld connections is limited only by the creativity of designers as they consider the accessibility of the weld area in the welding sequence.

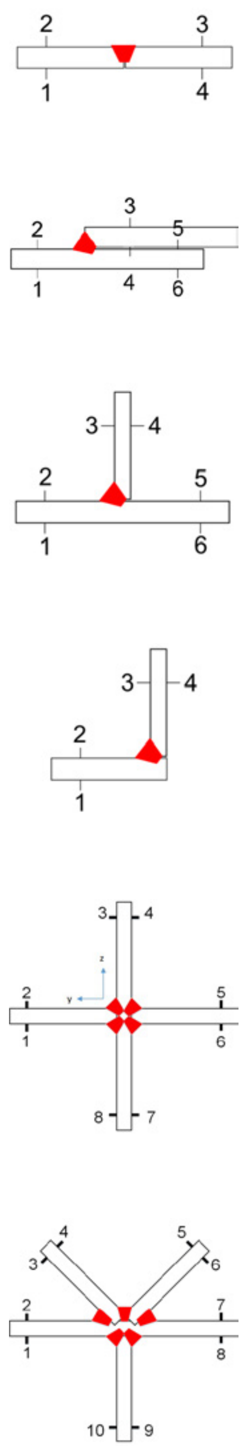
ANALYTICAL WELD ASSESSMENT

The choice of weld connections is limited only by the creativity of designers as they consider the accessibility of the weld area in the welding sequence. The wide variety of joints that must be considered for verification can become a challenge, especially when users want to connect a simulation-driven process encompassing the norms and regulations with which they must comply.

When discussing weld connections, it is important to distinguish between the joint and the weld. Weld types and joints must be described to completely explain the weld connection.

Joints are combined with welds to make weld joint. There are five primary joints used in welding: butt joint, corner joint, edge joint, lap joint, and tee joint. These meet a variety of weld types: fillet welds, groove welds, surfacing weld, plug weld, slot weld, flash weld, seam weld, spot weld, upset weld.

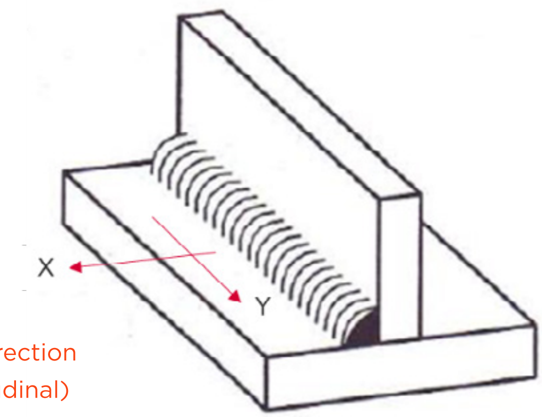
A simulation tool used for weld assessment must be capable to handle this variety and provide a standard process and platform to handle changing product configurations. This is a key success factor to improve the quality, speed, and robustness of the development process.



A selection of possible weld connections and their evaluation points.

WELD STRESS COMPONENTS

The evaluation of a weld seam must consider the different stress components to which the weld is subjected. These stress components can be determined in longitudinal and perpendicular to the weld seam and as shear stress in the plane. The weld assessment is always performed regarding three directional stress components:



σx – stress perpendicular to weld direction
σy – stress in weld direction (longitudinal)
τxy – shear stress in x/y-plane

These three stress components are compared to a limit value which is derived from the weld detail specific Wohler curve and finally combined to an equivalent utilization value.

REGULATORY COMPLIANCE

Norms and regulations for the assessment of welded structures can fill meters of bookshelves. Identifying what is important to accommodate in a digital development process and setting up the evaluations according to defined standards as well as individual evaluation methods can become a challenge.

The most important norms and regulations in the industry for weld assessment and certification are DVS , EuroCodes, and the FKM guideline.

- DVS is used primarily in the development of railroad vehicles.
- FKM is a regulation that applies to a wide variety of industries but is predominantly used in industrial machinery.
- Eurocode is most often used in steel construction and civil engineering projects.

While these regulators are applied in different industries, they also vary from each other. DVS and FKM analyze and assess the "utilization," Eurocode identifes the "damage" value of a weld.

FKM Guideline

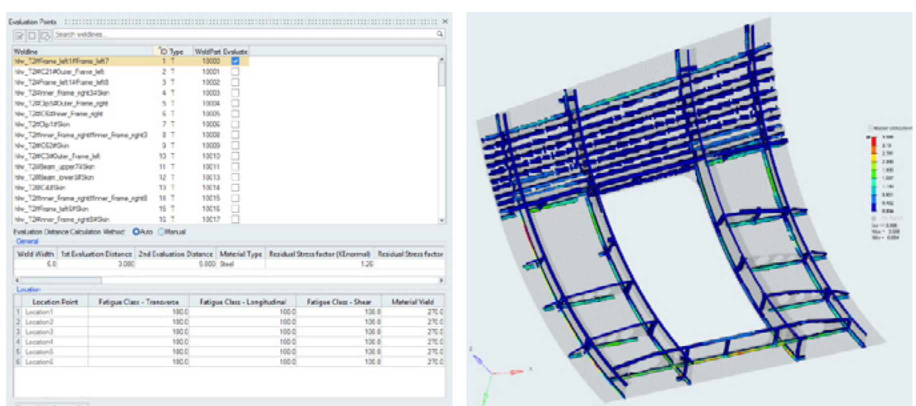
The FKM guideline "Analytical Strength Assessment of Components," is a standard developed by the German Forschungskuratorium Maschinenbau e.V. (FKM), which provides a general procedure to calculate the strength of components in mechanical engineering. The FKM guideline outlines analytical procedures for static and fatigue strength assessment of structural components made of steel, casted components, and aluminum. The procedures are available for both welded and unwelded calculations.

Eurocode

Eurocode 3 (often abbreviated to EC 3) is the name of the European standard EN 1993 entitled Design and Construction of Steel Structures and is part of the Eurocode series. EN 1993, which was adopted as a national standard by the member states of the European Committee for Standardization (CEN), is subdivided into a total of 20 sub-standards. This is part of the European code practiced and established by the European Committee of Standardization. Eurocode 3 applies to the design of steel and Eurocode 9 to the design of aluminum structures.

DVS 1612 & DVS 1608

The DVS 1612 guideline is for the design and endurance strength analysis of steel welded joints in rail-vehicle construction and applies to welded joints in railway structures published by the German Welding Society. The DVS 1608 guideline is for the design and strength assessment of welded structures from aluminum alloys in railway applications published by the German Welding Society.



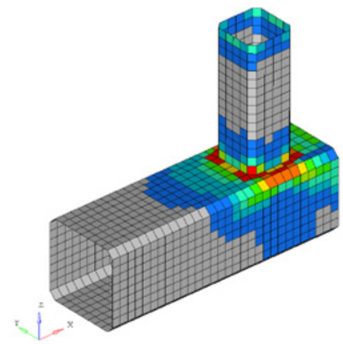
Weld assessment methods and regulations implementation.

Interested in details about implementing FKM, DVS, and EC regulations? Contact us.

FEA MODELING

Simulation challenges evaluating weld joints:

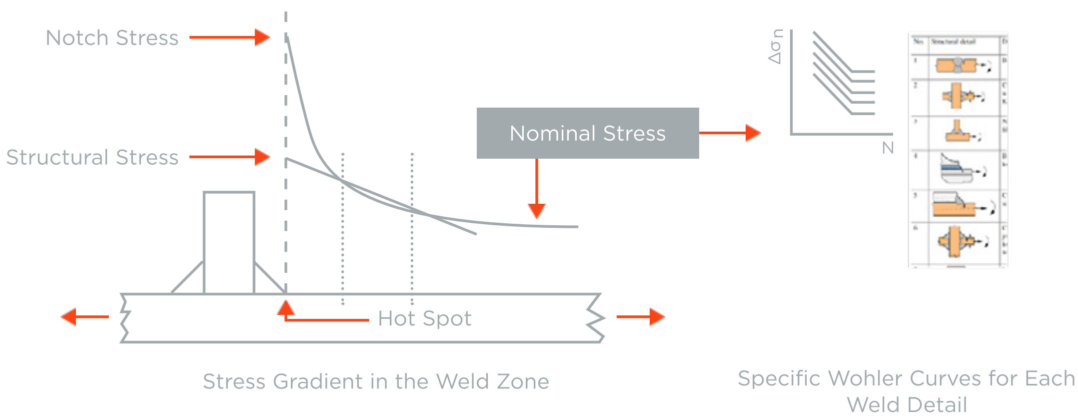
- Coarse overall model
- Rough shell elements
- Weld is not modelled
- Stress results in weld zone unsuitable
- High number and variation of welds
- Choose the right approach



Weld constructions that require weld certification are typically modelled with shell-elements to solve the finite element simulations efficiently. Primarily due to the sheer size of their structure, these FEA nominal stress models are typically characterized by a very rough discretization and often do not have detailed modeling of the weld joint itself. The alternative is an evaluation based on a structural stress or notch stress approach, but these require significant higher modeling effort.

WELD ASSESSMENT APPROACHES

Following the assumption that in a defined distance from the weld the stress is constant, this so-called "nominal stress" is the basis for the evaluation. The advantage gained with this approach is that no detailed model of the weld is needed. Local notch effects from weld and connected parts are captured by specific Wohler curves that need to be assigned to the individual weld situation.

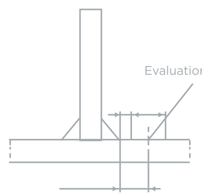


Weld stress determination considers the stress gradient in the weld zone.

The structural stress concept is characterized by less modeling effort in CAD and FEA. Compared to nominal stress concept the effort is higher as you need to consider more meshing restrictions assuring an element centroid located in each evaluation point. In post-processing, the time required to read out the data is higher because more points must be evaluated. The computing and memory requirements are very low.

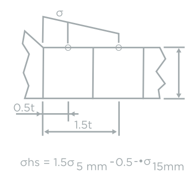
The notch stress concept means more modeling effort and high computing time, as all weld grooves need to be considered, but instead of selecting specific woehler curves for the individual weld situation, there is only one "global" woehler curve required which can be applied to all assessed weld grooves. In practical application this approach is used for detail studies on submodels of critical weld situations as the calculation effort is significant.

Nominal Stress
Coarse Shell Model
Evaluation point in certain distance from the weld.



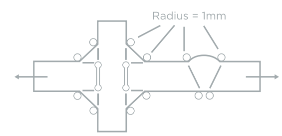
Implemented in HyperLife for DVS 1608 & EC3

Structural Stress
Fine Shell Model
2-3 Evaluation points as supporting points for stress extrapolation.



Implemented in HyperLife for FKM-Guideline

Notch Stress
Detailed Solid Model
Modeling of weld throat and tow with a radius of 1mm.
Evaluation directly at the notch.



Applicable by Base Material Assessment on Surface Membrane

Comparing approaches for weld stress determination.

The most practical way is to consider the nominal stresses. If the structure is too complex for normal stresses, then the structure stress approach (which may be referred to as hot spot stress) is the method of choice.

ANALYTICAL WORKFLOW

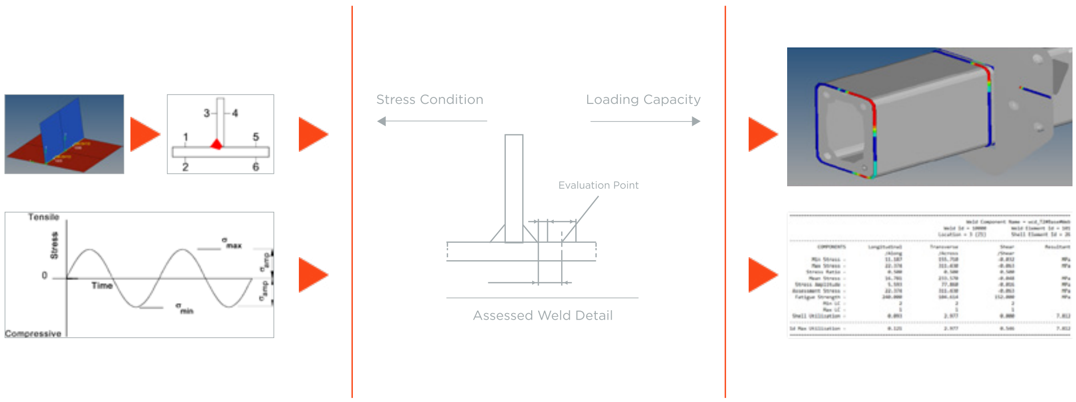
Input: The FEA model is the basis input and an automated routine assists to define the individual weld lines and assessment points. The evaluation is performed on the top and bottom of each connected sheet. Based on the stress results of the given load cases, stress ranges are determined automatically based on min/max value across all load cases or by predefined load events.

Important to note: In this routine the assessment according to Eurocode is different compared to the other standards. In Eurocode the differentiation between tension and compression is not made and the influence of mean stress is not considered.

Weld Assessment: Depending on the given regulation the degree of utilization (FKM, DVS) or the damage value (Eurocode) is processed for each evaluation point for all weld elements. The damage value in the Eurocode process has some differences as a number of cycles are compared instead of the stress directly.

- The degree of utilization is identified for each weld detail by comparing the maximum stress amplitude from the simulation against the permitted fatigue strength.
- The stress conditions are determined by the maximum stress range for each considered load cycle (in special cases this can be pure tension or pure compression). Individual safety and bonus factors complete the identification of the maximum stress amplitude.
- The loading capacity is determined be the individual weld detail categories that are influenced by notch details, Woehler curves, roughness, etc. of the individual weld detail. Additional factors including temperature and sheet thickness complete the value for the permitted fatigue strength.

Output: As an output the values for the weld utilization or damage can be assessed as contour plot and detailed ASCII-Output for each weld.



General workflow of weld certification.

EFFICIENCY IN THE WELD CERTIFICATION PROCESS

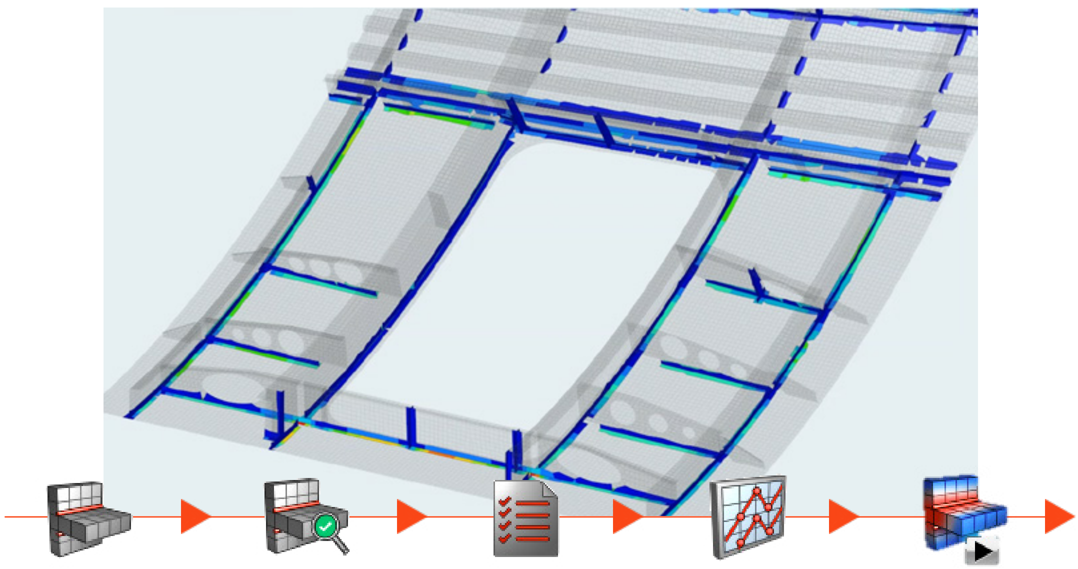
Organizations are motivated to seek efficiency in the process in different ways including faster weld evaluation, reducing mistakes, increasing accuracy, and cutting costs.

Weld Certification Process Check list:

- **The process automates repetitive tasks:**
- Weld lines are detected automatic by their individual geometry features
- A screening process sets critical weld lines in focus
- The workflow follows a guided sequence to assure result quality
- **The process/platform is open:**
- The process is applicable to multiple CAE solvers
- The platform allows the consideration of different weld regulations
- **The process is extendable:**
- The process can cover individual and changing requirements
- The implementation allows the modification of the assessment

AUTOMATED WELD CERTIFICATION

Welds need to be verified against mechanical or fatigue requirements. Depending on the industry, product, and customer, various verification methods exist. The process of manually preparing the weld line for verification, calculating the weld line utilization, and processing the results involves many steps and a lot of effort. Thus, there is a need for straightforward, accurate, and reproducible pre-processing and post-processing automation.



Verifying welds against the evaluation requirements in a guided certification process unlocks tremendous potential in product performance time and cost savings:

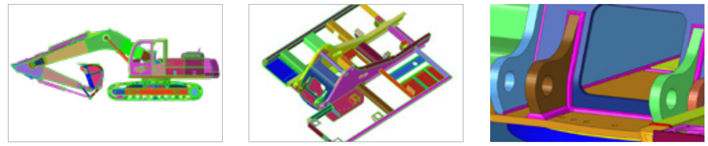
- Faster weld evaluation (including the stages of pre, screening, evaluation, and post)
- Less scope for mistakes (guided, simplified, and automated process)
- More accurate results (calculation at all required measure points)
- Cost effective (development time, material, and manufacturing time savings)

An automated process that identifies and classifies weld lines across an entire structure, then checks for fatigue issues throughout a structure and across multiple joint types, provides a consistent and efficient method to run a full weld line verification process. It allows organizations to better understand influence of weld lines on product performance. This creates a competitive advantage in saving meters and sometimes kilometers of weld lines.

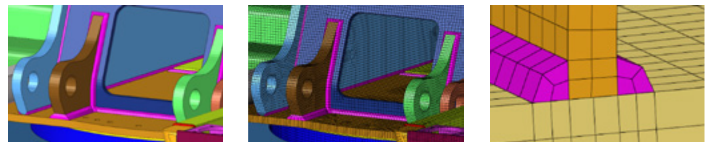
OPPORTUNITIES FOR AUTOMATION

Opportunities to increase the robustness and speed of weld certification exist throughout the process. In the preparation of the structural FEA model, the screening of the welds as well as the evaluation and documentation of the results, many repetitive tasks can be addressed with automation routines.

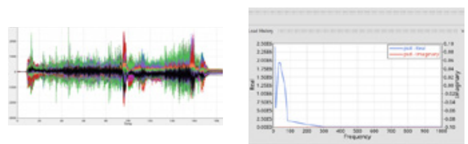
Accelerate Geometry Preparation



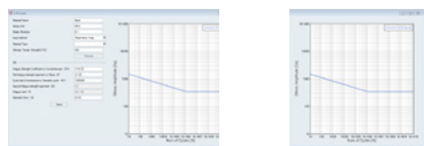
High-quality Meshing & Plate Connection



Load Identification & Load History Generation



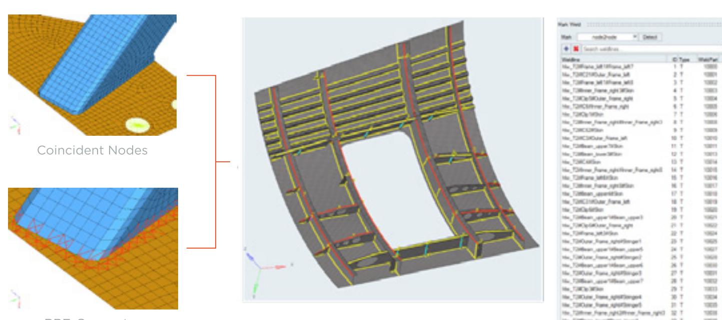
Fatigue Material Database



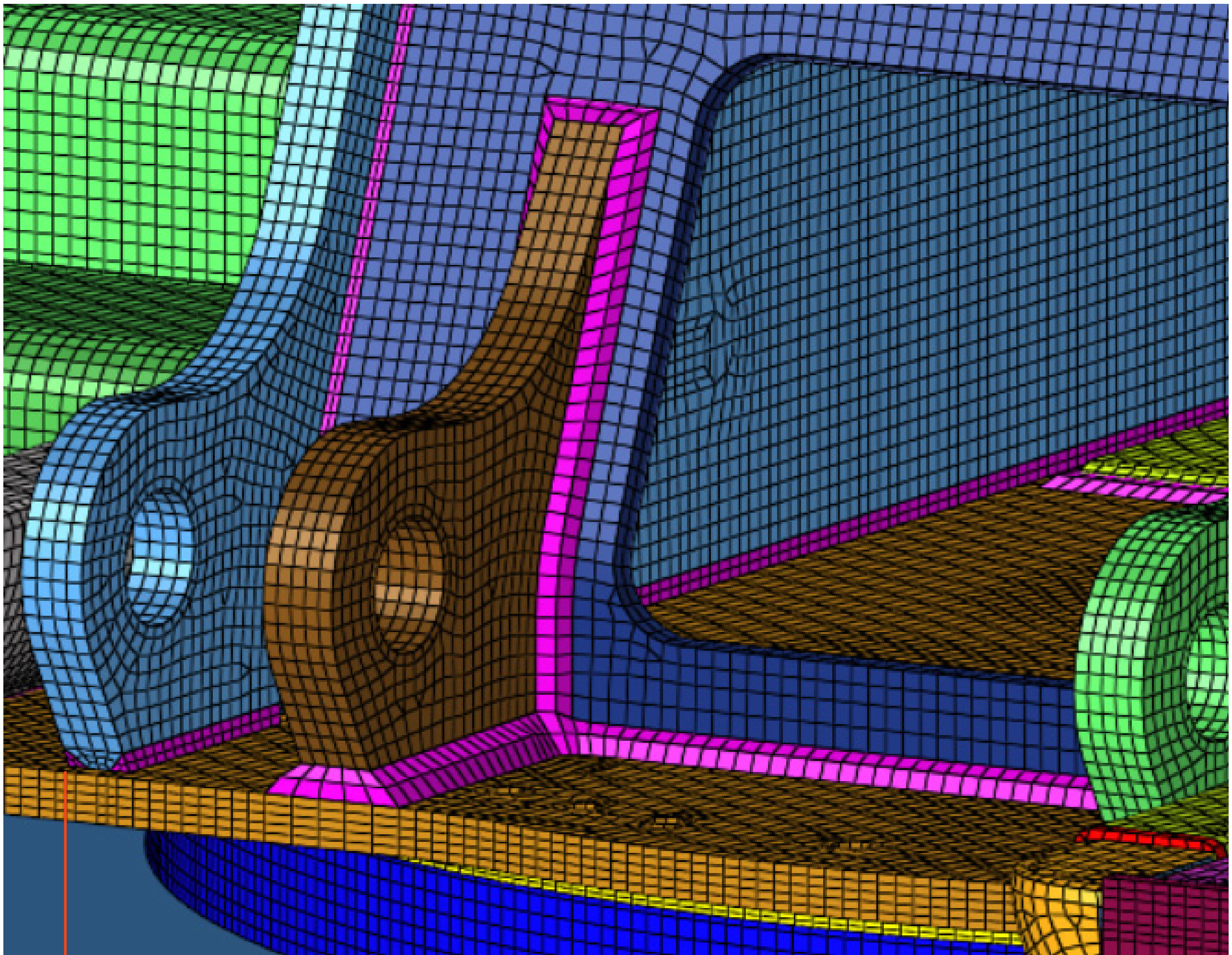
Important to mention are the imperative preconditions to a successful weld certification process, which include accurate geometry representation of the sheet metal construction, high-quality FEA model including the connection of the different metal sheets, appropriate load history, and the fatigue material data that are the basis for the weld assessment.

Model Preparation and Automatic Weld Detection

The first step to increase efficiency involves identifying which weld lines are required for evaluation. In the structural model, weld lines need to be detected automatically based on the geometry characteristics. An algorithm that interprets the matching of the sheets and proposes weld types that can be created-approved, edited, or deleted accelerates the model preparation significant.



Automatically detected welds across the whole FE-model (marked with colored line) and categorized in the WeldLine-Browser of HyperLife.



To overcome bottlenecks that hinder efficient geometry preparation, high quality meshing and uncertain loading conditions, Altair HyperWorks™ processes became the backbone of digital toolchains across all industries.

Screening

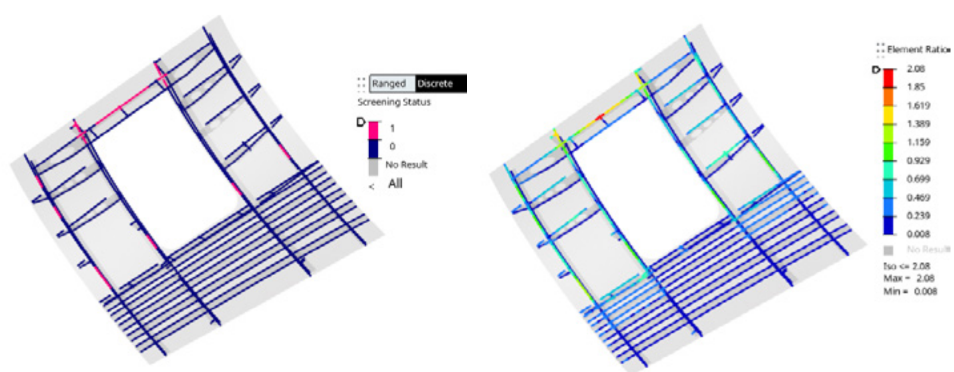
In situations where there are many welds in the model to consider, an upfront screening helps achieve process efficiency. An initial screening provides focus for critical areas so it is a key element to increase the productivity for the weld certification process.

Whether you need to consider DVS 1612, Eurocode 3, the FKM Guideline, or an individual method, a screening process minimizes the preparation and calculation efforts by reducing the number of welds that need to be included in the full evaluation to only those that are critical.

Identifying critical welds quickly is ideally based on a simplified method that requires only a few definitions. With an individual threshold stress value acceptable weld lines are identified rapidly.

When results are displayed as contour plots along with details of each weld in a process-oriented style, the provided guidance assures that all welds are considered appropriately.

> **Screening Concept:**
> With help of a simplified routine, areas that require further investigation can quickly be identified.
>
> The screening routine calculates a utilization ratio based on the von Mises stress value of an element with an user defined threshold value.



Preliminary calculation of utilization ratio and a comparison of the ratio of the von Mises stress value of an element against an individual threshold value.

Evaluation

After screening and specification of the applicable certification regulation analysts needs to define all required properties such as weld type, notch type, material, evaluation distance, and more. Based on the chosen regulation method, one must assure that all weld evaluation point properties are defined accordingly and materials and other unwelded certification parameters to the model's components are defined. This is a key element that requires automation through guiding dialogues and browsers.

Defining the fatigue history of a structure requires the efficient handling of multiple channels to capture the load histories accurately. Load histories paired with load steps to create the fatigue events set the basis for the analysis of the weld assessment.

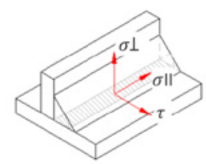
Loading can be very complex and come from a variety of sources. The efficient handling and review of the loading situation subcases is a key success factor of the certification process.

When defining load cycles, the different load channels need to be kept under control. Some of the amplitudes may require scaling. Multiple loads events and or point loads must be combined to represent the loading appropriately.

The weld certification calculation of the utilization is based on all stress components finally builds a combined utilization:

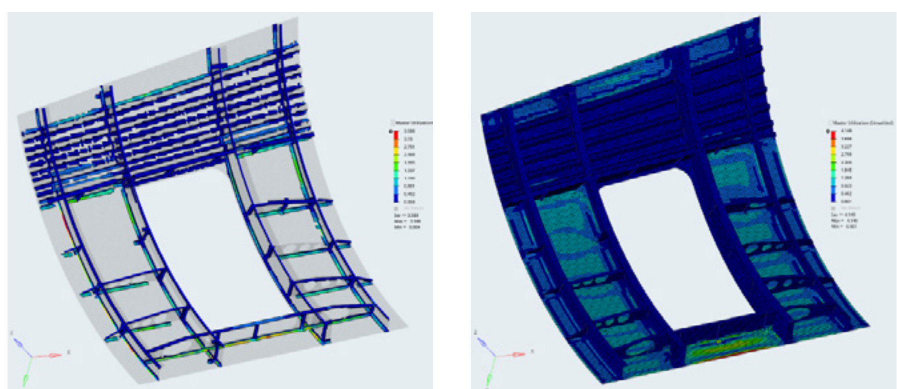
- transverse utilization (σ perpendicular)
- longitudinal utilization (σ parallel)
- shear utilization (τ)

combined utilization



Weld stress components.

The visualization concludes the process and provides the basis for the documentation. The results in form of contour plot together with annotations of the most critical weld lines allow an evaluation in the context of the given norms.

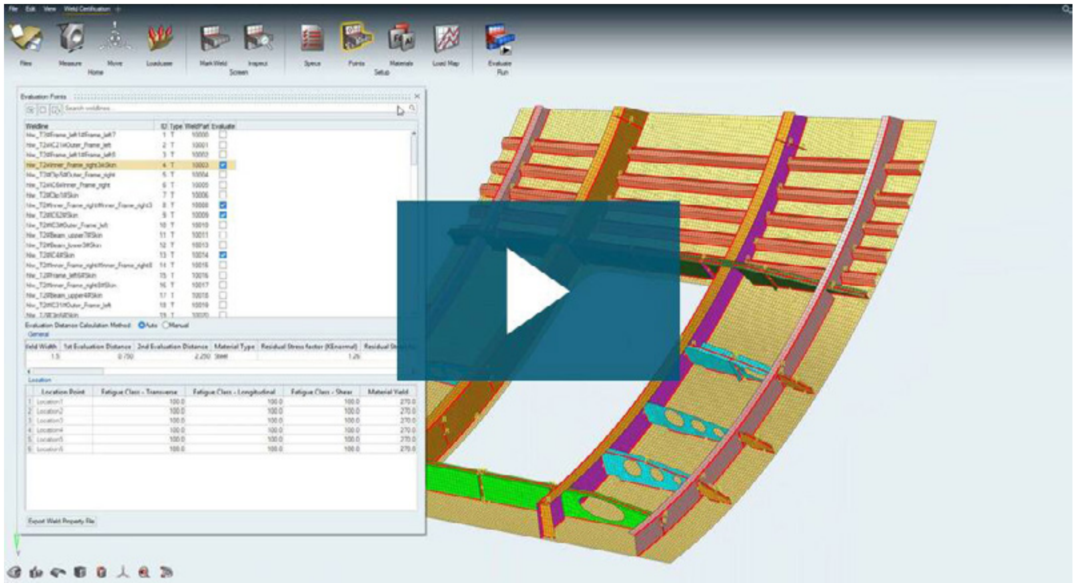


Utilization of welds and utilization of base material.

Depending on industry requirements and or company standards, documentation and reporting of results must be made available in Microsoft Office tools, XML, and other formats. Automation of these documentation needs allows more time to discuss, reflect, and interpret the results.

LEARN MORE

Explore the process in action and see how Altair HyperWorks™ Fatigue automates fatigue life and durability prediction workflows. The video shows the typical workflow to perform a weld certification with HyperWorks Fatigue.



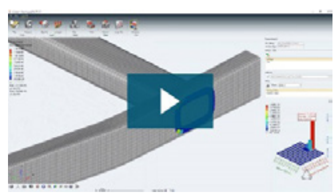
Watch the weld certification video.

Explore further workflows to perform fatigue life and durability predictions, spot weld fatigue analysis with HyperWorks Fatigue.

Stress Life Analysis

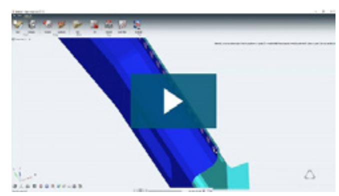
Watch the Workflow

Seam Weld Fatigue



Watch the Workflow

Spot Weld Fatigue



Watch the Workflow

WORKING WITH ALTAIR

Altair provides leading edge simulation technology and consulting services to Fortune 500 companies. With the industry's most comprehensive suite of physics solvers and integrated multiphysic workflows, pervasive optimization, and data analytics solutions, Altair is a powerful innovation partner for your next development program.

The evaluation and standard based certification of welded constructions is a repetitive and time-consuming process. This includes model preparation and verification calculations as well as the generation of reports for documentation, making the analysis of welded joints easier, faster, and more robust.

The Altair HyperWorks™ Fatigue weld certification tool provides a comprehensive library of weld types and provides guidance to distinguish between the connection types while assuring the correct definition according to the assessment method (FKM, DVS, Eurocode).

Weld certification flow diagram in HyperWorks Fatigue weld certification.

Compared to other weld fatigue methods, a central advantage of the HyperWorks Fatigue weld certification implementation is that it does not require dedicated modeling of the weld seam itself.

Interested in seeing HyperLife in action? Request a Trial.

Altair will work to understand your individual unique operating practices to ensure that your process meet your requirements. Our experts can:

- Evaluate current methods for modeling and simulating weld lines
- Align the automation solution base module accordingly
- Provide quick start focused support and periodic checkpoint assessments to ensure a successful user experience

Learn more about weld certification on the Altair Community.

Altair is a global technology company that provides software and cloud solutions in the areas of data analytics, simulation, and high performance computing (HPC). Altair enables organizations across broad industry segments to compete more effectively in a connected world while creating a more sustainable future.

To learn more, please visit www.altair.com