

A high-resolution image of the Earth's horizon from space, showing the blue atmosphere, white clouds, and brownish-green landmasses.

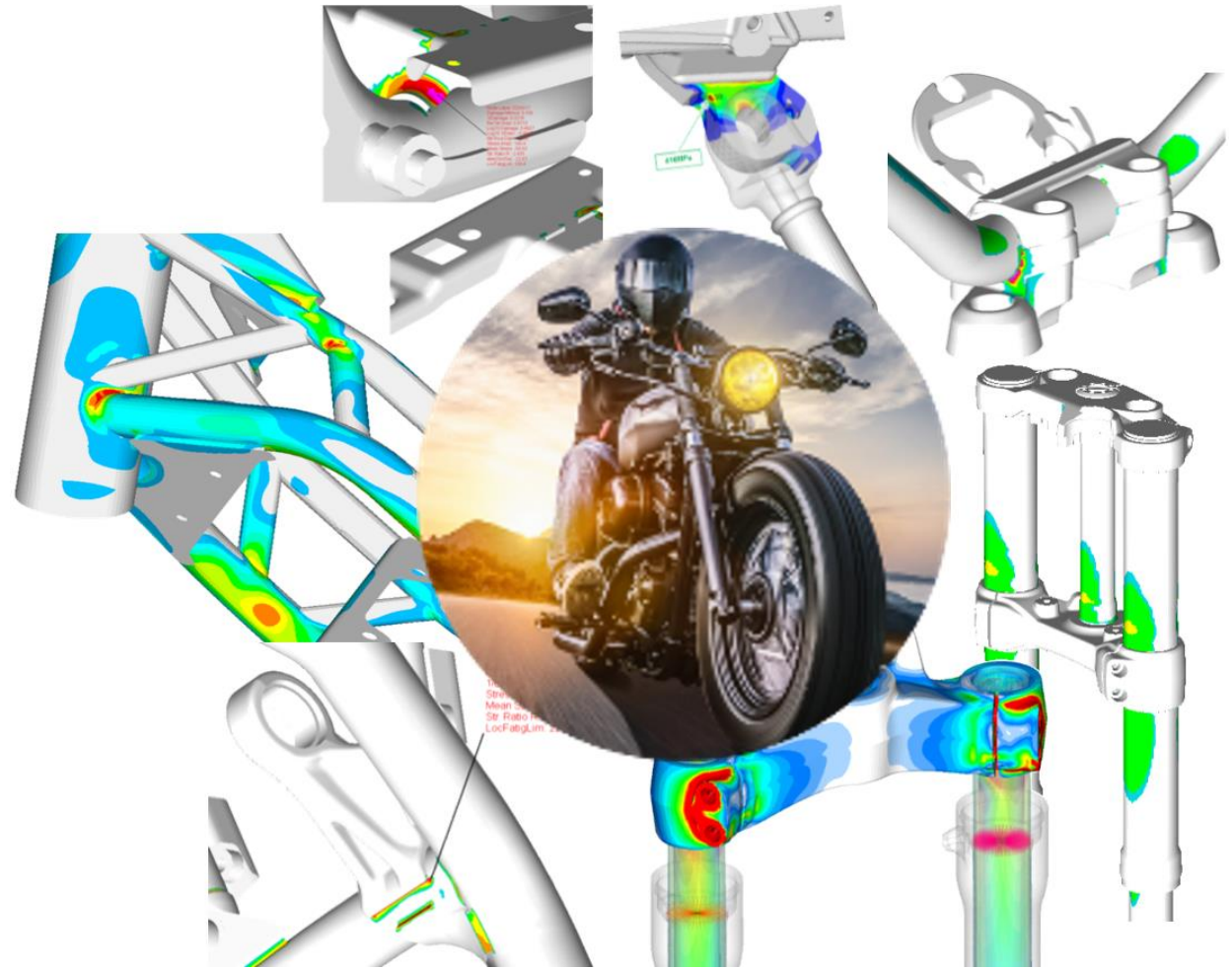
HOW RICARDO PREDICT LIFE OF MOTORCYCLE COMPONENTS

ECS SIMULATION CONFERENCE May 10th & 11th, 2023



HOW RICARDO PREDICT LIFE OF MOTORCYCLE COMPONENTS

ECS SIMULATION CONFERENCE
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RICARDO PRESENTATION

FEMFAT: Different modulus for different engineering problems

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EUROCODE 3

FATIGUE EVALUATION WITHOUT AND WITH FEMFAT APPLICATION

FEMFAT WELD DETAILS

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RICARDO COMPANY – OVERVIEW ON MOTORCYCLE DEPARTMENT

RICARDO Motorcycle is a international company composed by passionate and competent engineers of motorcycle industry with the capability to assist and lead a project in all its areas.

Ricardo offers an integrated product development.

Style, Engineering, Powertrain, Chassis and Electronic development are interacting together delivering great motorcycles.

Passionate enthusiasts

Our engineers live and breath the motorcycle and powersport industry. We are passionate about what we do which is why we are well placed to assist our clients with their engineering challenges.

Cost-effective solutions

We are dedicated to creating cost-effective solutions by using the latest virtual engineering software and tools to reduce development costs without compromising on quality or safety.

Market analysis

Engineering

- Project Management
 - Detail Design
 - **Analysis and Simulation**
 - Electric/Electronic
 - NVH
 - Proto-build and Testing
- ON**
- Chassis
 - Body components
 - Powertrain
 - Each part of a motorcycle

Styling design



RICARDO COMPANY – FOCUS ON ANALYSIS AND SIMULATION ACTIVITIES

Load Cases Analytical Evaluation

Full Stop Braking

Front Bump

Front Pothole Bump

Max Thrust

Rear Pothole Bump

Rear Bump

....



Some Ricardo's Tools

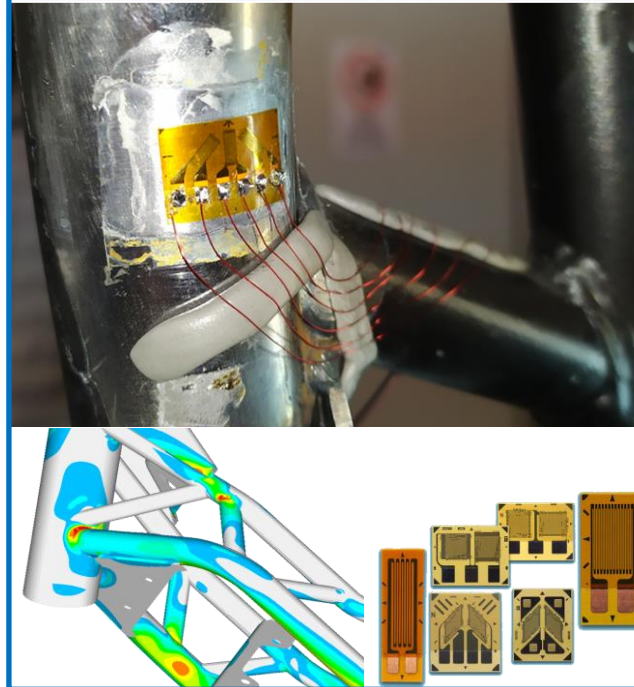
TO PERFORM ANALYSIS ON

- Vehicle Systems / Components
- Powertrain
- Transmission



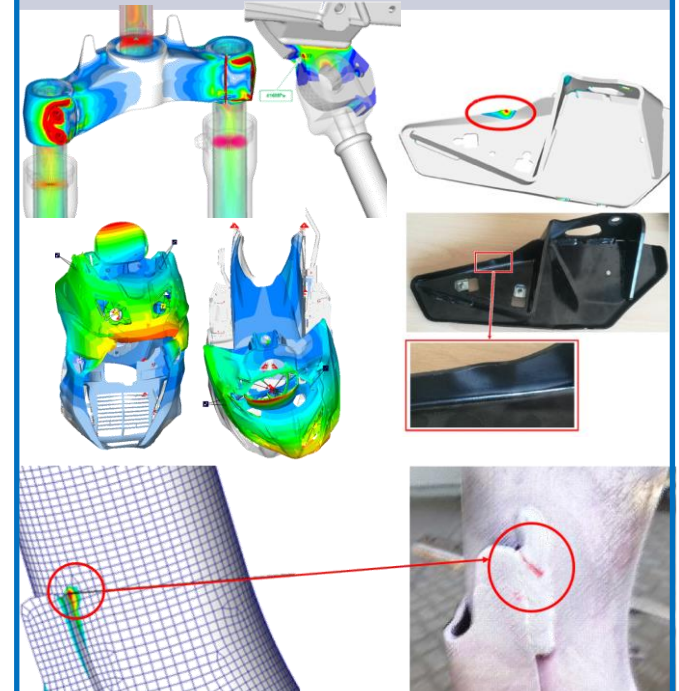
Strain Gauges Applications in Ricardo

To Validate the FEA models
 To Validate the hypothesized load cases
 To Evaluate the real safety factors
 To Monitor all critical areas found via FEA Analysis during the Road Tests and Fatigue Tests



Some type of analysis performed in Ricardo

Linear and non linear static analysis
 Modal Analysis
 FRF Analysis
 Stiffness Analysis
 Topology Optimization Analysis
 Fatigue Analysis



RICARDO COMPANY – FOCUS ON DESIGN PROCESS



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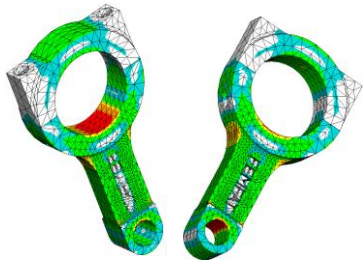
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FEMFAT MODULES

FEMFAT basic

The **BASIC** module enables analysis of the fatigue life or endurance safety of components subject to proportional loading.

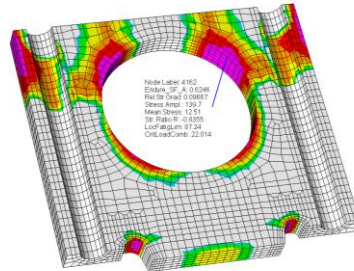
The ability to take a great number of possible influence factors into account makes it easier to obtain a realistic fatigue life prediction.



FEMFAT max

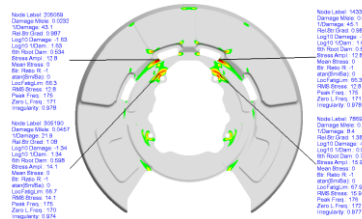
ChannelMAX, allows to study and combine load-time signals with the corresponding stresses from the unit load cases in FEMFAT. They are superimposed linearly.

TransMAX is the module of choice if the sequence of the load cases can be described by transient stress distributions.



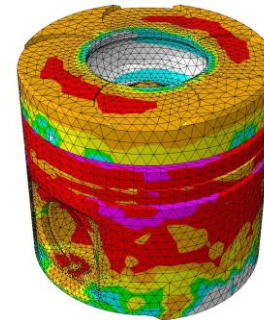
FEMFAT spectral

SPECTRAL uses the alternative description of signals in the frequency domain, so-called PSDs – Power Spectral Densities. The multiaxial damage analysis is carried out in the frequency domain.



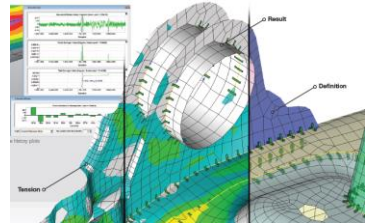
FEMFAT heat

HEAT allows the evaluation of low cycle fatigue for components subjected to a combination of thermal and mechanical loading. Thermo mechanical fatigue (TMF) analysis.



FEMFAT visualizer

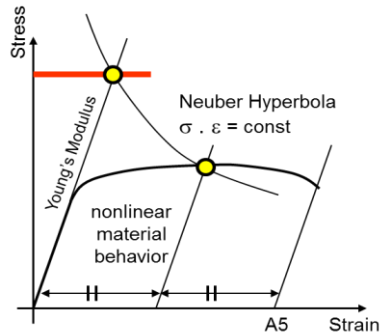
VISUALIZER is a fast, interface-independent 3D post processor for the display of FEMFAT results and FE stresses. Moreover, VISUALIZER also stands out with its functionality in the area of weld definition for shell models.



FEMFAT MODULS

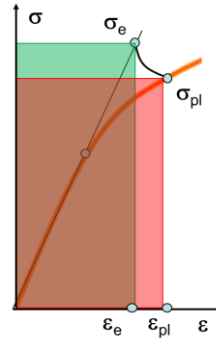
FEMFAT break

BREAK allows the calculation of static safety factors. FEMFAT break is available as an analysis target for BASIC and MAX



FEMFAT plast

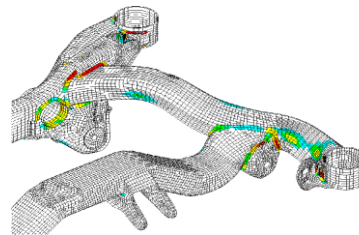
PLAST makes use of the Neuber correction to estimate the local elasto-plastic stresses in notches based on linear-elastic stresses.



FEMFAT weld

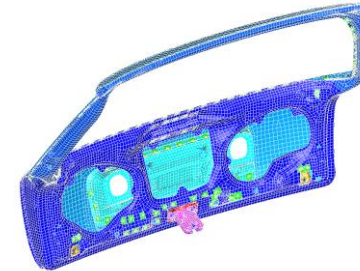
WELD allows the evaluation of welded seams for steel and aluminum considering the notch stress and using several standards (DIN 15018, EUROCODE 3 e 9, BS 7608, IIW).

It can be used in combination with BASIC, MAX and SPECTRAL



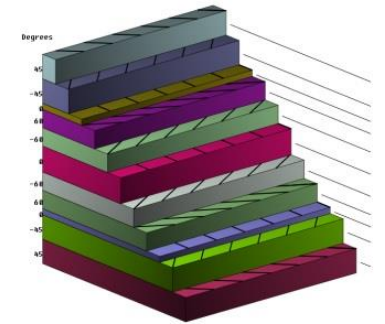
FEMFAT spot

SPOT allows the evaluation of welded in case of spot weld connection or in case of rivets connections. FEA models created with shell elements.



FEMFAT laminate

LAMINATE is a module for the analysis of continuous fiber-reinforced plastics, and it is only available in ChannelMAX.



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- **RICARDO** analysis methodology has been developed with the target to optimize stiffness (very important parameter for the motorcycle dynamic behaviour), stress distribution and fatigue resistance, minimizing the weight but reaching the expected life.
- **SPECIFIC LOAD CASES** are defined by RICARDO in order to simulate certain physical events such as braking events, bumps and holes to which the vehicle will be subjected in the real life.
- **FEA ANALYSES AND FATIGUE ANALYSES** met respectively the road tests and fatigue tests in the last two important projects. Both analyses were fundamental to introduce the appropriate improvements to the structure and therefore to achieve a safe and reliable development of the final products already in the calculation phase.
- **FEMFAT** play an important role in the RICARDO's process. This was proved in these last two important projects to predict the fatigue life of frames and other motorcycle components, and this has been confirmed by the validation tests carried out.

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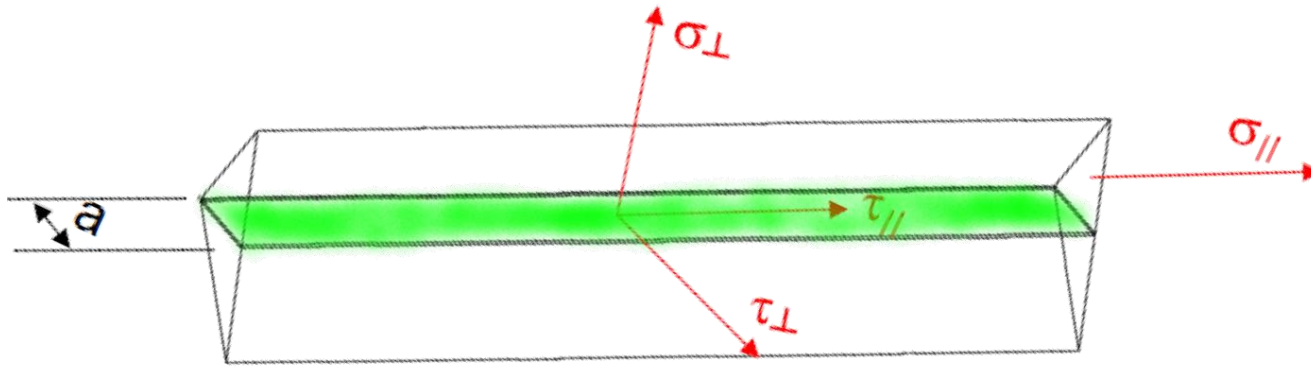
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Eurocode 3 Part 1-9: Welds Static Evaluation

Static stress must be calculated on the green reference plane (actual plane of the throat section).



Steel	β_w
S 235	0,8
S 275	0,85
S 355	0,9
S 420	1
S 460	1

$$\sqrt{\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)} \leq \frac{f_u}{\beta_w \cdot \gamma_{M2}} \quad \sigma_{\perp} \leq \frac{0.9 \cdot f_u}{\gamma_{M2}}$$

f_u = Material UTS

γ_M = safety factor

Eurocode 3 Part 1-9: Weld Fatigue Evaluation - Safe Life Approach

Safe Life Approach considers specific S/N curves and the stress values can be calculated considering one of these two possible methods:

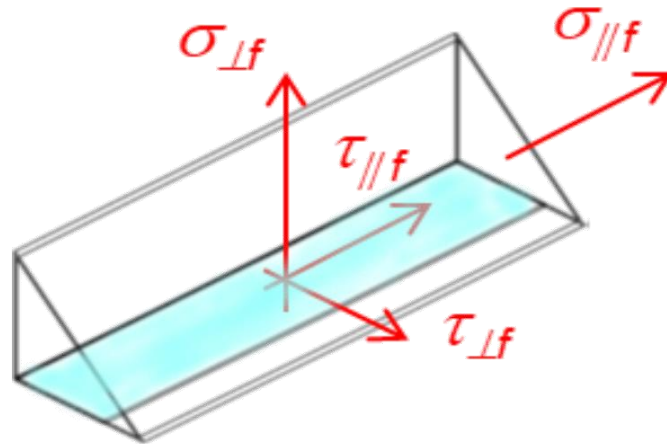
- **Nominal Stress Method**
- **Hot Spot Stress Method**

Nominal Stress Method:

Normal and tangential stress on the welds, are evaluated as follow:

$$\sigma_{Wf} = \sqrt{\sigma_{\perp f}^2 + \tau_{\perp f}^2}$$

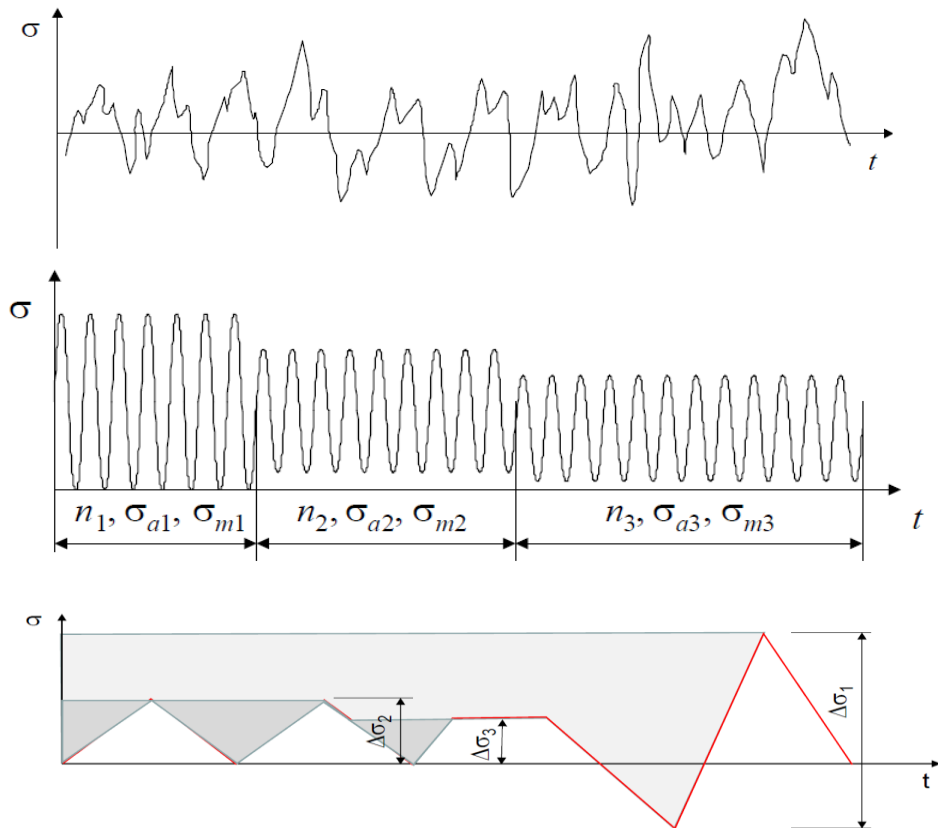
$$\tau_{Wf} = \tau_{\parallel f}$$



These stresses are calculated on the overturned throat section, so they are different from those used in static verification.

Eurocode 3 Part 1-9: Welds Fatigue Evaluation – Count of cycles and damage evaluation

- Rainflow method can be used to create the history load in order to evaluate an equivalent stress;
- Damage can be calculated using Miner rule.



i = i -th block applied on the component

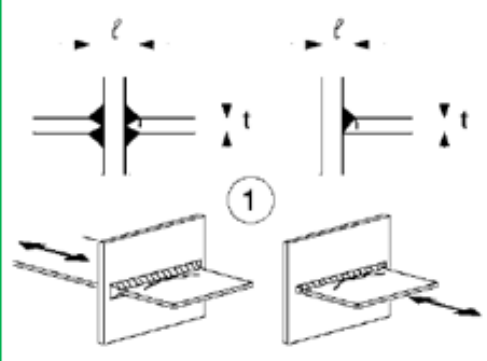
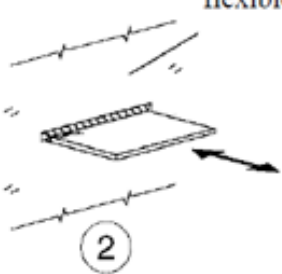
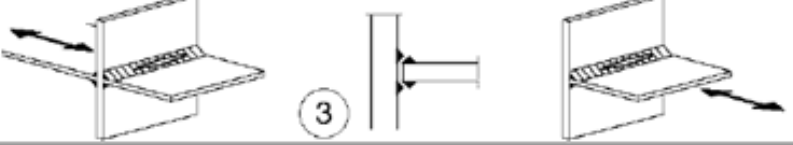
n_i = number of cycles relative to i -th block

N_i = Fatigue limit relative to i -th block

$$D_i = \frac{n_i}{N_i} \quad D = \sum D_i$$

Eurocode 3 Part 1-9: Categories

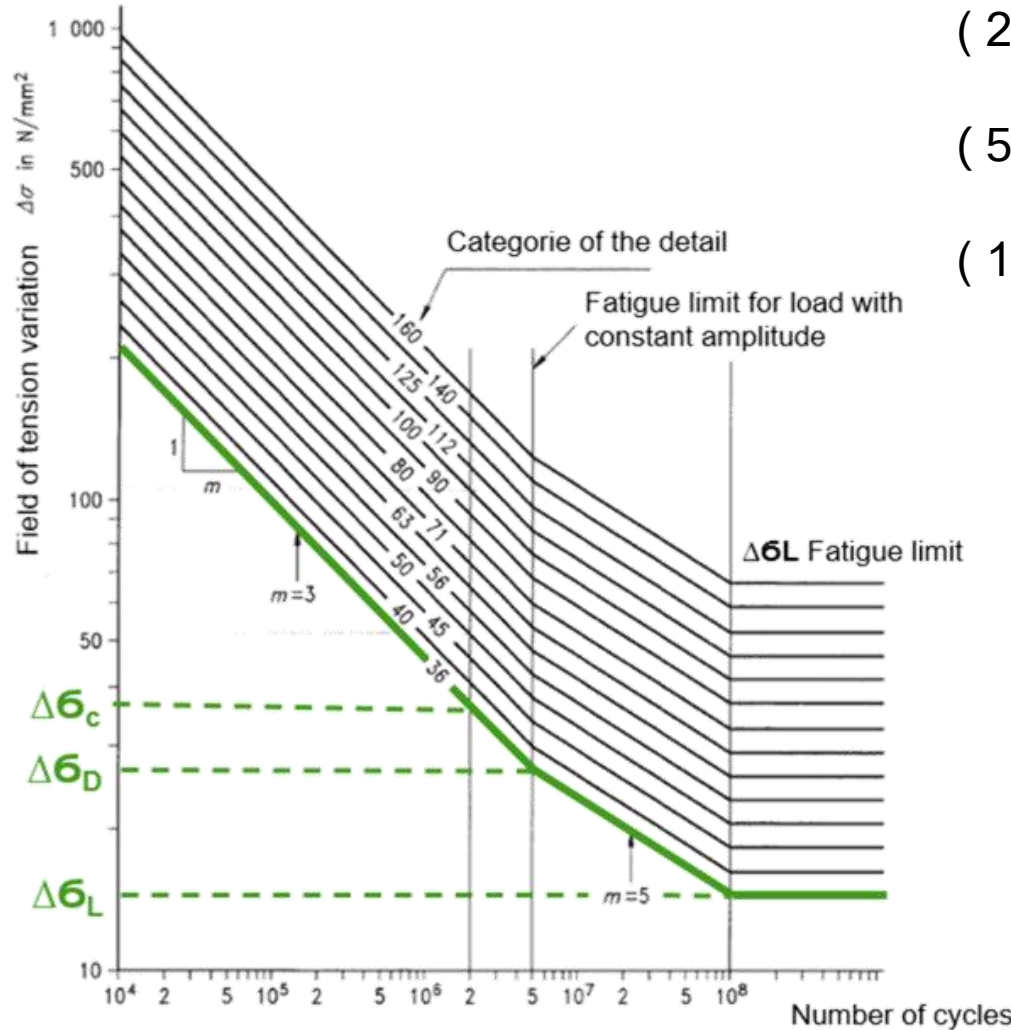
- The welded details are reported according to «categories» ($\Delta\sigma_C$ a $2 \cdot 10^6$ cycles) in dedicated tables.

Detail category	Constructional detail		Description	Requirements
80	$\ell < 50$ mm	all t [mm]	<u>Cruciform and Tee joints:</u> 1) Toe failure in full penetration butt welds and all partial penetration joints. 	1) Inspected and found free from discontinuities and misalignments outside the tolerances of EN 1090. 2) For computing $\Delta\sigma$, use modified nominal stress. 3) In partial penetration joints two fatigue assessments are required. Firstly, root cracking evaluated according to stresses defined in section 5, using category 36* for $\Delta\sigma_w$ and category 80 for $\Delta\tau_w$. Secondly, toe cracking is evaluated by determining $\Delta\sigma$ in the load-carrying plate.
71	$50 < \ell \leq 80$	all t		
63	$80 < \ell \leq 100$	all t		
56	$100 < \ell \leq 120$	all t		
56	$\ell > 120$	$t \leq 20$		
50	$120 < \ell \leq 200$ $\ell > 200$	$t > 20$ $20 < t \leq 30$		
45	$200 < \ell \leq 300$ $\ell > 300$	$t > 30$ $30 < t \leq 50$		
40	$\ell > 300$	$t > 50$		
As detail 1 in Table 8.5			2) Toe failure from edge of attachment to plate, with stress peaks at weld ends due to local plate deformations.	<u>Details 1) to 3):</u> The misalignment of the load-carrying plates should not exceed 15 % of the thickness of the intermediate plate.
36*			3) Root failure in partial penetration Tee-butt joints or fillet welded joint and effective full penetration in Tee-butt joint.	

- **Categorie**
- **Dimensional limitation**
- **Identification of the detail, indication of the relevant tensions and of the trigger point**
- **Requirements for verification**

Eurocode 3 Part 1-9: S/N curves for Normal Tensions

Detail category
112
100
100

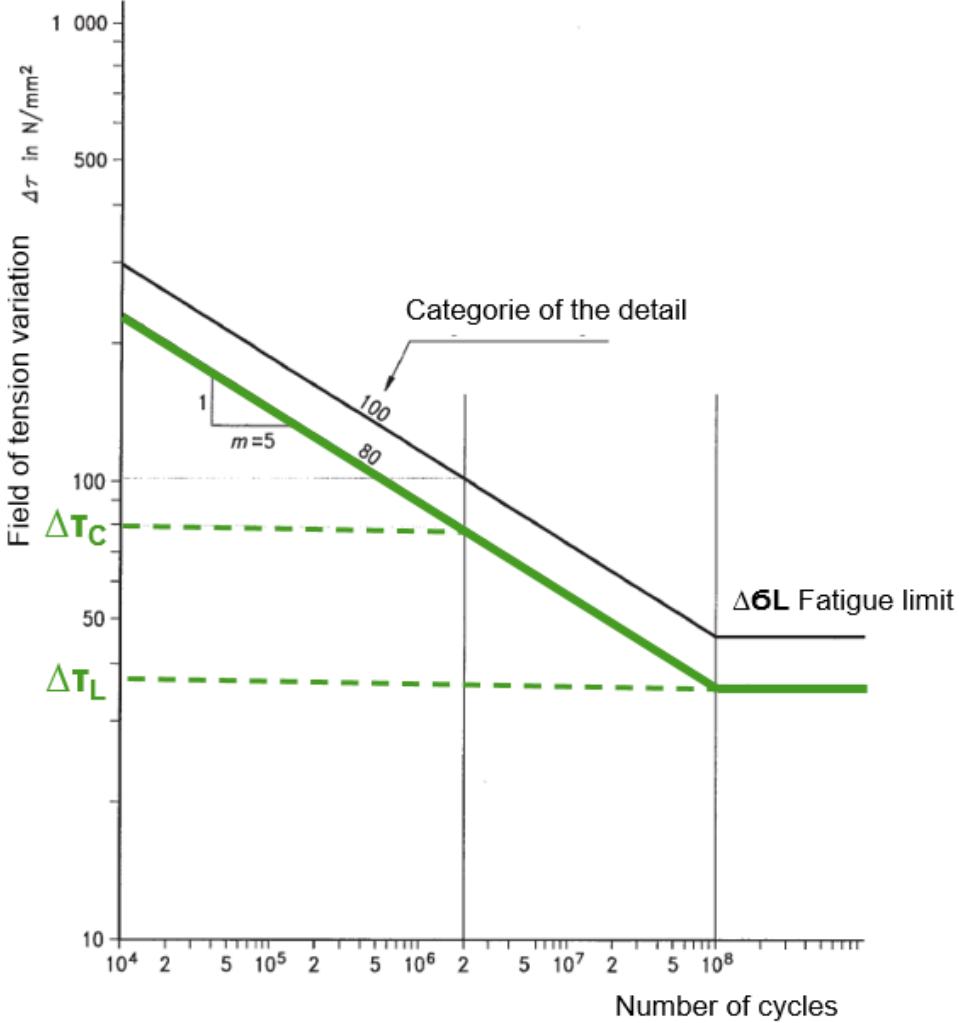


- (2E6, $\Delta\sigma_c$) = Detail Category
- (5E6, $\Delta\sigma_D$) = Fatigue Limit with constant amplitude
- (1E8, $\Delta\sigma_L$) = Cut-Off limit

$$\Delta\sigma_R = \begin{cases} \Delta\sigma_c \left(\frac{2 \cdot 10^6}{N_R} \right)^{1/3} & N_R \leq 5 \cdot 10^6 \\ \Delta\sigma_D \left(\frac{5 \cdot 10^6}{N_R} \right)^{1/5} & 5 \cdot 10^6 \leq N_R \leq 1 \cdot 10^8 \\ \Delta\sigma_L & 1 \cdot 10^8 \leq N_R \end{cases}$$
$$\Delta\sigma_D = 0.737 \cdot \Delta\sigma_c$$
$$\Delta\sigma_L = 0.549 \cdot \Delta\sigma_D = 0.405 \cdot \Delta\sigma_c$$

Eurocode 3 Part 1-9: S/N curves for Tangential Tensions

Detail category
112
100
100



(2E6, $\Delta\tau_C$) = Detail Category

(1E8, $\Delta\tau_L$) = Cut-Off limit

$$\Delta\tau_R = \begin{cases} \Delta\tau_C \left(\frac{2 \cdot 10^6}{N_R} \right)^{1/5} & N_R \leq 1 \cdot 10^8 \\ \Delta\tau_L & 1 \cdot 10^8 \leq N_R \end{cases}$$
$$\Delta\tau_L = 0.457 \cdot \Delta\tau_C$$

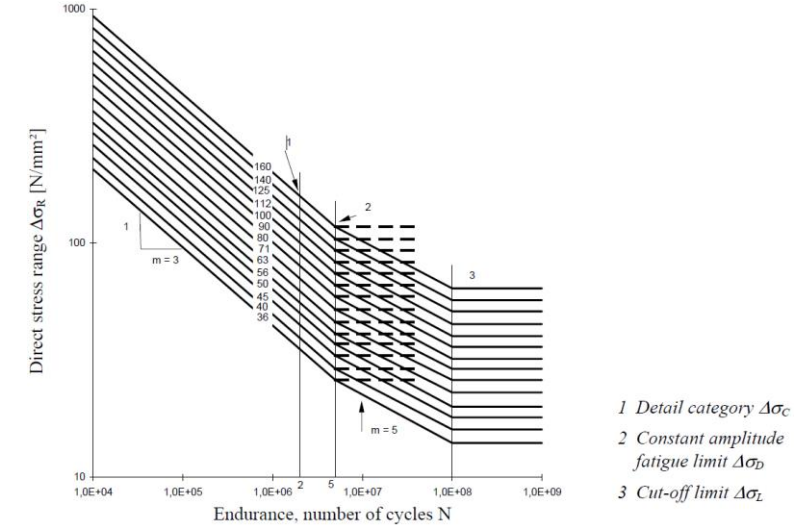
Eurocode 3 Part 1-9: Nominal Stress Range

$$\underbrace{\gamma_{Ff} \Delta \sigma_{E,2}}_{\text{Stress range design values}} = \underbrace{\lambda_1 \cdot \lambda_2 \cdot \dots \cdot \lambda_n}_{\text{Damage equivalent coefficients}} \cdot \underbrace{\Delta \sigma(\gamma_{Ff} \cdot Q_k)}_{\text{Stress ranges produced by applied loads:}}$$

From loads: $Q_{k,max}$ and $Q_{k,min}$

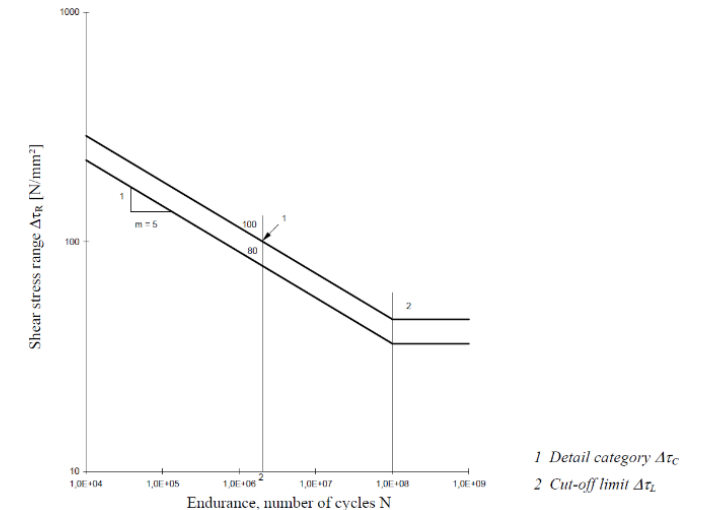
it is possible obtain the tensions $\bar{\sigma}(Q_{k,max})$ and $\bar{\sigma}(Q_{k,min})$,

and the associated $\Delta \bar{\sigma}(Q_k)$;

 $\Delta \sigma_{E,2} \Rightarrow$


$\Delta \sigma_{E,2}$ = Normal stress range that produce at 2E6 cycles, a damage equal to the damage produced by the actual load spectra

$\Delta \tau_{E,2}$ = Tangential stress range that produce at 2E6 cycles, a damage equal to the damage produced by the actual load spectral

 $\Delta \tau_{E,2} \Rightarrow$


Eurocode 3 Part 1-9: Verifications

A detail is verified if it has:

- **Nominal stress ranges, modified or geometric tensions** meet respectively the following relationships:

$$\Delta\sigma \leq 1.5 f_y; \quad \Delta\tau \leq 1.5 \frac{f_y}{\sqrt{3}}$$

- **Equivalent design tensions range** meet respectively the following relationships:

$$\gamma_{Ff} \Delta\sigma_{E,2} \leq \frac{\Delta\sigma_C}{\gamma_{Mf}}; \quad \gamma_{Ff} \Delta\tau_{E,2} \leq \frac{\Delta\tau_C}{\gamma_{Mf}}$$

γ_{Mf} is equal to 1.15 if the consequences of rupture are minor, 1.35 if they are severe.

- **In case of stress combination $\Delta\sigma_{E,2}$ and $\Delta\tau_{E,2}$** must be verified the following relationship:

$$\left(\frac{\gamma_{Ff} \Delta\sigma_{E,2}}{\Delta\sigma_C / \gamma_{Mf}} \right)^3 + \left(\frac{\gamma_{Ff} \Delta\tau_{E,2}}{\Delta\tau_C / \gamma_{Mf}} \right)^5 \leq 1.0$$

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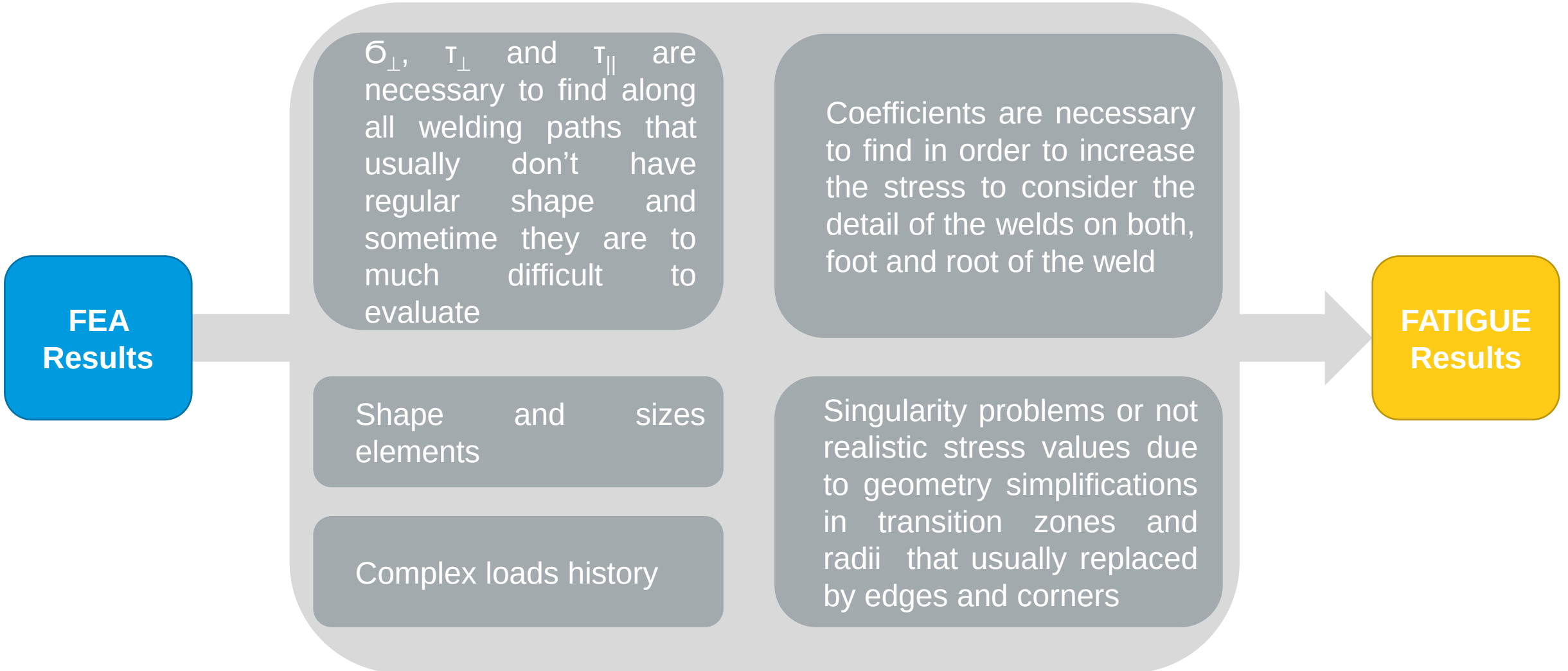
FATIGUE EVALUATION WITHOUT AND WITH FEMFAT APPLICATION

FEMFAT WELD DETAILS

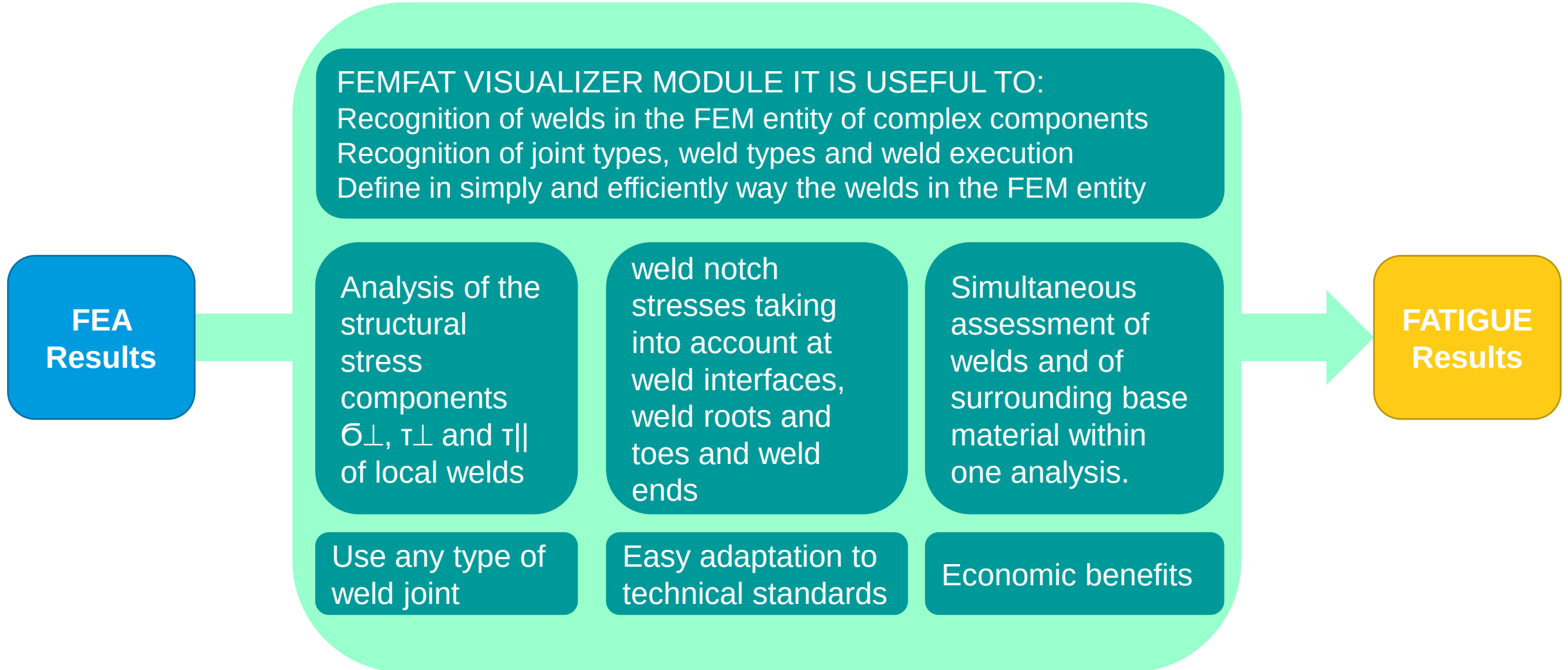
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FLOWCHART WITHOUT USING FEMFAT APPLICATION



FLOWCHART WITH USING FEMFAT APPLICATION



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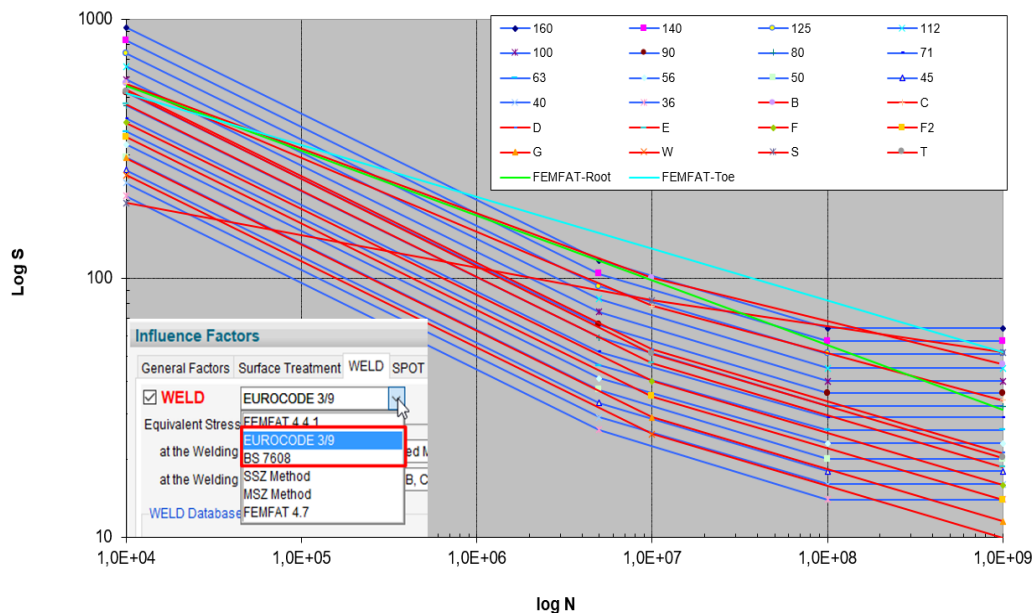
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FEMFAT WELD DETAILS

FEMFAT WELD Standards:

- Eurocode 3 (Design of Steel Structures)
- Eurocode 9 (Design of Aluminum Structures)
- British Standard 7608.
- FEMFAT 4,7

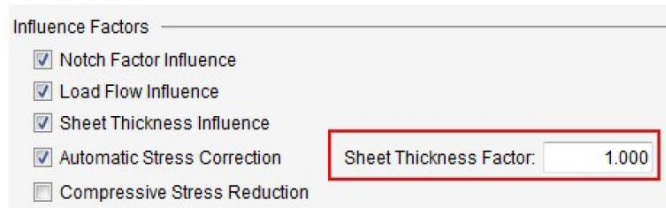
S-N Curves of Eurocode 3, BS 7608 and FEMFAT



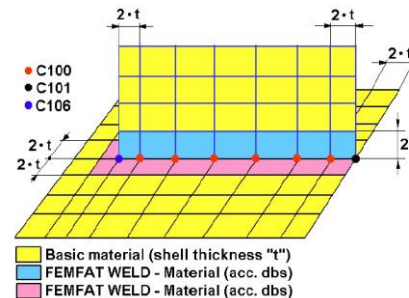
AUTOMATIC STRESS CORRECTION:

To prevent unrealistically high stress singularities in the assessment of the welds, the following options are available:

- enable the automatic stress correction in FEMFAT



- Follow the below dimension of the elements



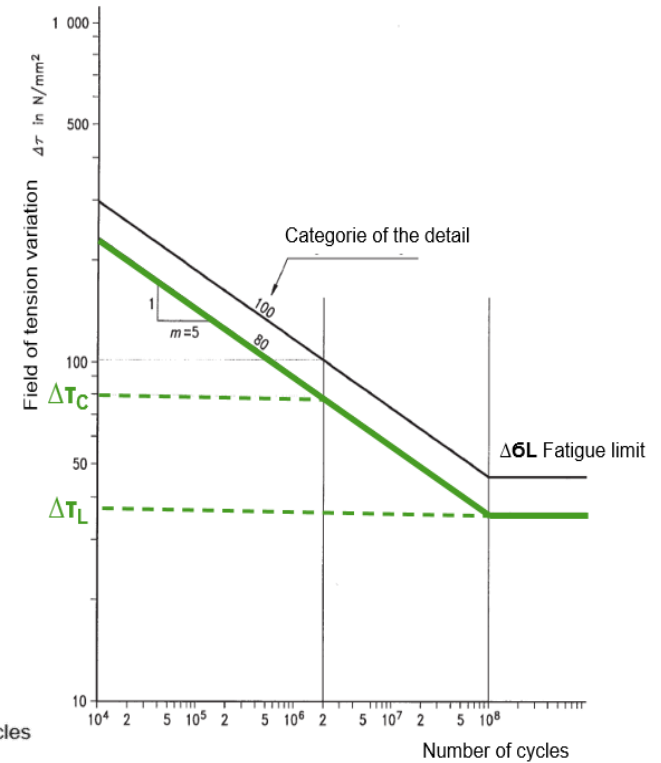
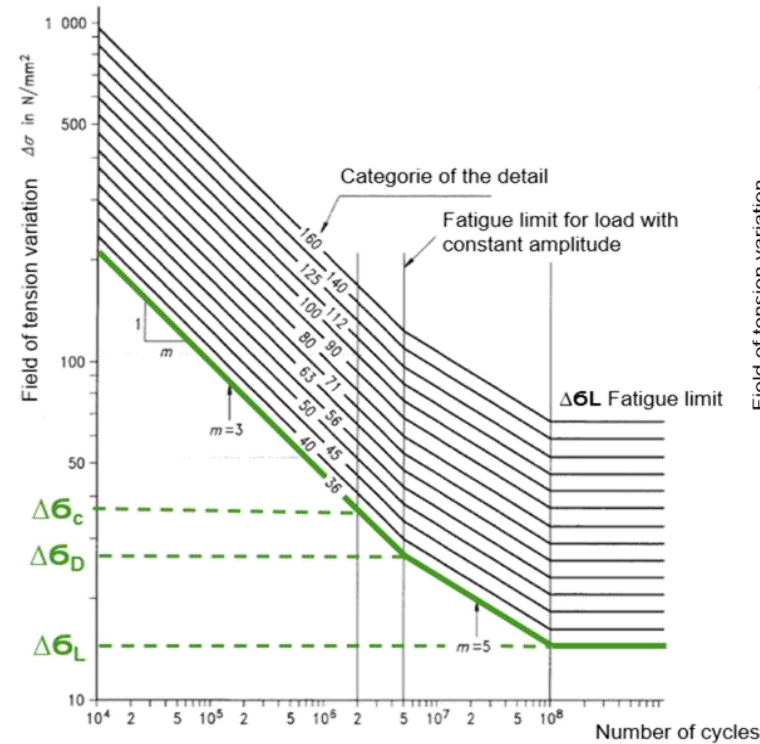
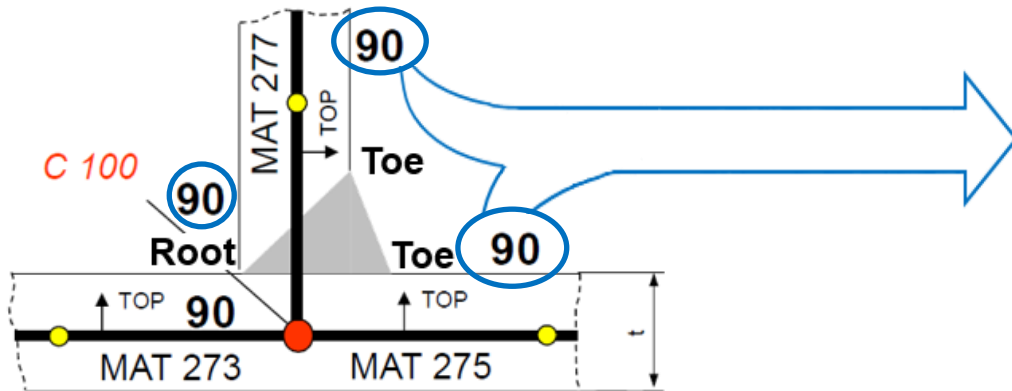
FEMFAT WELD DETAILS

DETAIL EXAMPLE AND NOTCH STRESSES:

The weld notch endurance stress is the amplitude stress ($\bar{\sigma}_a$) at mean stress $\bar{\sigma}_m = 0.0$ which can be endured until cracking. It is considered in each weld detail on root and toe function of the requested standard.

WELD TYPE: T-WELD, STRUCTURAL STRESS APPROACH
SEAM SHAPE: One Sided Weld, Full Penetration

Detail category perpendicular: 90
Detail category parallel: 100
Detail category weld end: 90



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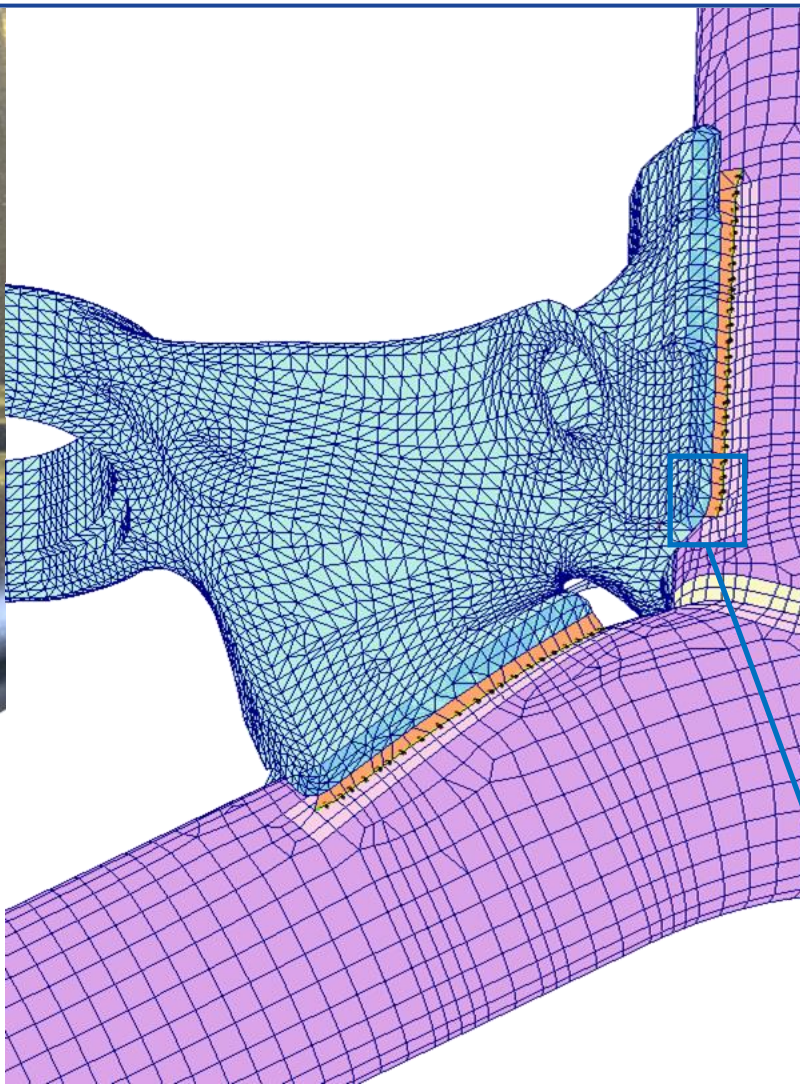
FEMFAT WELD DETAILS

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RICARDO CASE STUDIES

Example of weld seams creation using FEMFAT VISUALIZER



Standard: Eurocode 3

Weld Type

☒ T-JOINT, Structural Stress Approach (Solid-Shell)

One Sided Weld, Full Penetration, Shell-Base, Solid-Web (90/100)

WELD Definition

Weld Type/Seam Shape

- BUTT-JOINT
- BUTT-JOINT WITH HOLLOW SECTION
- T-JOINT, non load carrying, full penetration
- T-JOINT, non load carrying, or load carrying full penetration
- T-JOINT, load carrying without full penetration
- T-JOINT, Structural Stress Approach
- T-JOINT, LATTICE GIRDER JOINTS
- ☒ T-JOINT, Structural Stress Approach (Solid-Shell)
- CRUCIFORM-JOINT, full penetration
- CRUCIFORM-JOINT, without full penetration
- CRUCIFORM-JOINT, Structural Stress Approach

Weld Seam

Name: Seam 154

Length: 40.6377

Welding Finish: normal

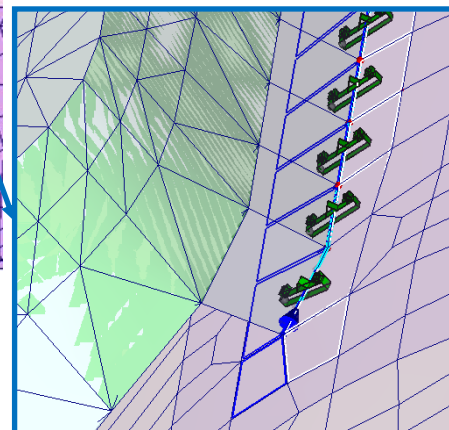
Assessment of welding seam end

☐ Ignore PID changes at welding seam end definitions

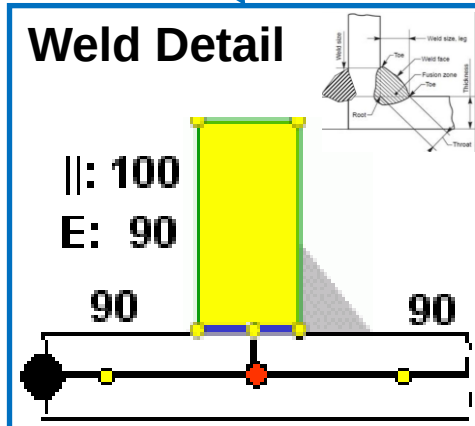
☐ Ignore sheet intersections at welding seam end definitions

☒ Seam checked by user

OK



Weld Detail



RICARDO CASE STUDIES

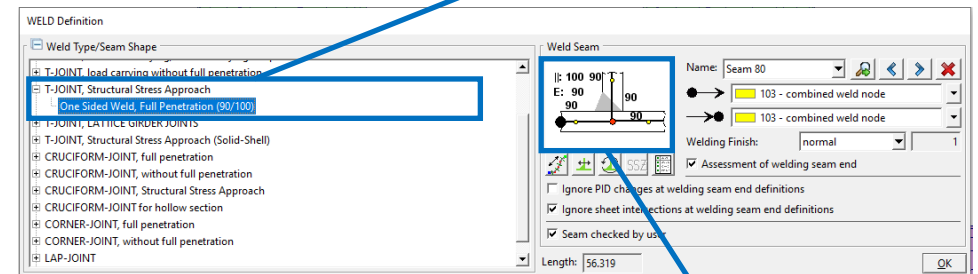
Example of weld seams creation using FEMFAT VISUALIZER

Standard: Eurocode 3

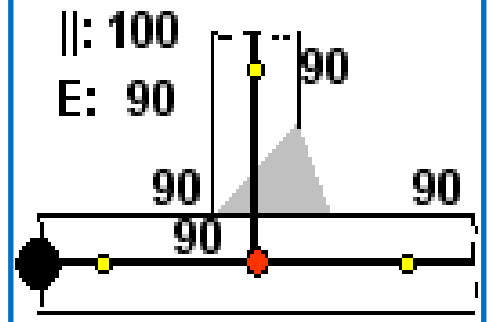
Weld Type

☒ T-JOINT, Structural Stress Approach

One Sided Weld, Full Penetration (90/100)

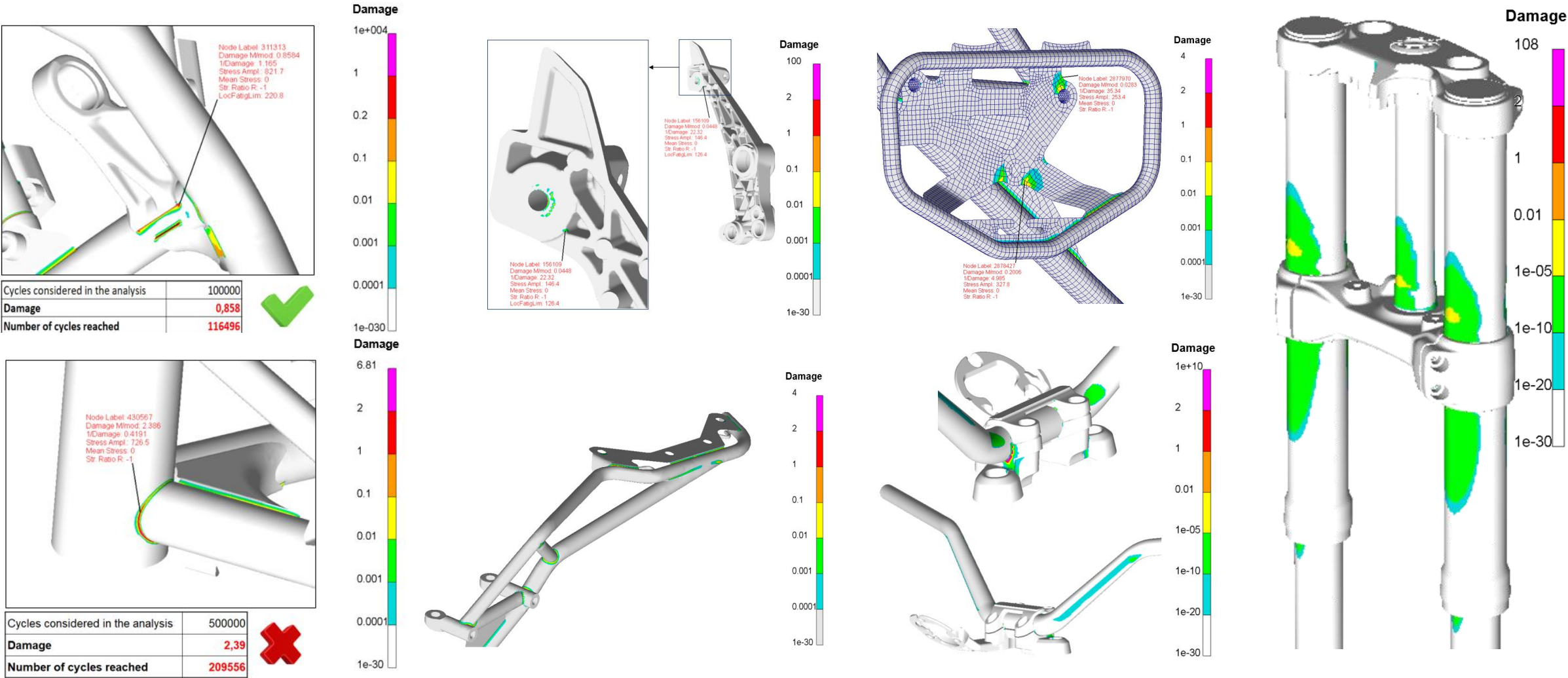


Weld Detail



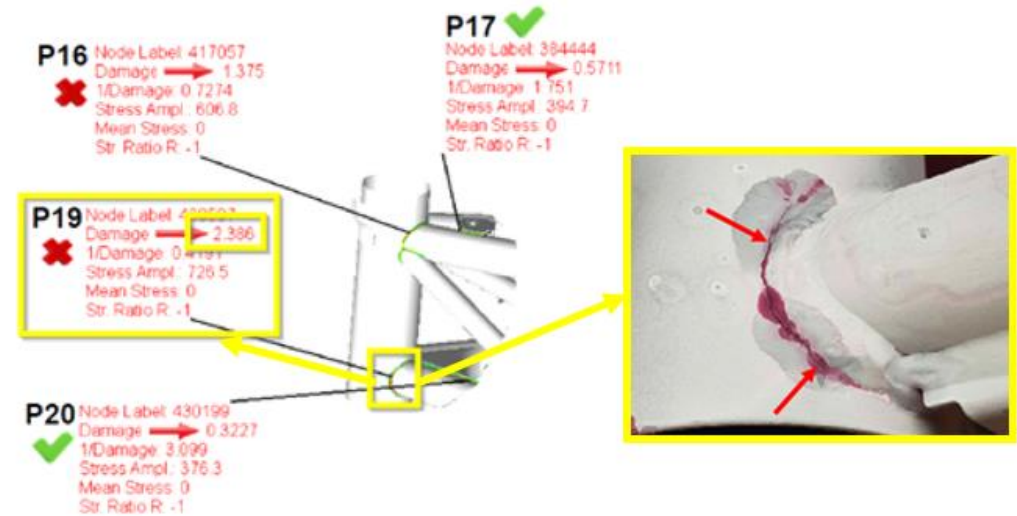
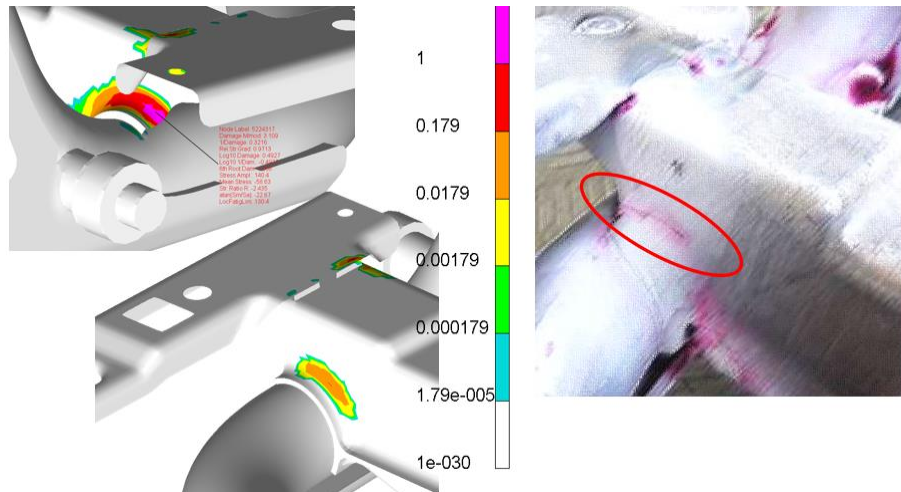
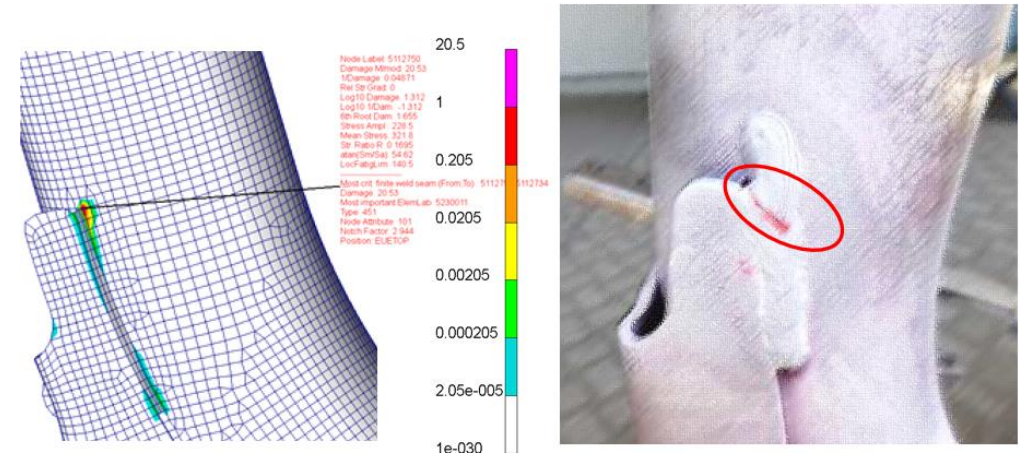
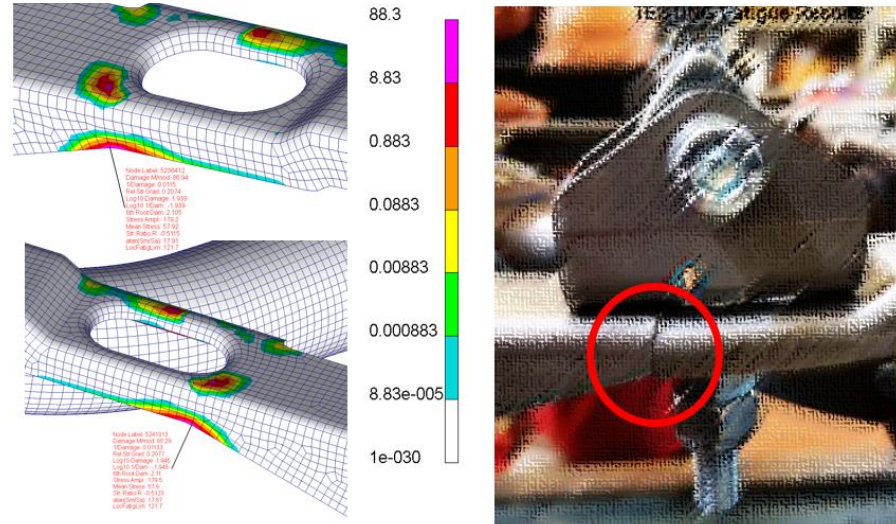
RICARDO CASE STUDIES

Examples of fatigue evaluation using FEMFAT for some motorcycle components



RICARDO CASE STUDIES

FEMFAT Results vs Testing Results for some motorcycle components during design development process



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CONCLUSIONS

- From the case study presented in this webinar, **excellent correspondences were found between fatigue analyzes** (conducted first through FEM analysis and subsequently using FEMFAT), **and the fatigue tests conducted on dedicated test benches.**



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