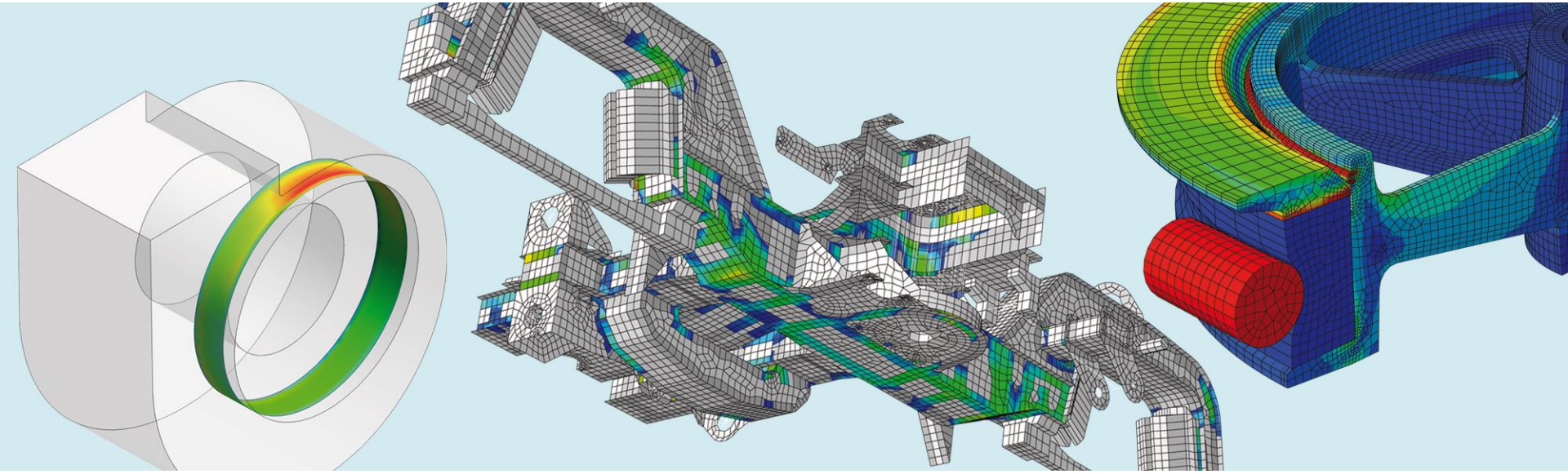
simulation solutions CAE

LIMIT stress evaluation



CAE Simulation & Solutions

Maschinenbau Ingenieurdienstleistungen GmbH

Dr. Wolfgang Krach, Dr. Walter Vonach, Dr. Nikolaus Friedl

Who we are:

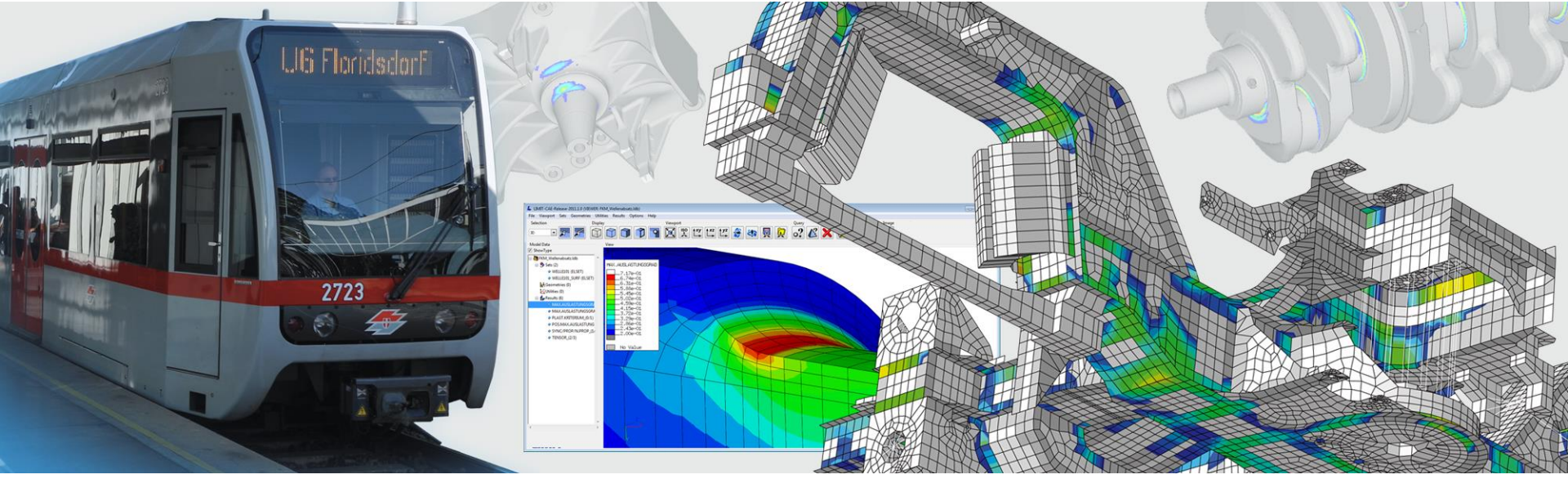
- **Engineering service provider**
  - Based in Vienna, Austria
  - Company founded 2003
- **Main fields of activities**
  - Structural mechanics
    - Strength assessments of structures
    - Simulation of production processes
    - More than 700 projects conducted
  - Computational fluid dynamics
    - Since 2010
    - Flow and heat transfer projects
  - Software development
    - Primarily for internal use
    - LIMIT since 2004, available for customers since 2010

Services
from idea to design

	Stand Alone Applications			CAD - Integrated
Draft	Catia			SWX
Finite Element Analysis Strength assessments	Hyperworks Abaqus	Patran/Nastra Marc	LIMIT	SWX / Simulation
Flow Simulation / Energy Transfer	Fluent / OpenFoam			SWX / Flow Simulation
Measurments/Tests				

Software Sales

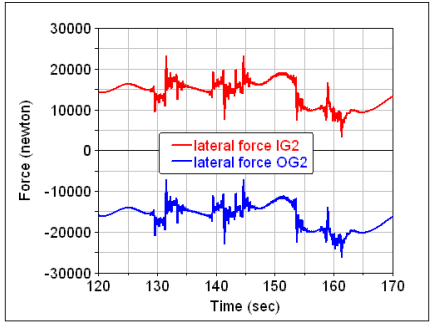
		MSC Software	LIMIT stress evaluation	SOLIDWORKS
Training/Support		FEA Topics	All	All



Efficient and conforming-to-standard fatigue assessment with LIMIT

Main Objective

- Finding critical loads and load cycle numbers
- Checking all critical positions
- Applying different design codes
  - Strong focus on welds and
  - Large structures



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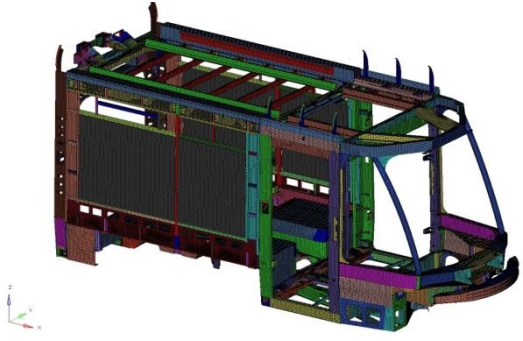


LIMIT Within the Simulation Process

Design: 3D-CAD

FE model
Patran, Hypermesh, Abaqus/CAE, ANSYS, NX

Finite Element Input
.bdf, .out, .dat, .inp

FE Solver
Nastran, Abaqus, ANSYS

FE Results
.fil, .odb, .op2, .rst

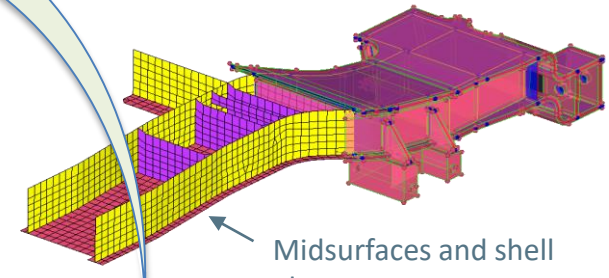
LIMIT-CAE
Definition of assessments in the GUI

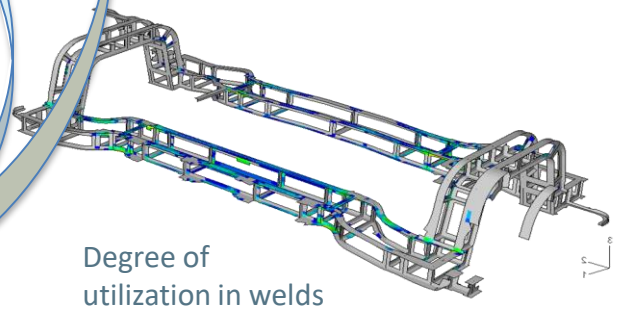
LIMIT-SOLVER
Analysis

LIMIT-VIEWER
Post processing

Global iteration loop, changing geometry

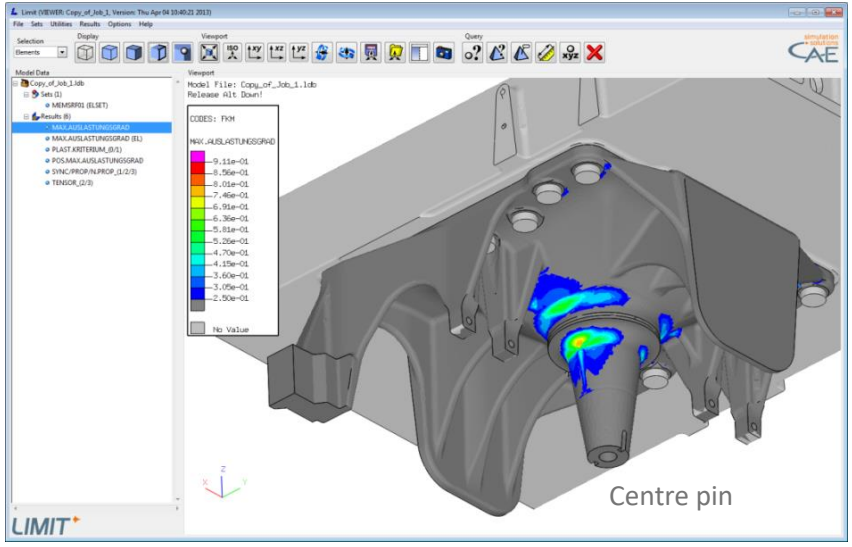
Local loop, e.g. changing weld quality



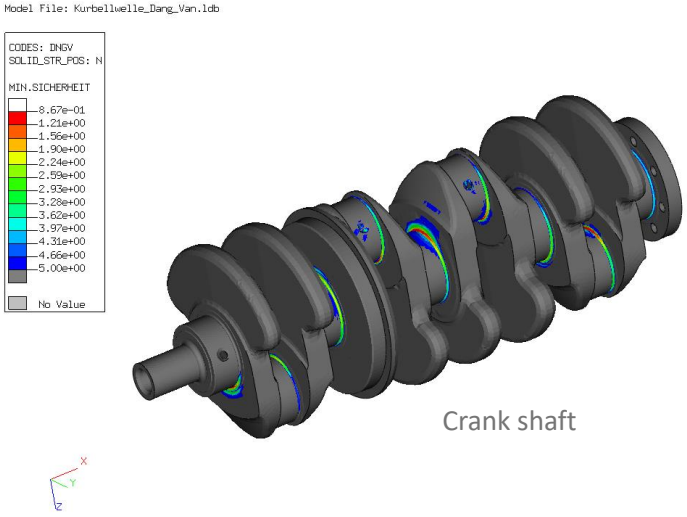


Assessment of base material

- static strength / fatigue strength
- Very efficiently using FKM guideline, 6th edition



Centre pin



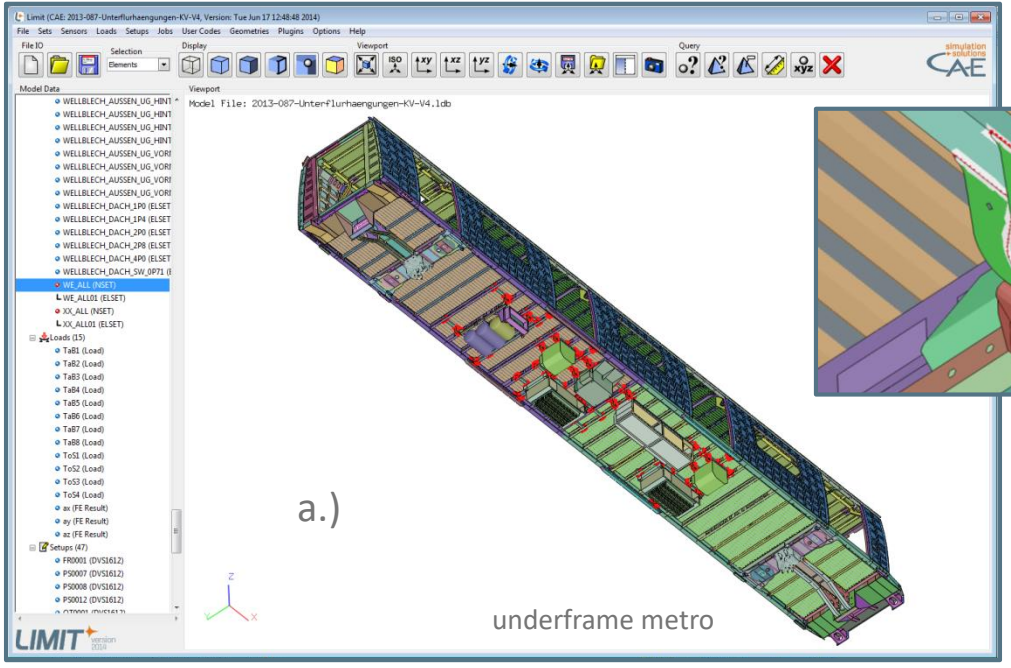
Crank shaft

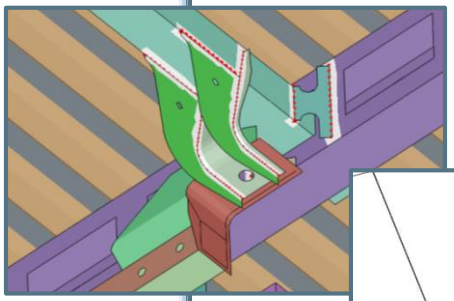
Effects taken into account

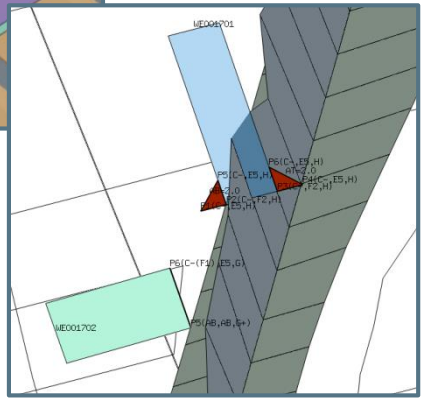
- stress gradients normal to surface
- surface factors
- temperature

Assessment of welds with nominal or structural hot spot stresses

a.) complex structures b.) simple definition of welds c.) visual check of weld geometry

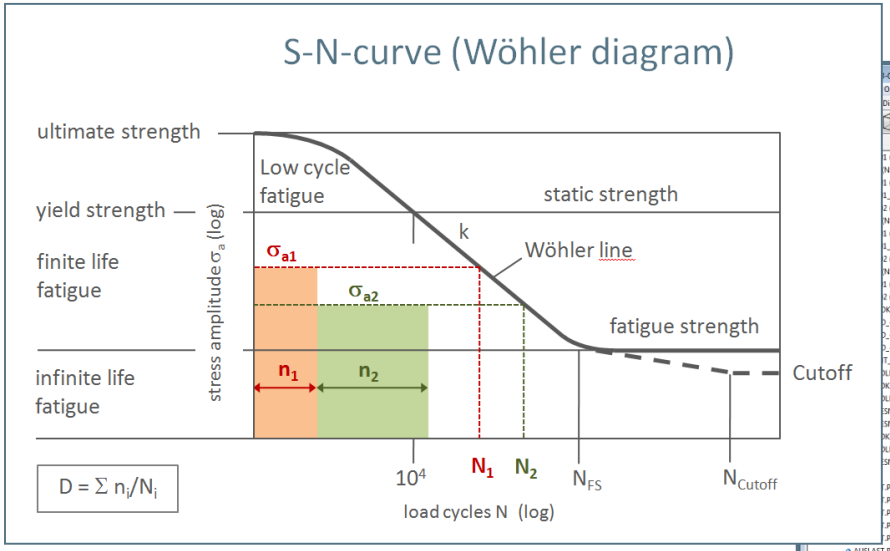


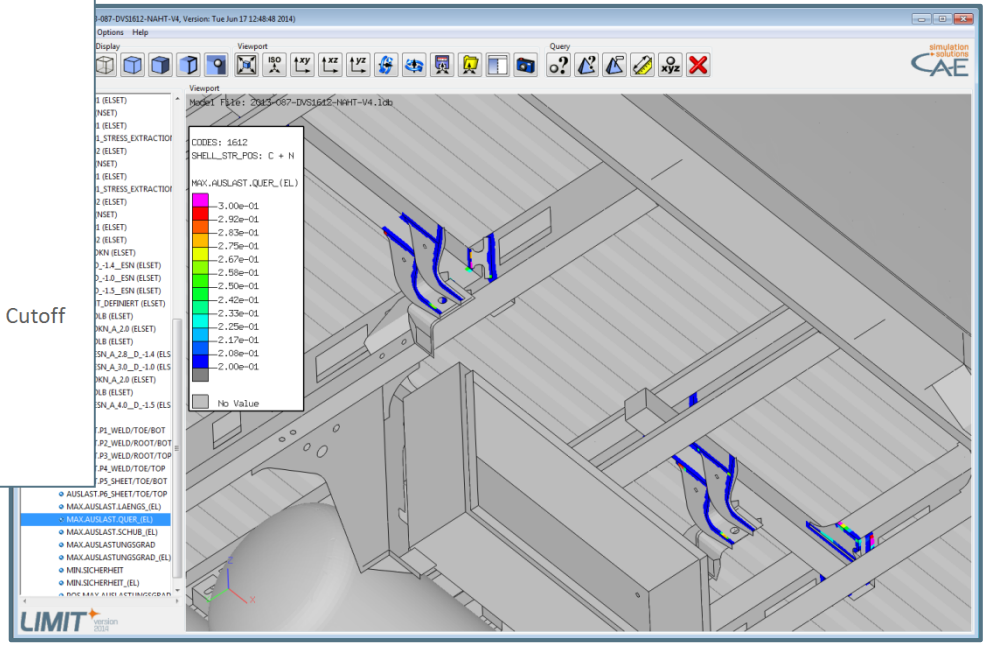




Assessment of welds with nominal or structural hot spot stresses

- static and fatigue assessment
- numerous codes available
- simple post processing





Features/Facts

Assessments:

- *Static strength*
- *Fatigue strength*
- *Finite life strength*

Stress types:

- *Nominal stress*
- *Structural hot spot stress*
- *Local stress*
- *Embedded sensors*

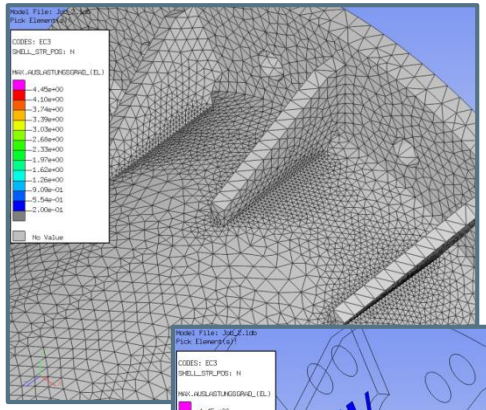
Codes/Guidelines:

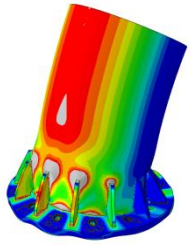
- *FKM-Guideline*
- *Eurocode 3 and 9*
- *DVS 1612 / 1608*
- *User defined*
- *Crane code : DIN15018, EN13001*

Interfaces:

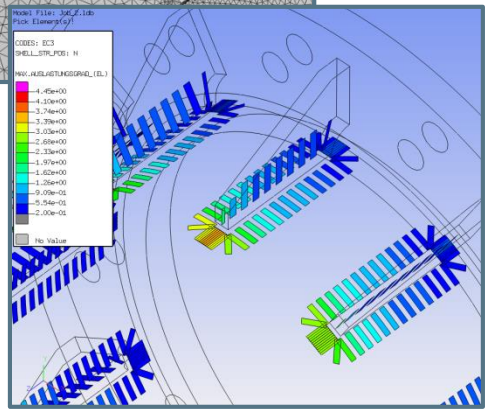
- *Nastran / NX Nastran*
- *Radioss / Optistruct*
- *Ansys*
- *Abaqus*
- *Catia FE (Tetras)*
- *SolidWorks*

Mesh Tet10





Flange



Structural hot spot assessment

Advantages using LIMIT

- **Reduction of time-to-market**
- **Reduction of risk of failure**
  - Comprehensive and accurate assessment
  - Quality is improved, especially compared to manual assessment
  - Saves money due to less cases of warranty
- **Simple to use for engineers => low costs for training**

fatigue cracks in welds

References

- AMST-Systemtechnik GmbH
- AUDI, Werkzeugkonstruktion, Germany
- Bühler AG, Switzerland
- China Energine International Ltd.
- FEMCOS-Ingenieurbüro mbH, Germany
- Gardner Denver Schopfheim GmbH, Germany
- IBV-Engineering, Germany
- IFF Engineering & Consulting GmbH, Germany
- Ludwig Engel KG, Austria
- Liebherr-Transportation Systems GmbH & Co KG
- PESA Bydgoszcz SA, Poland
- Prisma Engineering, Austria
- RUAG Schweiz AG, Switzerland
- Stadler Valencia, Spain
- STREICHER Maschinenbau GmbH & Co. KG, Germany
- TUV Rheinland Rail Sciences, Inc., Nebraska, USA
- Vossloh Locomotives, Kiel

Stress Concepts for Welded Structures

Weld Analysis with LIMIT

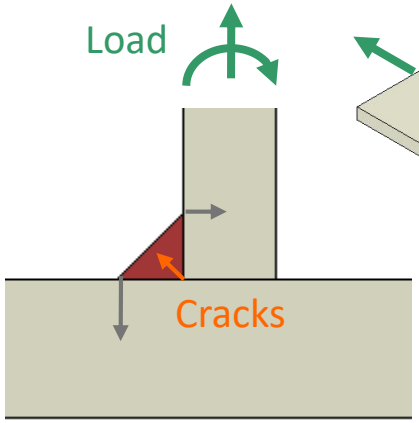
Single sided fillet weld

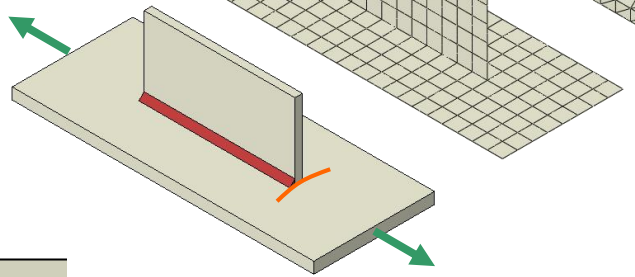
- Fillet throat critical => stresses in throat needed!

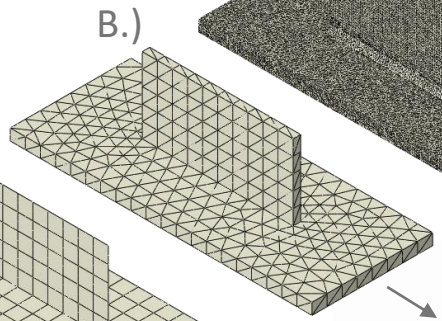
A.) Using section forces from shell model

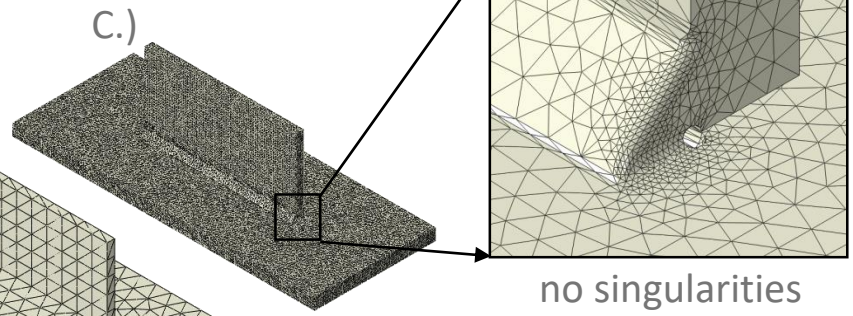
B.) Using section forces from solid model & LIMIT sensors

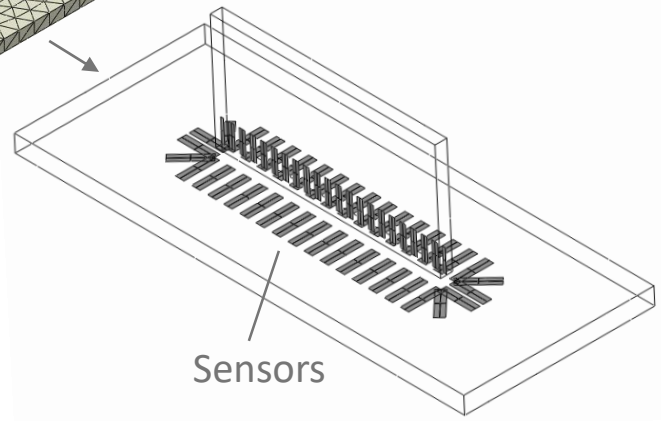
C.) R1-effective notch











Weld Analysis with LIMIT

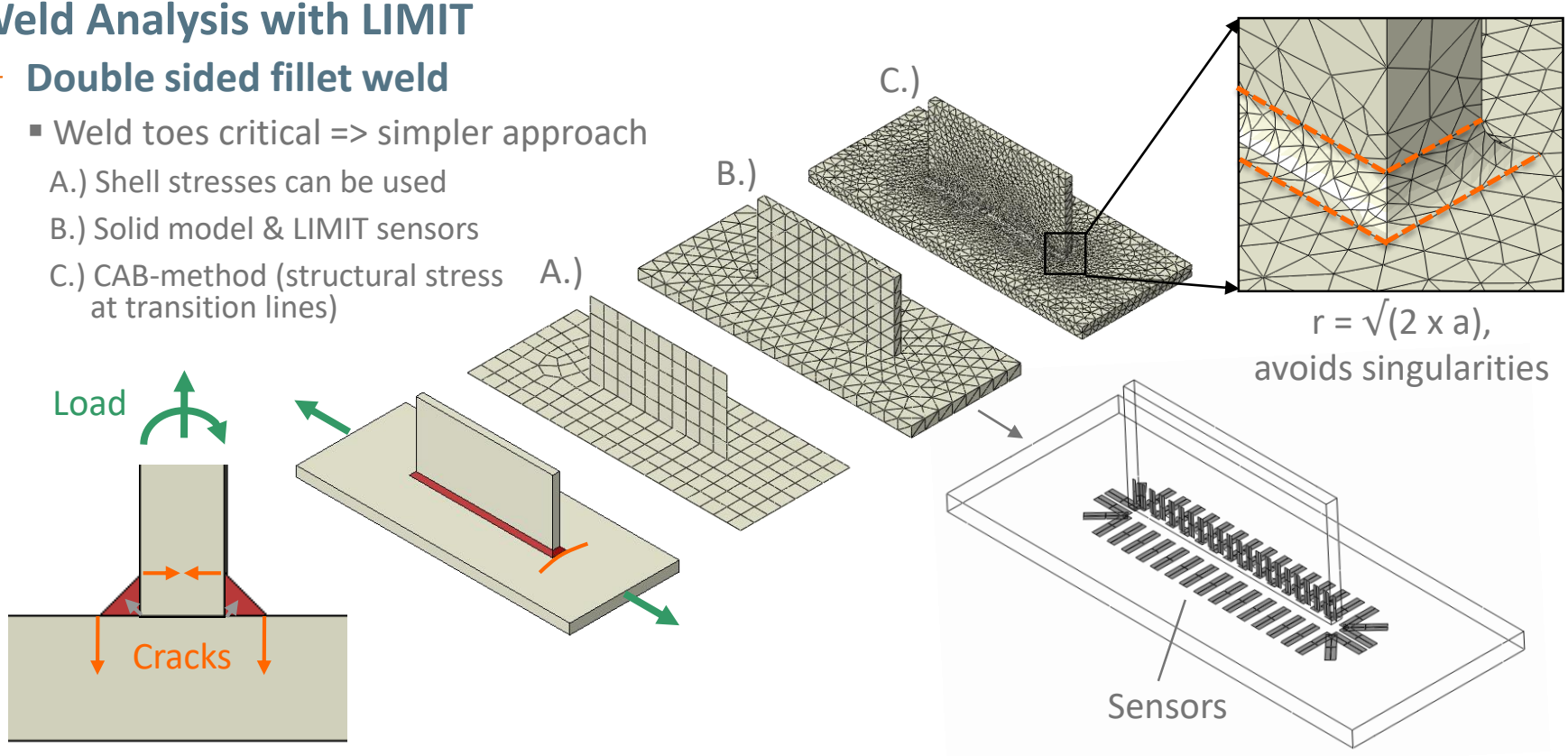
Double sided fillet weld

- Weld toes critical => simpler approach

A.) Shell stresses can be used

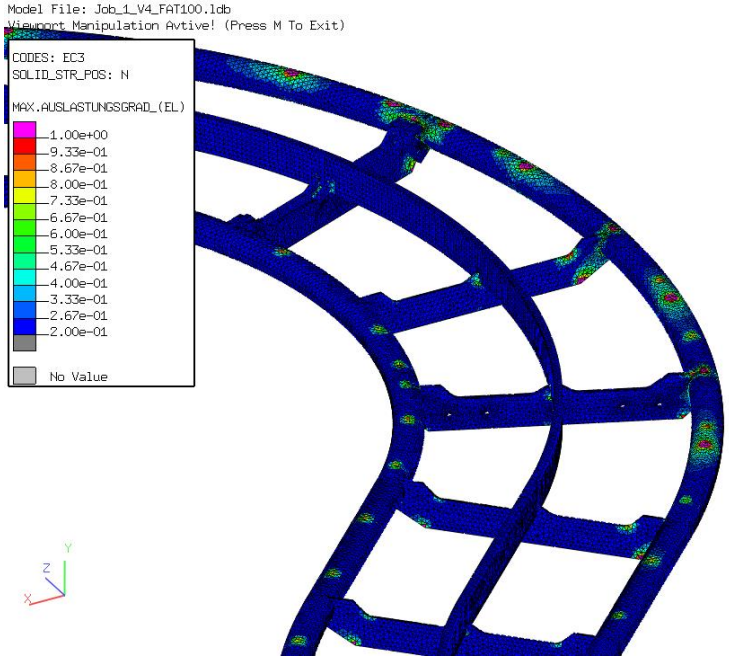
B.) Solid model & LIMIT sensors

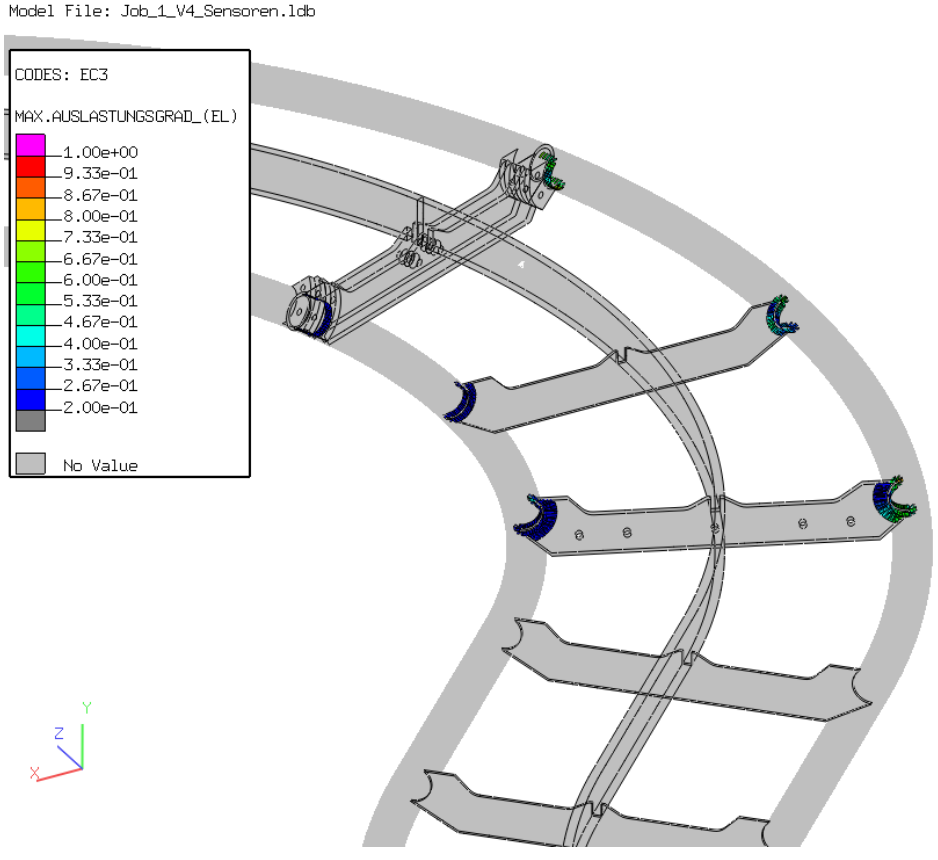
C.) CAB-method (structural stress at transition lines)



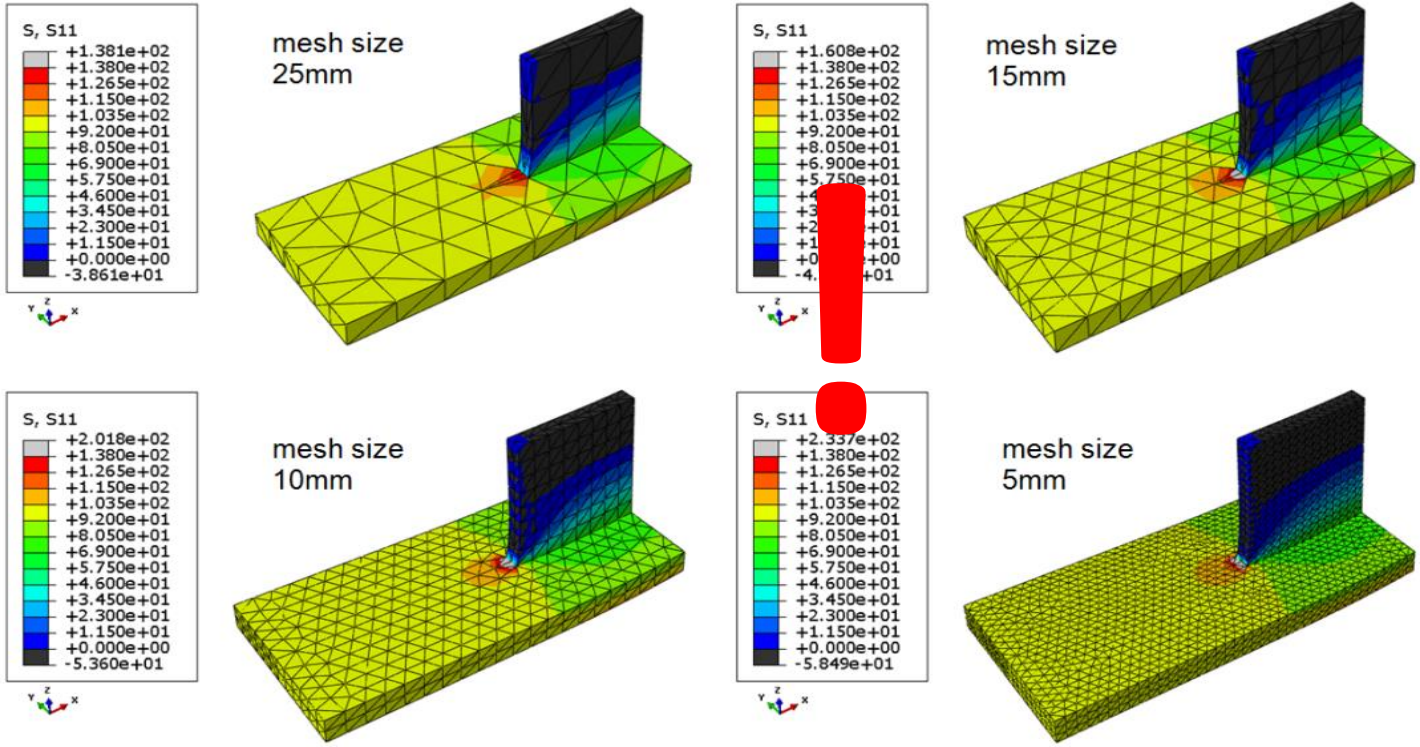
Weld Analysis with LIMIT

- **Example: Solid modeling & weld assessment with sensors**



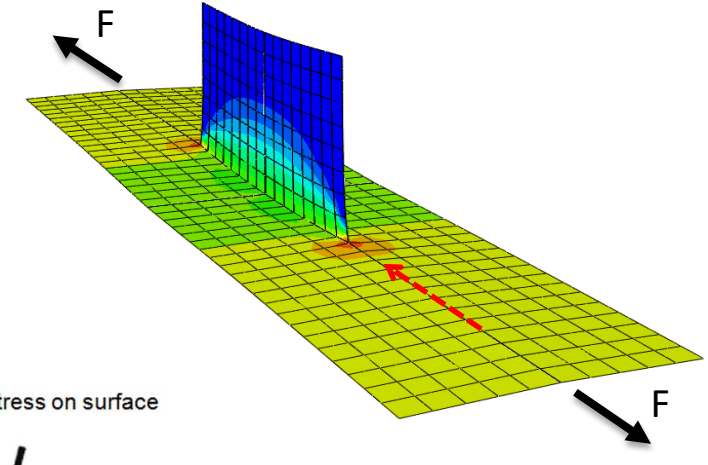


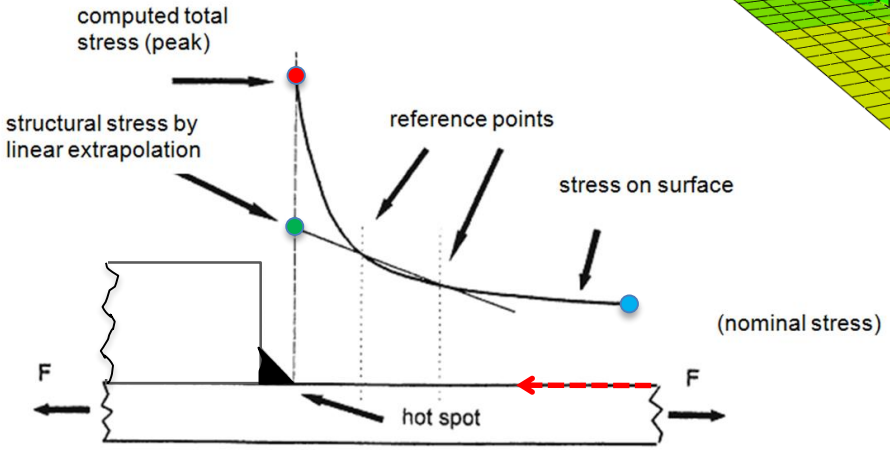
Strongly mesh dependant results:



Stress concepts for welded structures

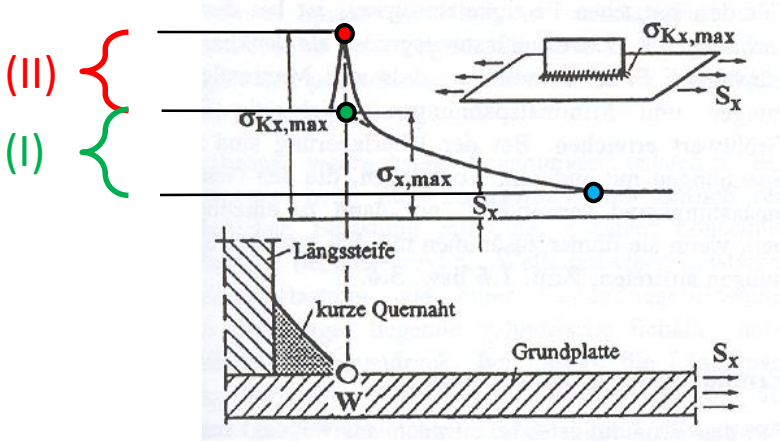
- **Nominal stress**
  - classic concept
- **Notch stress (peak stress)**
- **Structural hot spot stress (IIW)**



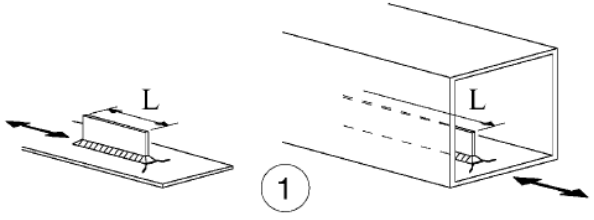


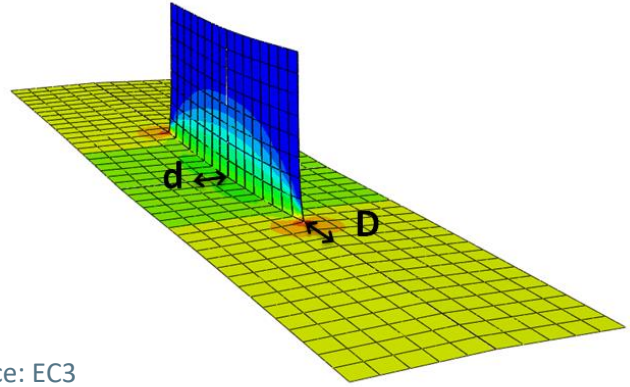
Nominal stresses

- **Stresses relating to nominal section**
- **Permissible stresses include:**
  - Stress increase due to change in stiffness (I)
  - Local notch effect through weld root or weld toe (II)



Kerbfall	Konstruktionsdetail	
80	$L \leq 50$mm	
71	$50 < L \leq 80$ mm	
63	$80 < L \leq 100$ mm	
56	$L > 100$ mm	

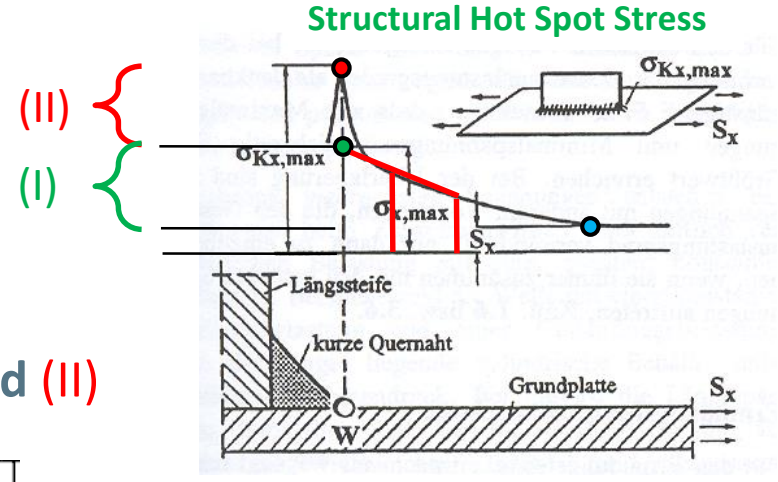


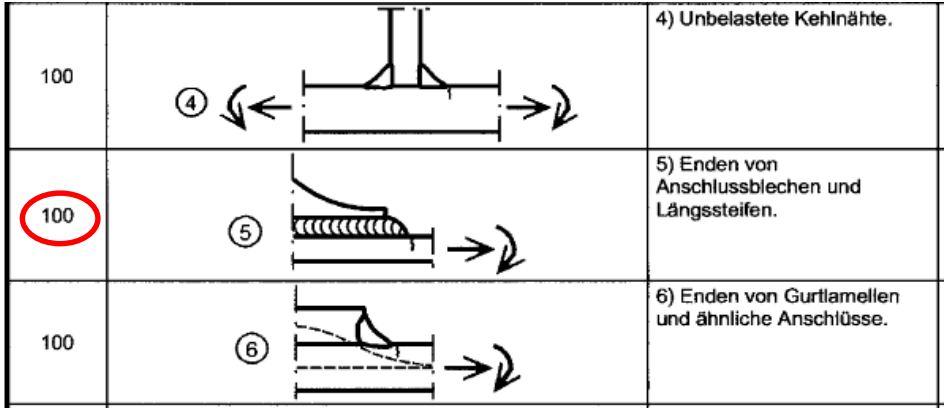


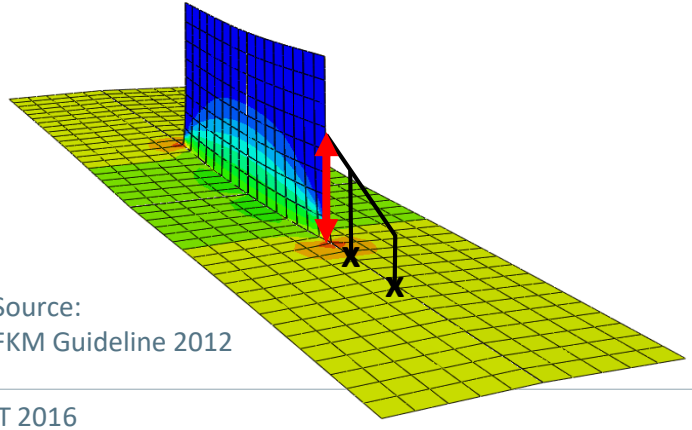
Source: EC3

Structural hot spot stress

- According to IIW
  (International Institute of Welding)
- Stresses include structural effect (I)
- Permissible values include notch of weld (II)





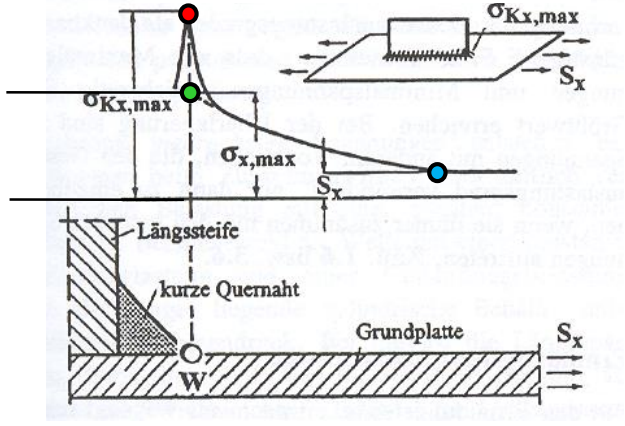


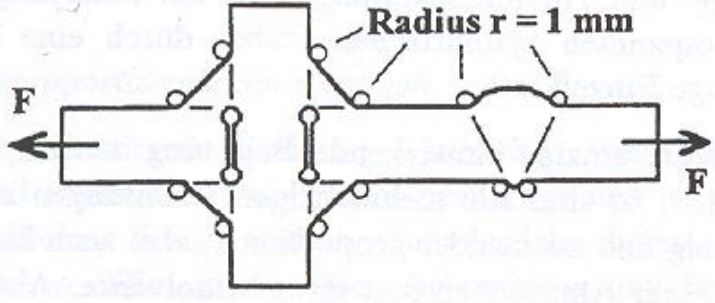
Source:
FKM Guideline 2012

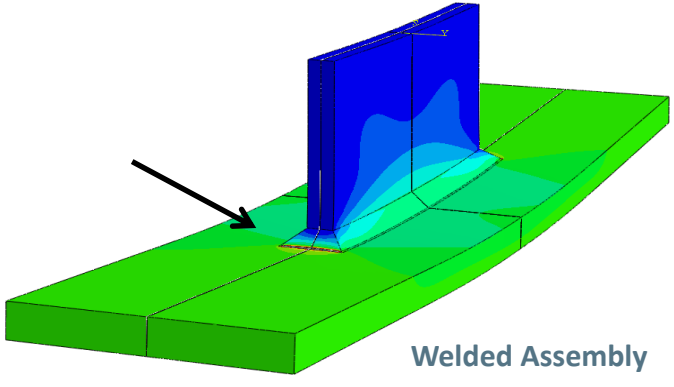
Effective notch stress

- According to Radaj
- Toe and root modeled with Radius 1mm
- Linear elastic analysis
- Calculate stress range
- For structural steel: FAT 225 (at 2 mio. cycles)
- Only for detail studies usable

Notch stress



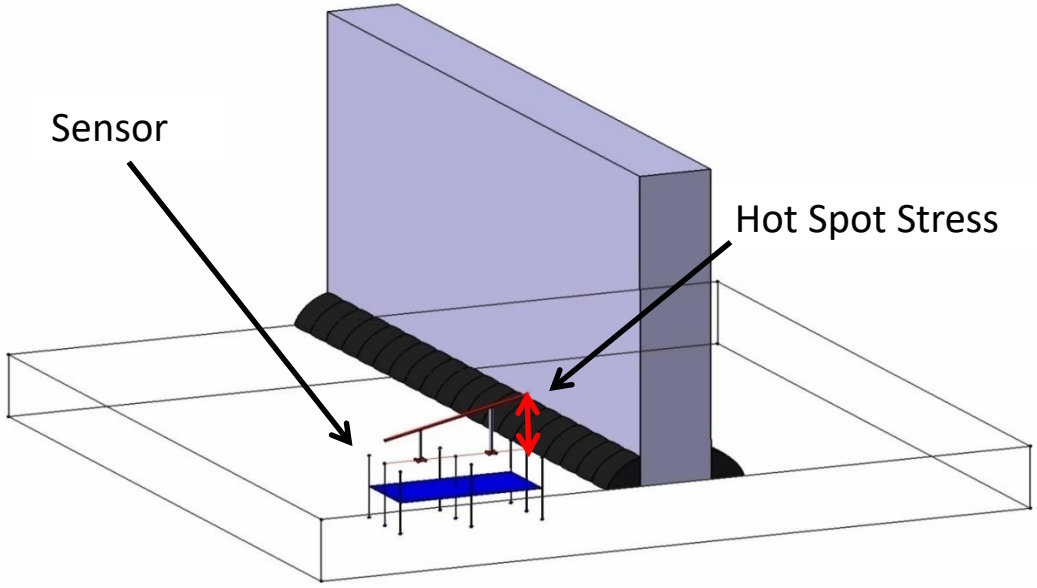




Welded Assembly

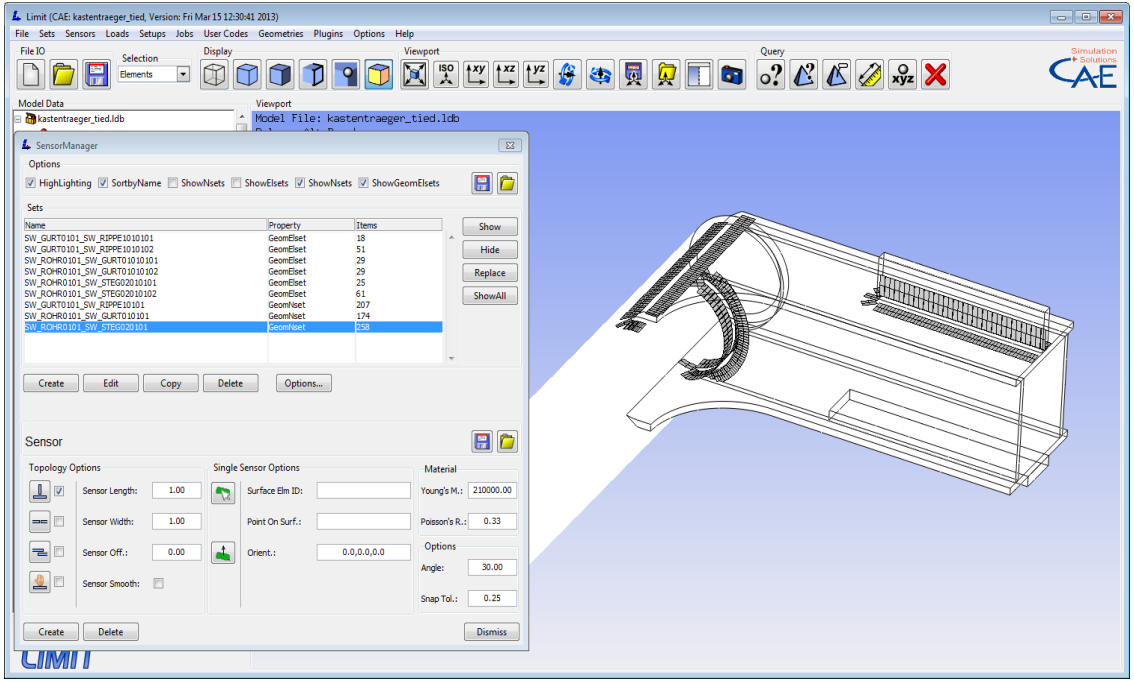
Structural Hot Spot / Nominal Stresses for Solid Elements

- Sensors embedded within the solid model
- Extracting structural stresses for weld toes
- Linear extrapolation scheme according to IIW
- Averaged stress data comparable to shell results



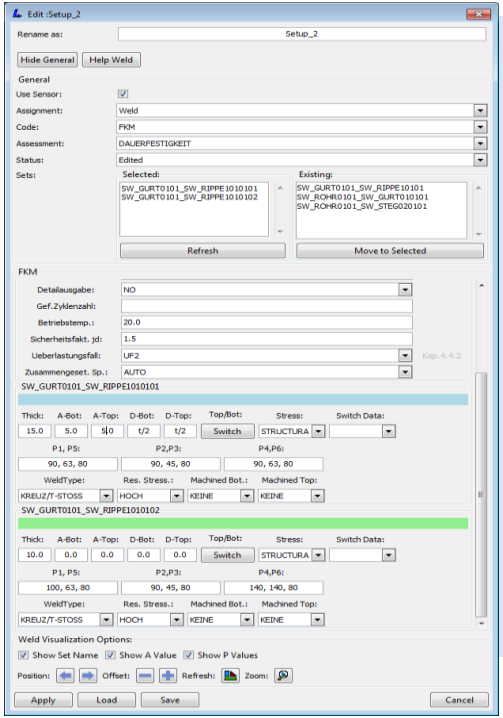
Structural Hot Spot Stresses for Solid Elements

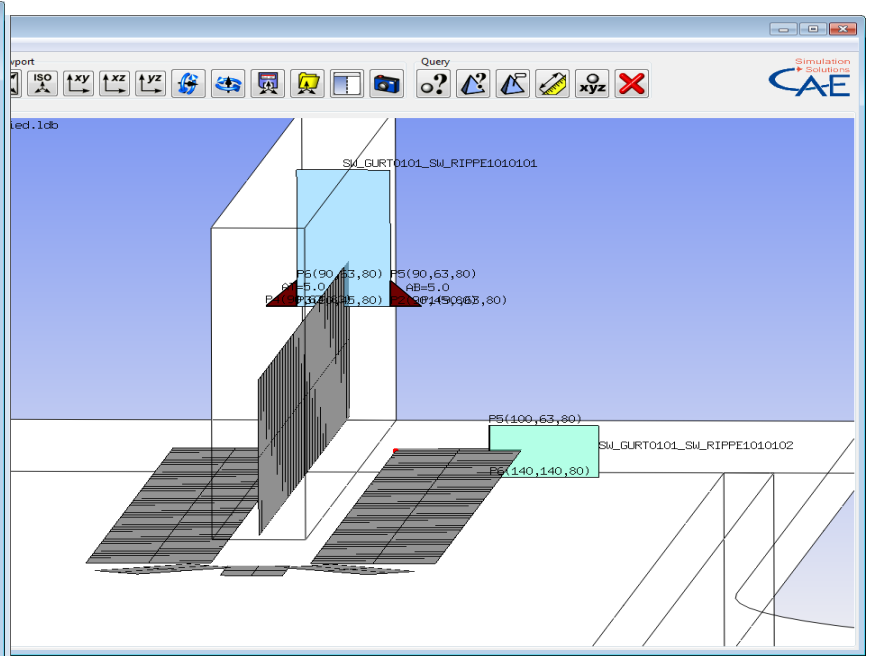
- Generation of sensors with *LIMIT* SensorManager



Structural Hot Spot Stresses for Solid Elements

- Sensors: definition of welds in same way as for shells

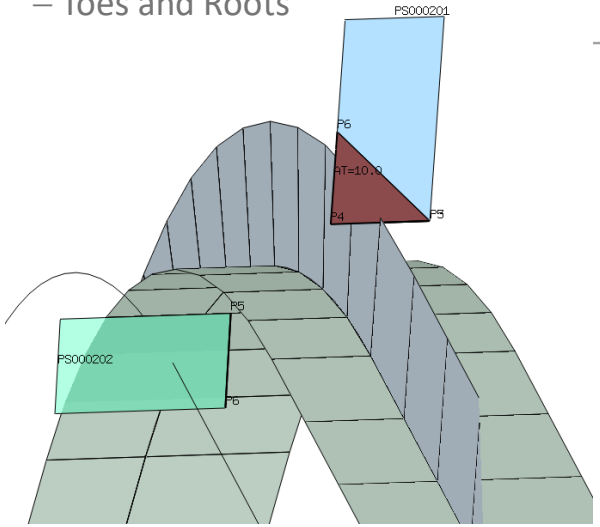


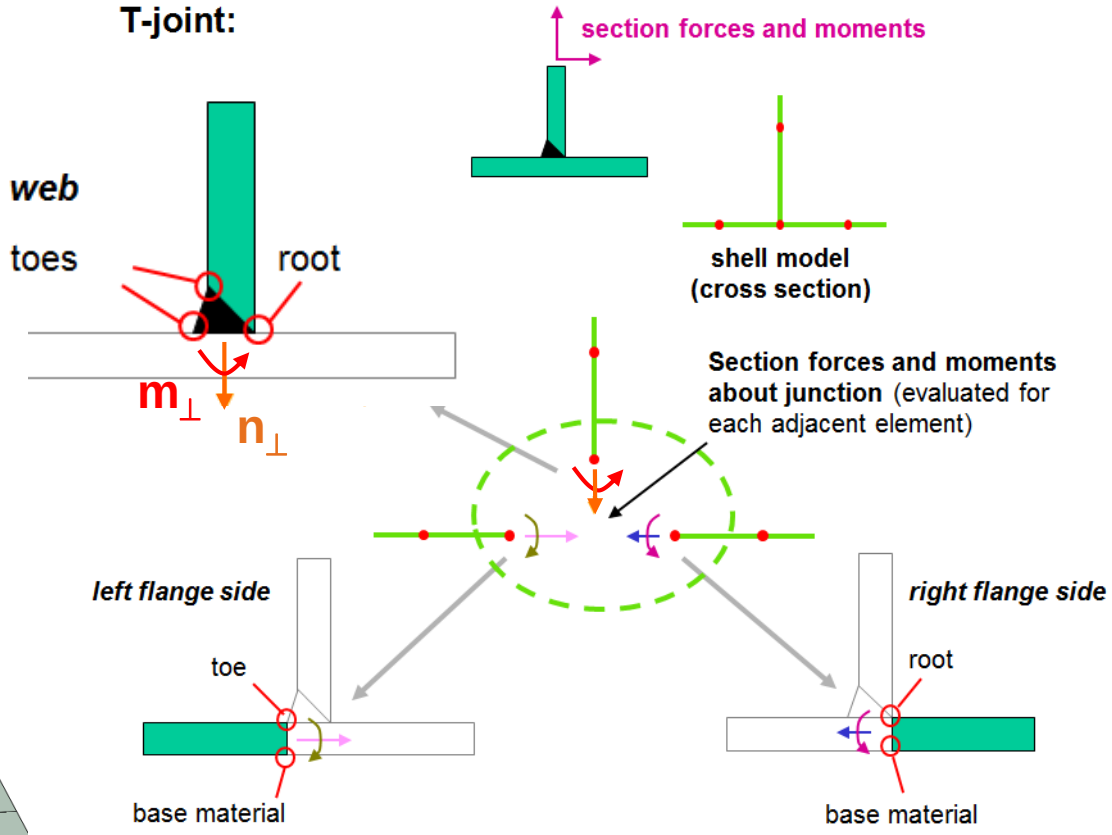


Weld Analysis with LIMIT

Basic features of LIMIT

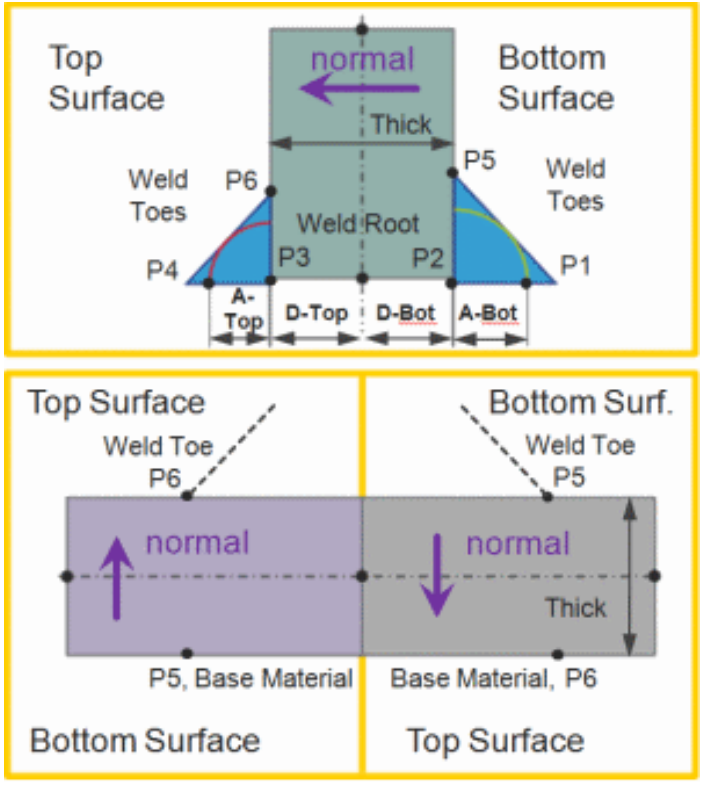
- Checking all critical points (red circles)
  - Base material
  - Weld section
  - Toes and Roots





Assessment Points within LIMIT

- **Are used to perform the fatigue analysis for potential areas of crack initiation**
- **Are defined relative to shell normal**
- **P1 to P4 …. Weld Section**
  - P1, P4 … toe
  - P2, P3 … root
- **P5 and P6 …. Base Material**
- **Weld dimensions**
  - A-Bot … welded from bottom side
  - A-Top … welded from top side
- **Root Position (midplane to root)**
  - D-Bot … welded from bottom side
  - D-Top … welded from top side



Single sided fillet weld, Stresses in P6

- t … sheet thickness
- continously welded
- P6 … stresses caculated for sheet thickness

Stress longitudinal to weld direction:

$\sigma_{II,6} = \sigma_{II,Top}$

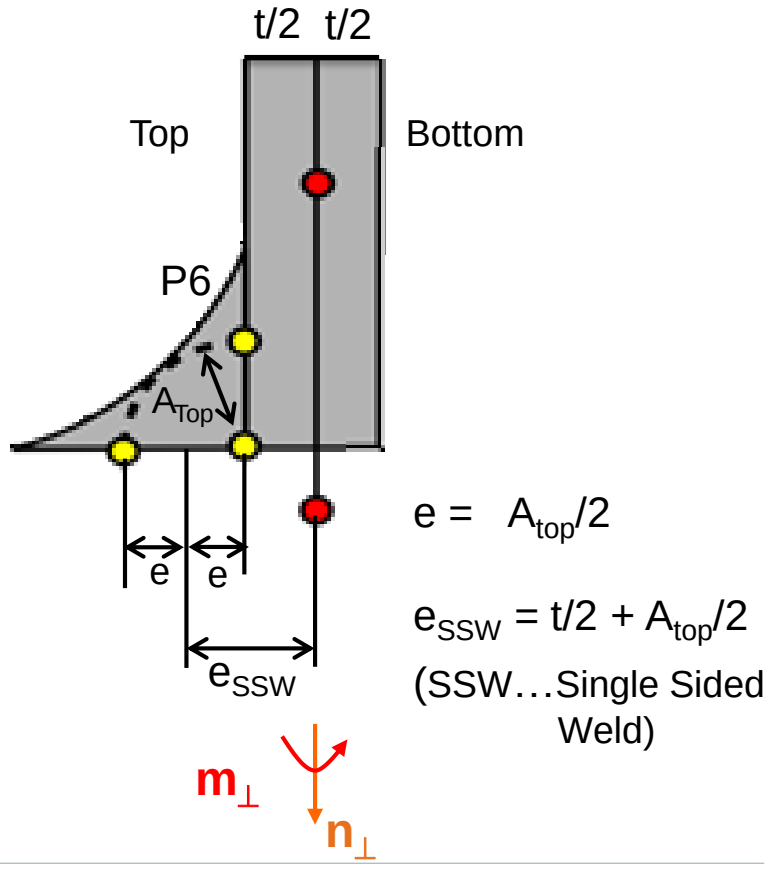
Stress lateral to weld direction:

$\sigma_{\perp,P6} = n_\perp / t + (m_\perp + n_\perp e_{EXC}) / (t^2/6)$

$e_{EXC} = e_{SSW}$ …free (FKM)
$e_{EXC} = e_{SSW/2}$…constrained

Shear in weld (in plane):

$\tau_{II,P6} = s_{II} / t$



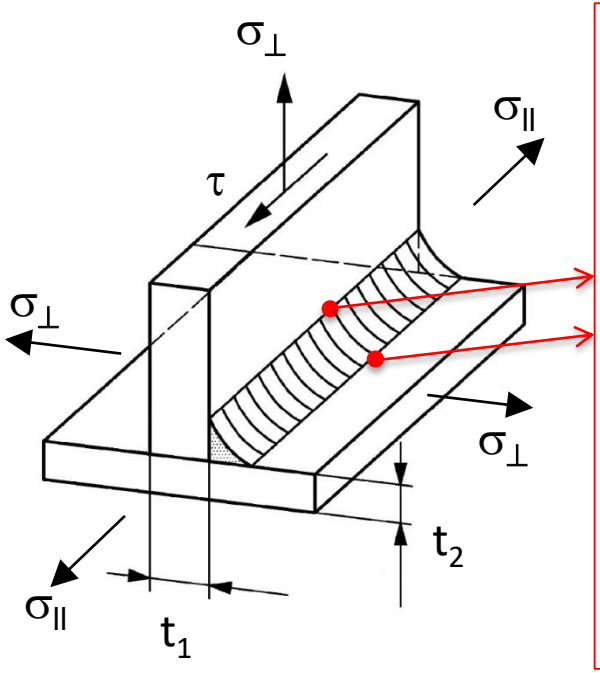
$e = A_{top}/2$

$e_{SSW} = t/2 + A_{top}/2$

(SSW…Single Sided Weld)

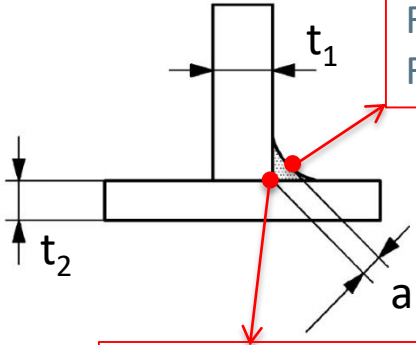
FAT classes, one sided fillet weld:

Typical values:



Nominal stress, toe:
$FAT_{\parallel} = 100$
$FAT_{\perp} = 71 \div 80$
$FAT_{\tau} = 80$

Structural stress, toe (IIW)
$FAT_{\parallel} = 100$
$FAT_{\perp} = 100$
$FAT_{\tau} = 80$



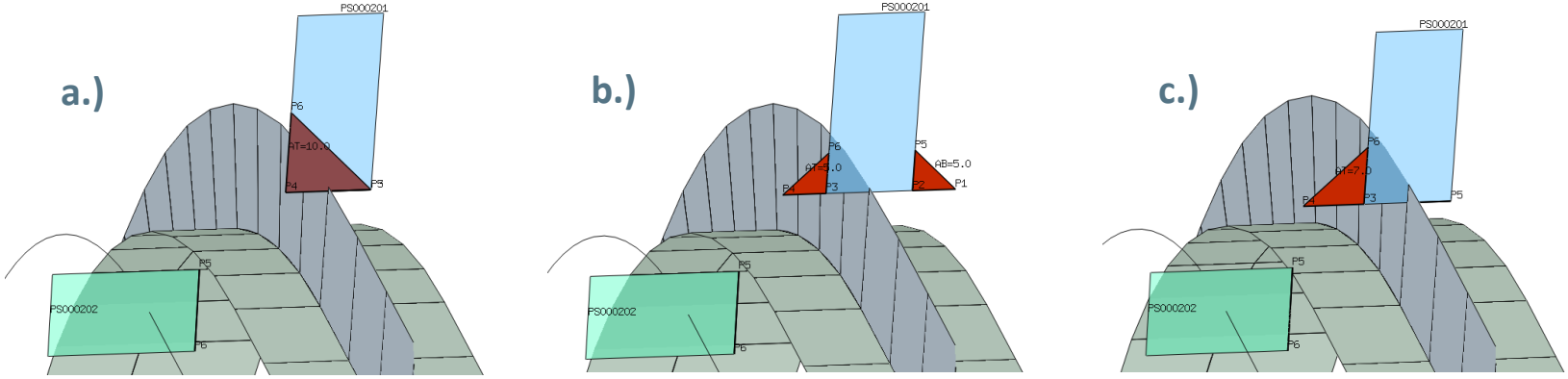
Only nominal stress, toe:
$FAT_{\parallel} = 100$
$FAT_{\perp} = 71$
$FAT_{\tau} = 80$

Only nominal stress, root:
$FAT_{\parallel} = 100$
$FAT_{\perp} = 36$ + Excentricity!
$FAT_{\tau} = 80$

Typical results

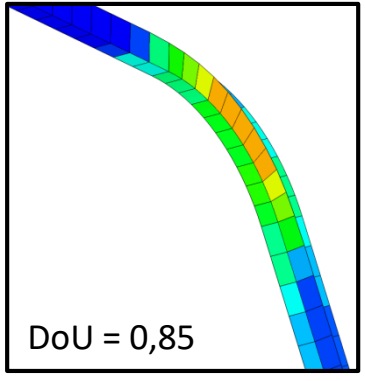
In the following section results are compared and documented for different weld types :

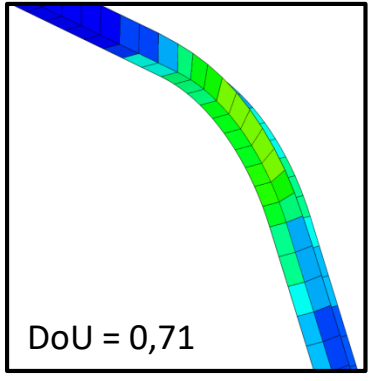
- **a.) One sided full penetration weld**
- **b.) Double sided fillet weld**
- **c.) One sided fillet weld**

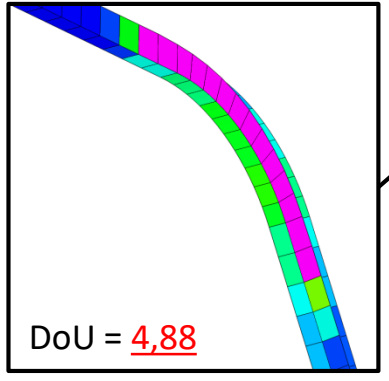


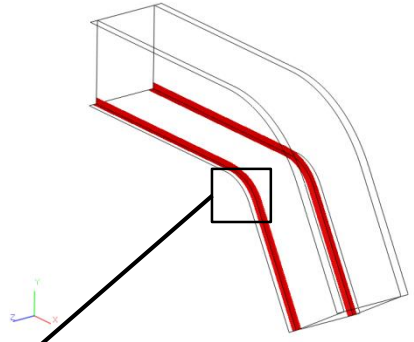
Comparison for different geometries

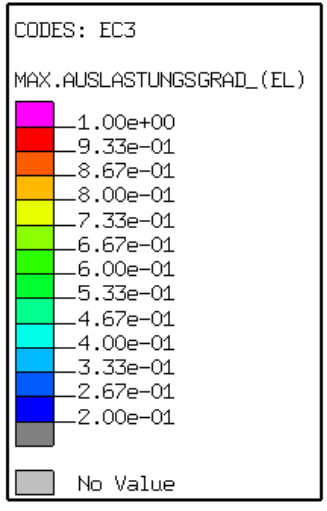
Degree of Utilization (DoU)

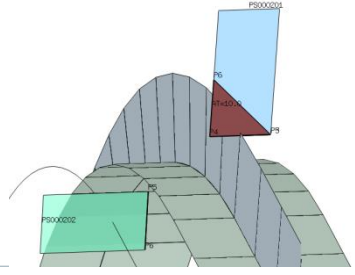


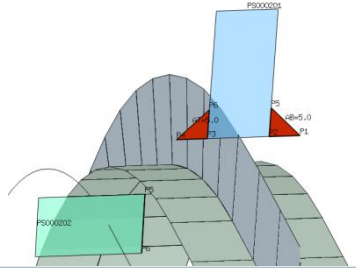


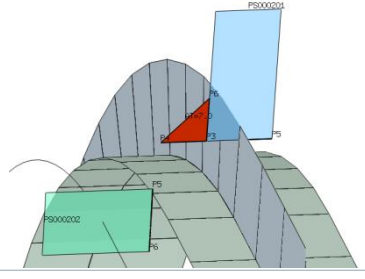


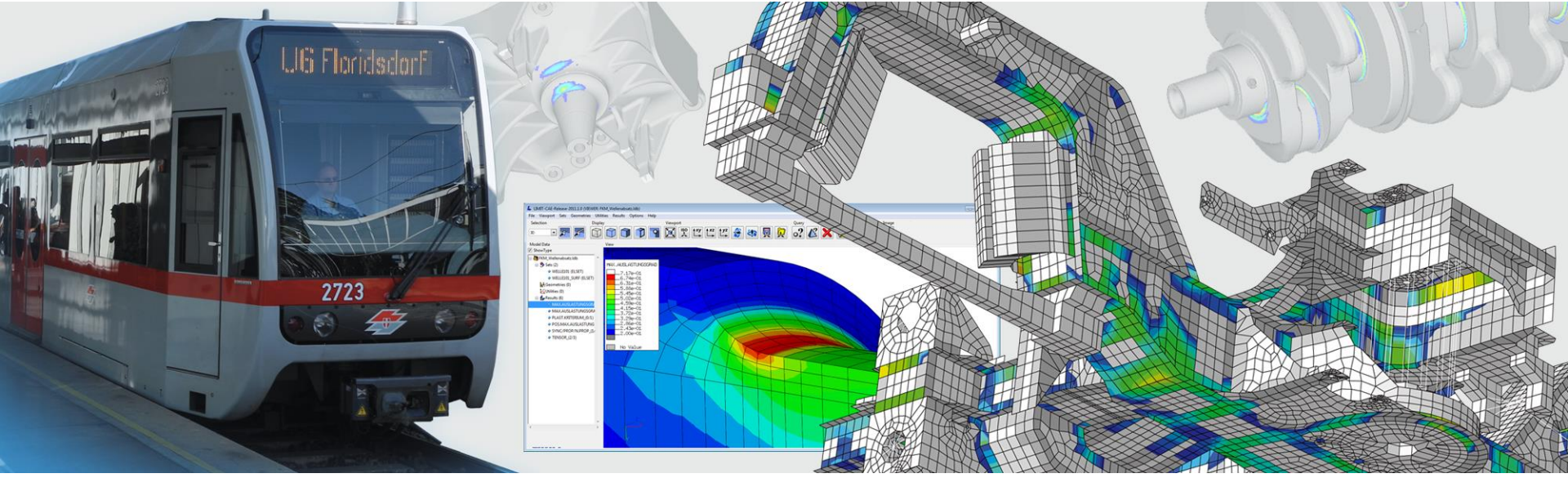












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