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STADLER

Clevere Lösungen auf der Schiene

FEMFAT

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Efficient Modeling and Evaluation of Welding Seams at Stadler Rail Altenrhein/Switzerland

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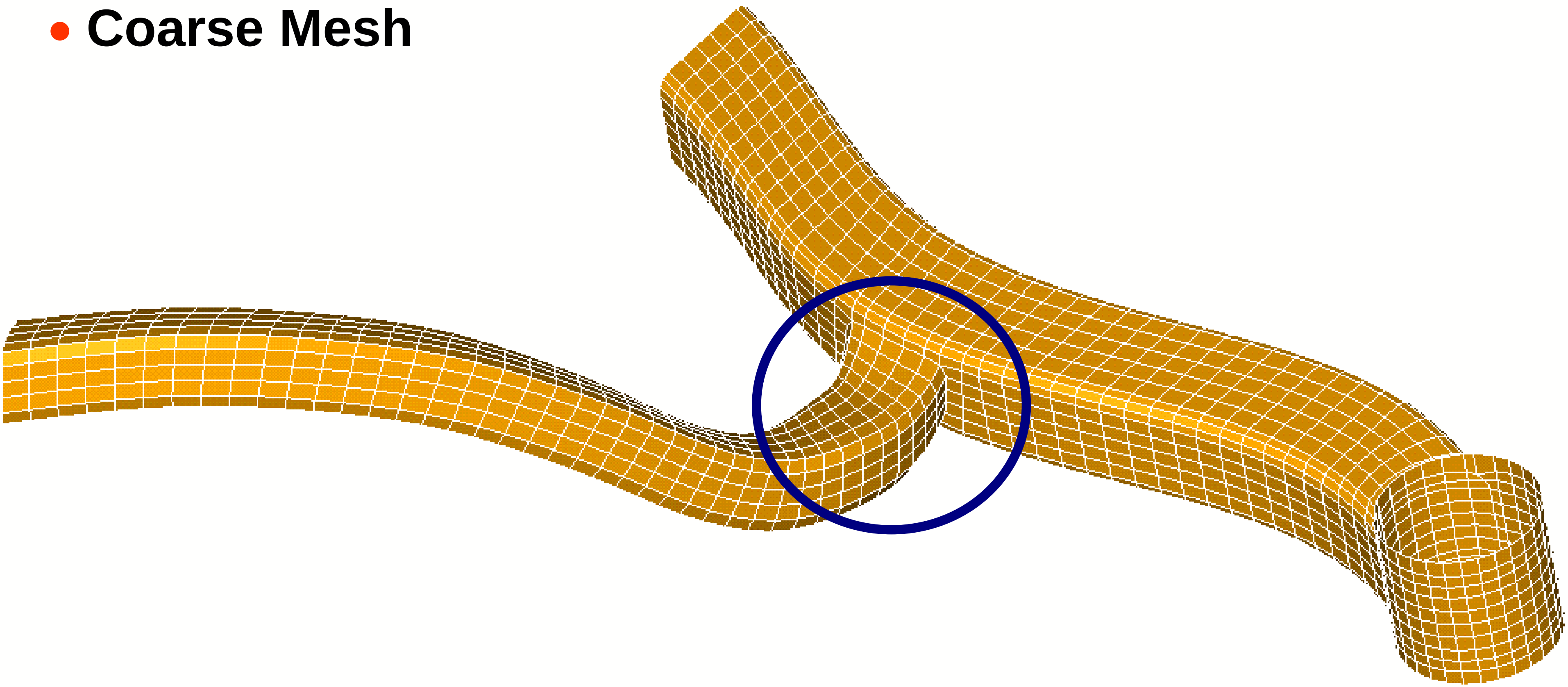
- **Weld seam modeling in FE-Preprocessors**
- **Weld seam modeling in FEMFAT Visualizer instead**
- **Fatigue analysis of Weld seams in FEMFAT WELD (proposed method by Stadler Rail)**
- **Procedure at STADLER RAIL for weldseam modeling**
  - FE meshing in Hypermesh
  - Weld seam definition in FEMFAT VISUALIZER – half model
  - Dummy analysis for output file
  - mirror the definition to the other half (external tool)
  - Fatigue analysis with FEMFAT

Weld seam modeling in FE-Preprocessors

- Setup of FE Model
- For Example With Shell Elements
- Coarse Mesh



Weld seam modeling in FE-Preprocessors

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- Definition of Weld Seams
  According to Modeling Guidelines
- Weld Nodes are recognised by Node colour or Coord. System
- Weld Type is Recognised by Element ID
- No Modification of Material Properties

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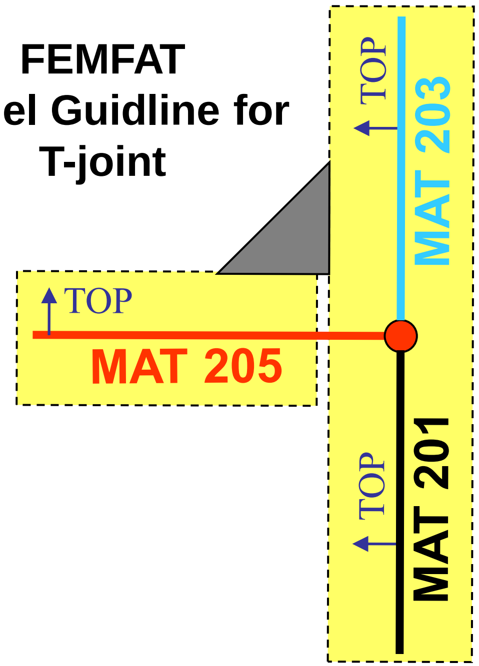
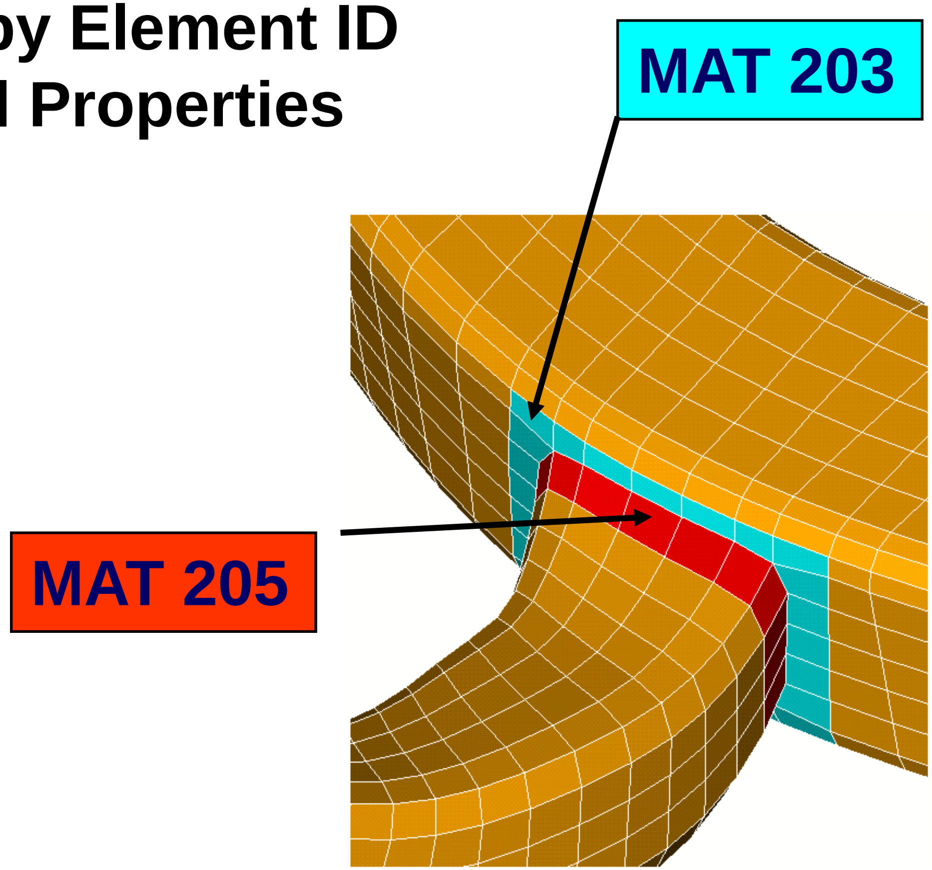
Model Guidline for
T-joint



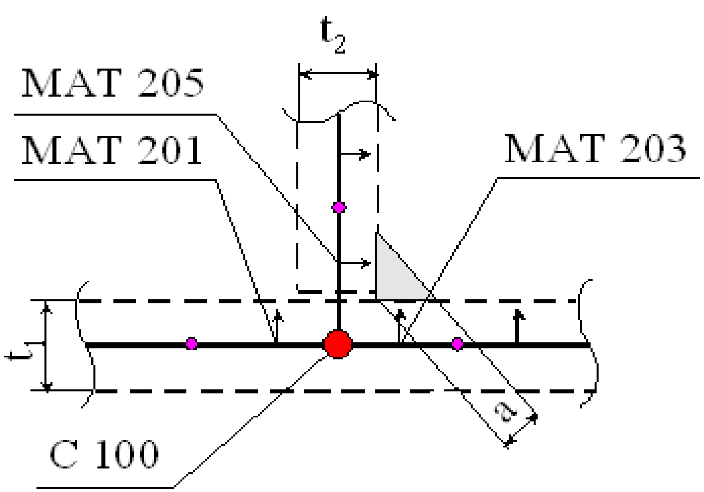


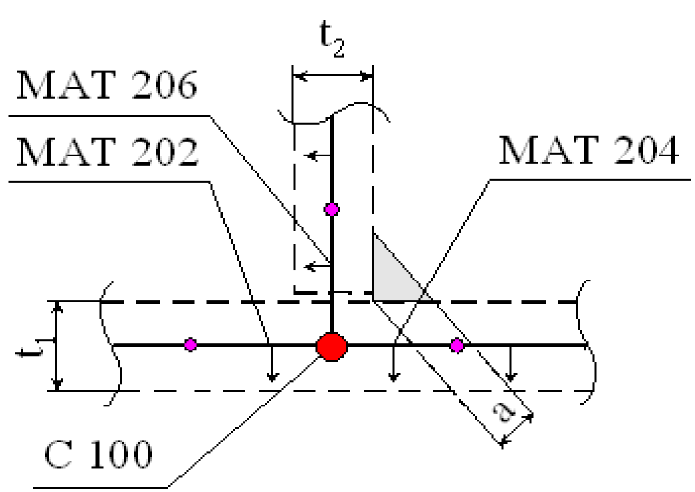
Modeling Guideline for T-Joint

Weldtype: **T-JOINT**
Seamform: One sided fillet weld

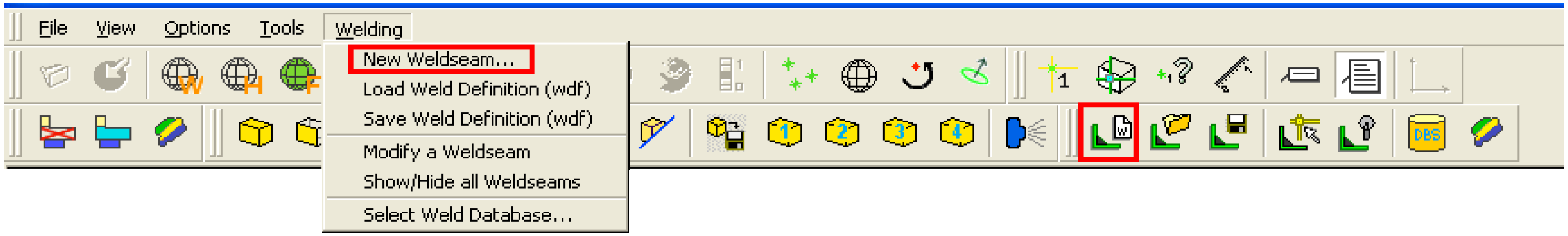
2D Modelling:

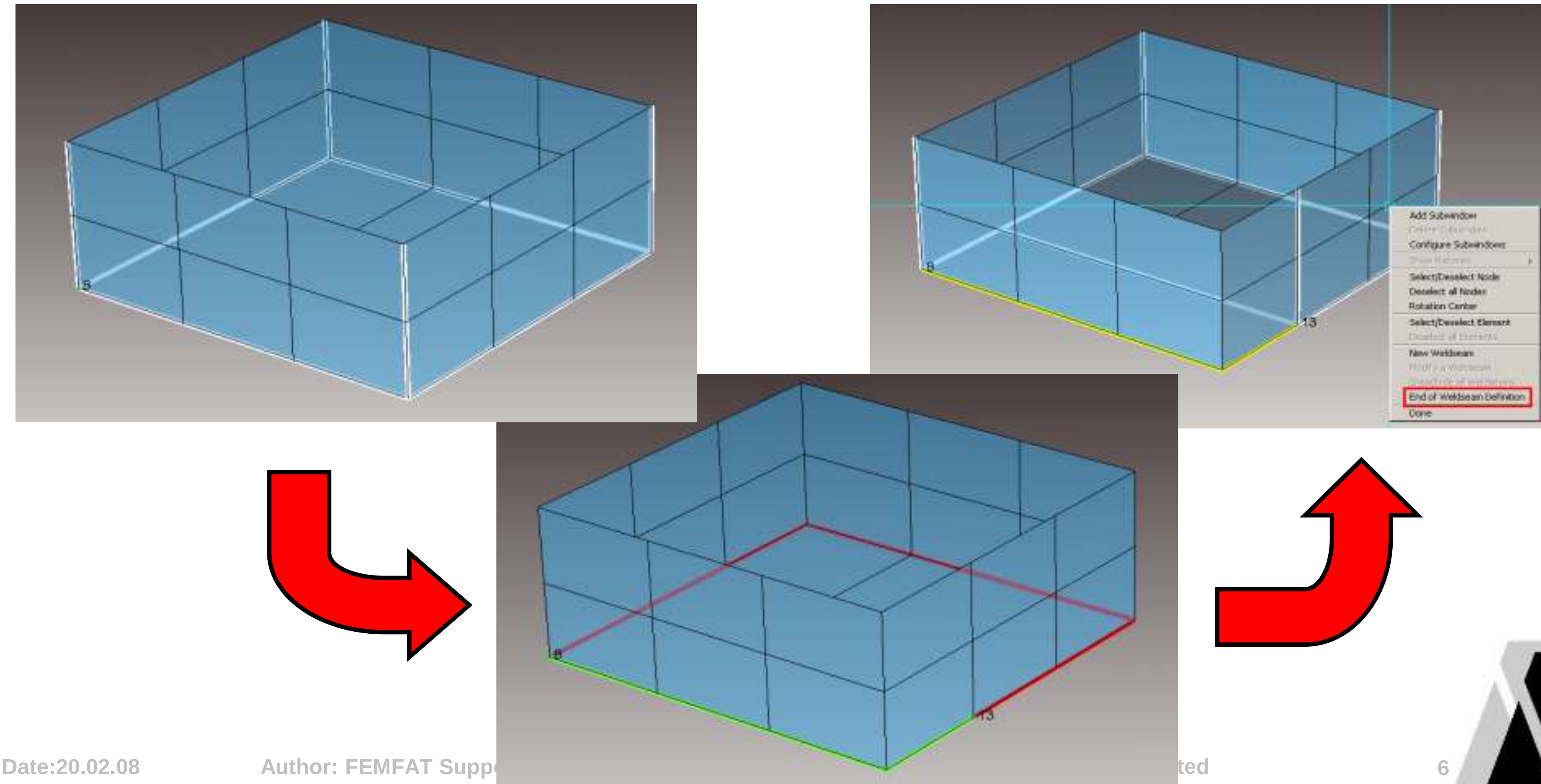
Element type : THIN SHELL (quadrilateral, triangle)
Element material number : MAT201 - MAT206
Weld seam node colour : C100 ... normal weld seam node
C101 ... weld seam end, not welded around
C102 ... weld seam end, welded around





Weld seam modeling in FEMFAT Visualizer





Weld seam modeling in FEMFAT Visualizer

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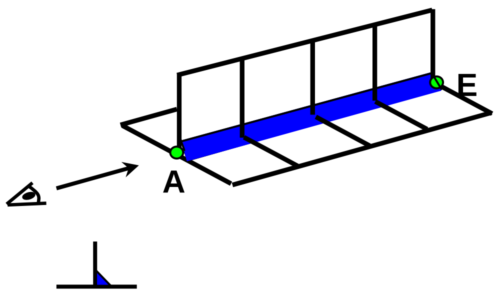
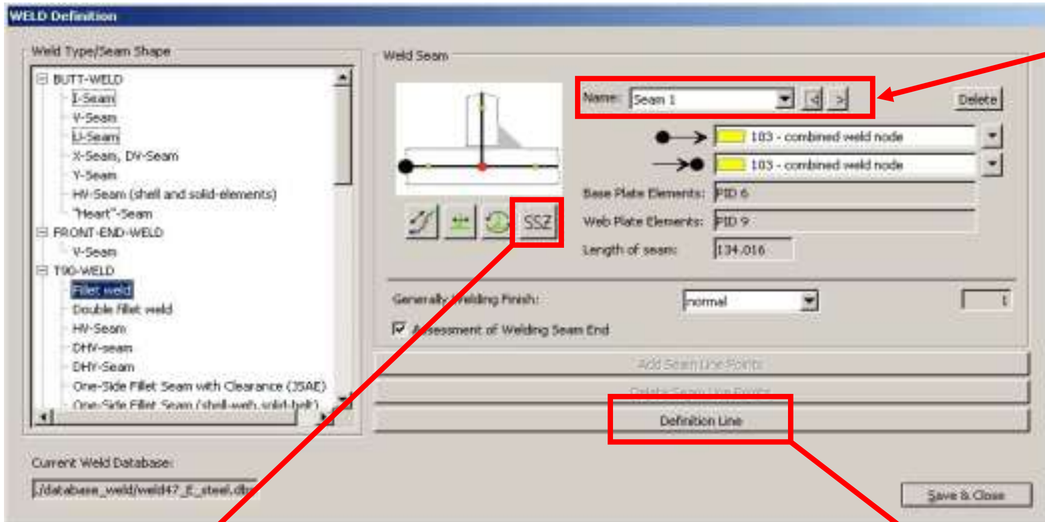
Definition of Weld Type, Seam Shape, Welded Side

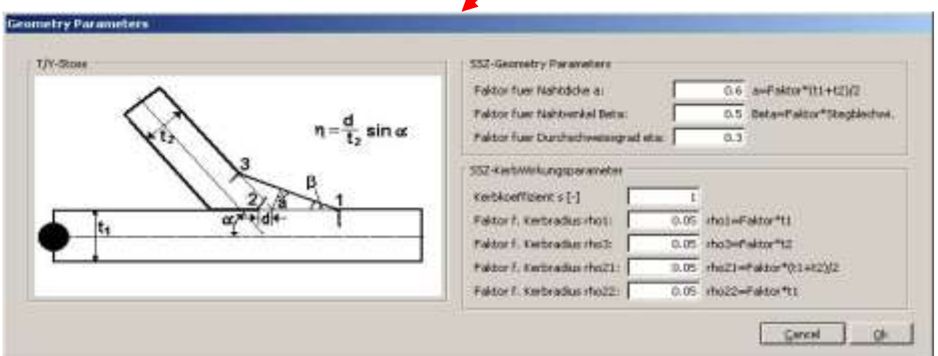
Example:

T-Joint welded at one side

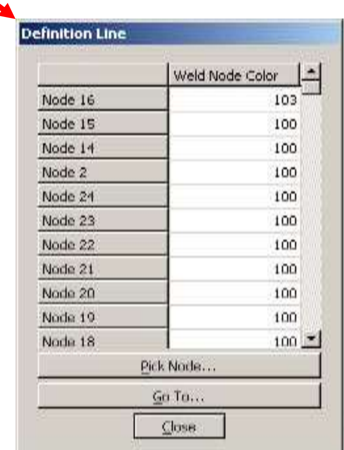




Selection of welding seam



Definition of welding seam start nodes, mid nodes, end nodes, etc. by colors



Benefit: Visualization of Detailed Geometry

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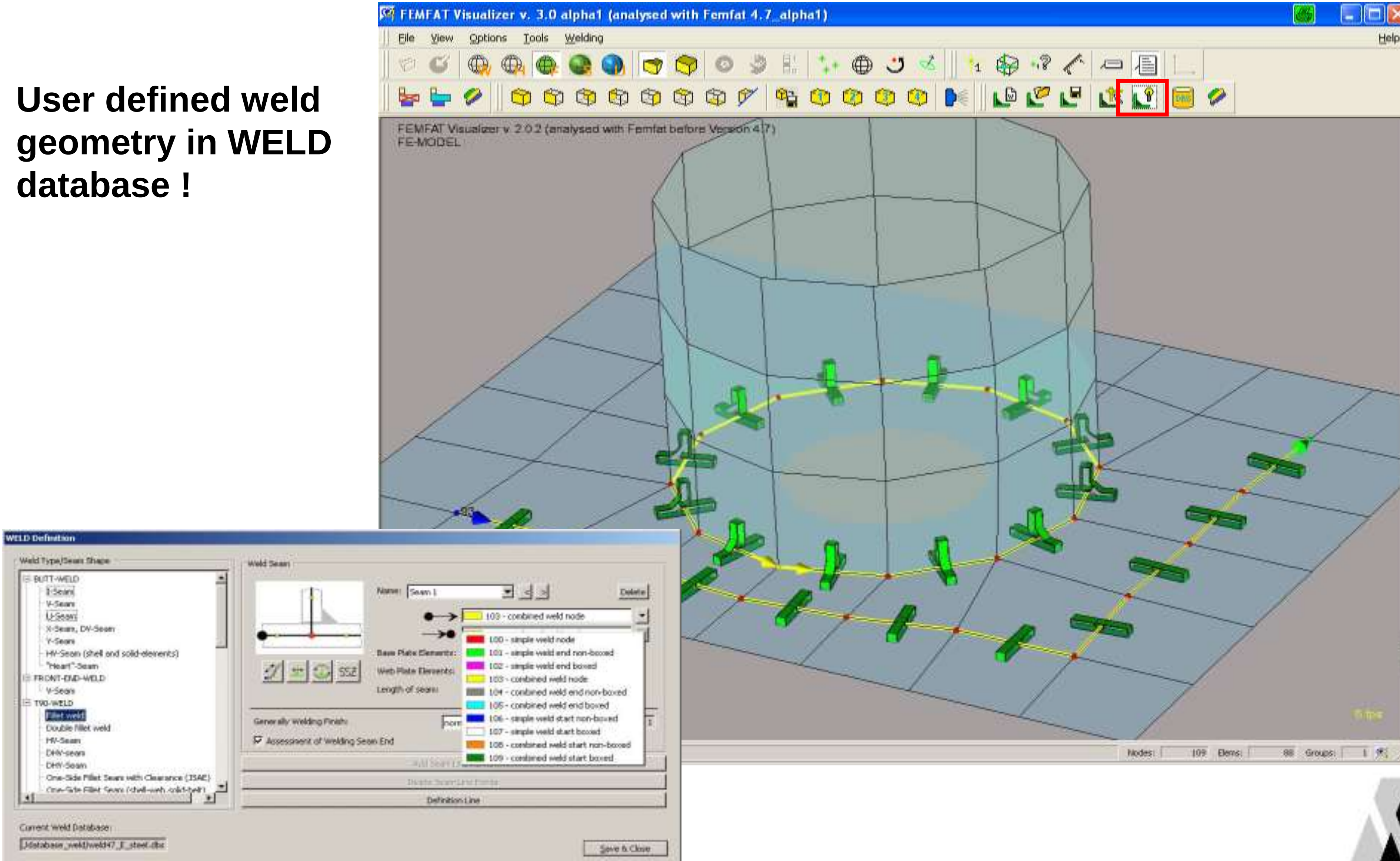
User defined weld geometry in WELD database !



Fatigue analysis of Weld seams in FEMFAT WELD

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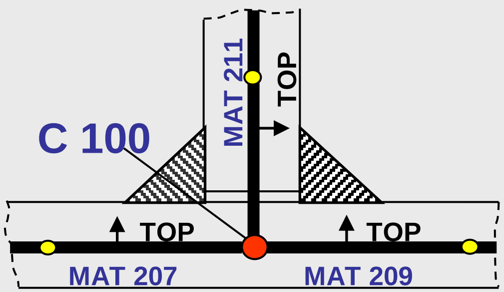
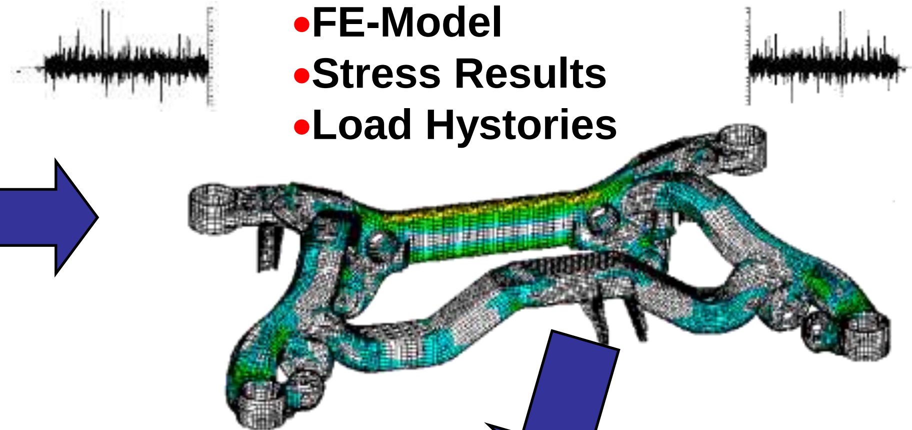
Modelling Guideline



- FE-Model
- Stress Results
- Load Hystories

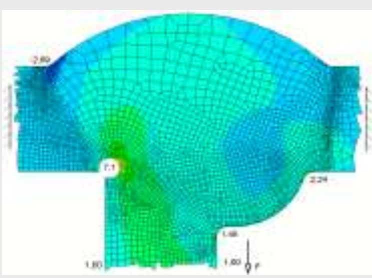


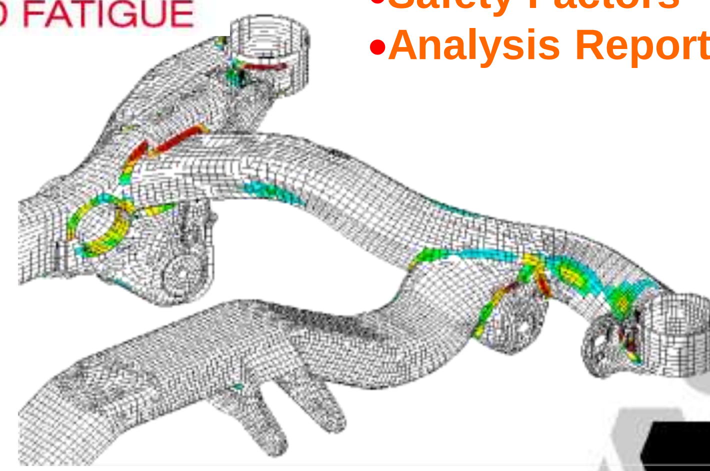
FEMFAT weld

FINITE ELEMENT METHOD FATIGUE

- Damage (1/Life)
- Safety Factors
- Analysis Report

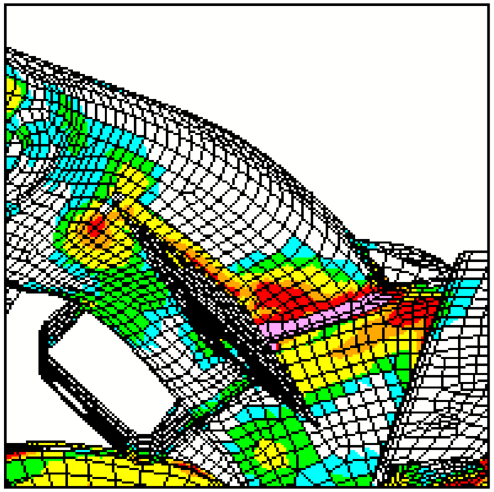
WELD Database





Calculations in FEMFAT WELD

Structural Stresses • **Notch Factors** = **Notch Stresses**



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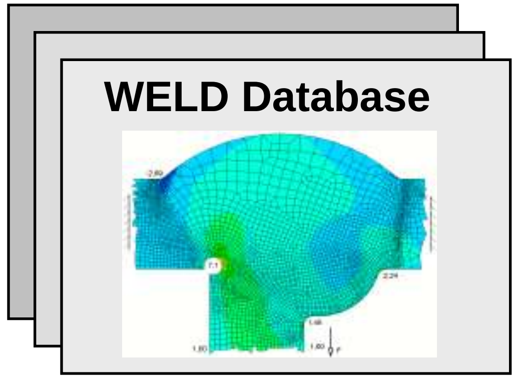

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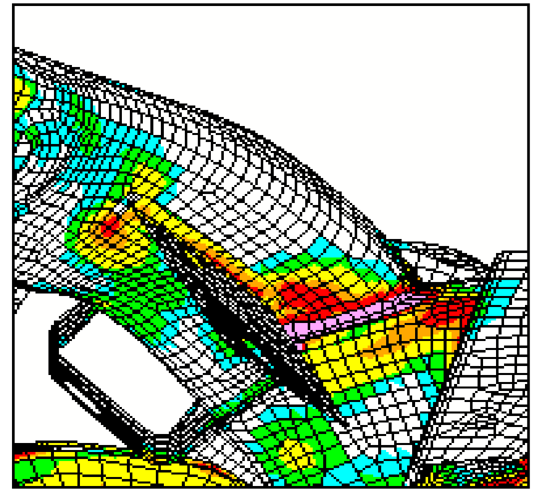

- Structural Stresses out of FE Results
- All details are stored in open FEMFAT WELD database
  - **Weld S/N Curve**
  - **Haigh – Diagram form Mean Stress Influence**
  - **Influence of Shell Thickness**
  - **Notch factors**
- Notch Stresses are Structural Stresses multiplied by Notch factor

Assessment of structural stress

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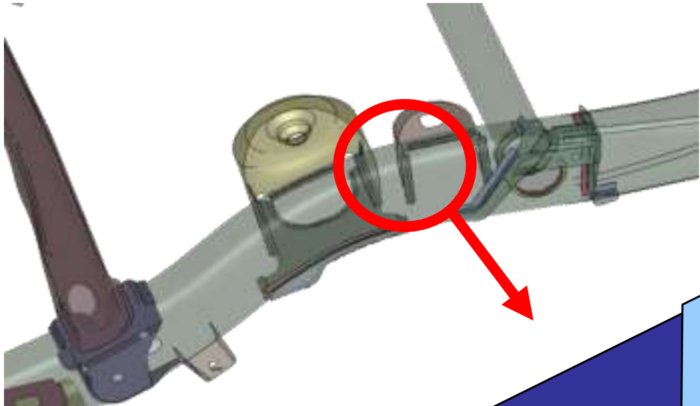

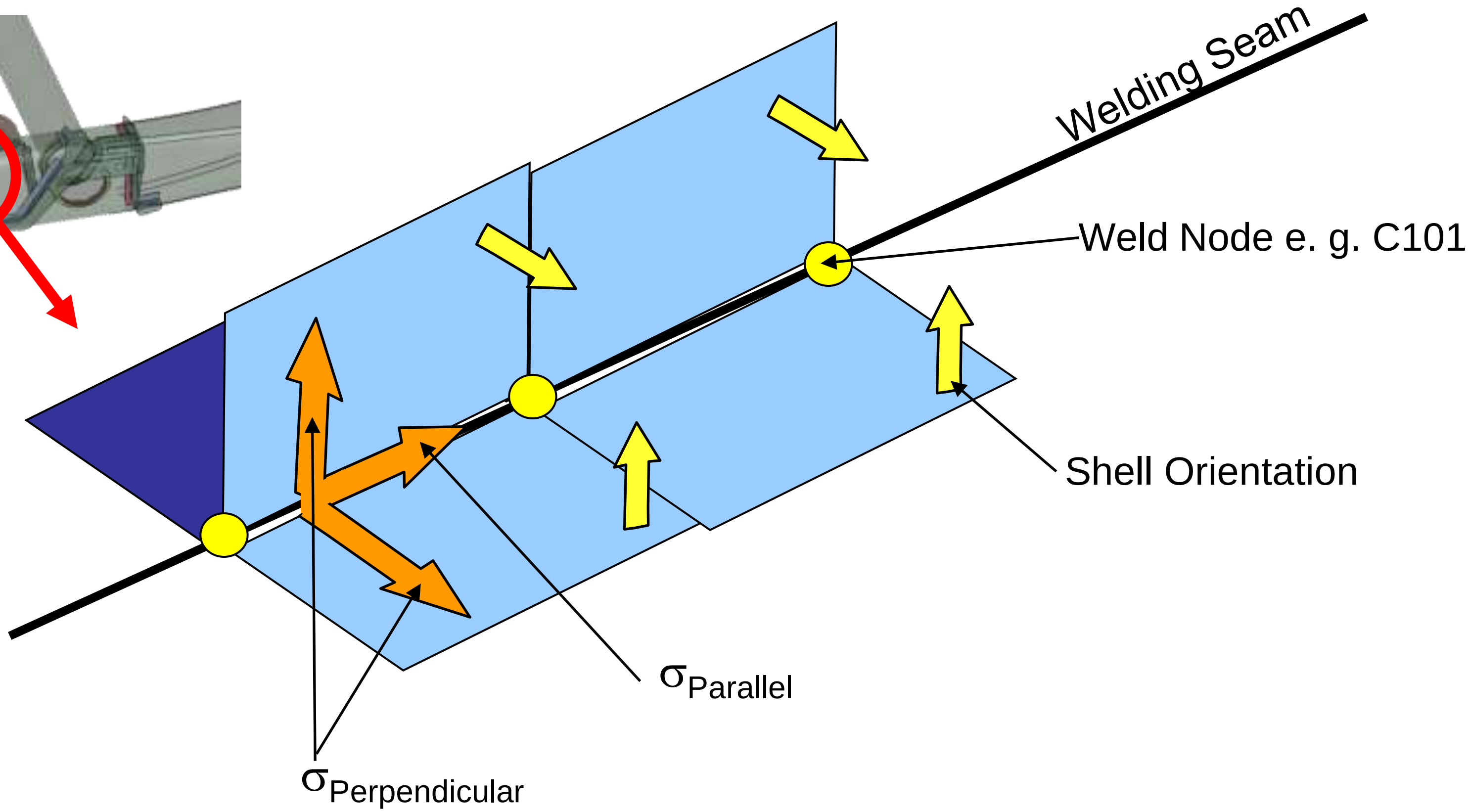

- Anisotropic Strength Characteristics for Welding Seams
- Stresses Perpendicular and Parallel to Seam are Critical
- Transformation to local Coordinate System

Read the appropriate notch factors from FEMFAT WELD Database

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```
$====================================================================================
$ T-Weld, Double Fillet-Weld                                 Situation: 05-01-96
$ --------------------------
$
$ Data for a node in the middle of the weld seam
$
$    MNT MNB UTL1 UTL2 UTL3 UBL1 UBL2 UBL3 WTL1 WTL2 WTL3 WBL1 WBL2 WBL3 SPTO SPBO
$    ------------------------------------------------------------------------------
 207 212     1.85 1.85 1.98                1.61 1.61 1.61
 208     212               1.85 1.85 1.98                1.61 1.61 1.61
 209 211     1.85 1.85 1.98                1.61 1.61 1.61
 210     211               1.85 1.85 1.98                1.61 1.61 1.61
 211         2.65 1.76      2.65 1.76      2.16 0.42      2.16 0.42
 212         2.65 1.76      2.65 1.76      2.16 0.42      2.16 0.42
$
$         BEPKT 1        BEPKT 2        BEPKT 3        BEPKT 4
$      Inclination    Inclination    Inclination    Inclination
$    Cycle Endur.   Cycle Endur.   Cycle Endur.   Cy
$    ---------------------------------------------------
N207         5.00           5.00           4.00
E207      1800000        1800000        1000000
N208         5.00           5.00           4.00
E208      1800000        1800000        1000000
N209         5.00           5.00           4.00
E209      1800000        1800000        1000000
N210         5.00           5.00           4.00
```

Including
- Notch Factors
- S/N Curves
- Haigh Diagram
- Weld Endurance Limit
- Thickness Influence Factors

Notch Factors for different Directions acc. Radaij

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The notch stress in **perpendicular direction** follows to:

$$\sigma_{\perp,notch} = \sigma_{\perp,nominal} \bullet \alpha_{\perp}$$

The notch stress in **longitudinal direction** follows to:

$$\sigma_{\|,notch} = \sigma_{\|,nominal} \bullet \alpha_{\|} = \sigma_{\|,nominal} + \nu \bullet (\sigma_{\perp,notch} - \sigma_{\perp,nominal})$$

The notch **shear stress** follows with $\alpha_{\tau} = (\alpha_{\perp} + 1)/2$ to:

$$\tau_{notch} = \tau_{nominal} \bullet \alpha_{\tau} = \tau_{nominal} \bullet (\alpha_{\perp} + 1)/2$$

$\alpha_{\perp}$ ... notch factor perpendicular to the weld seam ← from the database.

Equivalent Stress/Endurance Safety:

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DIN 15018:

$$\frac{1}{S} = \sqrt{\left(\frac{1}{S_\perp}\right)^2 + \left(\frac{1}{S_\parallel}\right)^2 - sig(\sigma_\perp \cdot \sigma_\parallel)\left(\frac{1}{S_\perp \cdot S_\parallel}\right) + \left(\frac{1}{S_\tau}\right)^2}$$

$$\frac{\sigma_{a,Equivalent}}{\sigma_{A,Equivalent}} = \sqrt{\left(\left(\frac{\sigma_{a,parallel}}{\sigma_{A,parallel}}\right)^2 + \left(\frac{\sigma_{a,perpendicular}}{\sigma_{A,perpendicular}}\right)^2 - \left(\frac{\sigma_{a,parallel}}{\sigma_{A,parallel}}\right) \bullet \left(\frac{\sigma_{a,perpendicular}}{\sigma_{A,perpendicular}}\right) + \left(\frac{\tau_{a,parallel}}{\tau_{A,parallel}}\right)^2\right)}$$

DVS 1608:

$$a_V = \sqrt{a_\perp^2 + a_\parallel^2 + f(\Phi) \cdot a_\perp \cdot a_\parallel + a_\tau^2} \Rightarrow D_V = a_V^{keff}$$

$$\frac{1}{S} = \sqrt{\left(\frac{1}{S_\perp}\right)^2 + \left(\frac{1}{S_\parallel}\right)^2 + f(\Phi) \cdot \left(\frac{1}{S_\perp \cdot S_\parallel}\right) + \left(\frac{1}{S_\tau}\right)^2}$$

BS 7608:

$$\frac{\sigma_a}{\sigma_A} = \sqrt{MAX\left[\left(\frac{\sigma_{a\perp}}{\sigma_{A\perp}}\right)^2, \left(\frac{\sigma_{a\parallel}}{\sigma_{A\parallel}}\right)^2\right] + \left(\frac{\tau_a}{\tau_A}\right)^2}$$

Every Standard:

$$\frac{\sigma_a}{\sigma_A} = \frac{\sigma_{a\perp}}{\sigma_{A\perp}} \quad ; \quad \frac{\sigma_a}{\sigma_A} = \frac{\sigma_{a\parallel}}{\sigma_{A\parallel}} \quad ; \quad \frac{\sigma_a}{\sigma_A} = \frac{\tau_a}{\tau_A}$$

Procedure at STADLER RAIL for weldseam modeling

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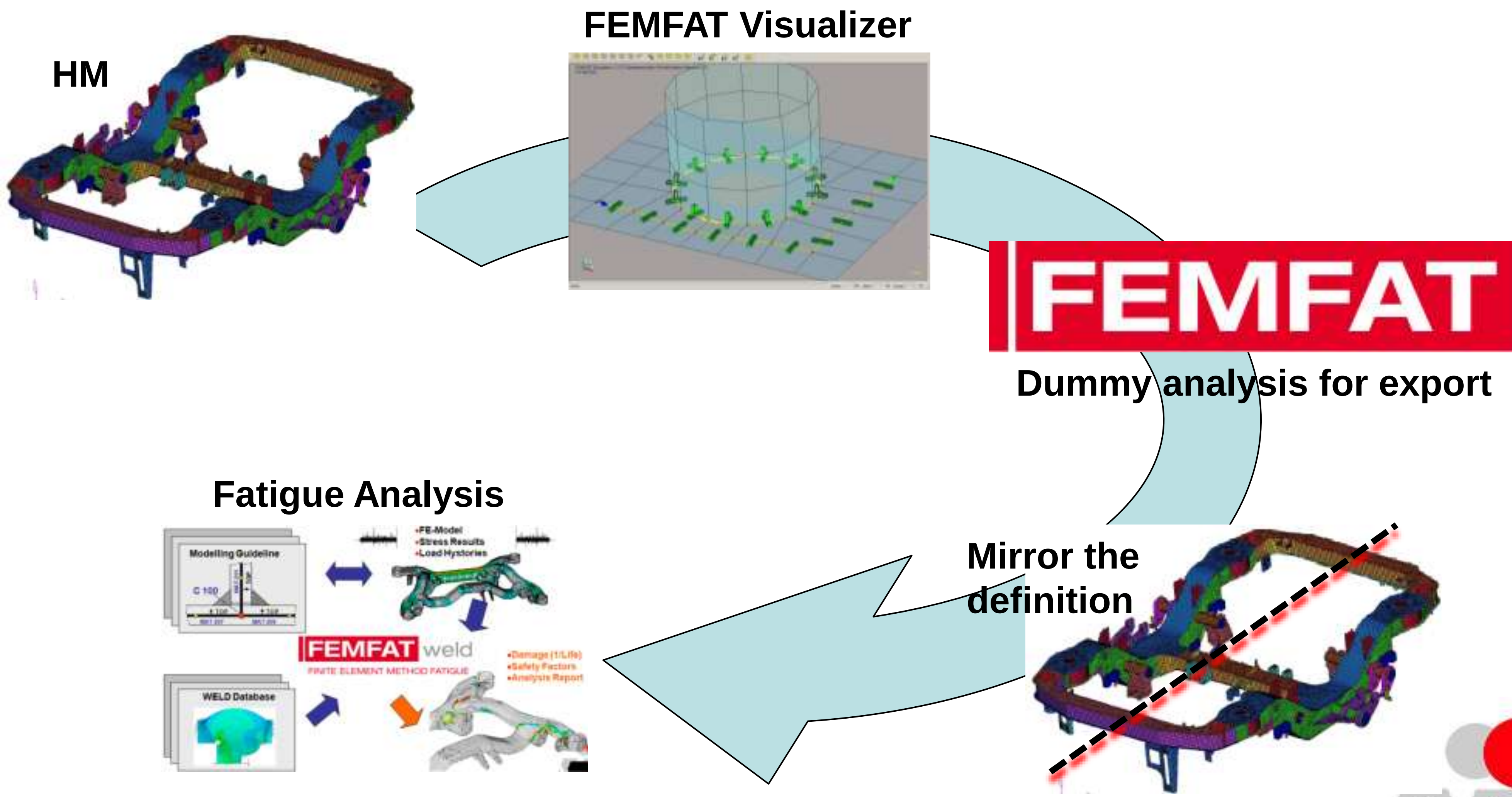

Conclusion

- **Stadler Rail limits the time for weldseam modeling to about 60%**
- **Additional time for the dummy analysis is small.**
- **The script for mirroring the definitions from ALTAIR was worth the money within the second project.**
- **The fatigue results on the complete structure (symmetric results for symmetric loads) make the railway authorities happy.**

Loadcase definition and combination

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Algerien																							
Fliel																							
MDG	UIC_Lastea																						
datum_04_03_2007_kuja																							
END_OF_HEADER																							
	Spalte 1	Spalte 2	Spalte 3	Spalte 4	Spalte 5	Spalte 6	Spalte 7	Spalte 8	Spalte 9	Spalte 10	Spalte 11	Spalte 12	Spalte 13	Spalte 14	Spalte 15	Spalte 16	Spalte 17	Spalte 18	Spalte 19	Spalte 20	Spalte 21	Spalte 22	Spalte 23
	0	0	-9,81	1,2	1,2	0	0	0	-55,006	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	0	0	-9,81	1,2	1,2	13,5	0	3,755	-55,006	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	0	0	-9,81	1,2	1,2	13,5	0	3,755	-55,006	0	0	0	0	0	0	0	0	0	0	0	0	-1	1
	0	0	-9,81	1,0	1,0	0	0	0	-55,006	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	0	0	-9,81	1,0	1,0	13,5	0	3,755	-55,006	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	0	0	-9,81	1,0	1,0	13,5	0	3,755	-55,006	0	0	0	0	0	0	0	0	0	0	0	0	-1	1
	0	0	-9,81	1,2	1,2	0	0	0	55,006	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	0	0	-9,81	1,2	1,2	-13,5	3,755	0	55,006	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	0	0	-9,81	1,2	1,2	-13,5	3,755	0	55,006	0	0	0	0	0	0	0	0	0	0	0	0	-1	1
	0	0	-9,81	1,0	1,0	0	0	0	55,006	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	0	0	-9,81	1,0	1,0	-13,5	3,755	0	55,006	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	0	0	-9,81	1,0	1,0	-13,5	3,755	0	55,006	0	0	0	0	0	0	0	0	0	0	0	0	-1	1
	0	0	-9,81	1,35	1,35	0	0	0	0	9,6	10,8	12	-9,6	0	0	0	0	0	0	0	0	0	1
	0	0	-9,81	1,65	1,65	0	0	0	0	-9,6	-10,8	-12	9,6	0	0	0	0	0	0	0	0	0	1
	0	0	-9,81	1,35	1,35	0	0	0	0	0	0	0	0	0	0	0	0	2,042	2,042	-2,042	-2,042	0	1
	0	0	-9,81	1,65	1,65	0	0	0	0	0	0	0	0	0	0	0	0	-2,042	-2,042	2,042	2,042	0	1
	-1,422	0	-9,81	1,35	1,35	13,5	0	1,070	-27,509	4,8	5,4	6	-4,8	0	0	-1,1	0	0	0	0	0	0	1
	1,422	0	-9,81	1,65	1,65	-13,5	1,070	0	27,509	-4,8	-5,4	-6	4,8	0	0	1,1	0	0	0	0	0	0	1
	0	0	-9,81	1,0	1,0	13,5	0	1,070	-27,509	4,8	5,4	6	-4,8	-39,509	14,057	-1,1	0	0	0	0	0	0	1
	0	0	-9,81	1,2	1,2	-13,5	1,070	0	27,509	-4,8	-5,4	-6	4,8	39,509	-14,057	1,1	0	0	0	0	0	0	1
	-1,525	0	-9,81	1,35	1,35	13,5	0	1,070	-27,509	4,8	5,4	6	-4,8	0	0	-1,1	1,275	0	0	0	0	0	1
	1,525	0	-9,81	1,65	1,65	-13,5	1,070	0	27,509	-4,8	-5,4	-6	4,8	0	0	1,1	-1,275	0	0	0	0	0	1