



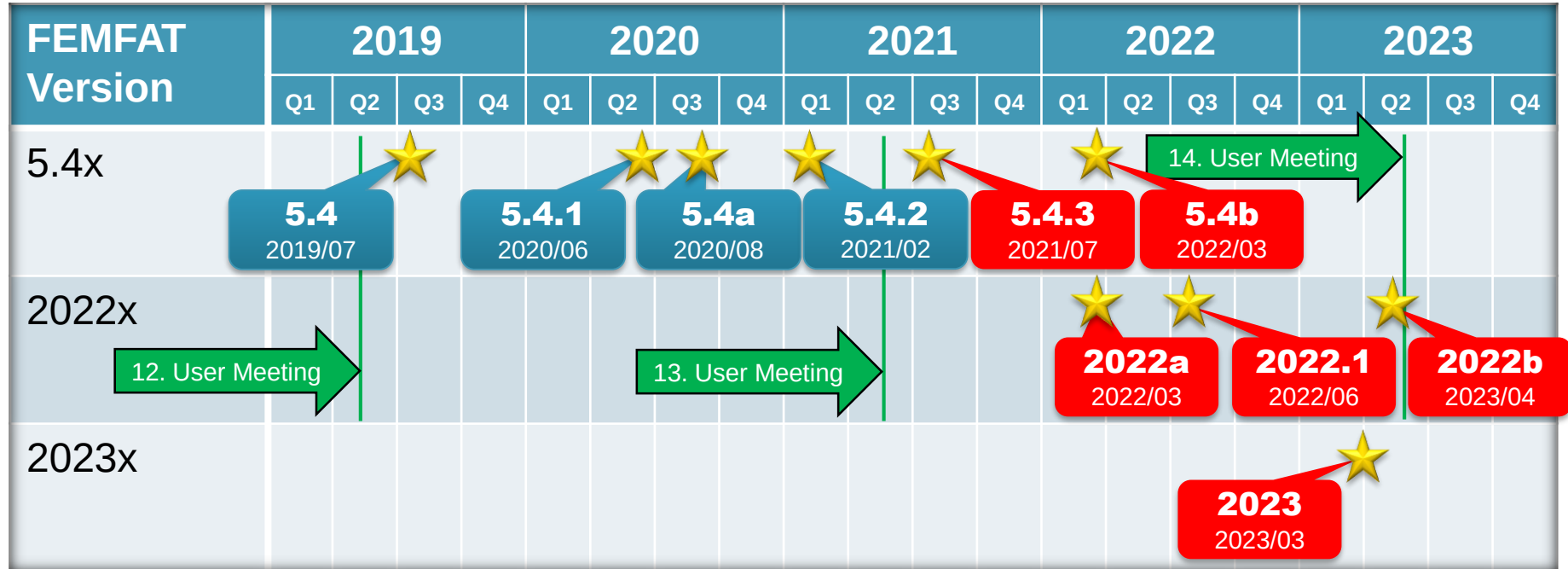
FEMFAT 2023 News and More

Christian Gaier, Manager FEMFAT
Development, Magna

ECS Simulation Conference, 10th – 11th May 2023
Linz, Austria

History of FEMFAT Releases

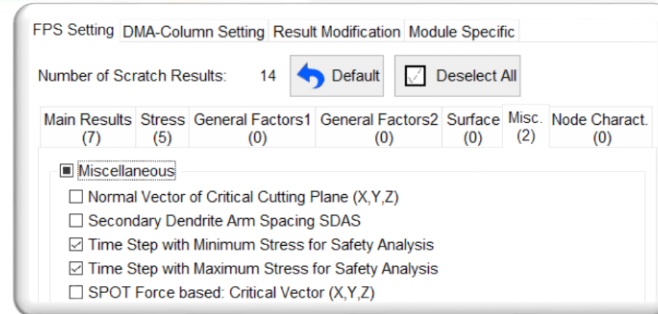
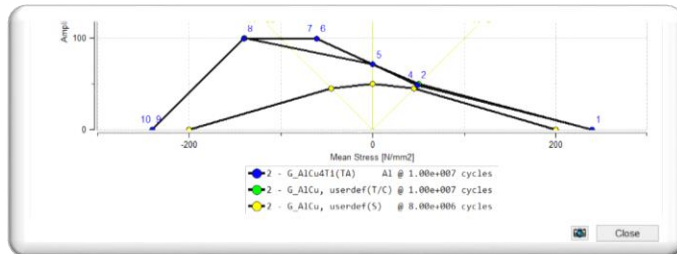
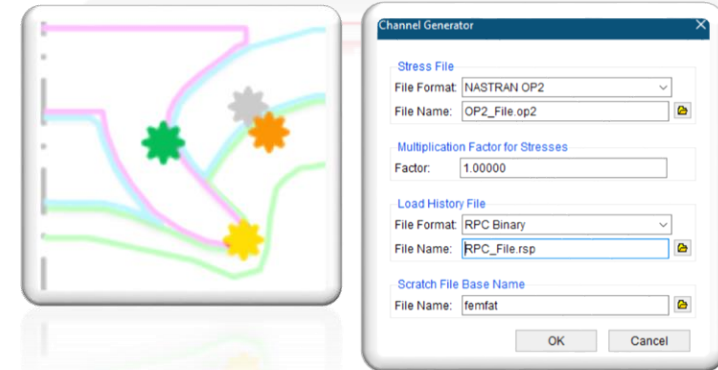
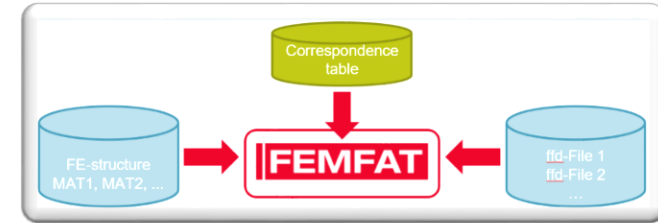
- About two new versions are released every year.
- Major release = **2022**, Service release = **2022a**, New features = **2022.1**
- Latest version **FEMFAT 2023** release in March 2023!



FEMFAT 5.4.3 released 2021 Juli



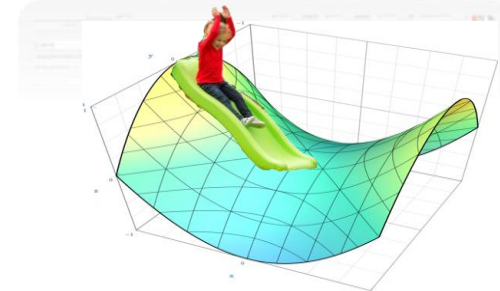
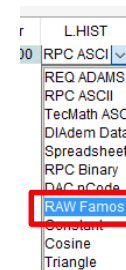
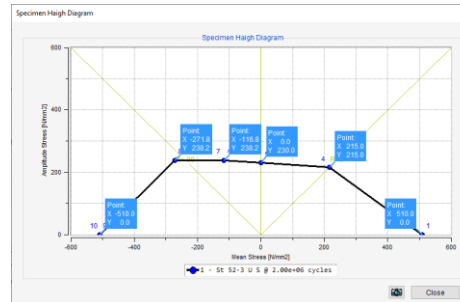
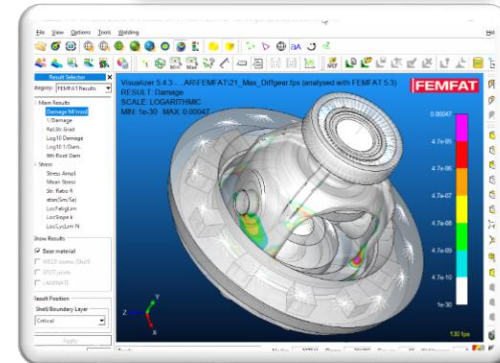
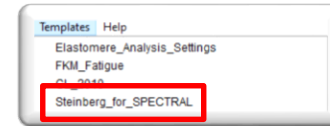
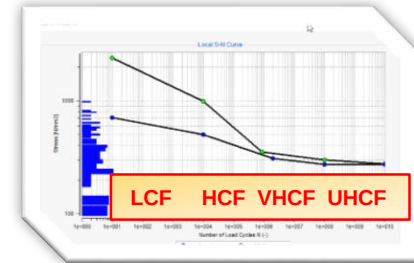
- **Highlights**
 - Automatic material assignment
 - Automatic channel generation and assignment of load time data to channels
 - SPOT: New advanced self piercing rivet model
- **Methods**
 - WELD Automatic Stress Correction: Evaluation distance 0 for root assessment
 - Combination of influence factors according to the German FKM-Guideline
 - BREAK: Static safety factor analysis available in STRAIN Calc
- **Textual and graphical output**
 - Critical load combination - separate output of times for maximum and minimum stress
 - WELD: Pro-file output of both ROOT and TOE results as table
 - Output of cycle limit in Haig-diagram
- **Interfaces**
 - ESI HDF5 stress interface for SPECTRAL
 - Accelerated ABAQUS interface (import of elemental/nodal forces only if needed)



FEMFAT 2022a released 2022 March



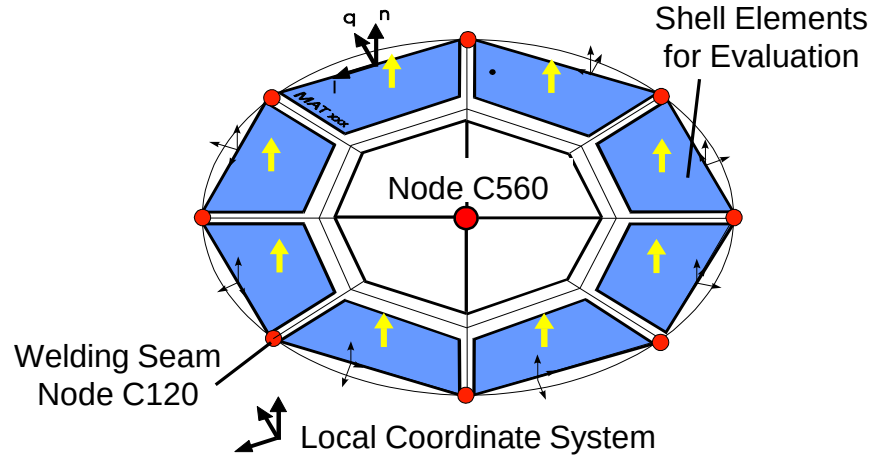
- Highlights
 - New multi-segment S-N curve model
 - VISUALIZER: New graphic kernel and enhanced post processing possibilities
 - **VISUALIZER: Handling with space mouse**
- Methods
 - The new stress gradient method with vector reconstruction is the default setting
 - **SPOT: Assessment of Flow Drill Screws (FDS) is possible**
 - **SPECTRAL: Analysis according to Steinberg three-band method**
- Textual and graphical output
 - Display exact point coordinates in the S-N and Haigh diagram
 - Simultaneous output of SPOT detailed results and base material results to dma-file
 - **SPOT in ChannelMAX: Output of the history of superimposed section forces as CSV file**
- Miscellaneous
 - ALTAIR licensing for FEMFAT inside ANSYS
 - **ChannelMAX load histories: New FAMOS-interface**



Assessment of Flow Drill Screws (FDS) with

FEMFAT spot

- In FEMFAT 2022a, the evaluation of plates joined with flow-drill screws (FDS) is possible with the SPOT method "SPOT STRESS".
- For this purpose, the standard SPOT database "SpotDB_2022_standard.xml" has been extended by two data blocks for steel and aluminum.



SPOT in ChannelMAX: Output of the History of Superimposed Section Forces as CSV file

Group all beams of interest

Supported formats:

- ❖ NASTRAN (*.op2)
- ❖ ABAQUS (*.odb)
- ❖ MEDINA (*.bof)

Define the group name in the SPOT database

```
14 <general>
15 <spot_connection_base_name>myConnection</spot_connection_base_name>
16 <force_output_for_beams>
17 <group>ForceOutput</group>
18 </force_output_for_beams>
19 </general>
```

Activate **SPOT** and request the FORCE OUTPUT in the Influence Factor menu

Connection Types for Analysis

Spot Welding Rivet Superelement Misc.

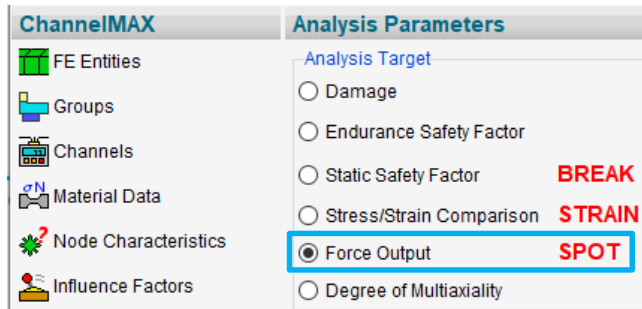
☒ FORCE OUTPUT

Base File Name

femfat_balken_ForceOutput.csv

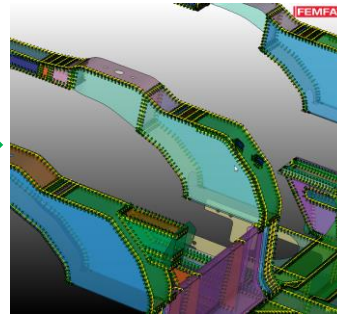
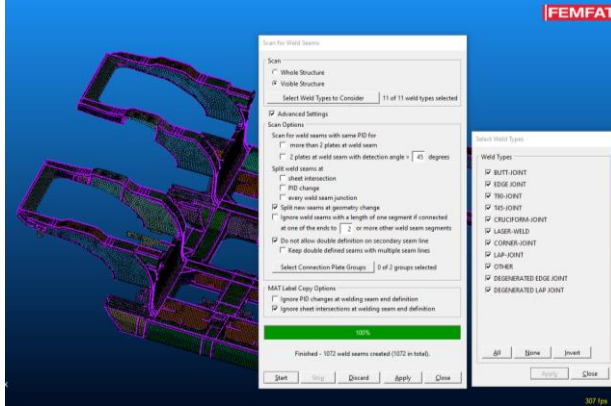
With the analysis target 'Force Output' an optional separate output is possible

1. Output-File = project name + '_ForceOutput' + '_E131.csv'
 2. Output-File = project name + '_ForceOutput' + '_E131.csv'
 - ...
- (for all beam elements identified)

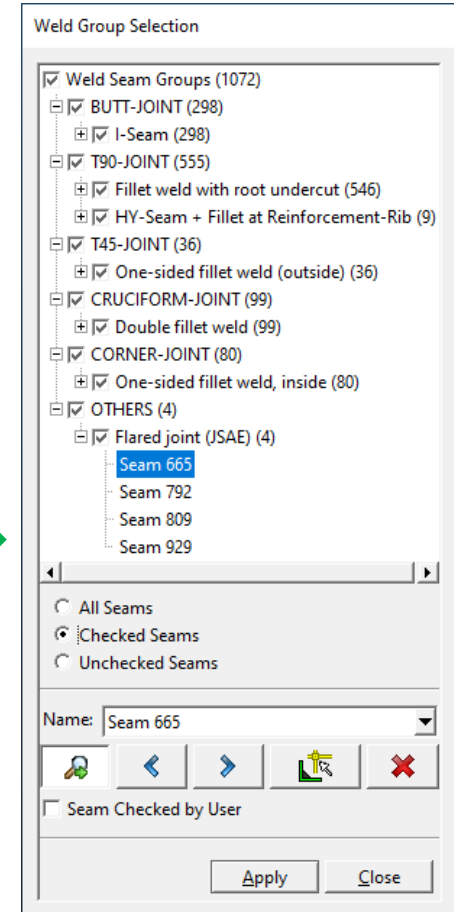


	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	E131	N1	N168											
2	Time	Steps	Fx	Fy	Fz	Mx	My	Mz	Fx	Fy	Fz	Mx	My	Mz
3		1	1.00E+05	2.87E+01	-6.22E+01	8.93E+01	-5.34E+01	6.80E+02	1.00E+05	2.87E+01	-6.22E+01	8.93E+01	-1.16E+02	6.51E+02
4		2	8.09E+04	2.32E+01	-5.03E+01	7.23E+01	-4.32E+01	5.50E+02	8.09E+04	2.32E+01	-5.03E+01	7.23E+01	-9.35E+01	5.27E+02
5		3	3.09E+04	8.87E+00	-1.92E+01	2.76E+01	-1.65E+01	2.10E+02	3.09E+04	8.87E+00	-1.92E+01	2.76E+01	-3.57E+01	2.01E+02
6		4	-3.09E+04	-8.87E+00	1.92E+01	-2.76E+01	1.65E+01	-2.10E+02	-3.09E+04	-8.87E+00	1.92E+01	-2.76E+01	3.57E+01	-2.01E+02
7		5	8.09E+04	-2.32E+01	5.03E+01	-7.23E+01	4.32E+01	-5.50E+02	-8.09E+04	-2.32E+01	5.03E+01	-7.23E+01	9.35E+01	-5.27E+02
8		6	-1.00E+05	-2.87E+01	6.22E+01	-8.93E+01	5.34E+01	-6.80E+02	-1.00E+05	-2.87E+01	6.22E+01	-8.93E+01	-1.16E+02	-6.51E+02
9		7	-8.09E+04	-2.32E+01	5.03E+01	-7.23E+01	4.32E+01	-5.50E+02	-8.09E+04	-2.32E+01	5.03E+01	-7.23E+01	9.35E+01	-5.27E+02
10		8	-3.09E+04	-8.87E+00	1.92E+01	-2.76E+01	1.65E+01	-2.10E+02	-3.09E+04	-8.87E+00	1.92E+01	-2.76E+01	3.57E+01	-2.01E+02

Integration of WELDseamScanner in VISUALIZER

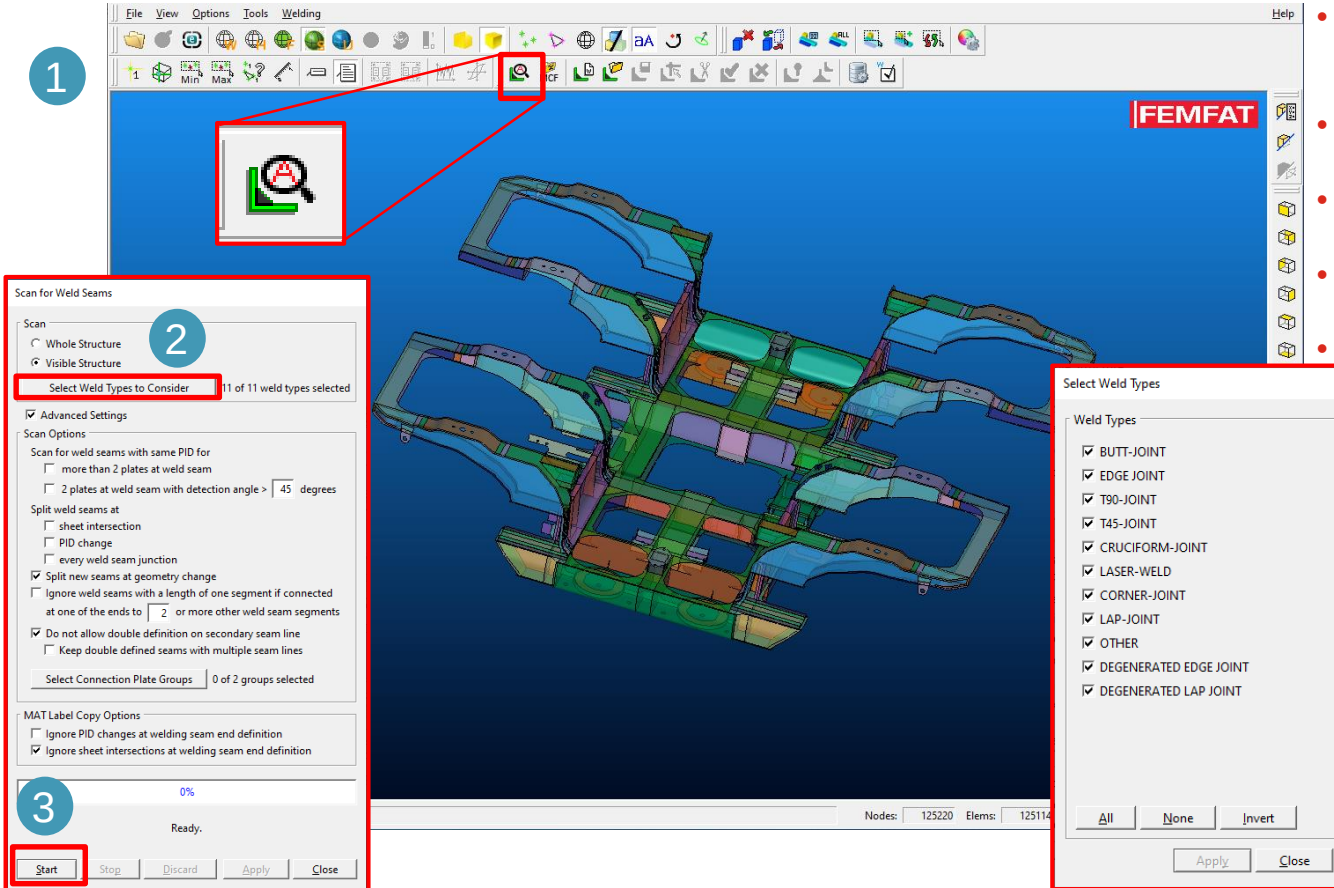


- VISU: Enhancement of Weld Group Selection dialog
- VISU: Split of weld seams
- VISU: Picking of weld seam segments
- xMCF Interface: <appdata/> block was moved in <custom_attributes_list/> and updated to xMCF V 3.1.1
- ANSYS+CDB: read PIDs und MAT-IDs



Integration of WELDseamScanner in VISUALIZER

- Fully automatic detection and definition of weld lines for whole or visible structure.
- Various options to optimize the scan results.
- Summary of generated weld seams
- All weld seam lines are marked in the model
- Generated weld seams should be checked by the user.



1

2

3

0%

Ready.

Start Stop Discard Apply Close

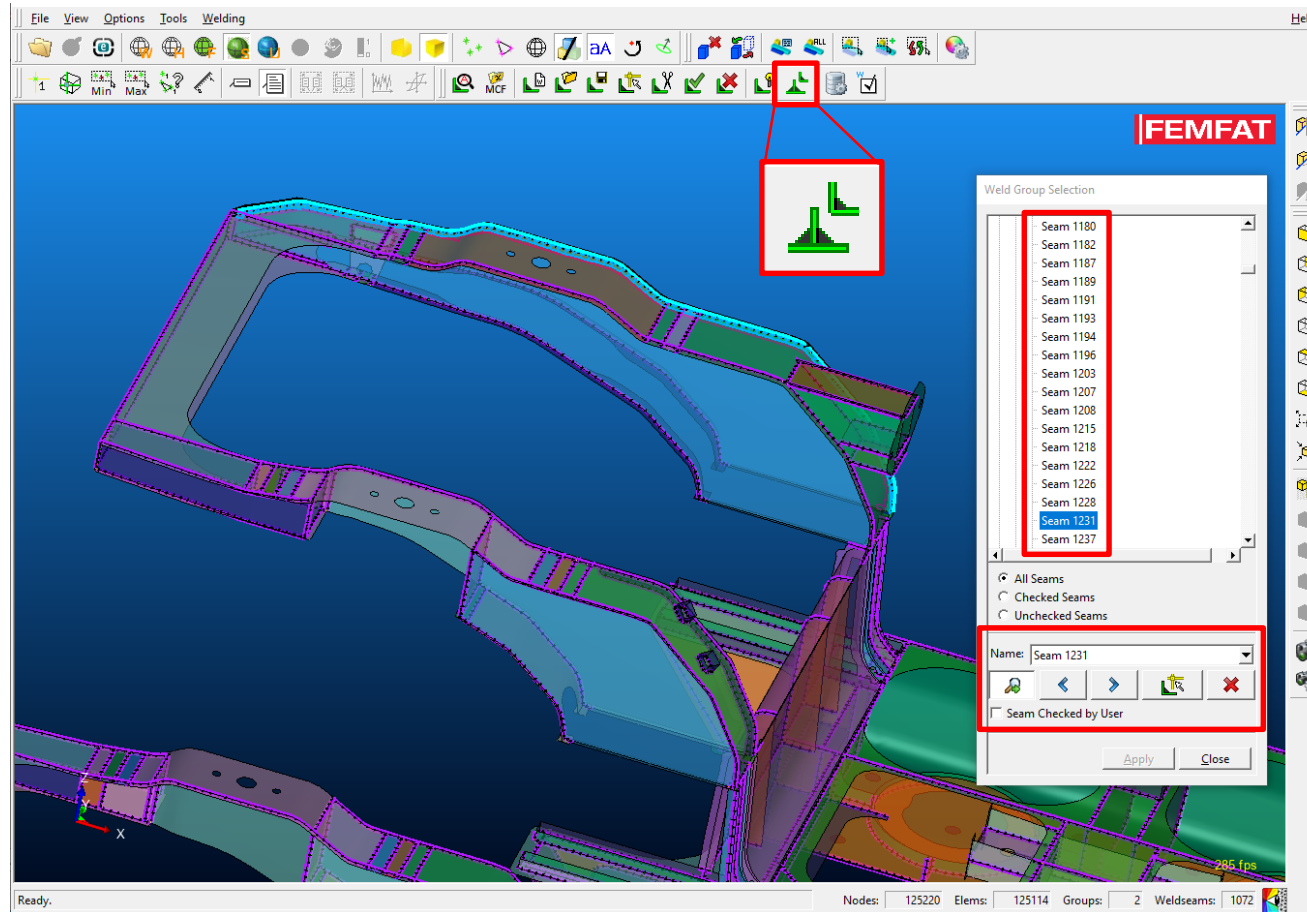
Nodes: 125220 Elms: 125114

Weld Seam Scanner Result

1072 weld seams generated:

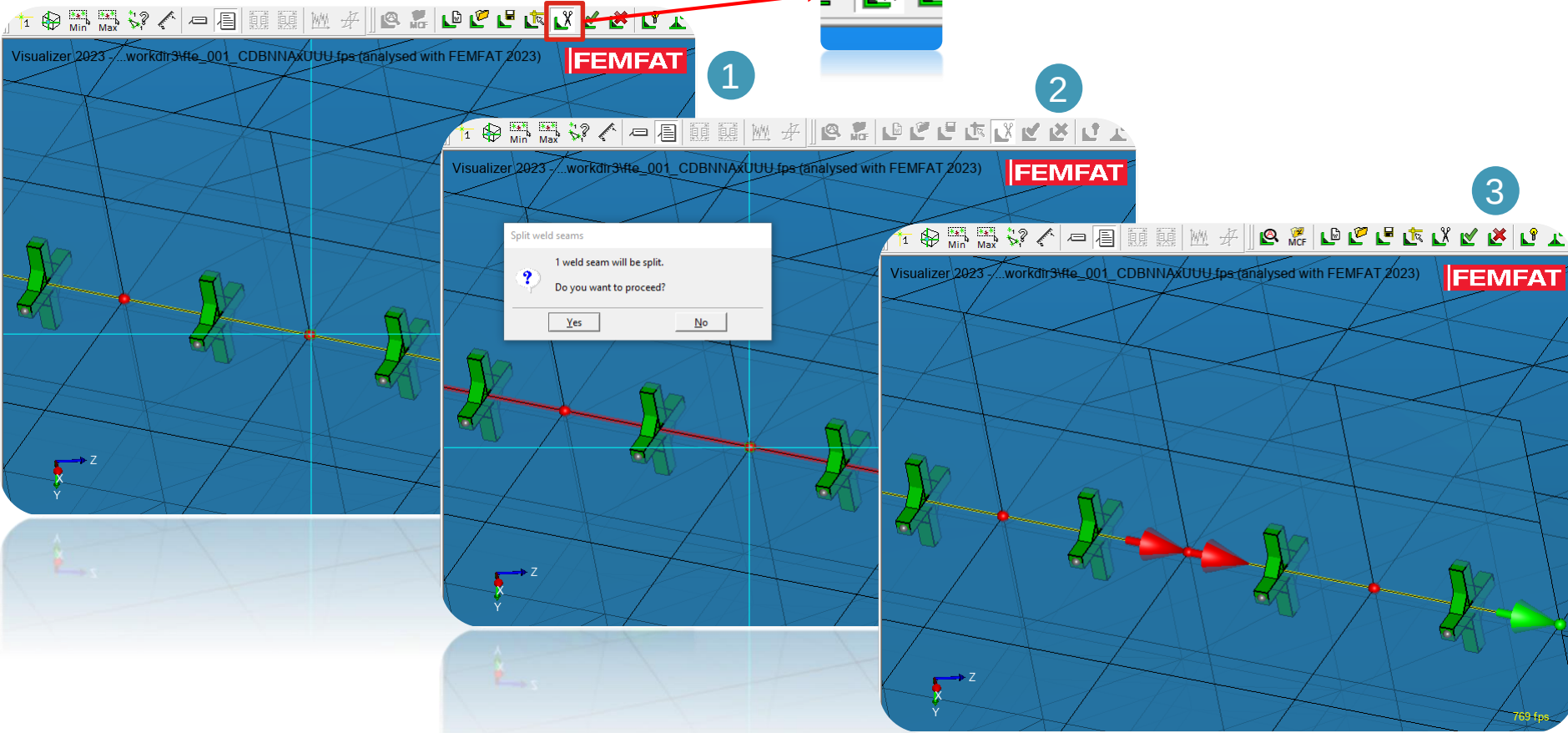
WELD type	No.
BUTT-JOINT	298
CORNER-JOINT	80
CRUCIFORM-JOINT	99
DEGENERATED EDGE JOINT	0
DEGENERATED LAP JOINT	0
EDGE JOINT	0
LAP-JOINT	0
LASER-WELD	0
OTHER	4
T45-JOINT	36
T90-JOINT	555

Enhancement of Weld Group Selection Dialog



- List of seams for each joint type.
- Focus on selected weld seam.
- Weld Definition dialog accessible directly.
- Deletion of selected weld seams.

Split of WELD seams



• Highlights

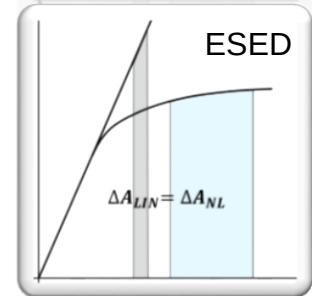
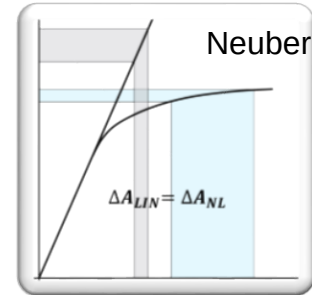
- New PLAST method in MAX: Incremental Neuber/ESED (Equivalent Strain Energy Density) with exact sequence influence
- New material generator with revised GUI for short fiber reinforced plastic
- New NASTRAN HDF5 interface with module selection
- VISUALIZER: Results display on cutting plane
- Template for FEMFAT analysis according to the newest FKM-Guideline 2020 including new WELD-databases for high, moderate and low residual stresses

• WELD & VISUALIZER

- VISUALIZER WELD Definition: Default settings for each weld seam type
- VISUALIZER WELD Definition: Save settings for seam shape, start and end type
- VISUALIZER WELD Definition: Apply settings of current seam to other visible seams
- VISUALIZER WELD Database for DVS1612 standard for steel
- Up to 100 user defined master SN-curves for SolidWELD
- WELD sensitivity analysis also in batch mode possible

• SPECTRAL

- Acceleration: Scratch file generation only for selected modes
- Multiple steps in FE results file: Select step with modal stresses, no restart required (ABAQUS, ESI)



• Methods

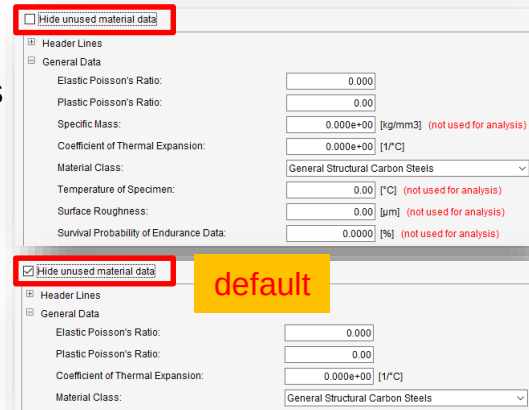
- Adjustable material parameter “sensitivity of non-proportionality” for rotating principal stresses influence
- Update material generator for nodular cast iron according to the newest FKM-Guideline 2020
- SPOT: Range of Dispersion and survival probability can be defined for each joint type and S-N curve
- STRAIN Calc: Support of technological size influence, surface residual stresses, degree of multiaxiality and rotating principal stresses influence

• Interfaces

- Support of axisymmetric ABAQUS CAXA* elements
- NX NASTRAN: Support of incomplete quadratic elements (including pyramids)
- ANSYS: Support of quadratic pyramids
- Separate output (*.dma) for base material, WELD, SPOT and LAMINATE results

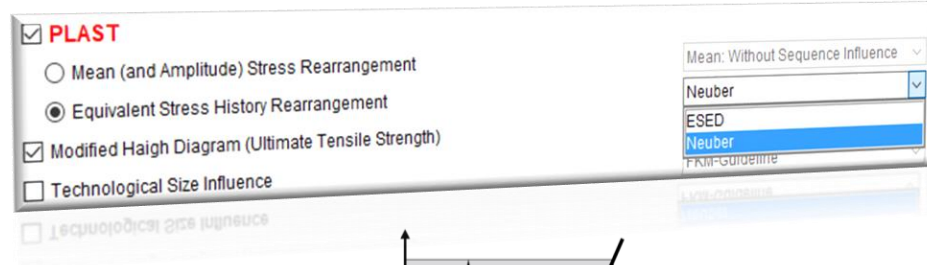
• Miscellaneous

- Group creation for PID/MID (automatic completion with nodes)
- Combination of multi-material file with automatic material assignment
- Masking of unused material parameters →
- Acceleration of new stress gradient analysis method (vector reconstruction only for non-filtered nodes)
- FEMFAT -queue command for ALTAIR licensing
- 20 aluminum ffd-files supplied with temperature dependent parameters

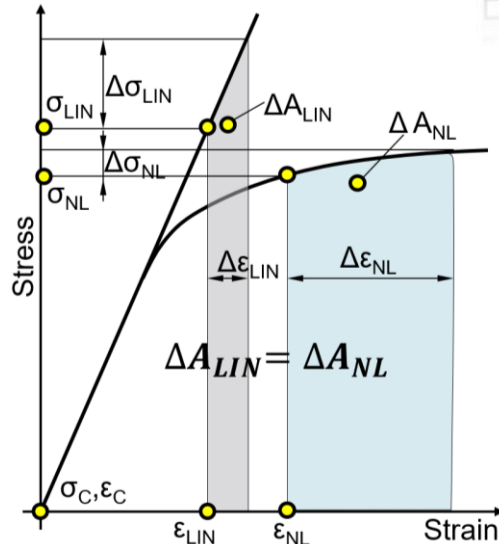


2 Variants of the New PLAST Method in MAX

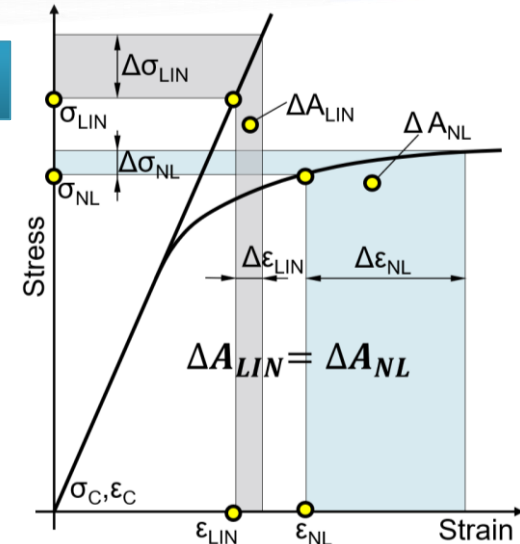
- Supported Methods
 - Incremental ESED (Equivalent Strain Energy Density)
 - Incremental Neuber approach



ESED

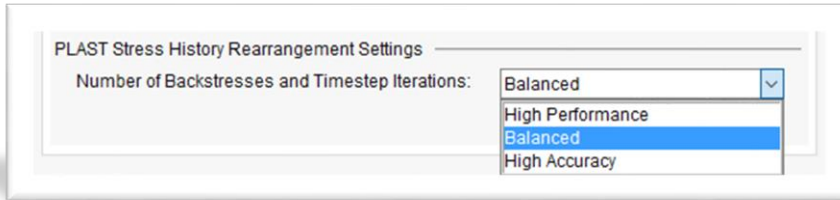


Neuber



Description of the New PLAST Method in MAX

- Any chosen equivalent stress is used e.g., default “Scaled Normal Stress in Critical Plane”
- Uniaxial Neuber approach in cutting plane
- Calculation of elasto-plastic stress-strain at each time point of the entire equivalent stress history before Rainflow counting
- Sequence influence is fully considered
- Material plasticity is based on C- γ -values (like ABAQUS), which are fully automatically derived from the Ramberg-Osgood parameters n' and K'
- C- γ pairs are output in the *.pro file and can be used directly for FEA!
- Easy to use due to 3 accuracy settings



- Similar computational speed for short and medium length time histories due to fast & optimized algorithm
- For long time histories, the new PLAST method is slower

Data for PLAST with Equivalent Stress History Rearrangement

Temperature: 20.0°C

Cyclic Coefficient of Hardening 1400.70 [N/mm²]
Cyclic Exponent of Hardening 0.11 [-]

Nonlinear Data:

Backstress_i	C_i	Gamma_i
1	2.450240e+05	1.560800e+03
2	2.739565e+04	1.405737e+02
3	3.439368e+03	1.419215e+01
4	5.186301e+02	1.165260e+00

RMS Fitting Error 2.7 [N/mm²]

Linear Data:

Yield Stress at Zero Plastic Strain 503.73 [N/mm²]
Young's Modulus 210000 [N/mm²]

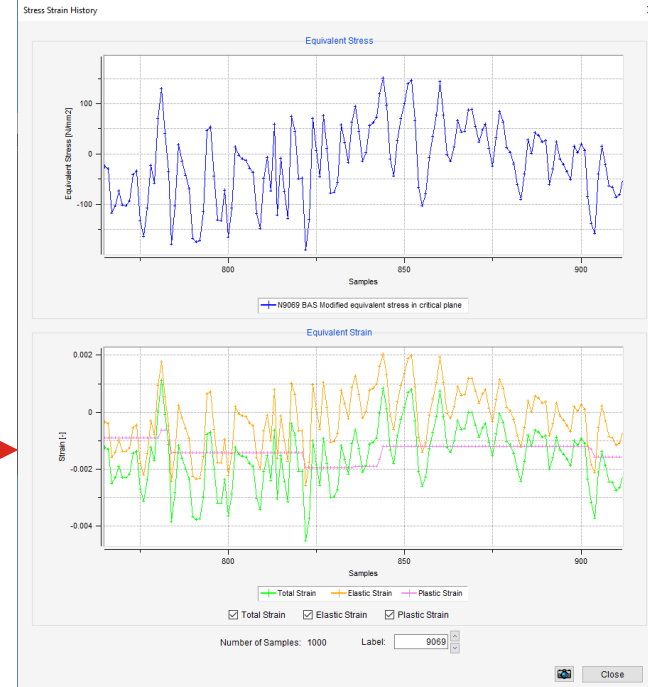
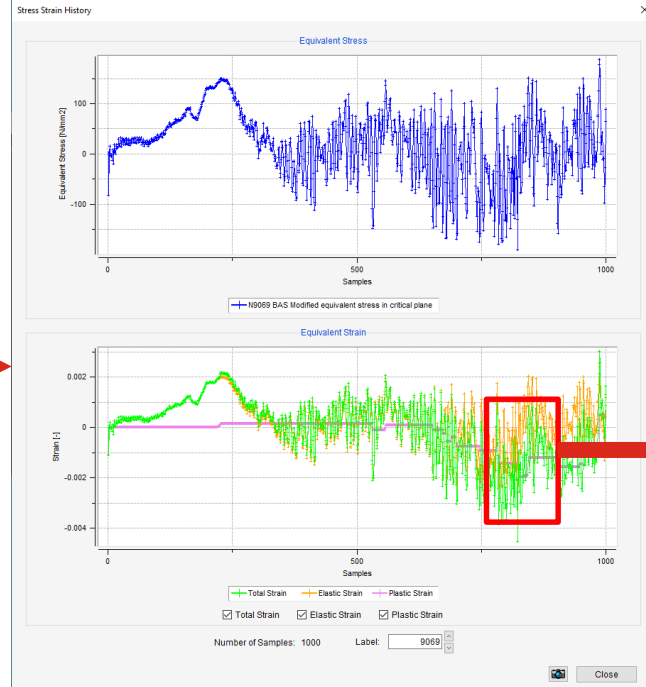
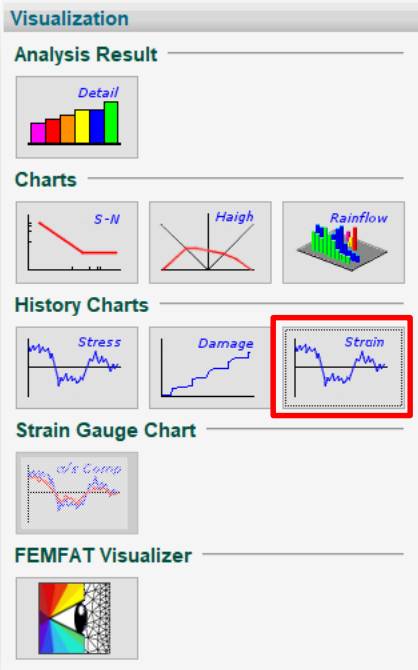
New PLAST – Temperature Influence

- Isothermal temperature influence can be considered
- Output of the temperature dependent parameters in the report file

Temperature: 100.0°C		
Cyclic Coefficient of Hardening	1400.70	[N/mm ²]
Cyclic Exponent of Hardening	0.11	[-]
Nonlinear Data:		
Backstress_i	C_i	Gamma_i
1	2.450240e+05	1.560800e+03
2	2.739565e+04	1.405737e+02
3	3.439368e+03	1.419215e+01
4	5.186301e+02	1.165260e+00
RMS Fitting Error	2.7	[N/mm ²]
Linear Data:		
Yield Stress at Zero Plastic Strain	503.73	[N/mm ²]
Young's Modulus	210000	[N/mm ²]
Temperature: 150.0°C		
Cyclic Coefficient of Hardening	1281.64	[N/mm ²]
Cyclic Exponent of Hardening	0.11	[-]
Nonlinear Data:		
Backstress_i	C_i	Gamma_i
1	2.243337e+05	1.560800e+03
2	2.504443e+04	1.405737e+02
3	3.150212e+03	1.419215e+01
4	4.740180e+02	1.165260e+00
RMS Fitting Error	2.5	[N/mm ²]
Linear Data:		
Yield Stress at Zero Plastic Strain	460.92	[N/mm ²]
Young's Modulus	210000	[N/mm ²]

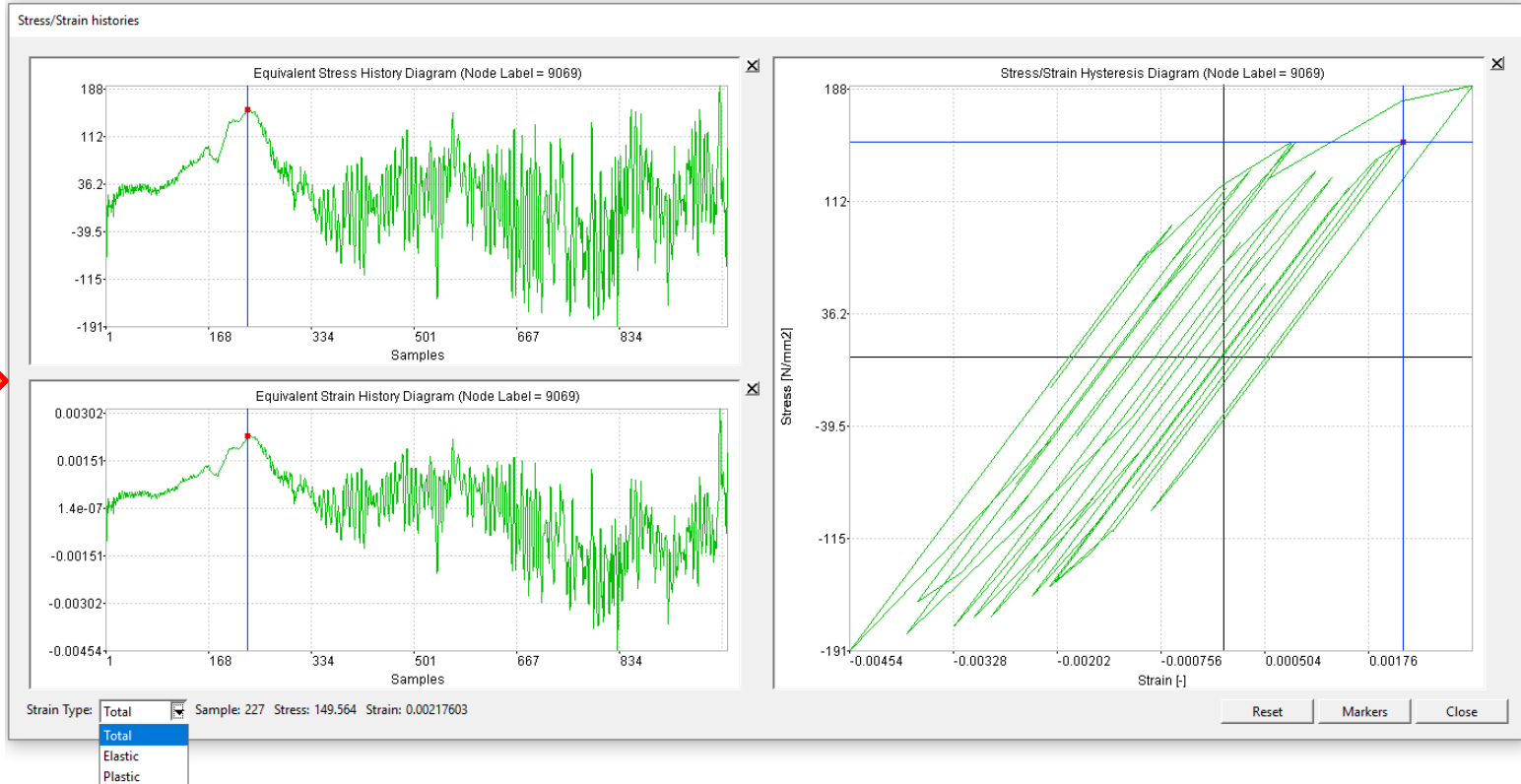
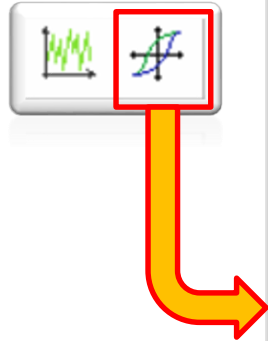
New PLAST – Graphics Outputs

- Output of stresses and strains for selected nodes (FPS and ASCII format)



New PLAST - Graphics Outputs in VISUALIZER

- New stress-strain plots including hysteresis



New Material Generator for Short Fiber Reinforced Plastics



Supported Matrix Materials

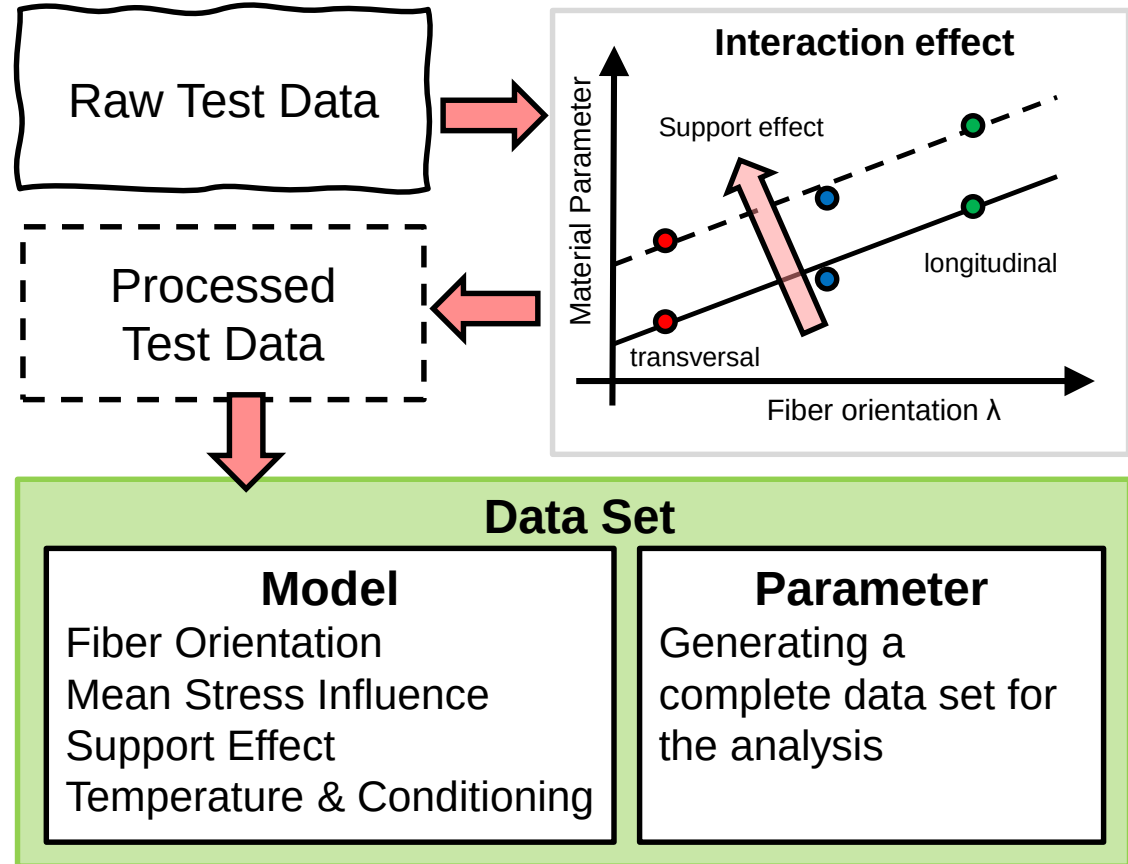
- PPA dry
- PPA conditioned
- PEEK
- PA66 dry
- PA66 conditioned
- PP
- PA12

Supported Fiber Material

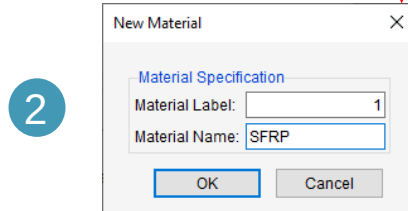
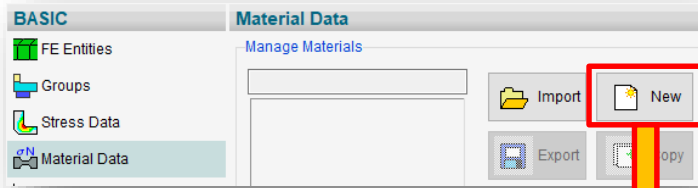
- Glass fiber
- Carbon fiber

Material data output

- Static and dynamic data in parallel and perpendicular direction



Material Generator for Short Fiber Reinforced Plastics



New design

Additional settings

Reliable fatigue data estimation
without any need of expensive tests!

3

The 'Material Generator' dialog box is shown. The 'Define Material Parameters' section is active. The 'Material Group' is set to 'Iron', 'Material Class' is 'Iron', and 'Material Parameter' is 'Polymer'. Below this is a table of material properties:

	Tension	Pressure	Bending	Shear
Ultimate Strength	0.0	0.0	0.0	0.0 [N/mm2]
Yield Strength	0.0	0.0	0.0	0.0 [N/mm2]
Pulsating Strength	0.0	0.0	0.0	0.0 [N/mm2]
Alternating Strength	0.0	0.0	0.0	0.0 [N/mm2]

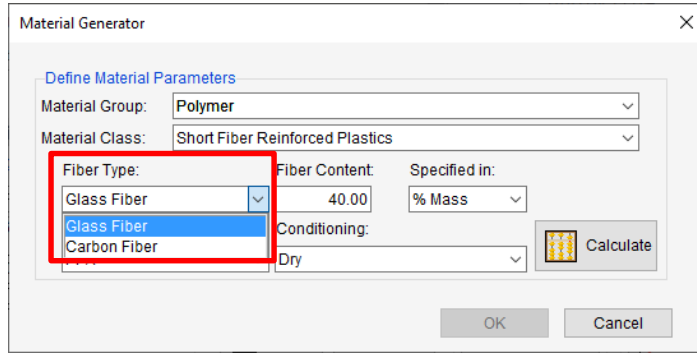
Below the table, there are several input fields for material properties:

- Remarks: [Empty field]
- Data Source: [Empty field]
- Young's Modulus: 0.00 [N/mm2]
- Elongation at Rupture A5: 0.00 [%]
- Cyclic Hardening Coefficient K': 0.000000 [N/mm2]
- Cyclic Hardening Exponent n': 0.000000
- Slope of S-N Curve: 0.00
- Cycle Limit: 0
- Survival Probability: 0.0000 [%]
- Thickness of Specimen for Gradient Influence: 0.0 [mm]
- Thickness of Specimen for Tech. Size Influence: 0.0 [mm]
- Roughness of Specimen: 0.0 [μm]
- Fatigue Strength Coefficient Sigma_f: 0.000000 [N/mm2]
- Fatigue Strength Exponent b: 0.000000
- Fatigue Ductility Coefficient Epsilon_f: 0.000000
- Fatigue Ductility Exponent c: 0.000000

At the bottom right, there are 'OK' and 'Cancel' buttons.

Material Generator for Short Fiber Reinforced Plastics

4



Material Generator

Define Material Parameters

Material Group: Polymer

Material Class: Short Fiber Reinforced Plastics

Fiber Type: Glass Fiber

Fiber Content: 40.00

Specified in: % Mass

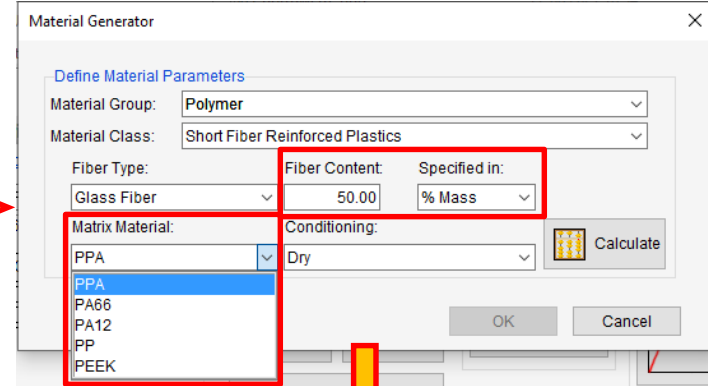
Conditioning: Dry

Calculate

OK Cancel



5



Material Generator

Define Material Parameters

Material Group: Polymer

Material Class: Short Fiber Reinforced Plastics

Fiber Type: Glass Fiber

Fiber Content: 50.00

Specified in: % Mass

Matrix Material: PPA

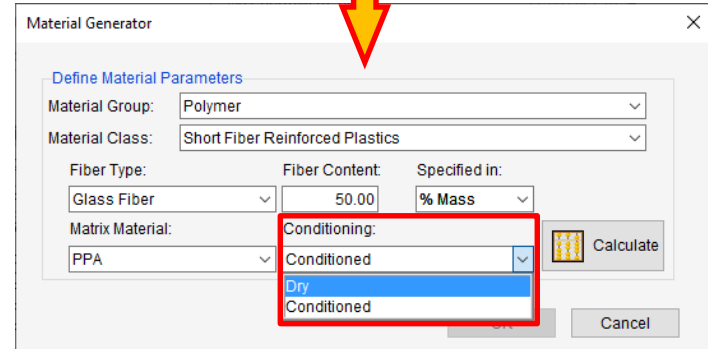
Conditioning: Dry

Calculate

OK Cancel



6



Material Generator

Define Material Parameters

Material Group: Polymer

Material Class: Short Fiber Reinforced Plastics

Fiber Type: Glass Fiber

Fiber Content: 50.00

Specified in: % Mass

Matrix Material: PPA

Conditioning: Dry

Calculate

OK Cancel

New design

Additional settings

Reliable fatigue data estimation
without any need of expensive tests!

Material Generator for Short Fiber Reinforced Plastics

Material Generator

Define Material Parameters

Material Group: Polymer

Material Class: Short Fiber Reinforced Plastics

Fiber Type: Glass Fiber Fiber Content: 50.00 Specified in: % Mass

Matrix Material: PPA Conditioning: Conditioned

Calculate

OK Cancel



Material Generator

Define Material Parameters

Material Group: Polymer

Material Class: Short Fiber Reinforced Plastics

Fiber Type: Glass Fiber Fiber Content: 50.00 Specified in: % Mass

Matrix Material: PPA Conditioning: Conditioned

Calculate

Material Parameters Parallel to Fiber

	Tension	Pressure	Bending	Shear
Ultimate Strength	235.0	665.0	361.9	166.2 [N/mm2]
Yield Strength	188.0	532.0	289.5	133.0 [N/mm2]
Pulsating Strength	81.5	0.0	125.5	57.6 [N/mm2]
Alternating Strength	61.1	61.1	94.1	43.2 [N/mm2]

Young's Modulus: 18000.00 [N/mm2]

Elongation at Rupture A5: 2.46 [%]

Portion of Fibers: 0.85

Slope of S-N Curve: 11.40

Cycle Limit: 1000000

MINER Modified Parameter a: 1.00

MINER Modified Parameter b: 0.00

Material Parameters Perpendicular to Fiber

Young's Modulus: 11951.68 [N/mm2]

Ultimate Strength Tension: 125.10 [N/mm2]

Ultimate Strength Compression: 354.00 [N/mm2]

Yield Strength Tension: 100.10 [N/mm2]

Yield Strength Compression: 283.20 [N/mm2]

Pulsating Endurance Strength Tension: 37.40 [N/mm2]

Alternating Endurance Strength: 28.00 [N/mm2]

Elongation at Rupture A5: 4.61 [%]

Portion of Fibers: 0.20

OK Cancel

8

Tensile values can be modified analogous to existing material generator

New design

Additional settings

Reliable fatigue data estimation without any need of expensive tests!

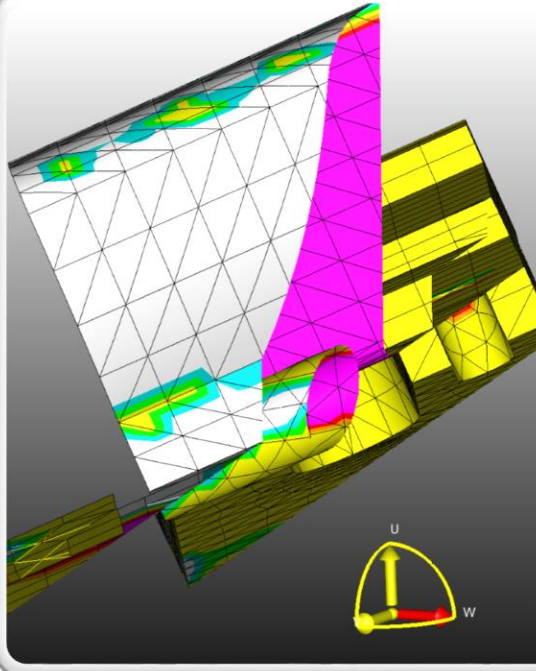
Fiber Content: 40.00 Specified in: % Volume

Recalculation of fiber content

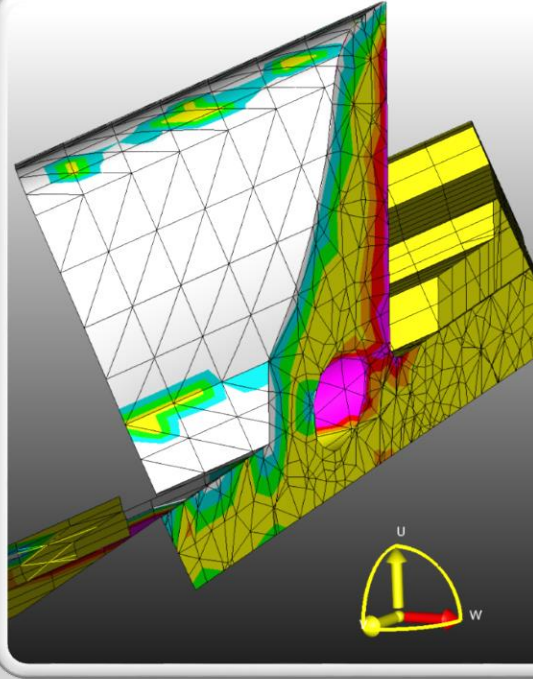
54.35 [% Mass]

FEMFAT visualizer – Cutting Plane with Results

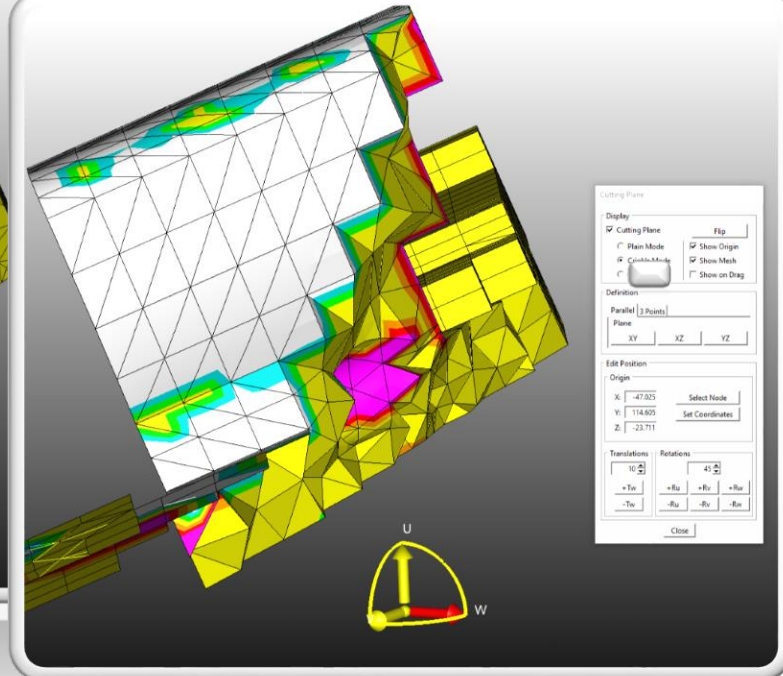
Off Mode (like in 2022.1)



Plain Mode

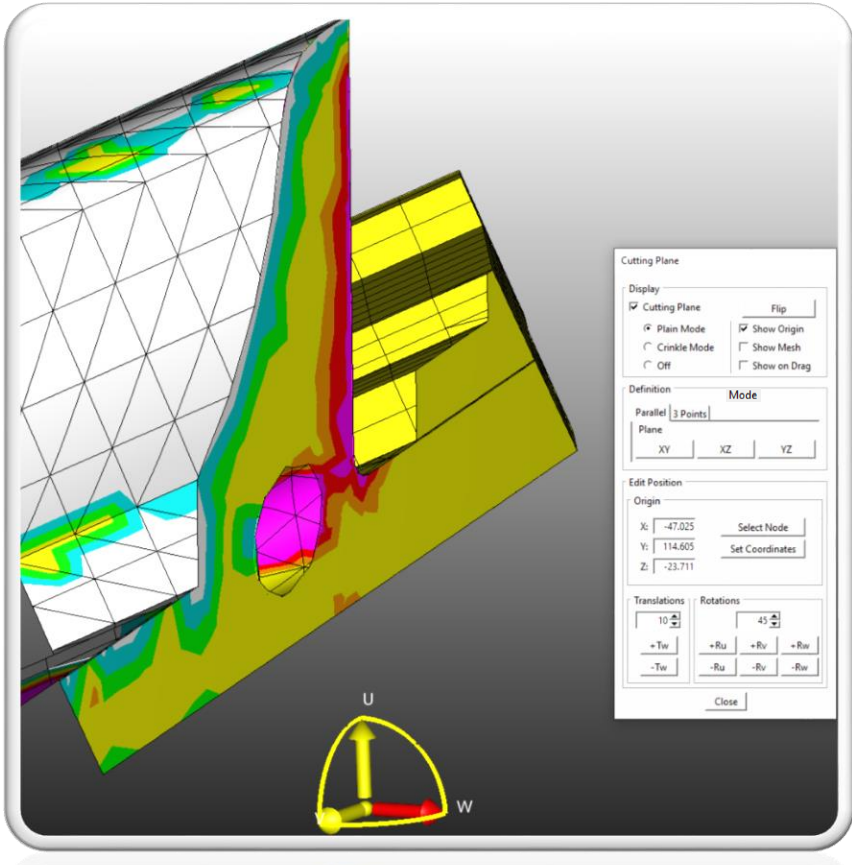
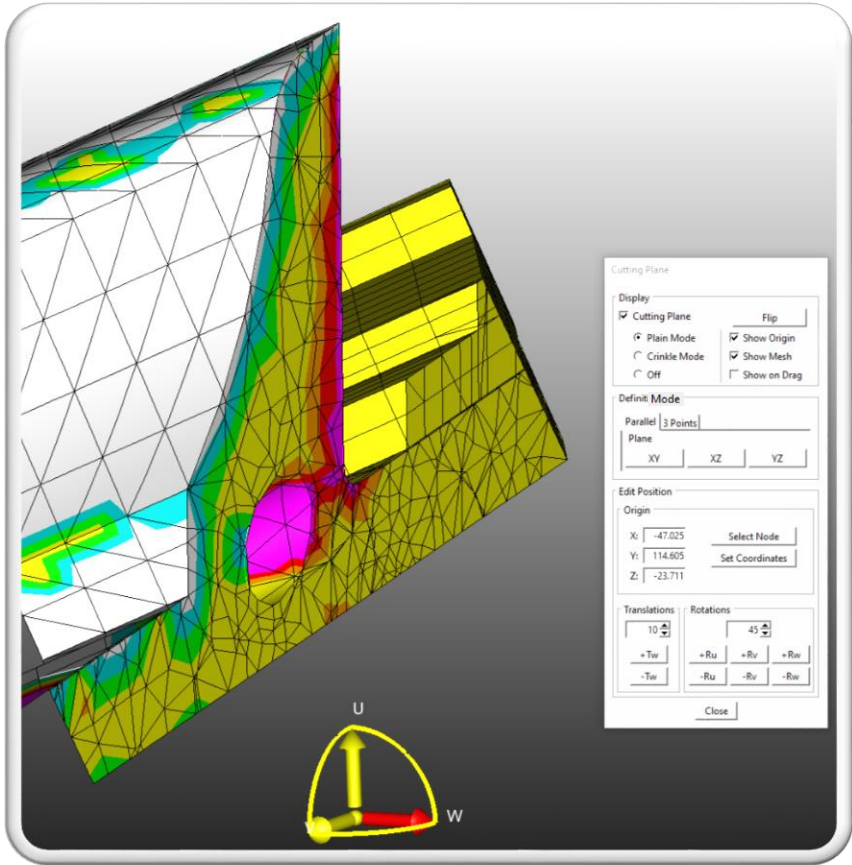


Crinkle Mode



Show Mesh

On/Off

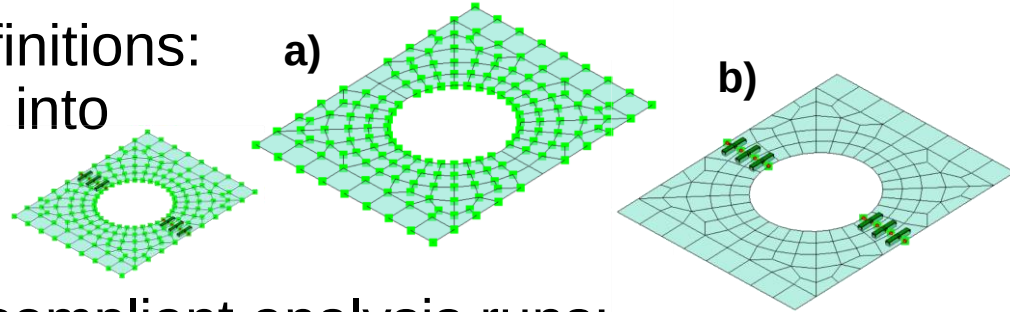


Assessment acc. to FKM guideline – New 'FKM_Fatigue' template

- Processes that are automatically handled by the template:

- If the model includes weld definitions:

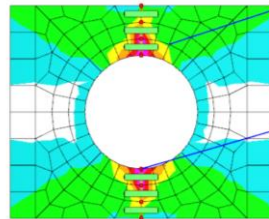
Division of the selected group into 2 analysis groups, one each for **a)** base material **b)** welds



- Perform 4 downstream FKM-compliant analysis runs:

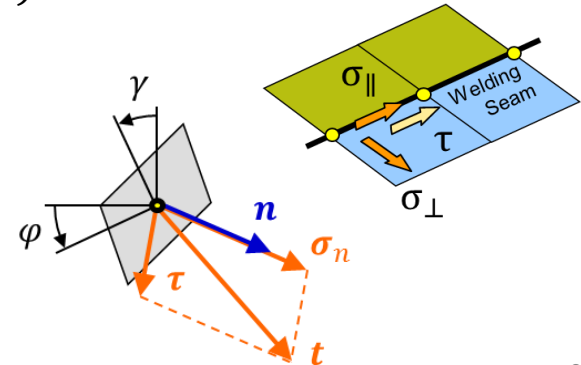
- 1 analysis acc. to cutting plane method for base material (σ_n and τ)
- 1 analysis per stress component for welds ($\sigma_{\perp}$, $\sigma_{\parallel}$ and τ)

- Determination of cyclic degree of utilization a and damage D



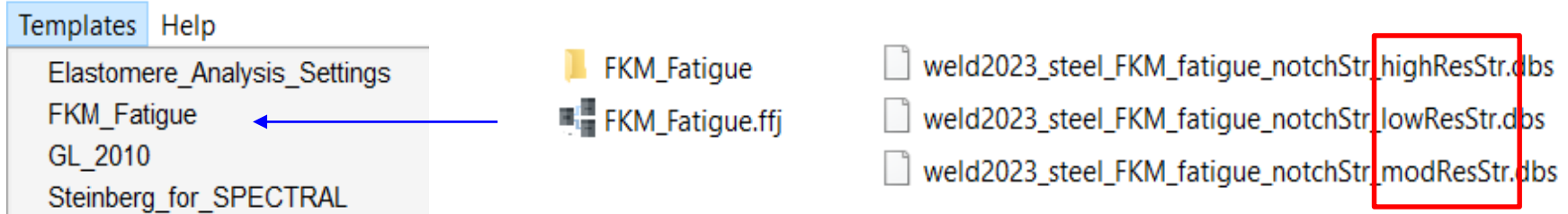
Node Label: 500
a_max: 0.1699
D_max: 1.416e-04

Node Label: 161
a_max: 0.4258
D_max: 0.07714



Assessment acc. to FKM guideline – Workflow

- The template is available for BASIC and MAX.
- The following user inputs precede the execution of the template:
 1. Import of **Weld Definition Files** (generated based on FKM WELD database)
 2. Assignment of **Node Characteristics** (required for FKM-compliant assessment / optional)
 3. Activation of optional **Influence Factors** (optional for constant stress & rotating principal stresses)
 4. Definition of **Stress in Cutting Plane** (optional for base material)
 5. Selection of **Analysis Group** (completed analysis group with nodes and elements)
- The template can be loaded in GUI. The associated *.ffj file (incl. sub files) and the FKM WELD databases for high, moderate and low residual stresses are in the installation directory:



Modeling Guideline acc. DVS 1612 Standard for Steel

- 60 typical weld seam types have been implemented in a new WELD database for DVS1612



Weld Type: T-WELD

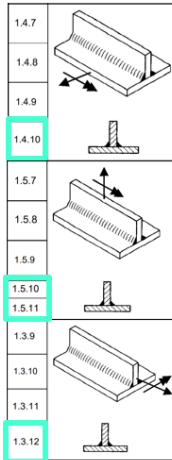
Seam Shape: Double Fillet Weld

2D Modelling:

Element type : THIN SHELL (linear or parabolic)

Element material label : MAT207 - MAT212

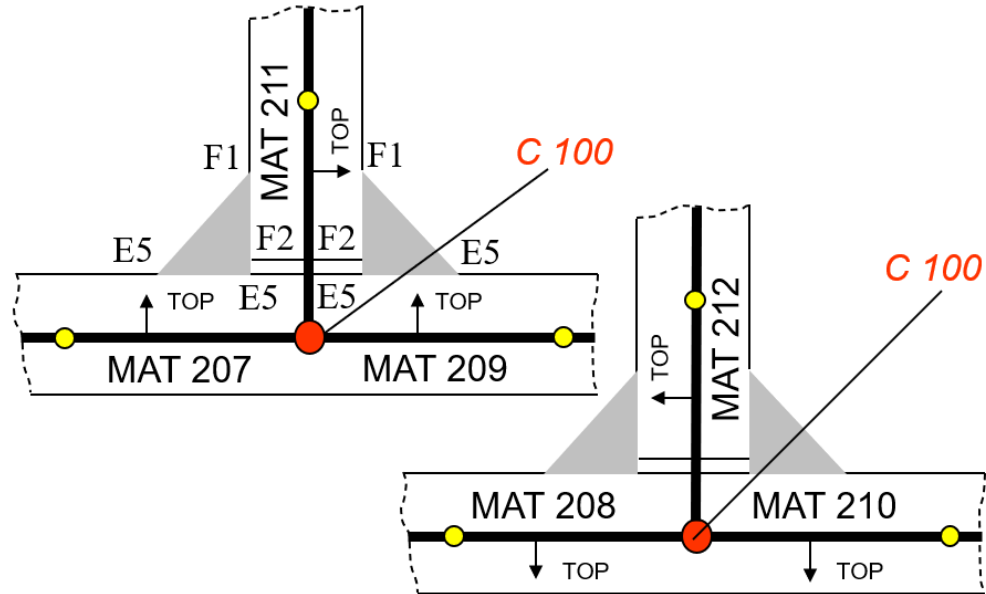
Equivalent MAT label : 207 = 209, 208 = 210, 211 = 212



Base Plate:
Toe & Root: E5

Web Plate:
Toe: F1 Root: F2

Parallel: C-
Shear: H
Weld Seam End: F1



Up to 100 User Defined Master SN-curves for SolidWELD



```
$ Master S/N curve for normal stresses and equivalent stresses respectively for rough solid models.
$ There is no S/N curve for shear stresses available.
$
$ SWSN1 ... Master S/N curve for SOLID WELD toe or trans_root_toe (predefined position identifier)
$ SWSN2 ... Master S/N curve for SOLID WELD root (predefined position identifier)
$ SWSN3 ... Master S/N curve for SOLID WELD start or trans_root_start (predefined position identifier)
$ SWSN4 ... Master S/N curve for SOLID WELD end or stop or trans_root_end (predefined position identifier)
$ SWSNx ... Master S/N curve for SOLID WELD for user defined position identifier
```

	Fatigue- strength (Ampl.)	Inclination	Cycle- limit	Survival- probabil.	Range of dispersion (10-90%)	Position identifier (max. 30 characters)
SWSN1	133.1	3.10	2000000.0	50.0	2.480	---
SWSN2	89.8	3.10	2000000.0	50.0	2.480	---
SWSN3	112.0	3.10	2000000.0	50.0	2.480	---
SWSN4	112.0	3.10	2000000.0	50.0	2.480	---
SWSNx	133.1	3.10	2000000.0	50.0	2.480	rolled

Column 96

SolidWELD Group Name:

FemfatSolidWeld_4711_rolled_butt-joint_5p3_6p7

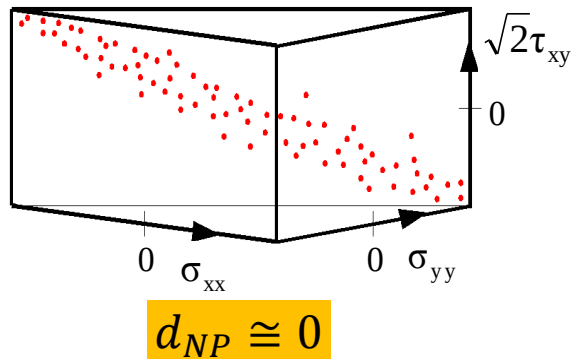


Identifier of the node position at the seam

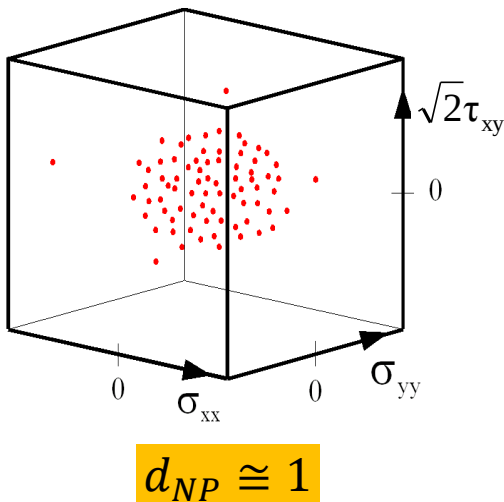
Define Sensitivity of Non-Proportionality



Almost proportional stress distribution



Strongly non-proportional stress distribution



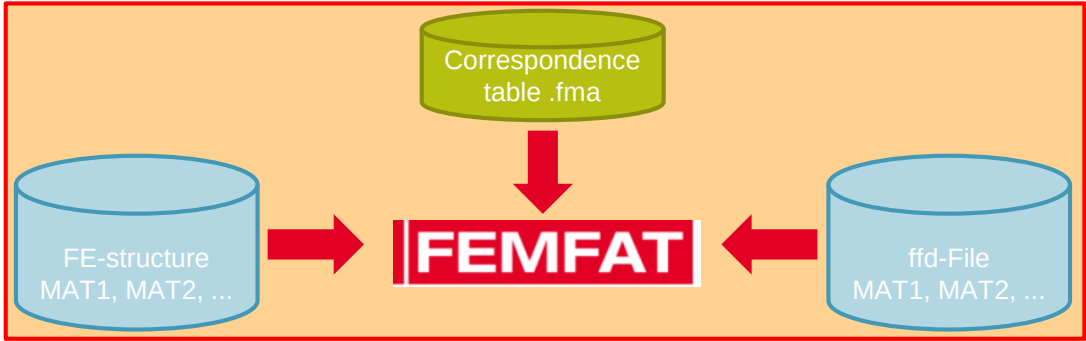
☒ Rotating Principal Stresses Influence

$$\sigma_{fl,new} = \sigma_{fl,old} \cdot (1 - S_{NP} \cdot d_{NP})$$

userdefparam_2023.dbs

\$ Material	Exponent for	Slope	Exponent	Diameter	Diameter	Constant	Constant	Sensiti-	...	...
\$ Class	Gradient -	Limit		deff,N,m	deff,N,p	ad,m	ad,p	vity of		
\$	Influence	AK2	AK3	in mm	in mm	for Kd,m	for Kd,p	nonprop.		
\$	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====
1	0.30	3.0	2.0	40.0	40.0	0.15	0.30	0.2775		
3	0.30	3.0	2.0	16.0	16.0	0.30	0.40	0.2775		
6	0.30	3.0	2.0	40.0	40.0	0.15	0.30	0.2775		
11	0.30	3.0	2.0	70.0	40.0	0.20	0.30	0.2775		

Combination of Multi-Material File with Automatic Material Assignment



Material Database Path (\$MatDBPath):						
SPOT automatic assignment: OFF						
# ON/OFF for activating/deactivating this feature						
WELD automatic assignment: OFF						
# ON/OFF for activating/deactivating this feature						
#	MID	PID	FEMFAT material file (.ffd)		Material description	Comment

1		1	multimat_2.ffd	MAT===alpha		
1		1	multimat_2.fid	MAT===beta		

MAT===alpha

```
MAT=== alpha
-1
218
16MnCr5 Case Hardening Steel, polished unnotched specimen
Blind hardened condition, 870 N/mm2
Source: TGL 6546 (16MnCr5)
0.3000E+000.7850E-050.1200E-04 15 20 20.00 1.00 90.000000
0.2100E+060.2100E+060.2100E+060.0000E+000.0000E+000.9000E+010.0000E+00
0.2100E+060.6600E+030.0000E+00
200.00000.1000E-02
```

MAT===beta

```
Case Hardening Steel
1 1 -1.00 0.00 0.00 7.50 1.00 20.00
11.00 2000000 310.00 0 0.00 0.00 0.00 90.000000
0.00 0
2.00 -1.00
-1
MAT===beta
-1
```



Forward. For all.