



Tutorial

# Eurocode3 and F.E.M. 1.001 Fatigue

Updated on: January 31st 2024

Tested with: SDC Verifier 2023 R2

Simcenter3D 2306

- This step-by-step tutorial demonstrates how to implement the fatigue check according F.E.M. 1.001 and Eurocode 3 in SDC Verifier.
- FEM 1.001 Fatigue and Eurocode 3 detailed review;
- Weld Finder Tool overview;
- Implementation in SDC Verifier;
- Fatigue tables and plots;
- The functionality of SDC Verifier Report Designer can be checked via the link to a separate tutorial (Slide 38).

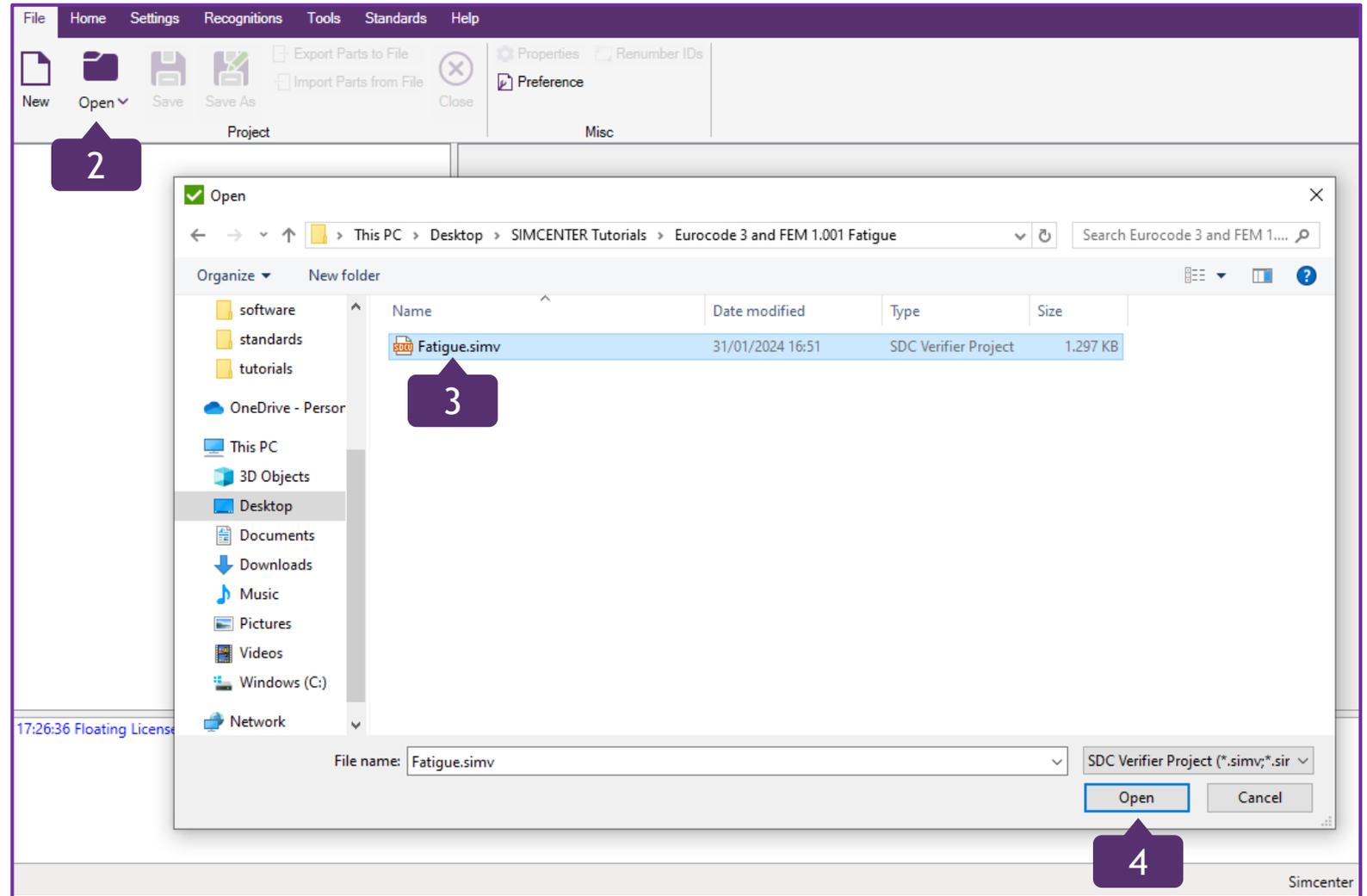
# Open the Starter Model

1 Launch SDC Verifier for Simcenter 3D

2 In *File* section, press *Open*

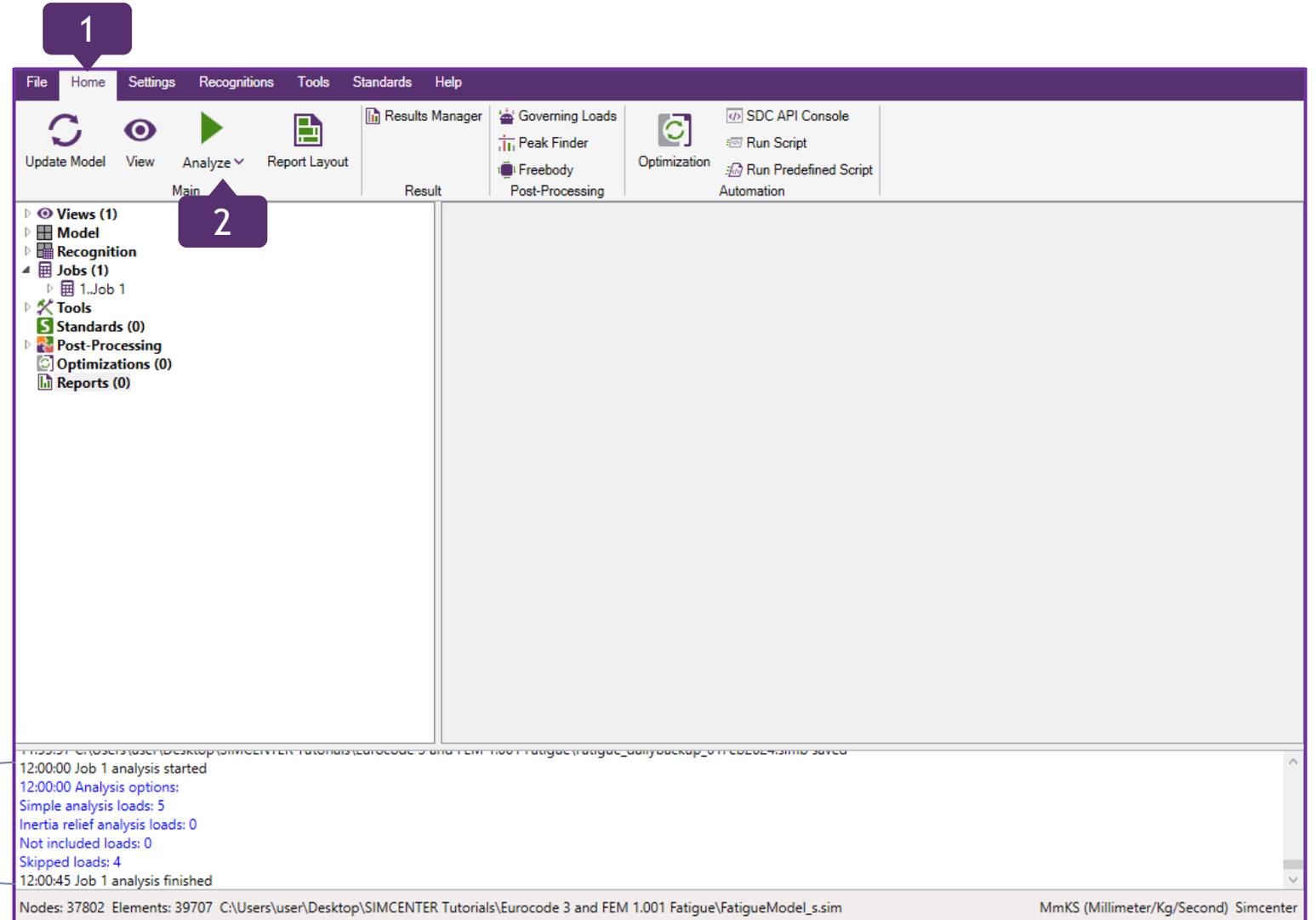
3 Select a project *Fatigue.simv*

4 Press *Open*



1 Go to *Home* section on the Ribbon

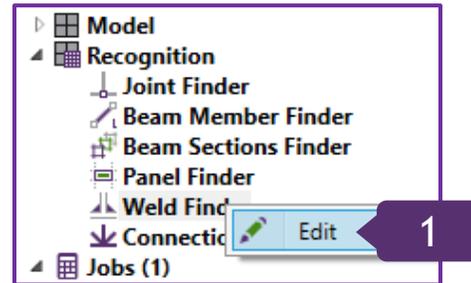
2 Press  on the toolbar to analyze Job



Job 1 analysis started and finished.

1 In the Model Tree, execute Recognition =>Weld Finder => Edit...

2 Press Find



Welds Finder

Welds Weld Strength Settings Hot Spot Stress

Filter: None = [ ] Apply Filter Find Weld by ID [ ] Navigate

ID	Title	Tensile Strength (Min) [kPa]	Yield Stress (Min) [kPa]	Is Symmetric	Is Curved	Nodes	Elements	Weld Parts
1	Weld 1 [-29600.2; 12381.47; 11532.5]	360000000	240000000	Yes	No	6	15	3
2	Weld 2 [-29600.2; 12060.8; 11532.5]	360000000	240000000	Yes	No	6	15	3
3	Weld 3 [-30610.2; 12381.47; 11532.5]	360000000	240000000	Yes	No	6	15	3
4	Weld 4 [-30610.2; 12060.8; 11532.5]	360000000	240000000	Yes	No	6	15	3
5	Weld 5 [-29600.2; 12598.47; 11532.5]	360000000	240000000	Yes	No	6	15	3
6	Weld 6 [-30610.2; 12598.47; 11532.5]	360000000	240000000	Yes	No	6	15	3
7	Weld 7 [-29600.2; 11658.35; 13135.66]	360000000	240000000	Yes	Yes	51	100	2
8	Weld 8 [-29587.7; 12268.61; 5470]	360000000	240000000	Yes	No	2	2	2
9	Weld 9 [-30622.7; 12268.61; 5470]	360000000	240000000	Yes	No	2	2	2
10	Weld 10 [-30610.2; 11658.35; 13135.66]	360000000	240000000	Yes	Yes	51	100	2
11	Weld 11 [-30105.2; 11668.6; 12095]	360000000	240000000	No	No	25	96	4
12	Weld 12 [-30610.2; 11197.58; 11430]	360000000	240000000	Yes	No	15	42	3
13	Weld 13 [-30610.2; 12221.14; 11430]	360000000	240000000	Yes	No	7	18	3
14	Weld 14 [-30610.2; 12489.97; 11430]	360000000	240000000	Yes	No	7	18	3
15	Weld 15 [-30610.2; 12673.54; 11430]	360000000	240000000	Yes	No	5	12	3
16	Weld 16 [-30610.2; 12381; 12094.9]	360000000	240000000	Yes	No	21	60	3
17	Weld 17 [-30610.2; 11977.98; 12095]	360000000	240000000	Yes	No	2	2	2
18	Weld 18 [-30610.2; 11921.73; 12095]	360000000	240000000	Yes	No	2	4	4
19	Weld 19 [-30610.2; 11752.98; 12095]	360000000	240000000	Yes	No	2	4	4
20	Weld 20 [-30610.2; 11696.73; 12095]	360000000	240000000	Yes	No	2	2	2
21	Weld 21 [-30610.2; 11290.04; 12095]	360000000	240000000	Yes	No	21	60	3
22	Weld 22 [-29600.2; 12381; 12094.9]	360000000	240000000	Yes	No	21	60	3
23	Weld 23 [-29600.2; 11977.98; 12095]	360000000	240000000	Yes	No	2	3	3
24	Weld 24 [-29600.2; 11921.73; 12095]	360000000	240000000	Yes	No	2	4	4
25	Weld 25 [-29600.2; 11837.36; 12095]	360000000	240000000	Yes	No	3	7	3
26	Weld 26 [-29600.2; 11752.98; 12095]	360000000	240000000	Yes	No	2	4	4
27	Weld 27 [-29600.2; 11696.73; 12095]	360000000	240000000	Yes	No	2	3	3
28	Weld 28 [-29600.2; 11290.04; 12095]	360000000	240000000	Yes	No	21	60	3
29	Weld 29 [-29600.2; 11197.58; 11430]	360000000	240000000	Yes	No	15	42	3

Settings Find [2] Set Parameter Check on Weld Design OK Cancel

Add, Edit, Combine and Remove Welds

Move Welds. Order is important when one element belongs to 2 Welds

Preview selected Welds

Plot of selected Welds in colors and with labels of IDs

**Note:** All weld nodes should belong to weld elements.

The option is automatically disabled when the weld is in Add mode and enabled when in Edit mode.

Is used to recognize weld elements from nodes. Enabled when the *Pick elements manually* option is turned ON.

After the recognition is finished, all welds are checked on the design. If all weld parts of single weld are welded or all weld parts are not-welded, they will be included to the list of welds that are recommended to be checked manually:

### 3 Press Close

Note: If a weld consists of only 2 parts (e.g. Angle-weld), all parts will be set as welded but weld will not be included to the list;

Check weld design is essential for Weld Strength checks. As this tutorial is devoted to Fatigue, the window is to be closed.

Check weld design

Unable to recognize weld parameters automatically. Welds that match one of the following criteria are displayed:

#	Type	Description	Issue
1	Warning	All weld parts in a weld are welded	Continuous parts in real model will be treated as welded
2	Warning	Different weld part lengths in a weld	Different area of the weld that will lead to stress variation
3	Error	Length of any weld part of a weld is zero	Possible mesh disconnectivity. Weld area is 0

ID	Title	Nodes	Elements	Length	Criterion	Welded	Non-Welded
61	Weld 61 [-30105.19; 12748.61; 5470]	25	72	1010	1	3	0
204	Weld 204 [-29768.28; 12268.61; 5470]	9	24	336.7	1	3	0
205	Weld 205 [-30105.18; 12268.61; 5470]	9	24	336.6	1	3	0
206	Weld 206 [-30442.12; 12268.61; 5470]	9	24	336.7	1	3	0

Buttons: Set welded parts by elements, Set non-welded parts by elements, Close

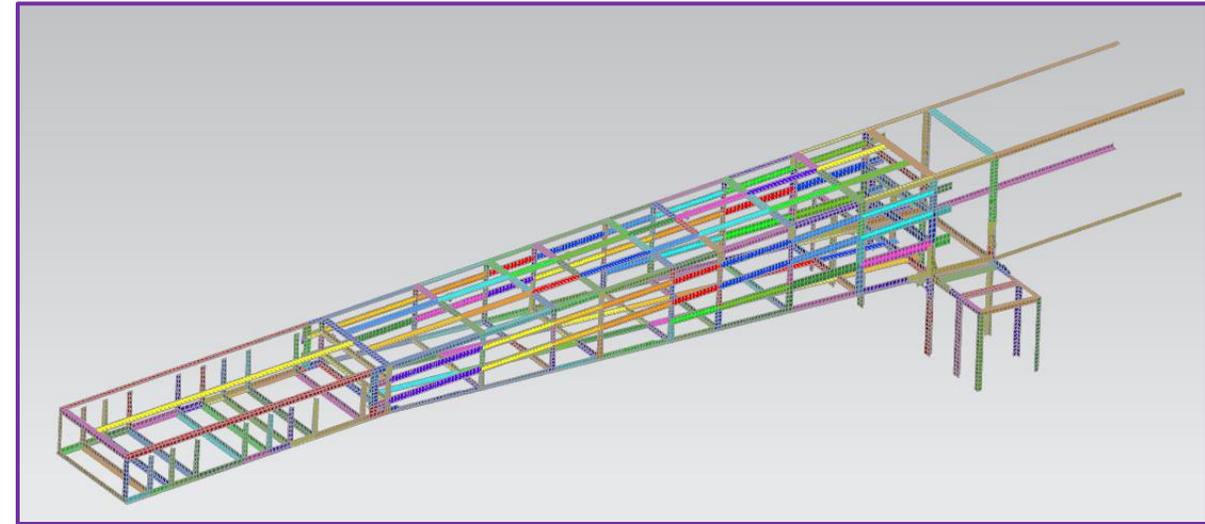
There some Welds with all welded parts were found; this message should be closed

# Weld Finder Plotting Functions

1 To plot all welds, in Welds Finder select them by combining Ctrl + A

2 Press  and select *Welds in colors*

3 Press *OK*



Welds Finder

Welds | Weld Strength Settings | Hot Spot Stress

Filter: None = Apply Filter Find Weld by ID: Navigate

ID	Title	Tensile Strength (Min) [kPa]	Yield Stress (Min) [kPa]	Is Symmetric	Is Curved	Nodes	Elements	Weld Parts
1	Weld 1 [-29600.2; 12381.47; 11532.5]	360000000	240000000	Yes	No	6	15	3
2	Weld 2 [-29600.2; 12060.8; 11532.5]	360000000	240000000	Yes	No	6	15	3
3	Weld 3 [-30610.2; 12381.47; 11532.5]	360000000	240000000	Yes	No	6	15	3
4	Weld 4 [-30610.2; 12060.8; 11532.5]	360000000	240000000	Yes	No	6	15	3
5	Weld 5 [-29600.2; 12598.47; 11532.5]	360000000	240000000	Yes	No	6	15	3
6	Weld 6 [-30610.2; 12598.47; 11532.5]	360000000	240000000	Yes	No	6	15	3
7	Weld 7 [-29600.2; 11658.35; 13135.66]	360000000	240000000	Yes	No	6	15	3
8	Weld 8 [-29587.7; 12268.61; 5470]	360000000	240000000	Yes	No	6	15	3
9	Weld 9 [-30622.7; 12268.61; 5470]	360000000	240000000	Yes	No	6	15	3
10	Weld 10 [-30610.2; 11658.35; 13135.66]	360000000	240000000	Yes	No	6	15	3
11	Weld 11 [-30105.2; 11668.6; 12095]	360000000	240000000	Yes	No	6	15	3
12	Weld 12 [-30610.2; 11197.58; 11430]	360000000	240000000	Yes	No	6	15	3
13	Weld 13 [-30910.2; 12221.14; 11430]	360000000	240000000	Yes	No	6	15	3
14	Weld 14 [-30610.2; 12489.97; 11430]	360000000	240000000	Yes	No	6	15	3
15	Weld 15 [-30610.2; 12673.54; 11430]	360000000	240000000	Yes	No	6	15	3
16	Weld 16 [-30610.2; 12381; 12094.9]	360000000	240000000	Yes	No	6	15	3
17	Weld 17 [-30610.2; 11977.98; 12095]	360000000	240000000	Yes	No	6	15	3
18	Weld 18 [-30610.2; 11921.73; 12095]	360000000	240000000	Yes	No	6	15	3
19	Weld 19 [-30610.2; 11752.98; 12095]	360000000	240000000	Yes	No	6	15	3
20	Weld 20 [-30610.2; 11696.73; 12095]	360000000	240000000	Yes	No	6	15	3
21	Weld 21 [-30610.2; 11290.04; 12095]	360000000	240000000	Yes	No	6	15	3
22	Weld 22 [-29600.2; 12381; 12094.9]	360000000	240000000	Yes	No	6	15	3
23	Weld 23 [-29600.2; 11977.98; 12095]	360000000	240000000	Yes	No	6	15	3
24	Weld 24 [-29600.2; 11921.73; 12095]	360000000	240000000	Yes	No	2	4	4
25	Weld 25 [-29600.2; 11837.36; 12095]	360000000	240000000	Yes	No	3	7	3
26	Weld 26 [-29600.2; 11752.98; 12095]	360000000	240000000	Yes	No	2	4	4
27	Weld 27 [-29600.2; 11696.73; 12095]	360000000	240000000	Yes	No	2	3	3
28	Weld 28 [-29600.2; 11290.04; 12095]	360000000	240000000	Yes	No	21	60	3
29	Weld 29 [-29600.2; 11197.58; 11430]	360000000	240000000	Yes	No	15	42	3

Plotting options menu:

- Welded/non-welded parts
- Weld parts
- Welds in colors
- Welds in colors + Labels of IDs
- Weld parts length + Labels of values
- Weld parts throat thickness + Labels of values
- Weld types + Labels of values
- Coordinate Systems
- Weld part throat
- Welded/non-welded parts + throat

Buttons: Settings, Find, Set Parameter, Check on Weld Design, OK, Cancel

The software offers an extensive variety of Plotting options that can be selected according to the user's objectives.

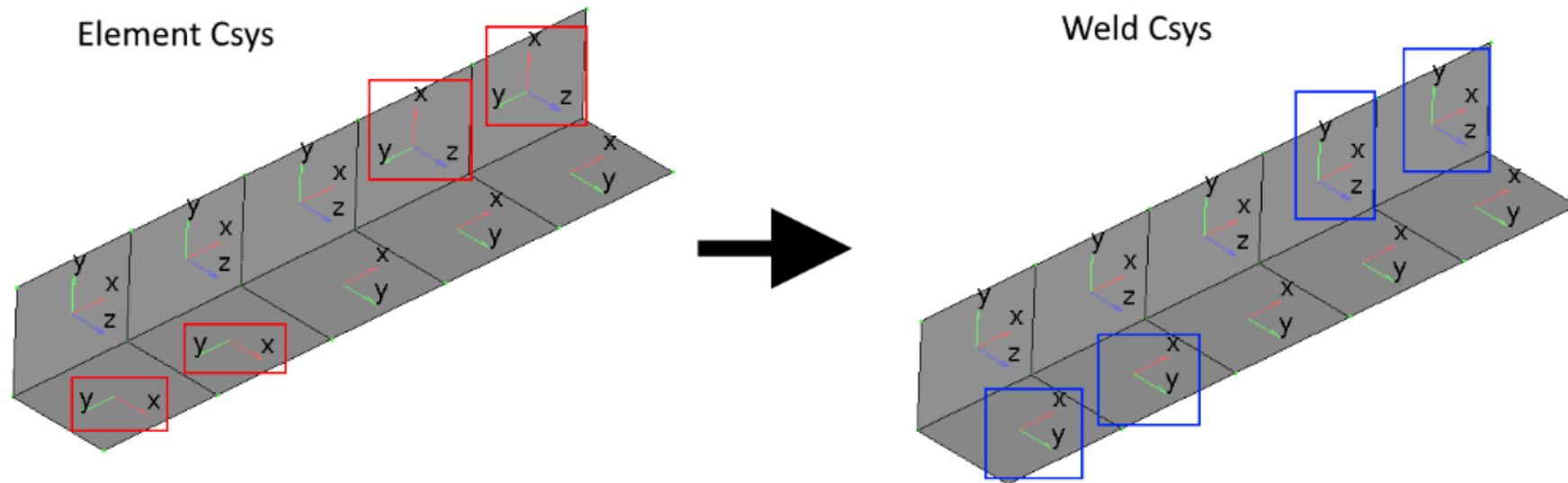
$$\sigma_{nn} = \frac{(\sigma_{xx} + \sigma_{yy})}{2} + \frac{(\sigma_{xx} - \sigma_{yy})}{2} * \cos 2\theta + \tau_{xy} * \sin 2\theta$$

$$\tau_{nt} = -\frac{(\sigma_{xx} - \sigma_{yy})}{2} * \sin 2\theta + \tau_{xy} * \cos 2\theta$$

$$\sigma_{tt} = \frac{(\sigma_{xx} + \sigma_{yy})}{2} - \frac{(\sigma_{xx} - \sigma_{yy})}{2} * \cos 2\theta - \tau_{xy} * \sin 2\theta$$

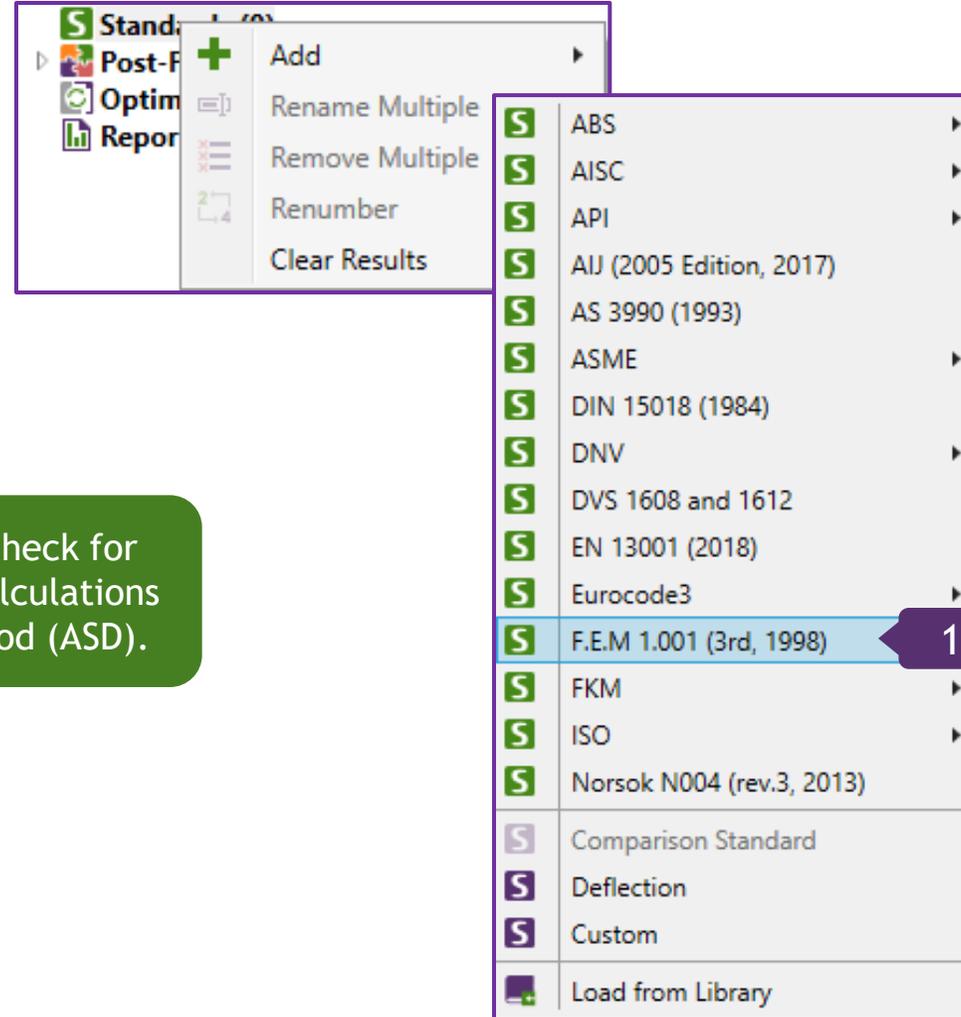
Stresses for Weld elements are automatically transformed in the direction of the corresponding Weld from Weld Finder Tool, using the Wedge Method. Stresses are transformed only for plate type elements.

$\sigma_{xx}, \sigma_{yy}, \tau_{xy}$  – original x, y and shear stress in local element x, y and shear directions  
 $\sigma_{tt}, \sigma_{nn}, \tau_{nt}$  – transformed x, y and shear stress in weld x, y and shear directions  
 $\theta$  – angle between the element and weld x directions.



1

In the *Model tree*, in Standards execute Add => F.E.M 1.001 (3rd, 1998)



F.E.M. 1.001 performs Static Stress Check and Fatigue Check for steel structures of crane and crane equipment. Fatigue calculations are performed according to Allowable Stress Design method (ASD).

## Allowable Stress Design method

The following formulae give for all values of  $\kappa$  the permissible stresses for fatigue

a)  $\kappa \leq 0$

- for tension :  $\sigma_t = 5 \cdot \sigma_w / (3 - 2 \cdot \kappa)$  (1)

- for compression :  $\sigma_c = 2 \cdot \sigma_w / (1 - \kappa)$  (2)

$\sigma_w$  is given in table above.

b)  $\kappa > 0$

- for tension  $\sigma_t = \sigma_0 / [1 - \kappa \cdot (1 - \sigma_0 / \sigma_{+1})]$  (3)

- for compression  $\sigma_c = 1,2 \cdot \sigma_t$  (4)

where  $\sigma_0$  = tensile stress for  $\kappa = 0$  is given by the formula (1) that is :

$$\sigma_0 = 1,66 \cdot \sigma_w$$

$\sigma_{+1}$  = tensile stress for  $\kappa = + 1$  that is the ultimate strength  $\sigma_R$  divided by the coefficient of safety 4/3 :

$$\sigma_{+1} = 0,75 \cdot \sigma_R$$

$\sigma_t$  is limited in every case to  $0,75 \cdot \sigma_R$ .

By way of illustration, fig. A.3.6.1. shows curves giving the permissible stress as a function of the ratio  $\kappa$  for the following cases :

- steel A.52 ;
- predominant tensile stress ;
- group E6 ;
- construction cases  $W_0, W_1, W_2$  for unwelded components and cases of construction for joints  $K_0$  to  $K_4$ .

The permissible stresses have been limited to 240 N/mm<sup>2</sup>, i.e. to the permissible stress adopted for checking for ultimate strength.

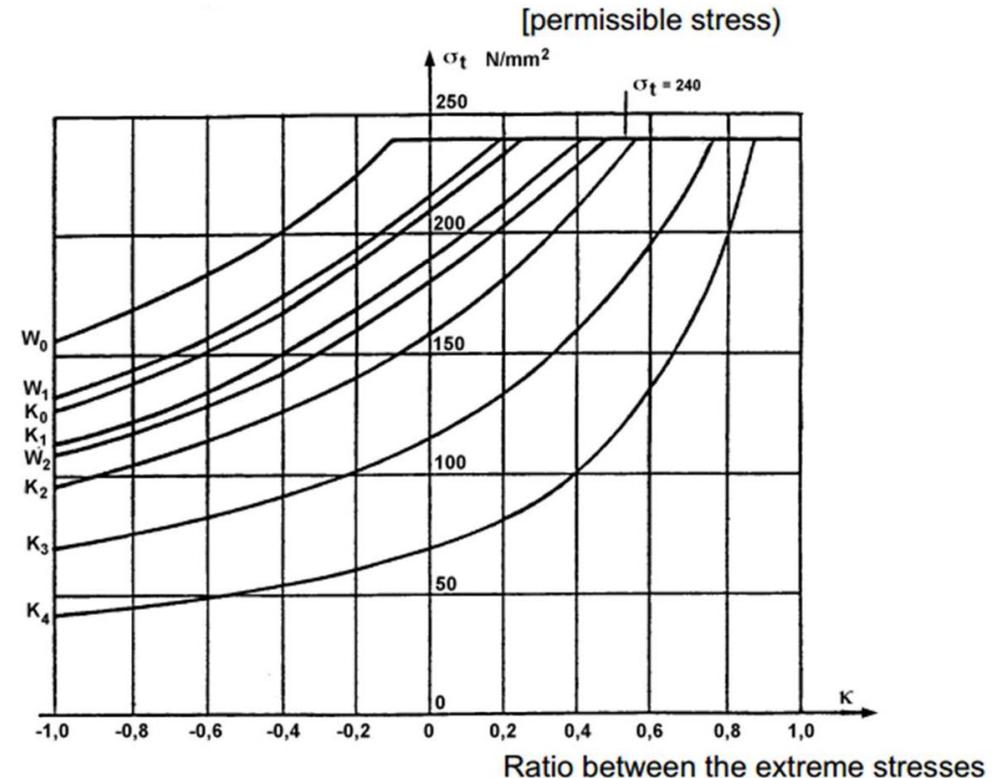


Figure A.3.6.1. - (A 52; tension; group E6)

- ▶ Weld/notch category determines fatigue resistance
- ▶ Division in welds / non welds for FEM 1.001:
  - ▶ W category is for non welded parts
  - ▶ K category is for welded parts
- ▶ Fatigue resistance is further specified by adding classes
  - ▶ W0-W2 for non-welded parts
  - ▶ K0-K4 for welded parts
- ▶ Better fatigue resistance results in lower class number

Weld Type, also called Notch Case, defines the elements that belong to a particular weld type (K0-K4 - joints affected by welding, W0-W2 - elements and joints, not affected by welding). Weld Type depends on a shape, a structural design, a whole pattern or a type and a quality of welds.

### Case W<sub>0</sub>

Reference	Description	Figure	Symbol
W <sub>0</sub>	Parent metal, homogeneous surface. Part without joints or breaks in continuity (solid bars) and without notch effects unless the latter can be calculated.		

### Case K<sub>0</sub> - Slight stress concentration

Reference	Description	Figure	Symbol
0,1	Parts butt-welded (S.Q.) at right angles to direction of forces		

### Case K<sub>1</sub> - Moderate stress concentration

Reference	Description	Figure	Symbol
1,1	Parts joined by butt welding (O.Q.) at right angles to the direction of the forces		

### Case K<sub>2</sub> - Medium stress concentration

Reference	Description	Figure	Symbol
2,1	Parts of different thickness butt welded (O.Q.) at right angles to the direction of the forces. Asymmetrical slope : 1 in 3 (or symmetrical slopes : 1 in 2)		
2,4	Cruciform joint made with K-welds (S.Q.) perpendicular to the direction of the forces		

### Case K<sub>3</sub> - Severe stress concentration

3,11	Butt weld with backing strip and no backing run. Backing strip secured by intermittent tack welds		
3,4	Cruciform joint made with K-weld (O.Q.) at right angles to the direction of the forces		

### Case K<sub>4</sub> - Very severe stress concentration

Reference	Description	Figure	Symbol
4,1	Parts of different thickness butt welded (O.Q.) at right angles to the direction of the forces. Asymmetrical position without blend slope		
4,4	Cruciform joint made with fillet weld (O.Q.) at right angles to the direction of the forces		

Stress Perpendicular to Weld			Stress Parallel with Weld			Shear		
<b>K1</b>			<b>K0</b>			<b>K0</b>		
<b>K2</b>			<b>K1</b>					

## No Weld (All Directions)

<b>W0</b>		In the software: $\tau_w(-1) = \sigma_w(-1) / \text{sqrt}(3)$
-----------	--	---

	$\sigma_w(-1)$ for $\kappa=-1$ , Element Group E6, Fe 360							
Notch group	<b>W0</b>	W1	W2	<b>K0</b>	<b>K1</b>	<b>K2</b>	K3	K4
Stress amplitude	147.8	125.7	103.5	127.5	113.8	95.6	68.3	41.0

Depends on Stress concentrations:

Case K<sub>0</sub> - Slight stress concentration

0,13	Gusset secured by butt-welding (S.Q.) at right angles to the direction of the forces		
------	--	--	--

Case K<sub>1</sub> - Moderate stress concentration

1,13	Gusset joined by butt welding (O.Q.) at right angles to the direction of the forces		
------	---	--	--

Case K<sub>2</sub> - Medium stress concentration

2,13	Butt weld (S.Q.) at right angles to the direction of the forces, made at intersection of flats, with welded auxiliary gussets. The ends of the welds are ground, avoiding notches		
------	---	--	--

Case K<sub>3</sub> - Severe stress concentration

3,13	Butt weld (O.Q.) at right angles to the direction of the forces at the intersection of flats with welded auxiliary gussets. The ends of the welds are ground, avoiding notches		
------	--	--	--

Case K<sub>4</sub> - Very severe stress concentration

4,11	Butt welds (O.Q.) at right angles to the direction of the forces, at the intersection of flats (no auxiliary gussets)		
------	---	--	--

(not included in this tutorial)

# Weld Type Classification. All Welds

1 Press to set Weld Type (A-3.6.1)

2 Press to Add Condition

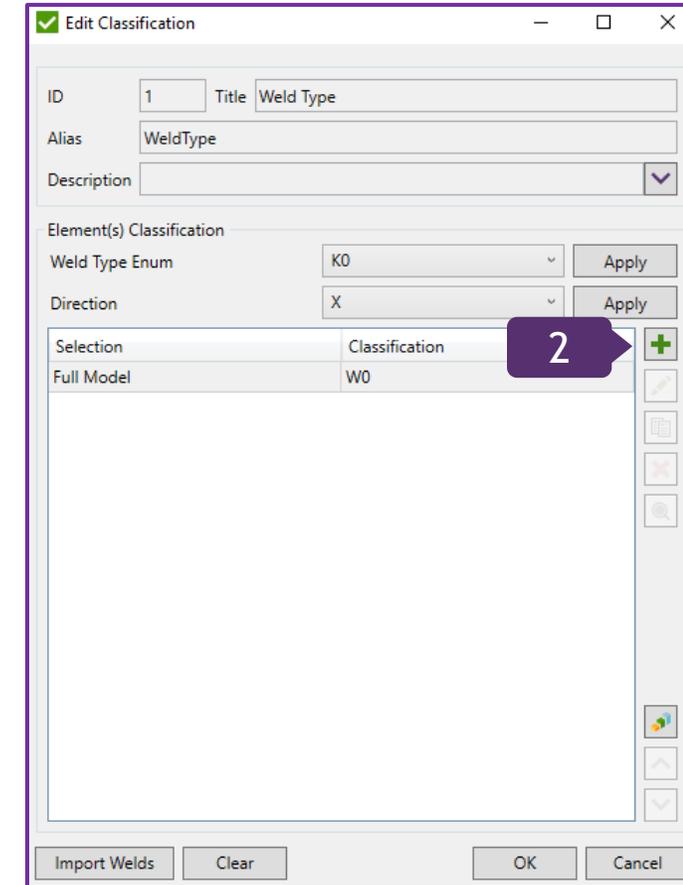
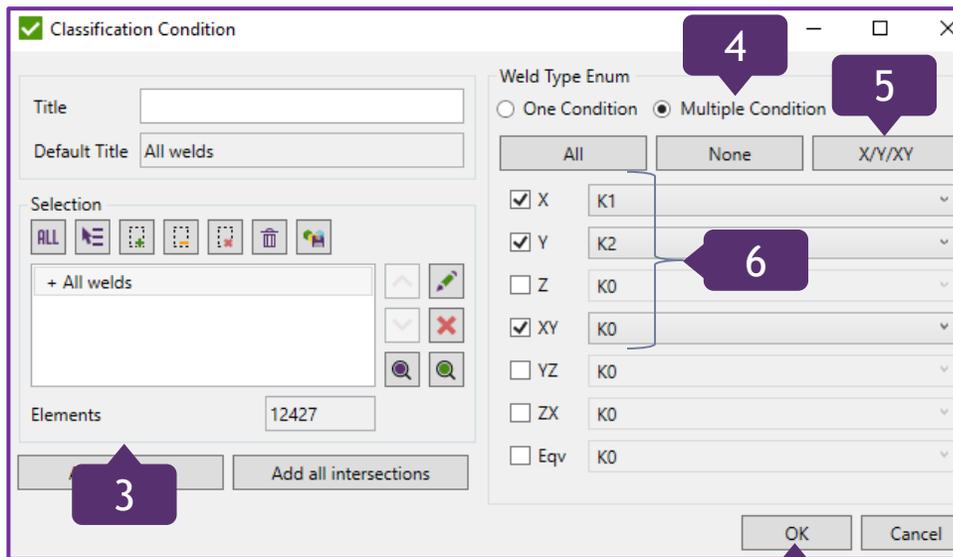
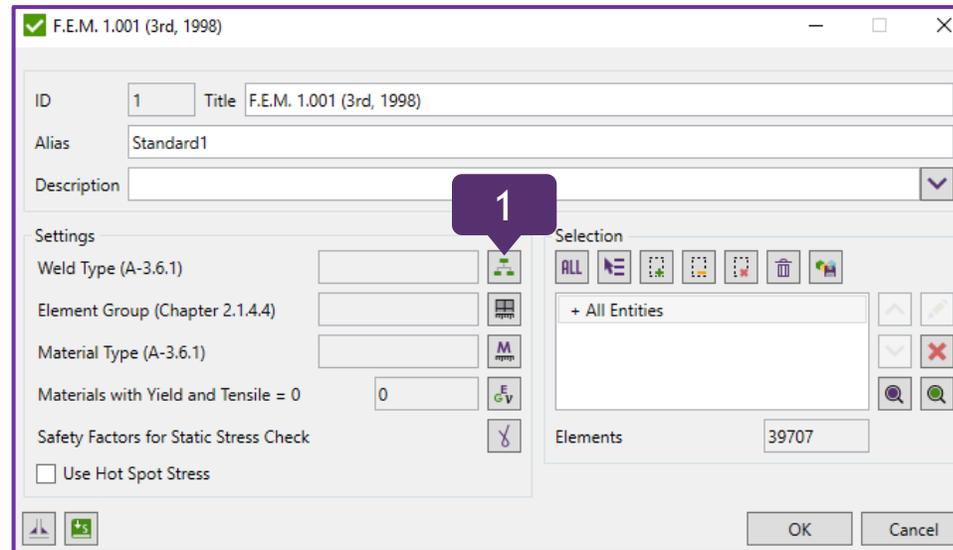
3 Press *Add all Welds*

4 Select *Multiple Conditions* options

5 Press *X/Y/XY*

6 X: K1 Y: K2 XY: K0

7 Press *OK*



# Weld Type Classification. Welds Intersections

- 1 Press to Add Condition
- 2 Click *Add all intersections*
- 3 Value: K2
- 4 Directions: X
- 5 Press *OK*

Selection	Classification
Full Model	W0
All welds	K1 (X)
All welds	K2 (Y)
All welds	K0 (XY)

Weld Type Enum:  One Condition  Multiple Condition

Value: K2

Direction:  X

At intersecting Welds all stresses are perpendicular to the weld direction. The last condition overwrites the previous ones, and settings in condition 2 => K1(X) are replaced with K2(X) for intersections.

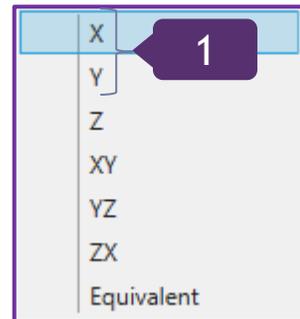
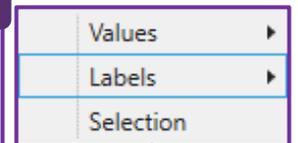
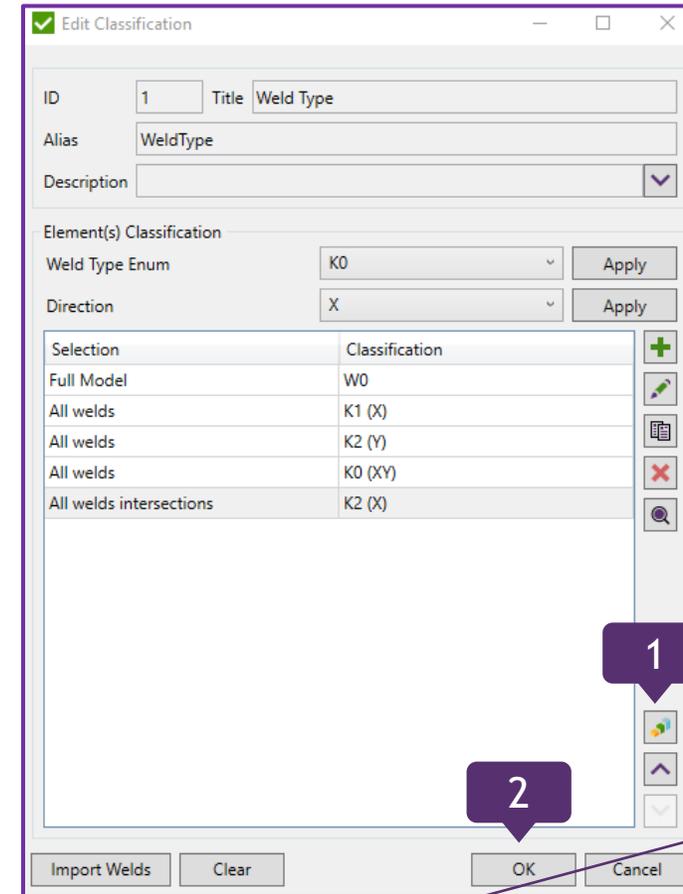
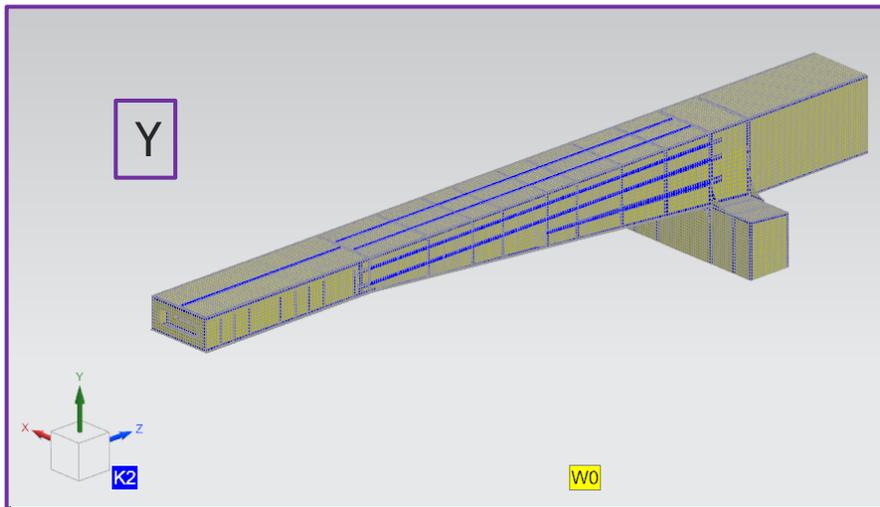
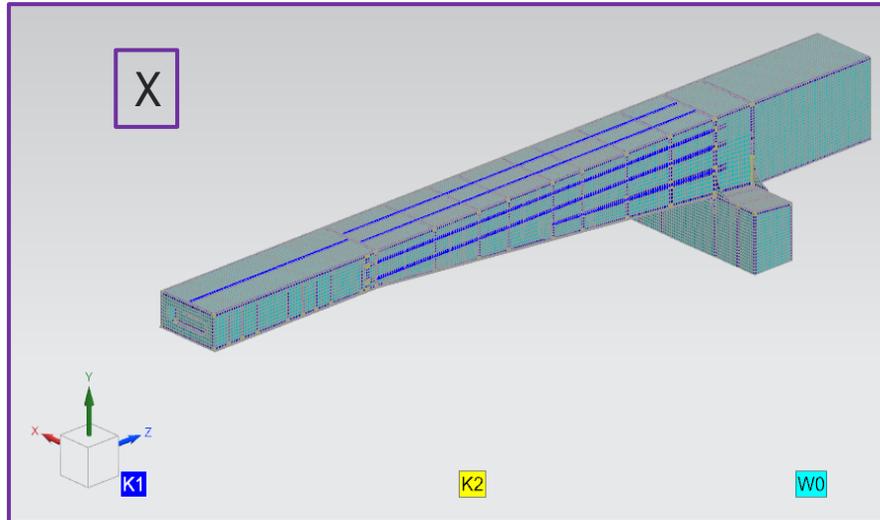
# Plot Weld Type Classification

1

Press  => Labels => Direction X, and then Y to make Plots for the full model

2

Press *OK*



Plots are displayed for the full model by default. In order to limit the displayed part, it is possible to change the Selection.

Element Group, also called Loading Group, depends on: Class of Utilization and Load Spectrum.

**Example of Load Cycles:**

Load Cycles	Number	Total
Moves per hour	30	
Hours per day	10	300
Days per year	300	90000
Number of Years	20	1800000
Total	Million:	1.8

**Class of Utilization B7 (1.8 million < 2 x 10^6)**

**Table T.2.1.4.2. - Classes of utilization**

Symbol	Total duration of use (number n of stress cycles)		
B0		n ≤	16 000
B1	16 000 <	n ≤	32 000
B2	32 000 <	n ≤	63 000
B3	63 000 <	n ≤	125 000
B4	125 000 <	n ≤	250 000
B5	250 000 <	n ≤	500 000
B6	500 000 <	n ≤	1 000 000
B7	1 000 000 <	n ≤	2 000 000
B8	2 000 000 <	n ≤	4 000 000
B9	4 000 000 <	n ≤	8 000 000
B10	8 000 000 <	n	

**Load Spectrum**

**Table T.2.1.4.3. - Spectrum classes**

Symbol	Spectrum factor $k_{sp}$	
P1	$k_{sp} \leq$	0,125
P2	0,125 < $k_{sp} \leq$	0,250
P3	0,250 < $k_{sp} \leq$	0,500
P4	0,500 < $k_{sp} \leq$	1,000

$$k_{sp} = (\sigma_1 / \sigma_{max})^c (n_1 / n) + (\sigma_2 / \sigma_{max})^c (n_2 / n) + \dots + (\sigma_r / \sigma_{max})^c (n_r / n) = \sum_{i=1}^r [ (\sigma_i / \sigma_{max})^c (n_i / n) ]$$

$$n_1 + n_2 + \dots + n_r = \sum_{i=1}^r n_i = n$$

**Element Group**

**Table T.2.1.4.4. - Component groups**

Stress Spectrum class	Class of utilization										
	B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
P1	E1	E1	E1	E1	E2	E3	E4	E5	E6	E7	E8
P2	E1	E1	E1	E2	E3	E4	E5	E6	E7	E8	E8
P3	E1	E1	E2	E3	E4	E5	E6	E7	E8	E8	E8
P4	E1	E2	E2	E4	E5	E6	E7	E8	E8	E8	E8

# Define Element Group

1

In F.E.M. 1.001 (3rd, 1998), press  to define Element Group

2

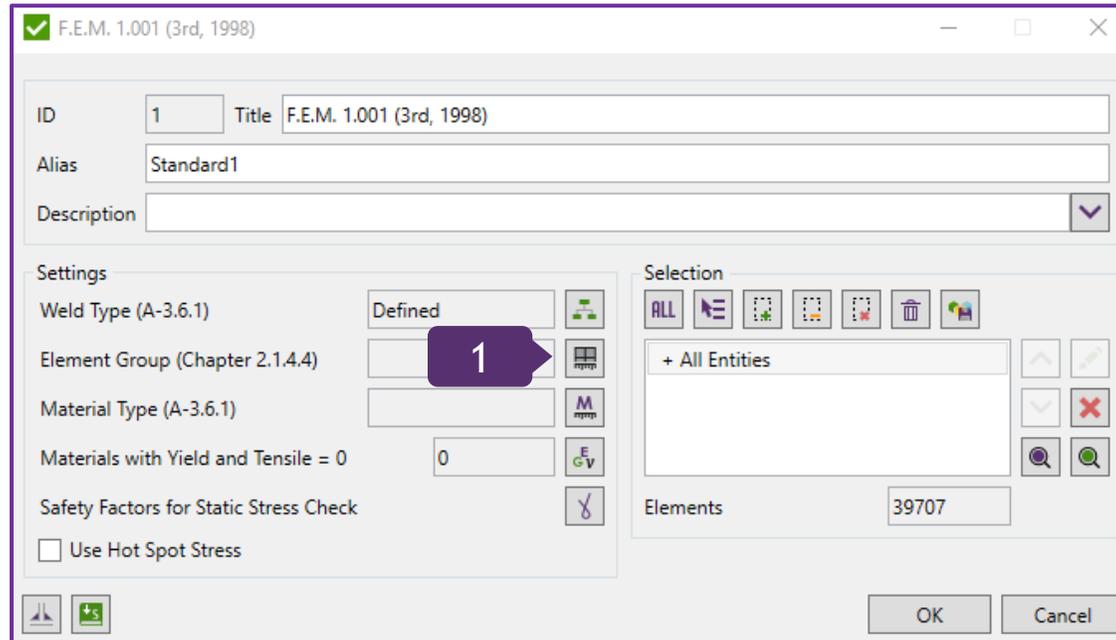
Select Element Group Enum: E6.

3

Press *To All*

4

Press *OK*



F.E.M. 1.001 (3rd, 1998)

ID: 1 Title: F.E.M. 1.001 (3rd, 1998)

Alias: Standard1

Description:

Settings

Weld Type (A-3.6.1): Defined

Element Group (Chapter 2.1.4.4):  1

Material Type (A-3.6.1): M

Materials with Yield and Tensile = 0: 0

Safety Factors for Static Stress Check: 

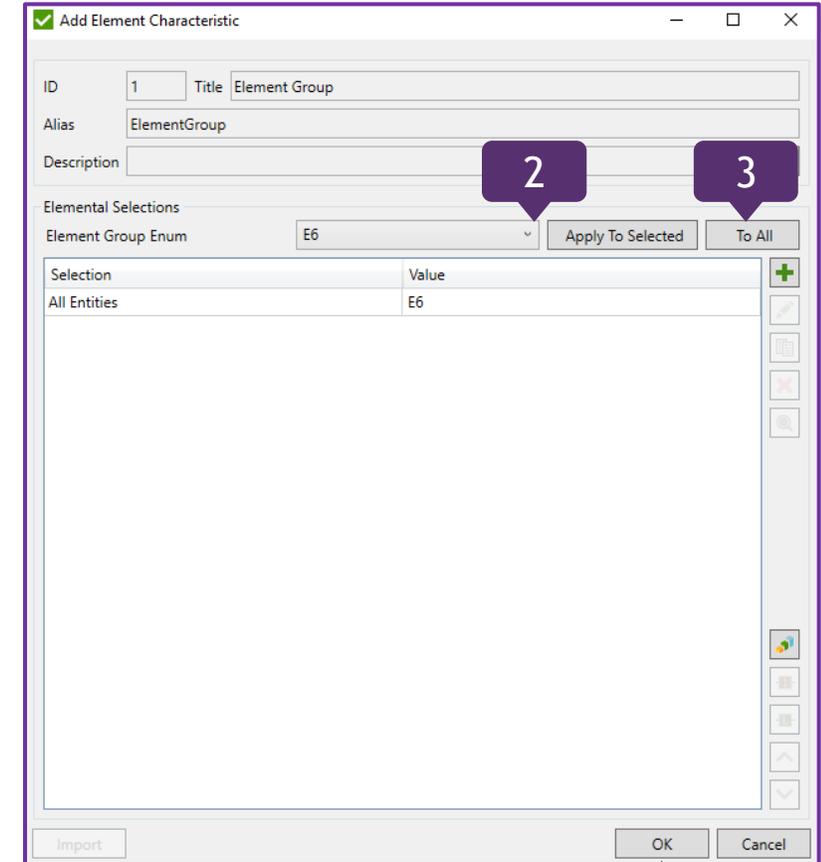
Use Hot Spot Stress

Selection

+ All Entities

Elements: 39707

OK Cancel



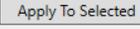
Add Element Characteristic

ID: 1 Title: Element Group

Alias: ElementGroup

Description:

Elemental Selections

Element Group Enum: E6   2 3

Selection	Value
All Entities	E6

Import OK Cancel

4

# Define Material Type

1

In F.E.M. 1.001 (3rd, 1998), press  to define Material Type

2

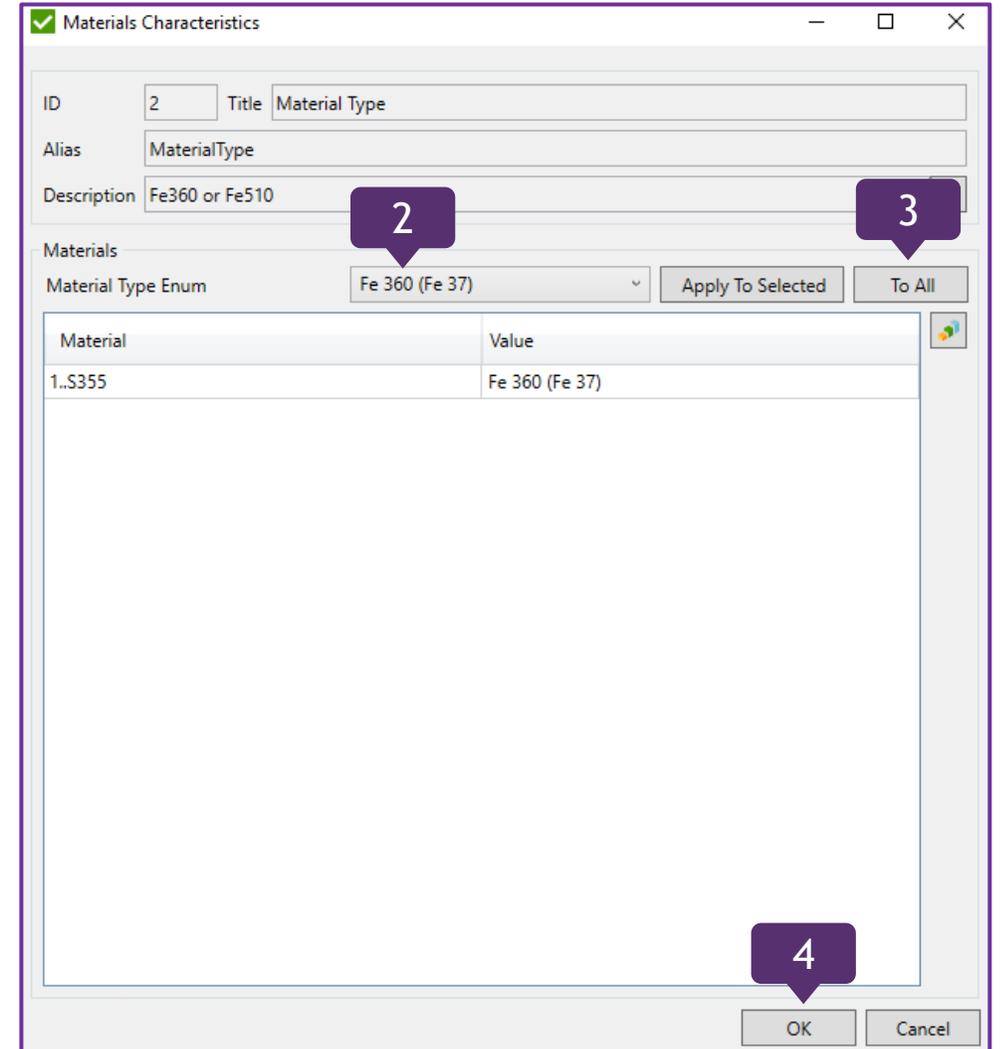
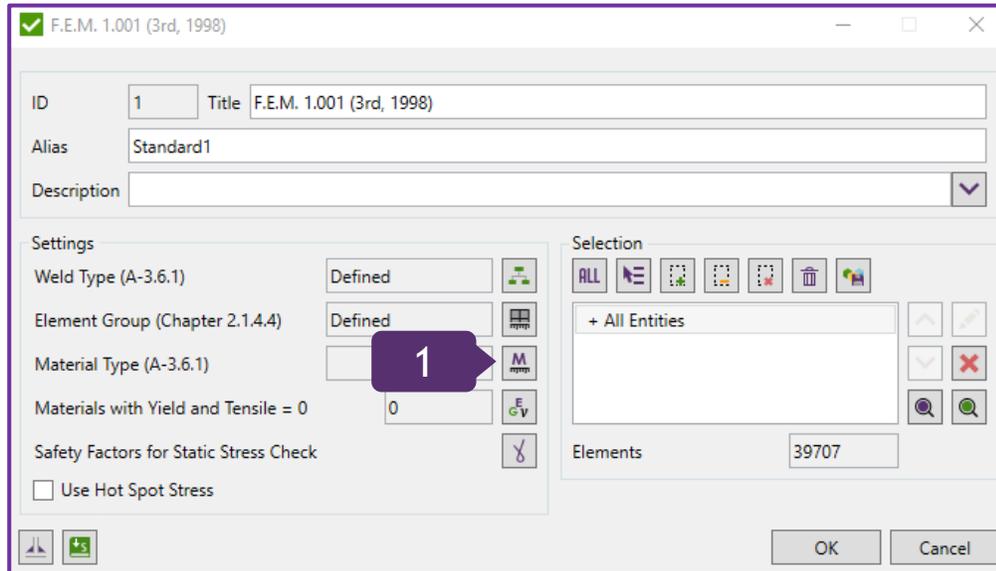
In Material Type Enum, select *Fe 360 (Fe 37)*

3

Press *To All*

4

Press *OK*



1 Selection: *All Entities*

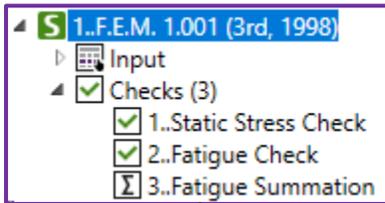
2 Press to edit material properties

The amount of materials with undefined Tensile or Yield is displayed in the field

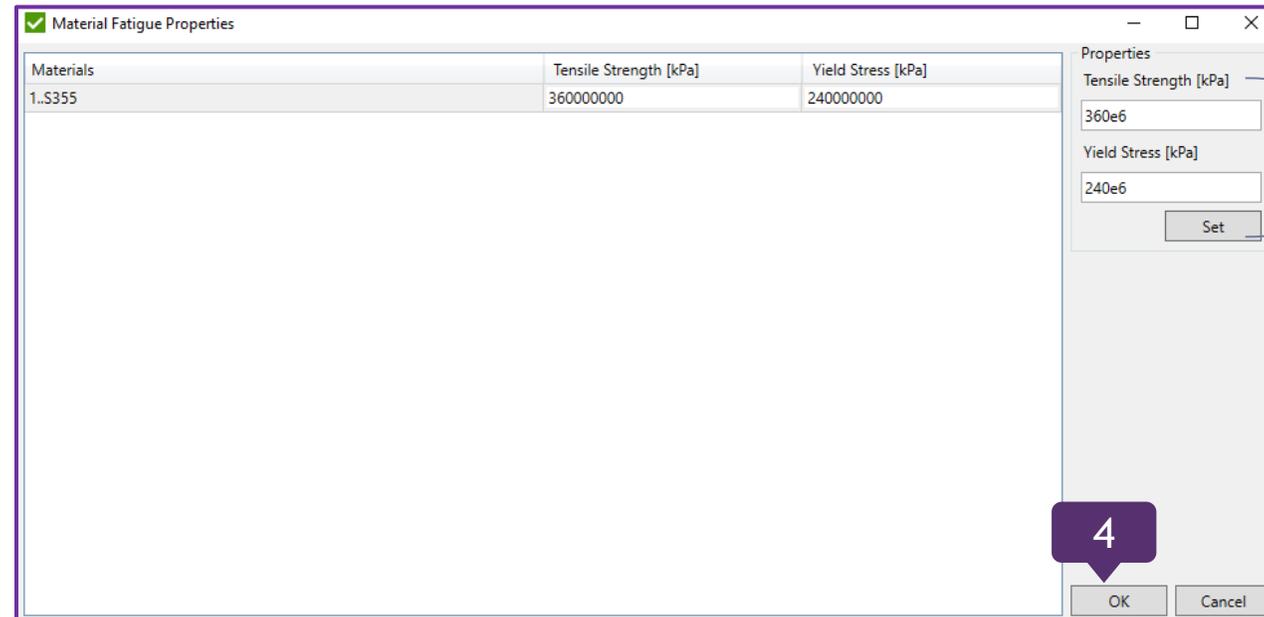
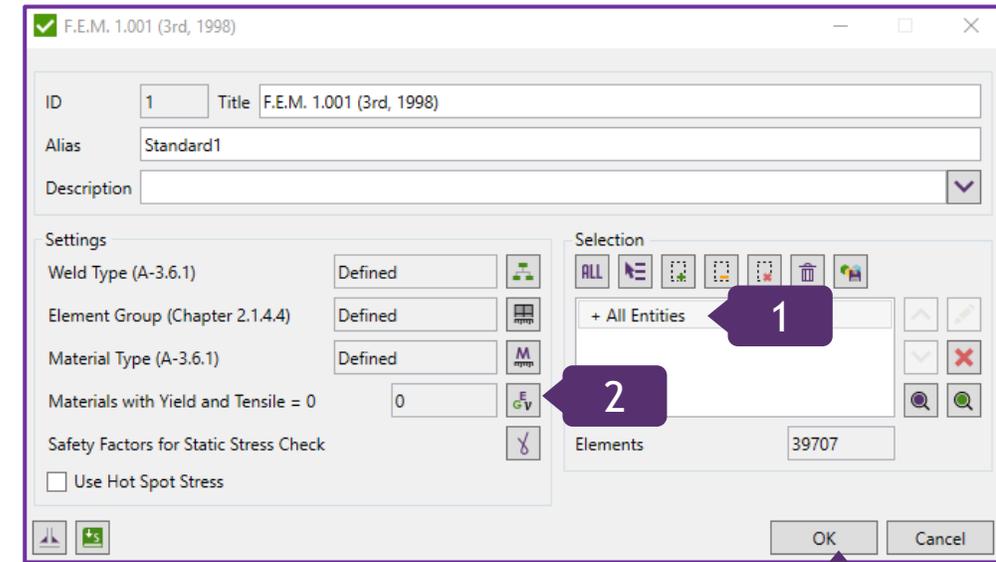
3 Tensile Strength: 360e6  
Yield Stress: 240e6 and Press *Set*

4 Press *OK*

5 Press *OK*



The Standard has ben created.



## Kappa Factor

$$\begin{aligned} K_x &= \sigma_{x \min} / \sigma_{x \max} \\ K_y &= \sigma_{y \min} / \sigma_{y \max} \\ K_{xy} &= \tau_{xy \min} / \tau_{xy \max} \end{aligned}$$

## Allowable Stress

- a)  $\kappa \leq 0$
- for tension :  $\sigma_t = 5 \cdot \sigma_w / (3 - 2 \cdot \kappa)$  (1)
  - for compression :  $\sigma_c = 2 \cdot \sigma_w / (1 - \kappa)$  (2)
- $\sigma_w$  is given in table above.
- b)  $\kappa > 0$
- for tension  $\sigma_t = \sigma_0 / [1 - \kappa \cdot (1 - \sigma_0 / \sigma_w)]$  (3)
  - for compression  $\sigma_c = 1,2 \cdot \sigma_t$  (4)

## Utilization Factor Combined

$$\begin{aligned} &(\sigma_{x \max} / \sigma_{xa})^2 + (\sigma_{y \max} / \sigma_{ya})^2 - \\ &\sigma_{x \max} \cdot \sigma_{y \max} / (|\sigma_{xa}| \cdot |\sigma_{ya}|) + \\ &(\tau_{xy \max} / \tau_{xya})^2 \leq 1 \end{aligned}$$

where the stress values  $\sigma_{xa}$ ,  $\sigma_{ya}$  and  $\tau_{xya}$  are those resulting from the application of formulae (1), (2), (3) and (4) limited to  $0,75 \cdot \sigma_R$ .

## Implementation of Formulas in SDC Verifier.

The screenshot shows the configuration for a custom check named "Fatigue Check". The ID is "2" and the alias is "Fatigue\_Check". The description is empty. The "Show Parameter Description" checkbox is checked. The "Options" section includes "Calculate Results over Directions" and "Calculate Results over Points" (both checked), "Load Calculation" set to "Load Group Only", and "Selection" set to "All Entities".

The parameters and replacements are defined as follows:

- Replacement = Use Hot Spot Stress (Use Hot Spot Stress)**  
All: `if(UseHotSpotStress = yes and Element.IsHotSpotCalculated = yes, yes, no)`
- Replacement = Stress AbsMax (Absolute Maximum Stress)**  
Description: Absolute maximum Weld or Hot Spot stress  
All: `if(Use_Hot_Spot_Stress = yes, S_HotSpotAbs, SWeldAbs)`
- Parameter = Kappa (Kappa Factor)**  
Description: Ratio between the extreme stresses. Chapter 3.6.4.  
All: `if(Stress_AbsMax = 0, 0, if(Use_Hot_Spot_Stress = yes, if(Stress_AbsMax > 0, S_HotSpotMin / S_HotSpotMax, S_HotSpotMax / S_HotSpotMin), if(Stress_AbsMax > 0, SWeldMin / SWeldMax, SWeldMax / SWeldMin)))`
- Parameter = Sf (Stress Fatigue)**  
Description: Permissible stress for fatigue depends on the element group (E1-E8) and weld type  
All: `Min(units.FromPaToCurrent(Switch(MaterialType, MaterialTypeEnum.Fe360Fe37, Sf_Fe360(ElementGroup, WeldType), MaterialTypeEnum.Fe510Fe52, Sf_Fe510(ElementGroup, WeldType))), 0.75 * Tensile)`
- Parameter = Sallow fatigue (Allowable Stress Fatigue)**  
Description: Appendix 3.6, formulas (1)-(4)  
All: `if(Kappa > 0, if(Stress_AbsMax > 0, 1, 1.2) * (5 / 3 * Sf) / (1 - (1 - (5 / 3 * Sf) / (0.75 * tensile)) * Kappa), if(Stress_AbsMax > 0, (5 * Sf) / (3 - 2 * Kappa), (2 * Sf) / (1 - Kappa)))`  
XY/YZ/ZX: `if(Kappa > 0, (5 / 3 * Sf) / (1 - (1 - (5 / 3 * Sf) / (0.75 * tensile)) * Kappa), (5 * Sf) / (3 - 2 * Kappa)) / if(WeldType <= WeldTypeEnum.K4, SQRT(2), SQRT(3))`  
Eqv: 0
- Parameter = Uf (Utilization Factor)**  
Description: Appendix 3.6, equivalent rule - (5)  
All: `Abs(Stress_AbsMax) / Sallow_Fatigue`  
Eqv: `pow(me.x, 2) + pow(me.y, 2) + pow(me.xy, 2) + pow(me.yz, 2) + pow(me.zx, 2) - sign(Stress_AbsMax.X) * me.x * sign(Stress_AbsMax.Y) * me.y - sign(Stress_AbsMax.Y) * me.y * sign(Stress_AbsMax.Z) * me.z - sign(Stress_AbsMax.Z) * me.z * sign(Stress_AbsMax.X) * me.x`  
Overall: `Max(me.x, me.y, me.z, me.xy, me.yz, me.zx, sqrt(me.eqv))`

1

Execute **Table (expand/extreme)** in Standards => Fatigue Check context menu

2

Load Group: **1..L1-L4**

Fatigue check supports only Load Groups. If only one load group exist in the project it will be selected automatically.

3

Direction/Parameter: **Stress Fatigue**

4

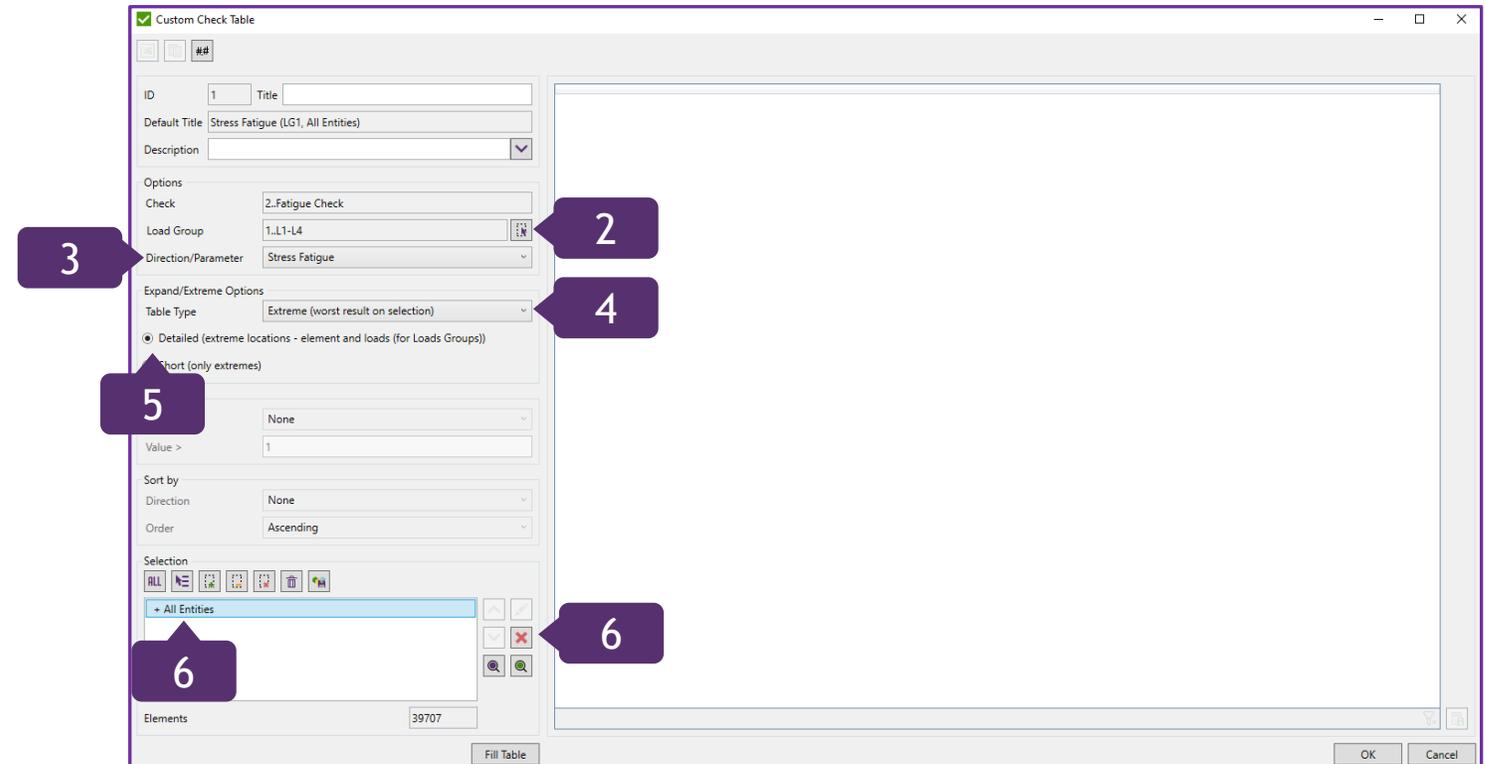
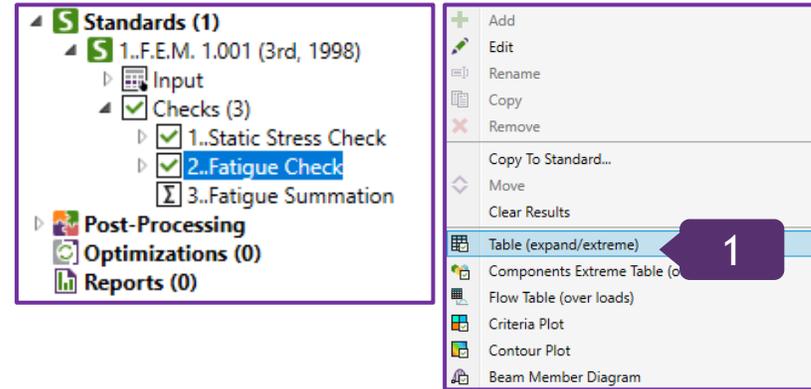
Table Type: **Extreme (worst result on selection)**

5

**Detailed (extreme locations-element and load (for Load Groups)) - ON**

6

Select **+All Entities** and press to remove them

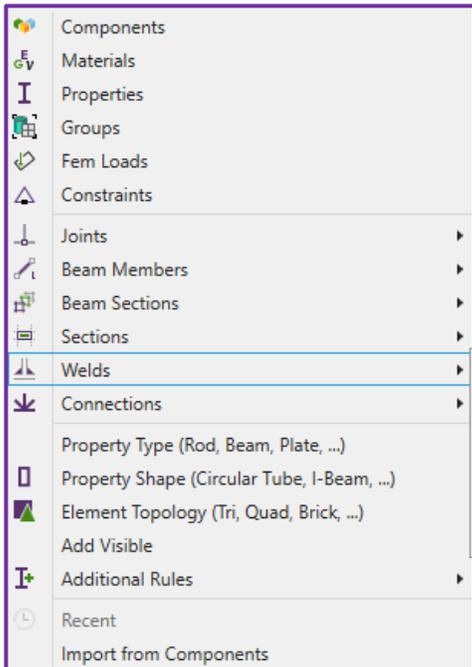


# Create Extreme Table (Continuation)

7 In Custom Check Table in *Selection* => press

8 Select *Welds* => *By Rule* and press *OK*

9 In *Selection*, press *Fill Table*; Press *OK*



Extreme	X [Pa]	Y [Pa]	Z [Pa]	XY [Pa]	YZ [Pa]	ZX [Pa]	Eqv [Pa]	Overall [Pa]
<b>Minimum</b>								
Value	95.60e+3	95.60e+3		127.50e+3			147.80e+3	0.00e+3
Element ID	499	326		326			1	1
<b>Maximum</b>								
Value	113.80e+3	95.60e+3		127.50e+3			147.80e+3	0.00e+3
Element ID	1	326		326			1	1
<b>Absolute</b>								
Value	113.80e+3	95.60e+3		127.50e+3			147.80e+3	0.00e+3
Element ID	1	326		326			1	1

Operation: Add  
Rule Type: All Welds

Welds:  
 All Welds  
 Weld Tips  
 Weld Exceptions  
 Plate Free Edges

Weld Parts:  
 Weld Ends: All  
 Weld Parts: Welded  
 Weld Intersections: All Connected Entities

Stress Fatigue is used in fatigue Allowable Stress calculations.

Stress Fatigue depends on:

- Weld Type (W0-W2, K0-K4);
- Element Group / Loading Group (B1-B6);
- Material Type ( St360/St37, St510/St52).

$$\kappa \leq 0$$

- for tension :  $\sigma_t = 5 \cdot \sigma_w / (3 - 2 \cdot \kappa) \quad (1)$

- for compression :  $\sigma_c = 2 \cdot \sigma_w / (1 - \kappa) \quad (2)$

**Table T.A.3.6.1.**  
Values of  $\sigma_w$  depending on the component group and construction case (N/mm<sup>2</sup>)

Component group	Unwelded components Construction cases						Welded components Construction cases (Steels St 37 to St 52, Fe 360 to Fe 510)				
	W <sub>0</sub>		W <sub>1</sub>		W <sub>2</sub>		K <sub>0</sub>	K <sub>1</sub>	K <sub>2</sub>	K <sub>3</sub>	K <sub>4</sub>
	Fe 360 St 37 St 44	St 52 Fe 510	Fe 360 St 37 St 44	St 52 Fe 510	Fe 360 St 37 St 44	St 52 Fe 510					
E1	249,1	298,0	211,7	253,3	174,4	208,6	(361,9)	(323,1)	(271,4)	193,9	116,3
E2	224,4	261,7	190,7	222,4	157,1	183,2	(293,8)	262,3	220,3	157,4	94,4
E3	202,2	229,8	171,8	195,3	141,5	160,8	238,4	212,9	178,8	127,7	76,6
E4	182,1	201,8	154,8	171,5	127,5	141,2	193,5	172,8	145,1	103,7	62,2
E5	164,1	177,2	139,5	150,6	114,9	124,0	157,1	140,3	117,8	84,2	50,5
E6	147,8	155,6	125,7	132,3	103,5	108,9	127,5	113,8	95,6	68,3	41,0
E7	133,2	136,6	113,2	116,2	93,2	95,7	103,5	92,4	77,6	55,4	33,3
E8	120,0	120,0	102,0	102,0	84,0	84,0	84,0	75,0	63,0	45,0	27,0

The screenshot shows the 'Custom Check Table' dialog in SDC Verifier. The 'Table Info' section indicates: 'All Welds, LG1.L1-L4, Parameter: Stress Fatigue, Detailed, Extreme'. The table displays results for 'Minimum' and 'Maximum' stress fatigue values across different directions (X, Y, Z, XY, YZ, ZX) and overall equivalent stress (Eqv) and overall stress (Overall).

Extreme	X [Pa]	Y [Pa]	Z [Pa]	XY [Pa]	YZ [Pa]	ZX [Pa]	Eqv [Pa]	Overall [Pa]
<b>Minimum</b>								
Value	95.60e+3	95.60e+3		127.50e+3			147.80e+3	0.00e+3
Element ID	499	326		326			1	1
<b>Maximum</b>								
Value	113.80e+3	95.60e+3		127.50e+3			147.80e+3	0.00e+3
Element ID	1	326		326			1	1
<b>Absolute</b>								
Value	113.80e+3	95.60e+3		127.50e+3			147.80e+3	0.00e+3
Element ID	1	326		326			1	1

A callout box points to the 'Maximum' row, stating: **Corresponding values of Stress fatigue in SDC Verifier:**

1

Execute **Criteria Plot** in Fatigue Check context menu

2

Parameter: *Utilization Factor*

3

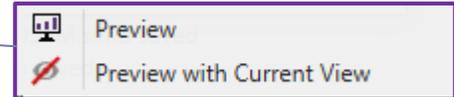
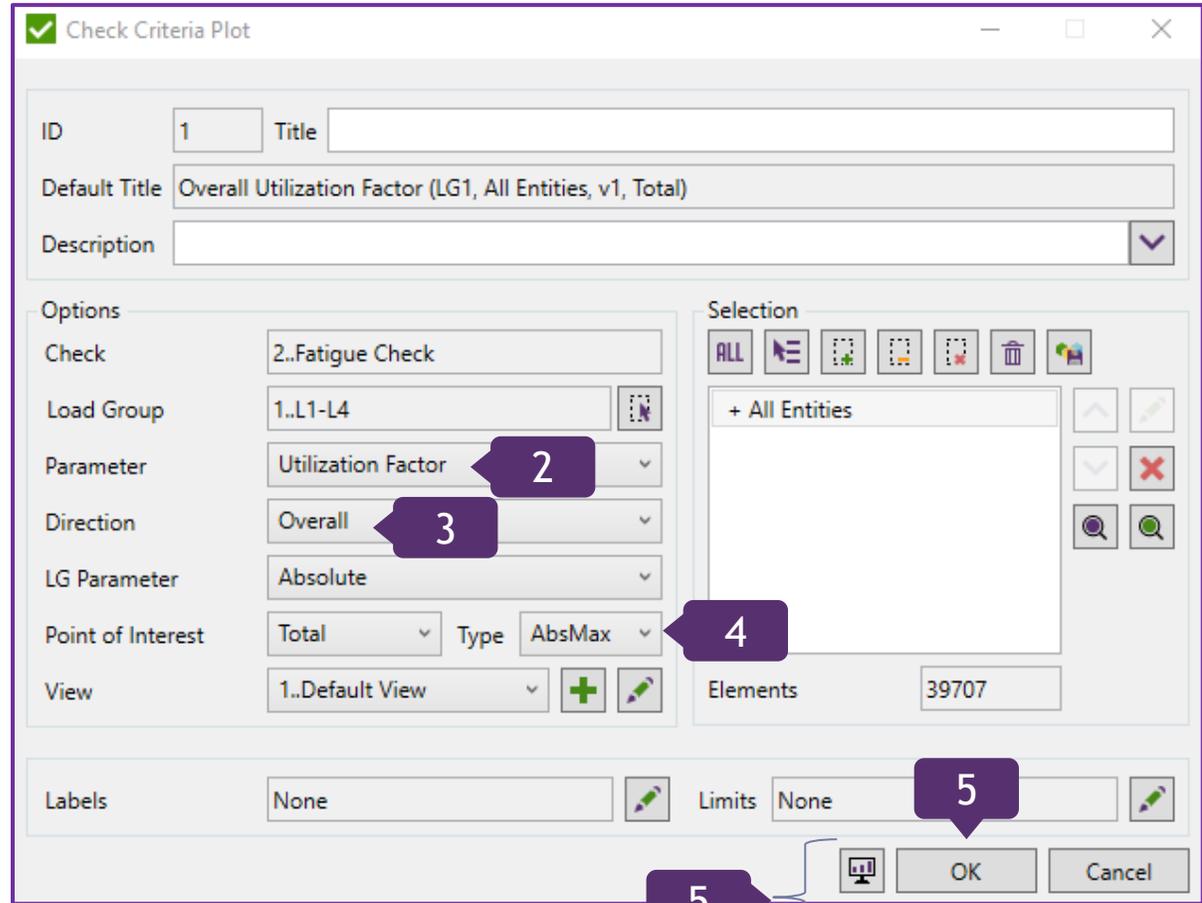
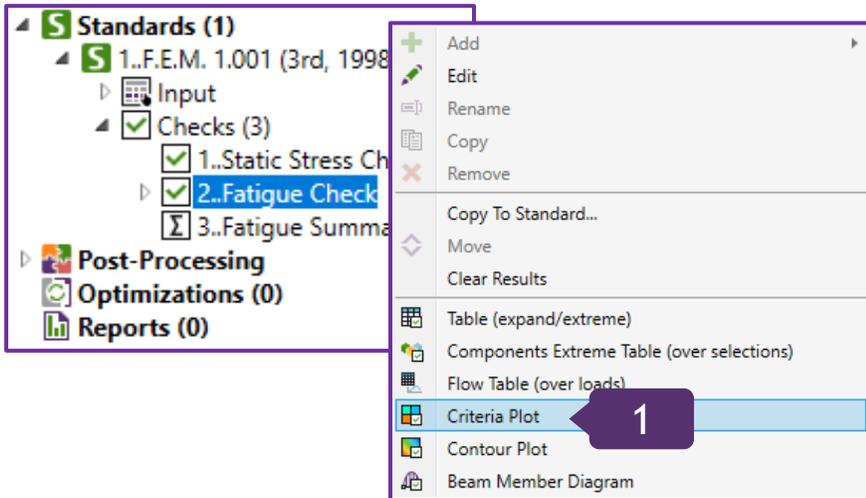
Direction: *Overall*

4

Point of interest: Total; Type: *AbsMax*

5

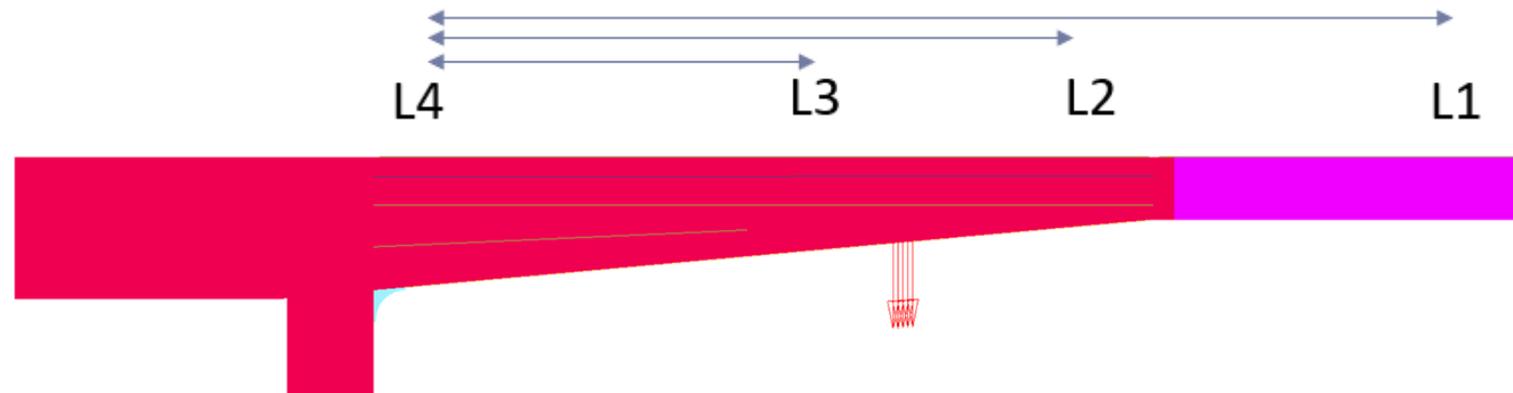
Press and then *Preview*;  
Press *OK*



Point of interest = AbsMax Total is an absolute maximum of Utilization Factors among all point of interest.

- ▶ A better fatigue damage can be made if load cycles are specified more accurately.
- ▶ Instead of 2 million load cycles from start to end:

Load cycle	Number of cycles	Content
L4-L1	0,5 e6	LS4, LS3, LS2, LS1, IL1
L4-L2	1,0 e6	LS4, LS3, LS2, IL1
L4-L3	0,5 e6	LS4, LS3, IL1



NB. Gravity load is also included, because the stress variation determines the fatigue damage.

# Add Fatigue Group (Stress History)

1

In the *Model tree* in Jobs, select **Fatigue Groups** **FG**

2

Title: *Detailed load cycles pattern*

3

Select Load Groups 1-3 and press **>**

The screenshot displays the SDC Verifier interface. The 'Model tree' on the left shows the 'Jobs (1)' folder expanded to '1..Job 1', with 'Individual Loads (5)' containing '1..Gravity', '2..L1', '3..L2', '4..L3', and '5..L4'. The 'Fatigue Groups (0)' folder is selected. The 'Add Fatigue Group' dialog box is open, showing 'ID' set to 4 and 'Title' set to 'Detailed load cycles pattern'. A list of selected load groups includes '1..L1-L4', '2..L3-L4', and '3..L2-L4'. The 'Fatigue Item Cycles' section shows a table with 'Title (0)' and 'Cycles' columns. The 'Total Amount of Cycles' is 0.

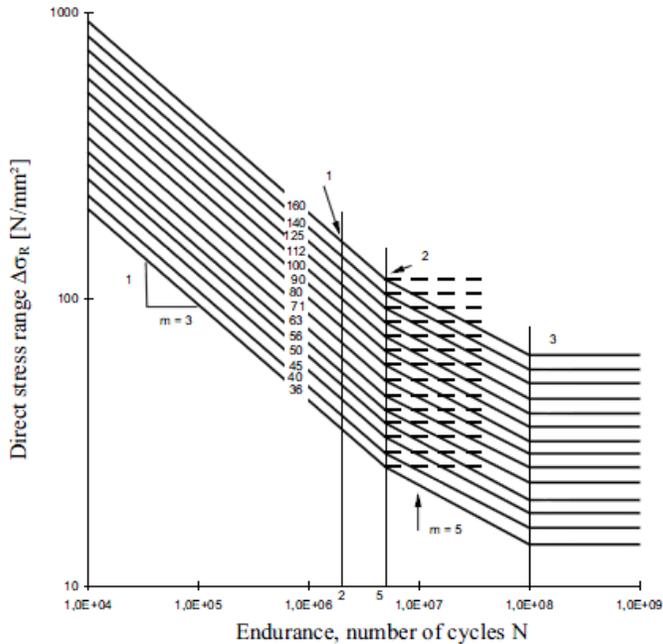
# Add Fatigue Group (Stress History) (Continuation)

4 Select 1..L1-L4 and 3..L3-L4

5 Fatigue Item Cycles: 0.5e+6 and press *Set to Selected*

6 Select 2..L2-L4 and double-click on Cycles cell; Set value 1e+6 and press Enter button

7 Press *Create*



Add Fatigue Group

ID: 4 Title: Detailed load cycles pattern

Description: [ ]

Fatigue Item Cycles: 0.5e+6 Set to Selected

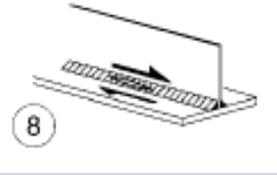
Title (3)	Cycles
1..L1-L4	500 000
2..L3-L4	500 000
3..L2-L4	1 000 000

Count: 0 Total Amount of Cycles: 2 000 000 Create

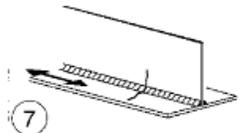
Fatigue Item Cycles: 0.5e+6 Set to Selected

Title (3)	Cycles
1..L1-L4	500 000
2..L3-L4	500 000
3..L2-L4	1e+6

Total Amount of Cycles is calculated automatically.

	Perpendicular to weld	Parallel with weld	Shear
Weld	80 	100 	80 
No weld	160 		100 

**Table 8.1: Plain members and mechanically fastened joints**

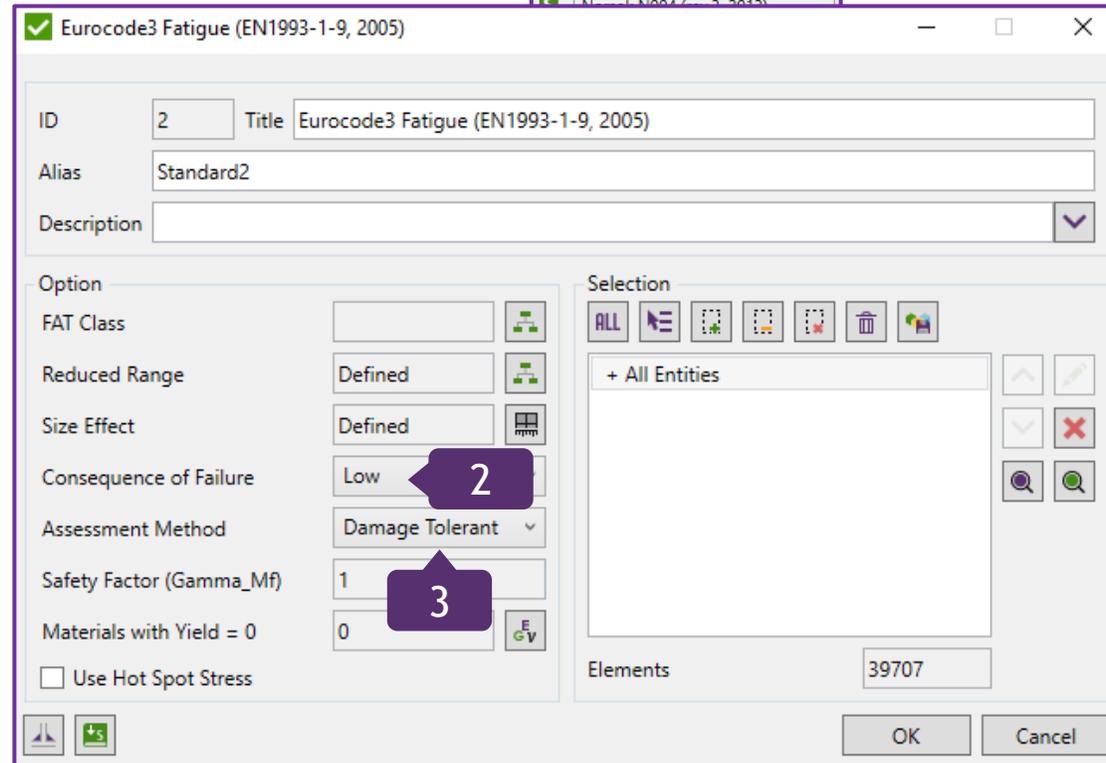
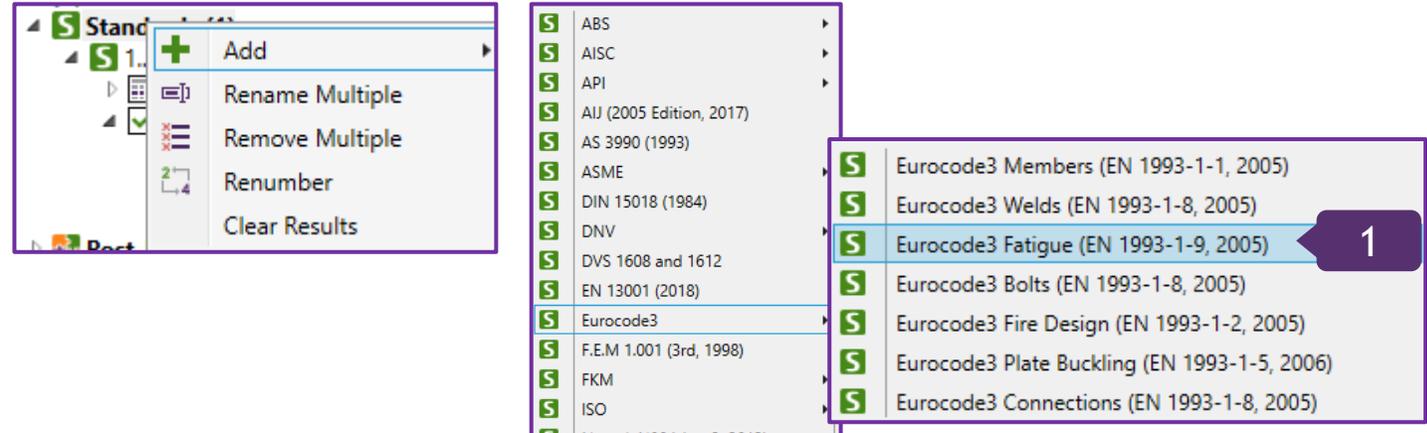
Detail category	Constructional detail	Description	Requirements
160	<p><b>NOTE</b> The fatigue strength curve associated with category 160 is the highest. No detail can reach a better fatigue strength at any number of cycles.</p> 	<p><u>Rolled and extruded products:</u></p> <p>1) Plates and flats; 2) Rolled sections; 3) Seamless hollow sections, either rectangular or circular.</p>	<p><u>Details 1) to 3):</u></p> <p>Sharp edges, surface and rolling flaws to be improved by grinding until removed and smooth transition achieved.</p>
100		<p>7) Repaired automatic or manual fillet or butt welds for categories 1) to 6).</p>	<p>7) Improvement by grinding performed by specialist to remove all visible signs and adequate verification can restore the original category.</p>

For determination of FAT classes check standard!  
In this tutorial only examples are given.

1 In Standards, execute *Add* => *Eurocode3*  
=> *Eurocode3 Fatigue (EN 1993-1-9, 2005)*

2 Consequence of Failure: *Low*

3 Assessment Method: *Damage Tolerant*



Safety Factor	Low consequence	High consequence
Damage tolerant	1.0	1.15
Safe life	1.15	1.35

1 Press to define FAT Class

2 Full Model: 160;  
Press *Apply*

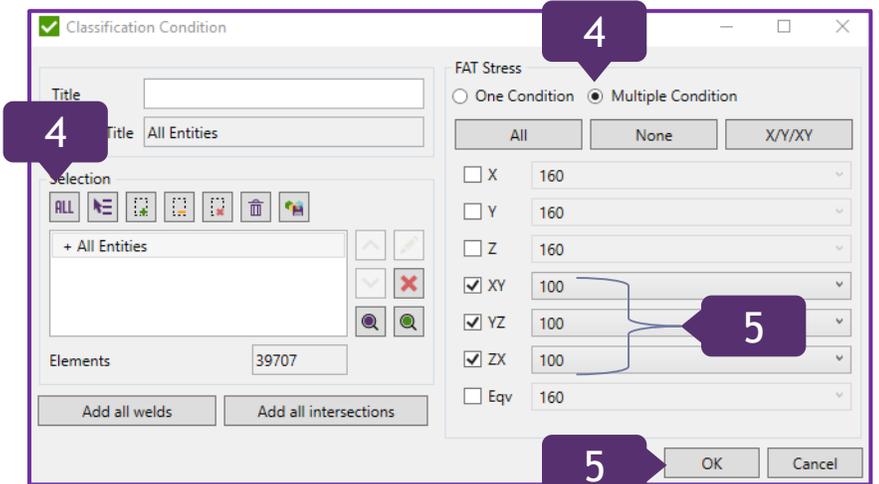
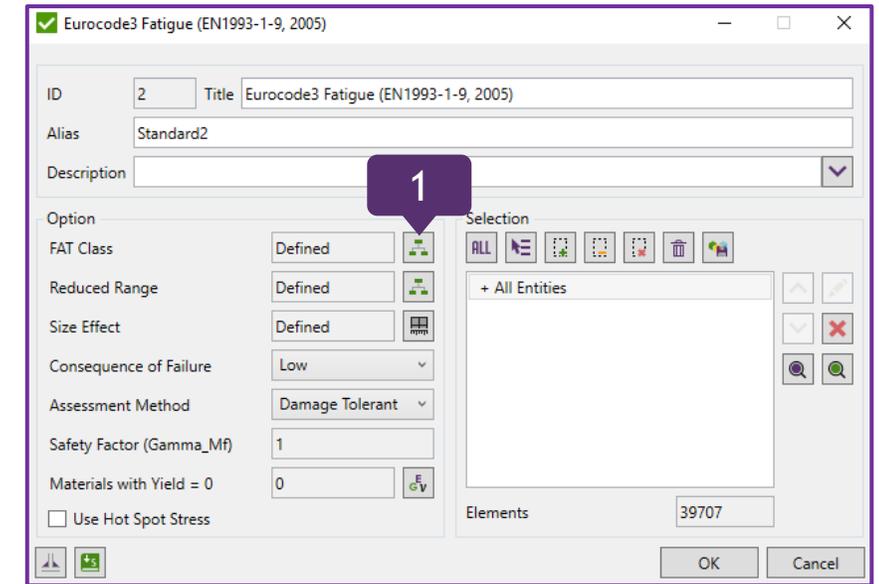
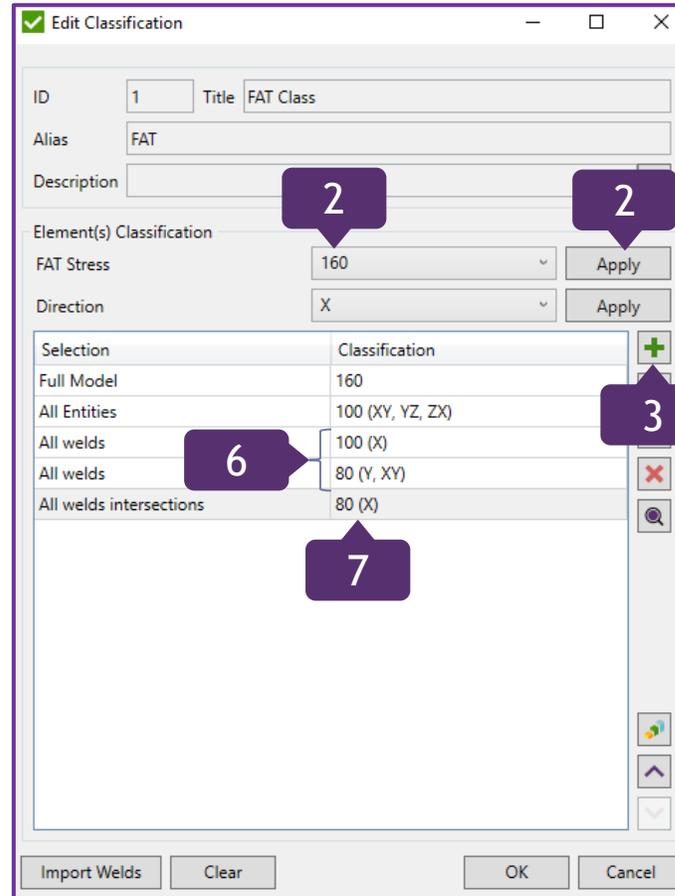
3 Press to add condition

4 Press to add *All Entities*;  
Activate *Multiple Condition*

5 *XY/YZ/ZX: 100 (No weld)*;  
Press *OK*

6 For all welds: *X: 100; Y/XY: 80*

7 For welds intersections: *X: 80*



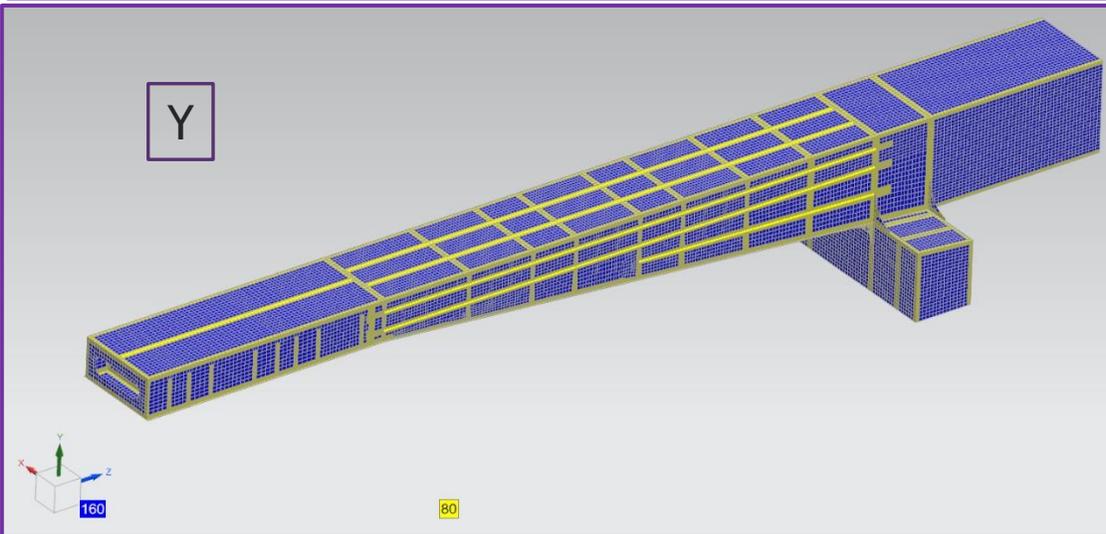
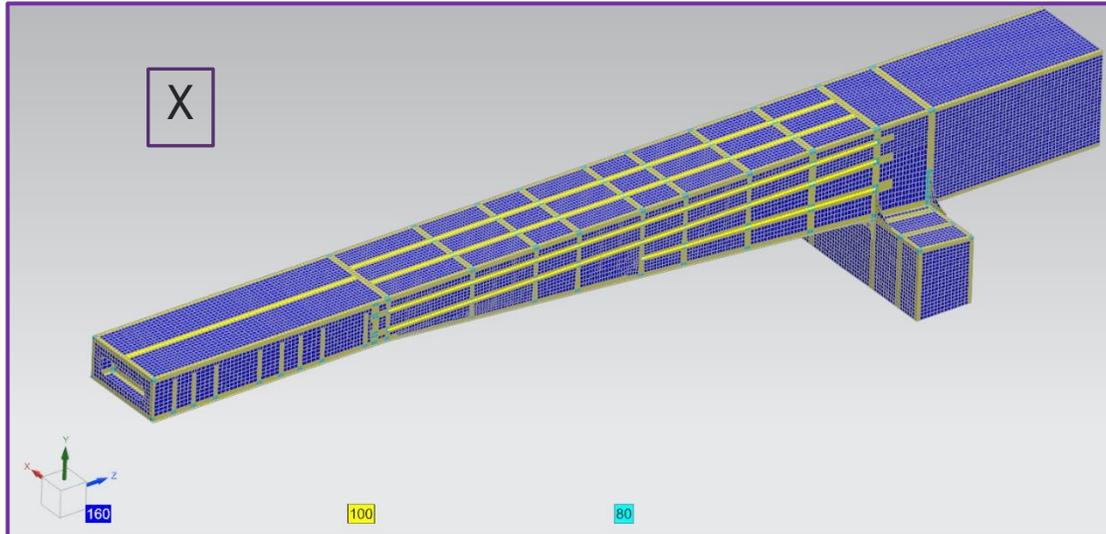
The detailed description of steps can be found on slides 15 and 16.

1

Press => Labels => Direction X, and then Y to make Plots

2

Press *OK*



**Edit Classification**

ID: 1 Title: FAT Class

Alias: FAT

Description: [dropdown]

Element(s) Classification

FAT Stress: 160 [Apply]

Direction: X [Apply]

Selection	Classification
Full Model	160
All Entities	100 (XY, YZ, ZX)
All welds	100 (X)
All welds	80 (Y, XY)
All welds intersections	80 (X)

Import Welds Clear OK Cancel

Values [dropdown]

Labels [dropdown]

Selection

X [1]

Y

Z

XY

YZ

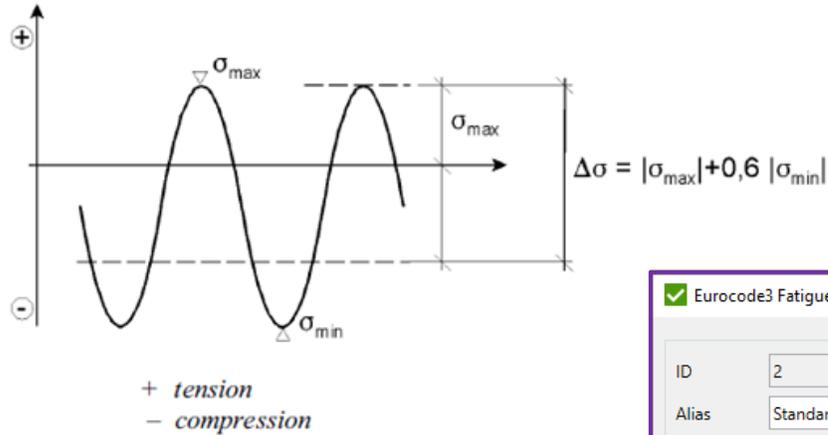
ZX

Equivalent

2

In non-welded details or stress-relieved welded details the effective stress range may be calculated by adding the tensile portion of the stress range and 60% of the magnitude of the compressive portion of the stress range:

EN 1993-1-9 : 2005 (E)



By default, delta stress is set to Not Reduced. Press to specify the selection which should use reduced stress range:

**Eurocode3 Fatigue (EN1993-1-9, 2005)**

ID: 2 Title: Eurocode3 Fatigue (EN1993-1-9, 2005)

Alias: Standard2

Option:

- FAT Class: Defined
- Reduced Range: **Defined**
- Size Effect: Defined
- Consequence of Failure: Low
- Assessment Method: Damage Tolerant
- Safety Factor (Gamma\_Mf): 1
- Materials with Yield = 0: 0

Selection: + All Entities

Elements: 39707

**Edit Classification**

ID: 2 Title: Reduced Range

Alias: ReducedRange

Description: In non-welded details or stress-relieved welded details the effective

Element(s) Classification:

Reduced Type: Not Reduced

Direction: X

Selection	Classification
Full Model	Not Reduced

For some details from tables 8.1 to 8.10, depending on the wall thickness, a *Size Effect* ( $k_s$ ) should be applied. By default size effect is not applied. Press to specify the selection which should use size effect:

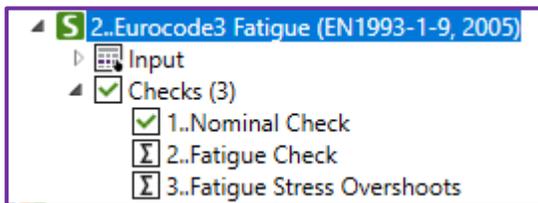
## 7.2.2 Size effect

(1) The size effect due to thickness or other dimensional effects should be taken into account as given in Table 8.1 to Table 8.10. The fatigue strength then is given by:

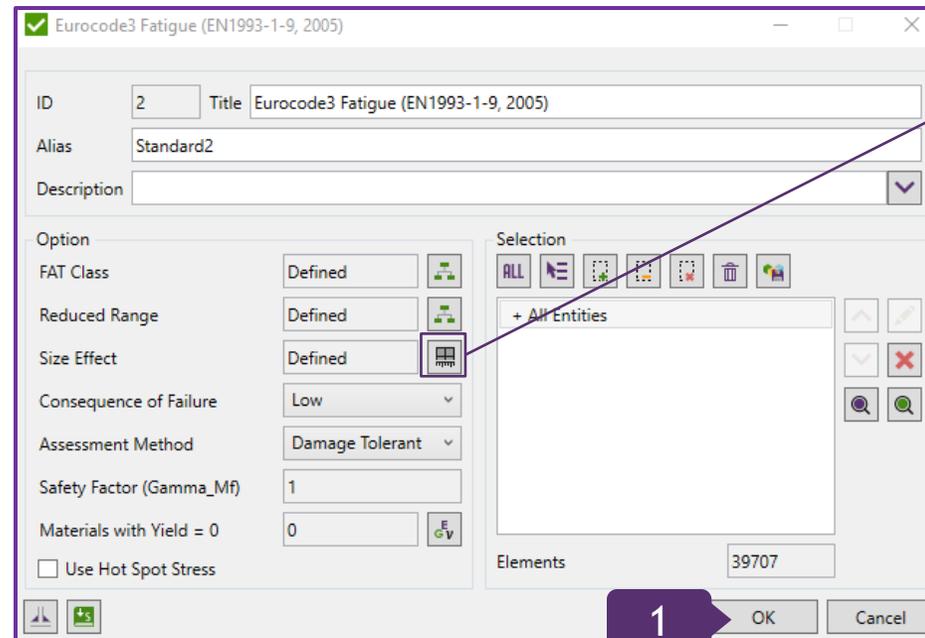
$$\Delta\sigma_{C,red} = k_s \Delta\sigma_C \quad (7.1)$$

1

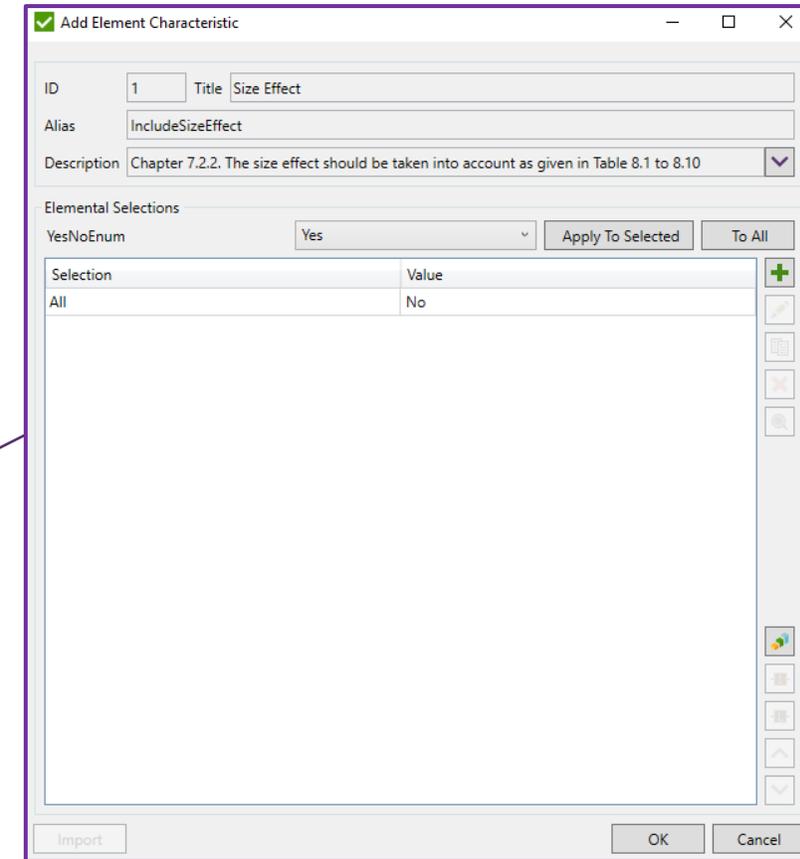
Press OK



The Standard has been created.



1



1

Execute **Criteria Plot** in 2..Fatigue Check context menu

2

Parameter: *Summed Damage*

3

Direction: *Overall*

4

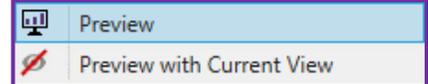
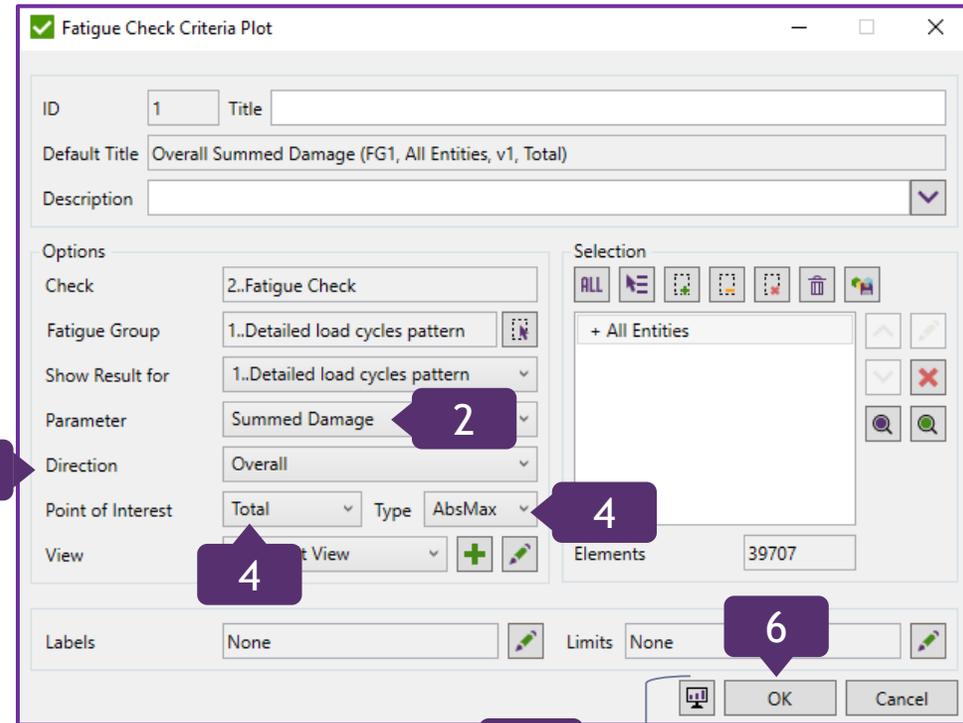
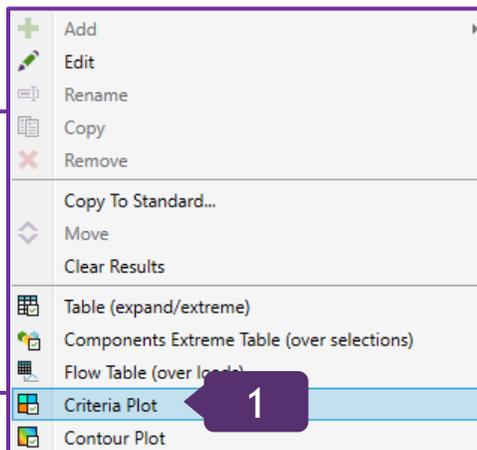
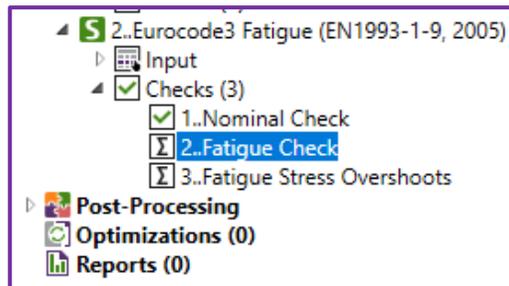
Point of interest: *Total*;  
Type: *AbsMax*

5

Press and then *Preview*

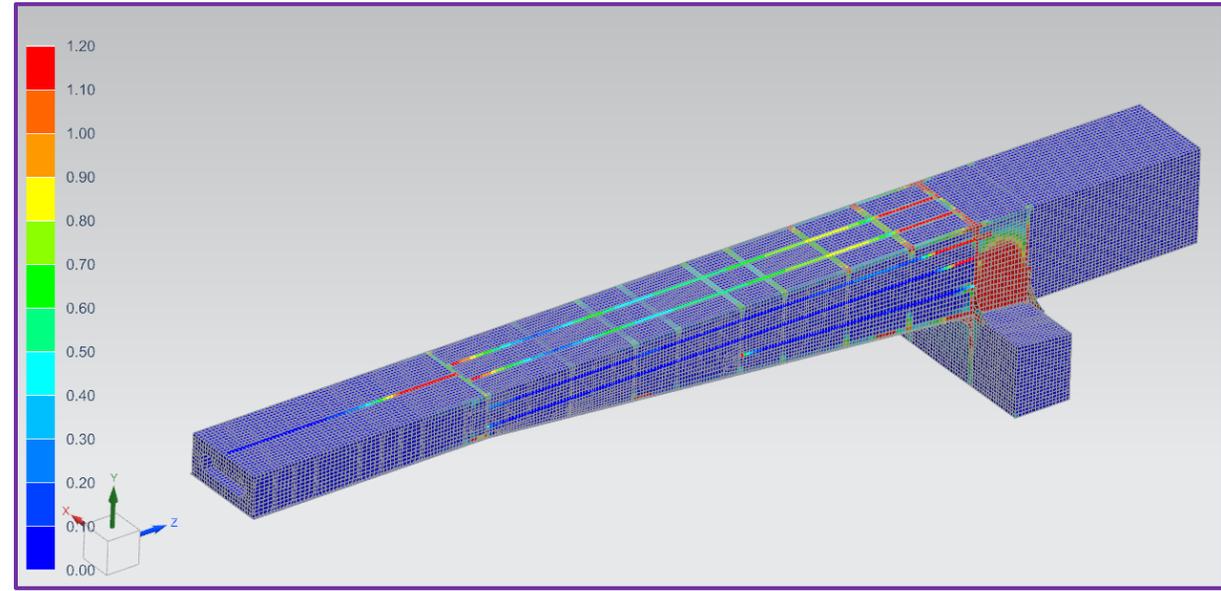
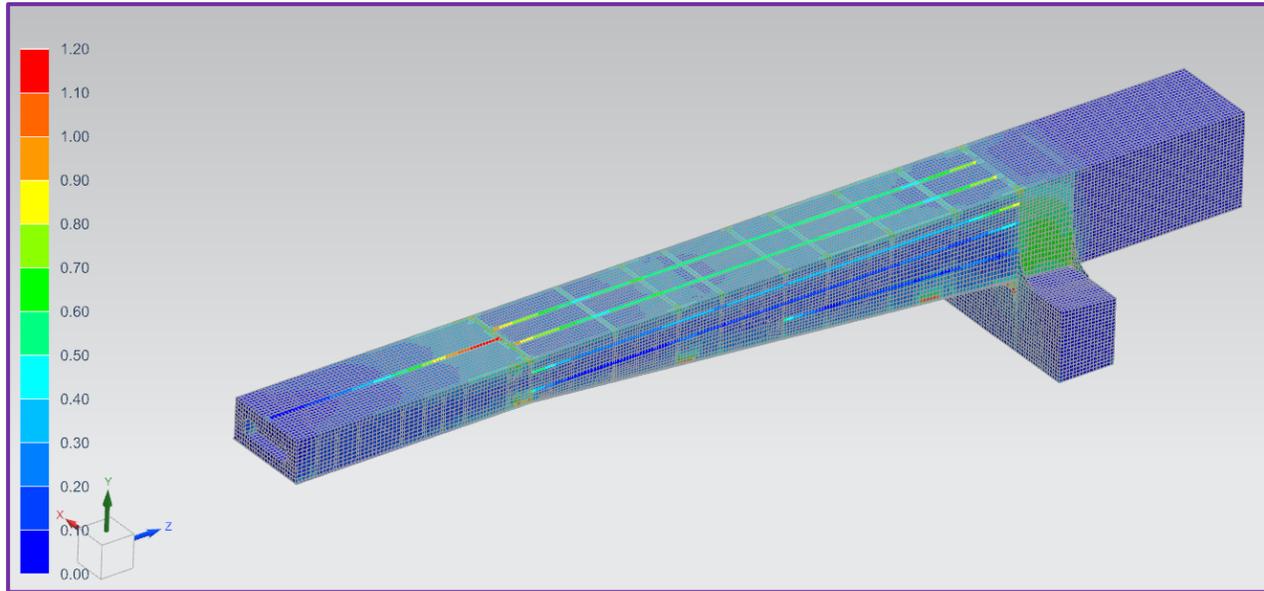
6

Press *OK*



F.E.M. 1.001 Utilization Factor

Eurocode 3 Utilization Factor at 2 million cycles



To learn how to obtain reports, please check a separate Tutorial that depicts the functionality of SDC Verifier Report Designer. It may be uploaded via this link:

<https://sdcverifier.com/tutorials/report-designer/>