



Tutorial
F.E.M. 1.001 and Eurocode3 Fatigue



3 Dec 2020
version 2020.0.2

Content



- ▶ 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;
- ▶ Implementation in SDC Verifier;
- ▶ Weld Finder Tool overview;
- ▶ Fatigue tables and plots;
- ▶ Report preparation and results.

Allowable Stress Design method

The following formulae give for all values of κ 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)

σ_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 σ_0 = tensile stress for $\kappa = 0$ is given by the formula (1) that is :

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

σ_{+1} = tensile stress for $\kappa = +1$ that is the ultimate strength σ_R divided by the coefficient of safety

$$4/3 : \quad \sigma_{+1} = 0,75 \cdot \sigma_R$$

σ_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 κ 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^2 , i.e. to the permissible stress adopted for checking for ultimate strength.

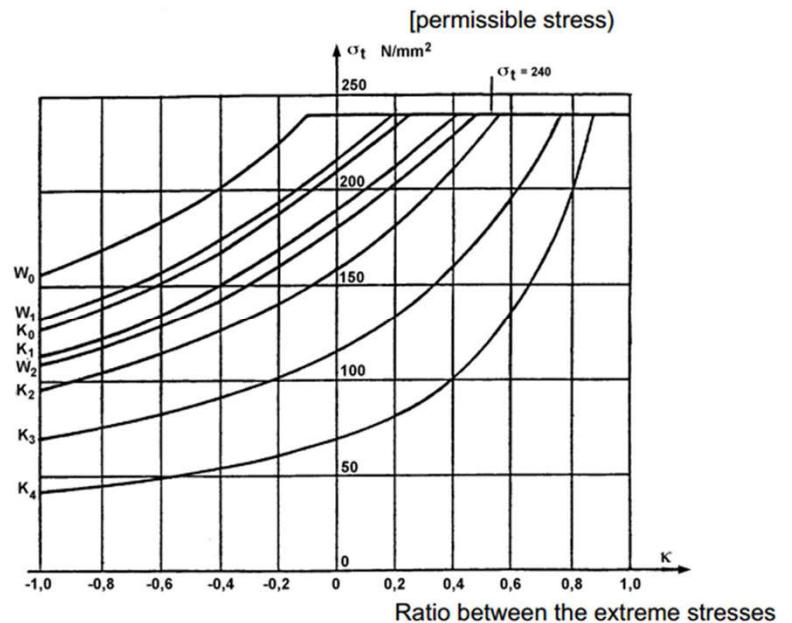


Figure A.3.6.1. - (A 52; tension; group E6)

Fatigue in SDC Verifier



Kappa Factor

$$\kappa_x = \sigma_{x \min} / \sigma_{x \max}$$

$$\kappa_y = \sigma_{y \min} / \sigma_{y \max}$$

$$\kappa_{xy} = \tau_{xy \min} / \tau_{xy \max}$$

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)

σ_w is given in table above.

b) $\kappa > 0$

- for tension $\sigma_t = \sigma_0 / [1 - \kappa \cdot (1 - \sigma_0 / \sigma_1)]$
- for compression $\sigma_c = 1,2 \cdot \sigma_t$

Utilization Factor Combined

$$(\sigma_{x \max} / \sigma_{xa})^2 + (\sigma_{y \max} / \sigma_{ya})^2 - \sigma_{x \max} \cdot \sigma_{y \max} / (|\sigma_{xa}| \cdot |\sigma_{ya}|) + (\tau_{xy \max} / \tau_{xy a})^2 \leq 1$$

Add Custom Check

Options

- Calculate Results over Directions
- Calculate Results over Points
- Load Calculation: Load Group Only
- Selection: All Entities

Parameters (4) / Replacements (0)

Parameter = Kappa (Kappa Factor)
Description: Ratio between the extreme stresses.
All: if(SweldAbs > 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, Fe360, Sf_Fe360(ElementGroup, WeldType), Fe510, 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(SweldAbs > 0, 1, 1.2) * (5 / 3 * Sf) / (1 - (1 - (5 / 3 * Sf) / (0.75 * tensile)) * Kappa), if(SweldAbs > 0, (5 * Sf) / (3 - 2 * Kappa), (2 * Sf) / (1 - Kappa)))
Eqv.: 0

Parameter = Uf (Utilization Factor)
Description: Appendix 3.6, equivalent rule - (5)
All: Abs(SweldAbs) / Sallow_fatigue
XY/YZ/ZX: Abs(SweldAbs) / (Sallow_fatigue / if(WeldType <= Weld_K4, SQRT(2), SQRT(3)))
Eqv.: pow(me.x, 2) + pow(me.y, 2) + pow(me.z, 2) + pow(me.xy, 2) + pow(me.yz, 2) + pow(me.zx, 2) - sign(SweldAbs.X) * me.x * sign(SweldAbs.Y) * me.y - sign(SweldAbs.Y) * me.y * sign(SweldAbs.Z) * me.z - sign(SweldAbs.Z) * me.z * sign(SweldAbs.X) * me.x
Overall: Max(me.x, me.y, me.z, me.xy, me.yz, me.zx, sqrt(me.eqv))

Buttons:

OK Cancel

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

Stress Fatigue

Stress Fatigue is used in Fatigue Allowable Stress calculations.

$$\kappa \leq 0$$

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

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

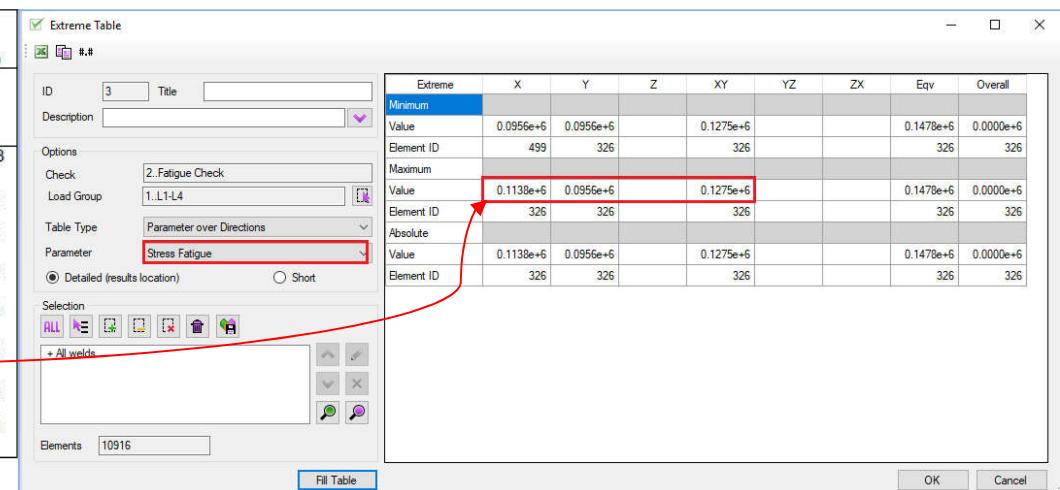
Stress Fatigue depends on:

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

Table T.A.3.6.1.
Values of σ_w depending on the component group and construction case (N/mm²)

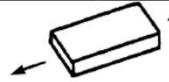
Com- ponent group	Unwelded components Construction cases						Welded components Construction cases (Steels St 37 to St 52, Fe 360 to Fe 510)				
	W ₀		W ₁		W ₂		K ₀	K ₁	K ₂	K ₃	K ₄
	Fe 360 St 37 St 44	Fe 510	Fe 360 St 37 St 44	Fe 510	Fe 360 St 37 St 44	Fe 510					
E1	249,1	298,0	211,7	253,3	174,4	208,6	(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	75,0	63,0	45,0	27,0	

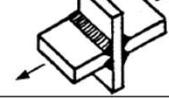
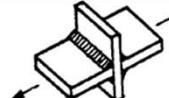
Corresponding values of Stress fatigue in SDC Verifier:



Weld Type

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

Case W ₀			
Reference	Description	Figure	Symbol
W ₀	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 ₀ - Slight stress concentration			
Reference	Description	Figure	Symbol
0,1	Parts butt-welded (S.Q.) at right angles to direction of forces		P 100 
Case K ₁ - 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		P 100 or P10 

Case K ₂ - 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		D 
Case K ₃ - 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		D 
Case K ₄ - 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		D 

Element Group

Element Group also called Loading Group depends on: Class of Utilization, 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)			
	n	<	n	\leq
B0				16 000
B1	16 000	<	n	\leq
B2	32 000	<	n	\leq
B3	63 000	<	n	\leq
B4	125 000	<	n	\leq
B5	250 000	<	n	\leq
B6	500 000	<	n	\leq
B7	1 000 000	<	n	\leq
B8	2 000 000	<	n	\leq
B9	4 000 000	<	n	\leq
B10	8 000 000	<	n	

Load Spectrum

Table T.2.1.4.3. - Spectrum classes

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

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

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

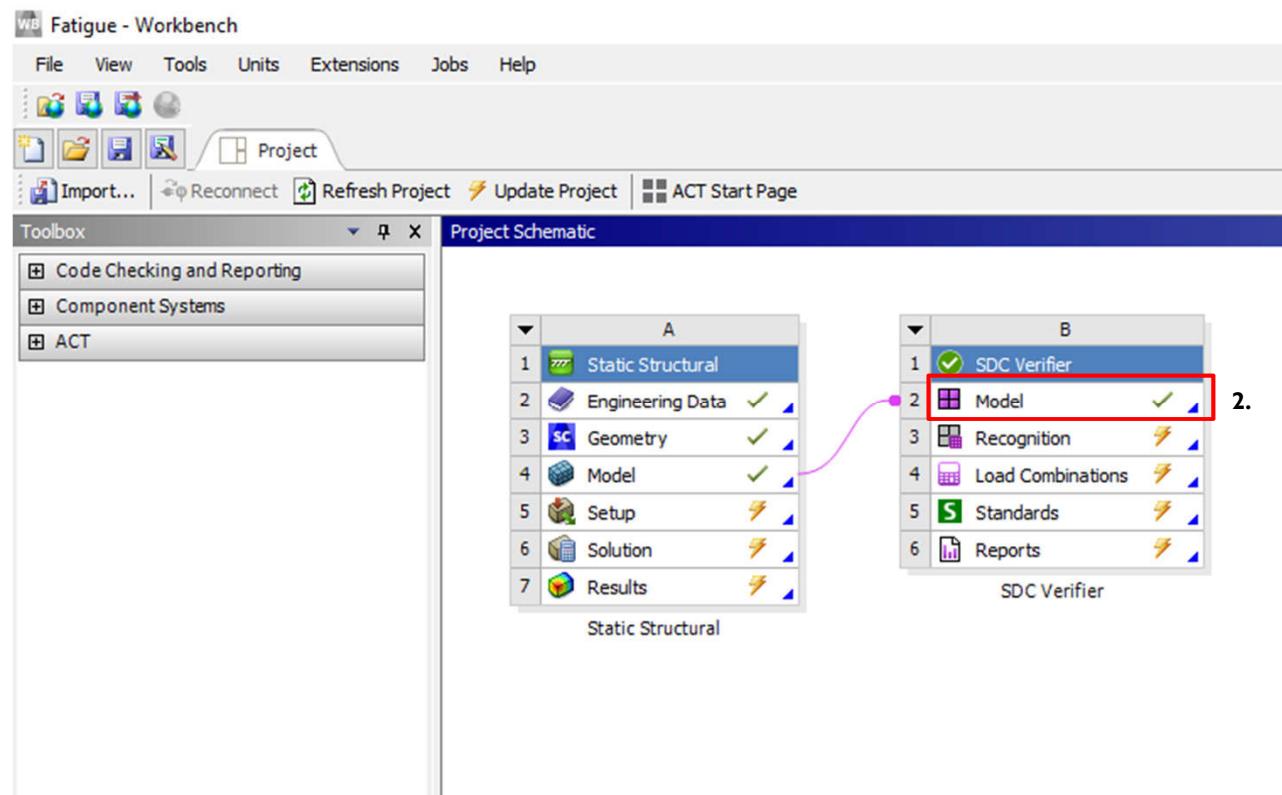
Element Group

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

Open the starter model

- 1 Open in ANSYS Workbench  FEM. 1.001 and Eurocode 3 Fatigue.wbpz
- 2 Double Click on  Model or in context menu click Edit



Run Analysis



1

Press to start Analysis in ANSYS

The screenshot shows the SDC Verifier 2020.0.2 interface. The top menu bar includes File, Settings, View, Model, Recognition, Job, Tool, Standard, Post-Processing, Automation, Results, Report, and Help. The toolbar below has various icons for file operations and analysis types. A red box highlights the play button icon in the toolbar. The left sidebar displays a tree view of the project structure:

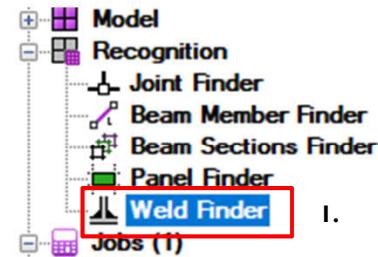
- Views (1)
- Model
 - Components (0)
 - Materials (2)
 - Properties (5)
 - FEM Loads (5)
 - Constraints (1)
- Recognition
- Jobs (1)
 - 1. Static Structural
 - Individual Loads (5)
 - Load Sets (4)
 - Load Groups (4)
 - Fatigue Groups (0)
 - Tables (0)
 - Plots (0)
- Tools
- Standards (0)
- Post-Processing
- Optimizations (0)
- Reports (0)

The main workspace is currently empty. The bottom status bar shows "Nodes: 21047 | Elements: 21367 | SYS.mechdb" and "MKS (Meter/Kg/Second) | Ansys". The command history at the bottom lists several log entries:

```
18:56:12 What they coefficients have been converted from 1 properties to elements
18:56:13 Updating Joint Finder...
18:56:13 Updating Beam Member Finder...
18:56:13 Updating Weld Finder...
18:56:13 Updating Beam Section Finder...
18:56:13 Updating Panel Finder...
18:56:13 Updating standards...
18:56:15 Project D:\Vitalik\Tutorial\for Ansys\Eurocode3 and FEM1.001 Fatigue\Input data\ANSYS 19.2\Fatigue_files\dp0\SDCvF\ACT\Fatigue.ansv was opened
```

Weld Finder

- 1 Execute Recognition => Weld Finder =>
Edit...
- 2 Press *Find.*
- 3 Press  to Export selected sections to components



Welds Finder

Welds Weld Strength Settings

Filter: None Apply Filter Find Weld by ID Navigate

ID	Title	Tensile (Min) [Pa]	Yield (Min) [Pa]	Is Symmetric	Is curved	Nodes	Elements	Weld Parts
1	Weld 1 [0.5; 1.09; -1.05]	42000000	0	Yes	Yes	39	76	2
2	Weld 2 [0.5; 0.15; -2.64]	42000000	0	Yes	No	5	12	3
3	Weld 3 [0.5; 0.37; -2.64]	42000000	0	Yes	No	5	12	3
4	Weld 4 [-0.5; 1.09; -1.05]	42000000	0	Yes	Yes	39	76	2
5	Weld 5 [-0.51; 0.48; -8.7]	42000000	0	No	No	2	2	2
6	Weld 6 [0.51; 0.48; -8.7]	42000000	0	No	No	2	2	2
7	Weld 7 [-0.5; 0.69; -2.64]	42000000	0	Yes	No	5	12	3
8	Weld 8 [0.5; 0.69; -2.64]	42000000	0	Yes	No	5	12	3
9	Weld 9 [-0.5; 0.37; -2.64]	42000000	0	Yes	No	5	12	3
10	Weld 10 [-0.5; 0.15; -2.64]	42000000	0	Yes	No	5	12	3
11	Weld 11 [-0.5; 1.52; -2.75]	42000000	0	Yes	No	10	27	3
12	Weld 12 [-0.5; 0.69; -2.75]	42000000	0	Yes	No	2	3	3
13	Weld 13 [-0.5; 0.53; -2.75]	42000000	0	Yes	No	7	18	3
14	Weld 14 [-0.5; 0.26; -2.75]	42000000	0	Yes	No	5	12	3
15	Weld 15 [-0.5; 0.08; -2.75]	42000000	0	Yes	No	4	9	3
16	Weld 16 [-0.5; 1.43; -2.08]	42000000	0	Yes	No	14	39	3
17	Weld 17 [-0.5; 0.92; -2.08]	42000000	0	Yes	No	7	24	4
18	Weld 18 [-0.5; 0.38; -2.08]	42000000	0	Yes	No	15	42	3
19	Weld 19 [0.5; 0.08; -2.75]	42000000	0	Yes	No	4	9	3
20	Weld 20 [0.5; 0.26; -2.75]	42000000	0	Yes	No	5	12	3
21	Weld 21 [0.5; 0.53; -2.75]	42000000	0	Yes	No	7	18	3
22	Weld 22 [0.5; 0.69; -2.75]	42000000	0	Yes	No	2	3	3
23	Weld 23 [0.5; 1.52; -2.75]	42000000	0	Yes	No	10	27	3
24	Weld 24 [0.5; 1.43; -2.08]	42000000	0	Yes	No	14	39	3
25	Weld 25 [0.5; 0.92; -2.08]	42000000	0	Yes	No	7	24	4
26	Weld 26 [0.5; 0.38; -2.08]	42000000	0	Yes	No	15	42	3
27	Weld 27 [0; 1.09; -2.08]	42000000	0	No	No	19	72	4
28	Weld 28 [0.5; 0.28; -9.5]	42000000	0	Yes	No	8	21	3
29	Weld 29 [0.5; 0.28; -10.27]	42000000	0	Yes	No	8	21	3
30	Weld 30 [0.5; 0.28; -10.8]	42000000	0	Yes	No	8	21	3
31	Weld 31 [0.5; 0.28; -11.07]	42000000	0	Yes	No	8	21	3
32	Weld 32 [0.5; 0.28; -10.27]	42000000	0	Yes	No	8	21	3

Set Parameters Check on Weld Design OK Cancel

2. **Find**

Add, Edit, Combine and Remove Welds.

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

Preview selected welds

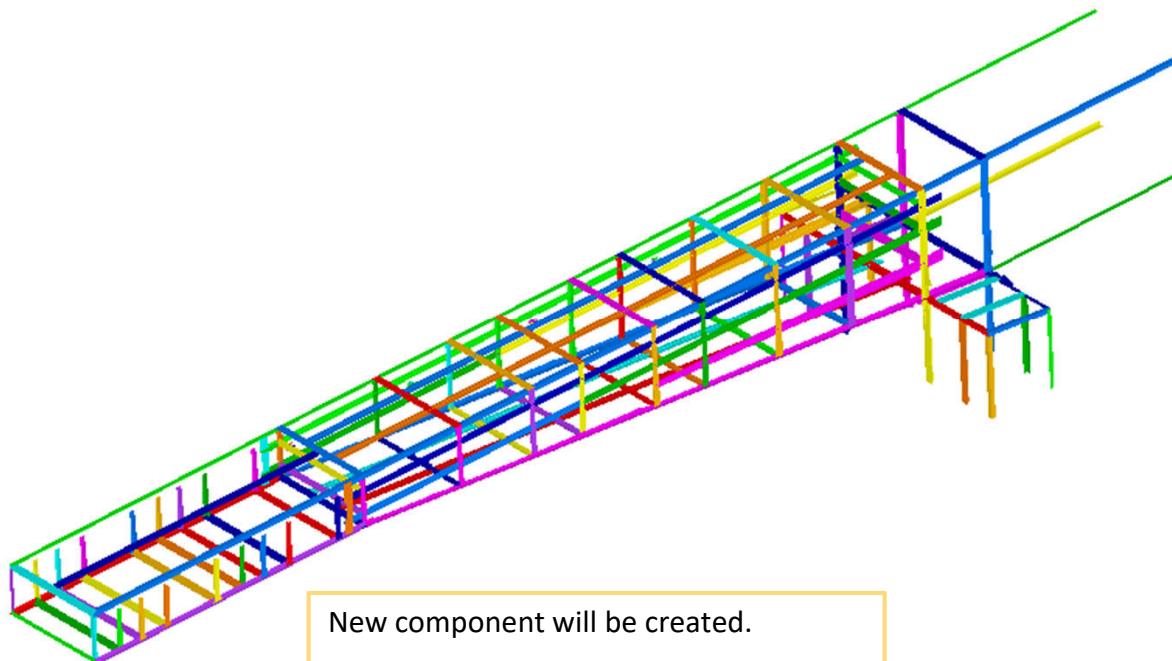
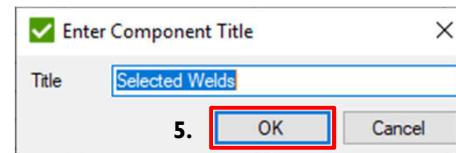
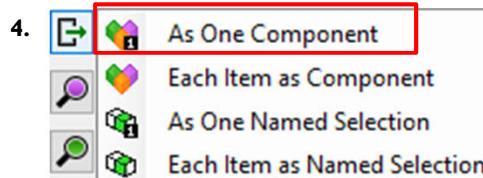
Plot of selected welds in colors and with labels of IDs

Weld Finder



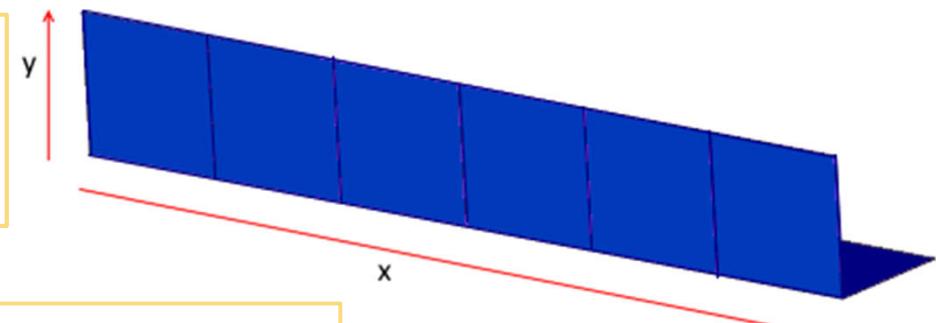
4 Click As One Component

5 Press OK.



Stress Transformation

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.



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

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

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

$\sigma_{xx}, \sigma_{yy}, \tau_{xy}$ – original x, y and shear stress in local element x, y and shear directions

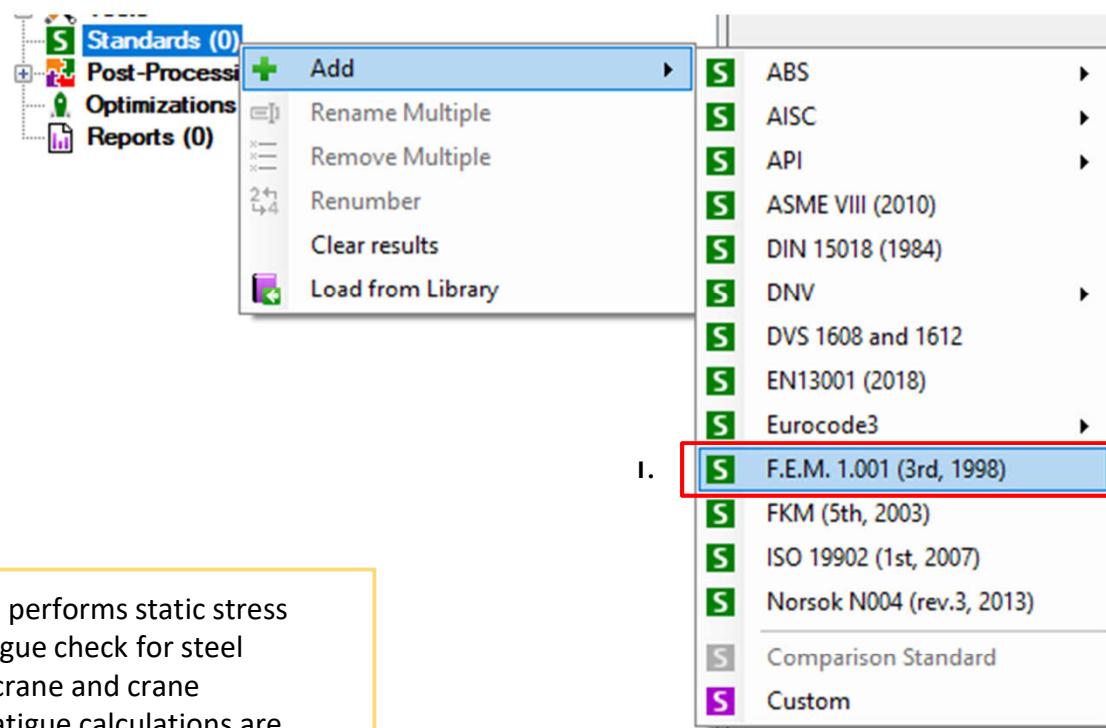
$\sigma_{tt}, \sigma_{nn}, \tau_{nt}$ – transformed x, y and shear stress in weld x, y and shear directions

θ – angle between the element and weld x directions.

Add FEM 1.001 standard

1

Execute **Add => F.E.M. 1.001** in
Standards context menu.



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).

F.E.M. 1.001 Standard



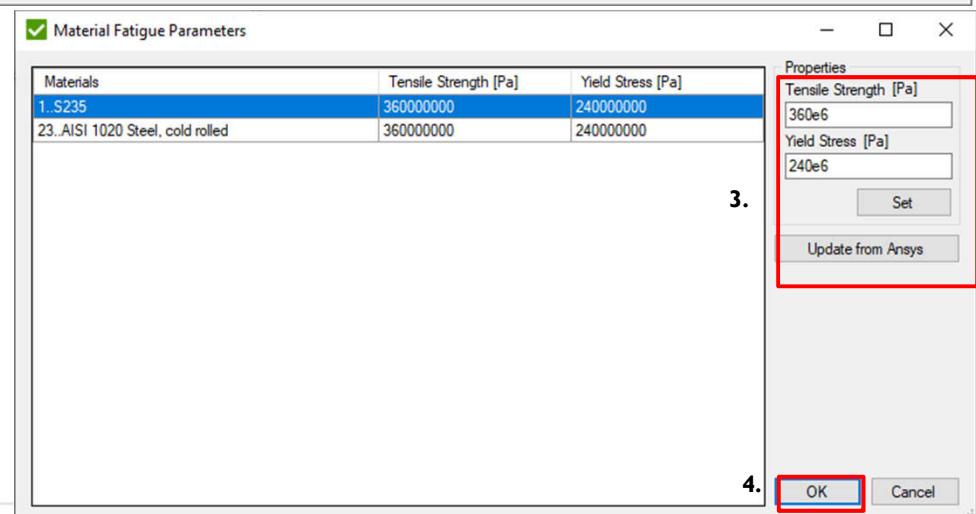
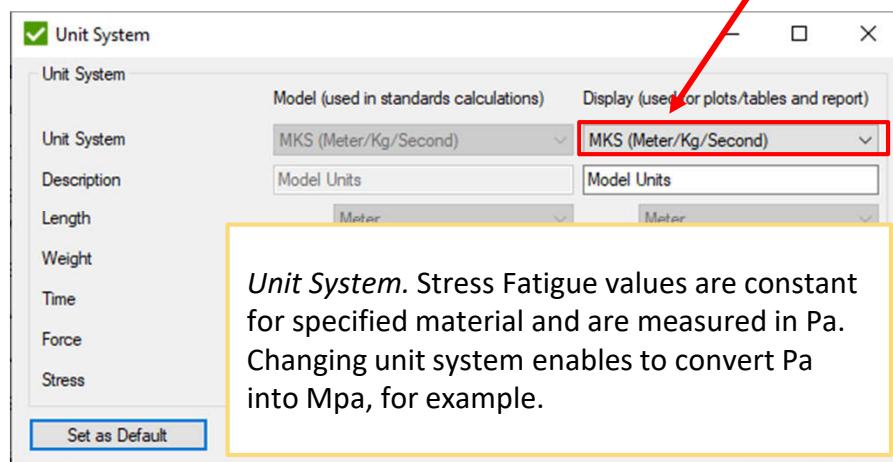
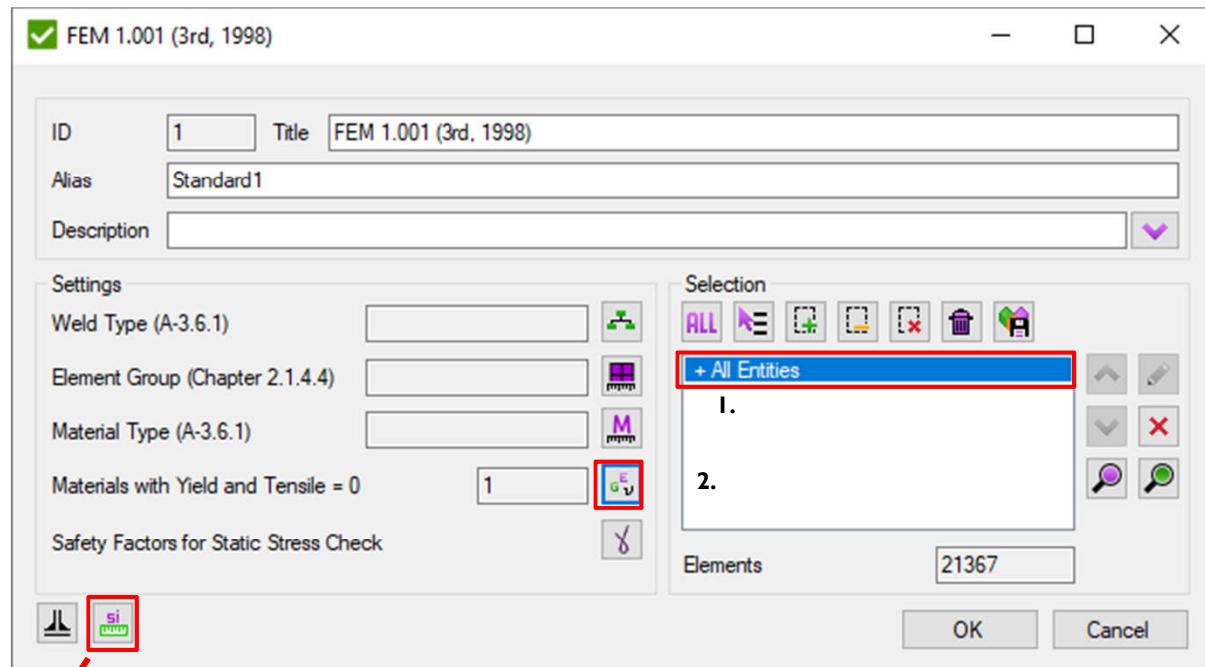
1 Selection: All Entities

2 Press to edit material properties.

Amount of materials with not defined Tensile or Yield is displayed in the field

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

4 Press OK.



Definition of weld categories



- ▶ Weld/notch category determines fatigue resistance
- ▶ Division in welds / non welds for FEM I.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 Classes depends on Weld Type

Non-weld group W0

nr.	description of the main types	symbol
W01	Part without hole and without joint, with a normal state of the surface, without notch behaviour.	

Slight notch behavior group K0

nr.	description of the main types	symbol
011	Parts, jointed by a <u>butt weld</u> of special quality, perpendicular to the direction of force.	

Moderate notch behavior group K1

nr.	description of the main types	symbol
111	Parts, jointed by a <u>butt weld</u> of ordinary quality, perpendicular to the direction of force.	

Medium notch behavior group K2

nr.	description of the main types	symbol
211	Profiles, jointed by butt welds of special quality, perpendicular to the direction of force.	

Great notch behavior group K3

311	Parts jointed by a <u>butt weld</u> with a <u>backing strap</u> , without sealing run and perpendicular to the direction of force. Backing strap fixed by tack welding.		>
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and a different connection type 351

nr.	description of the main types	symbol
351	Double bevel weld of ordinary quality, perpendicular to the direction of force, between crossing parts.	

Very great notch behavior group K4

nr.	description of the main types	symbol
412	Parts of different thickness, jointed by a <u>butt weld</u> of ordinary quality, perpendicular to the direction of force. Asymmetrical joint without slope.	

and a different connection type 451

451	Fillet welds of normal quality or single bevel weld (included fillet weld) with backing, perpendicular to the direction of force, between crossing parts.			
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Weld Type – stress direction



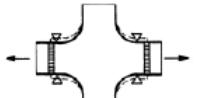
	Perpendicular to weld	Parallel with weld	Shear
Weld	K1	K2	K0
No weld	W0		$\tau_D(-1) = \sigma_D(-1) / \sqrt{3}$

Steel Grade	$\sigma_D(-1)$ for $\kappa=-1$ element group 5 St 52-3							
Notch group	W0	W1	W2	K0	K1	K2	K3	K4
Stress amplitude	163.8	130.3	104.2	118.8	106.1	89.1	63.6	38.2

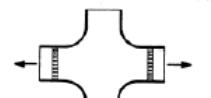
For beams SCF of connections can be included in the classification

Depends on Stress concentrations:

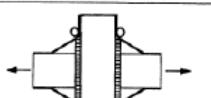
Slight notch behavior group K0

013	Gusset, jointed by <u>butt welds</u> of special quality, perpendicular to the direction of force.		 P 100  P 100
-----	---	---	--

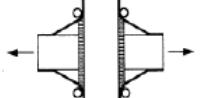
Moderate notch behavior group K1

113	Gusset, jointed by <u>butt welds</u> of ordinary quality, perpendicular to the direction of force.		 P or  P or P 100
-----	--	---	---

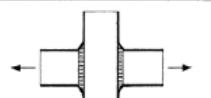
Medium notch behavior group K2

213	<u>Butt weld</u> of special quality and <u>continuous part</u> , both perpendicular to the direction of force, at a crossing of flanges with <u>in-welded corner plates</u> . The ends of the welds are ground to prevent them from notch behaviour.		 P 100  P 100
-----	--	---	--

Great notch behavior group K3

313	<u>Butt weld</u> of ordinary quality and <u>continuous part</u> both perpendicular to the direction of force, at a crossing of flanges with <u>welded corner plates</u> . The ends of the welds have been ground to prevent them from notch behaviour.		 P or  P or P 100
-----	--	---	---

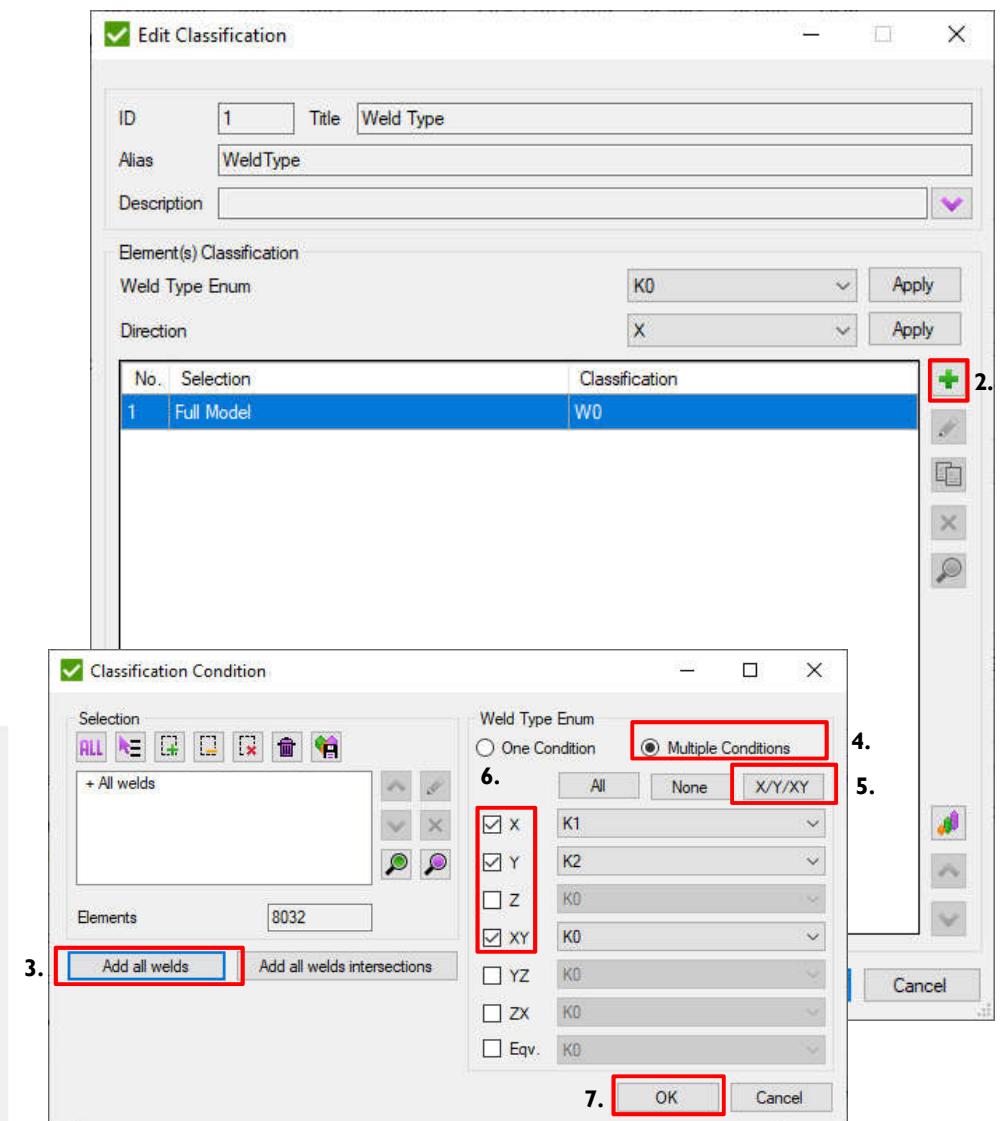
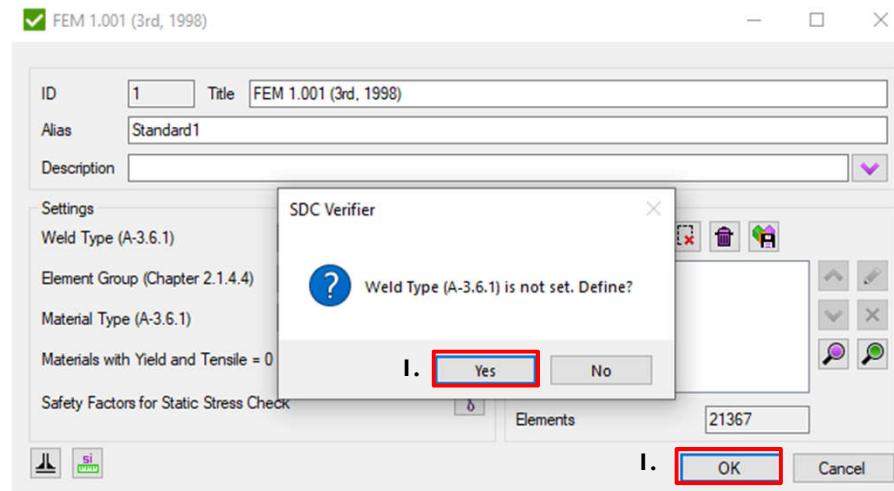
Very great notch behavior group K4

413	<u>Butt weld</u> of ordinary quality, perpendicular to the direction of force, at a crossing of flanges without corner plates.		 P  P
-----	--	---	--

(not included in this tutorial)

Weld Type Classification

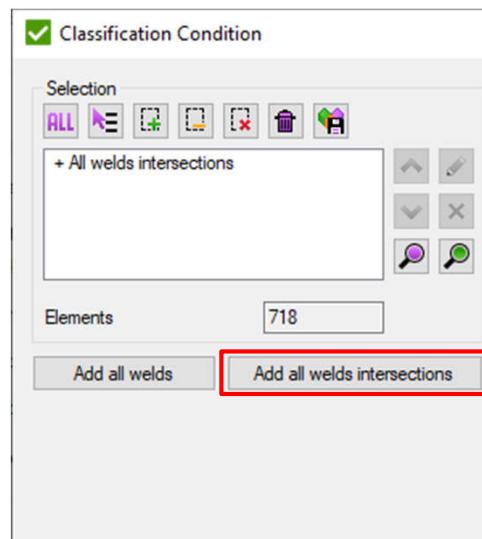
- 1 Press Ok-->Yes (*Define for the Weld Type*).
- 2 Press  to Add Condition.
- 3 Press Add all Welds
- 4 Select *Multiple Conditions* options
- 5 Press X/Y/XY
- 6 X: K1 Y: K2 XY: K0
- 7 Press OK



Weld Type classification intersecting welds



- 1 Press to Add Condition.
- 2 Click All welds intersections
- 3 Value: K2
- 4 Directions: X
- 5 Press OK



Edit Classification

ID	1	Title	Weld Type
Alias	WeldType		
Description			
Element(s) Classification			
Weld Type Enum	K0	Apply	
Direction	X	Apply	
No.	Selection	Classification	
1	Full Model	W0	
2	All welds	K1 (X)	
		K2 (Y)	
		K0 (XY)	

Classification Condition

Selection: + All welds intersections (Elements: 718)

Weld Type Enum:

- One Condition
- Multiple Conditions

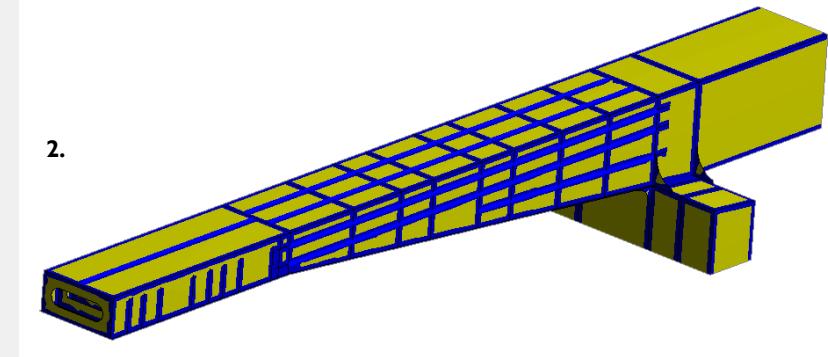
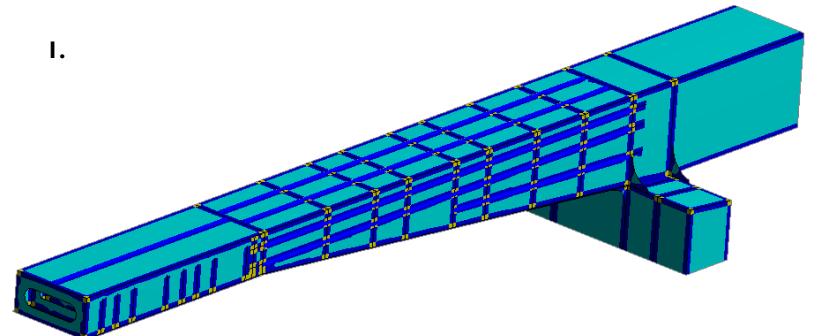
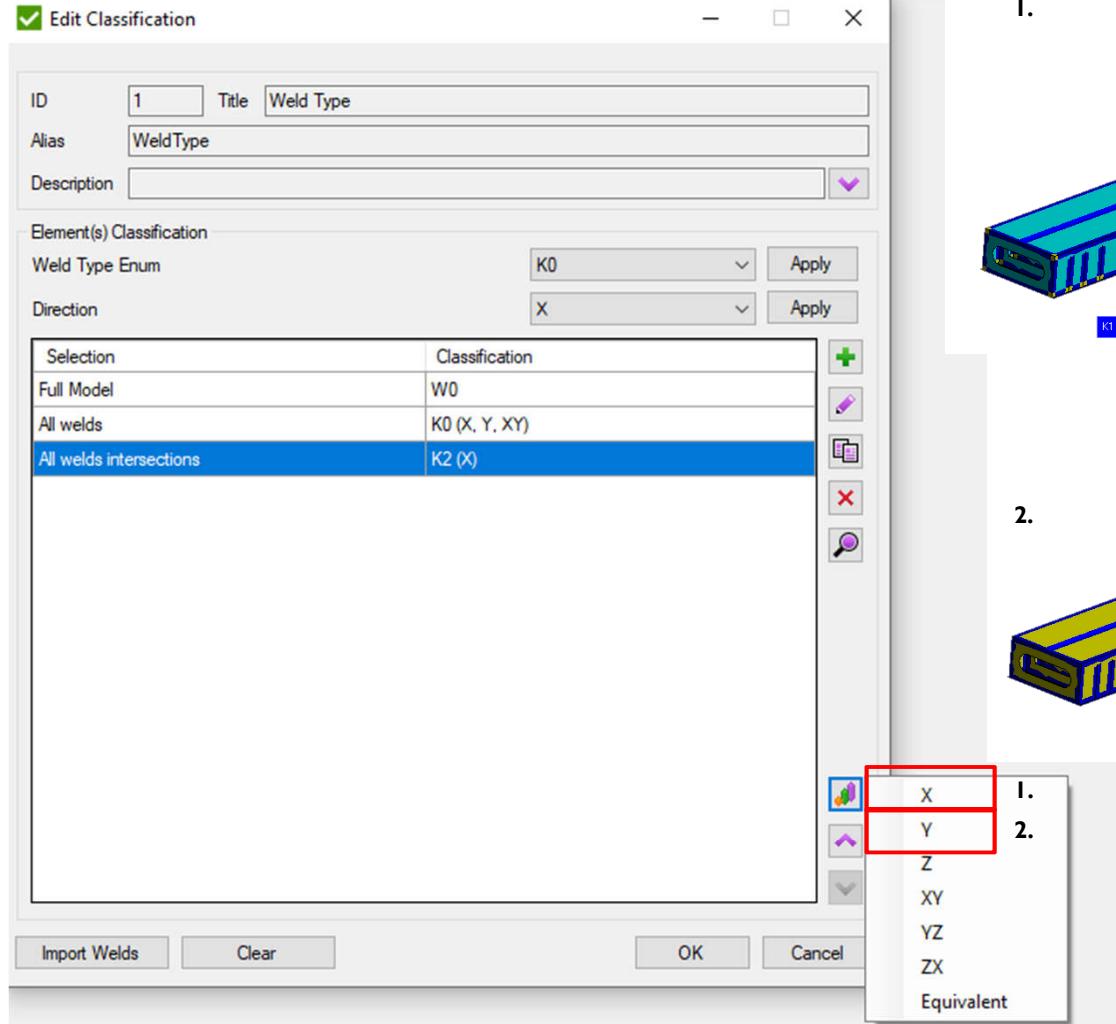
Value: K2

Directions:

1. All
2. None
3. X/Y/XY
4. X
5. Y
6. Z
7. XY
8. YZ
9. ZX
10. Equivalent

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

Check classification

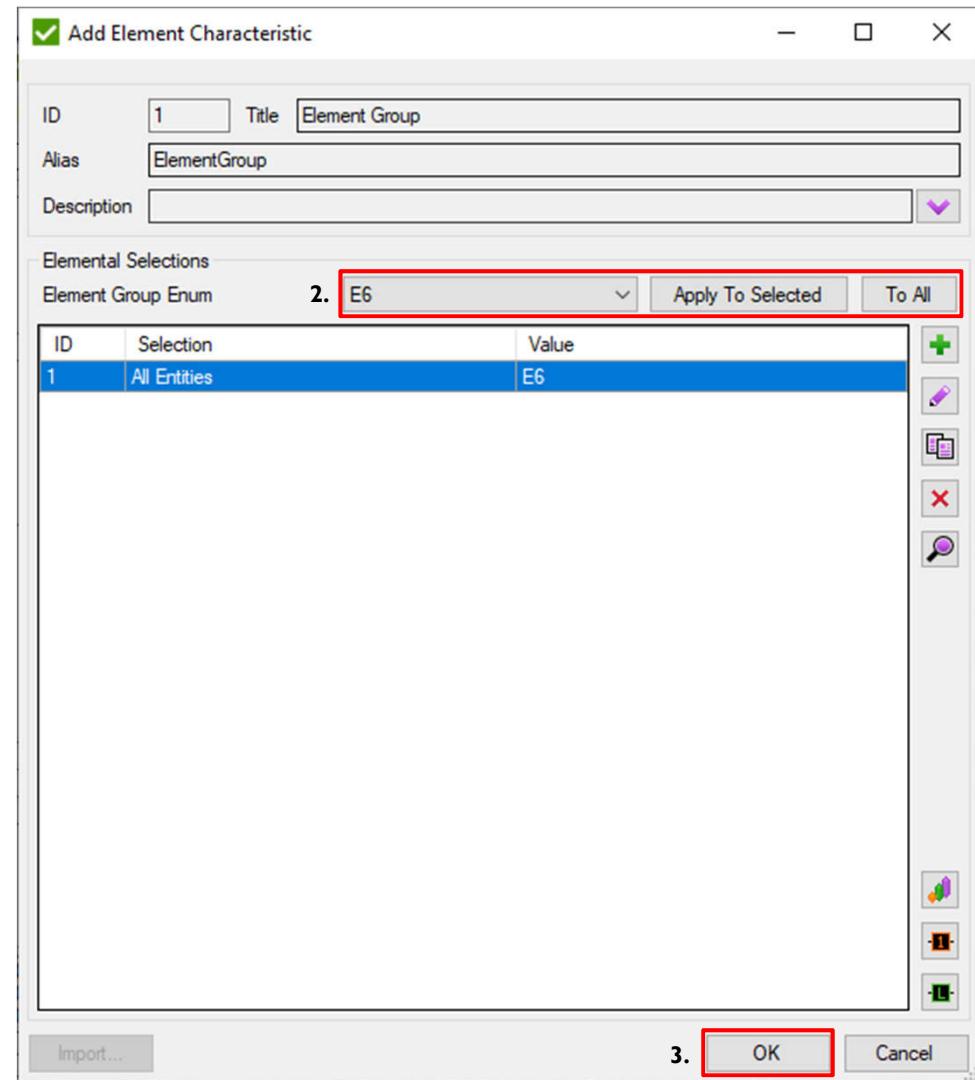


- X
Y
Z
XY
YZ
ZX
Equivalent
1.
2.

2.

Element Group classification

- 1 Press  for the Element Group.
- 2 Select Element Group: **E6**. Press *To All*.
- 3 Press *OK*.



Material Type classification



1 Press  for the Material Type.

2 Select Material Type: **Fe360 (Fe 37)**.
Press *To All*.

3 Press *OK*.

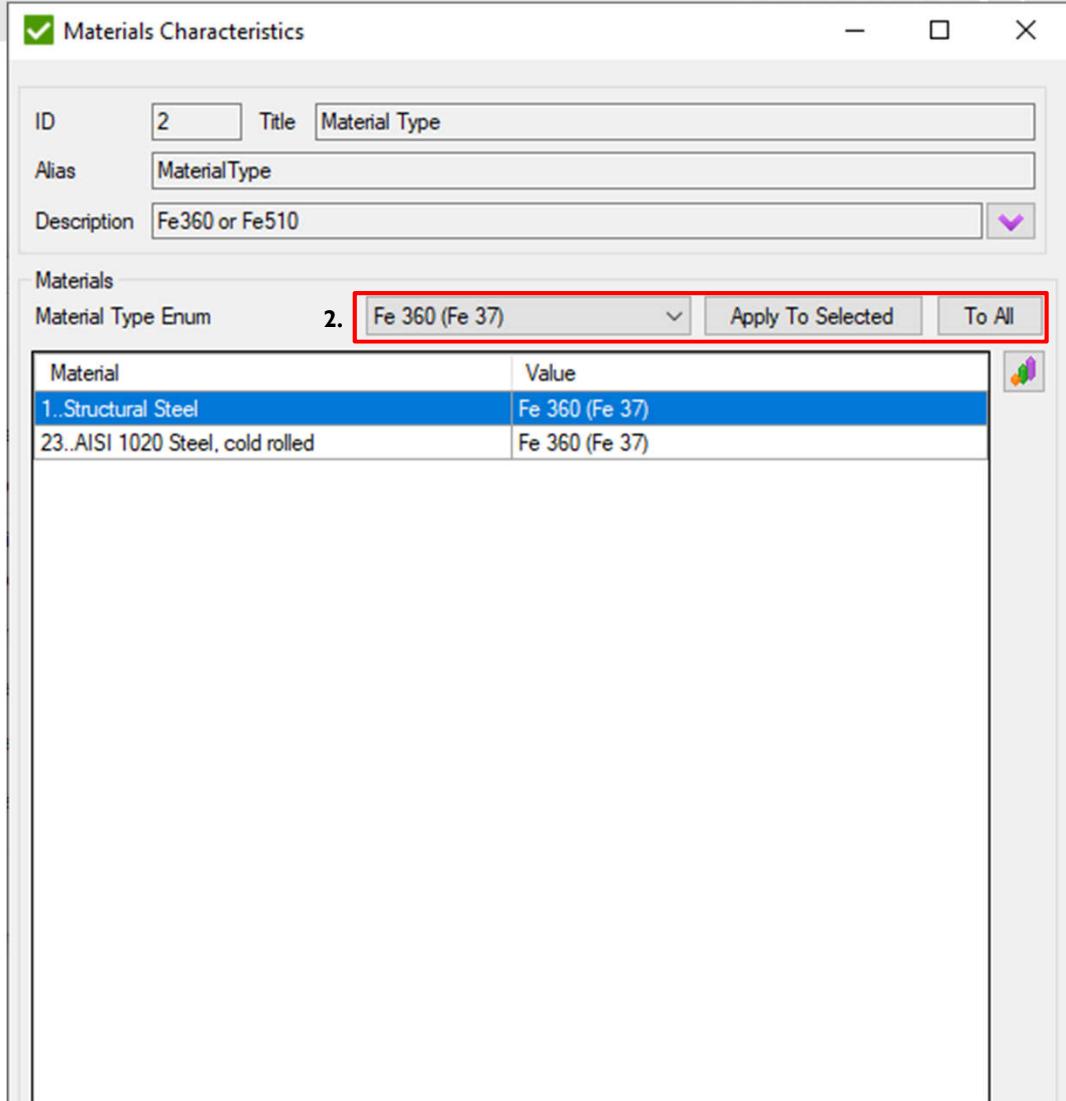
4 Press *OK* to create Standard.

Material Type defines which steel is used: St37 or St52. Stress Fatigue values are different for different materials.

Materials Characteristics

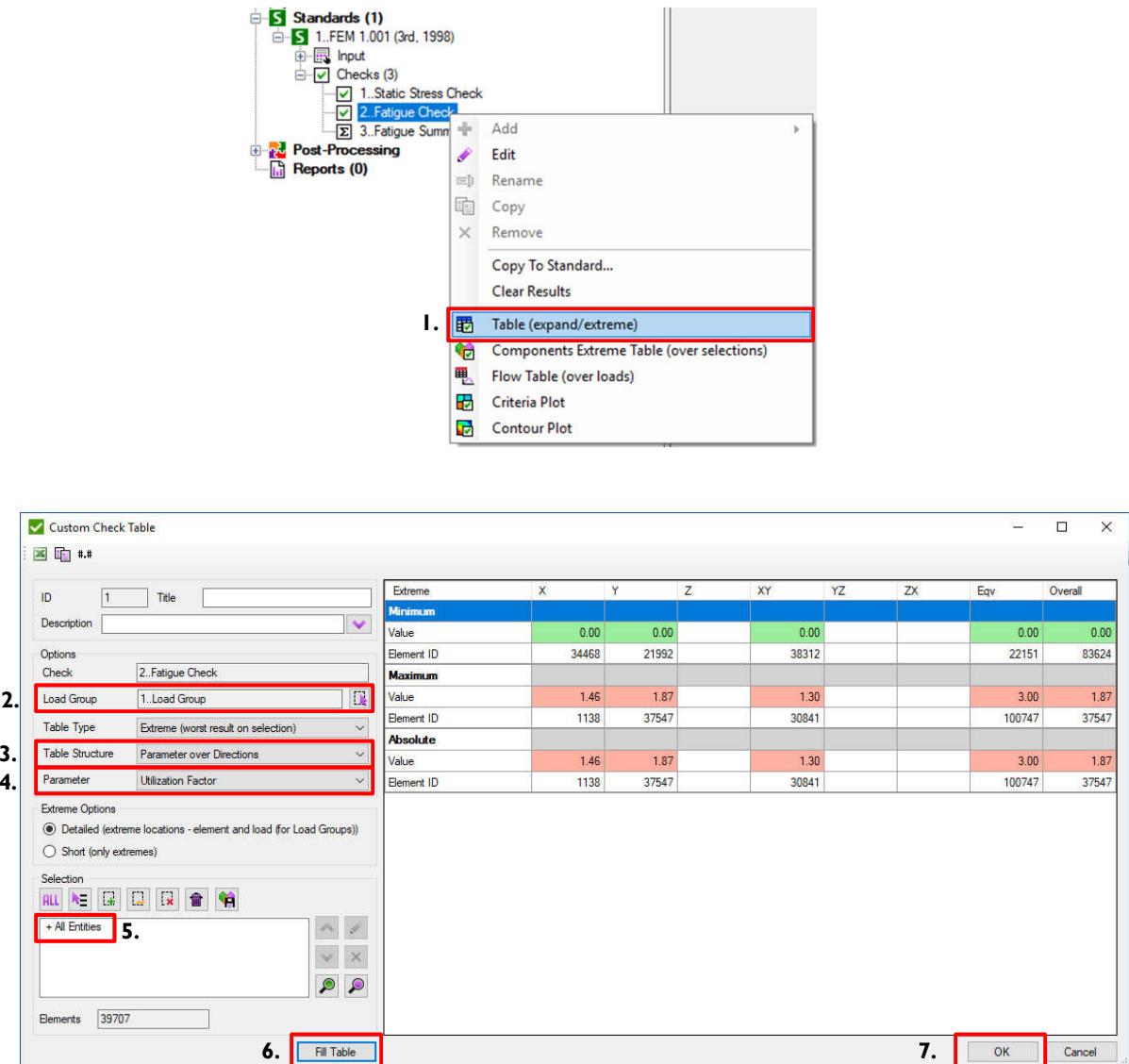
ID	2	Title	Material Type
Alias	MaterialType		
Description	Fe360 or Fe510		
Materials			
Material Type Enum	2. Fe 360 (Fe 37)	Apply To Selected	To All
Material	Value		
1..Structural Steel	Fe 360 (Fe 37)		
23..AISI 1020 Steel, cold rolled	Fe 360 (Fe 37)		

3. **OK** Cancel



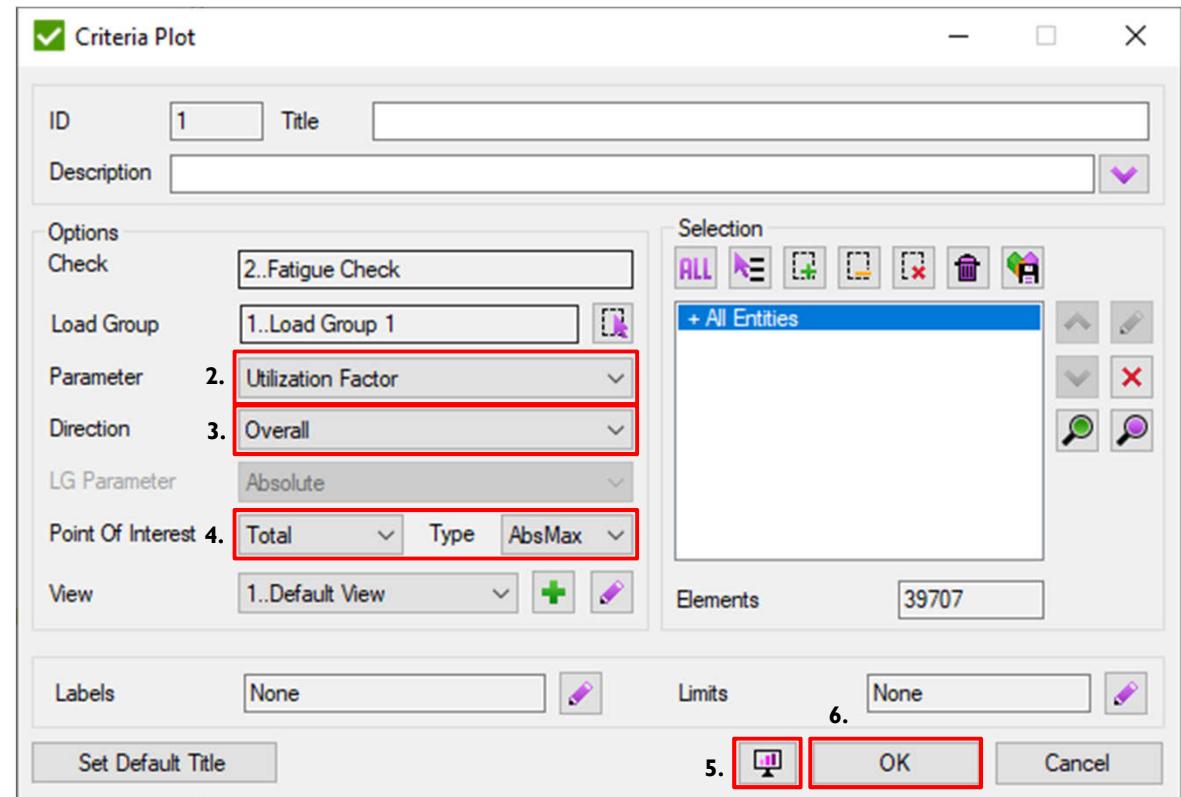
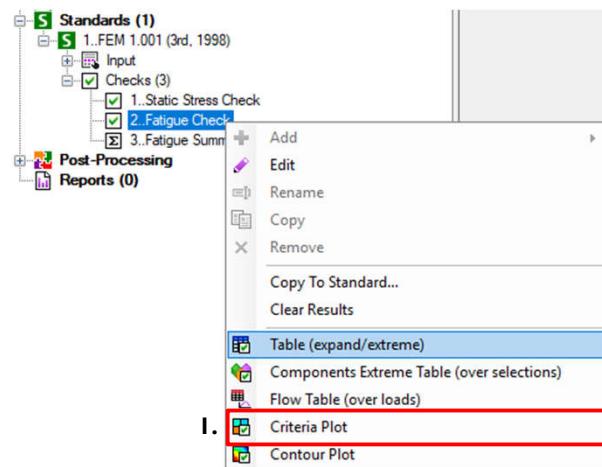
Create extreme table

- 1 Execute **Table (expand/extreme)** in **Fatigue Check** context menu.
- 2 Load: **1..Load Group1**.
- 3 Fatigue check supports only Load Groups. If only one load group exist in the project it will be selected automatically.
- 4 Table Type: **Parameter over Directions**.
- 5 Parameter: **Utilization Factor**.
- 6 Selection: **All Entities**.
- 7 Press **Fill Table**.
- 8 Press **OK**.



Create criteria plot

- 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  Preview
- 6 Press OK



Point of interest = AbsMax Total is absolute maximum utilization factors among all point of interest.

Report. Tables and plots

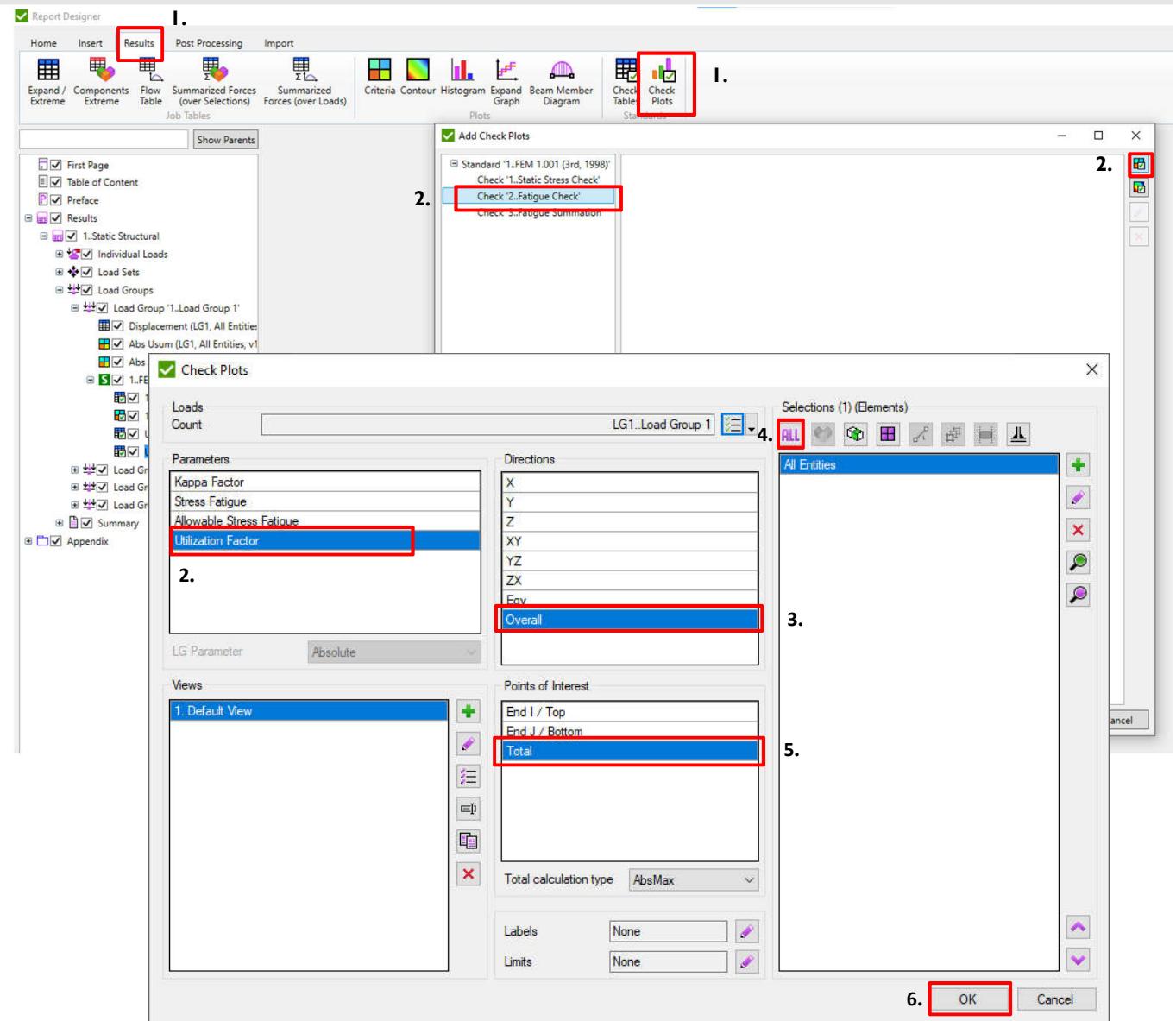
- 1 Results => Check Tables
- 2 Press => Check '2..Fatigue Check'
=>
- 3 Table Type: **Extreme.**
- 4 Load Group: **1..Load Group**
- 5 Selection: **All Entities.**
- 6 Parameter: **Utilization Factor.**
- 7 Press OK.

The screenshot shows the SDC Verifier software interface with several windows open:

- Top Left Window (Job Tables):** Shows the "Results" tab selected. A red box highlights the "Results" tab in the ribbon and the "Check Tables" icon in the toolbar.
- Top Right Window (Plots):** Shows the "Check Tables" icon highlighted with a red box.
- Bottom Left Window (Custom Check Table):** Shows the "Table Type" dropdown set to "Extreme (worst result on selection)" and the "Utilization Factor" parameter selected. A red box highlights the "Table Type" dropdown and the "Utilization Factor" parameter.
- Bottom Middle Window (Selections):** Shows the "Selections (1) (Elements)" section with "All Entities" selected. A red box highlights the "All Entities" button.
- Bottom Right Window (Buttons):** Shows the "OK" and "Cancel" buttons. A red box highlights the "OK" button.

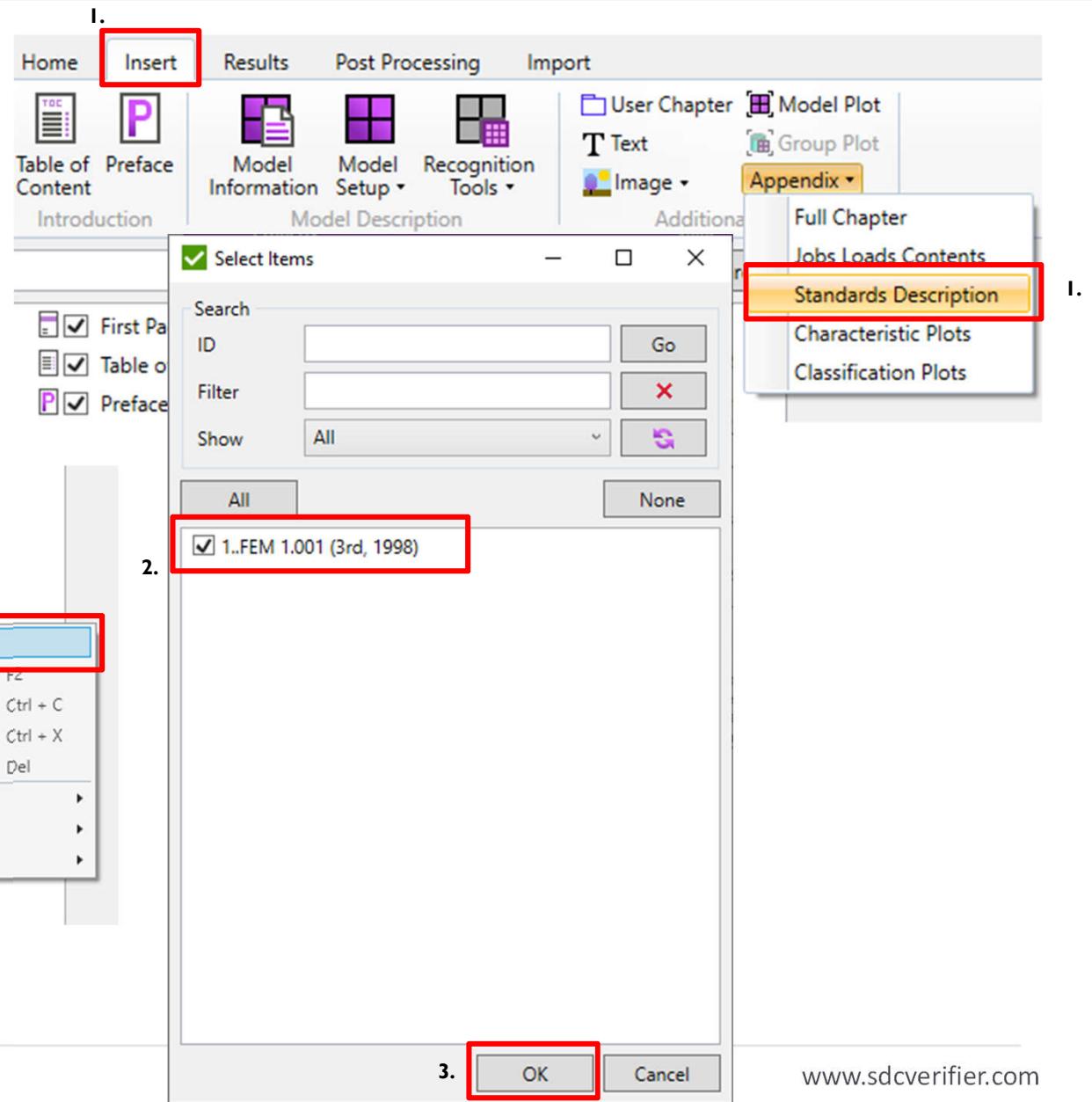
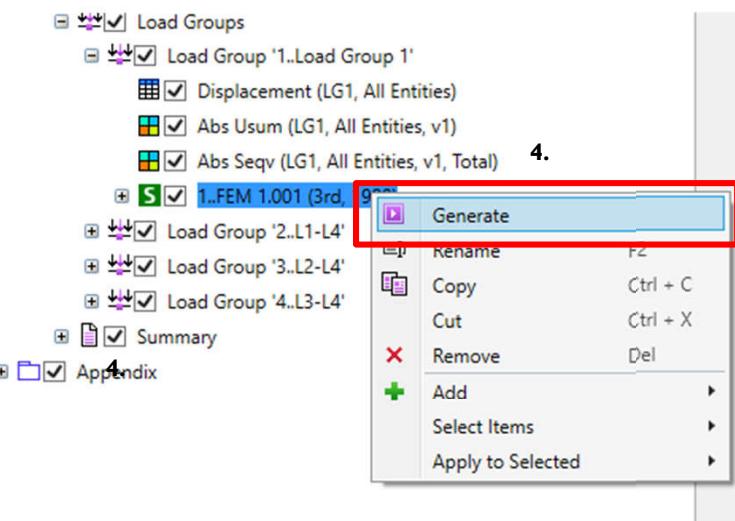
Report. Tables and plots

- 1 Results => Check Plots
- 2 Press => Check '2..Fatigue Check' =>
- 3 Direction: Overall
- 4 Point of Interest: Total.
- 5 Selection: All Entities.
- 6 Press OK.



Report. Fatigue Check

- 1 Insert => Appendix => Standards Description
- 2 Choose 1..FEM 1.001
- 3 Press OK.
- 4 Expand standard 1..FEM 1.001 => Generate.



Report. Results

2..Fatigue Check

Property	Value
Category	Elemental Custom Check
Selection	All Entities
Parameters	4
Alias (Parameter)	Kappa (Kappa Factor)
Description	Ratio between the extreme stresses
All	if(SweldAbs > 0, SweldMin / SweldMax, SweldMax / SweldMin)
Alias (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, Fe360, Sf_Fe360(ElementGroup, WeldType), Fe510, Sf_Fe510(ElementGroup, WeldType))), 0.75 * Tensile)
Alias (Parameter)	Sallow_fatigue (Allowable Stress Fatigue)
Description	Appendix 3.6, formulas (1)-(4)
All	if(Kappa > 0, if(SweldAbs > 0, 1, 1.2) * (5 / 3 * Sf) / (1 - (1 - (5 / 3 * Sf) / (0.75 * tensile)) * Kappa), if(SweldAbs > 0, (5 * Sf) / (3 - 2 * Kappa), (2 * Sf) / (1 - Kappa)))
Eqv	0
Alias (Parameter)	Uf (Utilization Factor)
Description	Appendix 3.6, equivalent rule - (5)
All	Abs(SweldAbs) / Sallow_fatigue
X/Y/Z/XZ	Abs(SweldAbs) / (Sallow_Fatigue / if(WeldType <= Weld_K4, SQRT(2), SQRT(3)))
Eqv	pow(me.x, 2) + pow(me.y, 2) + pow(me.z, 2) + pow(me.xy, 2) + pow(me.yz, 2) + pow(me zx, 2) - sign(SweldAbs.X) * me.x * sign(SweldAbs.Y) * me.y - sign(SweldAbs.Y) * me.y * sign(SweldAbs.Z) * me.z - sign(SweldAbs.Z) * me.z * sign(SweldAbs.X) * me.x
Overall	Max(me.x, me.y, me.z, me.xy, me.yz, me.zx, sqrt(me.eqv))

1..FEM 1.001 (3rd, 1998)

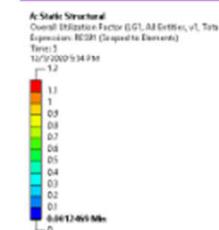
Unit System

Current Unit System = MKS (Meter/Kg/Second). It is used in calculations for the following standards: API RP 2A, ISO 19902, Norsok N004, DIN 15018, FEM 1.001 and Eurocode3.

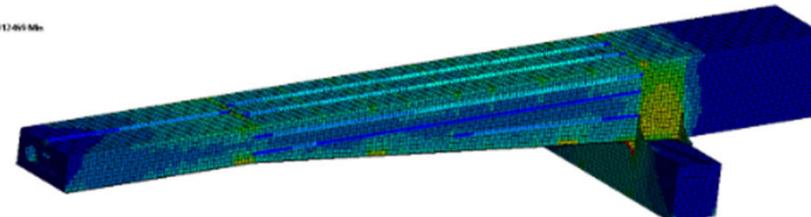
Utilization Factor (LG1, All Entities)

Standard	1..FEM 1.001 (3rd, 1998)		Check Parameter	[S1] 2..Fatigue Check Utilization Factor
Load Group	LG1..Load Group 1			
Selection	All Entities			
Extreme	X	Y	Z	XY
Minimum	0.00	0.00	0.00	0.00
Value	7637	2010	3978	7270
Element ID				4355
Maximum	1.58	1.36	1.04	2.58
Value	12005	17235	12011	12005
Element ID				12005
Absolute	1.58	1.36	1.04	2.58
Value	12005	17235	12011	12005
Element ID				12005

Overall Utilization Factor (LG1, All Entities, v1, Total)



ANSYS
2020 R2

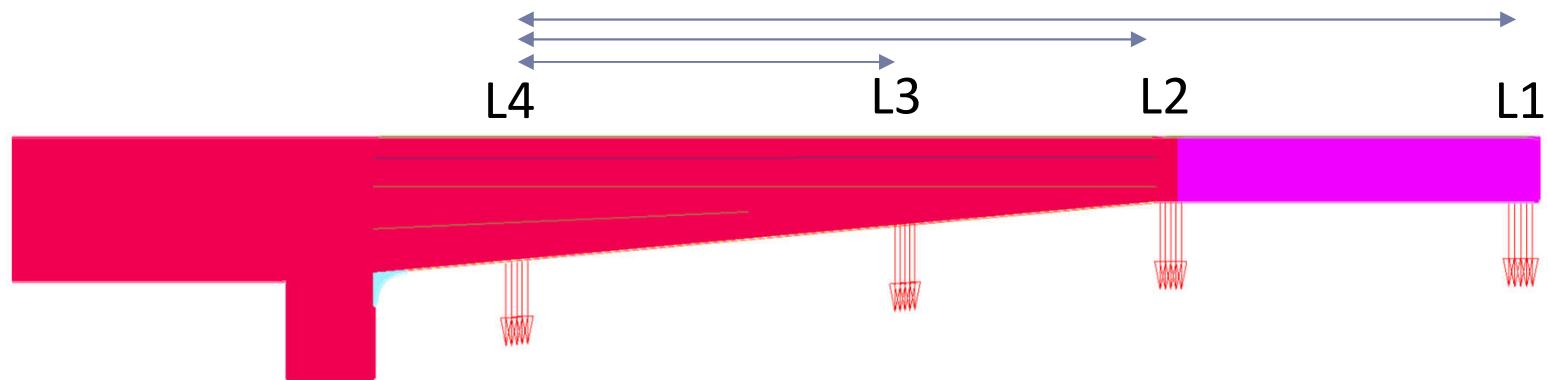


Check	[S1] 2..Fatigue Check	Point Parameter View	Total
Load Group	LG1..Load Group 1		Overall Utilization Factor
Selection	All Entities		1..Default View

Eurocode3 Stress history

- ▶ 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 Select Fatigue Groups in Navigation tree
- 2 Title: Detailed load cycles pattern
- 3 Select all groups and press
- 4 Select 1..L1-L4 and 3..L2-L4
- 5 Fatigue Item Cycles: **0.5e+6** and Set.
- 6 Set **1e+6** cycles for 2..L3-L4
- 7 Press *Create*

SDC Verifier 2020.0.2 - D:\Vitalik\Tutorial\for Ansys\Eurocode3 and FEM1.001 Fatigue\Input data\ANSYS 19.2\Fatigue_files\dp0\SDCv\ACT\Fatigue.ansv

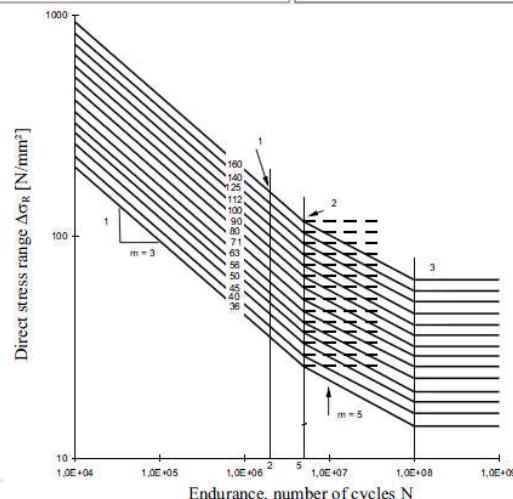
Add Fatigue Group

ID	1	Title	Detailed load cycles pattern	2.
Description				
Fatigue Item Cycles	0.5e6	Set to Selected		
1..Load Group 1	2..L1-L4 500000 3..L2-L4 1 000 000 4..L3-L4 500000			
Total amount of cycles	2 000 000			
3. Total number of load cycles is calculated automatically				

5.

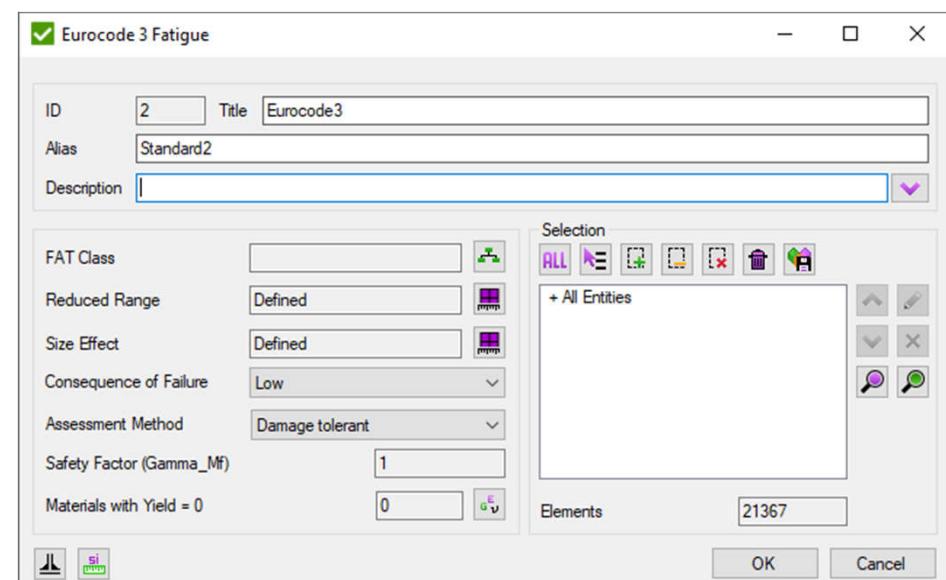
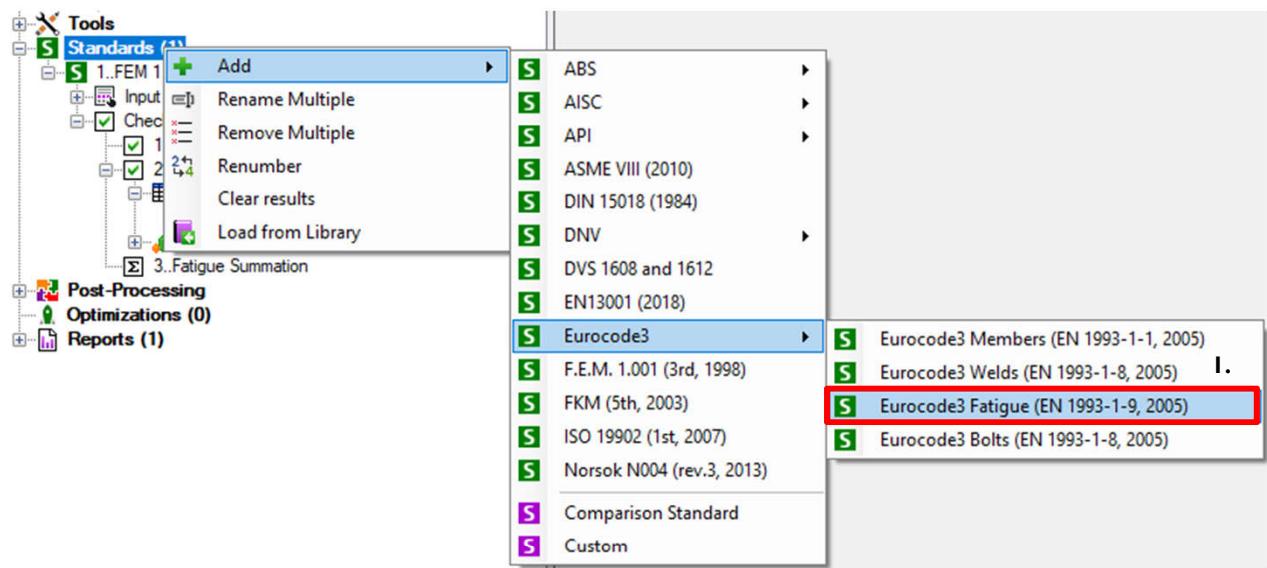
6.

7.



Fatigue calculation with Eurocode 3

- 1 Execute Add => Eurocode 3 Fatigue (EN 1993-1-9) in Standards context menu.
- 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

FAT classes Eurocode3

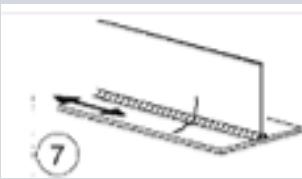
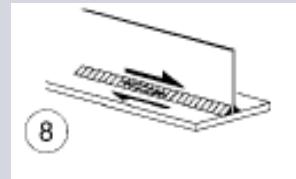
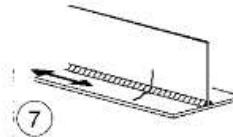
	Perpendicular to weld	Parallel with weld	Shear
Weld	80 	100 	80 
No weld	160 		100 

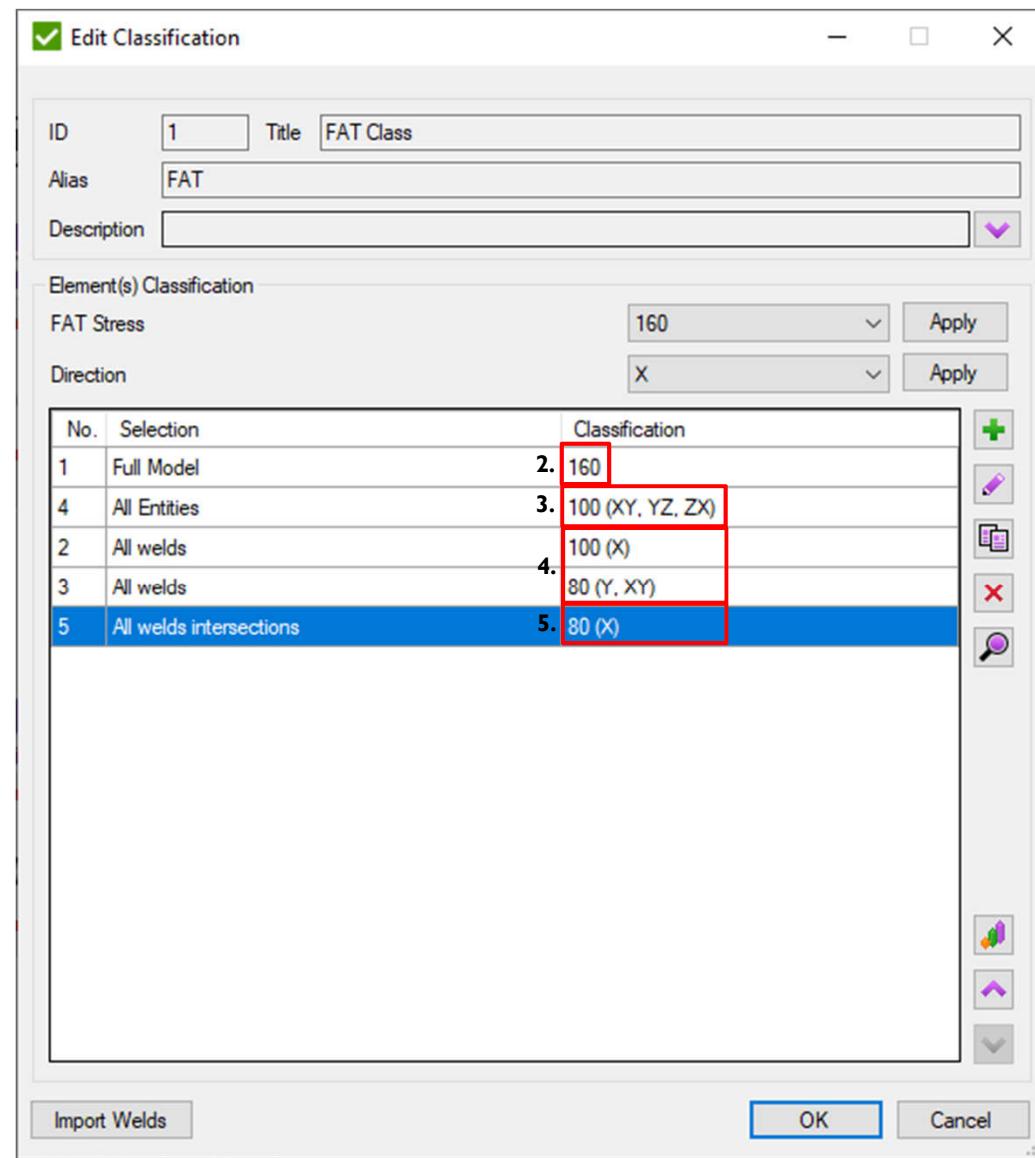
Table 8.1: Plain members and mechanically fastened joints

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

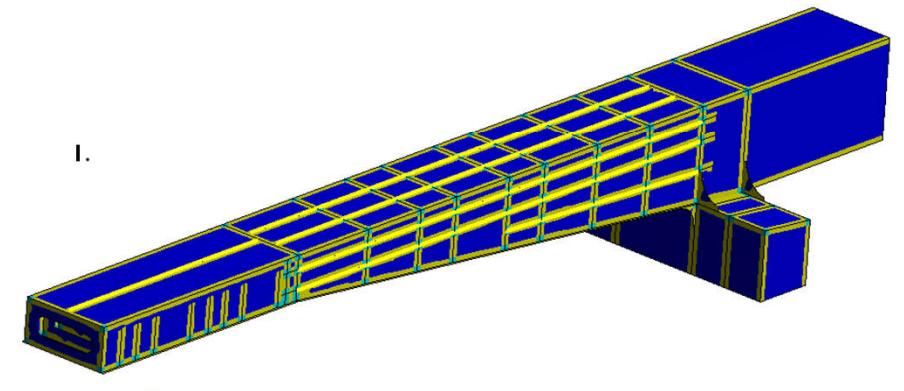
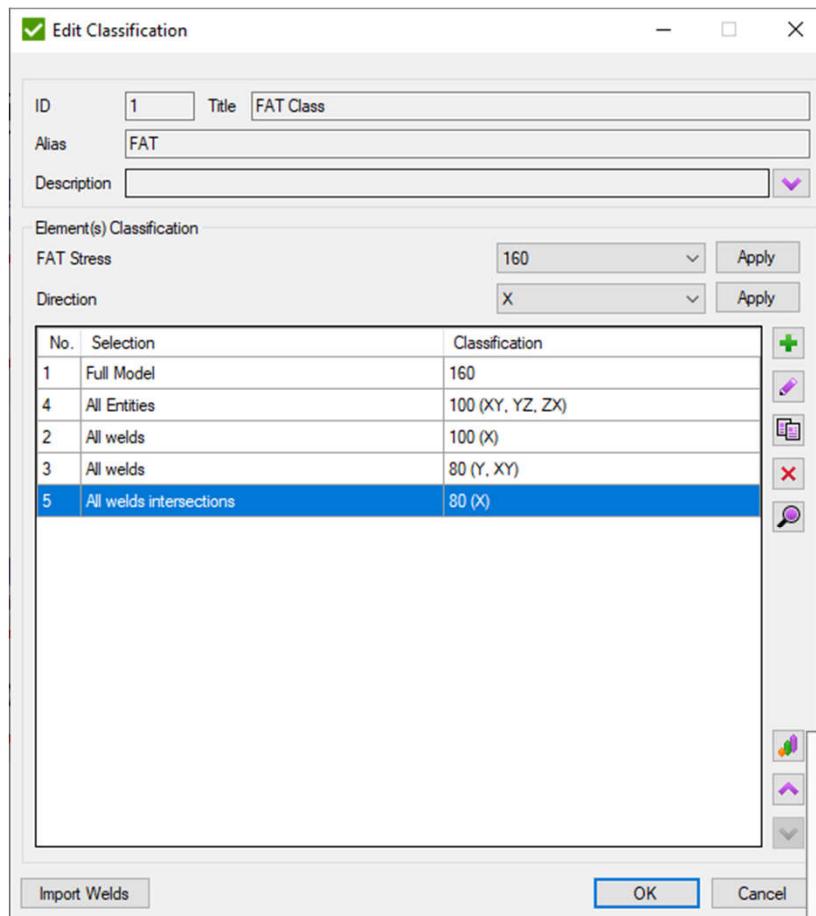
For determination of FAT classes check standard!
In this tutorial only examples are given

Eurocode3 Fat Class

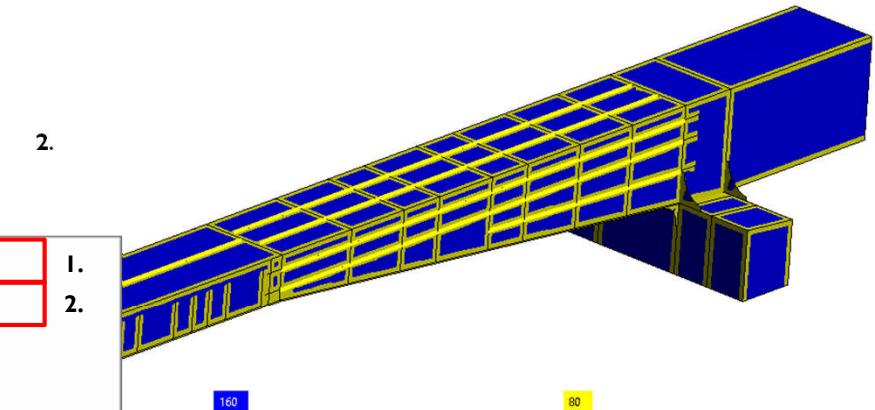
- 1 Press *Define* for the FAT Class.
- 2 Full Model: **160**
- 3 All Entities: **100 (No weld)**
- 4 For welds: X: **100**; Y/XY: **80**
- 5 For welds intersections: X: **80**



FAT classes plot

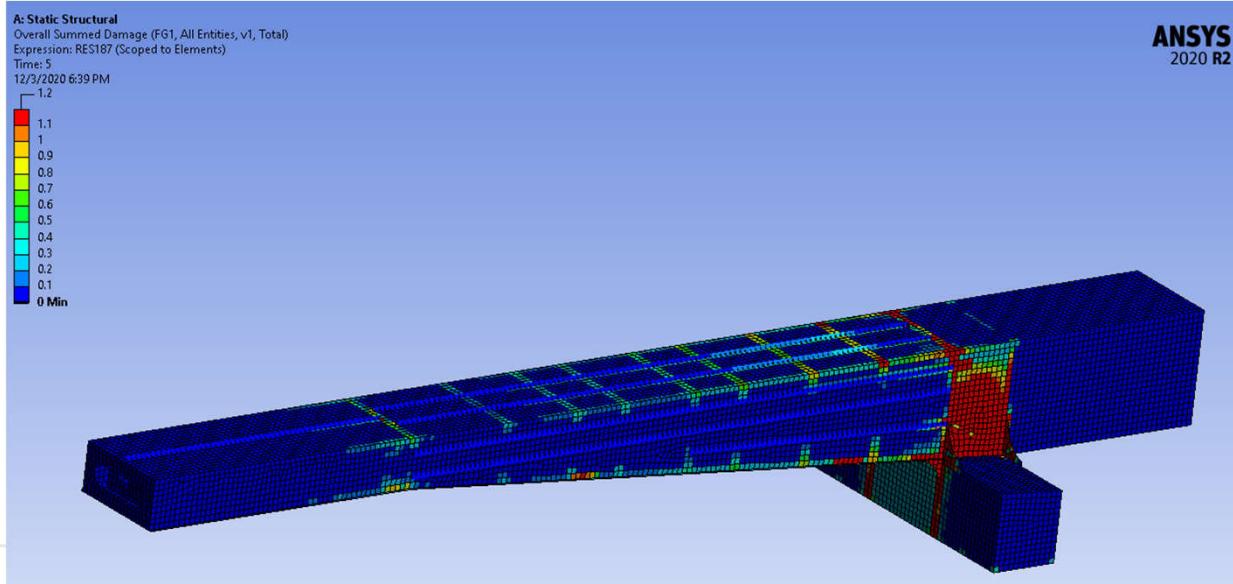
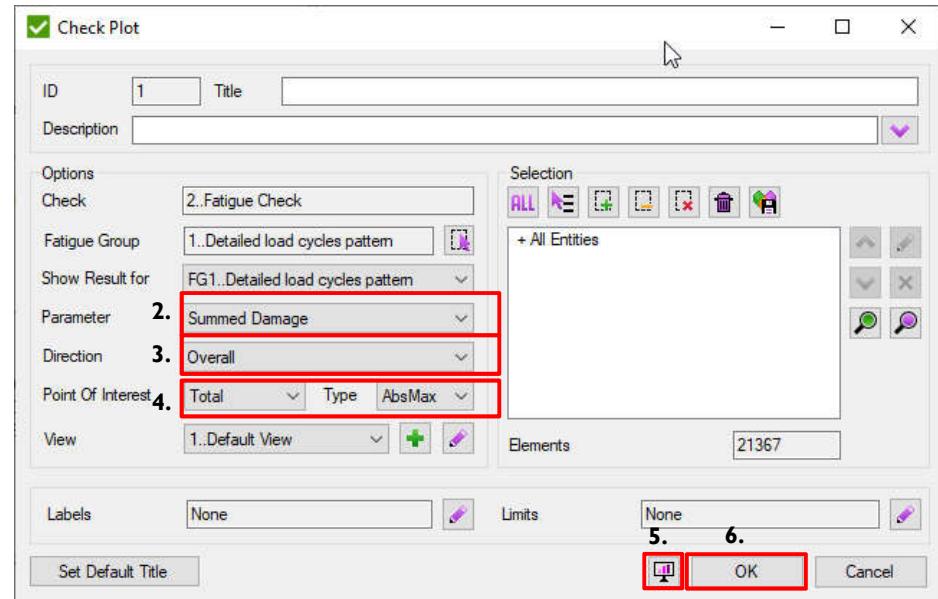


1. **X**
2. **Y**
- Z
XY
YZ
ZX
Equivalent



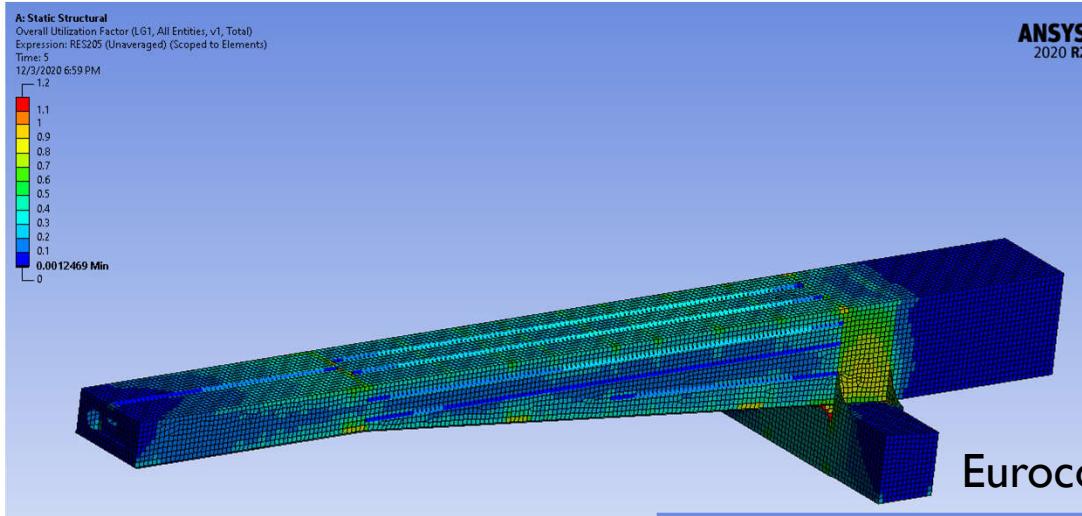
Fatigue Damage Plot

- 1 Execute *Criteria Plot* in **Fatigue Check** context menu
- 2 Parameter: **Summed Damage**
- 3 Direction: **Overall**
- 4 Point of interest: **Total** Type: **AbsMax**
- 5 Press  **Preview**
- 6 Press **OK**



Comparison

FEM 1.001 utilization factor



Eurocode 3 utilization factor at 2 million cycles

