



Tutorial

F.E.M. 1.001 and Eurocode3 Fatigue

ANSYS[®]

22 Jan 2020
version 5.3

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

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

σ_w is given in table above.

b) $\kappa > 0$

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

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

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 :

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

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.

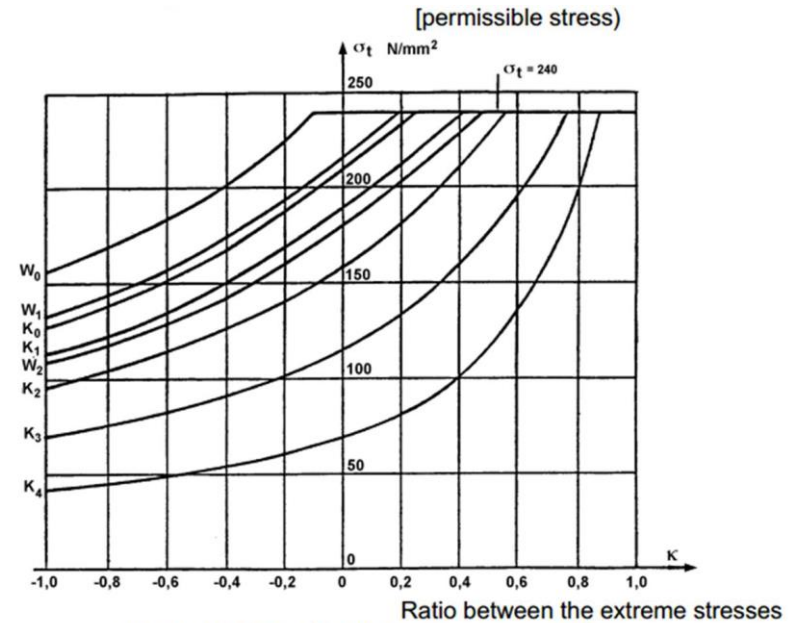


Figure A.3.6.1. - (A 52; tension; group E6)

Fatigue in SDC Verifier

Kappa Factor

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

Allowable Stress

- a) $\kappa \leq 0$
- for tension : $\sigma_t = 5 \cdot \sigma_w / (3 - 2 \cdot \kappa) \quad (1)$
 - for compression : $\sigma_c = 2 \cdot \sigma_w / (1 - \kappa) \quad (2)$
- 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

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

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

☒ Add Custom Check

ID

2

Title

Fatigue Check

Alias

Fatigue_Check

Description

☒ Show Parameter Description

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))`

Options

☒ Calculate Results over Directions

☒ Calculate Results over Points

Load Calculation

Load Group Only

Selection

All Entities

Clear results

OK

Cancel

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)

Component 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	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

Corresponding values of Stress fatigue in SDC Verifier:

Extreme Table

ID: 3 Title:

Description:

Options

Check: 2. Fatigue Check

Load Group: 1. L1-L4

Table Type: Parameter over Directions

Parameter: Stress Fatigue

Detailed (results location) Short

Selection: ALL

Elements: 10916

Extreme	X	Y	Z	XY	YZ	ZX	Ekv	Overall
Minimum								
Value	0.0956e+6	0.0956e+6		0.1275e+6			0.1478e+6	0.0000e+6
Element ID	499	326		326			326	326
Maximum								
Value	0.1138e+6	0.0956e+6		0.1275e+6			0.1478e+6	0.0000e+6
Element ID	326	326		326			326	326
Absolute								
Value	0.1138e+6	0.0956e+6		0.1275e+6			0.1478e+6	0.0000e+6
Element ID	326	326		326			326	326

Fill Table OK Cancel

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 W₀

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 K₀ - Slight stress concentration

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

Case K₁ - 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 K₂ - 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 K₃ - Severe stress concentration

Reference	Description	Figure	Symbol
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 K₄ - 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		

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** ($1.8 \text{ million} < 2 \times 10^6$)

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}	≤	0,125
P2	0,125	< k_{sp}	≤	0,250
P3	0,250	< k_{sp}	≤	0,500
P4	0,500	< k_{sp}	≤	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

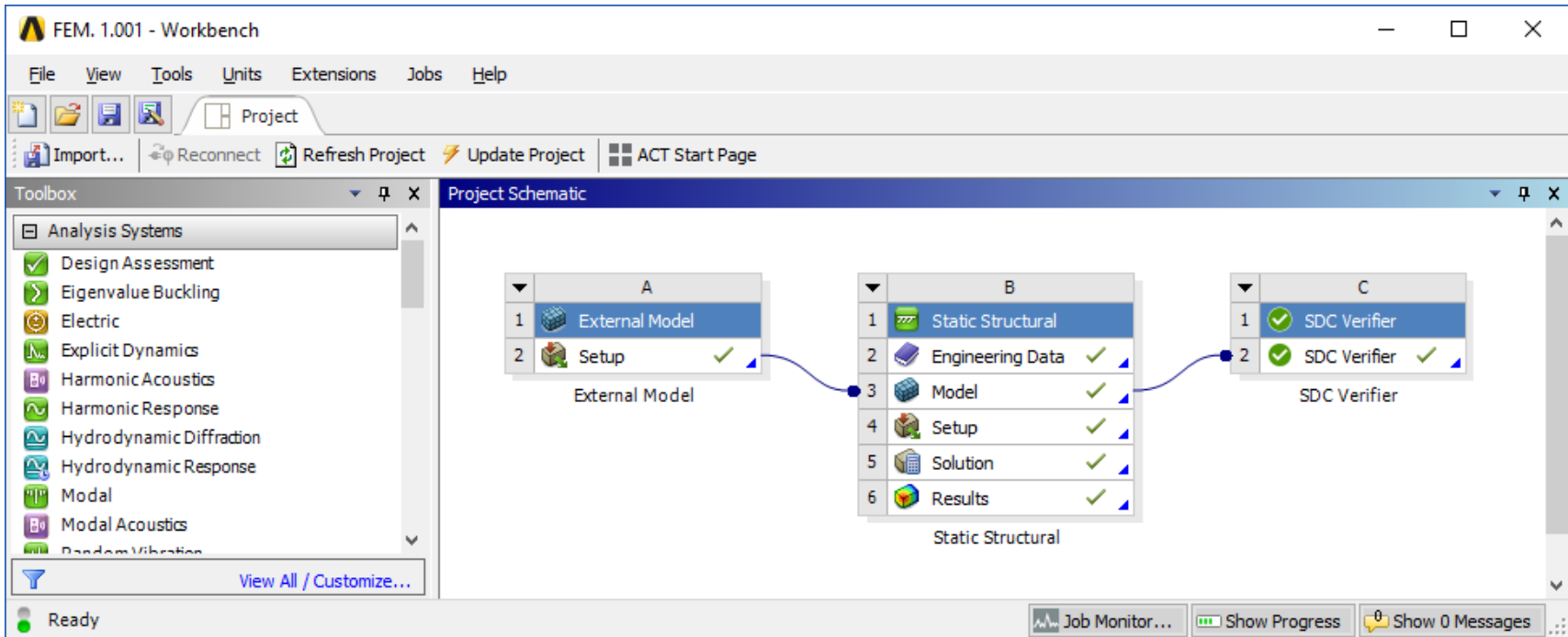
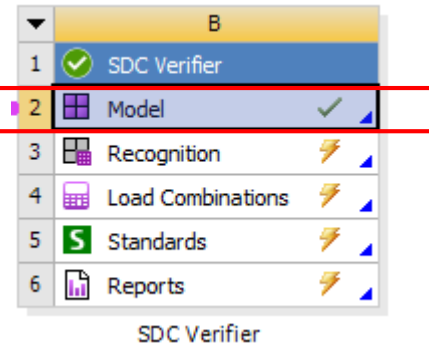
Stress Spectrum class	Class of utilization										
	B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
P1	E1	E1	E1	E1	E2	E3	E4	E5	E6	E7	E8
P2	E1	E1	E1	E2	E3	E4	E5	E6	E7	E8	E8
P3	E1	E1	E2	E3	E4	E5	E6	E7	E8	E8	E8
P4	E1	E2	E2	E4	E5	E6	E7	E8	E8	E8	E8

Open the starter model

1 Open in **ANSYS Workbench** 
FEM. 1.001 and Eurocode 3 Fatigue.wbpz

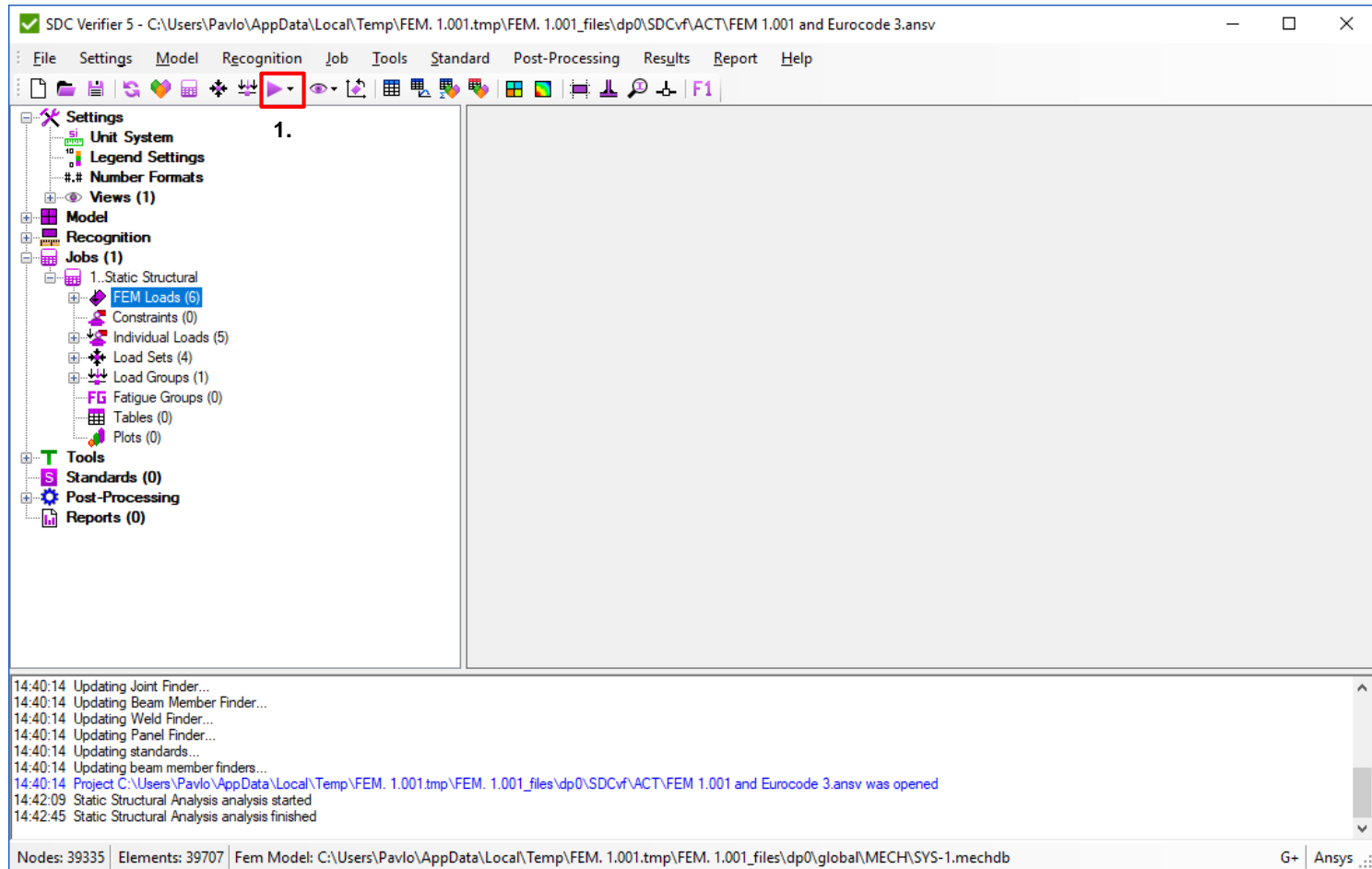
2 Double Click on  SDC Verifier 
or in context menu click **Edit**

2.



Run Analysis


1 Press  to start Analysis in ANSYS

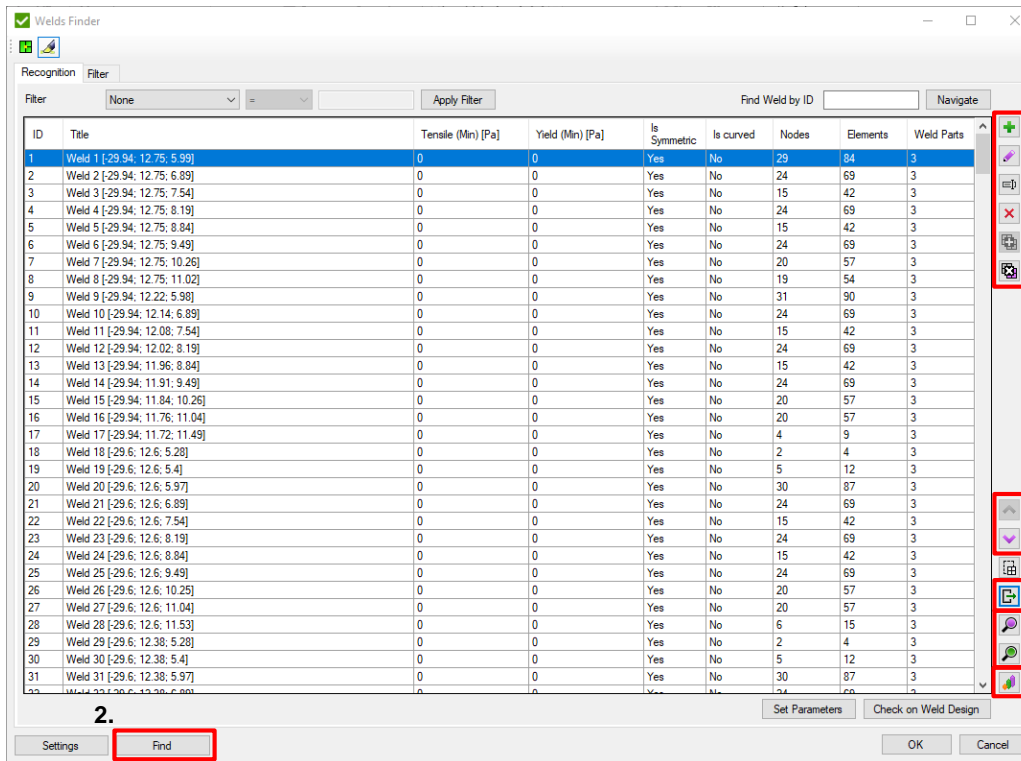
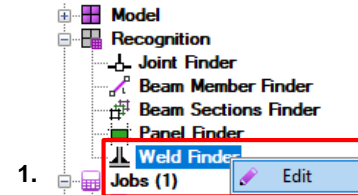


Weld Finder

1 Execute Recognition => **Weld Finder** => **Edit...**

2 Press *Find*.

3 Press  to Export selected sections to components



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

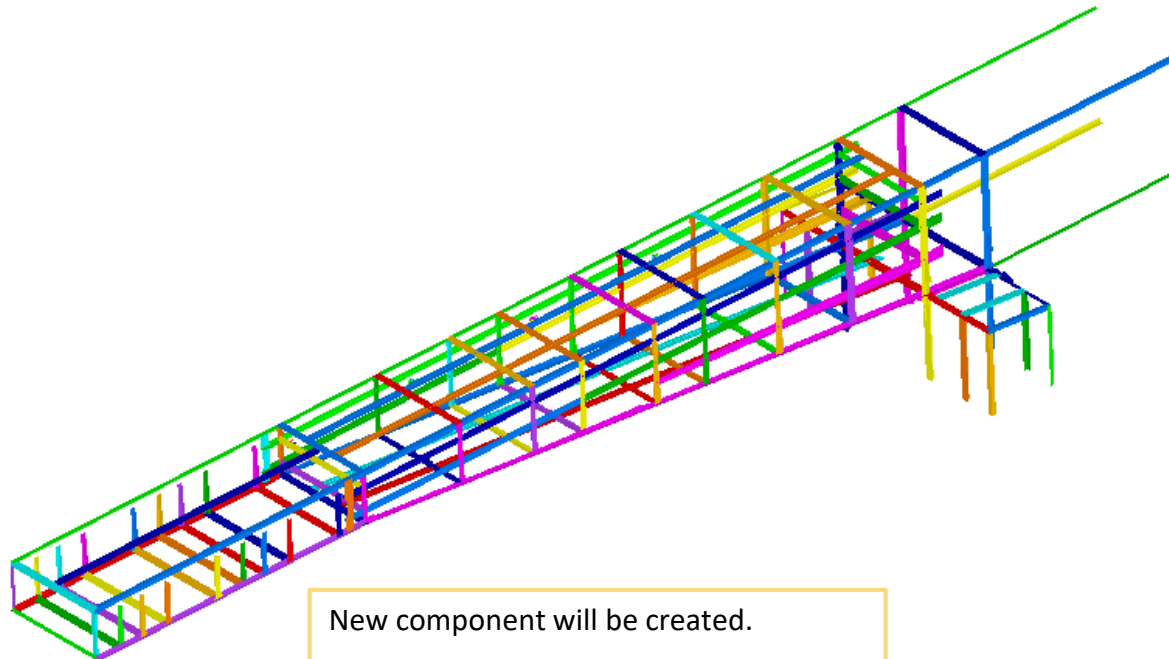
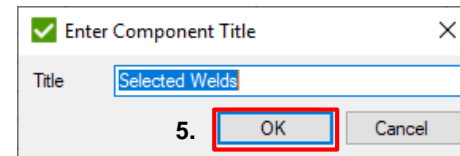
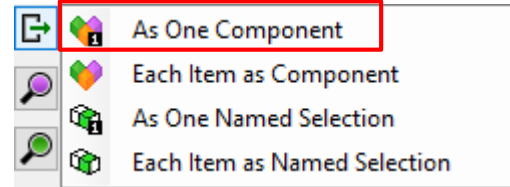
4

Click *As One Component*

5

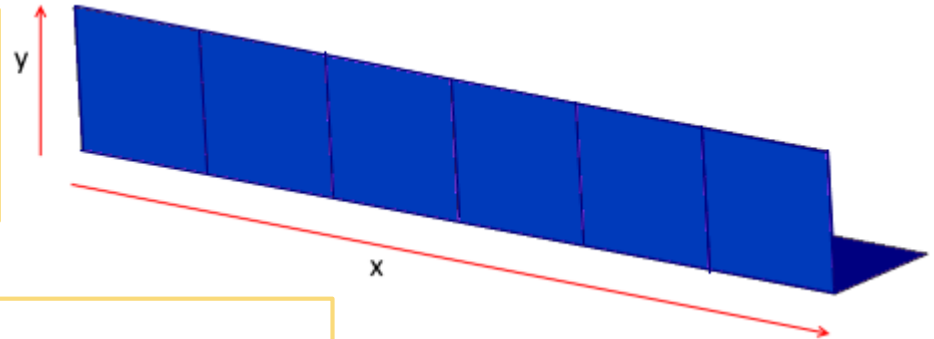
Press *OK*.

4.



New component will be created.

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

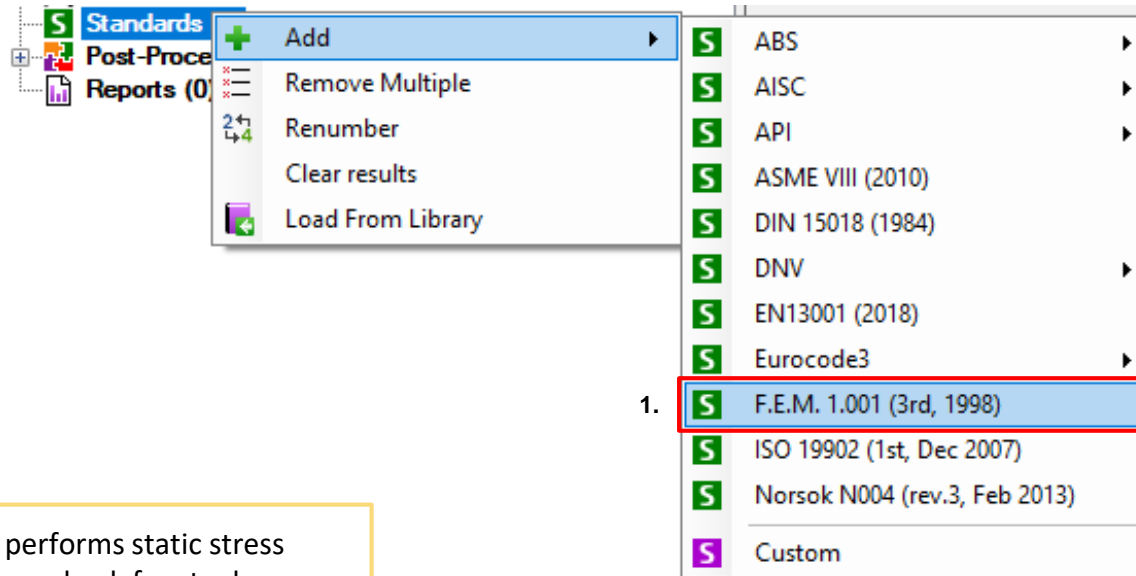
$\sigma_{tt}, \sigma_{nn}, \tau_{nt}$ – transformed x, y and shear stress in weld x, y and shear directions

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**

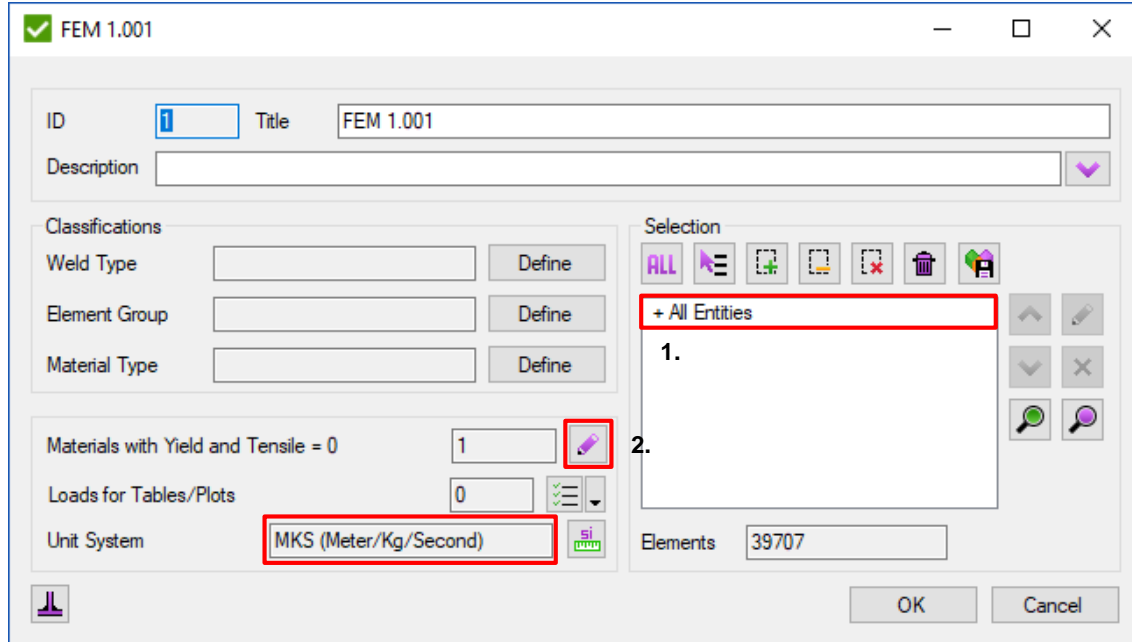
2 Press  to edit material properties.

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

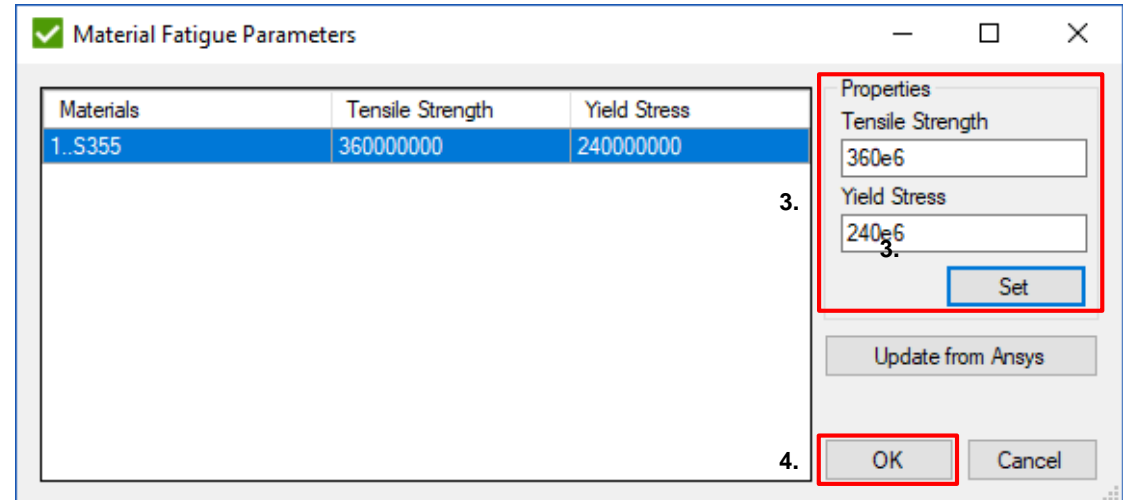
3 Tensile Strength: **360e6**
Yield Stress: **240e6** and Press **Set**.

4 Press **OK**.

Unit System. Stress Fatigue values are constant for specified material and are measured in Pa. Changing unit system enables to convert Pa into Mpa, for example.



The FEM 1.001 dialog box is shown. The ID is 1 and the Title is FEM 1.001. The Description field is empty. The Selection list shows '+ All Entities' and '1.'. The Materials with Yield and Tensile = 0 field shows 1. The Loads for Tables/Plots field shows 0. The Unit System is set to MKS (Meter/Kg/Second). The Elements field shows 39707. The OK and Cancel buttons are at the bottom right.



The Material Fatigue Parameters dialog box is shown. The Materials table lists material 1.S355 with Tensile Strength 360000000 and Yield Stress 240000000. The Properties section shows Tensile Strength 360e6 and Yield Stress 240e6. The Set button is highlighted. The OK and Cancel buttons are at the bottom right.

Materials	Tensile Strength	Yield Stress
1.S355	360000000	240000000

Properties

Tensile Strength: 360e6

Yield Stress: 240e6

Set


Update from Ansys

OK Cancel

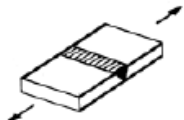


- ▶ Weld/notch category determines fatigue resistance
- ▶ Division in welds / non welds for FEM 1.001:
 - ▶ W category is for non welded parts
 - ▶ K category is for welded parts
- ▶ Fatigue resistance is further specified by adding classes
 - ▶ W0-W2 for non-welded parts
 - ▶ K0-K4 for welded parts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

Weld 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.		—

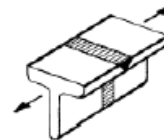


Slight notch behavior group K0

nr.	description of the main types		symbol
011	Parts, jointed by a butt weld of special quality, perpendicular to the direction of force.		 P 100  P 100

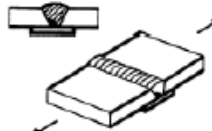
Moderate notch behavior group K1

nr.	description of the main types		symbol
111	Parts, jointed by a butt weld of ordinary quality, perpendicular to the direction of force.		 P or P 100  P or P 100

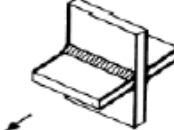
Medium notch behavior group K2

nr.	description of the main types		symbol
211	Profiles, jointed by butt welds of special quality, perpendicular to the direction of force.		 P 100  P 100

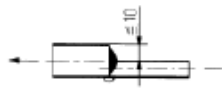


Great notch behavior group K3

311	Parts jointed by a butt weld with a backing strap, without sealing run and perpendicular to the direction of force. Backing strap fixed by tack welding.		>
-----	--	---	---

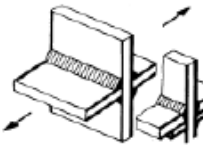


and a different connection type 351

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

Very great notch behavior group K4

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

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.		 D  D
-----	---	---	--

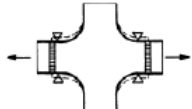


	Perpendicular to weld	Parallel with weld	Shear
Weld	K1	K2	K0
No weld	W0		$\tau_D(-1) = \sigma_D(-1) / \text{sqrt}(3)$

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

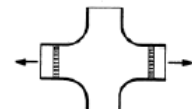


For beams SCF of connections can be included in the classification

Depends on Stress concentrations:

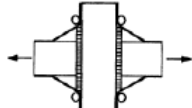


Slight notch behavior group K0

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

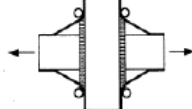


Moderate notch behavior group K1

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

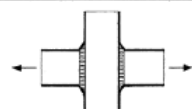


Medium notch behavior group K2

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

Great notch behavior group K3

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

Very great notch behavior group K4

413	Butt weld 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 *Define* for the Weld Type.

2

Press  to Add Condition.

3

Press *Add all Welds*

4

Select *Multiple Conditions* options

5

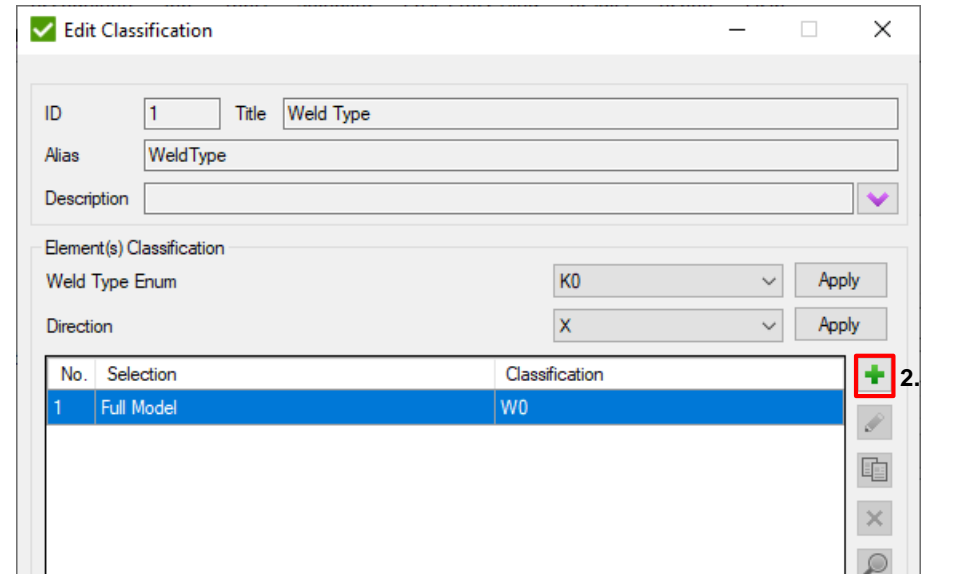
Press *X/Y/XY*

6

X: **K1** Y: **K2** XY: **K0**

7


Press *OK*





Edit Classification



ID: 1 Title: Weld Type

Alias: WeldType


Description: 

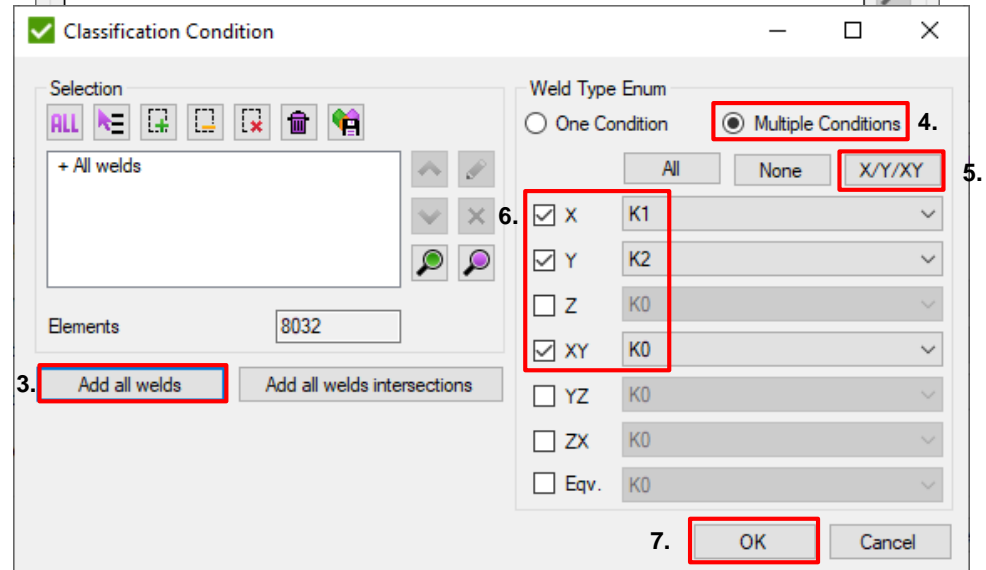
Element(s) Classification

Weld Type Enum: K0  








Direction: X  

No.	Selection	Classification
1	Full Model	W0

 2.



Classification Condition

Selection:       

+ All welds

Elements: 8032

Weld Type Enum

☐ One Condition ☒ Multiple Conditions 4.

All None **X/Y/XY** 5.

<input checked="" type="checkbox"/>	X	K1
<input checked="" type="checkbox"/>	Y	K2
<input type="checkbox"/>	Z	K0
<input checked="" type="checkbox"/>	XY	K0
<input type="checkbox"/>	YZ	K0
<input type="checkbox"/>	ZX	K0
<input type="checkbox"/>	Eqv.	K0

6.

3. **Add all welds** Add all welds intersections

7. **OK** Cancel

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  


Direction: X  


No.	Selection	Classification
1	Full Model	W0
2	All welds	K1 (X)
3	All welds	K2 (Y)
4	All welds intersections	K0 (XY)


 1.






































Check classification

✓ Edit Classification

ID: 1 Title: Weld Type

Alias: WeldType

Description:

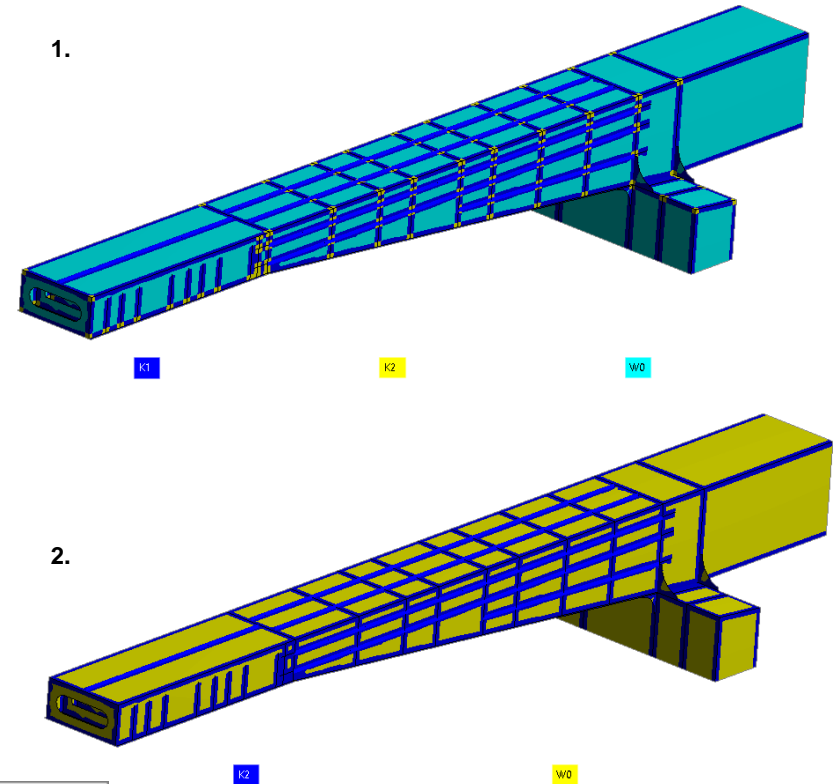
Element(s) Classification

Weld Type Enum: K0 Apply

Direction: X Apply

No.	Selection	Classification
1	Full Model	W0
2	All welds	K1 (X)
3	All welds	K2 (Y)
4	All welds	K0 (XY)
5	All welds intersections	K2 (X)


Import Welds OK Cancel



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

Element Group classification

1

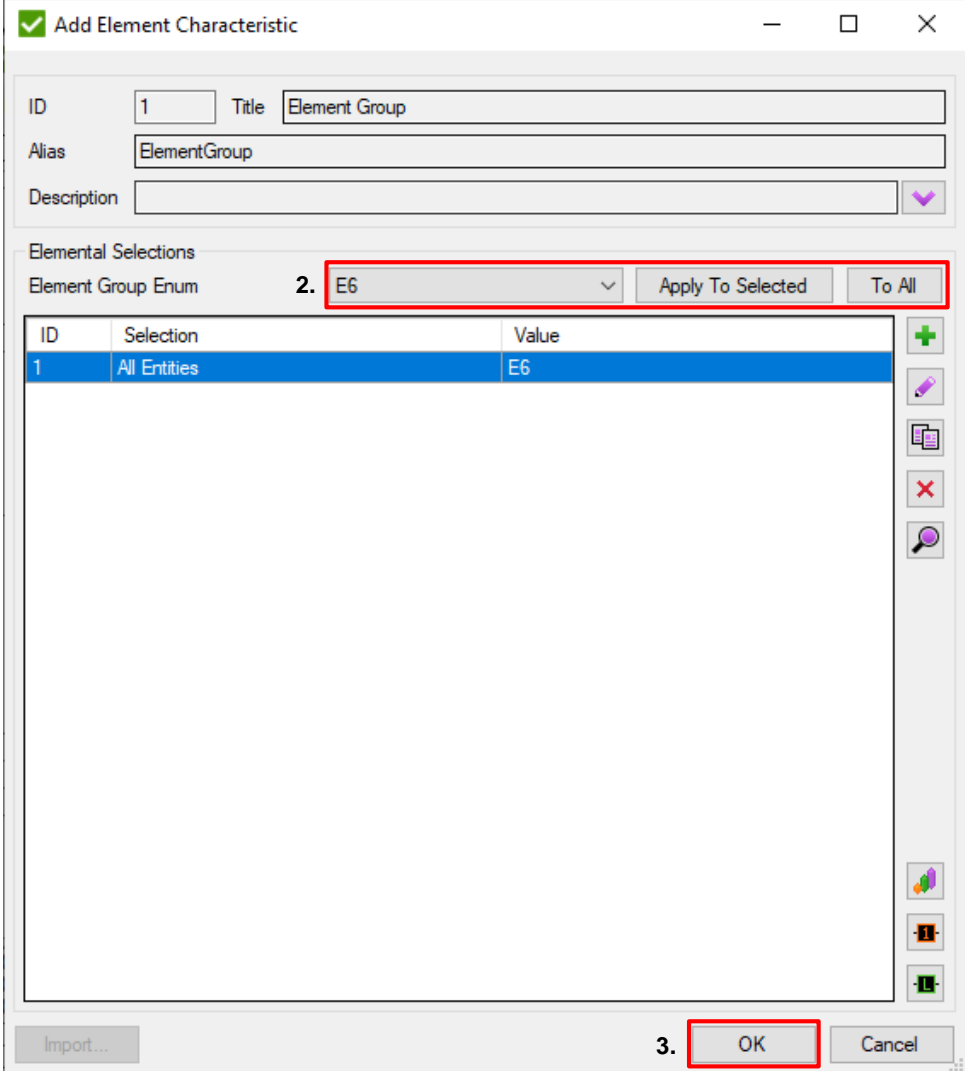
Press  for the Element Group.

2

Select Element Group: **E6**. Press *To All*.

3


Press *OK*.




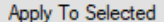

Add Element Characteristic

ID: 1 Title: Element Group

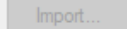
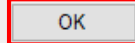

Alias: ElementGroup

Description: 


Elemental Selections

Element Group Enum: 2. E6   

ID	Selection	Value
1	All Entities	E6

Material Type classification

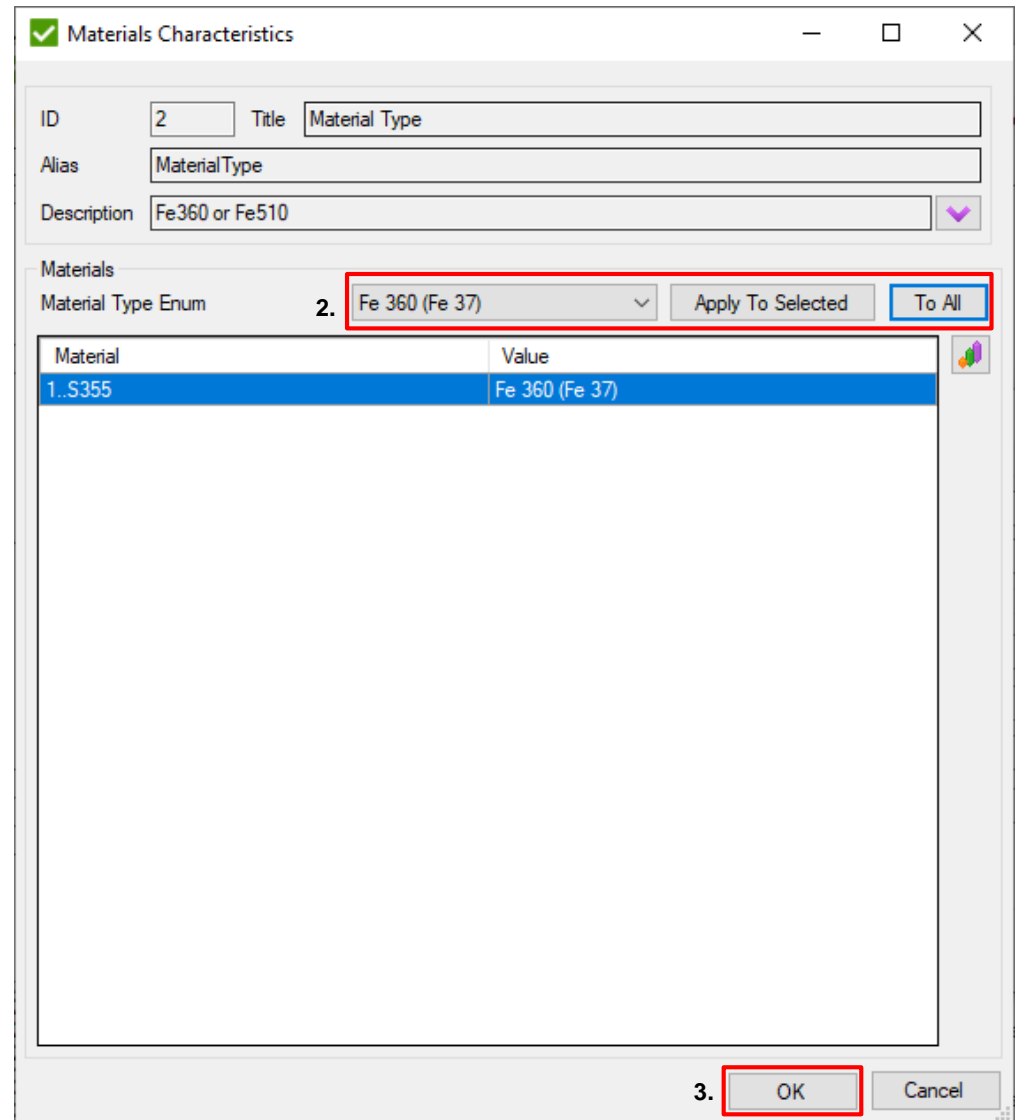
1 Press  for the Material Type.

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.




The dialog box 'Materials Characteristics' contains the following fields and controls:

- ID: 2
- Title: Material Type
- Alias: MaterialType
- Description: Fe360 or Fe510
- Materials section:
 - Material Type Enum: 2. Fe 360 (Fe 37) (highlighted with a red box)
 - Buttons: Apply To Selected, To All (highlighted with a red box)
- Table:

Material	Value
1..S355	Fe 360 (Fe 37)
- Buttons at the bottom: OK (highlighted with a red box), Cancel

Create extreme table

1 Execute  *Table (expand/extreme)* in **Fatigue Check** context menu.

2 Load: **1..Load Group1.**

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

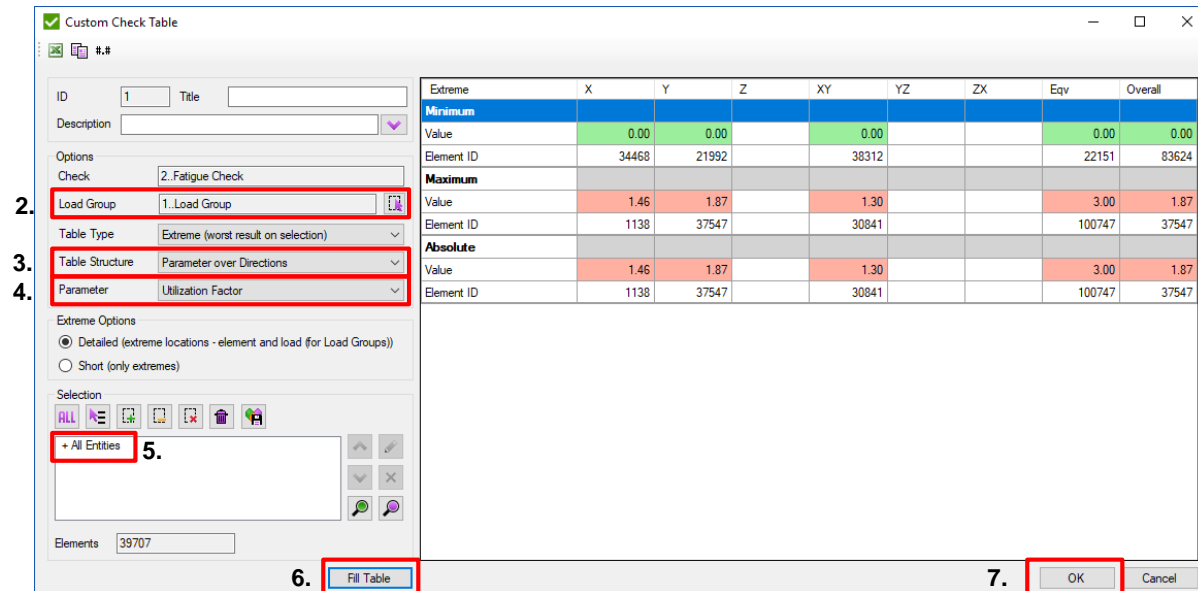
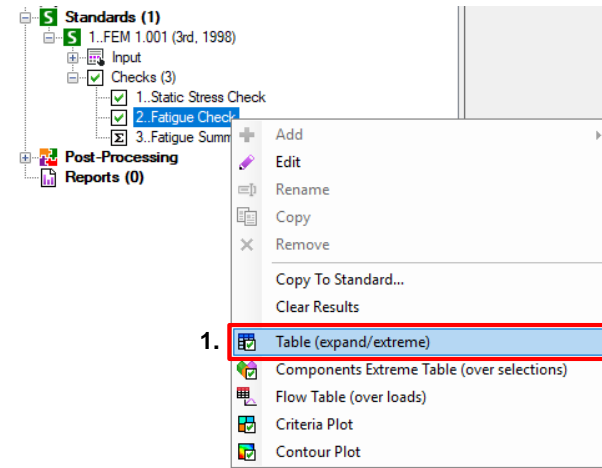
3 Table Type: **Parameter over Directions.**

4 Parameter: **Utilization Factor.**


5 Selection: **All Entities.**

6 Press *Fill Table*.

7 Press *OK*.



Create criteria plot

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

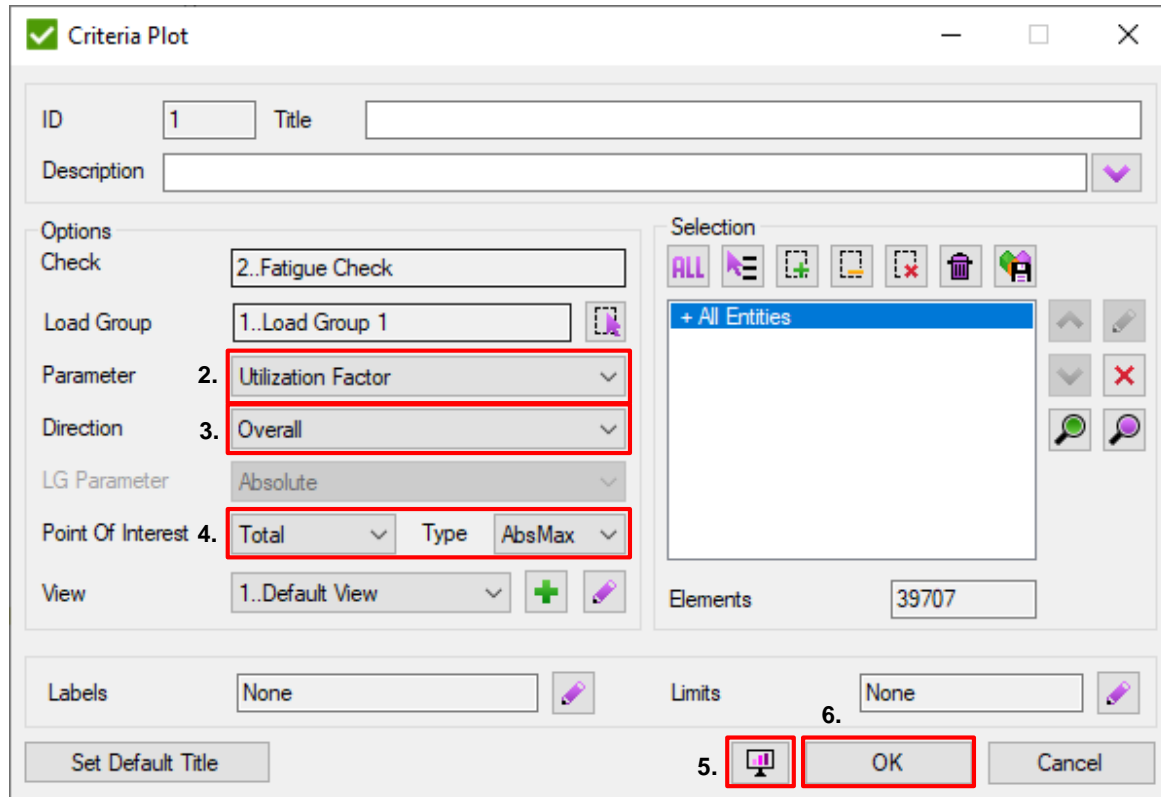
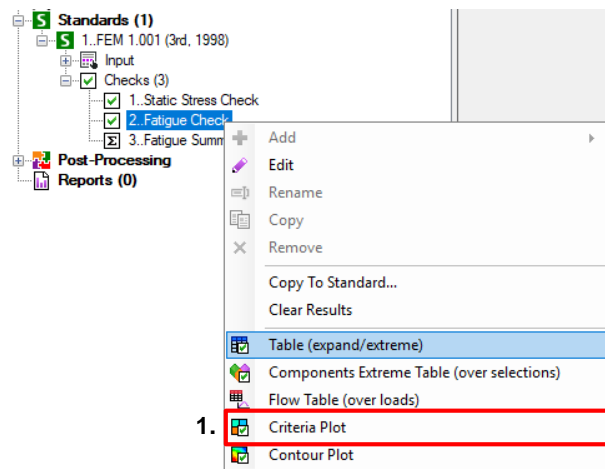
2 Parameter: **Utilization Factor**

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 Execute Reports => Add Report Designer
=> Results.

2 Click on *Expand/Extreme Tables* in
Fatigue Check context menu.

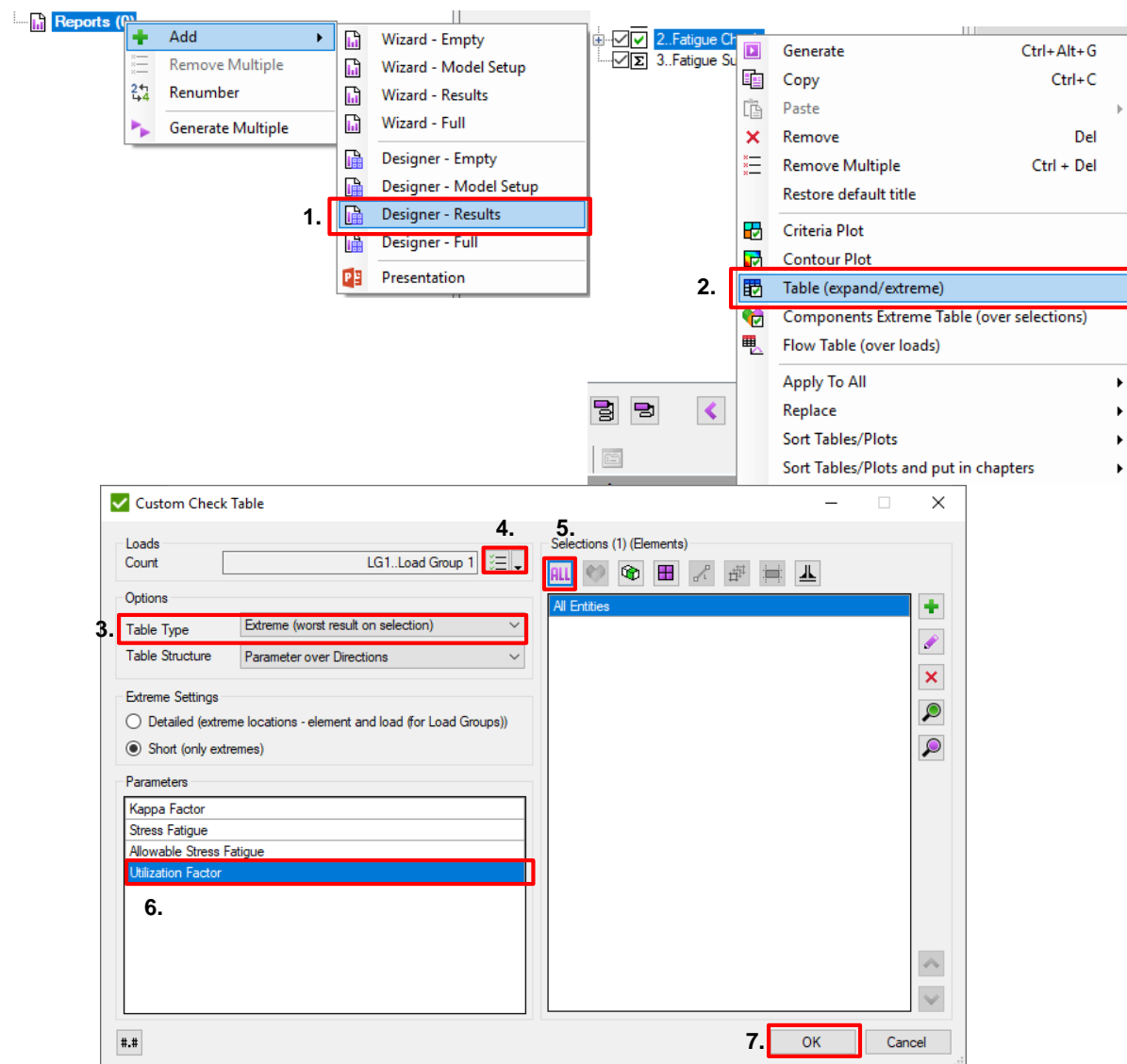
3 Table Type: **Extreme**.

4 Load Group: **1..Load Group**

5 Selection: **All Entities**.

6 Parameter: **Utilization Factor**.

7 Press **OK**.



Report. Tables and plots

1 Click on *Criteria Check Plot* in **Fatigue Check** context menu.

2 Parameter: **Utilization Factor**.

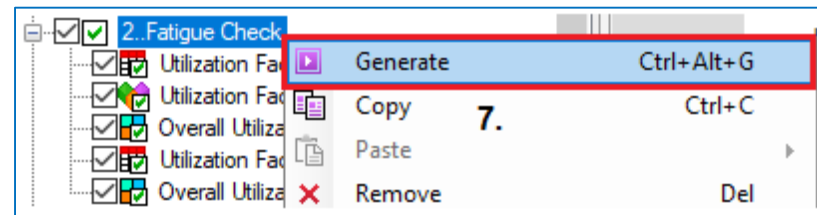
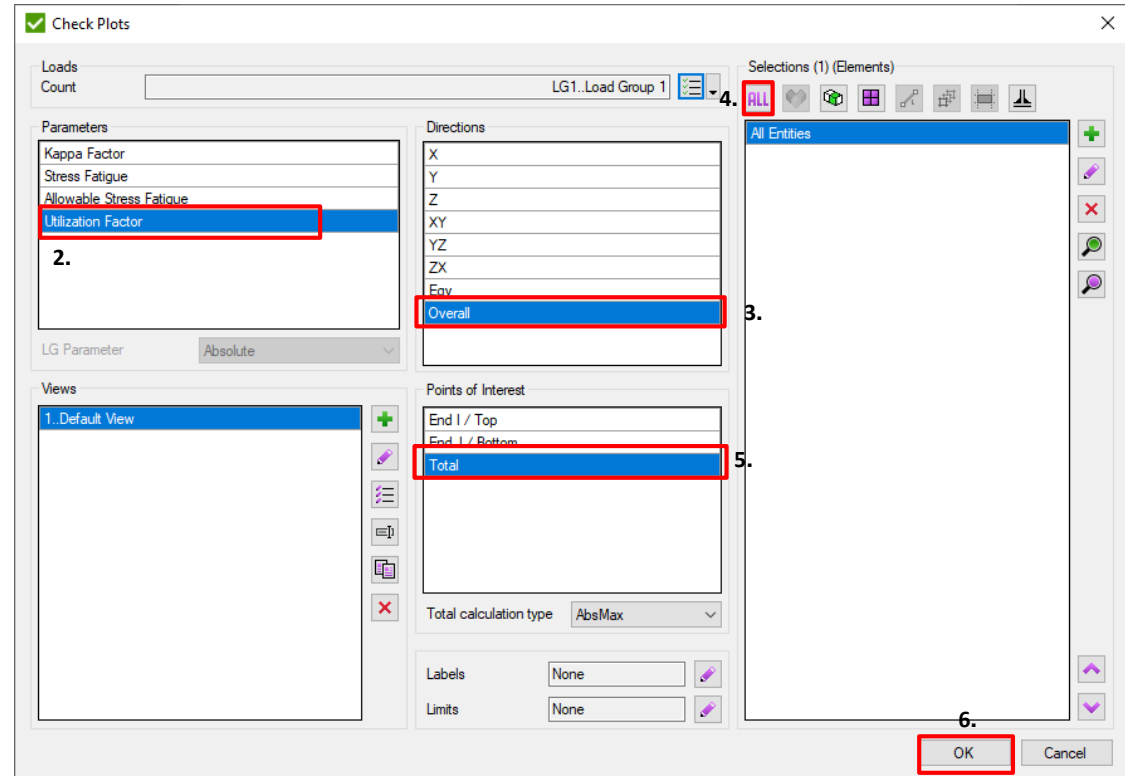
3 Direction: **Overall**

4 Point of Interest: **Total**.

5 Selection: **All Entities**.

6 Press **OK**.

7 **Generate**  check item



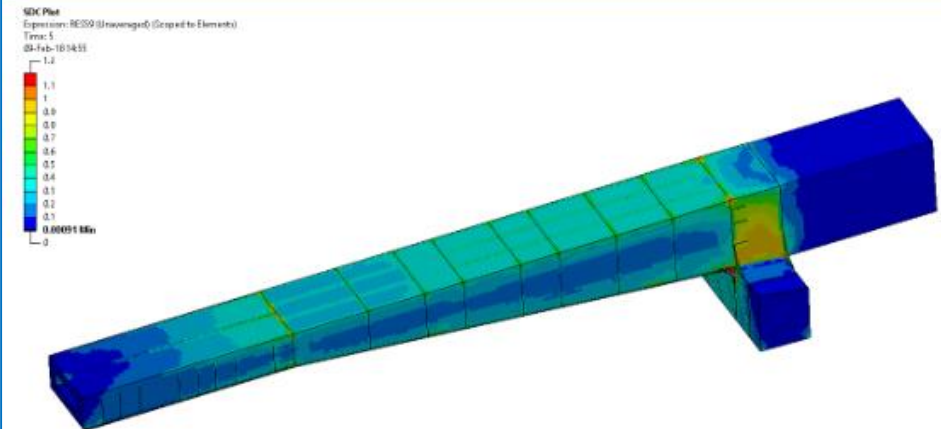
Report. Results

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	$\text{if}(\text{SweldAbs} > 0, \text{SweldMin} / \text{SweldMax}, \text{SweldMax} / \text{SweldMin})$
Alias (Parameter)	Sf (Stress Fatigue)
Description	Permissible stress for fatigue depends on the element group (E1-E8) and weld type
All	$\text{Min}(\text{units.FromPaToCurrent}(\text{Switch}(\text{MaterialType}, \text{Fe360}, \text{Sf_Fe360}(\text{ElementGroup}, \text{WeldType}), \text{Fe510}, \text{Sf_Fe510}(\text{ElementGroup}, \text{WeldType}))), 0.75 * \text{Tensile})$
Alias (Parameter)	Sallow_fatigue (Allowable Stress Fatigue)
Description	Appendix 3.6, formulas (1)-(4)
All	$\text{if}(\text{Kappa} > 0, \text{if}(\text{SweldAbs} > 0, 1, 1.2) * (5 / 3 * \text{Sf}) / (1 - (5 / 3 * \text{Sf}) / (0.75 * \text{tensile})) * \text{Kappa}), \text{if}(\text{SweldAbs} > 0, (5 * \text{Sf}) / (3 - 2 * \text{Kappa}), (2 * \text{Sf}) / (1 - \text{Kappa})))$
Eqv	0
Alias (Parameter)	Uf (Utilization Factor)
Description	Appendix 3.6, equivalent rule - (5)
All	$\text{Abs}(\text{SweldAbs}) / \text{Sallow_Fatigue}$
XY/YZ/ZX	$\text{Abs}(\text{SweldAbs}) / (\text{Sallow_Fatigue} / \text{if}(\text{WeldType} \leq \text{Weld_K4}, \text{SQRT}(2), \text{SQRT}(3)))$
Eqv	$\text{pow}(\text{me.x}, 2) + \text{pow}(\text{me.y}, 2) + \text{pow}(\text{me.z}, 2) + \text{pow}(\text{me.xy}, 2) + \text{pow}(\text{me.yz}, 2) + \text{pow}(\text{me.zx}, 2) - \text{sign}(\text{SweldAbs.X}) * \text{me.x} * \text{sign}(\text{SweldAbs.Y}) * \text{me.y} - \text{sign}(\text{SweldAbs.Y}) * \text{me.y} * \text{sign}(\text{SweldAbs.Z}) * \text{me.z} - \text{sign}(\text{SweldAbs.Z}) * \text{me.z} * \text{sign}(\text{SweldAbs.X}) * \text{me.x}$
Overall	$\text{Max}(\text{me.x}, \text{me.y}, \text{me.z}, \text{me.xy}, \text{me.yz}, \text{me.zx}, \text{sqrt}(\text{me.eqv}))$

Utilization Factor (LG1, All Entities)								
Standard	1..FEM 1.001			Check	[S1] 2..Fatigue Check			
Load Group	LG1..Load Group			Parameter	Utilization Factor			
Selection	All Entities							
Extreme	X	Y	Z	XY	YZ	ZX	Eqv	Overall
Minimum								
Value	0.00	0.00		0.00			0.00	0.00
Element ID	34468	21992		38312			22151	83624
Maximum								
Value	1.46	1.87		1.30			3.00	1.87
Element ID	1138	37547		30841			100747	37547
Absolute								
Value	1.46	1.87		1.30			3.00	1.87
Element ID	1138	37547		30841			100747	37547

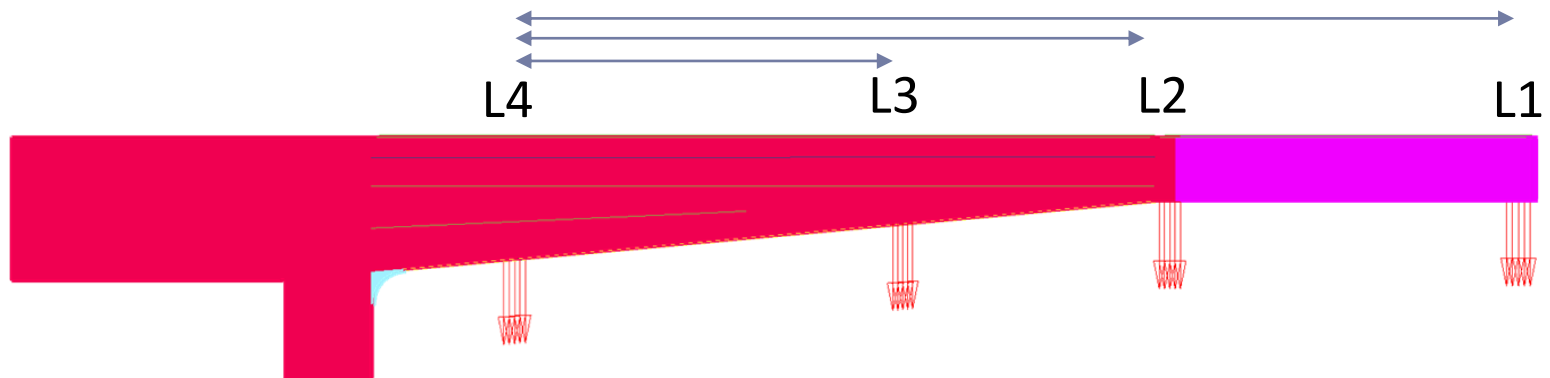
Overall Utilization Factor (LG1, All Entities, v1, Total)



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

- ▶ 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**

The screenshot shows the SDC Verifier 5.0 interface. The 'Add Fatigue Group' dialog is open, showing the following fields:

- ID:** 1
- Title:** Detailed load cycles pattern
- Description:** (empty)
- Fatigue Item Cycles:** 0.5e6
- Set:** (button)

The 'Fatigue Groups' tree on the left shows the following structure:

- 1. Static Structural
 - 2. FEM Loads (6)
 - 3. Constraints (0)
 - 4. Individual Loads (5)
 - 5. Load Sets (4)
 - 6. Load Groups (4)
 - 1. Load Group
 - 2. L1-L4
 - 3. L2-L4
 - 4. L3-L4

The 'Add Fatigue Group' dialog also shows a table of load groups:

Load Group	Cycles
2. L1-L4	500000
3. L2-L4	1000000
4. L3-L4	1500000

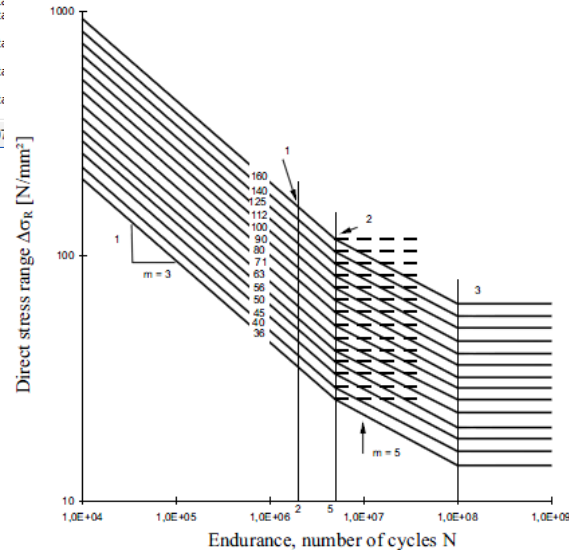
The 'Total amount of cycles' is 2000000. The 'Create' button is highlighted.

The bottom part of the screenshot shows a log window with the following text:

```

15:06:24 Saving backup file...
15:06:24 C:\Users\Pavlo\AppData\Local\Temp\FEM. 1.001.tmp\FEM. 1.001_files\dp0\SDCv\FCT\FEM 1.001 and Eurocode 3.ansv
15:11:24 C:\Users\Pavlo\AppData\Local\Temp\FEM. 1.001.tmp\FEM. 1.001_files\dp0\SDCv\FCT\FEM 1.001 and Eurocode 3.ansv
15:11:24 Saving backup file...
15:11:24 C:\Users\Pavlo\AppData\Local\Temp\FEM. 1.001.tmp\FEM. 1.001_files\dp0\SDCv\FCT\FEM 1.001 and Eurocode 3.ansv
15:16:24 C:\Users\Pavlo\AppData\Local\Temp\FEM. 1.001.tmp\FEM. 1.001_files\dp0\SDCv\FCT\FEM 1.001 and Eurocode 3.ansv
15:16:24 Saving backup file...
15:16:24 C:\Users\Pavlo\AppData\Local\Temp\FEM. 1.001.tmp\FEM. 1.001_files\dp0\SDCv\FCT\FEM 1.001 and Eurocode 3.ansv
    
```

The bottom part of the screenshot shows a plot of Direct stress range $\Delta\sigma_R$ [N/mm²] versus Endurance, number of cycles N . The plot shows three curves labeled 1, 2, and 3, representing different detail categories. The curves are plotted on a log-log scale. The y-axis ranges from 10 to 1000 N/mm², and the x-axis ranges from 1.0E+04 to 1.0E+08 cycles. The curves are labeled 1, 2, and 3, corresponding to the detail categories defined in the legend.



- 1 Detail category $\Delta\sigma_c$
- 2 Constant amplitude fatigue limit $\Delta\sigma_D$
- 3 Cut-off limit $\Delta\sigma_L$

Fatigue calculation with Eurocode 3

1

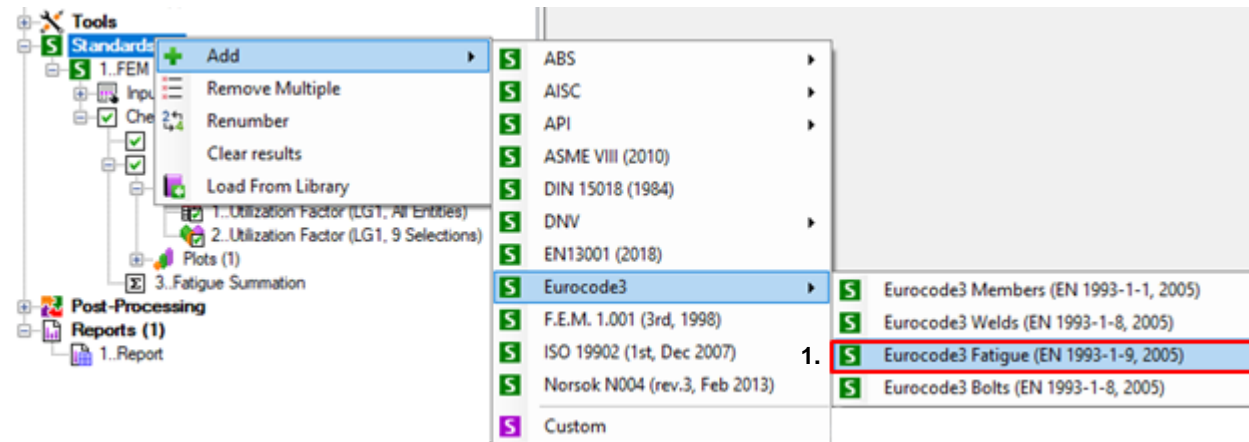
Execute *Add* => **Eurocode 3 Fatigue (EN 1993-1-9)** in Standards context menu.

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

Eurocode 3 Fatigue

ID: 2 Title: Eurocode 3

Description:

FAT Class: Define

Reduced Range: 2..Reduced Range Define

Consequence of Failure: Low

Assessment Method: Damage tolerant

Safety Factor (Gamma_Mf): 1

Materials with Yield = 0 0

Unit System: MKS (Meter/Kg/Second)

Selection: ALL

+ All Entities

Elements: 39707

OK Cancel


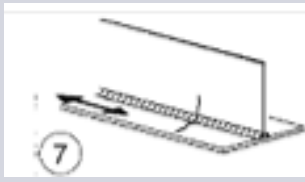
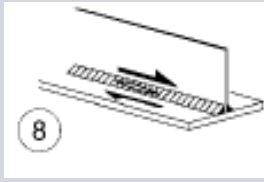



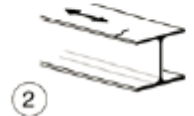
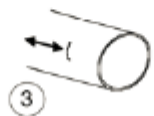
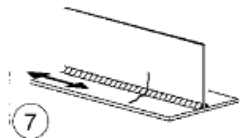
	Perpendicular to weld	Parallel with weld	Shear
Weld	80 	100 	80 
No weld	160 		100 

Table 8.1: Plain members and mechanically fastened joints

Detail category	Constructional detail	Description	Requirements
160	<p>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.</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

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**

Edit Classification

ID: 1 Title: FAT Class

Alias: FAT

Description:

Element(s) Classification

FAT Stress: 160

Direction: X

No.	Selection	Classification
1	Full Model	2. 160
4	All Entities	3. 100 (XY, YZ, ZX)
2	All welds	4. 100 (X)
3	All welds	5. 80 (Y, XY)
5	All welds intersections	6. 80 (X)

FAT classes plot

✓ Edit Classification

ID: 1 Title: FAT Class

Alias: FAT

Description:

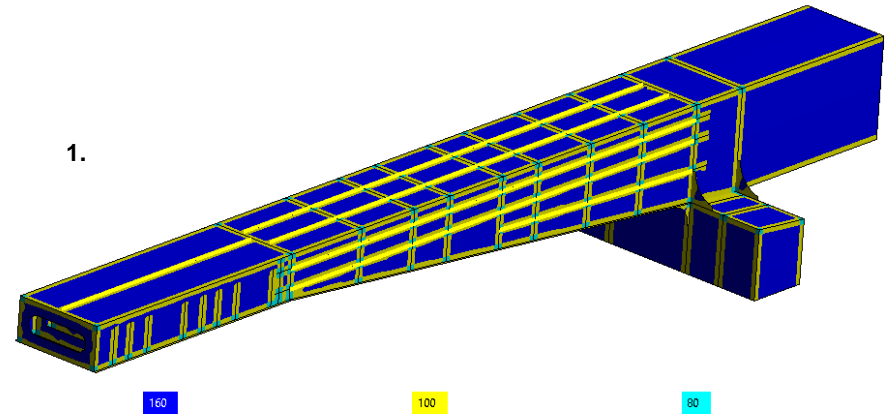
Element(s) Classification

FAT Stress: 160 Apply

Direction: X Apply

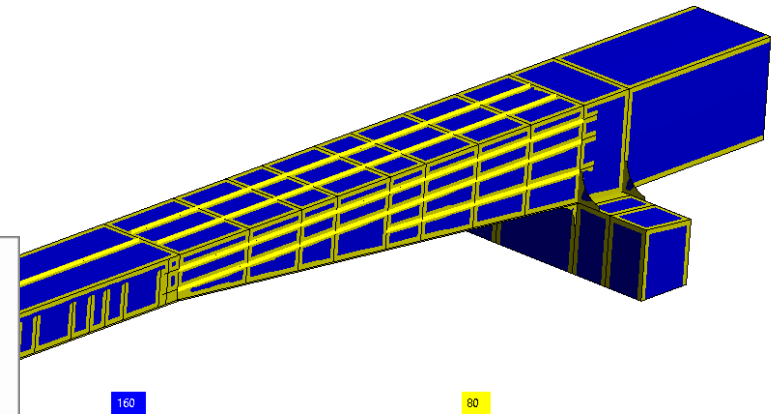
No.	Selection	Classification
1	Full Model	160
4	All Entities	100 (XY, YZ, ZX)
2	All welds	100 (X)
3	All welds	80 (Y, XY)
5	All welds intersections	80 (X)

Import Welds OK Cancel



2.

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

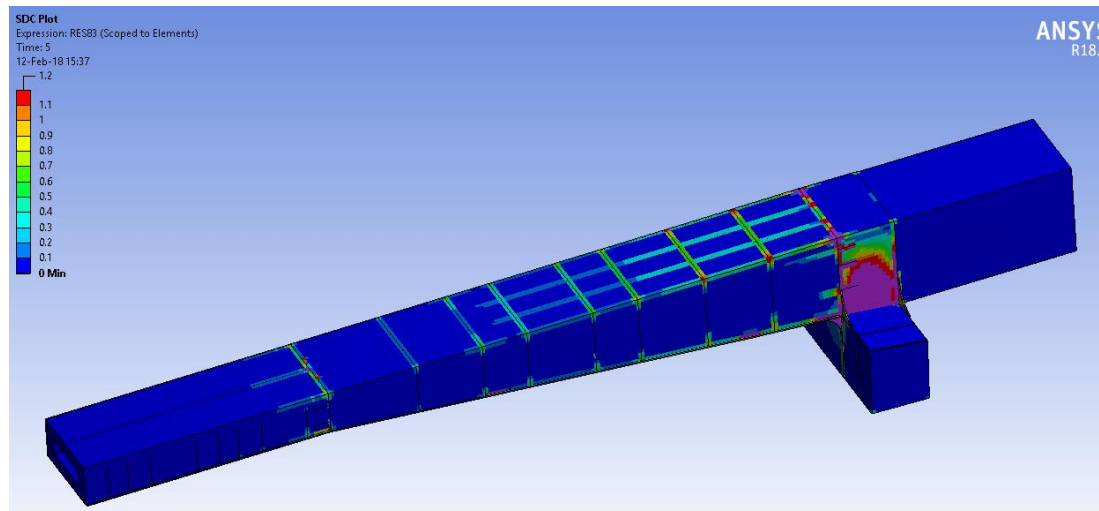
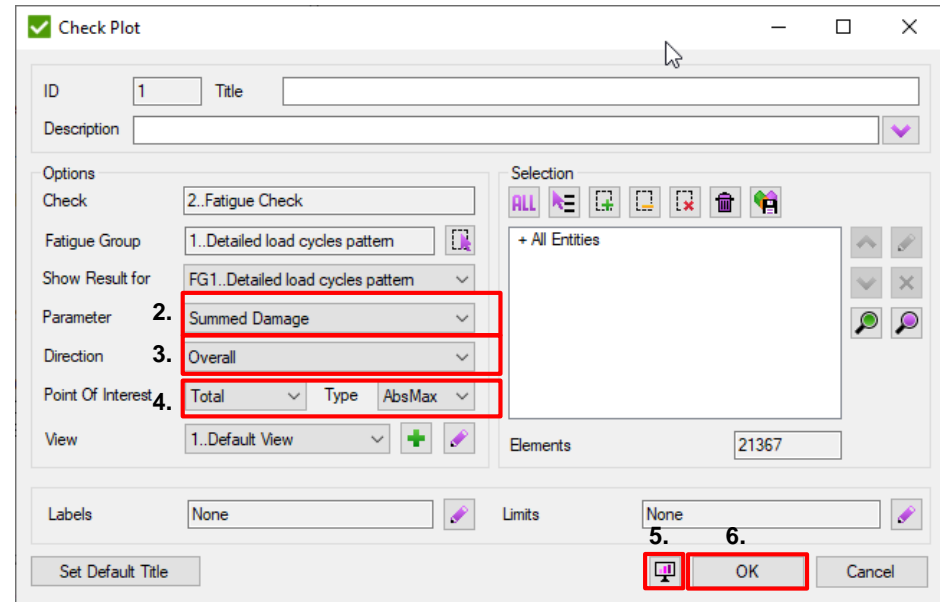
Point of interest: **Total** Type: **AbsMax**

5

Press  *Preview*

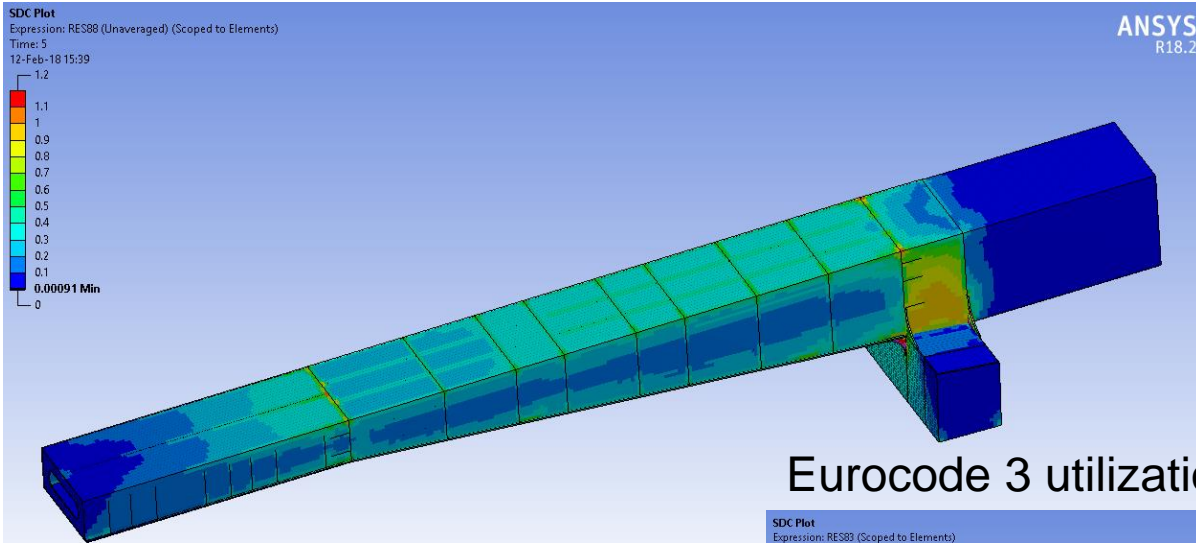
6

Press *OK*



Comparison

FEM 1.001 utilization factor



Eurocode 3 utilization factor at 2 million cycles

