



Tutorial  
**F.E.M. 1.001 and Eurocode3 Fatigue**

**Simcenter 3D**

13 Jan 2021  
version 2020.0.2

- ▶ This step-by-step tutorial demonstrates how to implement the fatigue check according F.E.M. 1.001 and Eurocode3 in SDC Verifier.
- ▶ FEM 1.001 Fatigue 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  $\kappa$  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  $240 \text{ N/mm}^2$ , i.e. to the permissible stress adopted for checking for ultimate strength.

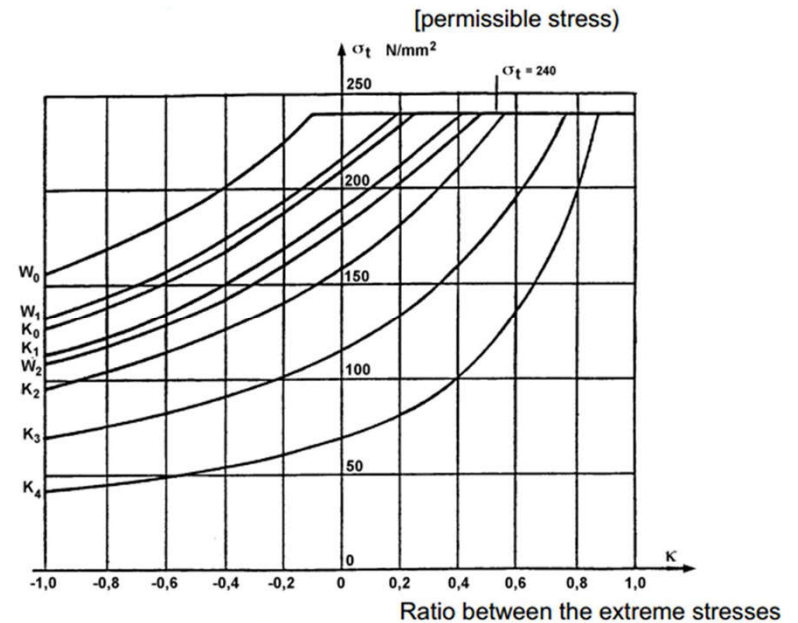


Figure A.3.6.1. - (A 52; tension; group E6)

# 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 :  $\sigma_c = 2 \cdot \sigma_w / (1 - \kappa) \quad (2)$
- $\sigma_w$  is given in table above.
- b)  $\kappa > 0$
- for tension  $\sigma_t = \sigma_0 / [1 - \kappa \cdot (1 - \sigma_0 / \sigma_{t1})]$
  - 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  $\sigma_{xa}$ ,  $\sigma_{ya}$  and  $\tau_{xya}$  are those resulting from the application of formulae (1), (2), (3) and (4) limited to  $0,75 \cdot \sigma_R$ .

**Add Custom Check**

ID:  Title:

Alias:

Description:

☒ Show Parameter Description

Options

☒ Calculate Results over Directions

☒ Calculate Results over Points

Load Calculation:

Selection:

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))`

Clear results

OK Cancel

# 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  $\sigma_w$  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

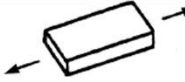
Corresponding values of Stress fatigue in SDC Verifier:

Extreme	X	Y	Z	XY	YZ	ZX	Eqv	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


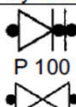
# Weld Type

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<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.		

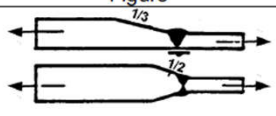

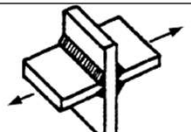
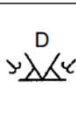
Case K<sub>0</sub> - Slight stress concentration

Reference	Description	Figure	Symbol
0,1	Parts butt-welded (S.Q.) at right angles to direction of forces		 P 100



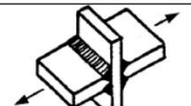
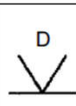
Case K<sub>1</sub> - Moderate stress concentration

Reference	Description	Figure	Symbol
1,1	Parts joined by butt welding (O.Q.) at right angles to the direction of the forces		 P 100 or P 10

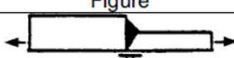

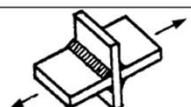
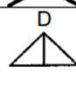
Case K<sub>2</sub> - Medium stress concentration

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		 D

Case K<sub>3</sub> - 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		 D

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		 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

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

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

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

Class of Utilization **B7** (1.8 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		$n$	$\leq$	16 000
B1	16 000	$<$	$n$	$\leq$ 32 000
B2	32 000	$<$	$n$	$\leq$ 63 000
B3	63 000	$<$	$n$	$\leq$ 125 000
B4	125 000	$<$	$n$	$\leq$ 250 000
B5	250 000	$<$	$n$	$\leq$ 500 000
B6	500 000	$<$	$n$	$\leq$ 1 000 000
B7	1 000 000	$<$	$n$	$\leq$ 2 000 000
B8	2 000 000	$<$	$n$	$\leq$ 4 000 000
B9	4 000 000	$<$	$n$	$\leq$ 8 000 000
B10	8 000 000	$<$	$n$	

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

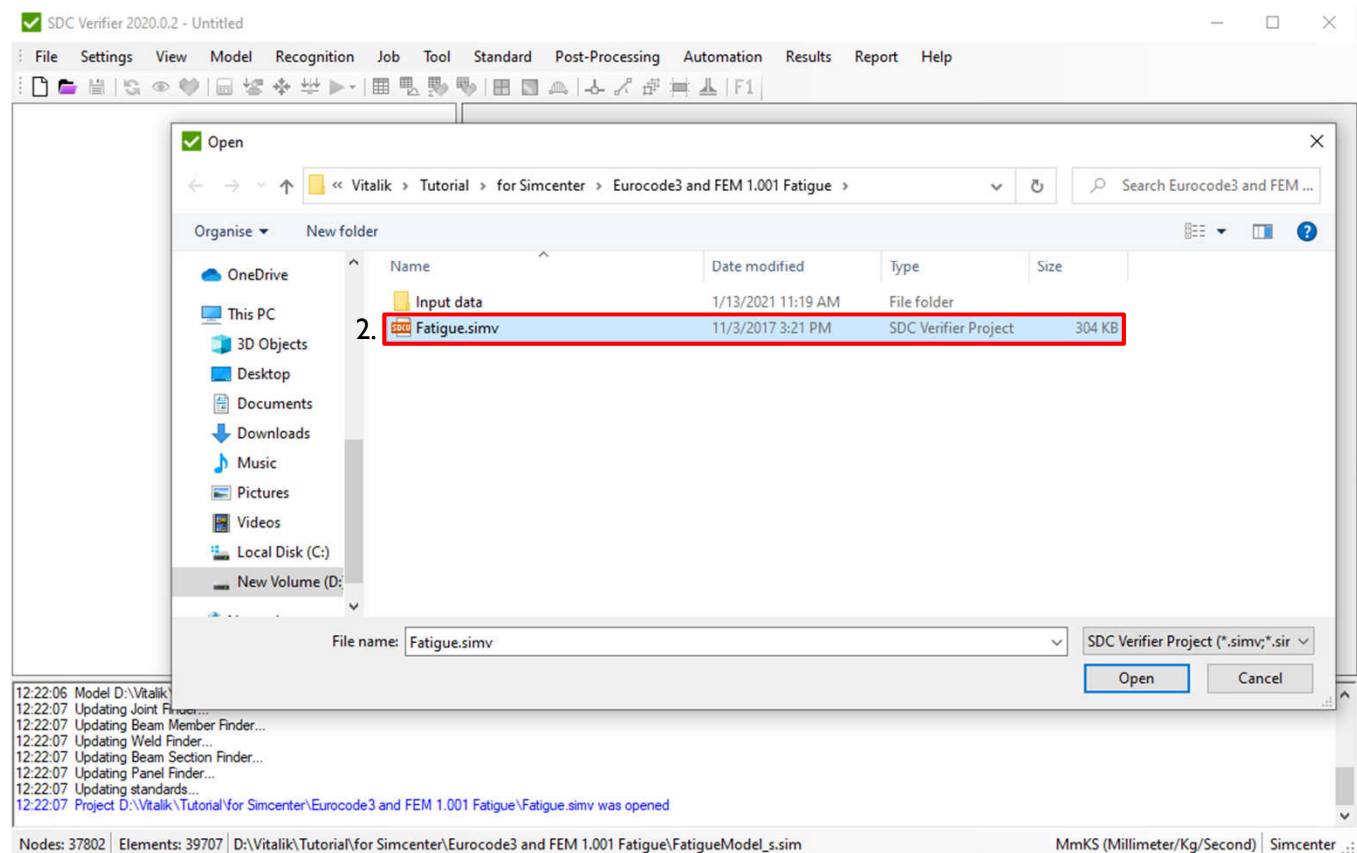
# Open the starter model

1

Launch **SDC Verifier** 

2


Open project **Fatigue**

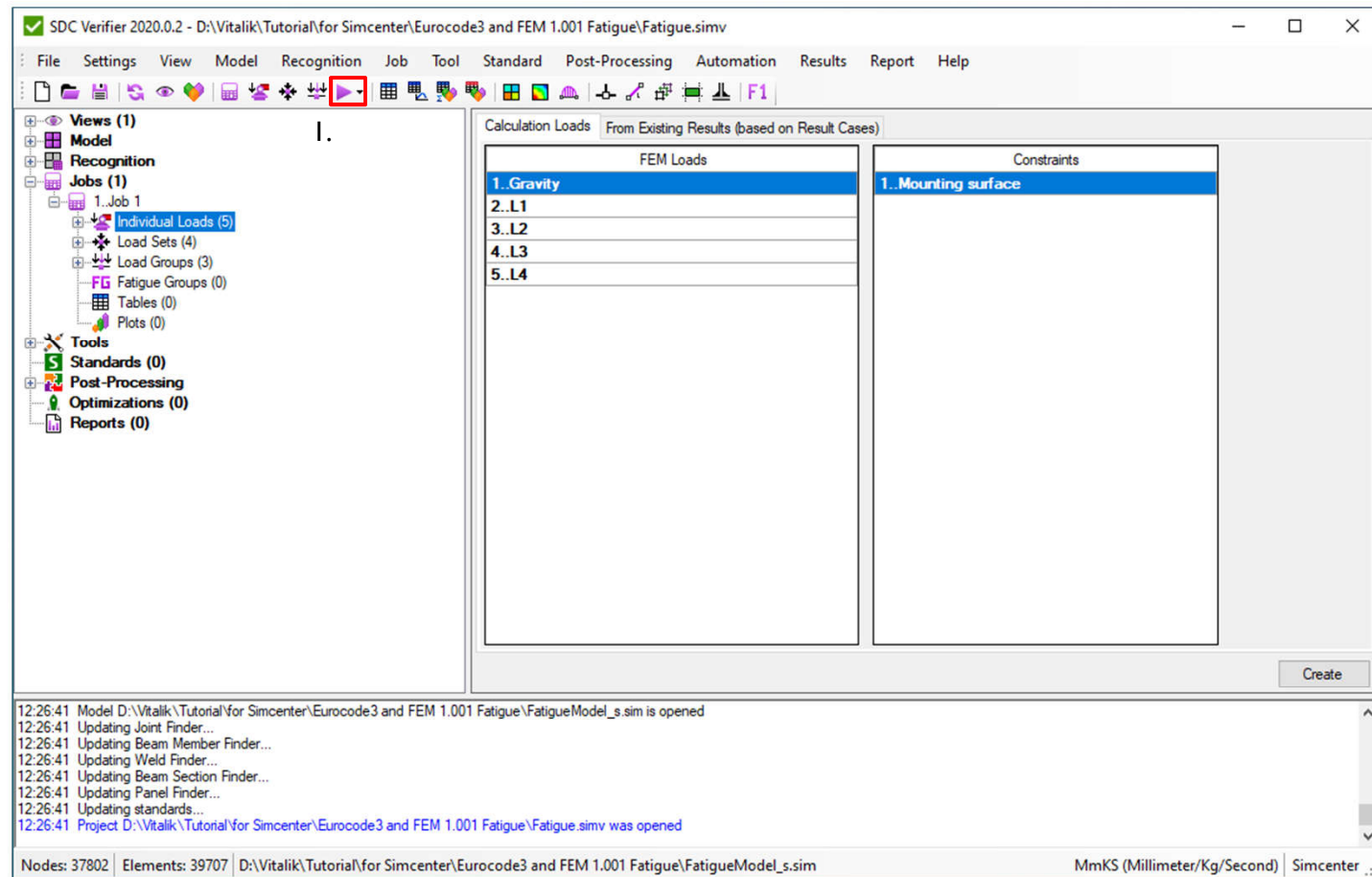




# Run Analysis

1

Press  to start Analysis in Simcenter



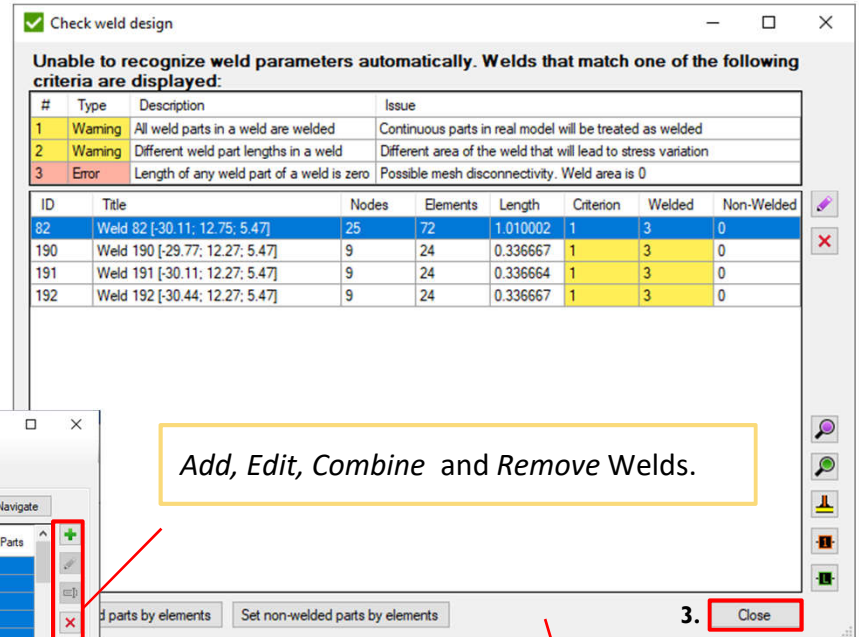
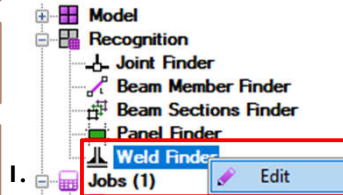
# Weld Finder

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

2 Press *Find*.

3 Press *Close*.

4 Press  to Export selected sections



Add, Edit, Combine and Remove Welds.

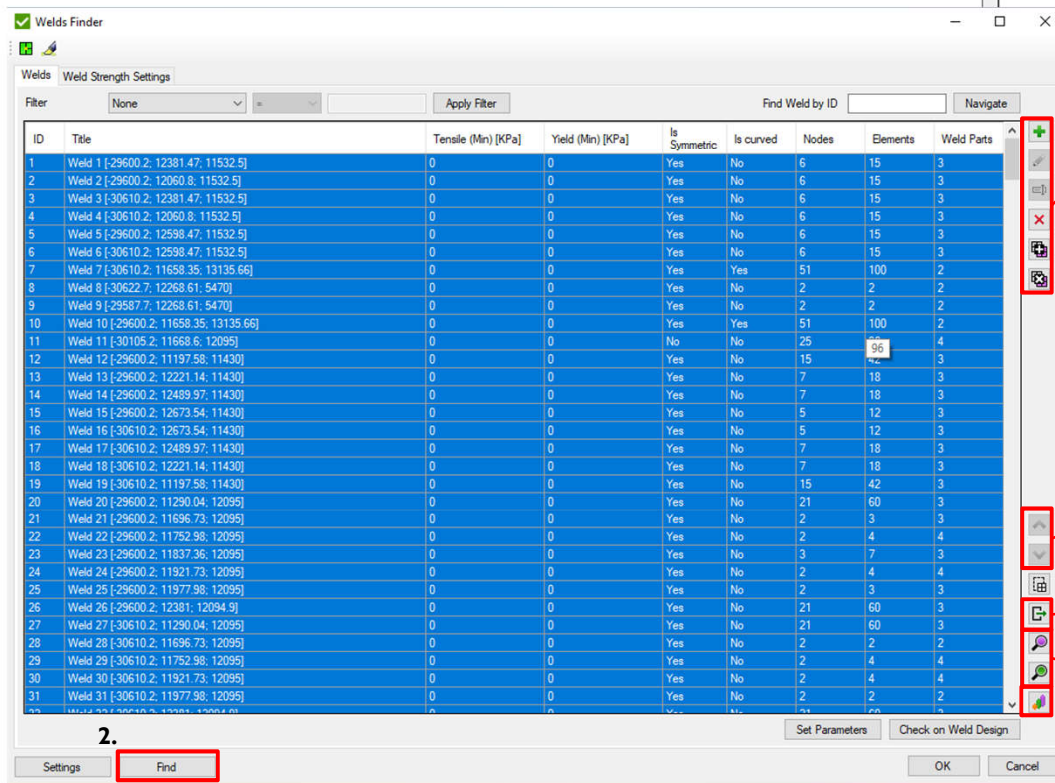
3. **Close**

There were found some Welds with all welded Parts; click to close this message

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

4. Plot of selected welds in colors and with labels of IDs

Preview selected welds



# Weld Finder. Export

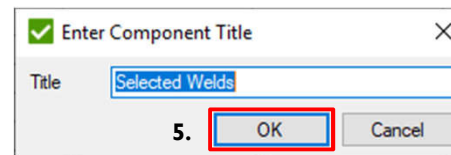
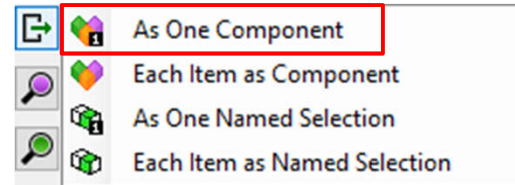
4

Click *As One Component*

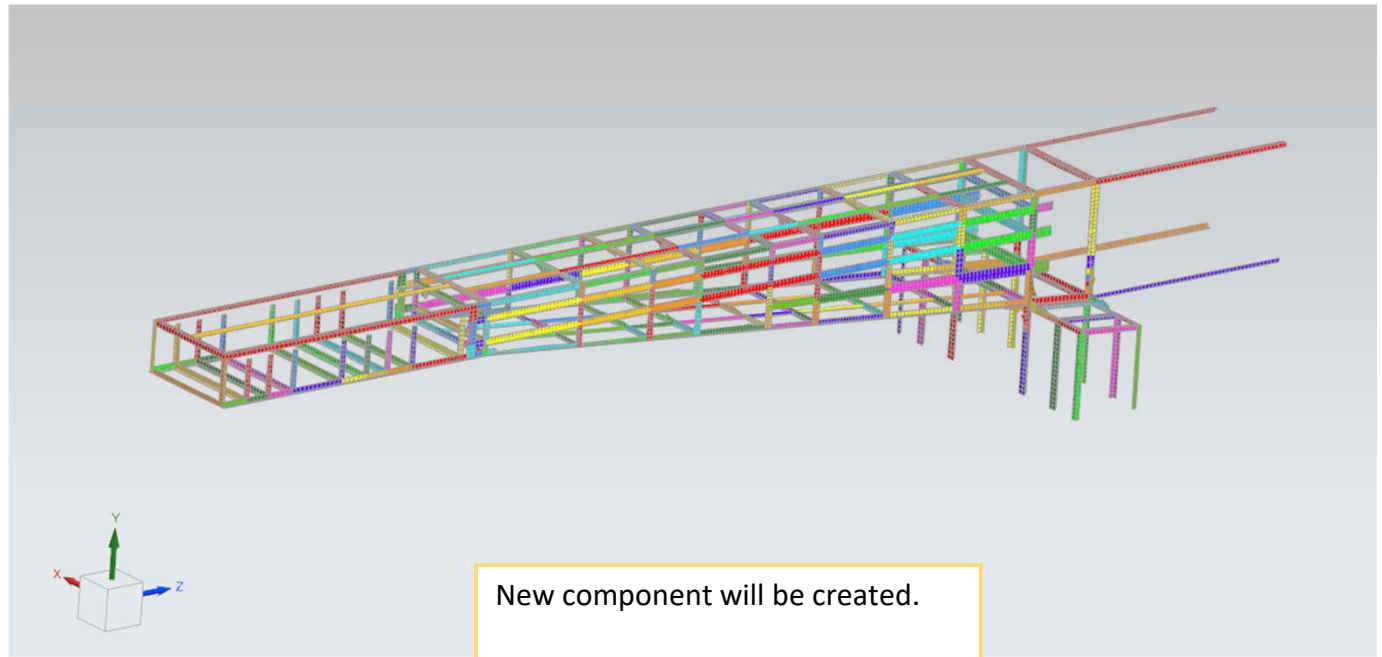
5

Press *OK*.

4.

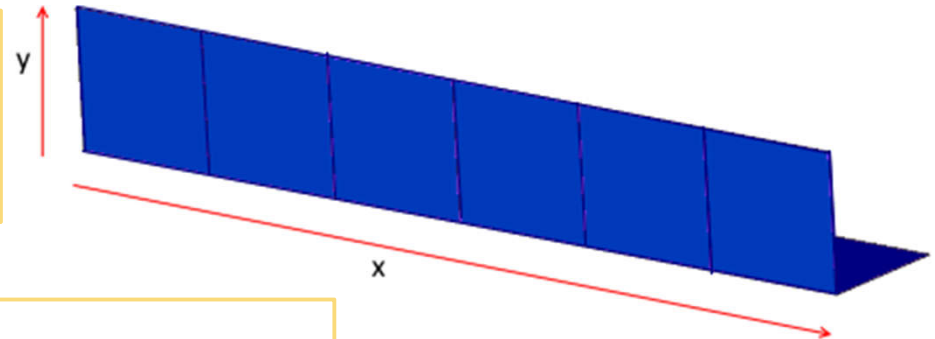


It is possible to export weld intersections into component (Nodal or Elemental)



# 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

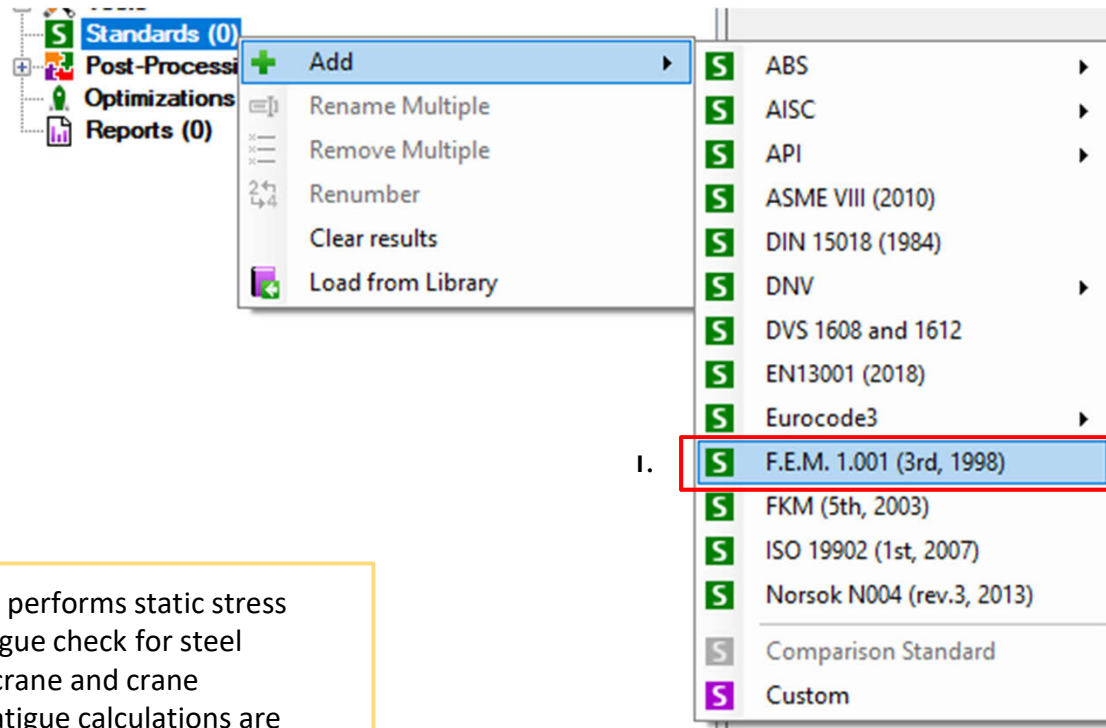
$\sigma_{tt}, \sigma_{nn}, \tau_{nt}$  – transformed x,y and shear stress in weld x,y and shear directions

$\theta$  – angle between the element and weld x directions.

# Add 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

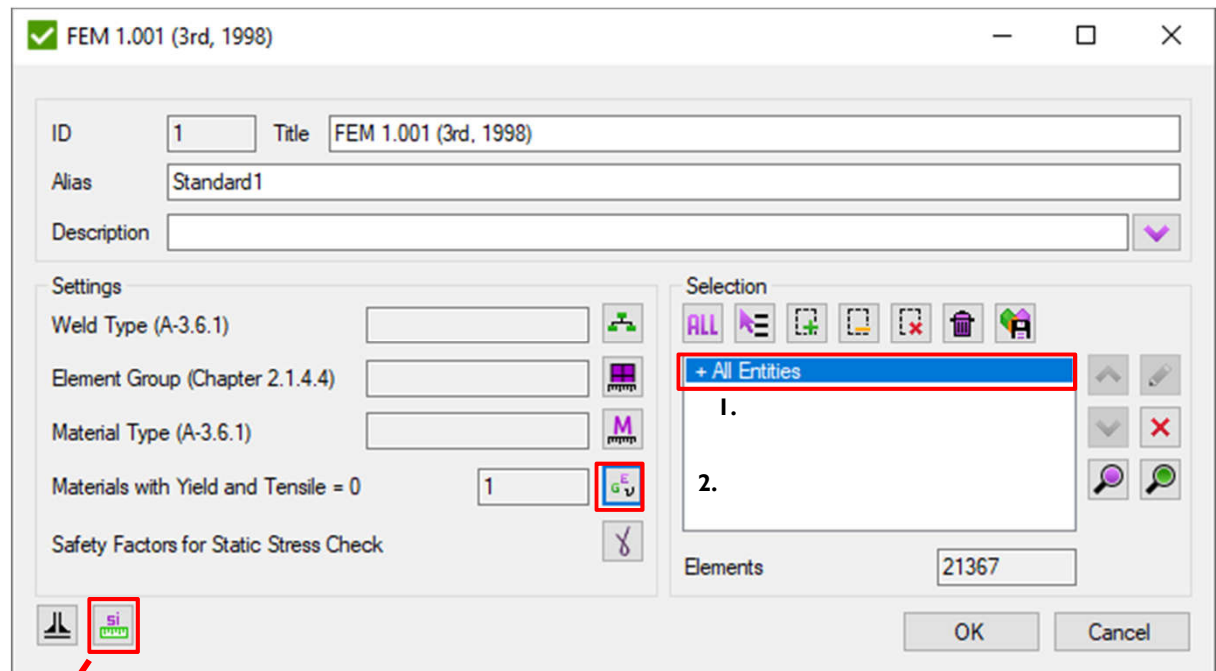
1 Selection: **All Entities**

2 Press  to edit material properties.

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

3 Tensile Strength: **470e6**  
Yield Stress: **355e6** and Press **Set**.

4 Press **OK**.



✓ FEM 1.001 (3rd, 1998)

ID: 1 Title: FEM 1.001 (3rd, 1998)

Alias: Standard1

Description:

Settings

Weld Type (A-3.6.1)

Element Group (Chapter 2.1.4.4)

Material Type (A-3.6.1)

Materials with Yield and Tensile = 0: 1

Safety Factors for Static Stress Check

Selection

ALL

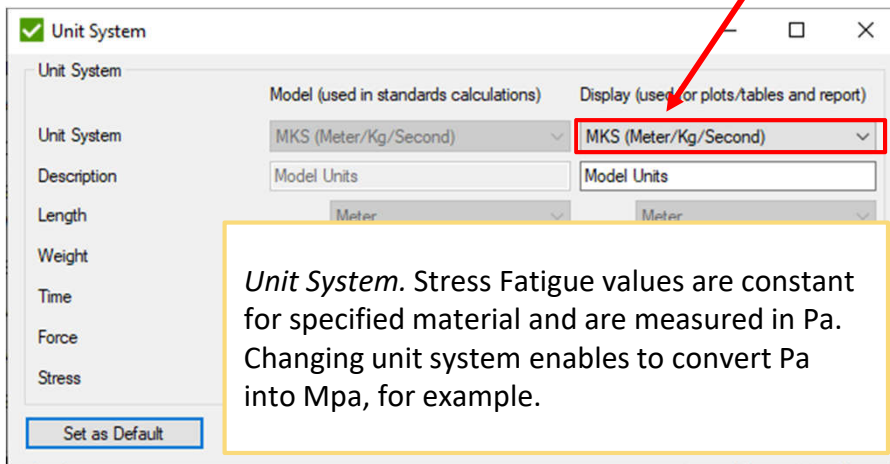
+ All Entities

1.

2.

Elements: 21367

OK Cancel



✓ Unit System

Unit System

Model (used in standards calculations)

Display (used for plots/tables and report)

Unit System: MKS (Meter/Kg/Second)

Description: Model Units

Length: Meter

Weight: Meter

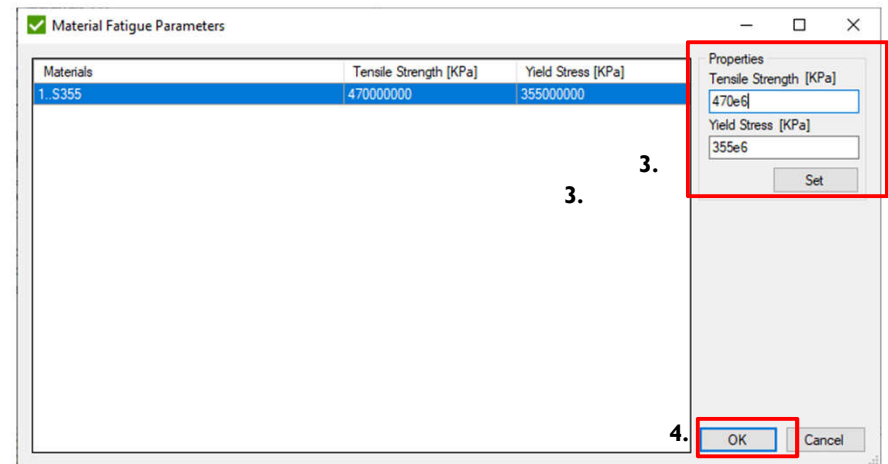
Time: Meter

Force: Meter

Stress: Meter

Set as Default

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.



✓ Material Fatigue Parameters

Materials	Tensile Strength [KPa]	Yield Stress [KPa]
1. S355	470000000	355000000

Properties

Tensile Strength [KPa]: 470e6

Yield Stress [KPa]: 355e6

Set

OK Cancel




# Definition of weld categories



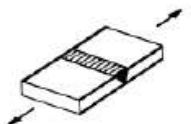


- ▶ Weld/notch category determines fatigue resistance
- ▶ Division in welds / non welds for FEM 1.001:
  - ▶ W category is for non welded parts
  - ▶ K category is for welded parts
- ▶ Fatigue resistance is further specified by adding classes
  - ▶ W0-W2 for non-welded parts
  - ▶ K0-K4 for welded parts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

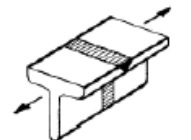


## Slight notch behavior group K0

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

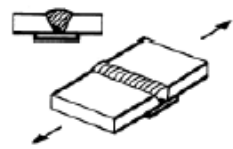

## Moderate notch behavior group K1

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

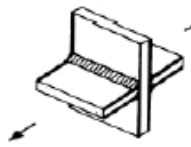

## Medium notch behavior group K2

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

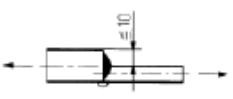


## Great notch behavior group K3

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.		
-----	--	---	---

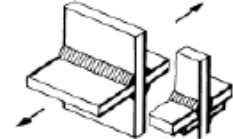


## and a different connection type 351

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

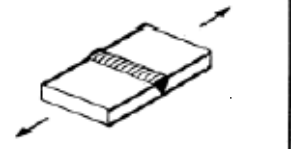
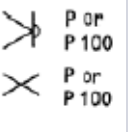
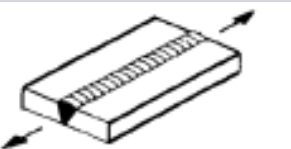
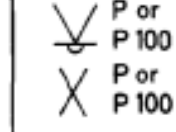
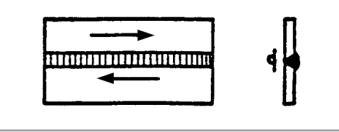
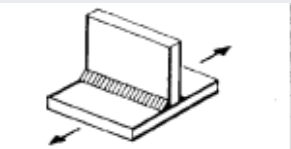


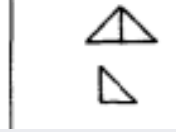

## Very great notch behavior group K4

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
-----	---	---	--

# Fatigue resistance depends on stress direction

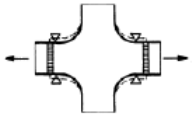


Stress perpendicular to weld			Stress parallel with weld			Shear	
K1			K0			K0	
K2			K1				
No weld (all directions)							
W0		In the software: $\tau_D(-1) = \sigma_D(-1) / \text{sqrt}(3)$					

Steel Grade	$\sigma_D(-1)$ for $\kappa=-1$ elemt 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

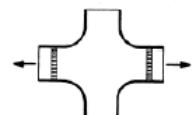


# For beams SCF of connections can be included in the classification

Depends on Stress concentrations:

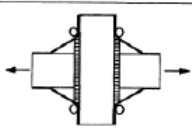


## Slight notch behavior group K0

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

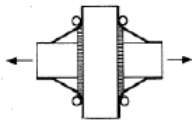


## Moderate notch behavior group K1

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

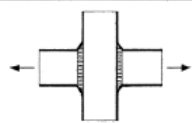


## Medium notch behavior group K2

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 Ok-->Yes (*Define* for the Weld Type).

2 Press  to Add Condition.

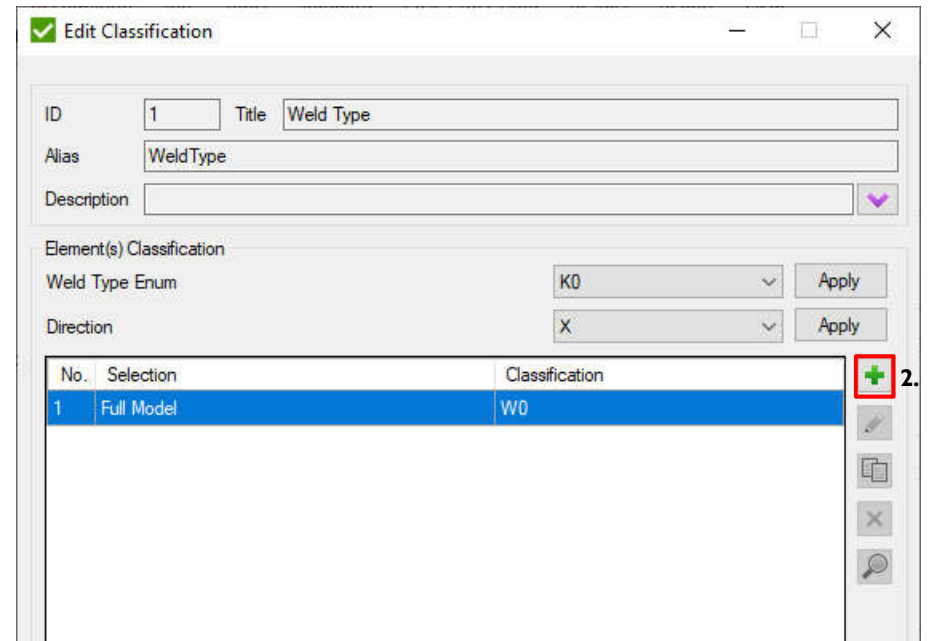
3 Press *Add all Welds*

4 Select *Multiple Conditions* options

5 Press X/Y/XY

6 X: K1 Y: K2 XY: K0


7 Press *OK*





**Edit Classification**



ID: 1 Title: Weld Type

Alias: WeldType


Description: 

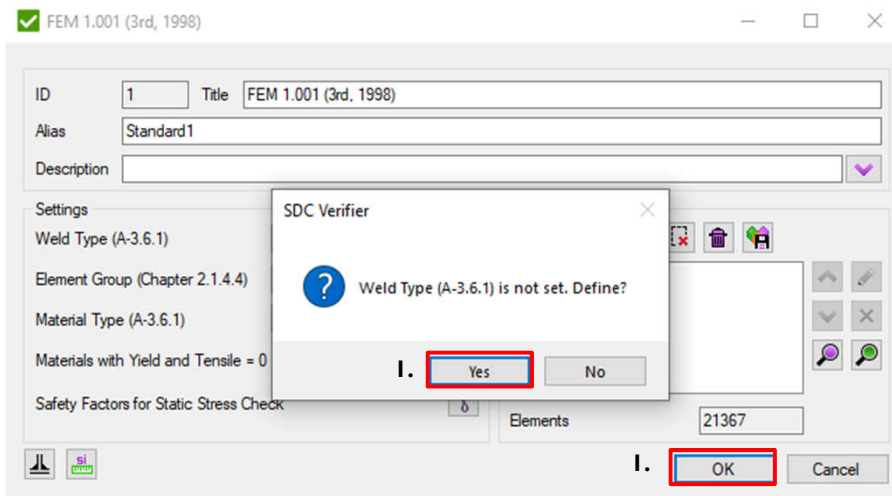
Element(s) Classification

Weld Type Enum: K0  

Direction: X  

No.	Selection	Classification
1	Full Model	W0


 2.



**FEM 1.001 (3rd, 1998)**

ID: 1 Title: FEM 1.001 (3rd, 1998)

Alias: Standard1

Description: 


Settings

Weld Type (A-3.6.1)

Element Group (Chapter 2.1.4.4)

Material Type (A-3.6.1)

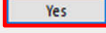

Materials with Yield and Tensile = 0

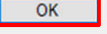

Safety Factors for Static Stress Check: 

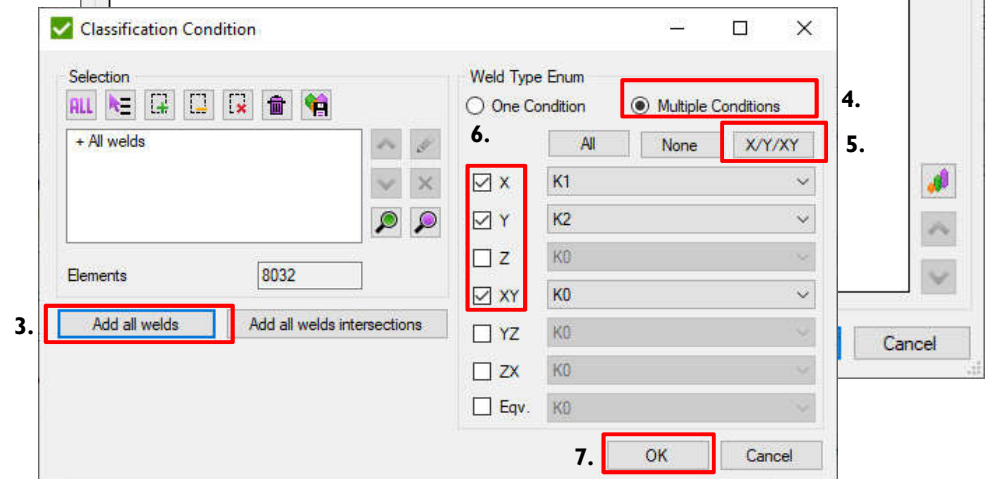
Elements: 21367

**SDC Verifier**








Weld Type (A-3.6.1) is not set. Define?

1.  

1.  



**Classification Condition**



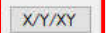
Selection:       


+ All welds


Elements: 8032


Weld Type Enum


☐ One Condition ☒ Multiple Conditions 4.


6.    5.


☒ X K1 


☒ Y K2 

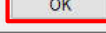

☐ Z K0 

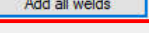
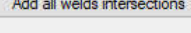
☒ XY K0 

☐ YZ K0 

☐ ZX K0 

☐ Eqv. K0 

7.  

3.  

# Weld Type classification 2

1 Press  to Add Condition.

2 Click *All welds intersections*














































3 Value: **K2**

4 Directions: **X**

5 Press *OK*

**Classification Condition**

Selection



# Check classification

☒ Edit Classification

ID: 1 Title: Weld Type

Alias: WeldType

Description:

Element(s) Classification

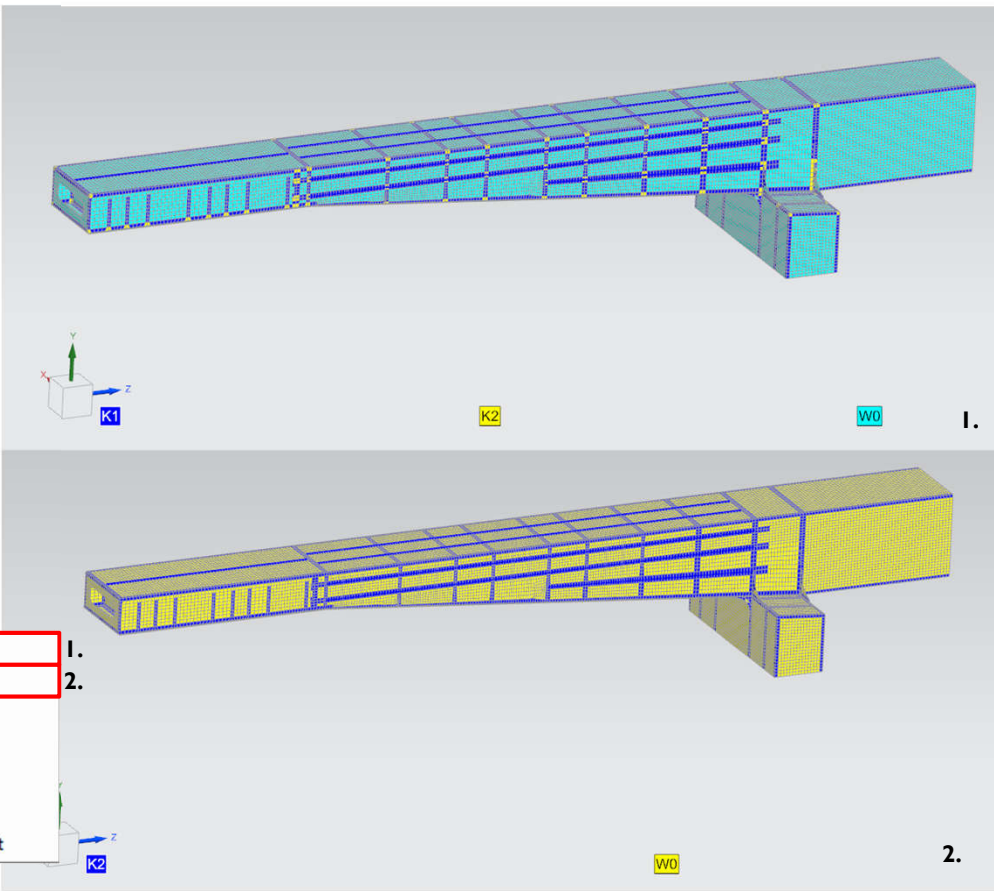
Weld Type Enum: K0 Apply

Direction: X Apply

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

Import Welds Clear OK Cancel

- X
- Y
- Z
- XY
- YZ
- ZX
- Equivalent



# Element Group classification

1 Press *Define* for the Element Group

2 Select Element Group: **E6**. Press *Apply*.

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

Import... 3.

# Material Type classification

1 Press *Define* for the Material Type.

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

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.S355	Fe 360 (Fe 37)

3. OK Cancel

# Create extreme table

1

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

2

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

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

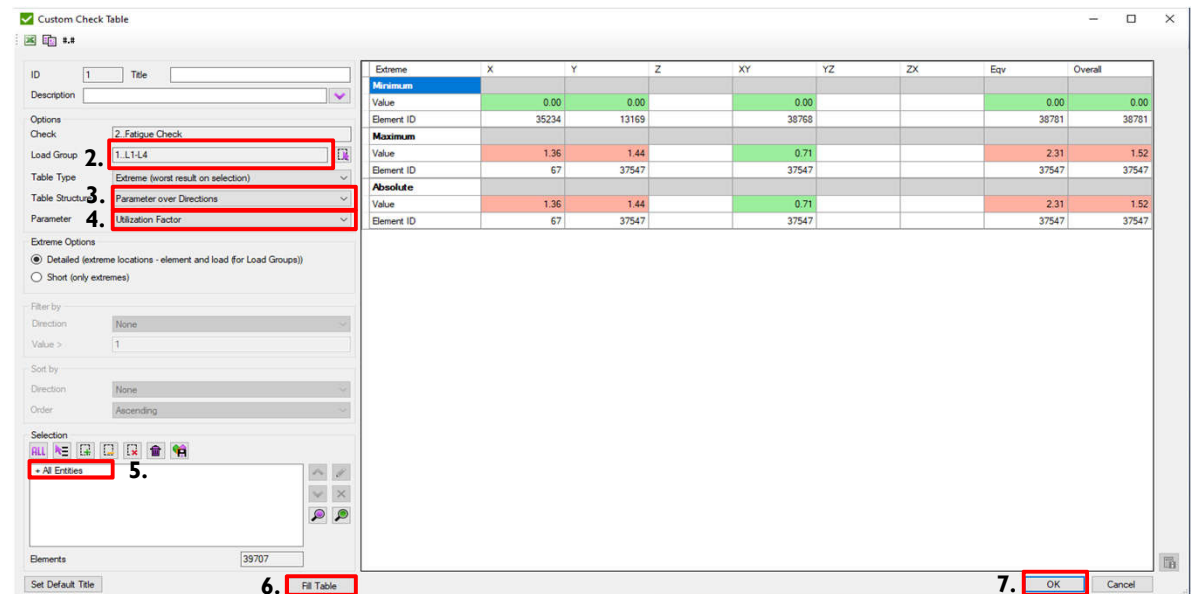
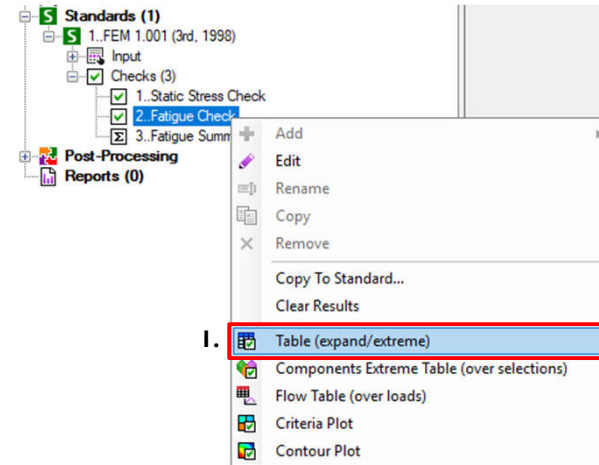
Selection: **All Entities**.

6


Press *Fill Table*.

7

Press *OK*.



# Create criteria plot

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

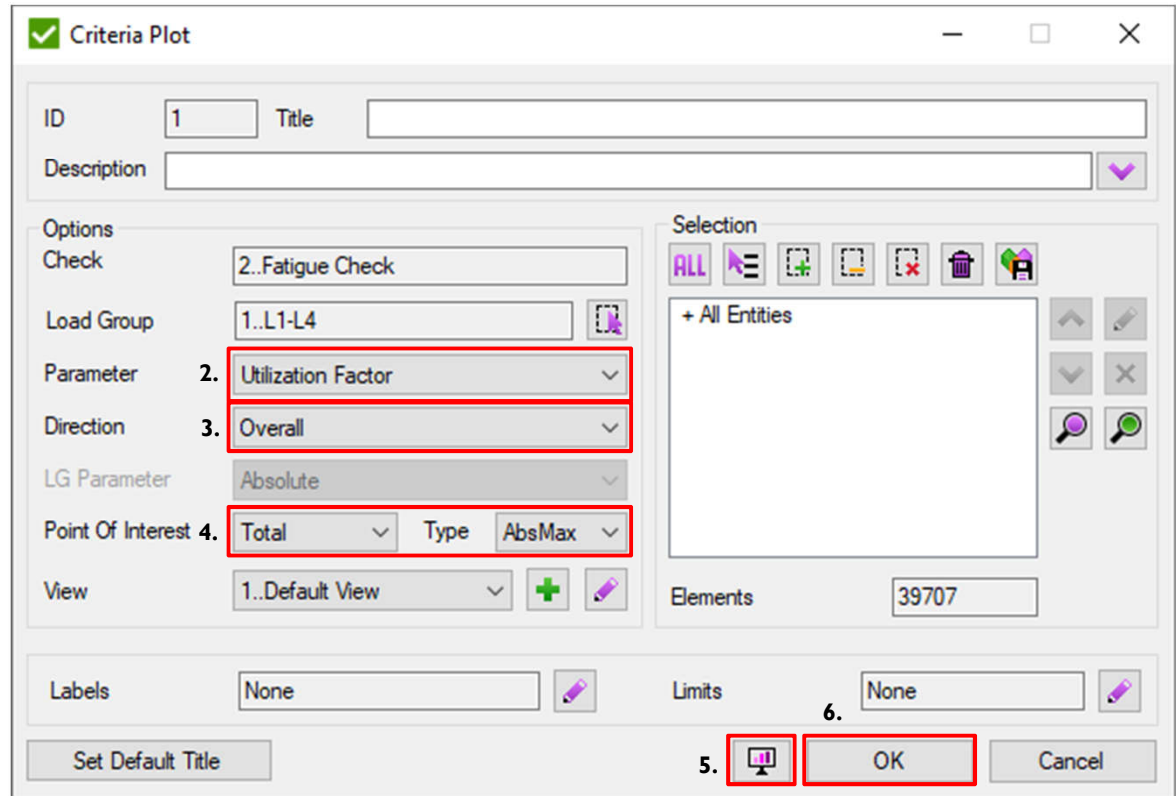
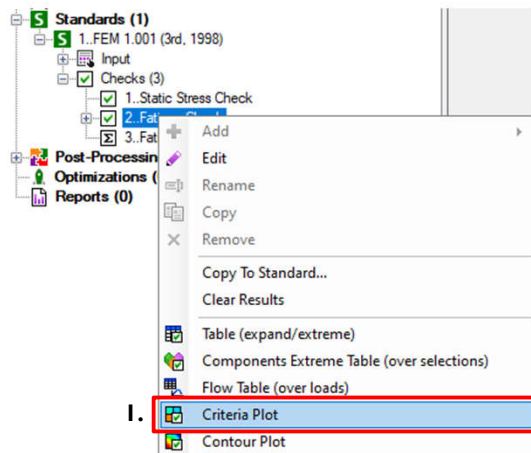
2 Parameter: **Utilization Factor**

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 Results => *Check Tables*

2 Press => Check '2..Fatigue Check'  
=> 

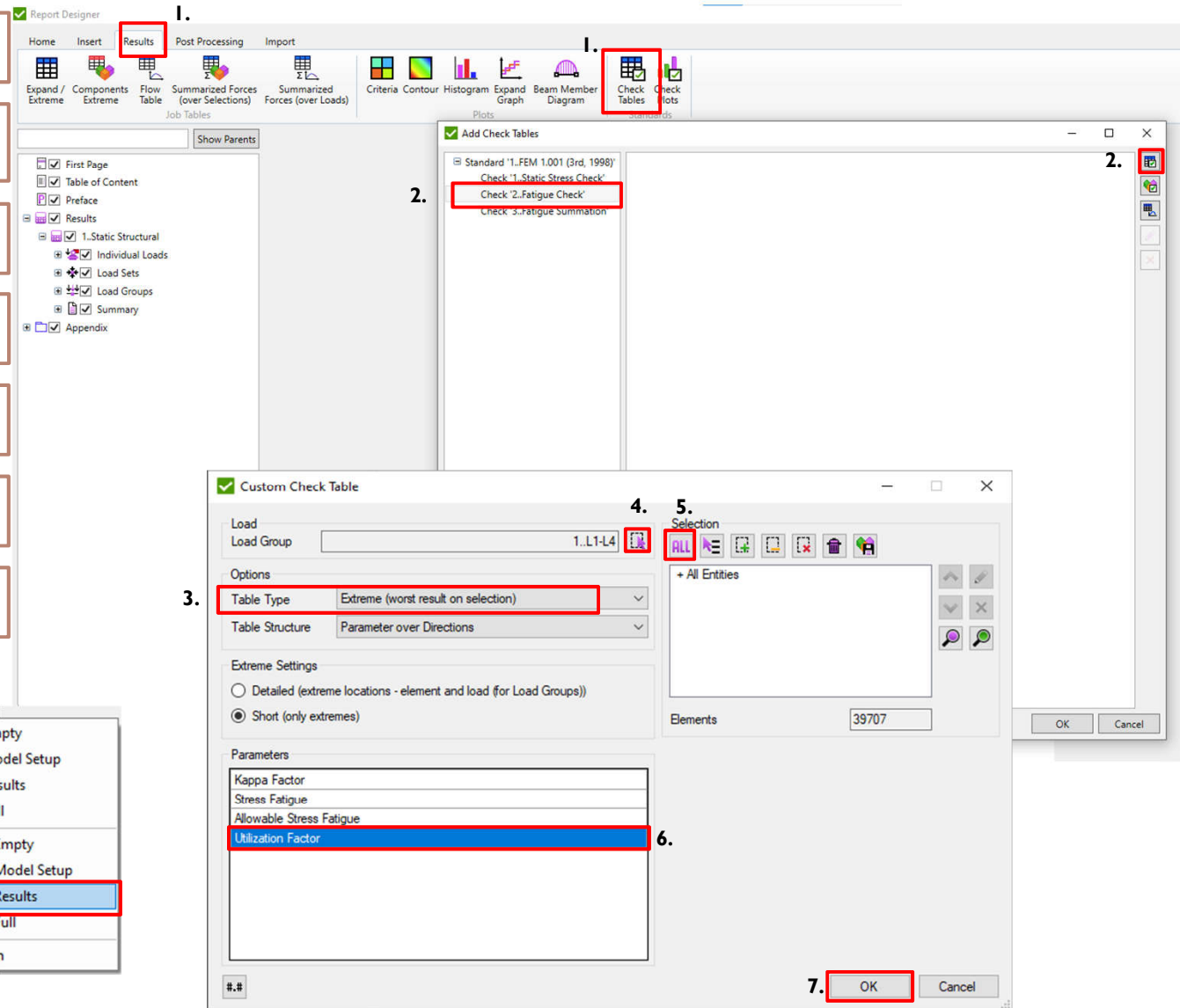
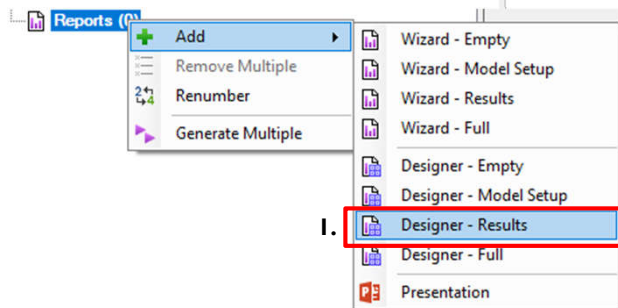
3 Table Type: **Extreme.**

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

5 Selection: **All Entities.**

6 Parameter: **Utilization Factor.**


7 Press OK.





# Report. Tables and plots

1 Results => *Check Plots*

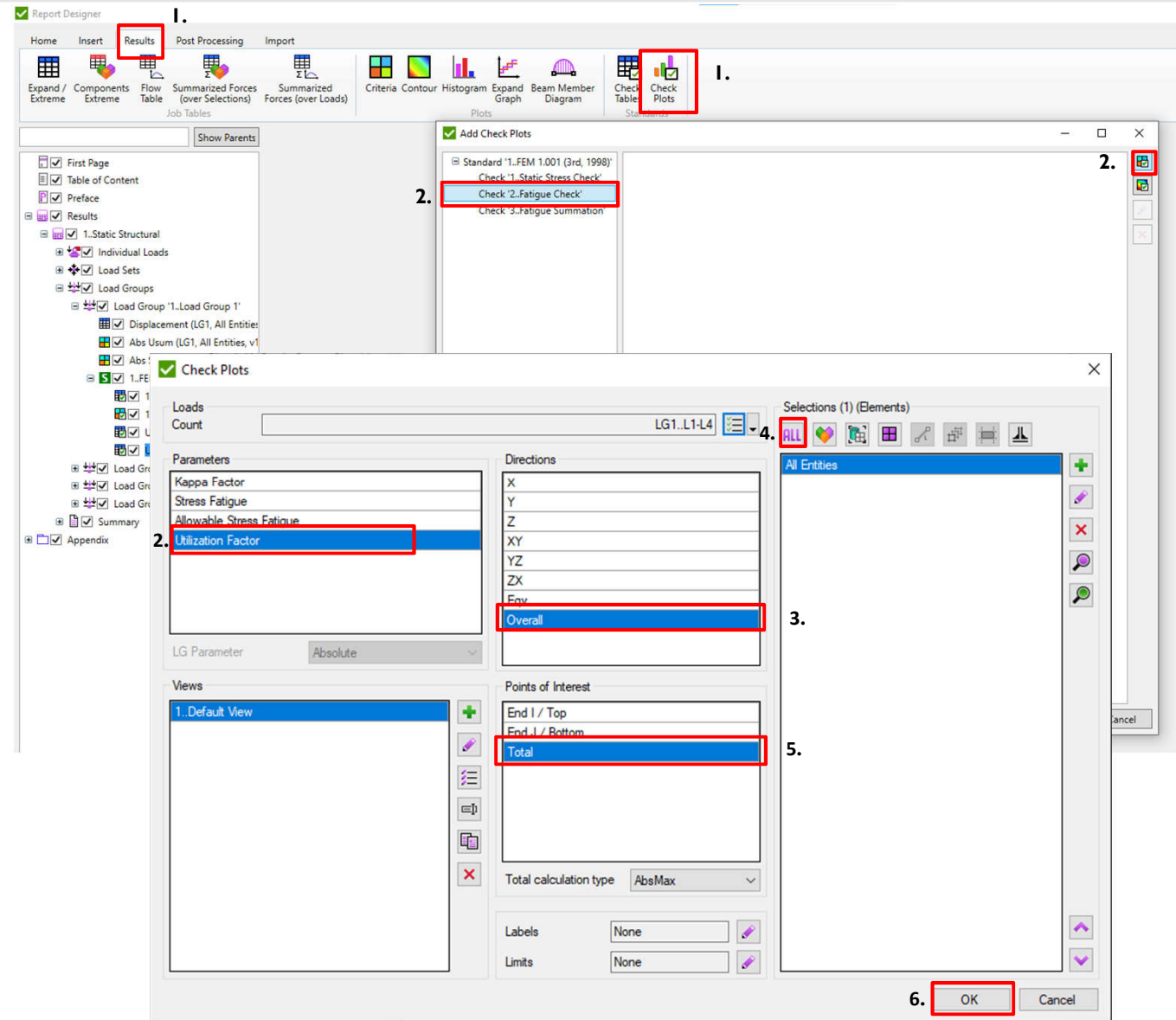
2 Press => *Check '2..Fatigue Check'* => 

3 Direction: **Overall**

4 Point of Interest: **Total**.

5 Selection: **All Entities**.

6 Press *OK*.



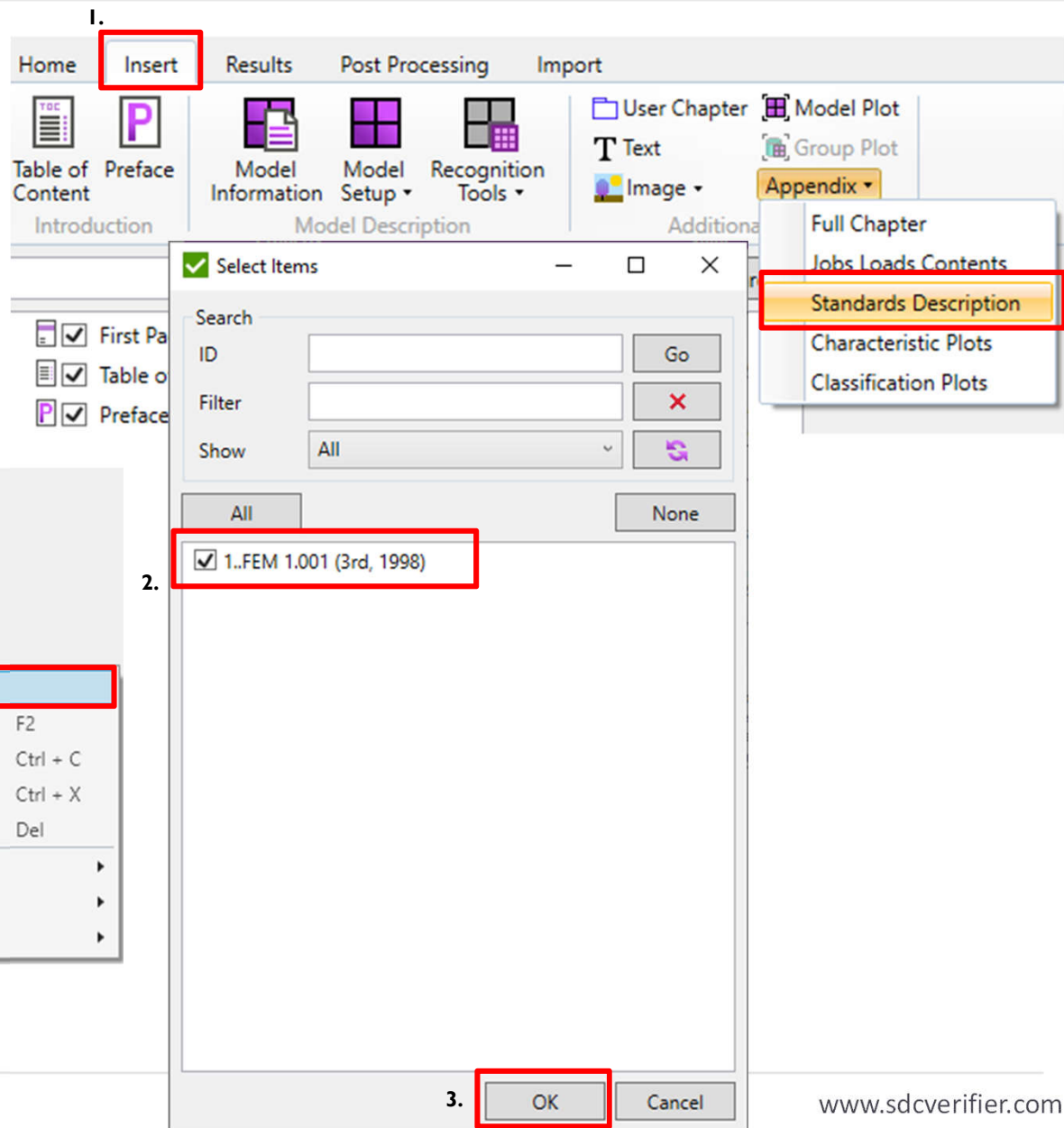
# Report. Tables and plots

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

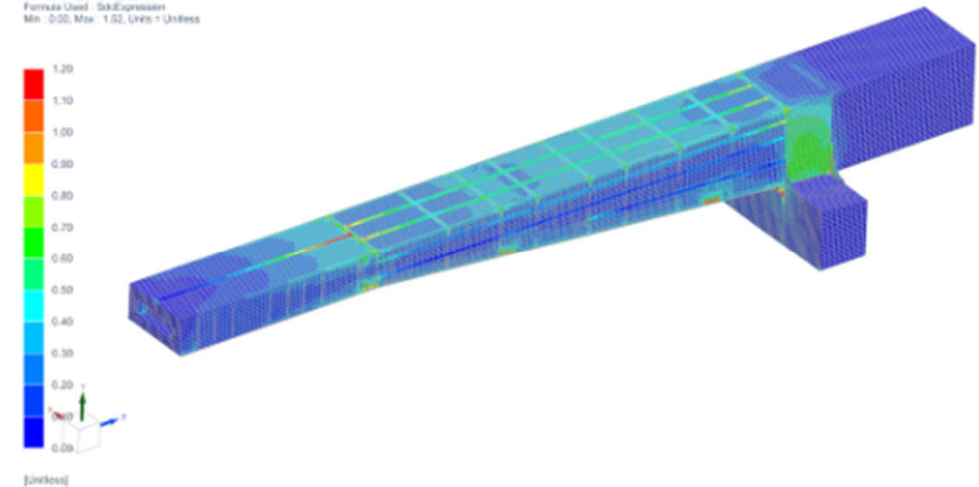
Property	Value
Category	Elemental Custom Check
Selection	All Entities
Parameters	4
Alias (Parameter)	Kappa (Kappa Factor)
Description	Ratio between the extreme stresses
All	$\text{if}(\text{SweldAbs} > 0, \text{SweldMin} / \text{SweldMax}, \text{SweldMax} / \text{SweldMin})$
Alias (Parameter)	Sf (Stress Fatigue)
Description	Permissible stress for fatigue depends on the element group (E1-E8) and weld type
All	$\text{Min}(\text{units.FromPaToCurrent}(\text{Switch}(\text{MaterialType}, \text{MaterialTypeEnum.Fe360Fe37}, \text{Sf\_Fe360}(\text{ElementGroup}, \text{WeldType}), \text{MaterialTypeEnum.Fe510Fe52}, \text{Sf\_Fe510}(\text{ElementGroup}, \text{WeldType}))), 0.75 * \text{Tensile}))$
Alias (Parameter)	Sallow_fatigue (Allowable Stress Fatigue)
Description	Appendix 3.6, formulas (1)-(4)
All	$\text{if}(\text{Kappa} > 0, \text{if}(\text{SweldAbs} > 0, 1, 1.2) * (5 / 3 * \text{Sf}) / (1 - (1 - (5 / 3 * \text{Sf}) / (0.75 * \text{tensile})) * \text{Kappa}), \text{if}(\text{SweldAbs} > 0, (5 * \text{Sf}) / (3 - 2 * \text{Kappa}), (2 * \text{Sf}) / (1 - \text{Kappa})))$
XY/YZ/ZX	$\text{if}(\text{Kappa} > 0, (5 / 3 * \text{Sf}) / (1 - (1 - (5 / 3 * \text{Sf}) / (0.75 * \text{tensile})) * \text{Kappa}), (5 * \text{Sf}) / (3 - 2 * \text{Kappa})) / \text{if}(\text{WeldType} \leq \text{WeldTypeEnum.K4}, \text{SQRT}(2), \text{SQRT}(3))$
Eqv	0
Alias (Parameter)	Uf (Utilization Factor)
Description	Appendix 3.6, equivalent rule - (5)
All	$\text{Abs}(\text{SweldAbs}) / \text{Sallow\_Fatigue}$
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 (3rd, 1998)			Check	[S1] 2..Fatigue Check			
Load Group	LG1..L1-L4			Parameter	Utilization Factor			
Selection	All Entities							
Extreme	X	Y	Z	XY	YZ	ZX	Eqv	Overall
Minimum	0.00	0.00		0.00			0.00	0.00
Maximum	1.36	1.44		0.71			2.31	1.52
Absolute	1.36	1.44		0.71			2.31	1.52

## 1..Overall Utilization Factor (LG1, All Entities, v1, Total)

FatigueModel\_v1 - Job 1 Linear Result  
 StaticData, Static Step 1  
 Members - Elemental Scalar  
 Formula Used - SdExpression  
 Min: 0.00, Max: 1.52, Units: Unitless

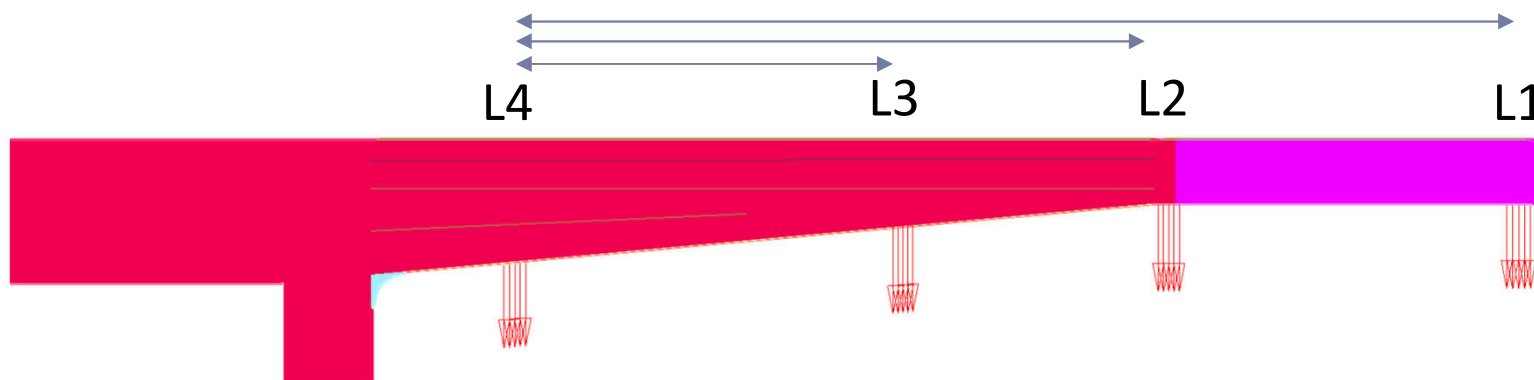


Check	[S1] 2..Fatigue Check	Point	Total
Load Group	LG1..L1-L4	Parameter	Overall Utilization Factor
Selection	All Entities	View	1..Default View

# 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**

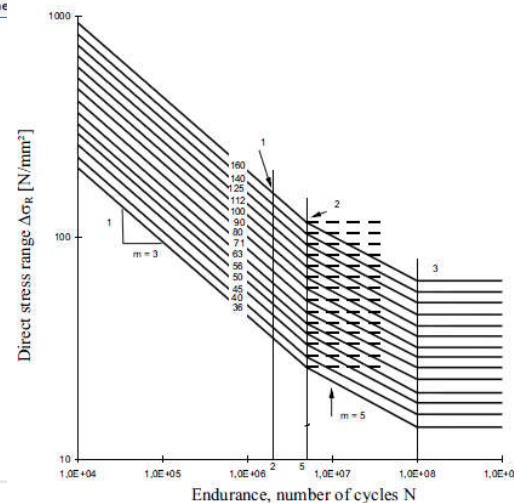
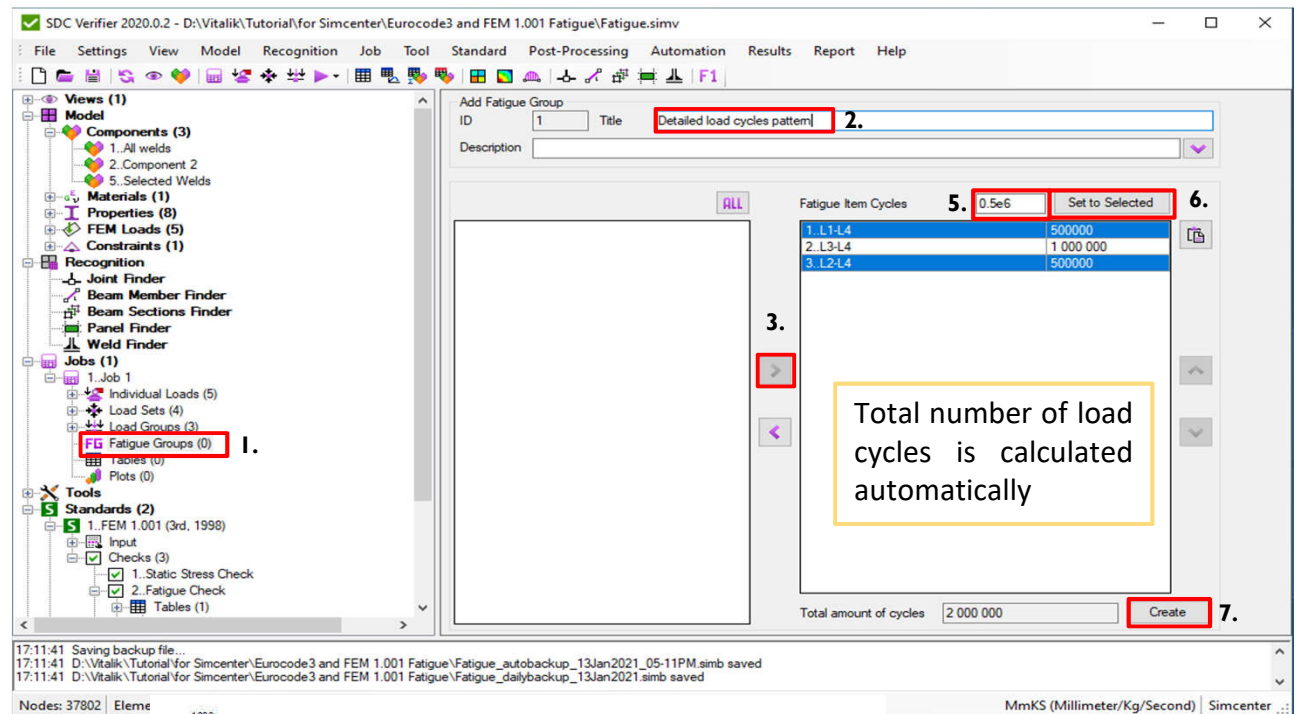
3 Select all groups and press 

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**



# Fatigue calculation with Eurocode 3

1

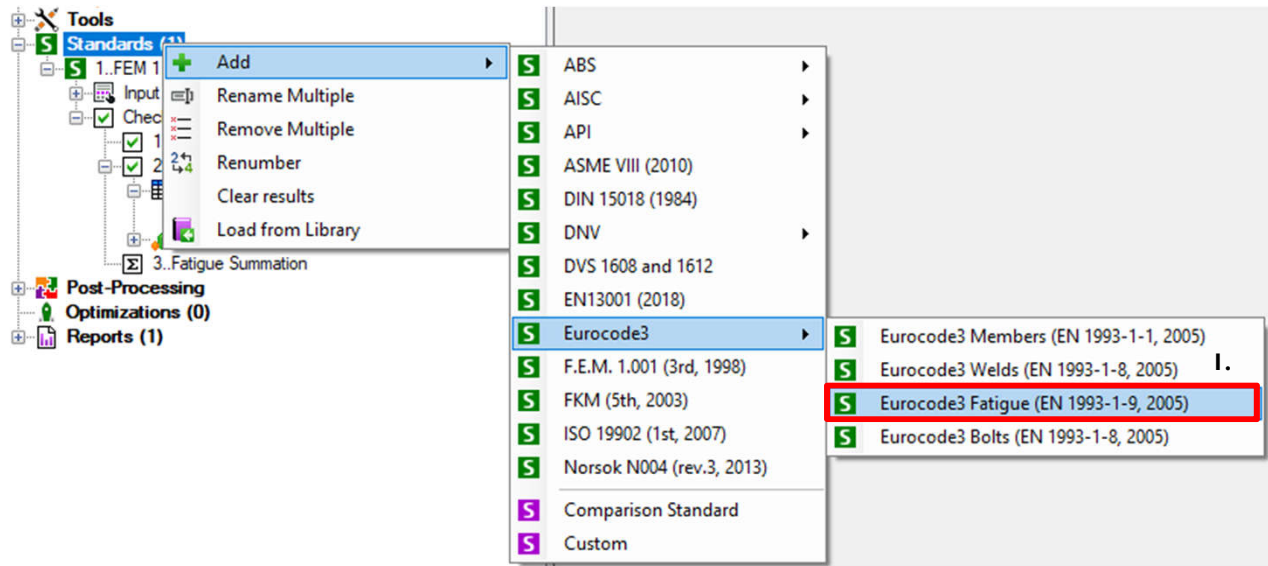
Execute *Add* => **Eurocode 3 Fatigue (EN 1993-1-9)** in Standards context menu.

2

Consequence of Failure: **Low**

3

Assessment Method: **Damage tolerant**



**Eurocode 3 Fatigue**

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

Alias: Standard2

Description:

FAT Class: [ ]

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


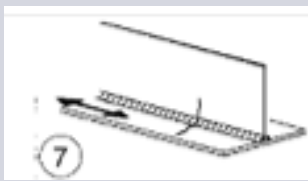
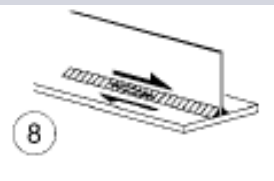


Elements: 39707

OK Cancel



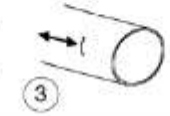
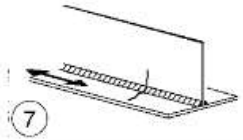
Safety Factor	Low consequence	High consequence
Damage tolerant	1.0	1.15
Safe life	1.15	1.35



# 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	<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

# Eurocode 3 formulas

✓ Fatigue Check

ID: 2 Title: Fatigue Check

Alias: Fatigue

Description:

☒ Show Parameter Description

Options

☒ Calculate Results over Directions

☒ Calculate Results over Points

Load Calculation: Load Group Summation

Selection: All Entities

Parameters (6) / Replacements (0)

**Parameter = Delta\_stress (Delta Stress)**  
*Description: The delta stress is the stress difference for a load group. For the equivalent delta stress the standard formula is used with the delta stress as input. The overall results give the maximum delta stress of the group in each of the 7 directions.*  
All: `if(ReducedRange = NotReduced, SweldDelta, if(SweldMax < 0, 0.6 * SweldMax, SweldMax) - if(SweldMin < 0, 0.6 * SweldMin, SweldMin))`  
XY/YZ/ZX: `SweldDelta`  
Eqv.: `sqrt(pow(me.x,2) + pow(me.y,2) + pow(me.z,2) - me.x * me.y - me.y * me.z - me.z * me.x + 3 * (pow(me.xy, 2) + pow(me.yz, 2) + pow(me.zx, 2)))`  
Overall: `AbsMax(me.x, me.y, me.z, me.xy, me.yz, me.zx, me.eqv)`

**Parameter = Sc (Fatigue Strength at 2 million cycles)**  
*Description: reference value of the fatigue strength at NC = 2 million cycles*  
All: `units.FromMPaToCurrent(SN(1, FAT)) / Gamma_Mf`

**Parameter = Fd (Fatigue Damage)**  
*Description: Fatigue damage of Load group*  
All: `case(Delta_Stress < Sc * Factor_c100; 0; Delta_Stress < Sc * Factor_c5; pow(Delta_Stress / (Sc * Factor_c5), 5) * ItemNumberOfCycles / 5m; Delta_Stress >= Sc * Factor_c5; pow(Delta_Stress / Sc, 3) * ItemNumberOfCycles / 2m)`

Clear results

OK Cancel

# 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


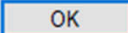

Description: 

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:

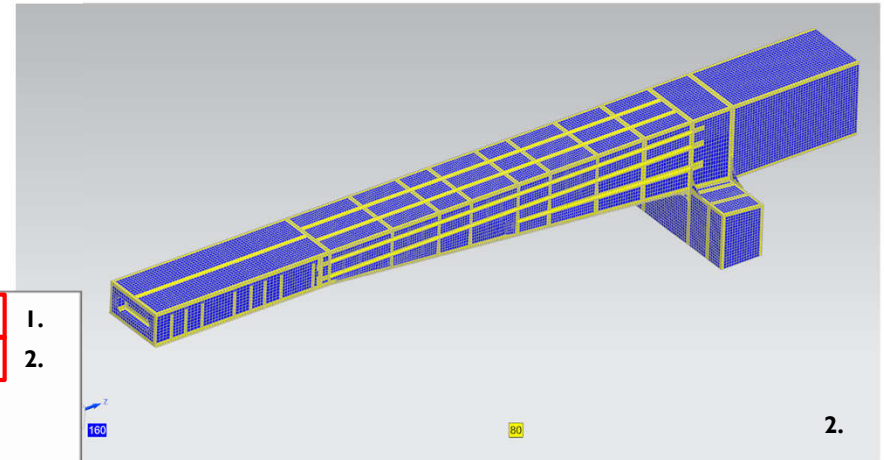
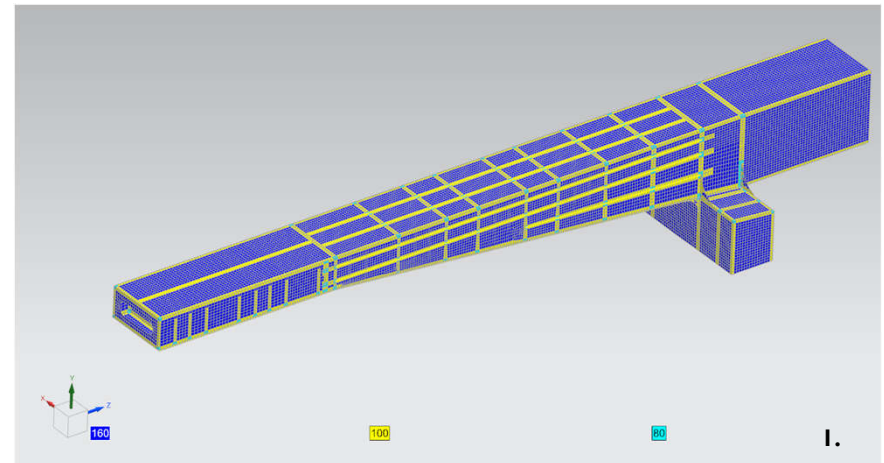
Element(s) Classification

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



- X
- 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*

**Check Plot**

ID: 1 Title:

Description:

Options

Check: 2..Fatigue Check

Fatigue Group: 1..Detailed load cycles pattern

Show Result for: FG1..Detailed load cycles pattern

Parameter: 2. Summed Damage

Direction: 3. Overall

Point Of Interest: 4. Total Type: AbsMax


View: 1..Default View

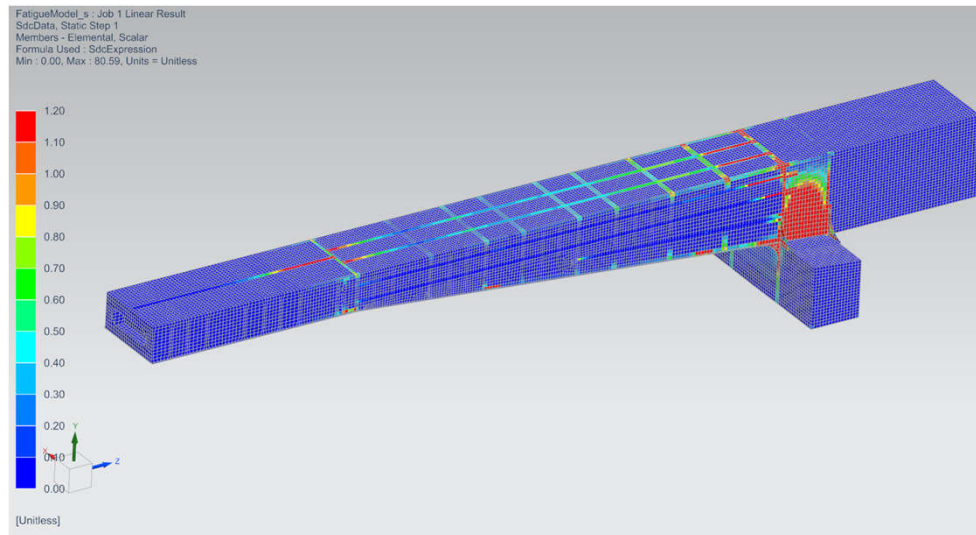
Selection

+ All Entities

Elements: 21367

Labels: None Limits: None

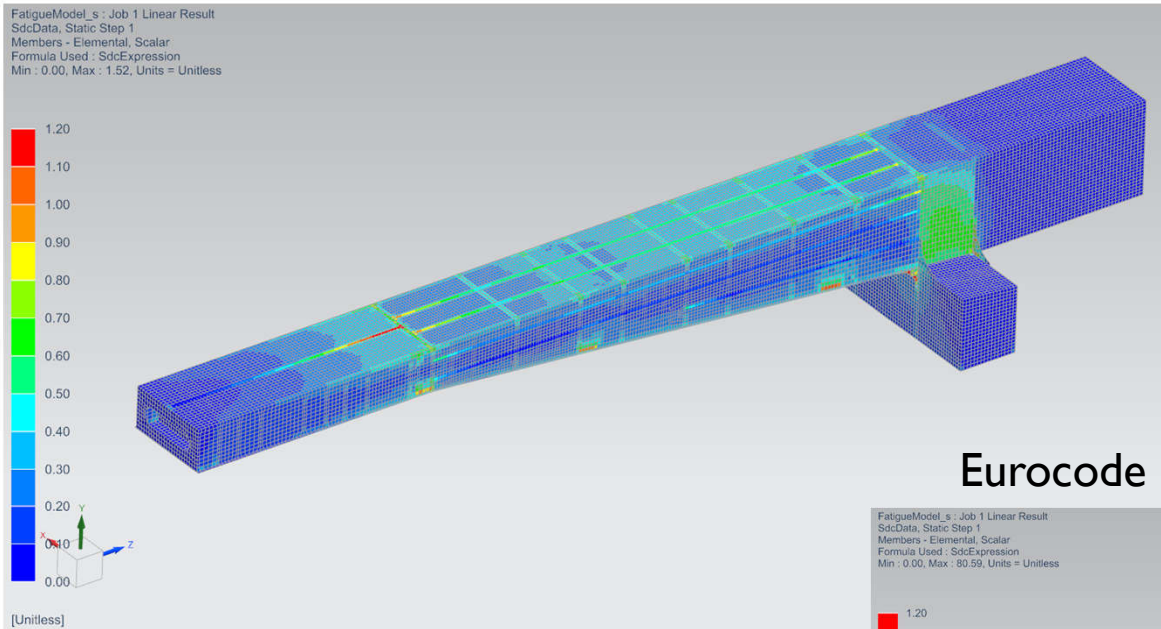
5.  6. **OK** Cancel





# Comparison

## FEM 1.001 utilization factor



## Eurocode 3 utilization factor at 2 million cycles

