



Fatigue according to F.E.M. 1.001 and compare with Eurocode 3

3.1.2017
version 4.0

Content

This step-by-step tutorial demonstrates how to implement the fatigue check according F.E.M. 1.001 in SDC Verifier.

The following steps are covered:

- ▶ FEM 1.001 Fatigue detailed review;
- ▶ Implementation in SDC Verifier;
- ▶ Weld Finder Tool overview;
- ▶ Fatigue tables and plots;
- ▶ Report preparation and results.

Fatigue F.E.M. 1.001

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.

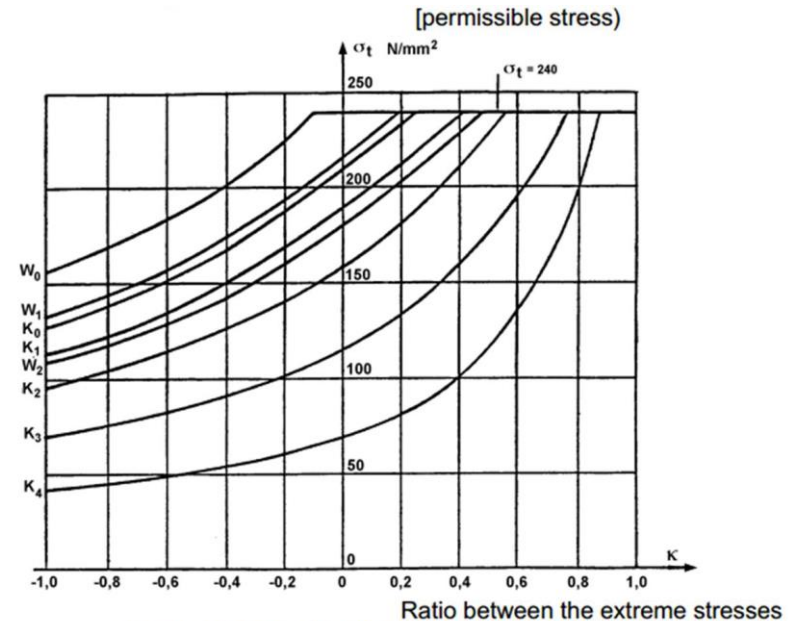


Figure A.3.6.1. - (A 52; tension; group E6)

Fatigue in SDC Verifier

Kappa Factor

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

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

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

Allowable Stress

a) $\kappa \leq 0$

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

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

σ_w is given in table above.

b) $\kappa > 0$

- for tension $\sigma_t = \sigma_o / [1 - \kappa \cdot (1 - \sigma_o / \sigma_{t1})]$ (3)

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

Utilization Factor Combined

$$\left(\frac{\sigma_{x \max}}{\sigma_{xa}} \right)^2 + \left(\frac{\sigma_{y \max}}{\sigma_{ya}} \right)^2 - \frac{\sigma_{x \max} \cdot \sigma_{y \max}}{|\sigma_{xa}| \cdot |\sigma_{ya}|} + \left(\frac{\tau_{xy \max}}{\tau_{xya}} \right)^2 \leq 1$$

Add Custom Check

ID: 2 Title: Fatigue Check

Alias: Fatigue_Check

Description:

☒ Show Parameter Description

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)
All: `if(SweldAbs > 0, SweldMin / SweldMax, SweldMax / SweldMin)`

Parameter = Sf (Stress Fatigue)
All: `Min(units.FromPaToCurrent(Switch(MaterialType, Fe360, Sf_Fe360(ElementGroup, WeldType), Fe510, Sf_Fe510(ElementGroup, WeldType))), Static_Check.Sallow)`

Parameter = Sallow_fatigue (Allowable Stress Fatigue)
All: `if (Kappa > 0, if(SweldAbs > 0, (5 / 3 * Sf) / (1 - (1 - (5 / 3 * Sf) / (0.75 * tensile))) * Kappa), (2 * Sf) / (1 - (1 - (2 * Sf) / (0.9 * tensile))) * Kappa), if(SweldAbs > 0, (5 * Sf) / (3 - 2 * Kappa), (2 * Sf) / (1 - Kappa)))`
Eqv.: 0

Parameter = Uf (Utilization Factor)
All: `Abs(SweldAbs) / Min(Static_Check.Sallow, Sallow_Fatigue)`
XY: `Abs(SweldAbs) / (Min(Static_Check.Sallow, Sallow_Fatigue / if(WeldType <= Weld_K4, SQRT(2), SQRT(3)))))`
YZ: `Abs(SweldAbs) / (Min(Static_Check.Sallow, Sallow_Fatigue / if(WeldType <= Weld_K4, SQRT(2), SQRT(3)))))`
ZX: `Abs(SweldAbs) / (Min(Static_Check.Sallow, 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 / 1.1))`

Clear results

OK Cancel

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 $0,75 \cdot \sigma_R$.

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)

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: 1 Title: Utilization Factor (LG1, All Entities)

Description:

Options: 2. Fatigue Check

Load Group: 1. Load Group 1

Table Type: Parameter over Directions

Parameter: Stress Fatigue

Selection: All welds

Elements: 12400

Extreme	X	Y	Z	XY	YZ	ZX	Eqv.	Overall
Minimum								
Value	95.60e+6	113.80e+6	127.50e+6				147.80e+6	0.00e+6
Element ID	1	326	326				1	1
Maximum								
Value	95.60e+6	113.80e+6	127.50e+6				147.80e+6	0.00e+6
Element ID	1	326	326				1	1
Absolute								
Value	95.60e+6	113.80e+6	127.50e+6				147.80e+6	0.00e+6
Element ID	1	326	326				1	1


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.


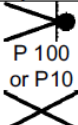
Case W₀

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.		

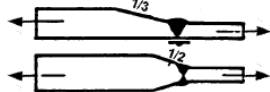

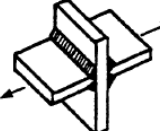

Case K₀ - Slight stress concentration

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		



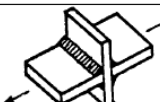

Case K₂ - Medium stress concentration

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

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

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 10⁶)

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

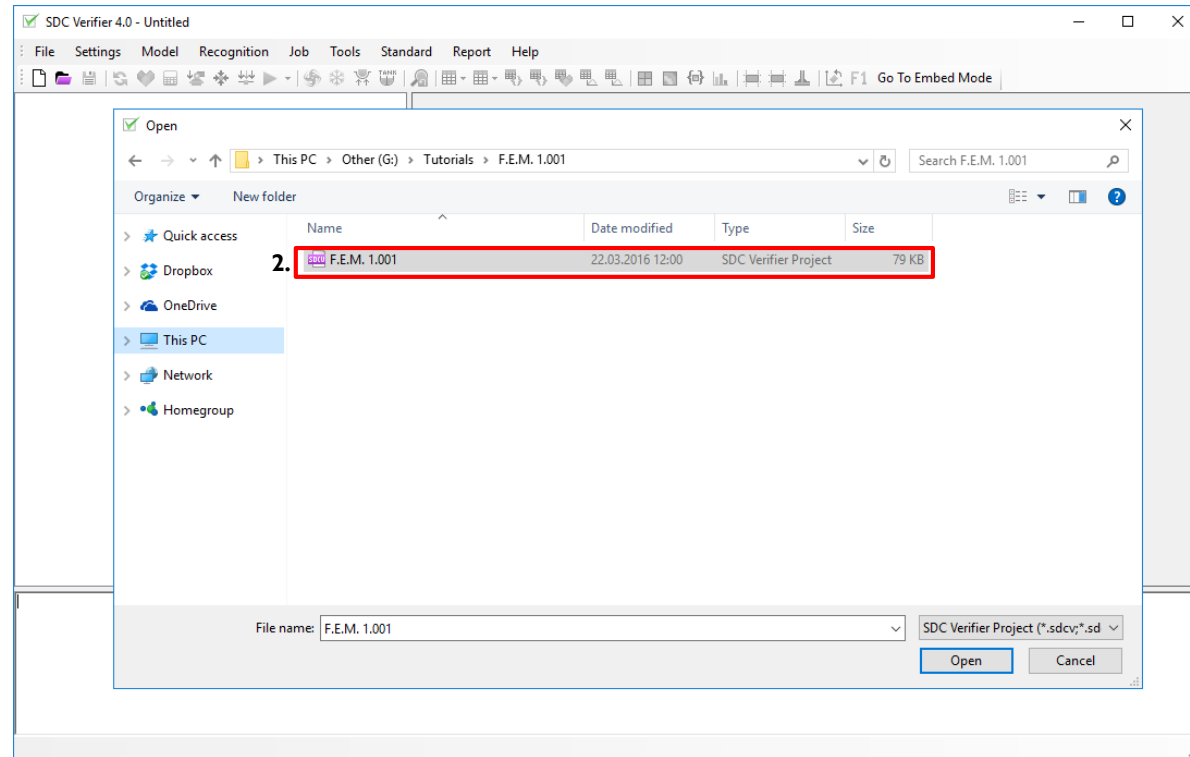
Open the starter model

1

Launch **SDC Verifier** 

2

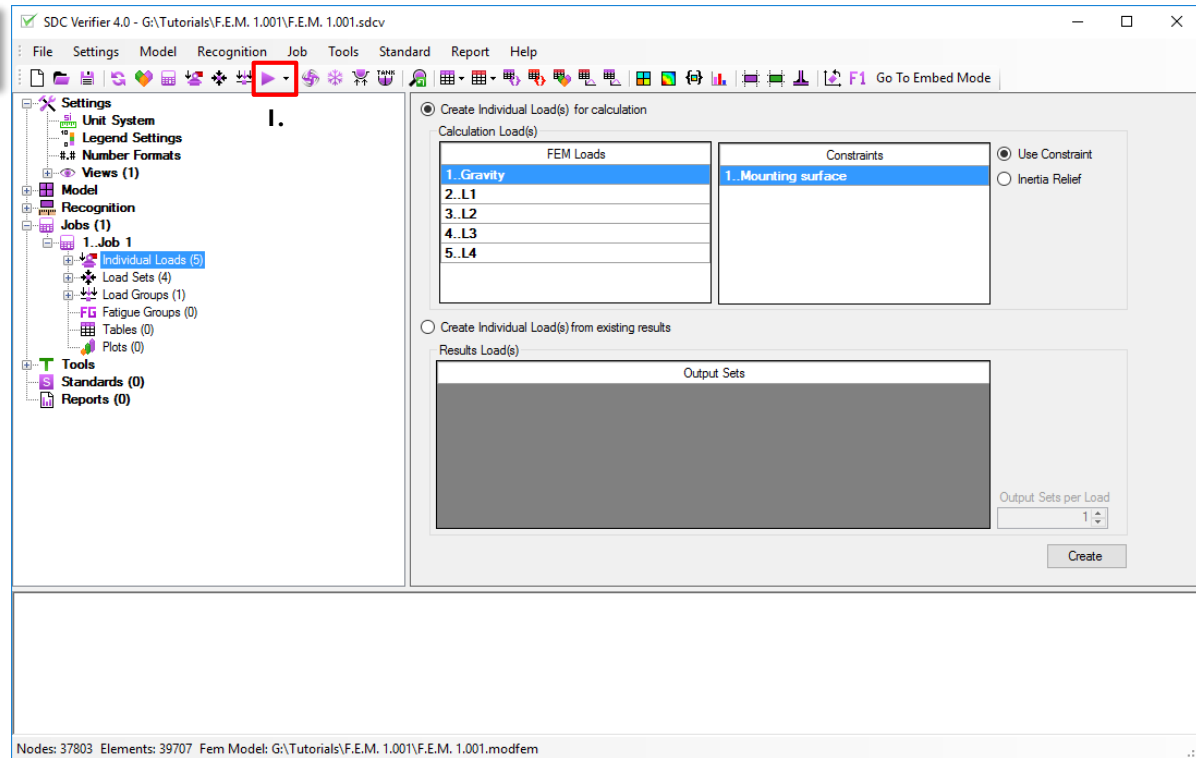
Open project *F.E.M. 1.001* from the directory *Tutorials/F.E.M. 1.001*.



Run Analysis

1

Press  to start Analysis in Femap

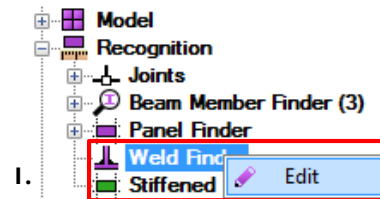


Weld Finder

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

2 Press *Find Welds*.

3 Press *Export*



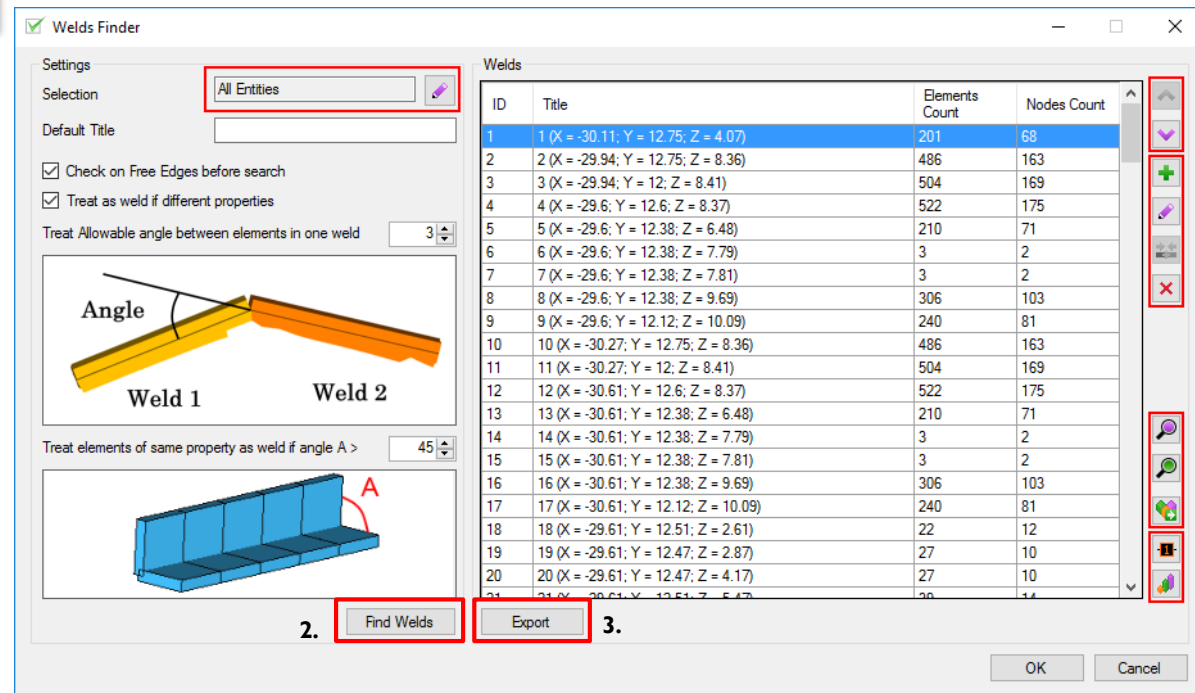
Selection - Part of the model where to find welds

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

Add, Edit, Combine and *Remove Welds*.

Preview and Export selected welds

Plot of selected welds in colors and with labels of IDs



Weld Finder. Export

4

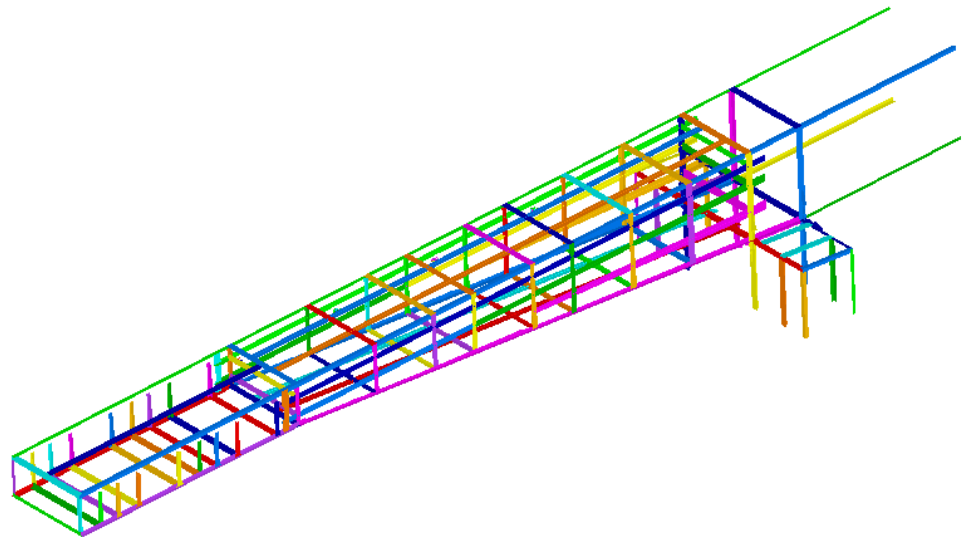
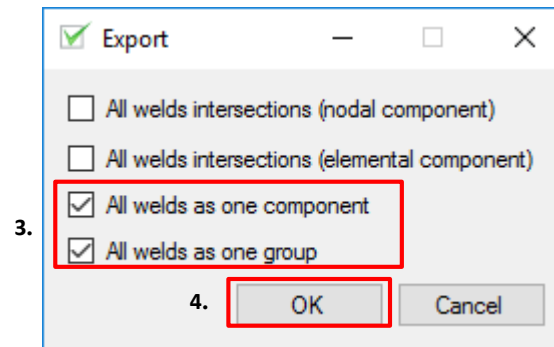
All welds as one component **ON**
All welds as one group **ON**

Femap group and new component will be created.

5

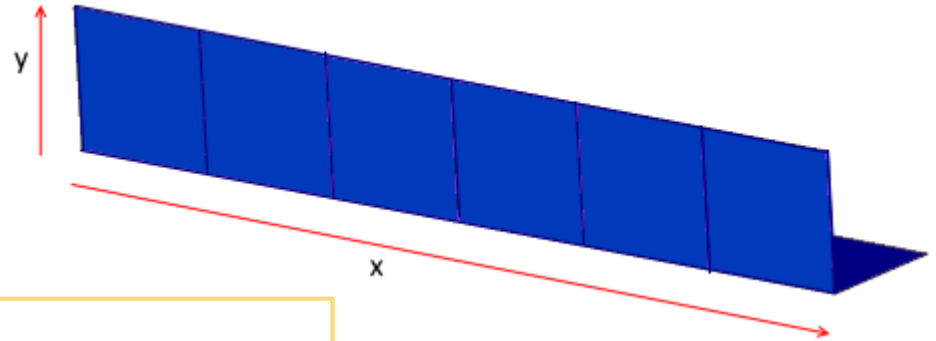
Press *OK*.

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

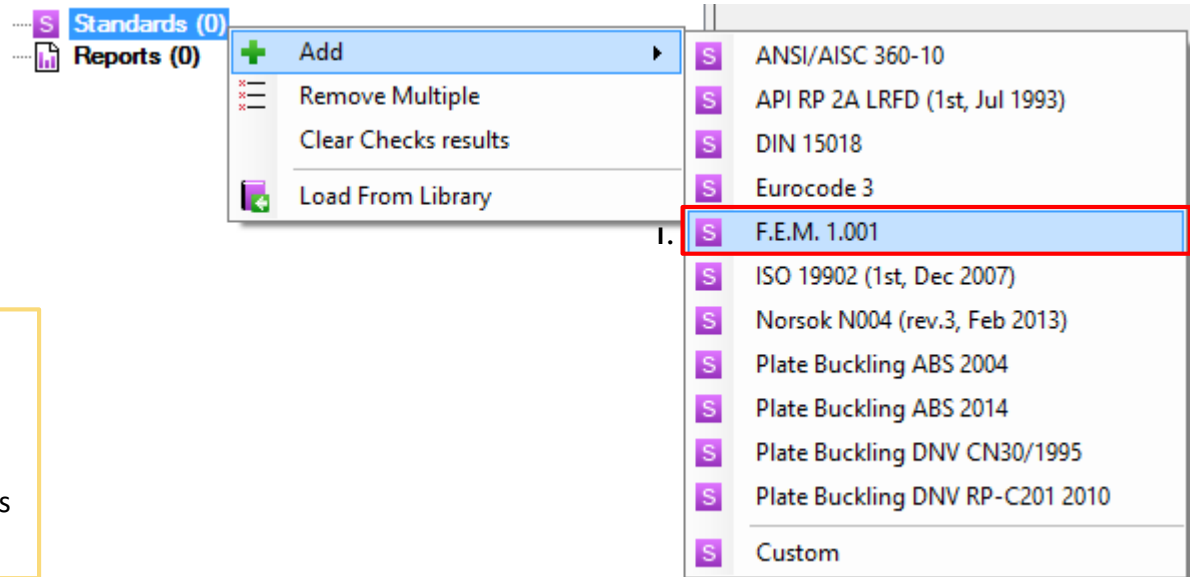
θ – angle between the element and weld x directions.

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**

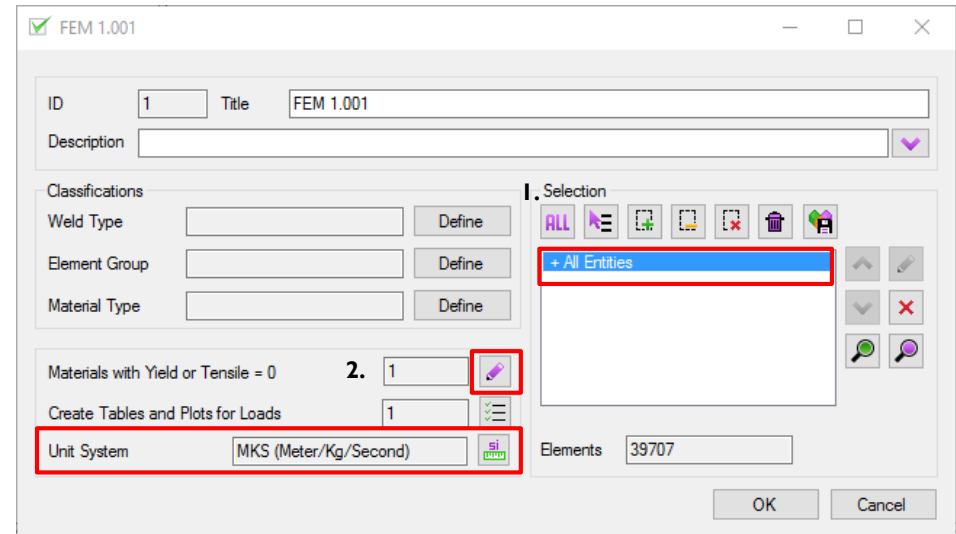
2 Press  to edit material properties.

Amount of materials with not defined Tensile or Yield are 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.



FEM 1.001

ID: 1 Title: FEM 1.001

Description:

Classifications

Weld Type: Define

Element Group: Define

Material Type: Define

Selection

+ All Entities

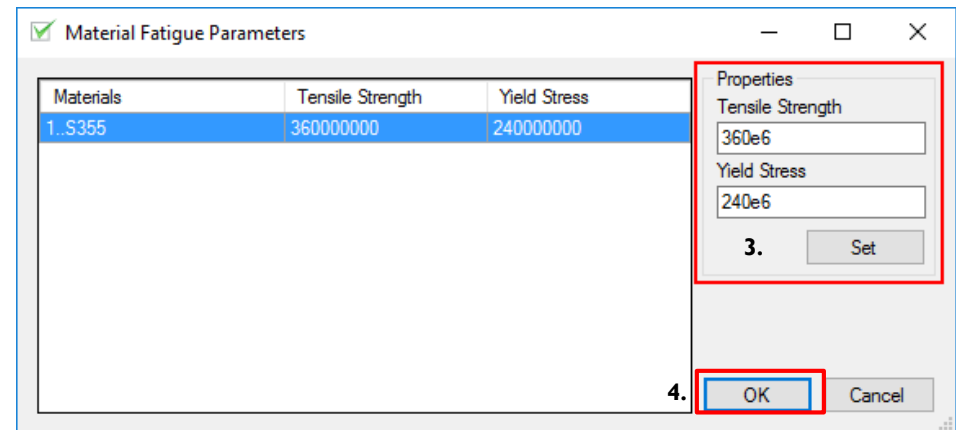
Materials with Yield or Tensile = 0: 2

Create Tables and Plots for Loads: 1

Unit System: MKS (Meter/Kg/Second)

Elements: 39707

OK Cancel



Material Fatigue Parameters

Materials	Tensile Strength	Yield Stress
1.S355	360000000	240000000

Properties

Tensile Strength: 360e6

Yield Stress: 240e6

3. Set


4. OK Cancel

Definition of weld categories

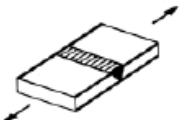


- ▶ Weld/notch category determines fatigue resistance
- ▶ Division in welds / non welds for FEM 1.001:
 - ▶ W category is for non welded parts
 - ▶ K category is for welded parts
- ▶ Fatigue resistance is further specified by adding classes
 - ▶ W0-W2 for non-welded parts
 - ▶ K0-K4 for welded parts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

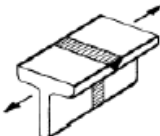


Slight notch behavior group K0

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

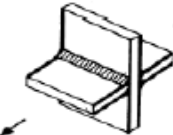

Medium notch behavior group K2

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.		
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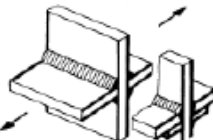


and a different connection type 351

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

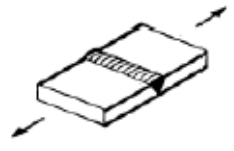
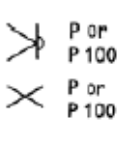
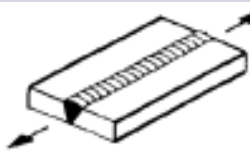
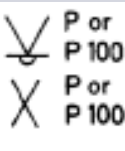
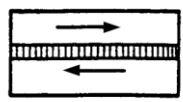

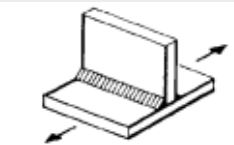

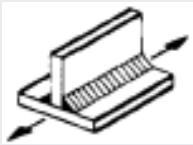
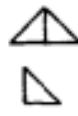
Very great notch behavior group K4

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		 P or P 100 X P or P 100	K0		 P or P 100 X P or P 100	K0		
K2			K1					

No weld (all directions)

W0



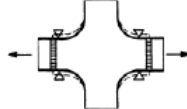


In the software: $\tau_D(-1) = \sigma_D(-1) / \text{sqrt}(3)$

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

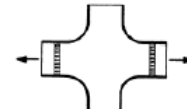


1. For beams SCF of connections can be included in the classification

Depends on Stress concentrations:

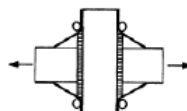


Slight notch behavior group K0

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

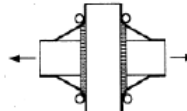


Moderate notch behavior group K1

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

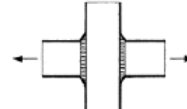


Medium notch behavior group K2

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

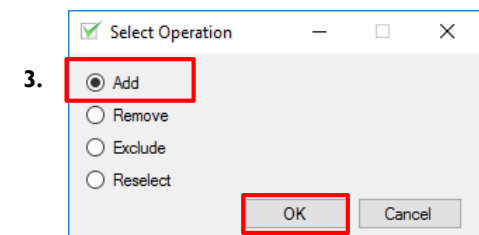
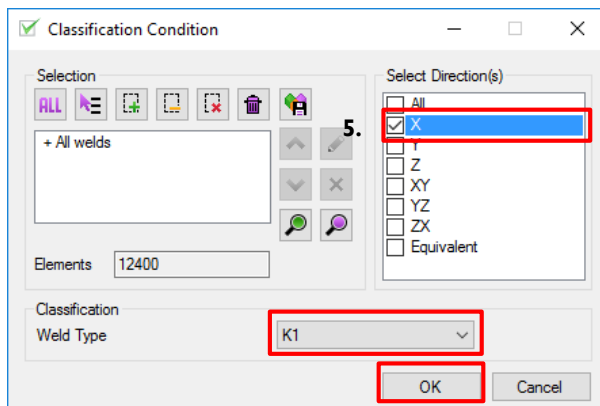
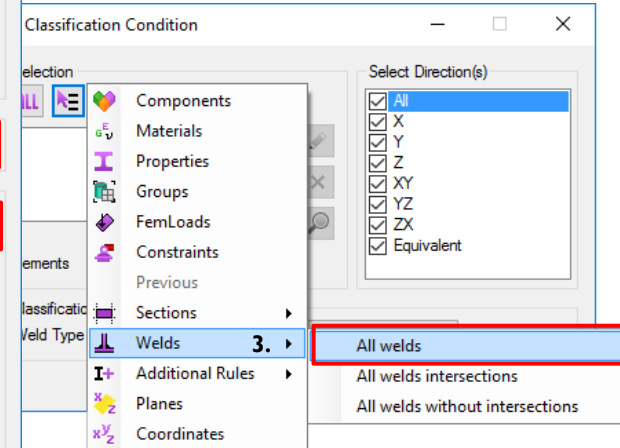
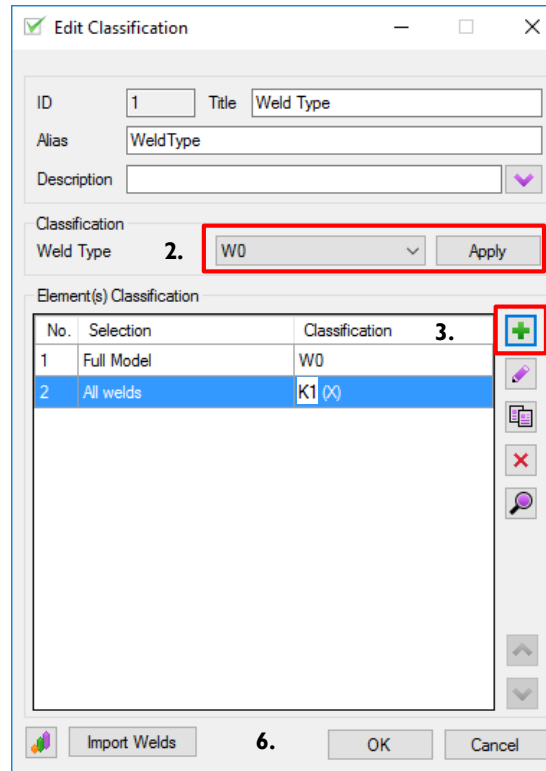
Very great notch behavior group K4

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 Select *Weld Type W0*. Press *Apply* to Full Model condition.
- 3 Press  *Add Condition*. Select All Welds Condition and select operation *Add*. Press *OK*.
- 4 Select *Weld Type: K1*.
- 5 Select direction X. Press *OK*.




Weld Type classification 2

6

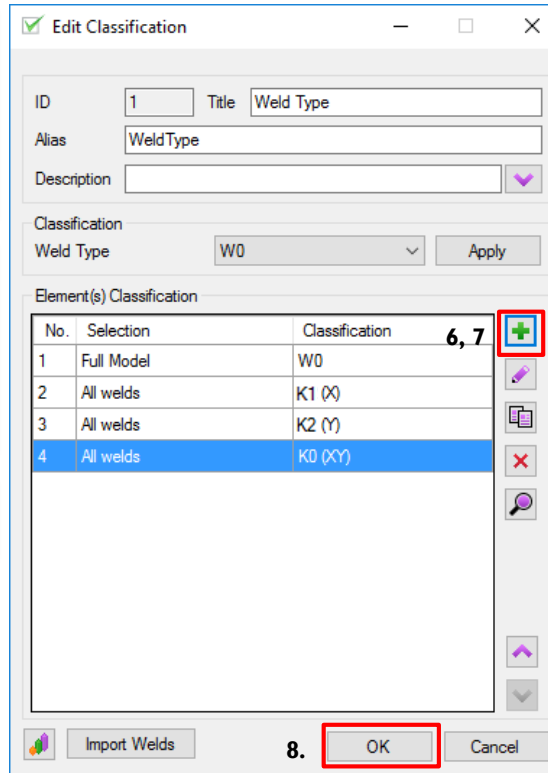
Press  **Add Condition.**
Selection: **All Welds.**
Weld Type: **K2.**
Direction: **Y.**
Press OK.

7

Press  **Add Condition.**
Selection: **All Welds**
Weld Type: **K0.**
Direction: **XY.**
Press OK.

8

Press OK.



Edit Classification

ID: 1 Title: Weld Type


Alias: WeldType

Description:

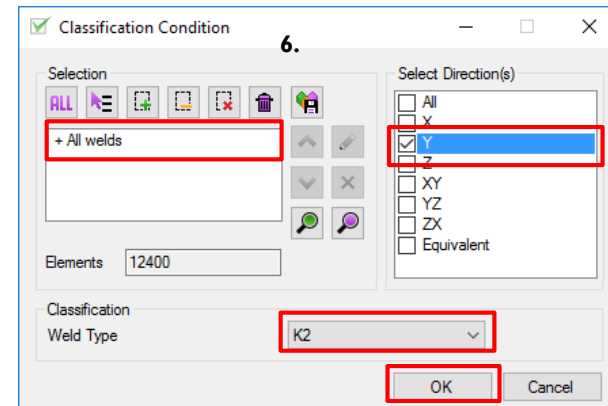
Classification: Weld Type W0 Apply

Element(s) Classification
















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

6, 7 

8. OK Cancel



Classification Condition 6.

Selection: ALL               

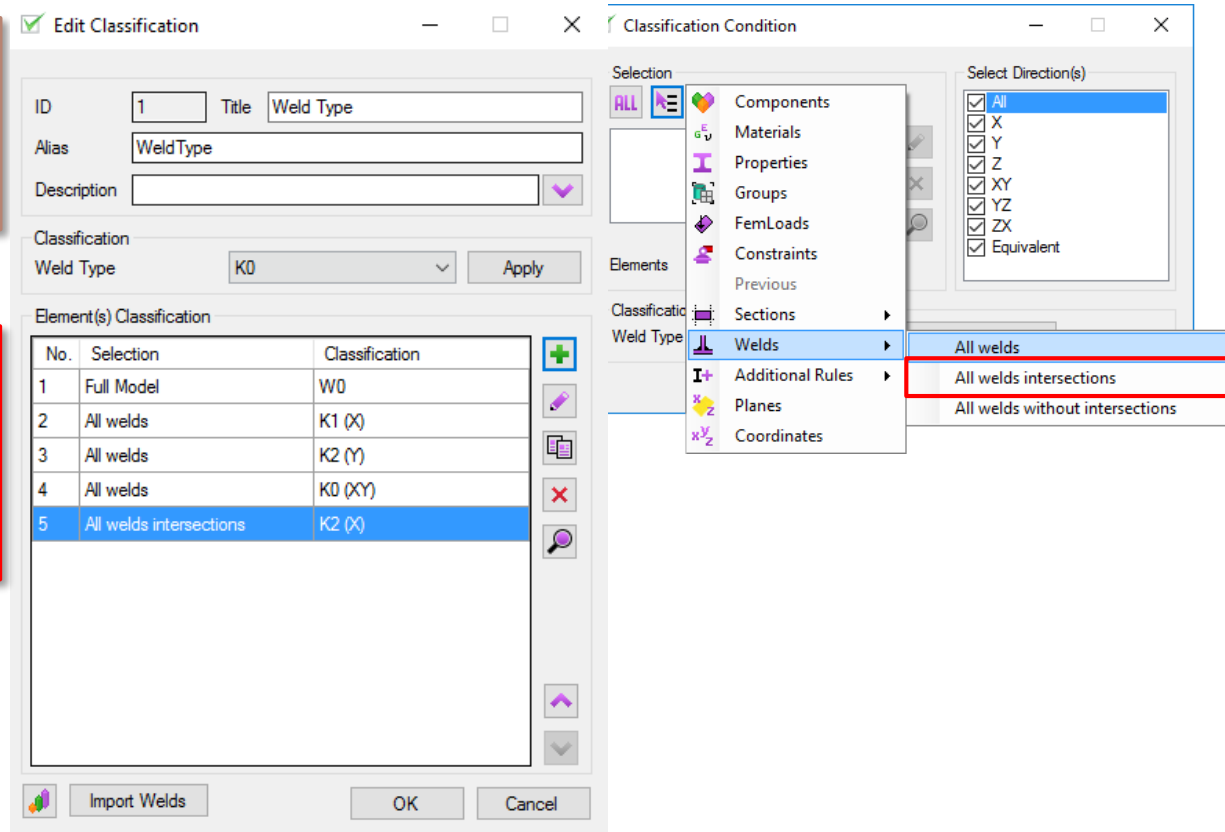
Weld Type classification intersecting welds

9

Press *Add Condition*.
Selection: **All Weld intersections**.
Weld Type: **K2**.
Direction: **X**.
Press OK.

The last line in the classification overwrites the previous lines
Therefor the settings of all weld intersections overwrites its original setting of KI in X direction

At intersecting welds all stresses are perpendicular to the weld direction



Check classification

✓ Edit Classification

ID: 1 Title: Weld Type

Alias: WeldType

Description:

Classification: Weld Type K0 Apply

Element(s) Classification

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

✓ Plot

Parameters: Direction X Plot Close

✓ Plot

Parameters: Direction Y Plot Close

9. 8. 7. 6. 5. 4. 3. 2. 1.

K1 K2 W0

K2 W0

Element Group classification

1 Press *Define* for the Element Group.

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

3 Press *OK*.

☒ Edit Classification

ID: 2 Title: Element Group

Alias: ElementGroup

Description:

Classification

Element Group: 2. E6 Apply

Element(s) Classification

No.	Selection	Classification
1	Full Model	E6

Import Welds 3. OK Cancel

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.

Edit Classification

ID: 3 Title: Material Type

Alias: MaterialType

Description: Fe360 or Fe510

Classification

Material Type: 2. Fe 360 (Fe 37) Apply

Element(s) Classification

No.	Selection	Classification
1	Full Model	Fe 360 (Fe 37)

Import Welds 3. OK Cancel

Create extreme table

1

Execute *Extreme Table* 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

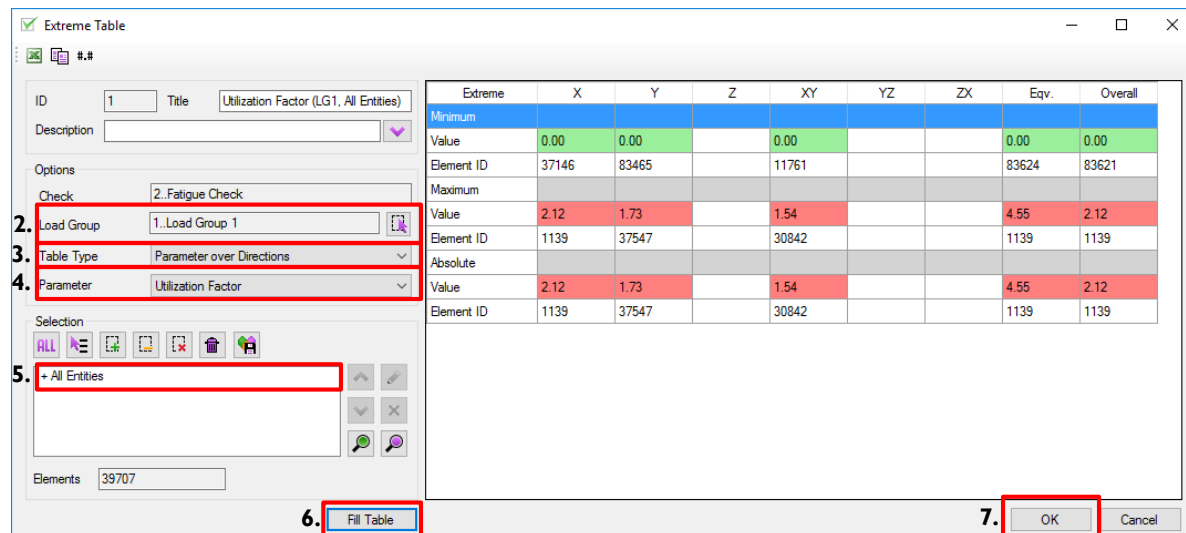
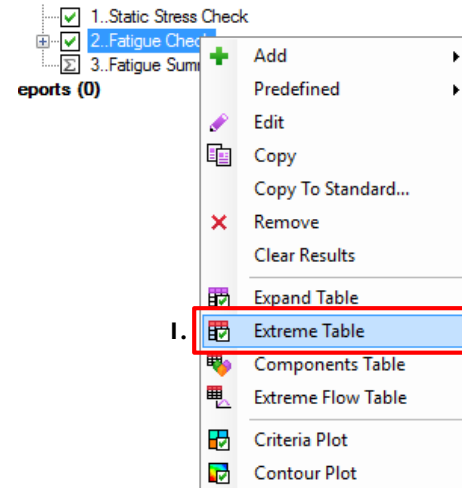
Selection: **All Entities.**

6

Press *Fill Table*.

7

Press *OK*.



Create components extreme table

1

Execute *Components Table* in **Fatigue Check** context menu.

2

Select *All* except 7, 8, 9.

3

Press *Fill Table*.

4

Press *OK*.

Properties 2.

Search ID Go

Filter X

- ☒ 4..stl plt 10 mm thks
- ☒ 5..stl plt 8 mm thks
- ☒ 6..stl plt 15 mm thks
- ☐ 7..stl plt 20 mm thks
- ☐ 8..stl plt 25 mm thks
- ☐ 9..stl plt 35 mm thks
- ☒ 10..stl plt 4 mm thks
- ☒ 11..stl plt 12 mm thks
- ☒ 12..stl plt 24 mm thks
- ☒ 13..stl L-bar 100x65x8 mm
- ☒ 14..stl L-bar 100x65x8 mm (top)
- ☒ 15..stl L-bar 100x65x8 mm (side)

Components Extreme Table

ID 2 Title

Description

Options

Check 2..Fatigue Check

Load Group 1..Load Group 1

Table Type Parameter Over Directions

Parameter Utilization Factor

Selections (9)

2. ☒ ALL ☐ ☐ ☐ ☐

Property 4..stl plt 10 mm thks
Property 5..stl plt 8 mm thks
Property 6..stl plt 15 mm thks
Property 10..stl plt 4 mm thks
Property 11..stl plt 12 mm thks
Property 12..stl plt 24 mm thks
Property 13..stl L-bar 100x65x8 mm
Property 14..stl L-bar 100x65x8 mm (top)
Property 15..stl L-bar 100x65x8 mm (side)

3.

4.

Selections	X	Y	Z	XY	YZ
4..stl plt 10 mm thks	0.69	0.94		0.29	
5..stl plt 8 mm thks	0.41	0.49		0.23	
6..stl plt 15 mm thks	2.12	1.15		1.54	
10..stl plt 4 mm thks	0.40	0.41		0.04	
11..stl plt 12 mm thks	1.39	1.73		1.25	
12..stl plt 24 mm thks					
13..stl L-bar 100x65x8 mm	1.14				
14..stl L-bar 100x65x8 mm (top)	0.77				
15..stl L-bar 100x65x8 mm (side)	1.07				

Components table displays results for multiple selections (e.g. properties, materials or components). For linear properties (beams, bars etc.) only X, Equivalent and Overall directions are displayed. If no elements belong to the property - empty fields are displayed.



Create criteria plot

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


2 Parameter: **Utilization Factor**

3 LG Parameter: **Absolute**

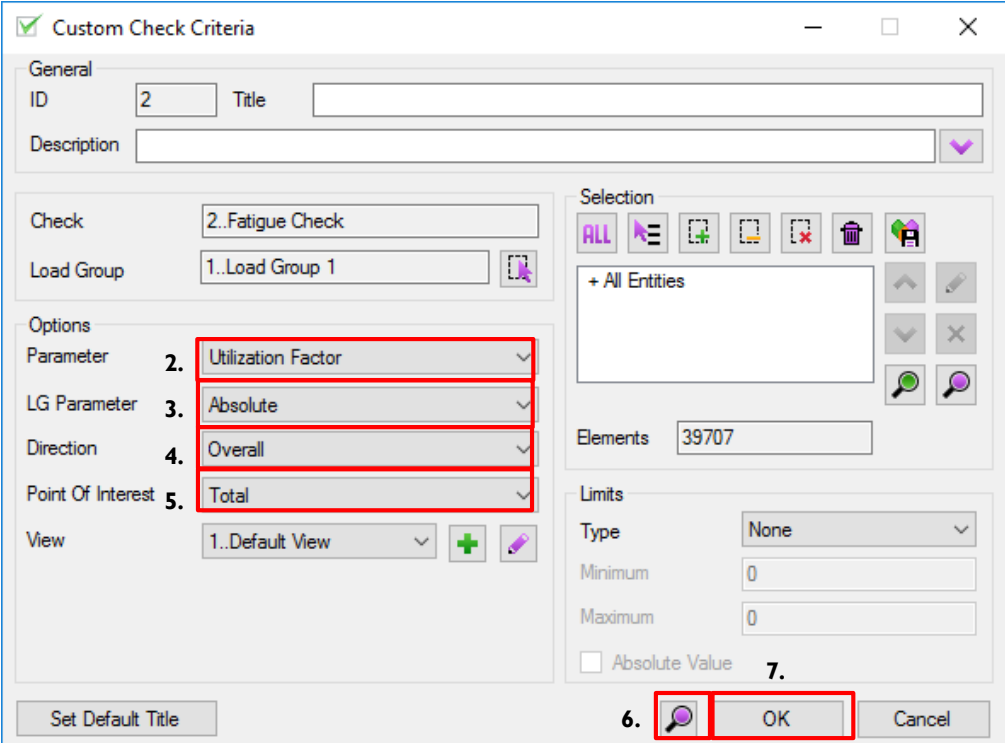
LG Parameter – enabled only for Load Groups. It defines which values to take (minimum, maximum or absolute maximum)

4 Direction: **Overall**

5 Point of interest: **Total**

6 Press  to preview Plot in Femap

7 Press OK



Report. Tables and plots

1 Execute Reports => Add Report Designer
=> Results.

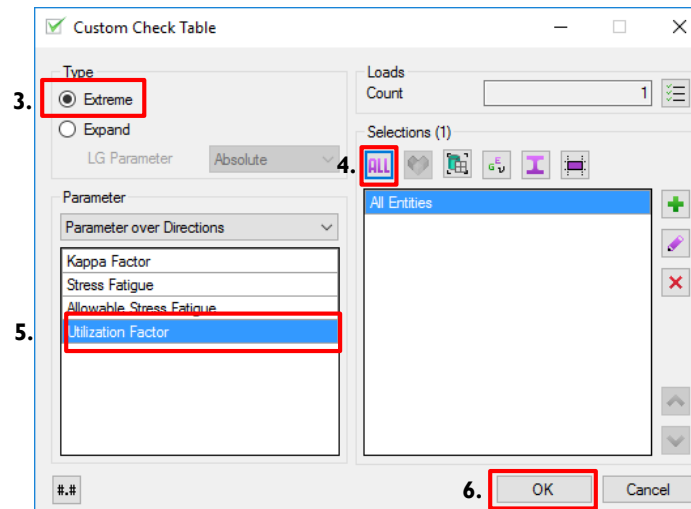
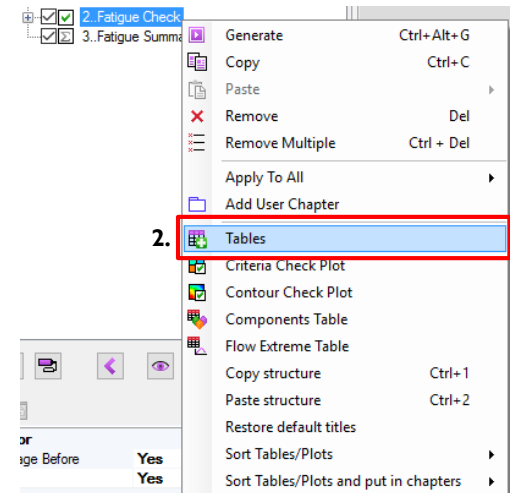
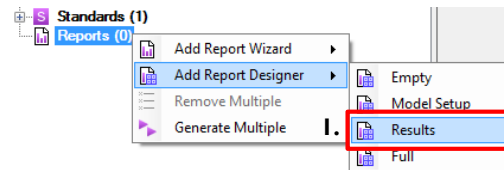
2 Click on **Tables** in **Fatigue Check** context menu.

3 Type: **Extreme**.

4 Selection: **All Entities**.

5 Parameter: **Utilization Factor**.

6 Press **OK**.



Report. Tables and plots

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


2 Parameter: **Utilization Factor**.

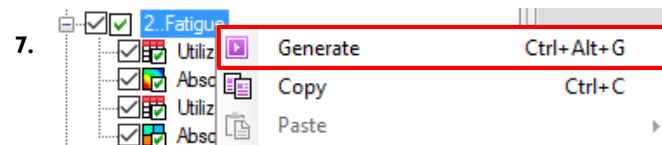
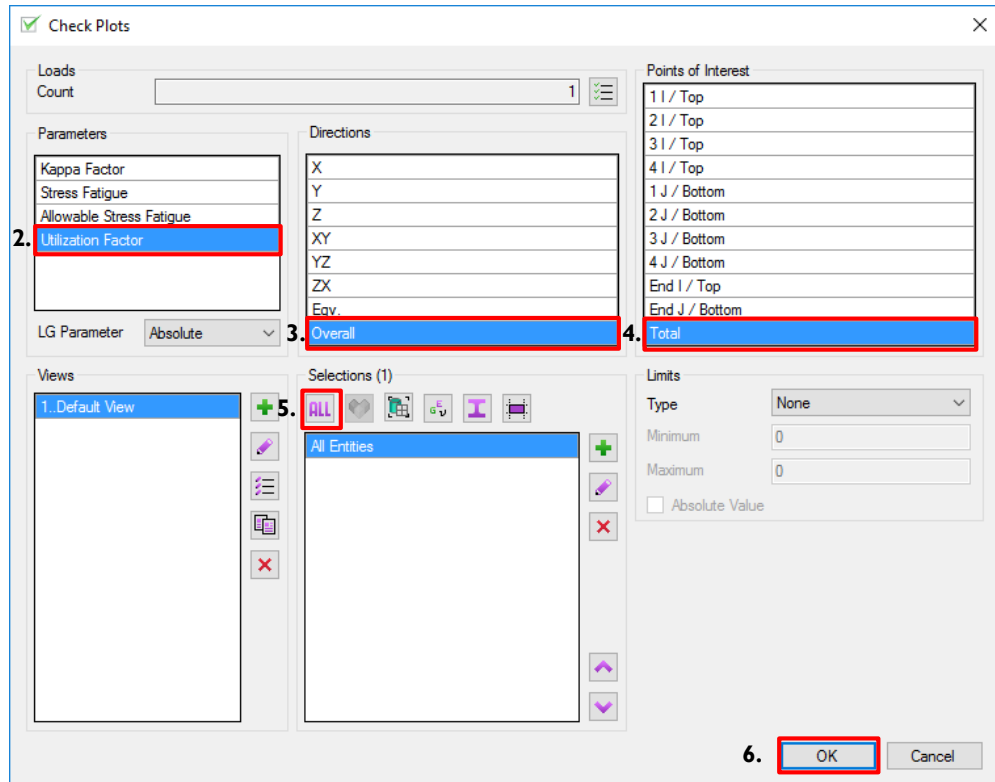
3 Direction: **Overall**.

4 Point of Interest: **Total**.

5 Selection: **All Entities**.

6 Press **OK**.

7 **Generate**  check item



Report. Results

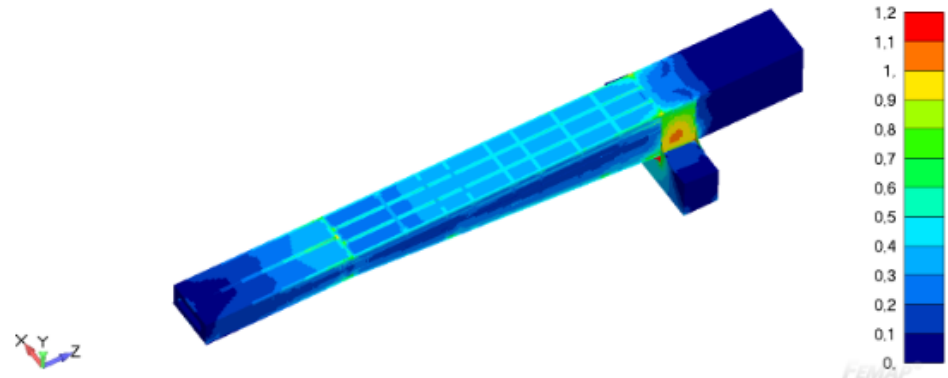
2..Fatigue Check

Property	Value
Category	Elemental Custom Check
Selection	All Entities
Parameters	4
Alias (Parameter)	Kappa (Kappa Factor)
All	$\text{if}(\text{SweldAbs} > 0, \text{SweldMin} / \text{SweldMax}, \text{SweldMax} / \text{SweldMin})$
Alias (Parameter)	Sf (Stress Fatigue)
All	$\text{Min}(\text{units.FromPaToCurrent}(\text{Switch}(\text{MaterialType}, \text{Fe360}, \text{Sf_Fe360}(\text{ElementGroup}, \text{WeldType}), \text{Fe510}, \text{Sf_Fe510}(\text{ElementGroup}, \text{WeldType}))), \text{Static_Check.Sallow})$
Alias (Parameter)	Sallow_fatigue (Allowable Stress Fatigue)
All	$\text{if}(\text{Kappa} > 0, \text{if}(\text{SweldAbs} > 0, (5 / 3 * \text{Sf}) / (1 - (5 / 3 * \text{Sf}) / (0.75 * \text{tensile})) * \text{Kappa}), (2 * \text{Sf}) / (1 - (1 - (2 * \text{Sf}) / (0.9 * \text{tensile})) * \text{Kappa})), \text{if}(\text{SweldAbs} > 0, (5 * \text{Sf}) / (3 - 2 * \text{Kappa}), (2 * \text{Sf}) / (1 - \text{Kappa})))$
Eqv.	0
Alias (Parameter)	Uf (Utilization Factor)
All	$\text{Abs}(\text{SweldAbs}) / \text{Min}(\text{Static_Check.Sallow}, \text{Sallow_Fatigue})$
XY	$\text{Abs}(\text{SweldAbs}) / (\text{Min}(\text{Static_Check.Sallow}, \text{Sallow_Fatigue}) / \text{if}(\text{WeldType} \leq \text{Weld_K4}, \text{SQRT}(2), \text{SQRT}(3))))$
YZ	$\text{Abs}(\text{SweldAbs}) / (\text{Min}(\text{Static_Check.Sallow}, \text{Sallow_Fatigue}) / \text{if}(\text{WeldType} \leq \text{Weld_K4}, \text{SQRT}(2), \text{SQRT}(3))))$
ZX	$\text{Abs}(\text{SweldAbs}) / (\text{Min}(\text{Static_Check.Sallow}, \text{Sallow_Fatigue}) / \text{if}(\text{WeldType} \leq \text{Weld_K4}, \text{SQRT}(2), \text{SQRT}(3))))$
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	$\text{Max}(\text{me.x}, \text{me.y}, \text{me.z}, \text{me.xy}, \text{me.yz}, \text{me.zx}, \text{sqrt}(\text{me.eqv} / 1.1))$

Utilization Factor (LG1, All Entities)

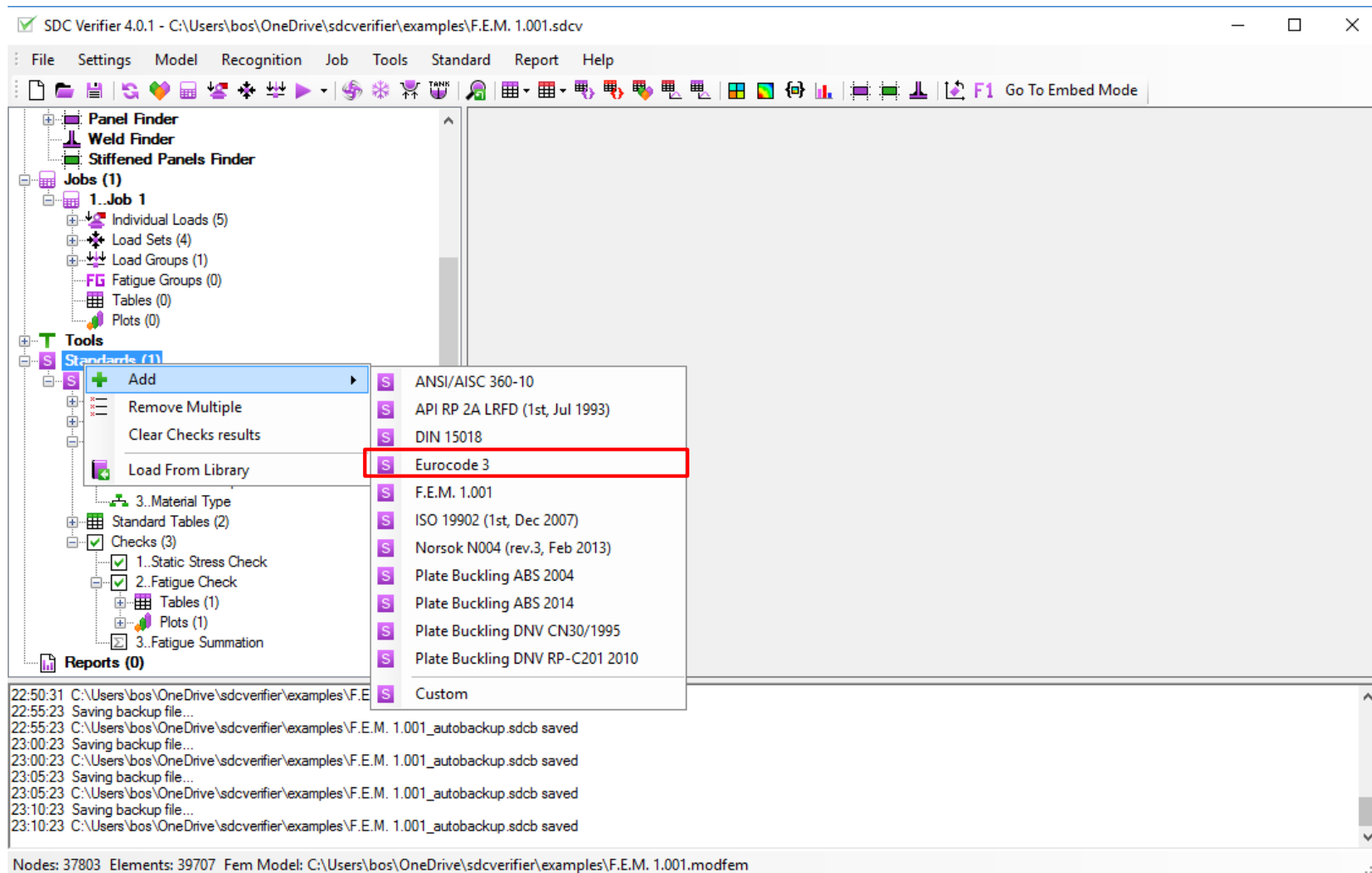
Standard	1..FEM 1.001			Check	2..Fatigue Check			
Load Group	1..Load Group 1			Parameter	Utilization Factor			
Selection	All Entities							
Extreme	X	Y	Z	XY	YZ	ZX	Eqv.	Overall
Minimum								
Value	0.00	0.00		0.00			0.00	0.00
Element ID	37146	83465		11761			83624	83621
Maximum								
Value	2.12	1.73		1.54			4.55	2.12
Element ID	1139	37547		30842			1139	1139
Absolute								
Value	2.12	1.73		1.54			4.55	2.12
Element ID	1139	37547		30842			1139	1139

Absolute Overall Utilization Factor (LG1, All Entities, 1..Default View)

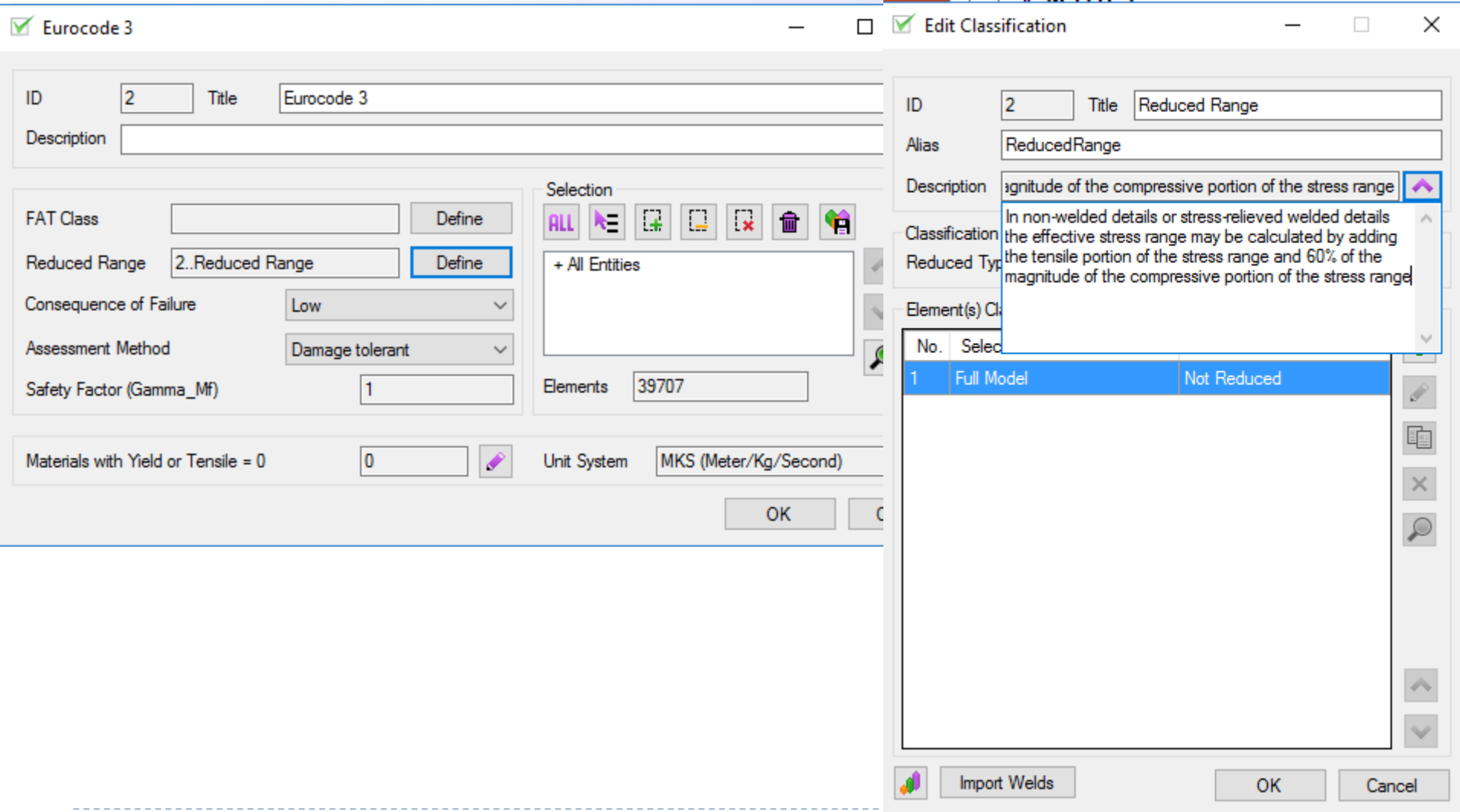


Check	2..Fatigue Check	Point	Total
Load Group	1..Load Group 1	Parameter	Overall Utilization Factor
Selection	All Entities	View	1..Default View

Fatigue calculation with Eurocode 3



Eurocode 3 settings



The image shows two overlapping software windows. The background window is titled 'Eurocode 3' and contains various input fields for defining a fatigue class. The foreground window is titled 'Edit Classification' and shows a detailed description for a 'Reduced Range' classification, along with a table of element classifications.

Eurocode 3 Dialog:

- ID: 2
- Title: Eurocode 3
- Description: (empty)
- FAT Class: (empty) [Define]
- Reduced Range: 2..Reduced Range [Define]
- Consequence of Failure: Low
- Assessment Method: Damage tolerant
- Safety Factor (Gamma_Mf): 1
- Materials with Yield or Tensile = 0: 0
- Unit System: MKS (Meter/Kg/Second)
- Selection: + All Entities
- Elements: 39707

Edit Classification Dialog:

- ID: 2
- Title: Reduced Range
- Alias: ReducedRange
- Description: magnitude of the compressive portion of the stress range
- Classification: In non-welded details or stress-relieved welded details the effective stress range may be calculated by adding the tensile portion of the stress range and 60% of the magnitude of the compressive portion of the stress range
- Reduced Type: (empty)
- Element(s) Classification:

No.	Selected	Classification
1	Full Model	Not Reduced

Buttons: OK, Cancel, Import Welds

Eurocode 3 formula's

☒ 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 (8) / 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: `SweldDelta`
YZ: `SweldDelta`
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 = m (m)
All: `if(ItemNumberOfCycles <= 5M, 3, if(ItemNumberOfCycles < 100M, 5, 1))`

Parameter = Fs (Fatigue Strength)
Description: Maximum delta stress for the number of load cycles in the group.
All: `if(ItemNumberOfCycles <= 5M, pow(SN(1, FAT), m) * 2M, if(ItemNumberOfCycles <= 100M, pow`

Clear results

OK Cancel

FAT classes (similar to weld/notch groups)

☒ Edit Classification

ID: 1 Title: FAT Class

Alias: FAT

Description:

Classification

FAT Stress: 160

Element(s) Classification

No.	Selection	Classification
1	Full Model	160

FAT classes Eurocode 3

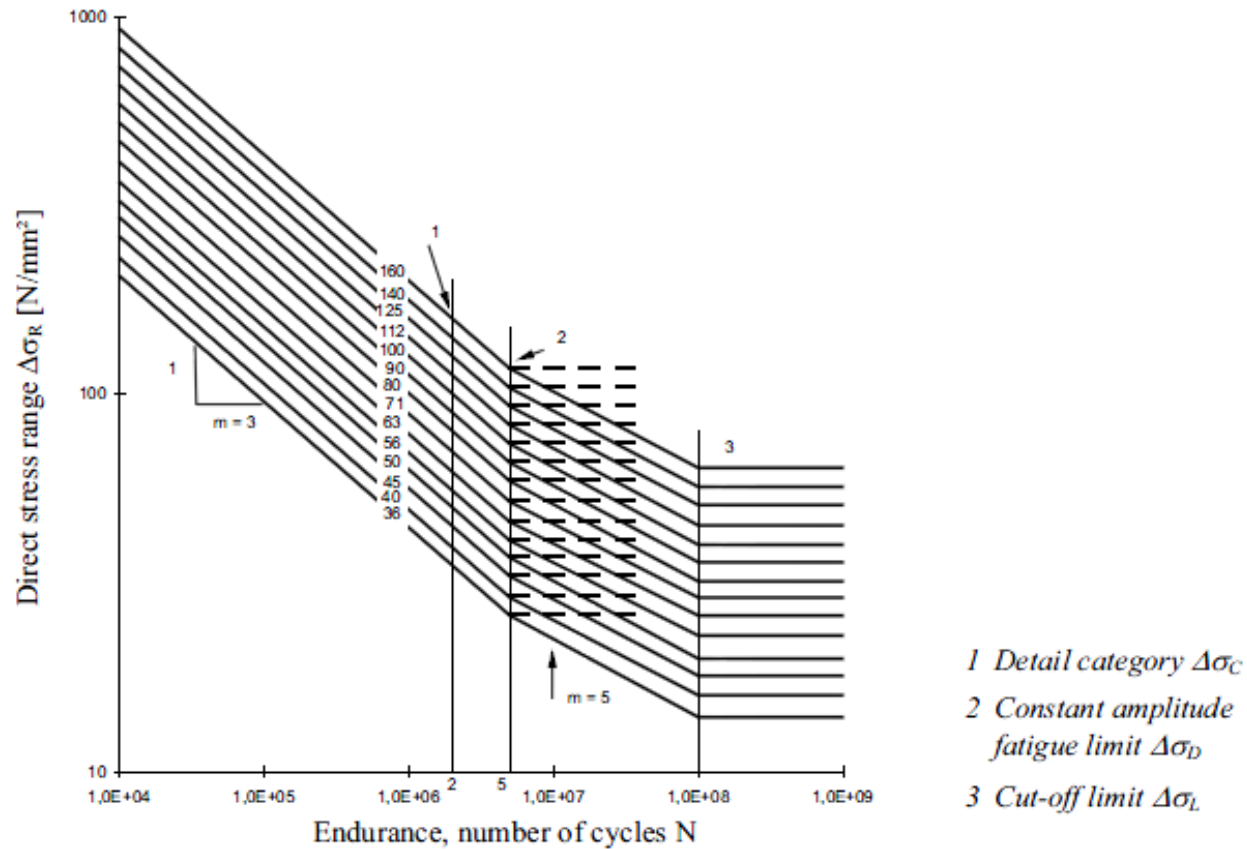


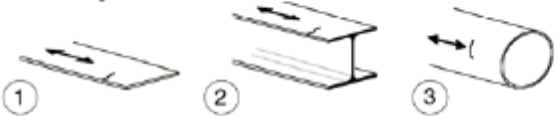

Figure 7.1: Fatigue strength curves for direct stress ranges

FAT classes Eurocode 3

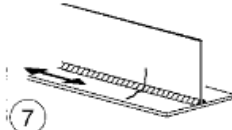
For determination of FAT classes check standard!
In this tutorial only examples are given


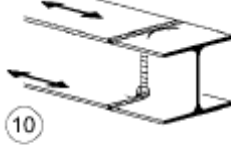
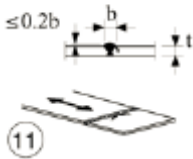
No welds:

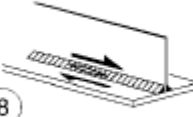
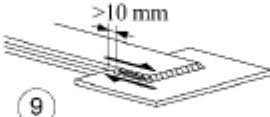
Table 8.1: Plain members and mechanically fastened joints

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 m = 5		<p>6) and 7) Rolled and extruded products as in details 1), 2), 3)</p>	<p><u>Details 6) and 7):</u></p> <p>$\Delta\tau$ calculated from: $\tau = \frac{V S(t)}{I t}$</p>

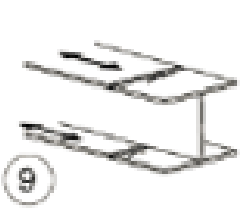
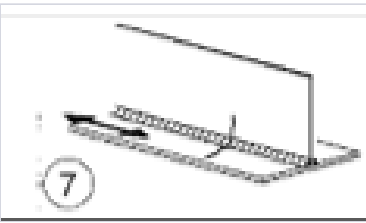
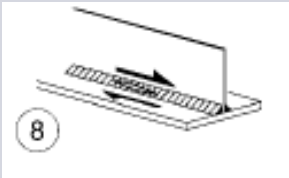


FAT classes Eurocode 3 welded

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.
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80	size effect for $t > 25 \text{ mm}$: $k_t = (25/t)^{0.2}$	  	<p>9) Transverse splices in welded plate girders without cope hole.</p> <p>10) Full cross-section butt welds of rolled sections with cope holes.</p> <p>11) Transverse splices in plates, flats, rolled sections or plate girders.</p> <ul style="list-style-type: none"> -The height of the weld convexity to be not greater than 20% of the weld width, with smooth transition to the plate surface. -Weld not ground flush -Weld run-on and run-off pieces to be used and subsequently removed, plate edges to be ground flush in direction of stress. -Welded from both sides; checked by NDT. <p><u>Detail 10:</u> The height of the weld convexity to be not greater than 10% of the weld width, with smooth transition to the plate surface.</p>
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80 $m=5$	 	<p>8) Continuous fillet welds transmitting a shear flow, such as web to flange welds in plate girders.</p> <p>9) Fillet welded lap joint.</p>	<p>8) $\Delta\tau$ to be calculated from the weld throat area.</p> <p>9) $\Delta\tau$ to be calculated from the weld throat area considering the total length of the weld. Weld terminations more than 10 mm from the plate edge, see also 4) and 5) above.</p>
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Eurocode 3 Fatigue resistance

Stress perpendicular to weld	Stress parallel with weld	Shear
<div>80</div> 	<div>100</div> 	<div>80</div> 
No weld (normal direction)		No weld (shear)
<div>160</div> 	<div>100</div> 	

Set FAT classes

☒ Edit Classification

ID: 1 Title: FAT Class

Alias: FAT

Description:

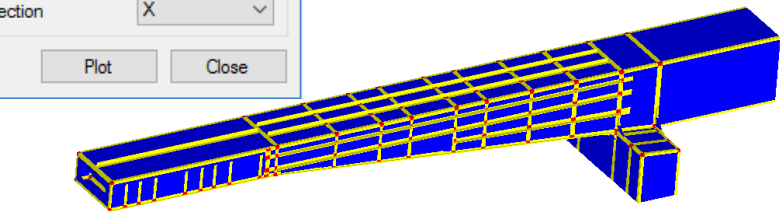
Classification: FAT Stress 160

Element(s) Classification

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)

☒ Plot

Parameters: Direction X



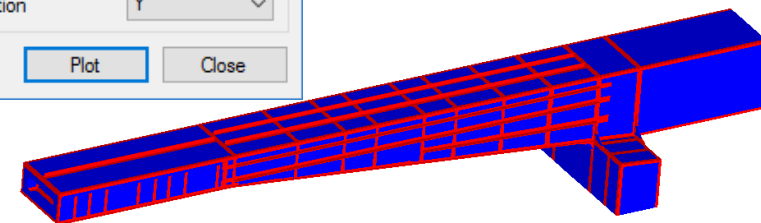
100

80

160

☒ Plot

Parameters: Direction Y



80

160



Set fatigue groups and number of cycles

SDC Verifier 4.0.1 - C:\Users\bos\OneDrive\sdcsverifier\examples\F.E.M. 1.001.sdcv

File Settings Model Recognition Job Tools Standard Report Help

Jobs (1)
1..Job 1
Individual Loads (5)
Load Sets (4)
Load Groups (1)
1..Load Group 1
Fatigue Groups (0)
Tables (0)
Plots (0)

Tools
Standards (2)
1..FEM 1.001
Constants (10)
Characteristics
Classifications (3)
1..Weld Type
2..Element Group
3..Material Type
Standard Tables (2)
Checks (3)
1..Static Stress Check
2..Fatigue Check
Tables (1)
Plots (1)
3..Fatigue Summation
2..Eurocode 3
Constants (9)
Characteristics

Add Fatigue Group
ID: 1 Title: Description: Fatigue Item Cycles: 1 Set

LG1 1..Load Group 1 2e6

Set number of cycles for this group with stress variation

Total amount of cycles: 2000000 Create

23:40:23 Saving backup file...
23:40:23 C:\Users\bos\OneDrive\sdcsverifier\examples\F.E.M. 1.001_autobackup.sdcv saved
23:42:24 Selection is empty
23:45:23 Saving backup file...
23:45:23 C:\Users\bos\OneDrive\sdcsverifier\examples\F.E.M. 1.001_autobackup.sdcv saved
23:49:49 Fatigue Group '1..Fatigue Group 1' created
23:50:23 Fatigue Group '1..Fatigue Group 1' removed
23:50:23 Saving backup file...
23:50:23 C:\Users\bos\OneDrive\sdcsverifier\examples\F.E.M. 1.001_autobackup.sdcv saved

Nodes: 37803 Elements: 39707 Fem Model: C:\Users\bos\OneDrive\sdcsverifier\examples\F.E.M. 1.001.modfem

Calculate and show fatigue damage

The screenshot displays the SDC Verifier 4.0.1 software interface. The main window shows the 'Recognition' tree on the left, with '2..Fatigue Check' highlighted. A context menu is open over this item, with 'Criteria Plot' selected. The 'Criteria Fatigue Check Plot' dialog is open, showing the following settings:

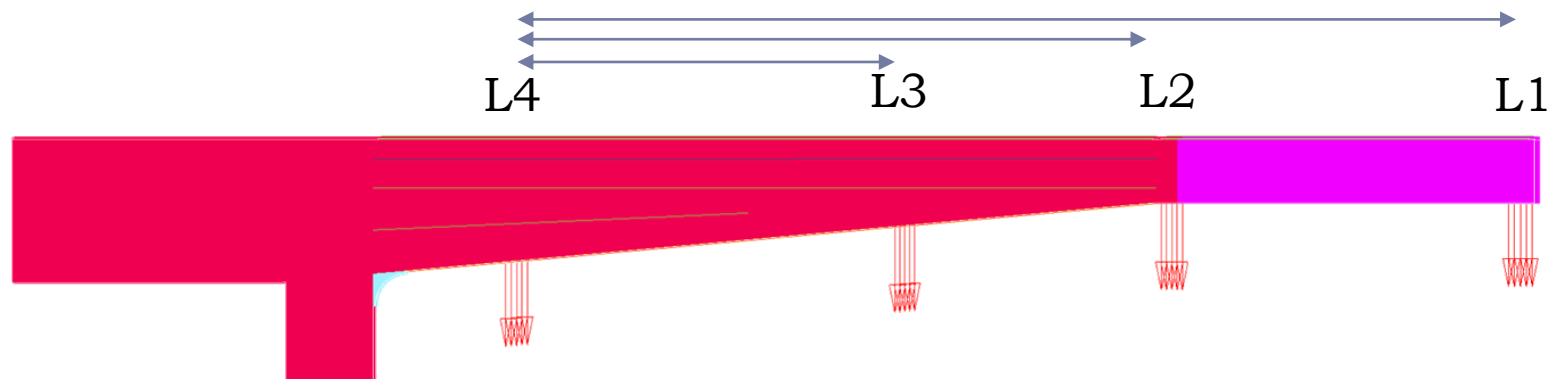
- General:** ID: 1, Title: (empty), Description: (empty)
- Check:** 2..Fatigue Check
- Fatigue Group:** 1..Fatigue Group 1
- Fatigue Item:** 1..Load Group 1
- Options:** Parameter: Summed Damage, LG Parameter: Absolute, Direction: Overall, Point Of Interest: Total, View: 1..Default View
- Selection:** ALL, + All Entities
- Elements:** 39707
- Limits:** Type: None, Minimum: 0, Maximum: 0, Absolute Value: (unchecked)

The status bar at the bottom indicates: Nodes: 37803 Elements: 39707 Ferr...

Better subdivision of load cycles

- ▶ 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

Make new load cycle groups

► Create load group L4-L3

SDC Verifier 4.0.1 - C:\Users\bos\OneDrive\projects\allseas_course\F.E.M. 1.001\F.E.M. 1.001_2.sdcv

File Settings Model Recognition Job Tools Standard Report Help

Go To Embed Mode

Settings

- Unit System
- Legend Settings
- Number Formats
- Views (1)
- Model
- Recognition
- Jobs (1)
 - 1..Job 1
 - Individual Loads (5)
 - 1..Gravity.Mounting surface
 - 2..L1.Mounting surface
 - 3..L2.Mounting surface
 - 4..L3.Mounting surface
 - 5..L4.Mounting surface
 - Load Sets (4)
 - Load Groups (1)
 - 1..Load Group 1
 - Fatigue Groups (1)
 - 1..Fatigue Group 1
 - Tables (0)
 - Plots (0)

- Tools
- Standards (1)
- 1..Eurocode 3
 - Constants (9)
 - Characteristics
 - Classification Types (3)

Add Load Group

ID: 2 Title: L4-L3

Description:

Safety Factor: 1

Factor: 1 Set

IL	Description	Factor
IL2	2..L1.Mounting surface	
IL3	3..L2.Mounting surface	
IL4	4..L3.Mounting surface	
IL5	5..L4.Mounting surface	
LS1	1..Load Set 1	
LS2	2..Load Set 2	
LG1	1..Load Group 1	

ALL IL LS LG

IL	Description	Factor
IL1	1..Gravity.Mounting surface	1
LS3	3..Load Set 3	1
LS4	4..Load Set 4	1

Select LS3, LS4 and IL1 gravity load)

Create

- Create load group L4-L2 in the same way
- Rename Load Group I into L4-L1



Create fatigue groups and set # of cycles

SDC Verifier 4.0.1 - C:\Users\bos\OneDrive\projects\allseas_course\F.E.M. 1.001\F.E.M. 1.001_2.sdcv

File Settings Model Recognition Job Tools Standard Report Help

Settings

- Unit System
- Legend Settings
- Number Formats
- Views (1)
- Model
- Recognition
- Jobs (1)
 - 1..Job 1
 - Individual Loads (5)
 - 1..Gravity.Mounting surface
 - 2..L1.Mounting surface
 - 3..L2.Mounting surface
 - 4..L3.Mounting surface
 - 5..L4.Mounting surface
 - Load Sets (4)
 - Load Groups (3)
 - 1..L4-L1
 - 2..L4-L3
 - 3..L4-L2
 - FG Fatigue Groups (1)**
 - FG 1..Overall damage
 - Tables (0)
 - Plots (0)
- Tools
- Standards (1)
 - 1..Eurocode 3
 - Constants (9)

Add Fatigue Group

ID: 2 Title: Detailed load cycles pattern

Description:

Fatigue Item Cycles: 1 Set

1..L4-L1	.5e6
2..L4-L3	1e6
3..L4-L2	.5e6

Set number of cycles

Total amount of cycles: 2000000 Create

Total number of load cycles is calculated automatically

Calculate and show fatigue damage

The screenshot displays the SDC Verifier 4.0.1 interface. The 'Check Fatigue Contour Plot' dialog box is open, showing the following settings:

- General: ID 2, Title (empty), Description (empty)
- Check: 2..Fatigue Check
- Fatigue Group: 2..Detailed load cycles pattern
- Fatigue Item: 1..L4-L1
- Options: Parameter Summed Damage, LG Parameter Absolute, Direction Overall, View 1..Default View
- Selection: + All Entities, Elements 39707
- Data Conversion: ☒ No Averaging, ☒ Use Corner Results

The 'Reports' tree on the left shows the following structure:

- Recognition
 - Joints
 - Beam Member Finder (3)
 - Panel Finder
 - Weld Finder
 - Stiffened Panels Finder
 - Jobs (1)
 - 1..Job 1
 - Individual Loads (5)
 - Load Sets (4)
 - Load Groups (1)
 - 1..Load Group 1
 - Fatigue Groups (1)
 - FG 1..Fatigue Group 1
 - Tables (0)
 - Plots (0)
 - Tools
 - Standards (2)
 - 1..FEM 1.001
 - 2..Eurocode 3
 - Constants (9)
 - Characteristics
 - Classifications (2)
 - Standard Tables (1)
 - Checks (2)
 - 1..Yield Check
 - 2..Fatigue Check
- Reports (0)

The 'Reports' tree also shows a list of actions: Saving backup file..., Fatigue Group '1..Fatigue Gro..., Saving backup file..., Fatigue Group '1..Fatigue Gro..., Saving backup file..., Expand Table, Extreme Table, Components Table, Extreme Flow Table, Criteria Plot, and Contour Plot. The 'Contour Plot' option is highlighted with a red box.

A red box highlights the 'No Averaging' checkbox in the 'Data Conversion' section of the dialog box. A red arrow points from this box to a text box that reads: "No average because results from welds are different from non weld results".