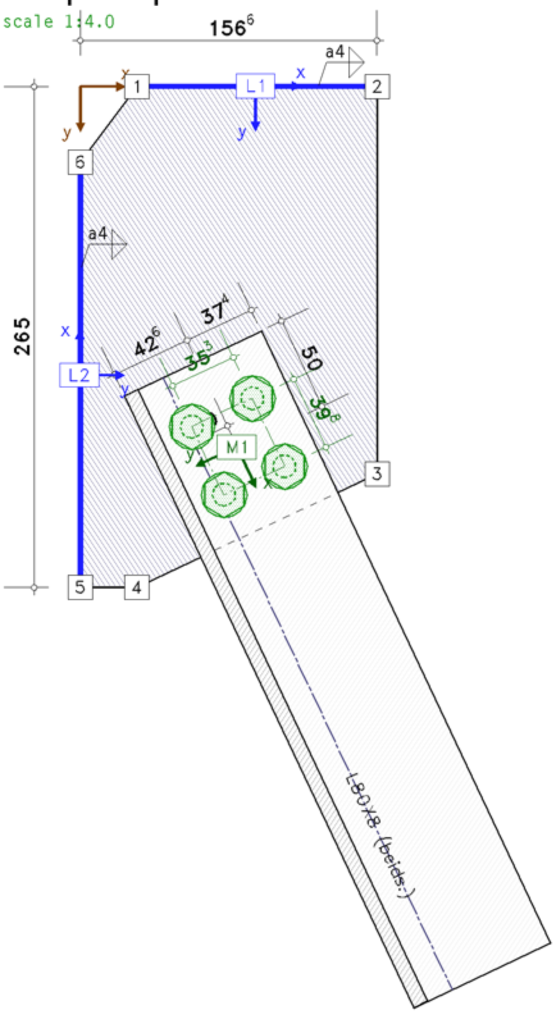
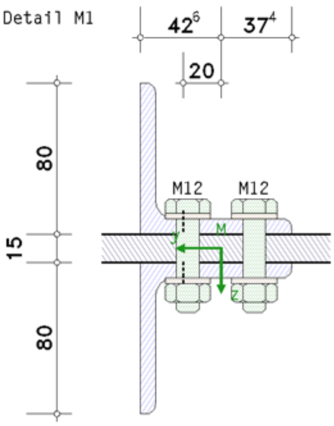
POS. 99: BSP. 1 - FRAME CORNER

gusset plate connection EC 3-1-8 (12.10), NA: Deutschland 4H-EC3FK version: 2/2019-2e

1. input report





steel grade
steel grade S235
bolts
bolt class 8.8, bolt size M12
large wrench size (high strength bolt), preloaded (for info: preloading $F_{p,C}^* = 0.7 \cdot f_{yb} \cdot A_s = 37.8$ kN)
thread included in the shear plane
connection
gusset plate: thickness $t_p = 15.0$ mm

	x_p mm	y_p mm		x_p mm	y_p mm
1	30.0	0.0	4	30.0	265.0
2	156.6	0.0	5	0.0	265.0
3	156.6	205.3	6	0.0	40.0

welds

weld L1 (load out-transfer): edge of gusset plate 1-2 (double-sided welded), length l_L = 126.6 mm

welds

fillet weld, double-sided, weld thickness a = 4.0 mm

weld L2 (load out-transfer): edge of gusset plate 5-6 (double-sided welded), length l_L = 225.0 mm

welds

fillet weld, double-sided, weld thickness a = 4.0 mm

bolts

group M1 (load in-transfer): load point x_M = 83.3 mm, y_M = 190.7 mm, twisting angle α_M = 64.75°

uniform arrangement of bolts on an area 40.0 x 35.0 mm² arround load point

2 vertical and 2 horizontal rows

joining section (double-sided connection)

section L 80 X 8

distance ref. to load point b_{M1} = 57.4 mm, b_{M2} = 22.6 mm, Δb_M = 20.0 mm, Δl_M = 50.0 mm

calculation

calculation of internal forces and moments with FE-method

elastic verification of gusset plate

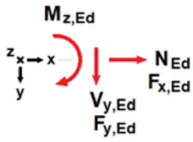
verification of welds with the directional method, weld thickness is checked

verification of bolts, check of distances

plastic verification of joining sections

internal forces and moments

Lk	$F_{x,Ed}$ N_{Ed} kN	LPkt.
1	150.00	M1



$F_{x,Ed}$,$F_{y,Ed}$,$M_{z,Ed}$: design loads ass. to load point; LPkt.: load point M=bolt group or L=welds regarded to beam

N_{Ed},$V_{y,Ed}$,$M_{z,Ed}$: design member forces of joining sections ass. to load point

partial safety factors for material

resistance of cross-sections γ_{M0} = 1.00

resistance of bolts, welds, plates in bearing γ_{M2} = 1.25

notes

plate bending due to excentric loading is not respected.

buckling is not inspected neither at gusset plate nor at joining sections.

distances between bolts at joining section (group 1)

x-direction: e_1 = 30.0 mm > 1.2·d_0 = 15.6 mm, e_1 = 30.0 mm < 4·t + 40 mm = 72.0 mm

x-direction: p_1 = 40.0 mm > 2.2·d_0 = 28.6 mm, p_1 = 40.0 mm < min(14·t, 200 mm) = 112.0 mm

y-direction: e_1 = 19.9 mm > 1.2·d_0 = 15.6 mm, e_1 = 19.9 mm < 4·t + 40 mm = 72.0 mm

y-direction: p_1 = 35.0 mm > 2.2·d_0 = 28.6 mm, p_1 = 35.0 mm < min(14·t, 200 mm) = 112.0 mm

minimum distance of bolts on gusset plate (group 1)

bolt 1: e_1 = 64.5 mm > 1.2·d_0 = 15.6 mm, e_1 = 64.5 mm < 4·t + 40 mm = 100.0 mm

bolt 1: p_1 = 35.0 mm > 2.2·d_0 = 28.6 mm, p_1 = 35.0 mm < min(14·t, 200 mm) = 200.0 mm

bolt 2: e_1 = 24.5 mm > 1.2·d_0 = 15.6 mm, e_1 = 24.5 mm < 4·t + 40 mm = 100.0 mm

bolt 2: p_1 = 35.0 mm > 2.2·d_0 = 28.6 mm, p_1 = 35.0 mm < min(14·t, 200 mm) = 200.0 mm

bolt 3: e_1 = 58.9 mm > 1.2·d_0 = 15.6 mm, e_1 = 58.9 mm < 4·t + 40 mm = 100.0 mm

bolt 3: p_1 = 35.0 mm > 2.2·d_0 = 28.6 mm, p_1 = 35.0 mm < min(14·t, 200 mm) = 200.0 mm

bolt 4: e_1 = 24.5 mm > 1.2·d_0 = 15.6 mm, e_1 = 24.5 mm < 4·t + 40 mm = 100.0 mm

bolt 4: p_1 = 35.0 mm > 2.2·d_0 = 28.6 mm, p_1 = 35.0 mm < min(14·t, 200 mm) = 200.0 mm

check of weld thickness (group 1)

plate thickness t_1 = 15.0 mm > 4 mm ok

plate thickness t_2 = 15.0 mm > 4 mm ok

NA-DE: plate thickness t_{max} ≥ 3 mm: weld thickness a = 4.0 mm > a_{min} = $t_{max}^{1/2}$ - 0.5 = 3.37 mm ok

weld thickness a = 4.0 mm < a_{max} = 0.7·t_{min} = 10.5 mm (welding technology, s. DIN 18800) ok

weld thickness a = 4.0 mm > a_{min} = 3 mm ok

check of weld thickness (group 2)

plate thickness t_1 = 15.0 mm > 4 mm ok

plate thickness t_2 = 15.0 mm > 4 mm ok

NA-DE: plate thickness t_{max} ≥ 3 mm: weld thickness a = 4.0 mm > a_{min} = $t_{max}^{1/2}$ - 0.5 = 3.37 mm ok

weld thickness a = 4.0 mm < a_{max} = 0.7·t_{min} = 10.5 mm (welding technology, s. DIN 18800) ok

weld thickness a = 4.0 mm > a_{min} = 3 mm ok

2. load distribution

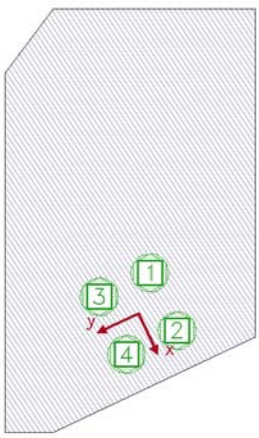
load combination 1:
bolts:
group M1

bolt 1:	x = 90.6 mm	y = 165.1 mm	F_x = -11.14 kN	F_y = 26.17 kN
bolt 2:	x = 107.6 mm	y = 201.3 mm	F_x = 27.28 kN	F_y = 8.05 kN
bolt 3:	x = 58.9 mm	y = 180.0 mm	F_x = 4.71 kN	F_y = 59.79 kN
bolt 4:	x = 76.0 mm	y = 216.2 mm	F_x = 43.13 kN	F_y = 41.67 kN

3. Lk 1

3.1. group of bolts M1 (load in-transfer)

load point x_M = 83.3 mm, y_M = 190.7 mm, α_M = 64.8°
loading $F_{x,Ed}$ = 150.00 kN, $F_{y,Ed}$ = 0.00 kN, $M_{z,Ed}$ = -3.00 kNm
The group consists of 4 bolts. Each bolt, forces F_x and F_y are working, which results from the devided loading.

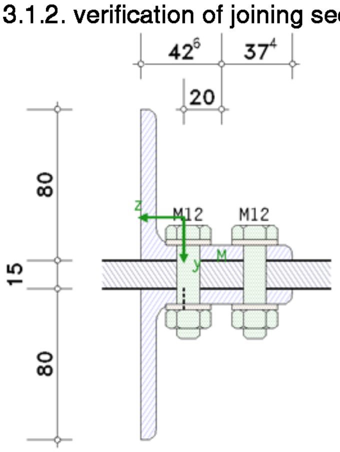


3.1.1. verification of bolts

U_v utilisation due to shear, U_b utilisation due to bearing resistance, U utilisation of bolts

bolt 1: $F_{x,1}$ = 18.92 kN $F_{y,1}$ = 21.24 kN F_1 = 28.44 kN
$U_{v,1}$ = 0.439 $U_{b,1}$ = 0.601 U_1 = = 0.601 < 1 ok
bolt 2: $F_{x,2}$ = 18.92 kN $F_{y,2}$ = -21.24 kN F_2 = 28.44 kN
$U_{v,2}$ = 0.439 $U_{b,2}$ = 0.601 U_2 = = 0.601 < 1 ok
bolt 3: $F_{x,3}$ = 56.08 kN $F_{y,3}$ = 21.24 kN F_3 = 59.97 kN
$U_{v,3}$ = 0.926 $U_{b,3}$ = 0.808 U_3 = = 0.926 < 1 ok
bolt 4: $F_{x,4}$ = 56.08 kN $F_{y,4}$ = -21.24 kN F_4 = 59.97 kN
$U_{v,4}$ = 0.926 $U_{b,4}$ = 0.832 U_4 = = 0.926 < 1 ok
total: U_v = 0.926 U_b = 0.832 U_{sc} = 0.926 < 1 ok

3.1.2. verification of joining section



plastic verification for N = 75.00 kN
main bending: N = 75.00 kN, resistance forces N_{max} = 227.22 kN, N_{min} = -173.94 kN ⇒ U_N = 0.241
total (possibly due to load increase): max U = 0.263 < 1 ok

verification of net cross-section for N_{Ed} = 75.00 kN
net cross-section with 2 bolts A_{net} = 1018.7 mm² ⇒ β = 0.9·A_{net} = 916.86 mm²
resistance $N_{u,Rd} = \beta \cdot f_u/\gamma_{M2}$ = 264.05 kN
verification: $U_{net} = N_{Ed}/N_{u,Rd}$ = 0.284 < 1 ok

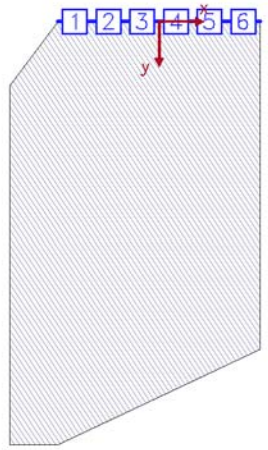
verification of shear block for N_{Ed} = 75.00 kN
shear resistance $V_{eff,Rd} = (0.5 \cdot A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/2}) / \gamma_{M0}$ = 95.65 kN
verification: $U_{eff} = N_{Ed}/V_{eff,Rd}$ = 0.784 < 1 ok

3.1.3. total

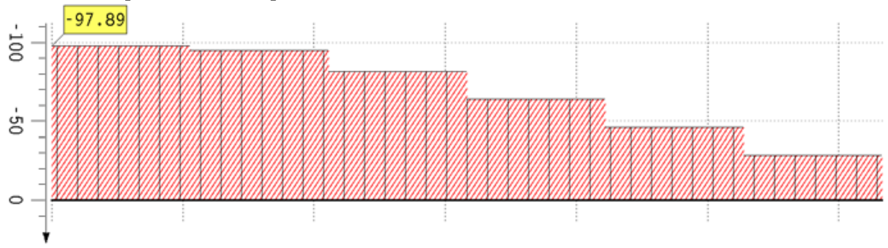
max U_{M1} = 0.926 < 1 ok

3.2. weld L1 (load out-transfer)

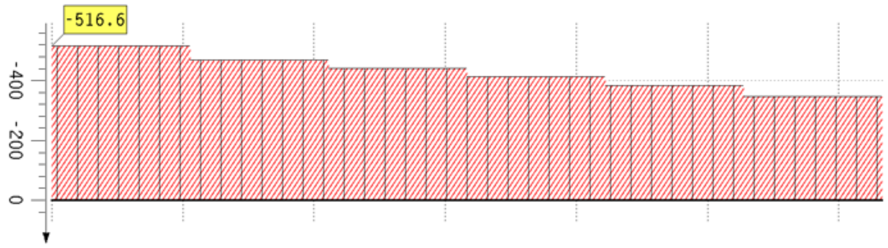
support point x_L = 93.3 mm, y_L = 0.0 mm, α_L = 0.0°, length l_L = 126.6 mm
one weld is divided into 6 sections. Each section, weld forces F_l and F_m are working,
which results from FEM-calculation: $\Sigma F_{x,i}$ = -8.72 kN, $\Sigma F_{y,i}$ = -54.22 kN, $\Sigma M_{z,i}$ = 0.25 kNm



3.2.1. cutting forces along f_l and across f_m



max f_l = -28.61 N/mm
min f_l = -97.89 N/mm
L = 126.6 mm

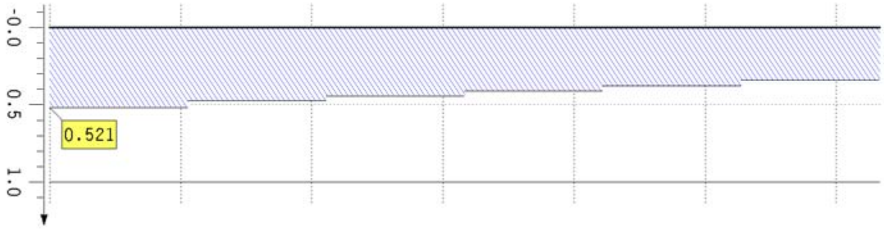


max f_m = -345.96 N/mm
min f_m = -516.58 N/mm
L = 126.6 mm

3.2.2. verification of welds

section 1: f_l = -97.9 N/mm, f_m = -516.6 N/mm ⇒ F_l = -2.07 kN, F_m = -10.90 kN, l_1 = 21.1 mm
$\sigma_{1,w,Ed}$ = 187.49 N/mm² < $f_{1w,d}$ = 360.00 N/mm² ⇒ U = 0.521 < 1 ok
$\sigma_{2,w,Ed}$ = 91.32 N/mm² < $f_{2w,d}$ = 259.20 N/mm² ⇒ U = 0.352 < 1 ok
section 2: f_l = -95.1 N/mm, f_m = -470.0 N/mm ⇒ F_l = -2.01 kN, F_m = -9.92 kN, l_2 = 21.1 mm
$\sigma_{1,w,Ed}$ = 171.19 N/mm² < $f_{1w,d}$ = 360.00 N/mm² ⇒ U = 0.476 < 1 ok
$\sigma_{2,w,Ed}$ = 83.08 N/mm² < $f_{2w,d}$ = 259.20 N/mm² ⇒ U = 0.321 < 1 ok
section 3: f_l = -81.6 N/mm, f_m = -441.3 N/mm ⇒ F_l = -1.72 kN, F_m = -9.31 kN, l_3 = 21.1 mm
$\sigma_{1,w,Ed}$ = 159.98 N/mm² < $f_{1w,d}$ = 360.00 N/mm² ⇒ U = 0.444 < 1 ok
$\sigma_{2,w,Ed}$ = 78.01 N/mm² < $f_{2w,d}$ = 259.20 N/mm² ⇒ U = 0.301 < 1 ok
section 4: f_l = -64.1 N/mm, f_m = -413.8 N/mm ⇒ F_l = -1.35 kN, F_m = -8.73 kN, l_4 = 21.1 mm
$\sigma_{1,w,Ed}$ = 148.90 N/mm² < $f_{1w,d}$ = 360.00 N/mm² ⇒ U = 0.414 < 1 ok
$\sigma_{2,w,Ed}$ = 73.14 N/mm² < $f_{2w,d}$ = 259.20 N/mm² ⇒ U = 0.282 < 1 ok
section 5: f_l = -46.0 N/mm, f_m = -382.3 N/mm ⇒ F_l = -0.97 kN, F_m = -8.07 kN, l_5 = 21.1 mm
$\sigma_{1,w,Ed}$ = 136.63 N/mm² < $f_{1w,d}$ = 360.00 N/mm² ⇒ U = 0.380 < 1 ok
$\sigma_{2,w,Ed}$ = 67.58 N/mm² < $f_{2w,d}$ = 259.20 N/mm² ⇒ U = 0.261 < 1 ok
section 6: f_l = -28.6 N/mm, f_m = -346.0 N/mm ⇒ F_l = -0.60 kN, F_m = -7.30 kN, l_6 = 21.1 mm
$\sigma_{1,w,Ed}$ = 122.94 N/mm² < $f_{1w,d}$ = 360.00 N/mm² ⇒ U = 0.342 < 1 ok
$\sigma_{2,w,Ed}$ = 61.16 N/mm² < $f_{2w,d}$ = 259.20 N/mm² ⇒ U = 0.236 < 1 ok
total: U_{sa} = 0.521 < 1 ok

3.2.3. utilisation U_{L1}



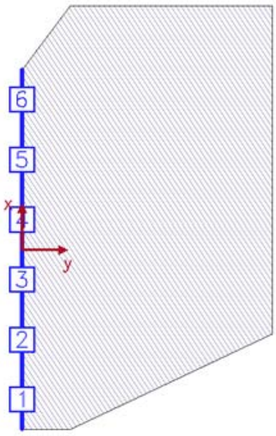
max U_{L1} = 0.521
L = 126.6 mm

3.2.4. total

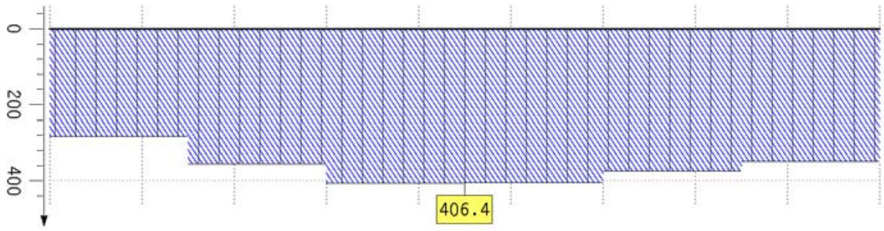
max U_{L1} = 0.521 < 1 ok

3.3. weld L2 (load out-transfer)

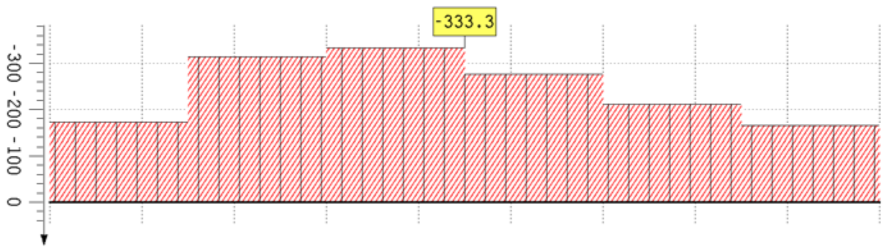
support point x_L = 0.0 mm, y_L = 152.5 mm, α_L = -90.0°, length l_L = 225.0 mm
one weld is divided into 6 sections. Each section, weld forces F_l and F_m are working,
which results from FEM-calculation: $\Sigma F_{x,i}$ = 81.44 kN, $\Sigma F_{y,i}$ = -55.26 kN, $\Sigma M_{z,i}$ = 0.28 kNm



3.3.1. cutting forces along f_l and across f_m



max f_l = 406.36 N/mm
min f_l = 283.05 N/mm
L = 225.0 mm



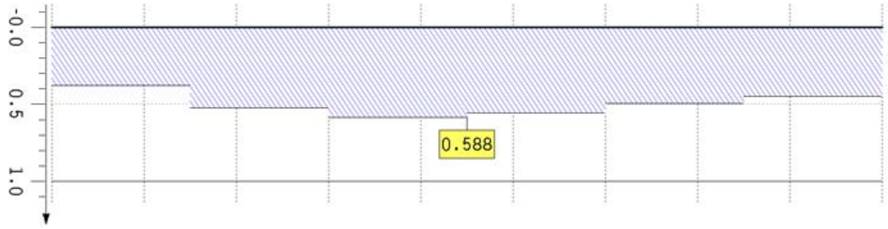
max f_m = -165.48 N/mm
min f_m = -333.28 N/mm
L = 225.0 mm

3.3.2. verification of welds

section 1: f_l = 283.0 N/mm, f_m = -172.4 N/mm ⇒ F_l = 10.61 kN, F_m = -6.47 kN, l_1 = 37.5 mm
$\sigma_{1,w,Ed}$ = 136.89 N/mm² < $f_{1w,d}$ = 360.00 N/mm² ⇒ U = 0.380 < 1 ok
$\sigma_{2,w,Ed}$ = 30.48 N/mm² < $f_{2w,d}$ = 259.20 N/mm² ⇒ U = 0.118 < 1 ok
section 2: f_l = 354.9 N/mm, f_m = -314.0 N/mm ⇒ F_l = 13.31 kN, F_m = -11.77 kN, l_2 = 37.5 mm
$\sigma_{1,w,Ed}$ = 189.56 N/mm² < $f_{1w,d}$ = 360.00 N/mm² ⇒ U = 0.527 < 1 ok
$\sigma_{2,w,Ed}$ = 55.50 N/mm² < $f_{2w,d}$ = 259.20 N/mm² ⇒ U = 0.214 < 1 ok
section 3: f_l = 406.4 N/mm, f_m = -333.3 N/mm ⇒ F_l = 15.24 kN, F_m = -12.50 kN, l_3 = 37.5 mm
$\sigma_{1,w,Ed}$ = 211.77 N/mm² < $f_{1w,d}$ = 360.00 N/mm² ⇒ U = 0.588 < 1 ok
$\sigma_{2,w,Ed}$ = 58.92 N/mm² < $f_{2w,d}$ = 259.20 N/mm² ⇒ U = 0.227 < 1 ok
section 4: f_l = 405.0 N/mm, f_m = -276.8 N/mm ⇒ F_l = 15.19 kN, F_m = -10.38 kN, l_4 = 37.5 mm
$\sigma_{1,w,Ed}$ = 200.81 N/mm² < $f_{1w,d}$ = 360.00 N/mm² ⇒ U = 0.558 < 1 ok
$\sigma_{2,w,Ed}$ = 48.93 N/mm² < $f_{2w,d}$ = 259.20 N/mm² ⇒ U = 0.189 < 1 ok
section 5: f_l = 373.5 N/mm, f_m = -211.8 N/mm ⇒ F_l = 14.00 kN, F_m = -7.94 kN, l_5 = 37.5 mm
$\sigma_{1,w,Ed}$ = 178.20 N/mm² < $f_{1w,d}$ = 360.00 N/mm² ⇒ U = 0.495 < 1 ok
$\sigma_{2,w,Ed}$ = 37.43 N/mm² < $f_{2w,d}$ = 259.20 N/mm² ⇒ U = 0.144 < 1 ok

section 6: f_l = 349.2 N/mm, f_m = -165.5 N/mm ⇒ F_l = 13.09 kN, F_m = -6.21 kN, l_6 = 37.5 mm
$\sigma_{1,w,Ed}$ = 162.11 N/mm² < $f_{1w,d}$ = 360.00 N/mm² ⇒ U = 0.450 < 1 ok
$\sigma_{2,w,Ed}$ = 29.25 N/mm² < $f_{2w,d}$ = 259.20 N/mm² ⇒ U = 0.113 < 1 ok
total: U_{sa} = 0.588 < 1 ok

3.3.3. utilisation U_{L2}



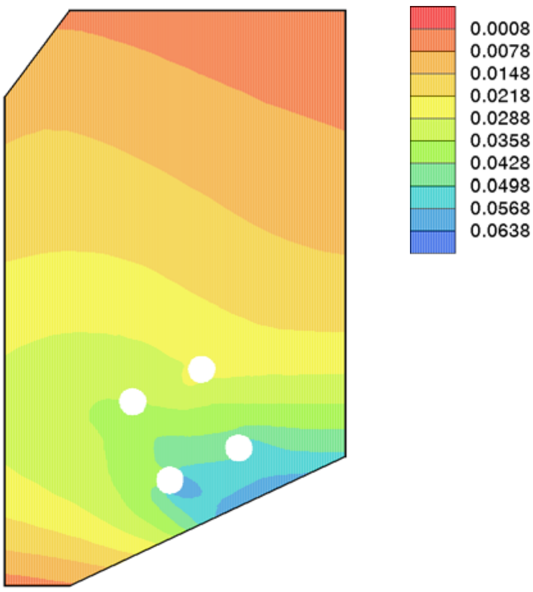
max U_{L2} = 0.588
L = 225.0 mm

3.3.4. total

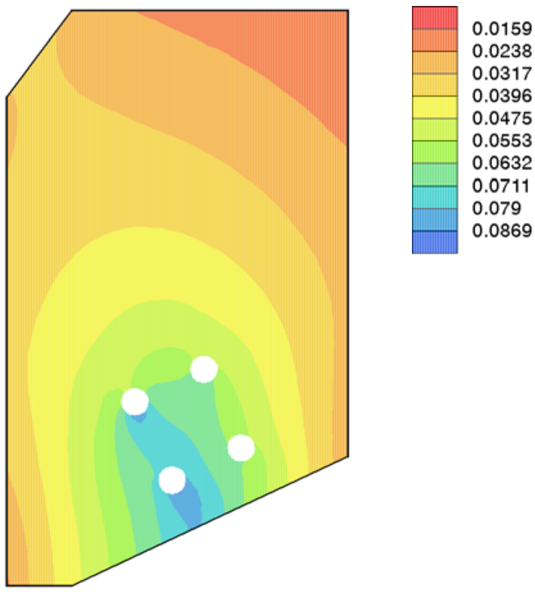
max U_{L2} = 0.588 < 1 ok

3.4. gusset plate

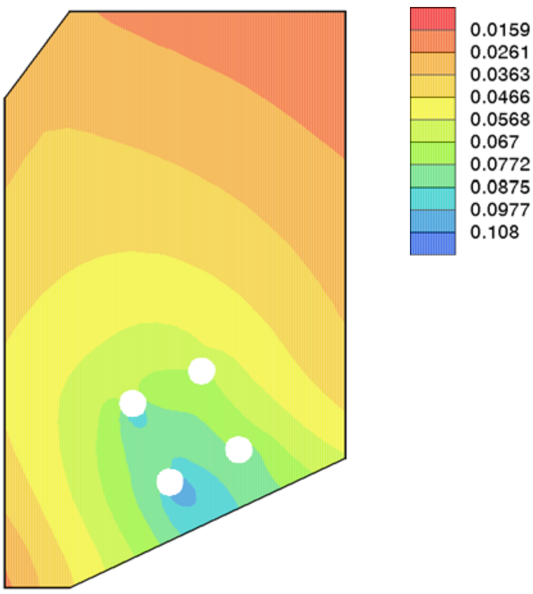
translations u_x [mm]
min u_x = 0.0008 mm, max u_x = 0.0635 mm



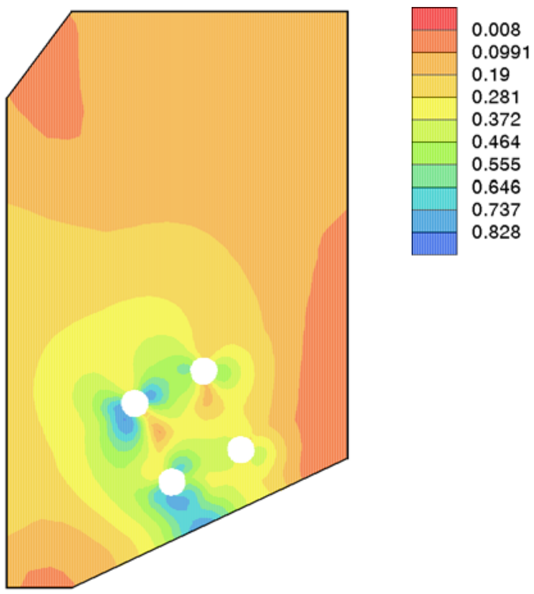
translations u_y [mm]
min u_y = 0.0159 mm, max u_y = 0.0873 mm



translations u [mm]
max u = 0.1074 mm



utilisation U_p
max U_p = 0.832



utilisation

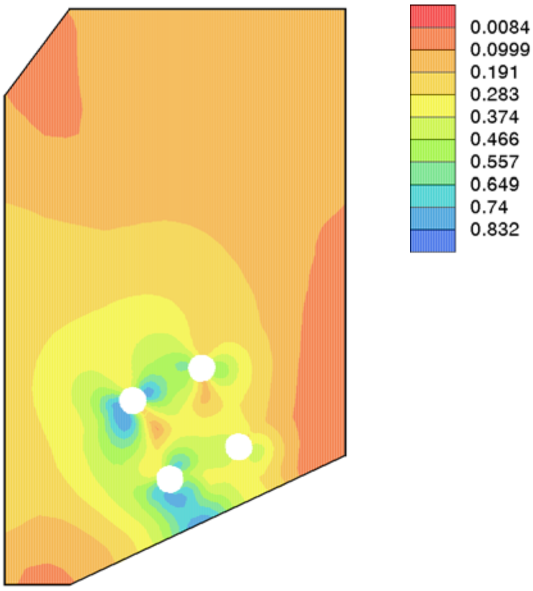
node	x	y	u_x	u_y	u	n_{xx}	n_{yy}	n_{xy}	σ	τ	σ_v	U_p
	mm	mm	mm	mm	mm	kN/m	kN/m	kN/m	N/mm²	N/mm²	N/mm²	
2	156.60	0.00	0.001	0.016	0.016	-12.04	348.33	14.34	23.63	0.96	23.69	0.101
71	89.32	237.02	0.050	0.079	0.093	2090.92	381.34	-1103.00	192.85	0.00	0.00	0.821
129	82.00	218.64	0.063	0.084	0.106	-629.66	626.48	-1000.73	72.52	66.72	136.43	0.581
130	80.61	220.78	0.063	0.087	0.107	176.09	-278.45	-1325.56	26.46	88.37	155.33	0.661
314	54.24	187.34	0.037	0.071	0.080	756.52	-227.13	1612.41	59.47	107.49	195.45	0.832

x,y: node coordinates; u_x,u_y,u: translations; n_{xx},n_{yy},n_{xy}: regarded normal stresses; σ,τ,σ_v: stresses; σ_v=0: σ,τ principal stresses
U_p: utilisation

4. final result

maximum utilisation of plate max U_p due to 1 Lk

max max U_p = 0.832



maximum utilisation of plate due to 1 Lk: max U_p with corresponding values

node	x	y	u_x	u_y	u	σ_x	τ	σ_v	U_p
	mm	mm	mm	mm	mm	N/mm²	N/mm²	N/mm²	
314	54.24	187.34	0.037	0.071	0.080	59.47	107.49	195.45	0.832

x,y: node coordinates; u_x,u_y,u: translations; n_{xx},n_{yy},n_{xy}: normal forces; σ,τ,σ_v: stresses; σ_v=0: σ,τ principal stresses
U_p: utilisation

maximum utilisation of bolts [Lk 1]	max U_{sc} = 0.926 < 1 ok
maximum utilisation of welds [Lk 1]	max U_{sa} = 0.588 < 1 ok
maximum utilisation of gusset plate [Lk 1]	max U_p = 0.832 < 1 ok
maximum utilisation	**max U = 0.926 < 1** ok

verification succeeded

5. Regulations

DIN EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;
Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010
DIN EN 1990/NA, Nationaler Anhang zur DIN EN 1990, Ausgabe Dezember 2010

DIN EN 1993-1-1, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau;
Deutsche Fassung EN 1993-1-1:2005 + AC:2009, Ausgabe Dezember 2010
DIN EN 1993-1-1/A1, Ergänzungen zur DIN EN 1993-1-1, Ausgabe Juli 2014
DIN EN 1993-1-1/NA, Nationaler Anhang zur DIN EN 1993-1-1, Ausgabe Dezember 2018

DIN EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-8: Bemessung von Anschlüssen;
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DIN EN 1993-1-8/NA, Nationaler Anhang zur DIN EN 1993-1-8, Ausgabe Dezember 2010