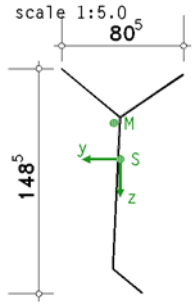
POS. 30: KINDMANN/FRICKEL 10.9.4

verification of cross-section EC 3-1-8 (12.10), NA: Deutschland

1. input report



steel

steel parameters:

char. yield strength ($t \le 40$ mm) $f_{y,40} = 240.0$ N/mm²
char. tensile strength ($t \le 40$ mm) $f_{u,40} = 360.0$ N/mm²
char. yield strength ($40 \text{ mm} < t \le 80$ mm) $f_{y,80} = 215.0$ N/mm²
char. tensile strength ($40 \text{ mm} < t \le 80$ mm) $f_{u,80} = 360.0$ N/mm²
char. yield strength ($t > 80$ mm) $f_{y,\infty} = 215.0$ N/mm²
char. tensile strength ($t > 80$ mm) $f_{u,\infty} = 360.0$ N/mm²
elastic modulus $E = 210000.0$ N/mm²

material safety factor

resistance of cross-sections $\gamma_{M0} = 1.10$

geometry

dimensions of cross-section: $y_{min} = -41.9$ mm, $y_{max} = 38.6$ mm, $z_{min} = -59.8$ mm, $z_{max} = 88.7$ mm
width,height of cross-section: $b = 80.5$ mm, $h = 148.5$ mm
centroid, rotation angle of main axis: $e_y = 0.0$ mm, $e_z = 0.0$ mm, $\alpha = -0.01$ °
distance shear center to centroid: $y_{SM} = 4.1$ mm, $z_{SM} = -23.8$ mm

cross-sectional area	A	=	2.25 cm²
bending moment of inertia	I_η	=	48.30 cm⁴
bending moment of inertia	I_ζ	=	5.54 cm⁴
section modulus	$W_{\eta+}$	=	5.45 cm³
section modulus	$W_{\eta-}$	=	8.08 cm³
section modulus	$W_{\zeta+}$	=	1.43 cm³
section modulus	$W_{\zeta-}$	=	1.32 cm³
torsional moment of inertia	I_T	=	0.01 cm⁴
warping moment of inertia	I_ω	=	20.74 cm⁶
section of cross-section	i_M	=	5.46 cm
section of cross-section	r_η	=	-1.92 cm
section of cross-section	r_ζ	=	6.55 cm
section of cross-section	r_ω	=	3.62

resistance

elastic verification, calculation as thin-walled cross-section
plastic verification with strain iteration
valid normal, shear-, equivalent stress: $\sigma_{x,Rd} = 218.2$ N/mm², $\tau_{Rd} = 126.0$ N/mm², $\sigma_{v,Rd} = 218.2$ N/mm²

internal forces and moments refering to local axes of cross-section

σ-generating forces (N, M) work at centroid, τ-generating forces (V, T_t) work at shear center
warping forces (T_ω, B) work at shear center
Lk 1: $M_{y,Ed} = 100.00$ kNcm, $V_{z,Ed} = 5.00$ kN, $M_{z,Ed} = 20.00$ kNcm, $V_{y,Ed} = 2.50$ kN, $T_{t,Ed} = 0.20$ kNcm
$T_{\omega,Ed} = 10.00$ kNcm

notes
buckling is not investigated.

2. Lk 1

2.1. verification of cross-section

internal forces and moments: M_y = 100.00 kNcm, V_z = 5.00 kN, M_z = 20.00 kNcm, V_y = 2.50 kN, T_t = 0.20 kNcm, T_ω = 10.00 kN

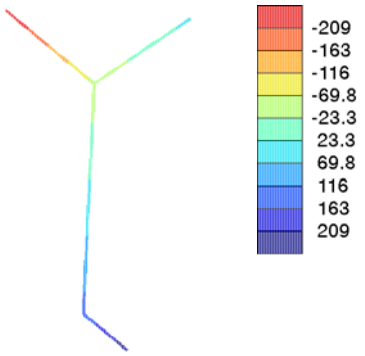
2.1.1. elastic verification

elastic verification for M_y = 1.00 kNm, V_z = 5.00 kN, M_z = 0.20 kNm, V_y = 2.50 kN
T_ω = 0.10 kNm
elastic stresses: max $|\sigma_x|$ = 261.81 N/mm², max τ = 106.28 N/mm², max σ_v = 265.85 N/mm²

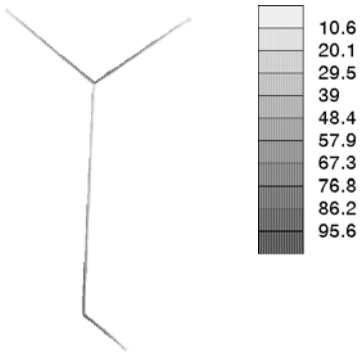
max σ_x	bei y = -14.9 mm, z = 87.9 mm:	σ_x = 235.92 N/mm², τ = -26.67 N/mm², σ_v = 240.40 N/mm²
min σ_x	bei y = 38.6 mm, z = -59.1 mm:	σ_x = -261.81 N/mm², τ = 26.67 N/mm², σ_v = 265.85 N/mm²
max τ	bei y = 3.2 mm, z = 74.2 mm:	σ_x = 142.22 N/mm², τ = 106.28 N/mm², σ_v = 232.62 N/mm²
max σ_v	bei y = 38.6 mm, z = -59.1 mm:	σ_x = -261.81 N/mm², τ = 26.67 N/mm², σ_v = 265.85 N/mm²

valid equivalent stress: $\sigma_{v,Rd}$ = 218.2 N/mm²
verification: σ_v = 265.85 N/mm² > $\sigma_{v,Rd}$ = 218.18 N/mm² ⇒ U_σ = 1.218 > 1 **fault !!**

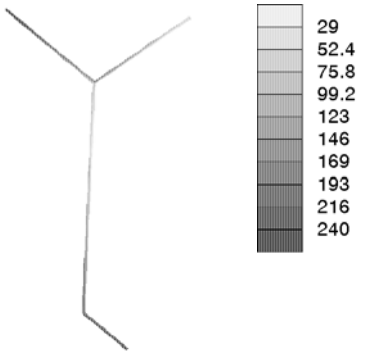
normal stresses σ_x [N/mm²]
min σ_x = -261.8, max σ_x = 235.9



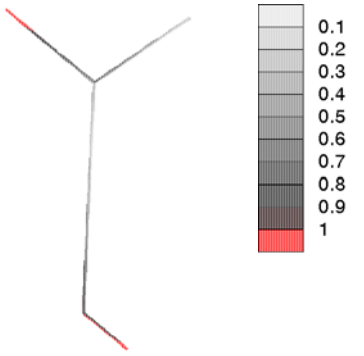
shear stresses τ [N/mm²]
max τ = 106.3



equivalent stresses σ_v [N/mm²]
max σ_v = 265.9



utilization U_σ
max U_σ = 1.218



stresses, utilizations

y mm	z mm	σ_x N/mm²	τ N/mm²	σ_v N/mm²	U_σ
0.0	0.8	-261.81	26.67	265.85	1.218 > 1
-53.5	147.7	235.92	26.67	240.40	1.102 > 1
-36.4	134.8	147.38	106.27	235.80	1.081 > 1

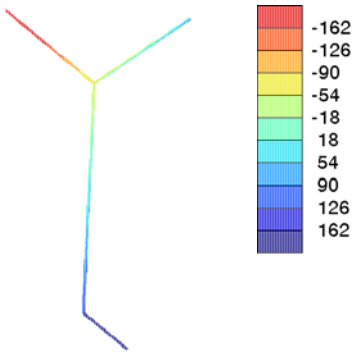
y,z: node coordinates; σ_x,τ,σ_v: stresses; U_σ: stress utilization

2.1.2. plastic verification

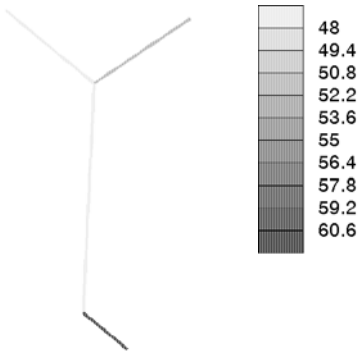
plastic verification for M_y = 1.00 kNm, V_z = 5.00 kN, M_z = 0.20 kNm, V_y = 2.50 kN
T_ω = 0.10 kNm
lines of cross-section:
1: y_a = 38.3 mm, z_a = -59.4 mm, y_e = 38.6 mm, z_e = -59.0 mm
2: y_a = -41.6 mm, z_a = -55.6 mm, y_e = -41.3 mm, z_e = -56.0 mm
3: y_a = -0.2 mm, z_a = -27.5 mm, y_e = 0.3 mm, z_e = -27.3 mm
4: y_a = 4.6 mm, z_a = 72.4 mm, y_e = 5.1 mm, z_e = 72.6 mm
valid equivalent stress: $\sigma_{v,Rd}$ = 218.2 N/mm²
zero-line of limit of strains (plastic): y_0 = 1.25 cm, z_0 = -1.40 cm, α = 221.787°
limit of strains of cross-section (plastic): ε_{min} = -1.27 ‰, ε_{max} = 150.00 ‰
limit of normal stresses of cross-section (plastic): σ_{min} = -202.57 N/mm², σ_{max} = 189.78 N/mm²
limit of shear stresses of cross-section (plastic): τ_{min} = 46.47 N/mm², τ_{max} = 62.15 N/mm²
limit of equivalent stresses of cross-section (plastic): $\sigma_{V,min}$ = 82.98 N/mm², $\sigma_{V,max}$ = 218.18 N/mm²
limit stresses of lines of cross-section (plastic) in N/mm²:
1: σ_{min} = -202.57, σ_{max} = -49.35, τ = 46.47, $\sigma_{V,min}$ = 94.42, $\sigma_{V,max}$ = 217.98

2: σ_{min} = -100.03, σ_{max} = 86.59, τ = 52.04, $\sigma_{V,min}$ = 90.14, $\sigma_{V,max}$ = 134.66
3: σ_{min} = -72.06, σ_{max} = 133.57, τ = 47.88, $\sigma_{V,min}$ = 82.98, $\sigma_{V,max}$ = 157.22
4: σ_{min} = -124.48, σ_{max} = 189.78, τ = 62.15, $\sigma_{V,min}$ = 160.76, $\sigma_{V,max}$ = 218.18
load factor of shear stresses (plastic): $f_{\tau,pl}$ = 0.941 $\Rightarrow$ $U_{\tau,pl}$ = 1.062
max. load factor of normal stresses (plastic): $f_{\sigma,pl}$ = 0.942 $\Rightarrow$ $U_{\sigma,pl}$ = 1.061
total: utilization: U_{pl} = 1.062 > 1 **fault !!**

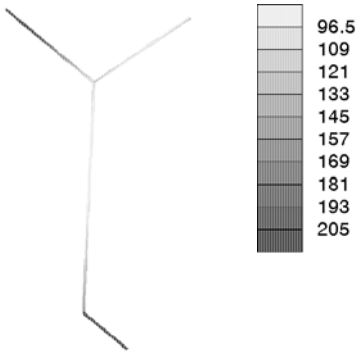
normal stresses σ_x [N/mm²]
min σ_x = -202.6, max σ_x = 189.8



shear stresses τ [N/mm²]
max τ = 62.2



equivalent stresses σ_v [N/mm²]
max σ_v = 218.2



stresses

y mm	z mm	σ_x N/mm²	τ N/mm²	σ_v N/mm²
0.0	0.8	-202.57	46.47	217.98
-33.5	132.4	-124.48	62.15	164.57
-52.9	148.5	189.78	62.15	218.18
-53.2	148.1	189.78	62.15	218.18

y,z: node coordinates; σ_x,τ,σ_v: stresses

3. final result

maximum utilization: resistance max U = 1.218 > 1 **fault !!**

resistance not ensured !!