2. CHS KT-joint (K)

The design of axial resistance of the CHS KT-joint is performed according to prEN 1993-1-8(2021), see Figure 2.1. The exact description and material properties of each member are given. The classification of hollow section truss-type joints as T, Y, X or K gap joints (which includes N-type joints) should be based on the method of force transfer in a joint but not on its physical appearance. Since there is no internal force in member 3, the KT joint considers as the K-joint.

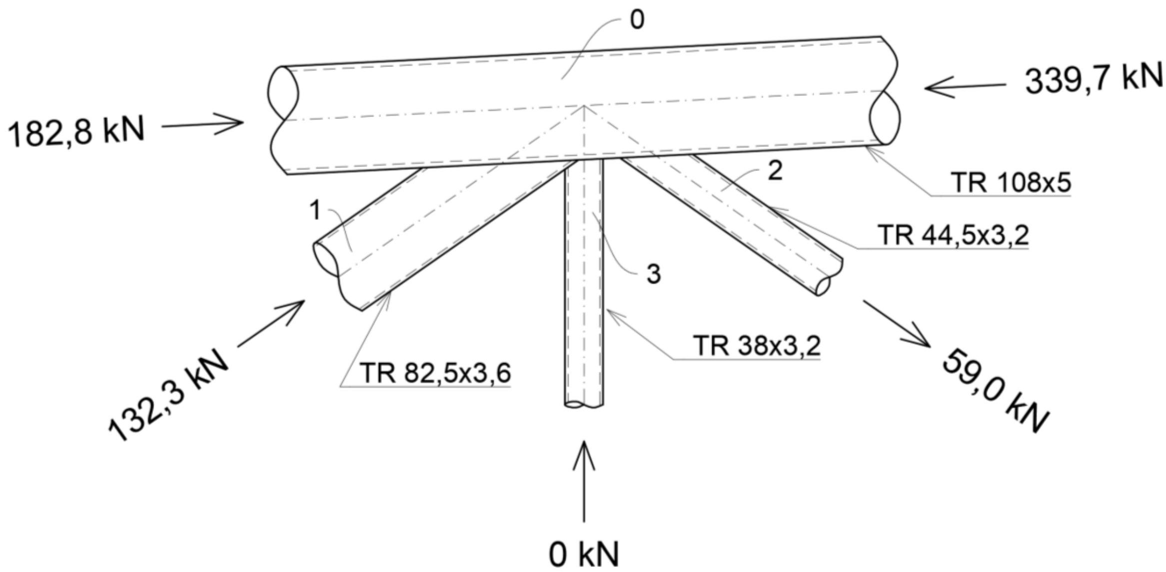

Figure 2.1 Joint geometry, internal forces

2.1. Symbols

d_i	is an overall diameter of CHS member i (i=0,1,2 or 3)
e	is an eccentricity of a joint
$f_{y,i}$	is a yield strength of member i (i=0,1,2 or 3)
A_i	is a cross sectional area of member i (i=0,1,2 or 3)
$W_{el,i}$	is an elastic section modulus of member i (i=0,1,2 or 3)
θ_i	is an included angle between brace member i and the chord (i=1,2 or 3)
β	is a ratio of the mean diameter or width of brace members, to that of the chord
γ	is a ratio of a chord width or diameter to twice its wall thickness
Q_f	is a chord stress factor

n	is a chord stress parameter
$\mathrm{C_f}$	is a material factor
$\mathrm{M_{ip,i,Ed}}$	is a design in-plane internal moment in member i (i=0,1,2 or 3)
$\mathrm{M_{op,i,Ed}}$	is a design out-of-plane internal moment in member i (i = 0, 1, 2 or 3)
$\mathrm{N_{i,Ed}}$	is a design internal axial force in member i (i=0,1,2 or 3)
$\mathrm{N_{i,Rd}}$	is a design resistance of a joint expressed in terms of the internal axial force in member i (i = 0, 1, 2 or 3)

2.2. Design forces

$\mathrm{N_{0,Ed}} = -339\ 700\ \mathrm{N}$

$\mathrm{M_{ip,0,Ed}} = 0{,}0\ \mathrm{Nmm}$

$\mathrm{M_{op,0,Ed}} = 0{,}0\ \mathrm{Nmm}$

$\mathrm{N_{1,Ed}} = -132\ 300\ \mathrm{N}$

$\mathrm{M_{ip,1,Ed}} = 0{,}0\ \mathrm{Nmm}$

$\mathrm{M_{op,1,Ed}} = 0{,}0\ \mathrm{Nmm}$

$\mathrm{N_{2,Ed}} = 59\ 000\ \mathrm{N}$

$\mathrm{M_{ip,2,Ed}} = 0{,}0\ \mathrm{Nmm}$

$\mathrm{M_{op,2,Ed}} = 0{,}0\ \mathrm{Nmm}$

$\mathrm{N_{3,Ed}} = 0{,}0\ \mathrm{N}$

$\mathrm{M_{ip,3,Ed}} = 0{,}0\ \mathrm{Nmm}$

$\mathrm{M_{op,3,Ed}} = 0{,}0\ \mathrm{Nmm}$

2.3. Material

$\mathrm{f_{y,0}} = 355{,}0\ \mathrm{MPa}$ $\quad$ $\mathrm{f_{y,1}} = 355{,}0\ \mathrm{MPa}$ $\quad$ $\mathrm{f_{y,2}} = 355{,}0\ \mathrm{MPa}$

2.4. Geometry of sections

$\mathrm{A_0} = 1\ 618\ \mathrm{mm^2}$

$\mathrm{W_{el,0}} = 39{,}8 \cdot 10^3 \mathrm{mm^3}$

2.5. Range of validity

$$0{,}2 \leq \frac{\mathrm{d_1}}{\mathrm{d_0}} = \frac{82{,}5}{108{,}0} = 0{,}76 \leq 1{,}0$$

$$0{,}2 \leq \frac{\mathrm{d_2}}{\mathrm{d_0}} = \frac{44{,}5}{108{,}0} = 0{,}41 \leq 1{,}0$$

$$\frac{d_1}{t_1} = \frac{82{,}5}{3{,}6} = 22{,}92 \leq 50$$

$$\frac{d_2}{t_2} = \frac{44{,}5}{3{,}2} = 13{,}91 \leq 50$$

$$10 \leq \frac{d_o}{t_0} = \frac{108{,}0}{5{,}0} = 21{,}60 \leq 50$$

$$-0{,}55 \leq \frac{e}{d_0} = \frac{0{,}0}{108{,}0} = 0{,}0 \leq 0{,}25$$

$$g = 41{,}6\ \mathrm{mm} \leq t_1 + t_2 = 3{,}2 + 3{,}6 = 6{,}8\ \mathrm{mm}$$

$$t_1 = 3{,}6\ \mathrm{mm} \leq t_0 = 5{,}0\ \mathrm{mm}$$

$$t_2 = 3{,}2\ \mathrm{mm} \leq t_0 = 5{,}0\ \mathrm{mm}$$

$$\theta_1 = 32{,}1° \leq 30°$$

$$\theta_2 = 37{,}9° \leq 30°$$

2.6. Geometric ratios

$$\gamma = \frac{d_0}{2 \cdot t_0} = \frac{108{,}0}{2 \cdot 5{,}0} = 10{,}80$$

$$\beta = \frac{d_1 + d_2}{2 \cdot d_0} = \frac{82{,}5 + 44{,}5}{2 \cdot 108{,}0} = 0{,}58$$

2.7. Design of axial resistance of the joint

$$n = \frac{N_{o,Ed}}{A_0 \cdot f_{y,o}} + \sqrt{\left(\frac{M_{ip,0,Ed}}{W_{el,0} \cdot f_{y,o}}\right)^2 + \left(\frac{M_{op,0,Ed}}{W_{el,0} \cdot f_{y,o}}\right)^2}$$

$$= \frac{-339\ 700}{1\ 618 \cdot 355} + \sqrt{\left(\frac{0{,}0}{39{,}8 \cdot 10^3 \cdot 355}\right)^2 + \left(\frac{0{,}0}{39{,}8 \cdot 10^3 \cdot 355}\right)^2} = -0{,}59$$

C_1	
$\mathbf{n}$ <0 (compression)	$n \geq 0$ (tension)
$\mathbf{C_1 = 0{,}45 - 0{,}25 * \beta}$	$C_1 = 0{,}20$

Table 2.1 Exponent for a chord stress factor

$$C_1 = 0{,}45 - 0{,}25 \cdot \beta = 0{,}45 - 0{,}25 \cdot 0{,}35 = 0{,}31$$

$$Q_f = (1 - |n|)^{C_1} = (1 - |-0{,}59|)^{0{,}31} = 0{,}76$$

C_f	
$\mathbf{f_y \leq 355\ MPa}$	$C_f = 1{,}0$
$\mathbf{355\ MPa < f_y \leq 460\ MPa}$	$C_f = 0{,}9$
$\mathbf{460\ MPa < f_y \leq 700\ MPa}$	$C_f = 0{,}8$

Tab. 2.2 Material factors to resistance

$C_f = 1{,}0$

2.7.1. Chord face failure

$$N_{1,Rd} = \frac{C_f \cdot \frac{f_{yo} \cdot t_0^2}{\sin \theta_1} \cdot (1{,}65 + 13{,}2 \cdot \beta^{1{,}6}) \cdot \gamma^{0{,}3} \cdot \left[1 + \frac{1}{1{,}2 + \left(\frac{g}{t_0}\right)^{0{,}8}}\right] \cdot Q_f}{\gamma_{M5}}$$

$$= \frac{1{,}0 \cdot \frac{355{,}0 \cdot 5{,}0^2}{\sin 32{,}1} \cdot (1{,}65 + 13{,}2 \cdot 0{,}58^{1{,}6}) \cdot 10{,}80^{0{,}3} \cdot \left[1 + \frac{1}{1{,}2 + \left(\frac{41{,}6}{5{,}0}\right)^{0{,}8}}\right] \cdot 0{,}76}{1{,}25}$$

$$= 171\ 065\ \mathrm{N}$$

$$N_{2,Rd} = \frac{\sin \theta_1}{\sin \theta_2} \cdot N_{1,Rd} = \frac{\sin 32{,}1}{\sin 37{,}9} \cdot 171\ 065 = 147\ 982\ \mathrm{N}$$

2.7.2. Punching shear failure

Validity of the punching shear check:

$d_1 = 82{,}5\ \mathrm{mm} \leq d_0 - 2 \cdot t_0 = 108{,}0 - 2 \cdot 5{,}0 = 98{,}0\ \mathrm{mm}$

$$N_{1,Rd} = \frac{C_f \cdot \frac{f_{yo}}{\sqrt{3}} \cdot t_0 \cdot \pi \cdot d_1 \cdot \frac{1 + \sin \theta_1}{2 \cdot \sin^2 \theta_1}}{\gamma_{M5}} = \frac{1{,}0 \cdot \frac{355{,}0}{\sqrt{3}} \cdot 5{,}0 \cdot \pi \cdot 82{,}5 \cdot \frac{1 + \sin 32{,}1}{2 \cdot \sin^2 32{,}1}}{1{,}25}$$
$$= 576\ 167\ \mathrm{N}$$

$$N_{2,Rd} = \frac{C_f \cdot \frac{f_{yo}}{\sqrt{3}} \cdot t_0 \cdot \pi \cdot d_2 \cdot \frac{1 + \sin \theta_1}{2 \cdot \sin^2 \theta_1}}{\gamma_{M5}} = \frac{1{,}0 \cdot \frac{355{,}0}{\sqrt{3}} \cdot 5{,}0 \cdot \pi \cdot 44{,}5 \cdot \frac{1 + \sin 37{,}9}{2 \cdot \sin^2 37{,}9}}{1{,}25}$$
$$= 245\ 158\ \mathrm{N}$$

Design resistance of the joint expressed in terms of the internal axial force in member 1 is $N_{1,Ed} = 39\ 281\ N$ and in member 2 is $N_{2,Rd} = 147\ 982\ \mathrm{N}$.

2.8. Design check

$$\frac{N_{1,Ed}}{N_{1,Rd}} = \frac{132\ 300}{171\ 065} = 0{,}77 \leq 1{,}0$$

$$\frac{N_{2,Ed}}{N_{2,Rd}} = \frac{59\ 000}{147\ 982} = 0{,}40 \leq 1{,}0$$

It is satisfied.