1. CHS Y-joint

Design of axial resistance of the CHS Y-joint is performed according to prEN 1993-1-8(2021), see Figure 1.1. The exact description and material properties of each member are given.

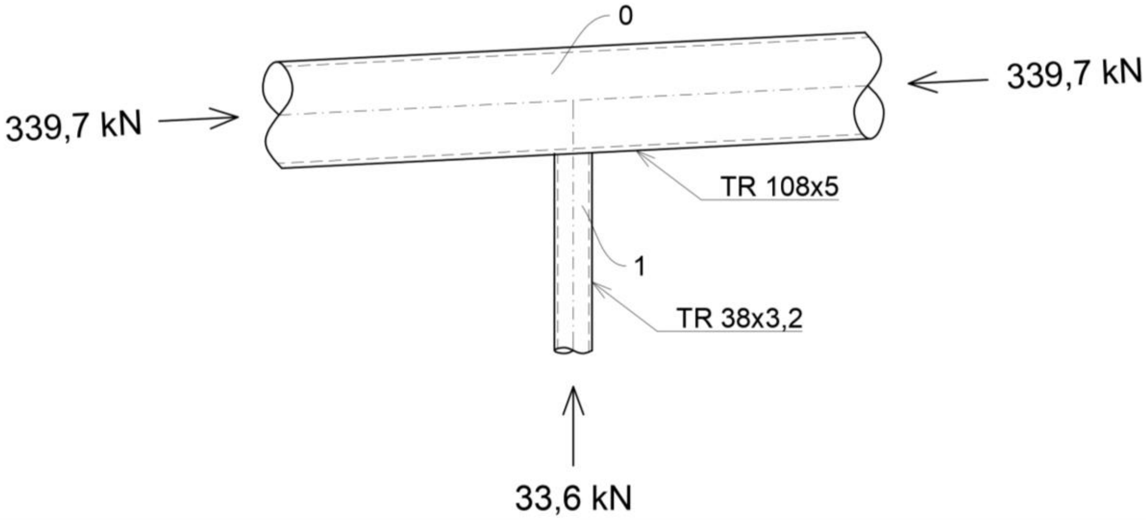

Figure 1.1 Joint geometry, internal forces

1.1. 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 a 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 the chord width or diameter to twice its wall thickness
Q_f	is a chord stress factor
n	is a chord stress parameter
C_f	is a material factor
$M_{ip,i,Ed}$	is a design in-plane internal moment in member i (i=0,1,2 or 3)

$M_{op,i,Ed}$ is a design out-of-plane internal moment in member i (i = 0, 1, 2 or 3)

$N_{i,Ed}$ is a design internal axial force in member i (i=0,1,2 or 3);

$N_{i,Rd}$ is a design resistance of a joint expressed in terms of the internal axial force in member i (i = 0, 1, 2 or 3)

1.2. Design forces

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

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

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

$N_{1,Ed} = -33\ 600\ N$

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

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

1.3. Material

$f_{y,0} = 355{,}0\ MPa$

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

1.4. Geometry of sections

$A_0 = 1\ 618\ mm^2$

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

1.5. Range of validity

$$0{,}2 \le \frac{d_1}{d_0} = \frac{38{,}0}{108{,}0} = 0{,}35 \le 1{,}0$$

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

$$\frac{d_1}{t_1} = \frac{38{,}0}{3{,}2} = 11{,}88 \le 50$$

$t_1 = 3{,}2\ mm \le t_0 = 5{,}0\ mm$

$\theta_1 = 87{,}1° \ge 30°$

1.6. Geometric ratios

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

$$\beta = \frac{d_1}{d_0} = \frac{38,0}{108,0} = 0,35$$

1.7. 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 1.1 Exponent for a chord stress factor

$$C_1 = 0,45 - 0,25 \cdot \beta = 0,45 - 0,25 \cdot 0,35 = 0,36$$

$$Q_f = (1 - |n|)^{C_1} = (1 - |-0,59|)^{0,36} = 0,72$$

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

Table 1.2 Material factors to resistance

$$C_f = 1,0$$

1.7.1. Chord face failure

$$N_{1,Rd} = \frac{C_f \cdot \frac{f_{yo} \cdot t_0^2}{\sin \theta_1} \cdot (2,6 + 17,7 \cdot \beta^2) \cdot \gamma^{0,2} \cdot Q_f}{\gamma_{M5}}$$

$$= \frac{1,0 \cdot \frac{355,0 \cdot 5,0^2}{\sin 87,1} \cdot (2,6 + 17,7 \cdot 0,35^2) \cdot 10,80^{0,2} \cdot 0,72}{1,25} = 39\ 281\ \mathrm{N}$$

1.7.2. Punching shear failure

Validity of the punching shear check:

$$d_1 = 38,0\ \mathrm{mm} \leq d_0 - 2 \cdot t_0 = 108,0 - 2 \cdot 5,0 = 98,0\ \mathrm{mm}$$

$$N_{1,Rd} = \frac{C_f \cdot \frac{f_{yo}}{\sqrt{3}} \cdot t_0 \cdot \pi \cdot d_1 \cdot \frac{1 + \sin \theta_1}{2 \cdot \sin^2 \theta_1}}{\gamma_{M5}} = \frac{1,0 \cdot \frac{355,0}{\sqrt{3}} \cdot 5,0 \cdot \pi \cdot 38,0 \cdot \frac{1 + \sin 87,1}{2 \cdot \sin^2 87,1}}{1,25}$$

$$= 98\ 060\ N$$

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

1.8. Design check

$$\frac{N_{1,Ed}}{N_{1,Rd}} = \frac{33\ 600}{39\ 281} = 0{,}86 \leq 1{,}0$$

It is satisfied.