detailed problems acc. to Eurocode 3

EC 3-1-9 (12.10), NA: Deutschland

steel grade

steel grade S 235

cross-section

beam: section HE300B

crane gantry

crane rail of flat steel, shear-resistant joined with the girder

connection with fillet welds: weld thickness a_w = 5.0 mm (continuous)

crane rail: width b_r = 50.0 mm, height of fretted rail h_r = 22.5 mm

moment of inertia, cross-sectional area of fretted rail I_{yr} = 4.75 cm⁴, A_r = 11.25 cm²

parameters

damage equivalent stress factors for crane class S2: λ_σ = 0.315, λ_τ = 0.500, crane class S3: $\lambda_{\sigma+}$ = 0.397, $\lambda_{\tau+}$ = 0.575

notch class / valid notch stresses:

Pt.	y_f mm	z_f mm	$\Delta\sigma_{x,Rd}$ N/mm²	$\Delta\tau_{Rd}$ N/mm²	$\Delta\sigma_{z,Rd}$ N/mm²	notch point	EC 3-1-9, tab.
4	-5.5	46.0	160.0	100.0	160.0	at beam web	8.1(2) 8.1(6) 8.10(1)

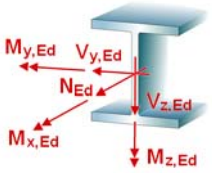
loading

Lk 1: $M_{y,Ed}$ = 100.3 kNm, $V_{z,Ed}$ = 47.8 kN

Lk 2: $M_{y,Ed}$ = -20.1 kNm, $V_{z,Ed}$ = -34.0 kN

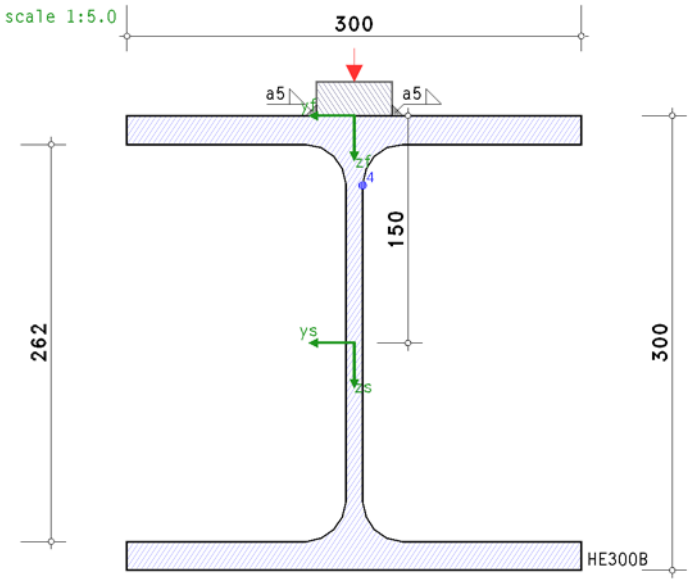
transverse loading on top flange:

design value of vertical wheel load $F_{z,Ed}$ = 79.60 kN



material safety factor

design concept: damage tolerance, damage consequence: high ⇒ fatigue strength γ_{Mf} = 1.15



Fatigue Design

cross-sectional properties

A = 149.08 cm², z_s = 150.0 mm, I_y = 25165.90 cm⁴, y_s = 0.0 mm, I_z = 8562.83 cm⁴

effective loading length from crane gantry

effective width $b_{eff} = b_r + h_r + t_{fo}$ = 91.5 mm ≤ b_{fo}

moment of inertia of crane rail with beam flange I_{rf} = 39.38 cm⁴

effective length $l_{eff} = 3.25 \cdot (I_{rf}/t_w)^{1/3}$ = 107.1 mm

local stresses from crane gantry

effective loading length refered ...

... to outer edge of flange $s_s = l_{eff} - 2 \cdot t_f$ = 69.1 mm / ... to web $s_w = l_{eff} + 2 \cdot r$ = 161.1 mm

local stresses ...

... at crane rail σ_{oz} = -104.7 N/mm², τ_o = 20.9 N/mm² / ... at weld σ_{oz} = -115.2 N/mm², τ_o = 23.0 N/mm²
... at beam web σ_{oz} = -44.9 N/mm², τ_o = 9.0 N/mm²

elastic stresses / stress ranges

$\Delta\sigma_{x,Ed} = \sigma_{x,max}-\sigma_{x,min}$, $\tau_{Ed} = \tau_{xz,max}-\tau_{xz,min} + 2\cdot\tau_o$, $\Delta\sigma_{z,Ed} = -\sigma_{oz}$

pt. 4:	y_f = -5.5 mm, z_f = 46.0 mm	Lk 1:	σ_x = -41.4 N/mm²	τ_{xz} = 15.1 N/mm²	
		2:	σ_x = 8.3 N/mm²	τ_{xz} = -10.7 N/mm²	
			$\Delta\sigma_{x,Ed}$ = 49.8 N/mm²	$\Delta\tau_{Ed}$ = 43.7 N/mm²	$\Delta\sigma_{z,Ed}$ = 44.9 N/mm²

equivalent constand amplitude stress range

$\Delta\sigma_{x,f} = \Delta\sigma_{x,Ed}\cdot\lambda_\sigma$, $\Delta\tau_f = \Delta\tau_{Ed}\cdot\lambda_\tau$, $\Delta\sigma_{z,f} = \Delta\sigma_{z,Ed}\cdot\lambda_\sigma$

pt. 4:	y_f = -5.5 mm, z_f = 46.0 mm	($\lambda_{\tau\sigma z+}$)	$\Delta\sigma_{x,f}$ = 15.7 N/mm²	$\Delta\tau_f$ = 25.1 N/mm²	$\Delta\sigma_{z,f}$ = 17.8 N/mm²

valid notch stresses

$\Delta\sigma_{x,Rd,f} = \Delta\sigma_{x,Rd}/\gamma_{Mf}$, $\Delta\tau_{Rd,f} = \Delta\tau_{Rd}/\gamma_{Mf}$, $\Delta\sigma_{z,Rd,f} = \Delta\sigma_{z,Rd}/\gamma_{Mf}$

pt. 4:	y_f = -5.5 mm, z_f = 46.0 mm	$\Delta\sigma_{x,Rd,f}$ = 139.1 N/mm²	$\Delta\tau_{Rd,f}$ = 87.0 N/mm²	$\Delta\sigma_{z,Rd,f}$ = 139.1 N/mm²

verification of notch stresses

pt. 4: y = -5.5 mm, z = 46.0 mm

$\Delta\sigma_{x,f}$ = 15.7 N/mm² < $\Delta\sigma_{x,Rd,f}$ = 139.1 N/mm² ⇒ $U_{\Delta\sigma x}$ = 0.113 ok.
$\Delta\tau_f$ = 25.1 N/mm² < $\Delta\tau_{Rd,f}$ = 87.0 N/mm² ⇒ $U_{\Delta\tau}$ = 0.289 ok.
$\Delta\sigma_{z,f}$ = 17.8 N/mm² < $\Delta\sigma_{z,Rd,f}$ = 139.1 N/mm² ⇒ $U_{\Delta\sigma z}$ = 0.128 ok.
interaction $U_i = U_{\Delta\sigma x}^3+U_{\Delta\sigma z}^3+U_{\Delta\tau}^5$ = 0.006 < 1 ok.

Final Result

fatigue design [pt. 4]: max U = 0.289 < 1 ok.

verification succeeded