detailed problems acc. to Eurocode 3
EC 3-1-9 (12.10), NA: Deutschland

steel grade
steel grade S 235

cross-section
beam: section HE360A

parameters
damage equivalent stress factors for crane class S1: \( \lambda_{e0} = 0.250 \), \( \lambda_{e1} = 0.436 \), crane class S2: \( \lambda_{e0} = 0.315 \), \( \lambda_{e1} = 0.500 \)

notch class / valid notch stresses:

<table>
<thead>
<tr>
<th>Pt.</th>
<th>( y_f )</th>
<th>( z_f )</th>
<th>( \Delta \sigma_{x, Rd} )</th>
<th>( \Delta \sigma_{p, Rd} )</th>
<th>( \Delta \sigma_{z, Rd} )</th>
<th>notch point</th>
<th>EC 3-1-9, tab.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-150.0</td>
<td>0.0</td>
<td>160.0</td>
<td>0.0</td>
<td>0.0</td>
<td>at top flange</td>
<td>8.1(2)</td>
</tr>
<tr>
<td>5</td>
<td>-5.0</td>
<td>305.5</td>
<td>160.0</td>
<td>100.0</td>
<td>160.0</td>
<td>at beam web</td>
<td>8.1(2) 8.1(6) 8.10(1)</td>
</tr>
<tr>
<td>6</td>
<td>-32.0</td>
<td>332.5</td>
<td>160.0</td>
<td>0.0</td>
<td>0.0</td>
<td>at bottom flange</td>
<td>8.1(2)</td>
</tr>
<tr>
<td>7</td>
<td>-150.0</td>
<td>332.5</td>
<td>160.0</td>
<td>0.0</td>
<td>0.0</td>
<td>at bottom flange</td>
<td>8.1(2)</td>
</tr>
<tr>
<td>8</td>
<td>-150.0</td>
<td>350.0</td>
<td>160.0</td>
<td>0.0</td>
<td>0.0</td>
<td>at bottom flange</td>
<td>8.1(2)</td>
</tr>
<tr>
<td>17</td>
<td>-136.0</td>
<td>332.5</td>
<td>160.0</td>
<td>0.0</td>
<td>0.0</td>
<td>due to crane gantry</td>
<td>8.1(2)</td>
</tr>
</tbody>
</table>

loading
Lk 1: EK 12
\[ M_{y,Ed} = 129.4 \text{ kNm}, \quad M_{z,Ed} = 4.6 \text{ kNm} \]
Lk 2: \[ M_{y,Ed} = 0.0 \text{ kNm}, \quad M_{z,Ed} = 0.0 \text{ kNm} \]

transverse loading on bottom flange:
design value of vertical wheel load \( F_{z,Ed} = 9.23 \text{ kN} \) (per side)
distance of wheel axles \( a_R = 100.0 \text{ cm} \)
distance of wheel from lateral edge of flange \( n_Y = 14.0 \text{ mm} \)
wheel at end of beam (supported lower flange), distance of the wheel from end of girder \( x_E = 20.0 \text{ cm} \)

material safety factor
fatigue strength \( \gamma_{M} = 1.60 \)

scale 1:5.0

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Fatigue Design

cross-sectional properties
A = 142.76 cm², ze = 175.0 mm, l_y = 33090.11 cm⁴, y_s = 0.0 mm, l_z = 7886.85 cm⁴

effective loading length from crane gantry
minimum distance of crane gantry wheel to the end of beam neglected xe = 200.0 mm < bu = 300.0 mm
wheel at distance xe = 200.0 mm ≤ 2.21²(−-(m+n)) = 349.0 mm from supported end of flange
effective length leff = 2.21²(−-(m+n))x_e = 701.3 mm
m = 109.4 mm, n = 14.0 mm (for xe = 1000.0 mm > 2.21²(−-(m+n))x_e = 701.3 mm)

local stresses from crane gantry at lower flange
σ_x Ed(0) = 159.3 N/mm², σ_yx Ed(1) = 159.3 N/mm², σ_yy Ed(2) = 159.3 N/mm²
σ_y Ed(0) = -57.4 N/mm², σ_yx Ed(1) = 159.3 N/mm², σ_yy Ed(2) = 0.0 N/mm²
75% of local stresses from crane gantry:
σ_x Ed(0) = 119.5 N/mm², σ_yx Ed(1) = 119.5 N/mm², σ_yy Ed(2) = 119.5 N/mm²
σ_y Ed(0) = -43.1 N/mm², σ_yx Ed(1) = 119.5 N/mm², σ_yy Ed(2) = 0.0 N/mm²

75% of local stresses from crane gantry:
σ_x Ed(0) = 89.6 N/mm², σ_yx Ed(1) = 89.6 N/mm², σ_yy Ed(2) = 89.6 N/mm²
σ_y Ed(0) = -32.3 N/mm², σ_yx Ed(1) = 89.6 N/mm², σ_yy Ed(2) = 0.0 N/mm²

elastic stresses / stress ranges
Δσ Ed = Δσ_x + μ Δσ_yx + Δσ_yy Ed = 1 N/mm²
pt. 1: y = -150.0 mm, z = 0.0 mm
Lk 1: σ_x = -59.7 N/mm²
Lk 2: σ_x = 0.0 N/mm²
Δσ_x Ed = 59.7 N/mm²

5: y = -5.0 mm, z = 305.5 mm
Lk 1: σ_x = 51.3 N/mm²
Lk 2: σ_x = 0.0 N/mm²
Δσ_x Ed = 51.3 N/mm²

6: y = -32.0 mm, z = 332.5 mm
Lk 1: σ_x = 63.5 N/mm²
Lk 2: σ_x = 0.0 N/mm²
Δσ_x Ed = 63.5 N/mm²

7: y = -150.0 mm, z = 332.5 mm
Lk 1: σ_x = 70.3 N/mm²
Lk 2: σ_x = 0.0 N/mm²
Δσ_x Ed = 70.3 N/mm²

8: y = -150.0 mm, z = 350.0 mm
Lk 1: σ_x = 77.2 N/mm²
Lk 2: σ_x = 0.0 N/mm²
Δσ_x Ed = 77.2 N/mm²

17: y = -136.0 mm, z = 332.5 mm
Lk 1: σ_x = 69.5 N/mm²
Lk 2: σ_x = 0.0 N/mm²
Δσ_x Ed = 69.5 N/mm²

equivalent constant amplitude stress range
Δσ Ed = Δσ_x Ed, Δσ_yx Ed = Δσ_yx Ed, Δσ_yy Ed = Δσ_yy Ed
pt. 1: y = -150.0 mm, z = 0.0 mm
Δσ_x Ed = 14.9 N/mm²

5: y = -5.0 mm, z = 305.5 mm
Δσ_x Ed = 12.8 N/mm²

6: y = -32.0 mm, z = 332.5 mm
Δσ_x Ed = 38.3 N/mm²

7: y = -150.0 mm, z = 332.5 mm
Δσ_x Ed = 40.0 N/mm²

8: y = -150.0 mm, z = 350.0 mm
Δσ_x Ed = 19.3 N/mm²

17: y = -136.0 mm, z = 332.5 mm
Δσ_x Ed = 39.8 N/mm²

valid notch stresses
Δσ Ed = Δσ_x Ed, Δσ_yx Ed = Δσ_yx Ed, Δσ_yy Ed = Δσ_yy Ed
pt. 1: y = -150.0 mm, z = 0.0 mm
Δσ_x Ed = 100.0 N/mm²

5: y = -5.0 mm, z = 305.5 mm
Δσ_x Ed = 100.0 N/mm²

6: y = -32.0 mm, z = 332.5 mm
Δσ_x Ed = 100.0 N/mm²

7: y = -150.0 mm, z = 332.5 mm
Δσ_x Ed = 100.0 N/mm²

8: y = -150.0 mm, z = 350.0 mm
Δσ_x Ed = 100.0 N/mm²

17: y = -136.0 mm, z = 332.5 mm
Δσ_x Ed = 100.0 N/mm²

verification of notch stresses
pt. 1: y = -150.0 mm, z = 0.0 mm
Δσ_x Ed = 14.9 N/mm² < Δσ_x Ed = 100.0 N/mm² ⇒ U_Δσ_x Ed = 0.149 ok.

5: y = -5.0 mm, z = 305.5 mm
Δσ_x Ed = 12.8 N/mm² < Δσ_x Ed = 100.0 N/mm² ⇒ U_Δσ_x Ed = 0.128 ok.

6: y = -32.0 mm, z = 332.5 mm
Δσ_x Ed = 38.3 N/mm² < Δσ_x Ed = 100.0 N/mm² ⇒ U_Δσ_x Ed = 0.383 ok.

7: y = -150.0 mm, z = 332.5 mm
Δσ_x Ed = 40.0 N/mm² < Δσ_x Ed = 100.0 N/mm² ⇒ U_Δσ_x Ed = 0.400 ok.

8: y = -150.0 mm, z = 350.0 mm
Δσ_x Ed = 19.3 N/mm² < Δσ_x Ed = 100.0 N/mm² ⇒ U_Δσ_x Ed = 0.193 ok.

17: y = -136.0 mm, z = 332.5 mm
Δσ_x Ed = 39.8 N/mm² < Δσ_x Ed = 100.0 N/mm² ⇒ U_Δσ_x Ed = 0.398 ok.
fatigue design [pt. 7]: \[ \text{max } U = 0.400 < 1 \text{ ok.} \]

verification succeeded