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

steel grade
steel grade S 355

cross-section
beam: section HE400B
transverse stiffeners: section parameters (flat steel):
  - height h = 120.0 mm, thickness t = 20.0 mm
  - recess at transverse stiffener cr,q = 27.0 mm

crane gantry
A-crane rail 55, floating with fillet welds joined with the girder
crane rail: head width b_h = 55.0 mm, bottom width b_r = 150.0 mm, height of fretted rail h_r = 59.0 mm
  - moment of inertia, cross-sectional area of fretted rail I_y = 134.00 cm^4, A_r = 37.30 cm^2

parameters
damage equivalent stress factors for crane class S2: \( \lambda_d = 0.315 \), \( \lambda_r = 0.500 \), crane class S3: \( \lambda_{cr} = 0.397 \), \( \lambda_{r+} = 0.575 \)
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_{y,Rd} )</th>
<th>( \Delta \sigma_{z,Rd} )</th>
<th>notch point</th>
<th>EC 3-1-9, tab.</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>-6.8</td>
<td>51.0</td>
<td>80.0</td>
<td>100.0</td>
<td>100.0</td>
<td>due to transv. stiff.</td>
<td>8.4(7) 8.1(6) 8.2(7)</td>
</tr>
</tbody>
</table>

loading
Lk 1: \( M_{y,Ed} = 301.0 \text{ kNm}, V_{z,Ed} = 290.0 \text{ kN} \)
Lk 2: \( M_{y,Ed} = -30.0 \text{ kNm}, V_{z,Ed} = 0.0 \text{ kN} \)
transverse loading on top flange:
design value of vertical wheel load \( F_{z,Ed} = 290.00 \text{ kN} \)

material safety factor
design concept: damage tolerance, damage consequence: high \( \Rightarrow \) fatigue strength \( \gamma_{MH} = 1.15 \)

scale 1:5.0

\[ A 55 \]

\[ 300 \]

\[ 352 \]

\[ 400 \]

HE400B
Fatigue Design

cross-sectional properties
A = 197.78 cm², z₁ = 200.0 mm, i₁ = 57680.93 cm⁴, y₁₂ = 0.0 mm, i₁₂ = 10819.05 cm⁴

effective loading length from crane gantry
effective width b_eff = b₁ + h₁ + fo = 233.0 mm ≤ b₀
effective moment of inertia of beam flange I₁_eff = b₁h₁fo²/12 = 26.84 cm⁴
moment of inertia of crane rail I₁ = 134.00 cm⁴
effective length l₁ = 3.25 ((l₁ + l₁_eff)/l₁)^(1/3) = 159.9 mm

local stresses from crane gantry
effective loading length referred...
... to outer edge of flange s₁ = l₁eff - 2·f₁ = 111.9 mm / ... to web s₁w = l₁eff + 2·f₁ = 213.9 mm
local stresses...
... at crane rail σ₁₂ = -191.9 N/mm², τ₁ = 38.4 N/mm² / ... at weld σ₁₂ = -259.1 N/mm², τ₁ = 51.8 N/mm²
... at beam web σ₁₂ = -100.4 N/mm², τ₁ = 20.1 N/mm²

elastic stresses / stress ranges
\[Δσ₁₁, Ed = Δσ₁₁, Ed + Δσ₁₁, t(α₁₂)\]
pt. 19: y₁ = -6.8 mm, z₁ = 51.0 mm

Lk 1:
\[σ₁ = -77.8 N/mm², τ₁ = 54.5 N/mm², Δσ₁₁, Ed = 85.5 N/mm², Δτ₁₁, Ed = 94.6 N/mm², Δσ₁₁, t = 100.4 N/mm²\]

equivalent constant amplitude stress range
\[Δσ₁₁, Ed = Δσ₁₁, Ed - Δσ₁₁, t(α₁₂)\]
pt. 19: y₁ = -6.8 mm, z₁ = 51.0 mm

(λ₁₁₂) \[Δσ₁₁, t = 26.9 N/mm², Δτ₁₁, t = 54.4 N/mm², Δσ₁₁, t = 39.9 N/mm²\]

valid notch stresses
\[Δσ₁₁, Rd₁ = Δσ₁₁, Rd₁ - Δσ₁₁, Rd₁(α₁₂)\]
pt. 19: y₁ = -6.8 mm, z₁ = 51.0 mm

\[Δσ₁₁, Rd₁ = 69.6 N/mm², Δτ₁₁, Rd₁ = 87.0 N/mm², Δσ₁₁, Rd₁ = 87.0 N/mm²\]

verification of notch stresses
pt. 19: y₁ = -6.8 mm, z₁ = 51.0 mm

\[Δσ₁₁, t = 26.9 N/mm² < Δσ₁₁, Rd₁ = 69.6 N/mm² \Rightarrow U_{Δτ₁₁} = 0.387 \text{ ok.}\]
\[Δτ₁₁ = 54.4 N/mm² < Δτ₁₁, Rd₁ = 87.0 N/mm² \Rightarrow U_{Δτ₁₁} = 0.626 \text{ ok.}\]
\[Δσ₁₁, t = 39.9 N/mm² < Δσ₁₁, Rd₁ = 87.0 N/mm² \Rightarrow U_{Δσ₁₁} = 0.458 \text{ ok.}\]
interaction U₁ = U_{Δσ₁₁} + U_{Δτ₁₁} = 0.250 < 1 \text{ ok.}\]

Final Result

fatigue design [pt. 19]: \[\max U = 0.626 < 1 \text{ ok.}\]

verification succeeded