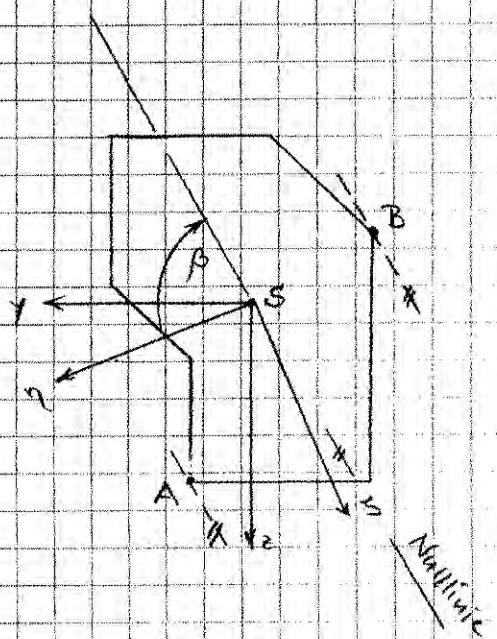
zu 1) $\alpha = -(45° + 21{,}62°) = -66{,}62°$

$$\tan\beta = \frac{I_1}{I_2} \cdot \tan\alpha = \frac{1843\,cm^4}{599\,cm^4} \cdot \tan(-66{,}62°)$$

$$\tan\beta = -7{,}1169$$

$$\beta = -82{,}00°$$



zu 2) $M_{by} = M_b \cdot \cos\alpha = M_b \cdot \cos(-66{,}62°) = 0{,}3968 \cdot M_b$

$M_{bz} = M_b \cdot \sin\alpha = M_b \cdot \sin(-66{,}62°) = -0{,}9179 \cdot M_b$

Punkt A: $y_A = 2{,}37\,cm$; $z_A = 7{,}24\,cm$

$\eta_A = 7{,}24\,cm \cdot \sin 21{,}62° + 2{,}37\,cm \cdot \cos 21{,}62° = 4{,}87\,cm$

$\zeta_A = 7{,}24\,cm \cdot \cos 21{,}62° - 2{,}37\,cm \cdot \sin 21{,}62° = 5{,}86\,cm$

Punkt B: $y_B = -4{,}63\,cm$; $z_B = -2{,}76\,cm$

$\eta_B = -2{,}76\,cm \cdot \sin 21{,}62° - 4{,}63\,cm \cdot \cos 21{,}62° = -5{,}32\,cm$

$\zeta_B = -2{,}76\,cm \cdot \cos 21{,}62° + 4{,}63\,cm \cdot \sin 21{,}62° = -0{,}86\,cm$

$$\sigma_B^A = \frac{0,3968 \cdot M_b}{1843\,cm^4} \cdot 5,86\,cm + \frac{0,9179 \cdot M_b}{599\,cm^4} \cdot 4,87\,cm$$

$$\sigma_B^A = 0,00872\,\frac{1}{cm^3} \cdot M_b$$

$$\sigma_B^B = \frac{0,3968 \cdot M_b}{1543\,cm^4} \cdot (-0,86\,cm) + \frac{0,9179 \cdot M_b}{599\,cm^4} \cdot (-5,32\,cm)$$

$$\sigma_B^B = -0,00834\,\frac{1}{cm^3} \cdot M_b$$

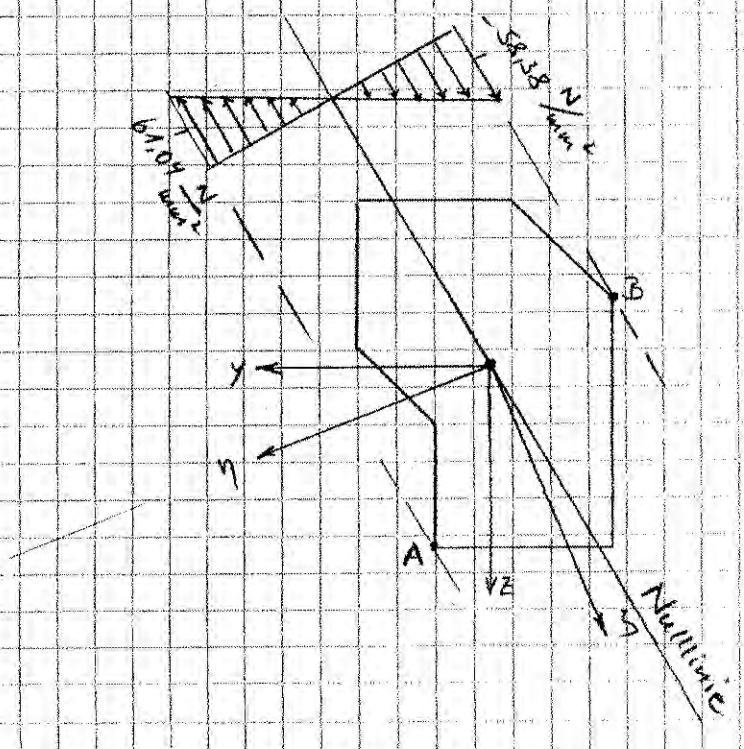
$$M_{bzul} = \frac{\sigma_{bzul}}{0,00872\,\frac{1}{cm^3}} = \frac{70\,\frac{N}{mm^2}}{0,00872 \cdot \frac{1}{10^3\,mm^3}} = 8027523\,N \cdot mm$$

$$M_{bzul} = 8,027\,kN \cdot m$$

zu 3)

$$\sigma_b^A = 0,00872\,\frac{1}{cm^3} \cdot 700\,kN \cdot cm = 6,104\,\frac{kN}{cm^2} = 61,04\,\frac{N}{mm^2}$$

$$\sigma_b^B = -0,00834\,\frac{1}{cm^3} \cdot 700\,kN \cdot cm = -5,838\,\frac{kN}{cm^2} = -58,38\,\frac{N}{mm^2}$$



zu 1)

Bereich I

$$W_T = 0{,}348 \cdot R^3 = 0{,}348 \cdot (4\,cm)^3 = 22{,}272\,cm^3$$

$$\tau = \frac{M_T}{W_T} = \frac{100\,KN \cdot cm}{22{,}272\,cm^3} = 4{,}490\,\frac{KN}{cm^2} = 44{,}90\,\frac{N}{mm^2}$$ (1)

Bereich II

$$A_m = \frac{\pi \cdot (3{,}8\,cm)^2}{2} = 22{,}682\,cm^2$$

$$\tau = \frac{M_T}{2 \cdot A_m \cdot t} = \frac{100\,KN \cdot cm}{2 \cdot 22{,}682\,cm^2 \cdot 0{,}4\,cm}$$ (1)

$$\tau = 5{,}511\,\frac{KN}{cm^2} = 55{,}11\,\frac{N}{mm^2}$$

zu 2)

Bereich I

$$I_T = 0{,}296 \cdot R^4 = 0{,}296 \cdot (4\,cm)^4 = 75{,}776\,cm^4$$

$$\varphi_B = \frac{M_T}{G \cdot I_T} \cdot l = \frac{1 \cdot 10^6\,N \cdot mm \cdot 1500\,mm}{8{,}1 \cdot 10^4\,\frac{N}{mm^2} \cdot 75{,}776 \cdot 10^4\,mm^4}$$

$$\varphi_B = 0{,}02444 \triangleq 1{,}400^\circ$$ (1)

Bereich II

$$I_T = \frac{4 \cdot A_m^2}{\oint \frac{ds}{t}}$$

$$\oint \frac{ds}{t} = \frac{1}{0{,}4\,cm} \cdot (\pi \cdot 3{,}8\,cm + 2 \cdot 3{,}8\,cm) = 48{,}845$$ (1)

$$I_T = \frac{4 \cdot (22{,}682\,cm^2)^2}{48{,}845} = 42{,}131\,cm^4$$ (1)

$$\varphi_c = 0{,}02444 + \frac{1 \cdot 10^6\ N \cdot mm \cdot 500\ mm}{8{,}1 \cdot 10^4 \frac{N}{mm^2} \cdot 42{,}131 \cdot 10^4\ mm^4}$$

$$\varphi_c = 0{,}03909 \hat{=} 2{,}24° \quad (1)$$

zu 3)

$$\varphi_c = 0{,}02444 + \frac{1 \cdot 10^6\ N \cdot mm \cdot 500\ mm}{8{,}1 \cdot 10^4 \frac{N}{mm^2} \cdot I_T} = \frac{2°}{180°} \cdot \pi$$

$$\frac{6172{,}84\ mm^4}{I_T} = 0{,}03491 - 0{,}02444 = 0{,}01047$$

$$I_T = \frac{6172{,}84\ mm^4}{0{,}01047} = 589574\ mm^4 \quad (1)$$

$$I_T = \frac{4 \cdot (22{,}682 \cdot 10^2\ mm^2)^2}{\frac{\pi \cdot 38\ mm + 2 \cdot 38\ mm}{t}} = 589574\ mm^4$$

$$t = \frac{589574\ mm^4 \cdot 195{,}381\ mm}{2057825\ mm^4}$$

$$t = 5{,}59\ mm \quad (1)$$

zu 1)

$$I = \frac{\pi \cdot (60\,mm)^4}{64} = 636173\,mm^4$$

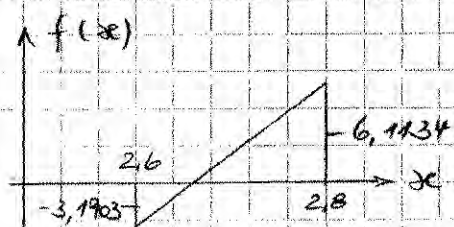
$$A = \frac{\pi \cdot (60\,mm)^2}{4} = 2827\,mm^2$$

$$\delta = \frac{200\,\frac{N}{mm} \cdot (2000\,mm)^3}{2,1 \cdot 10^5\,\frac{N}{mm^2} \cdot 636173\,mm^4} = 11,976$$

$$f(\varkappa) = 2 \cdot \varkappa^3 + 11,976 \cdot \tan\varkappa - 11,976 \cdot \varkappa = 0$$

$$f(2,6) = -3,1903$$

$$f(2,8) = 6,1134$$

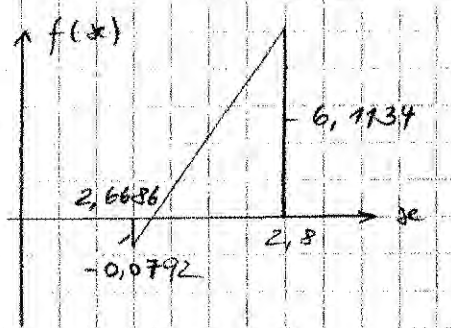


$$\frac{\Delta\varkappa}{3,1903} = \frac{0,2}{3,1903 + 6,1134}$$

$$\Delta\varkappa = 0,0686$$

$$\varkappa_{Neu} = 2,6686$$

$$f(2,6686) = -0,0792$$



$$\frac{\Delta\varkappa}{0,0792} = \frac{2,8 - 2,6686}{6,1134 + 0,0792}$$

$$\Delta\varkappa = 0,0017$$

$$\varkappa_{Neu} = 2,6703$$

$$\frac{F_K}{E \cdot I} \cdot l^2 = \varkappa^2$$

$$F_K = \frac{\varkappa^2 \cdot E \cdot I}{l^2} = \frac{2,6703^2 \cdot 2,1 \cdot 10^5\,\frac{N}{mm^2} \cdot 636173\,mm^4}{(2000\,mm)^2}$$

$$F_k = 238152\,N$$

$$F_{zul} = \frac{F_k}{\nu} = \frac{238152\,N}{5} = 47630\,N$$

zu 2) $$\frac{E \cdot I \cdot \pi^2}{s_k^2} = F_k$$

$$s_k = \sqrt{\frac{E \cdot I \cdot \pi^2}{F_k}}$$

$$s_k = \sqrt{\frac{2{,}1 \cdot 10^5 \frac{N}{mm^2} \cdot 636173\,mm^4 \cdot \pi^2}{238152\,N}}$$

$$s_k = 2353\,mm$$

zu 3) $$i = \sqrt{\frac{I}{A}} = \frac{d}{4} = 15\,mm$$

$$\lambda = \frac{s_k}{i} = \frac{2353\,mm}{15\,mm} = 156{,}9 > \lambda_{grenz} = 105$$

$\Rightarrow$ elastische Rechnung o.k.