



AKADEMIA EDUKACYJNO - INŻYNIERSKA

[www.e-MECHANiK.com.pl](http://www.e-MECHANiK.com.pl)

**MATURA STUDIA PRAKTYKA STAŻ PRACA BIZNES PRZEMYSŁ STEAM**

KOMPLEKSOWE WSPARCIE EDUKACYJNE ON – LINE NA KAŻDYM ETAPIE KSZTAŁCENIA INŻYNIERSKIEGO

email: [kontakt@e-mechanik.com.pl](mailto:kontakt@e-mechanik.com.pl)

web: [www.e-MECHANiK.com.pl](http://www.e-MECHANiK.com.pl)

fb: [www.facebook.com/groups/emechanik](https://www.facebook.com/groups/emechanik)

tel: (+48) - 697-165-075

# PODSTAWY KONSTRUKCJI MASZYN II

## "WYTRZYMAŁOŚĆ ZŁOŻONA – WAŁ MOTOREDUKTORA"

### PROJEKT

Oblicz:

– średnicę minimalną

dla układu wału motoreduktora jaką należy dobrać, aby na pewno przeniósł on zadane obciążenie zewnętrzne.

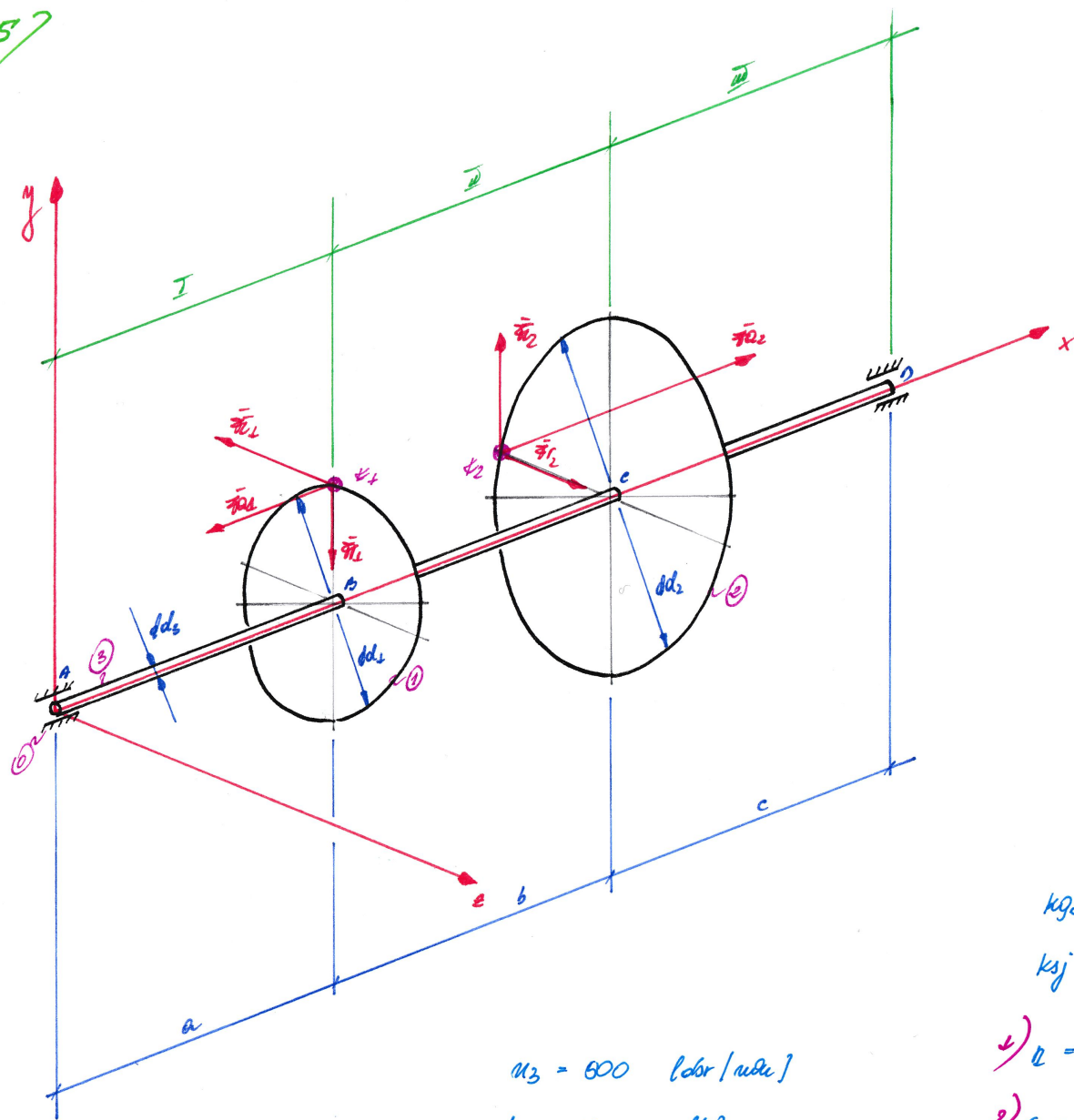
#### DANE:

- 1)  $\varnothing d_1, Fa_1, Fr_1, F\tau_1 = OK$  ;  $L_H = OK$   
2)  $\varnothing d_2, Fa_2, Fr_2 = OK$   
3)  $a_3, b_3, c_3, k_{go}, k_{sj}, n_3 = OK$

#### SZUKAM:

$\varnothing d_3, F\tau_2 = ?$

15



szukany:  
 $d_3 = ?$

$n_3 = 800 \text{ [obr/min]}$   
 $L_4 = 22000 \text{ [h]}$

DANE:

$a = 80 \text{ [mm]} = 0.08 \text{ [m]}$   
 $b = 50 \text{ [mm]} = 0.05 \text{ [m]}$   
 $c = 40 \text{ [mm]} = 0.04 \text{ [m]}$

1)  $d_1 = 100 \text{ [mm]} = 0.1 \text{ [m]}$   
2)  $d_2 = 120 \text{ [mm]} = 0.12 \text{ [m]}$

1)  $F_{t1} = 2100 \text{ [N]}$   
 $F_{r1} = 1000$   
 $F_{a1} = 1000$

2)  $F_{t2} = ?$   
 $F_{r2} = 1200$   
 $F_{a2} = 800$

$k_{g0} = 100 \text{ [MPa]} = 100 \cdot 10^6 \text{ [Pa]}$   
 $k_{sj} = 120 \text{ [MPa]} = 120 \cdot 10^6 \text{ [Pa]}$

1)  $r_1 = \frac{1}{2} d_1 = \frac{1}{2} \cdot 100 = 50 \text{ [mm]} = 0.05 \text{ [m]}$   
2)  $r_2 = \frac{1}{2} d_2 = \frac{1}{2} \cdot 120 = 60 \text{ [mm]} = 0.06 \text{ [m]}$

$F_{i2}$

$\sum M_{ix} = 0$

~~$=$~~

$$- \bar{F}_{i1} \cdot r_1 + \bar{F}_{i2} \cdot r_2 = 0$$

$$\bar{F}_{i1} \cdot r_1 = \bar{F}_{i2} \cdot r_2$$

$$\bar{F}_{i2} = \frac{r_1}{r_2} \bar{F}_{i1}$$

$$\Rightarrow \bar{F}_{i2} = \frac{0,05}{0,06} \cdot 2100 = 0,833 \cdot 2100 = \underline{1749,3 \text{ [N]}}$$

$M_3$

$M_3 = \bar{F} \cdot r$

~~$=$~~

$$M_{31} = \bar{F}_{i1} \cdot r_1$$

$$\underline{M_{31}} = 2100 \cdot 0,05 = \underline{105 \text{ [Nm]}}$$

$$M_{32} = \bar{F}_{i2} \cdot r_2$$

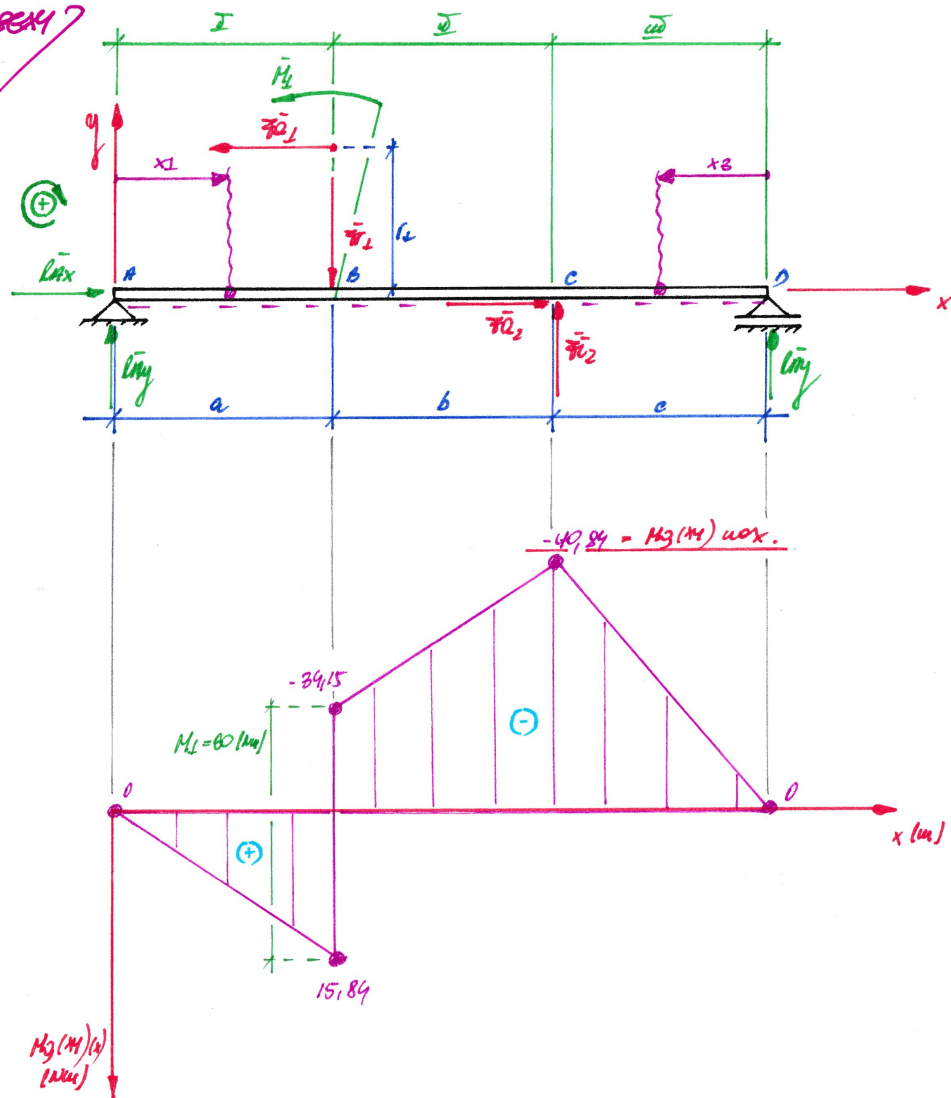
$$\underline{M_{32}} = 1749,3 \cdot 0,06 = \underline{105 \text{ [Nm]}}$$

$$\Rightarrow \underline{M_{31}} = M_{32} = M_{33} = \underline{105 \text{ [Nm]}}$$

~~$=$~~



SEXY



1) REAK CJS.

$$\begin{aligned} \text{I)} \quad & \sum F_{ix} = 0 \\ \text{II)} \quad & \sum F_{iy} = 0 \\ \text{III)} \quad & \sum M_{iA} = 0 \end{aligned}$$

$$\begin{aligned} \text{I)} \quad & R_{Ax} + F_{2x} = 0 \\ \text{II)} \quad & R_{Ay} - F_{1y} + F_{2y} + R_{Dy} = 0 \\ \text{III)} \quad & F_{1x} \cdot a - F_{2x} \cdot (a+b) - R_{Dy} \cdot (a+b+c) - M_L = 0 \end{aligned}$$

$$M_L = F_{1x} \cdot r_L$$

$$M_L = 1000 \cdot 0.05 = 50 \text{ [Nm]}$$

$$\text{I)} \quad R_{Ax} = -F_{2x}$$

$$R_{Ax} = -800 \text{ [N]}$$

$$\begin{aligned} R_{Ax} &= -800 \text{ [N]} \\ R_{Ay} &= 264,1 \\ R_{Dy} &= -1013,4 \end{aligned}$$

$$\text{II)} \quad R_{Dy} = \frac{F_{1x} \cdot a - F_{2x} \cdot (a+b) - M_L}{a+b+c}$$

$$\begin{aligned} R_{Dy} &= \frac{1000 \cdot 0.06 - 1449,3 \cdot (0.06+0.05) - 80}{0.06 + 0.05 + 0.08} = \frac{60 - 192,92 - 80}{0.18} = \\ &= \frac{-182,92}{0.18} = -1013,4 \text{ [N]} \end{aligned}$$

$$\text{III)} \quad R_{Ay} = F_{1y} - F_{2y} - R_{Dy}$$

$$R_{Ay} = 1000 - 1449,3 - (-1013,4) = 264,1 \text{ [N]}$$

spe 7

$$\sum M_D = 0$$

=

$$R_{my} \cdot (a+b+c) - F_{rL} \cdot (b+c) + F_{r2} \cdot c - M_L = 0$$

$$264,1 \cdot (0,06 + 0,05 + 0,04) - 1000 \cdot (0,05 + 0,04) + 1448,3 \cdot 0,04 - 80 = 0$$

$$264,1 \cdot 0,18 - 1000 \cdot 0,12 + 1448,3 \cdot 0,04 - 80 = 0$$

$$44,53 - 120 + 122,45 - 80 = 0$$

$$50 - 50 = 0$$

$$L = P$$

$$\begin{cases} R_{ax} = -800 \text{ [N]} \\ R_{my} = 264,1 \\ R_{ay} = -1013,4 \end{cases}$$

2) продолжить.

1)  $0 \leq x_1 < a = 0,06 \text{ km}$

$$M_3(x_1) = k_{ny} \cdot x_1 = 264,1 x_1 \quad (\text{Nmm})$$

$$M_3(0) = 0$$

$$M_3(0,06) = 15,84$$

II)  $0,06 \leq x_2 < 0,11$

$$\begin{aligned} M_3(x_2) &= M_3^I - F_{I,2}(x_2 - a) - M_1 = \\ &= 264,1 x_2 - 1000(x_2 - 0,06) - 50 = \\ &= 264,1 x_2 - 1000 x_2 + 60 - 50 = \\ &= -735,9 x_2 + 10 \end{aligned}$$

$$M_3(0,06) = -39,15$$

$$M_3(0,11) = -49,94$$

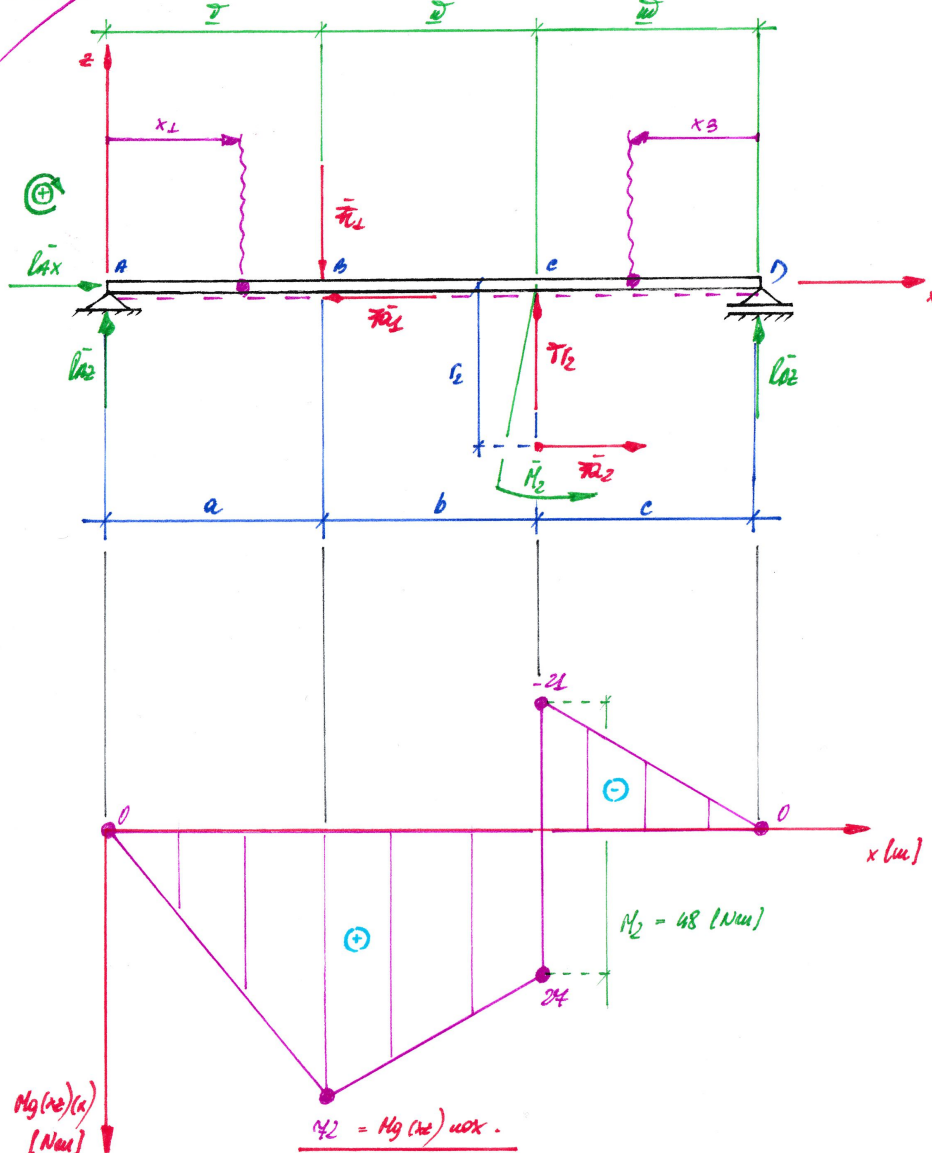
III)  $0 \leq x_3 < c = 0,04 \text{ km}$

$$M_3(x_3) = k_{ny} \cdot x_3 = -1013,4 x_3$$

$$M_3(0) = 0$$

$$M_3(0,04) = -40,54$$

95x2



1) REACTS.

$$\begin{aligned} \text{I)} \quad & \sum F_{ix} = 0 \\ \text{II)} \quad & \sum F_{iz} = 0 \\ \text{III)} \quad & \sum M_{iA} = 0 \end{aligned} \quad \rightarrow \quad \begin{aligned} \text{I)} \quad & R_{Ax} - F_{1x} = 0 \\ \text{II)} \quad & R_{Az} - F_{1z} + F_{2z} + R_{Dz} = 0 \\ \text{III)} \quad & F_{1z} \cdot a - F_{2z} \cdot (a+b) - R_{Dz} \cdot (a+b+c) - M_2 = 0 \end{aligned}$$

$$M_2 = F_{2z} \cdot r_2$$

$$M_2 = 800 \cdot 0,06 = 48 \text{ [Nm]}$$

$$\begin{aligned} \text{I)} \quad & R_{Ax} = F_{1x} \\ & R_{Ax} = 1000 \text{ [N]} \end{aligned} \quad \rightarrow \quad \begin{aligned} R_{Ax} &= 1000 \text{ [N]} \\ R_{Az} &= 1200 \\ R_{Dz} &= -300 \end{aligned}$$

$$\begin{aligned} \text{II)} \quad & R_{Dz} = \frac{F_{1z} \cdot a - F_{2z} \cdot (a+b) - M_2}{a+b+c} \\ & R_{Dz} = \frac{2100 \cdot 0,06 - 1200 \cdot (0,06+0,05) - 48}{0,06 + 0,05 + 0,04} = \frac{126 - 132 - 48}{0,18} \\ & = \frac{-54}{0,18} = -300 \text{ [N]} \end{aligned}$$

$$\begin{aligned} \text{II)} \quad & R_{Az} = F_{1z} - F_{2z} - R_{Dz} \\ & R_{Az} = 2100 - 1200 - (-300) = 1200 \text{ [N]} \end{aligned}$$

SPE

$$\sum M_D = 0$$

$$R_{A2} \cdot (a + b + c) - F_{D1} \cdot (b + c) + F_{D2} \cdot c - M_2 = 0$$

$$1200 \cdot (0,06 + 0,05 + 0,04) - 2100 \cdot (0,05 + 0,04) + 1200 \cdot 0,04 - 48 = 0$$

$$1200 \cdot 0,18 - 2100 \cdot 0,12 + 1200 \cdot 0,04 - 48 = 0$$

$$216 - 252 + 84 - 48 = 0$$

$$48 - 48 = 0$$

$$L = P$$

$$\Rightarrow \begin{cases} R_{Ax} = 1000 \text{ [N]} \\ R_{A2} = 1200 \\ R_{D2} = -300 \end{cases}$$

2) РЕЗЮМЕНТ.

1)  $0 \leq x_1 < a - 0,06 \text{ м}$

$$M_3(x_1) = R_{A2} \cdot x_1 = 1200 x_1 \quad [\text{Nm}]$$

$$M_3(0) = 0$$

$$M_3(0,06) = 72$$

4)  $0,06 \leq x_2 < 0,11$

$$\begin{aligned} M_3(x_2) &= M_3^I - F_{E1} \cdot (x_2 - a) = \\ &= 1200 x_2 - 2100 \cdot (x_2 - 0,06) = \\ &= 1200 x_2 - 2100 x_2 + 126 = \\ &= -900 x_2 + 126 \end{aligned}$$

$$M_3(0,06) = 72$$

$$M_3(0,11) = 24$$

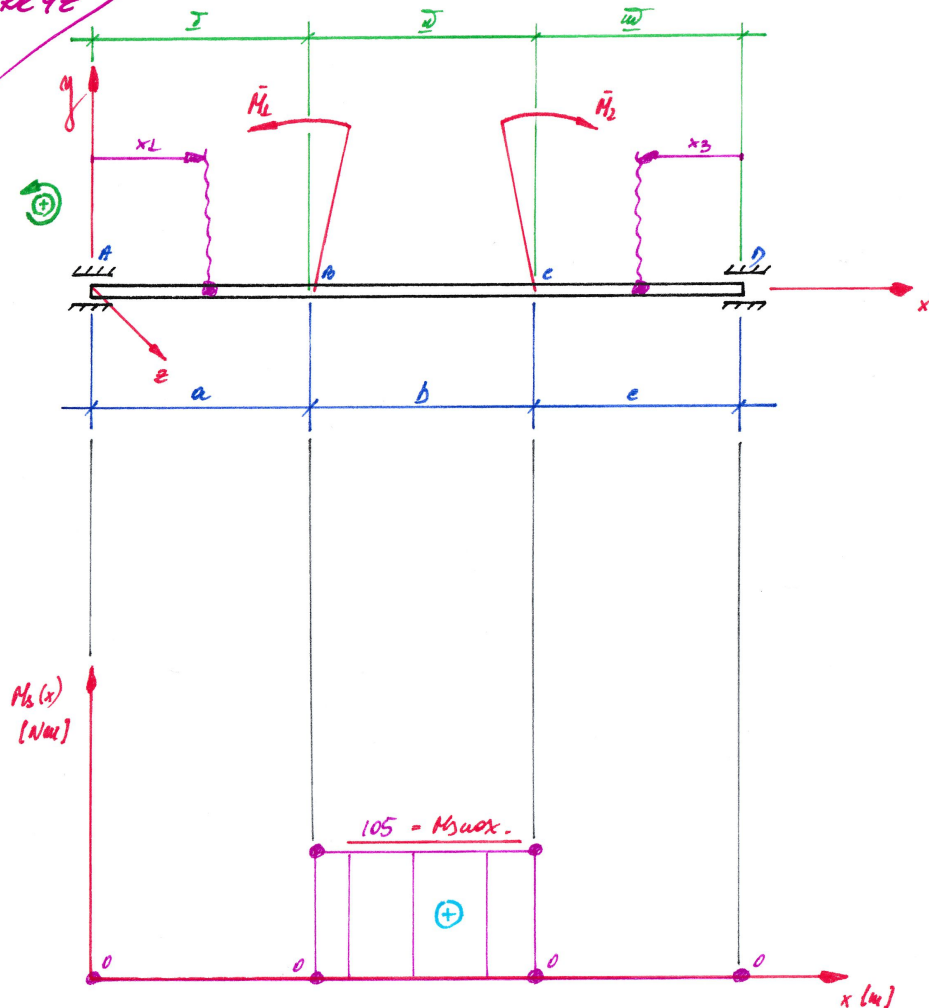
III)  $0 \leq x_3 < c - 0,04 \text{ м}$

$$M_3(x_3) = R_{D2} \cdot x_3 = -300 x_3$$

$$M_3(0) = 0$$

$$M_3(0,04) = -12$$

3x242



↓ ПОЗВЯЗКА.

I)  $0 \leq x_1 < a = 0.06 \text{ м}$

$$M_3(x_1) = 0 \quad [N \cdot m]$$

$$M_3(0) = 0$$

$$M_3(0.06) = 0$$

II)  $0.06 \leq x_2 < 0.11$

$$M_3(x_2) = M_3^I + M_1 = 0 + 105 = 105$$

$$M_3(0.06) = 105$$

$$M_3(0.11) = 105$$

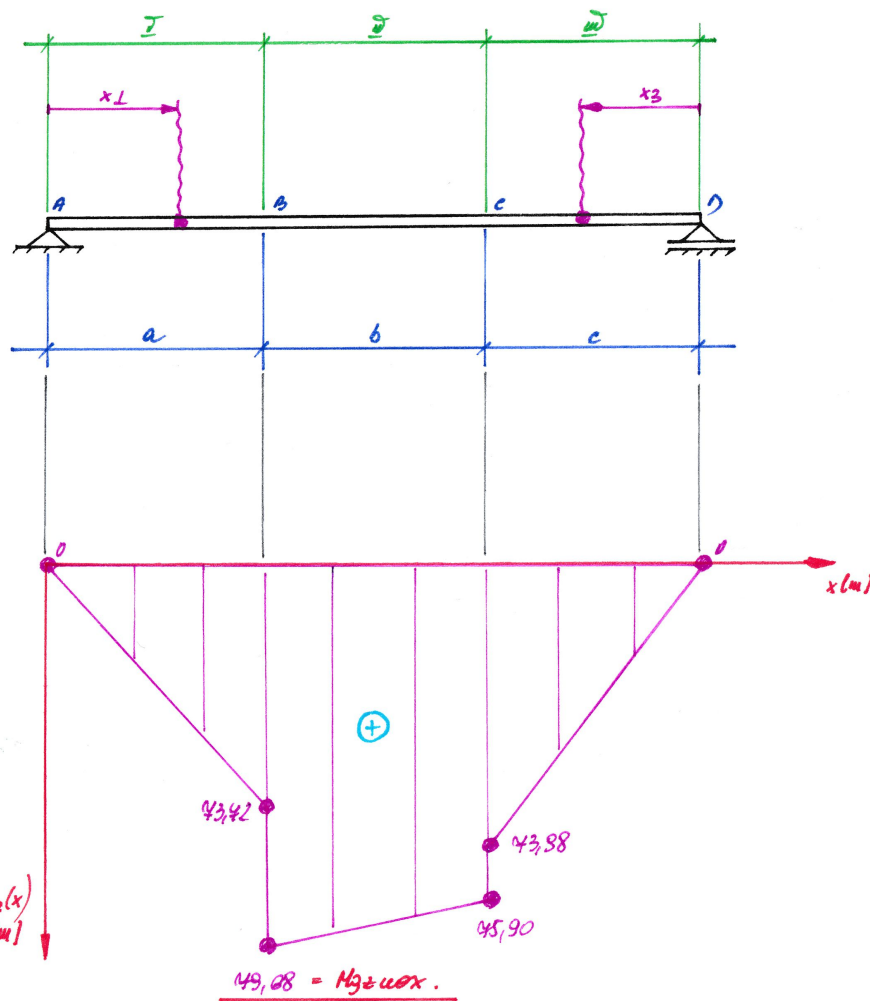
III)  $0 \leq x_3 < c - 0.04 \text{ м}$

$$M_3(x_3) = 0$$

$$M_3(0) = 0$$

$$M_3(0.04) = 0$$

$M_{g2}$



$$M_{g2max} = 49,08 \text{ [Nm]}$$

$$M_{smax} = 105$$

$$M_{smax} > M_{g2max}$$

1) PRELIMINARY

$$M_{g2} = M_{g1}(x_1) + M_{g2}(x_2)$$

$$M_{g2} = \sqrt{M_{g1}^2(x_1) + M_{g2}^2(x_2)}$$

$$1) \ 0 \leq x_1 < a = 0,06 \text{ [m]}$$

$$M_{g2}(0) = \sqrt{(0)^2 + (0)^2} = 0 \text{ [Nm]}$$

$$M_{g2}(0,06) = \sqrt{(15,84)^2 + (42)^2} = 43,42$$

$$II) \ 0,06 \leq x_2 < 0,11$$

$$M_{g2}(0,06) = \sqrt{(-39,15)^2 + (42)^2} = 49,08$$

$$M_{g2}(0,11) = \sqrt{(-40,84)^2 + (24)^2} = 45,90$$

$$III) \ 0 \leq x_3 < c = 0,04 \text{ [m]}$$

$$M_{g2}(0) = \sqrt{(0)^2 + (0)^2} = 0$$

$$M_{g2}(0,04) = \sqrt{(-40,94)^2 + (-21)^2} = 43,98$$

-10-



M<sub>2</sub>

$$M_{2\max} = 49,88 \text{ [Nm]}$$

$$M_{3\max} = 105$$

=>

$$M_3 > M_{2\max}$$

$$M_2 = \sqrt{\left(\frac{2}{\alpha} \cdot M_{2\max}\right)^2 + M_3^2}$$

$$\alpha = \frac{k_{90}}{k_{3j}}$$

$$\alpha = \frac{100 \cdot 10^6}{120 \cdot 10^6} = 0,83$$

↓ przetwarz.

I)  $0 \leq x_1 < a = 0,06 \text{ [m]}$

$$M_2(0) = \sqrt{\left(\frac{2}{0,83} \cdot 0\right)^2 + (0)^2} = 0 \text{ [Nm]}$$

$$M_2(0,06) = \sqrt{\left(\frac{2}{0,83} \cdot 43,42\right)^2 + (0)^2} = 144,65$$

II)  $0,06 \leq x_2 < 0,11$

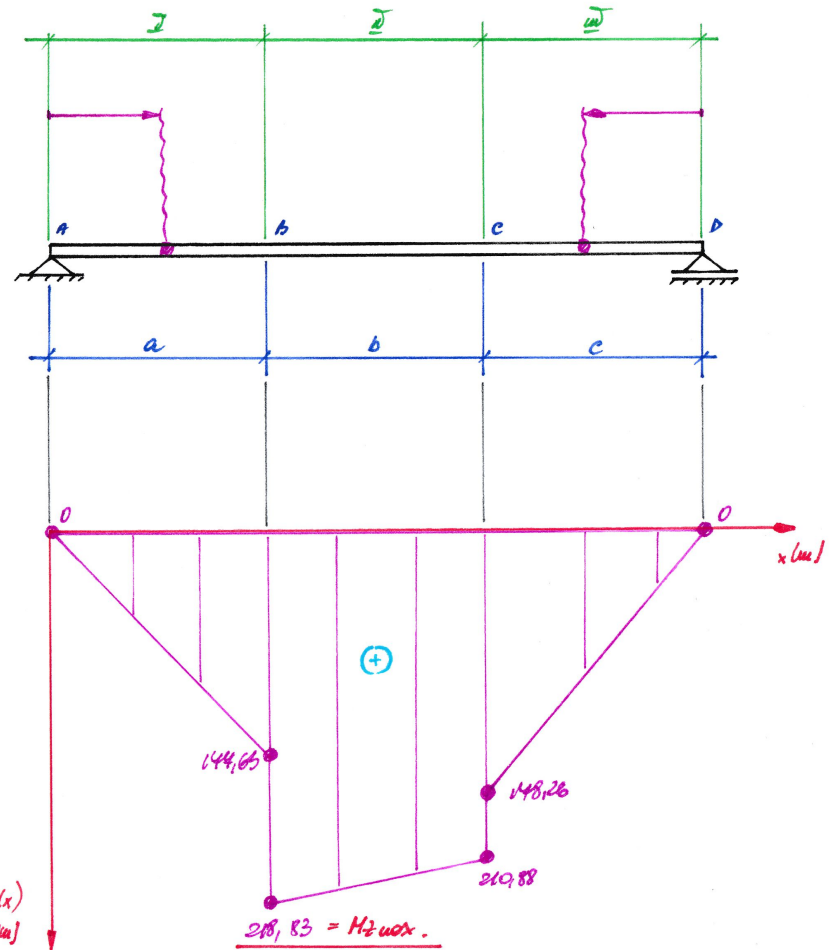
$$M_2(0,06) = \sqrt{\left(\frac{2}{0,83} \cdot 49,88\right)^2 + (105)^2} = 218,83$$

$$M_2(0,11) = \sqrt{\left(\frac{2}{0,83} \cdot 95,90\right)^2 + (105)^2} = 210,88$$

III)  $0 \leq x_3 < c = 0,04 \text{ [m]}$

$$M_2(0) = \sqrt{\left(\frac{2}{0,83} \cdot 0\right)^2 + (0)^2} = 0$$

$$M_2(0,04) = \sqrt{\left(\frac{2}{0,83} \cdot 43,88\right)^2 + (0)^2} = 148,26$$



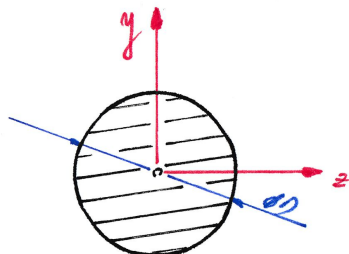
22

$$\sigma_2 = \frac{M_2}{W_2} \leq k_2$$

$$W_2 = \frac{I_2}{y_{max}}$$

$$I_2 = \frac{\pi D^4}{64}$$

$$y_{max} = \frac{1}{2} D$$



$$k_2 = k_{go}$$

$$\frac{M_2}{W_2} \leq k_2$$

$$\frac{\frac{M_2}{\frac{\pi D^4}{64}}}{\frac{1}{2} D} \leq k_2$$

$$\frac{32 M_2}{\pi D^3} \leq k_2$$

$$D \geq \sqrt[3]{\frac{32 M_2}{\sigma_2}}$$

$$D \geq \sqrt[3]{\frac{32 M_2}{\sigma_2}} = \sqrt[3]{\frac{32 M_2}{3,14 \cdot 100 \cdot 10^6}} =$$

$$= \sqrt[3]{\frac{32 M_2}{0,314} \cdot 10^{-9}} = \sqrt[3]{101,91 M_2 \cdot 10^{-9}} =$$

$$= 4,64 \cdot 10^{-3} \cdot \sqrt[3]{M_2} \quad [m] =$$

$$= 4,64 \cdot 10^{-3} \cdot \sqrt[3]{M_2} \cdot 10^3 \quad [mm] =$$

$$= 4,64 \cdot \sqrt[3]{M_2}$$

$$D \geq 4,64 \cdot \sqrt[3]{M_2}$$

$$I) \quad 0 \leq x_1 < a = 0,06 \text{ [m]}$$

$$D(0) = 4,64 \cdot \sqrt[3]{0} = 0 \quad [mm]$$

$$D(0,06) = 4,64 \cdot \sqrt[3]{144,63} = 26,25$$

$$II) \quad 0,06 \leq x_2 < 0,11$$

$$D(0,06) = 4,64 \cdot \sqrt[3]{218,83} = 28,14$$

$$D(0,11) = 4,64 \cdot \sqrt[3]{219,88} = 24,43$$

$$III) \quad 0 \leq x_3 < 0,04 \text{ [m]}$$

$$D(0) = 4,64 \cdot \sqrt[3]{0} = 0$$

$$D(0,04) = 4,64 \cdot \sqrt[3]{148,26} = 26,28$$

$$I) a) D(0) = 30 \quad [mm]$$

$$b) D(0,06) = 35$$

$$II) b) D(0,06) = 35$$

$$c) D(0,11) = 39$$

$$III) c) D(0,11) = 39$$

$$d) D(0,18) = 28$$

c)

$$P = x \cdot \sigma \cdot P_p + y \cdot P_w$$

$$\bar{P}_p = \bar{m}_y + \bar{m}_z$$

$$P_p = \sqrt{\bar{m}_y^2 + \bar{m}_z^2}$$

$$\Rightarrow \underline{P_p} = \sqrt{(264,4)^2 + (1200)^2} = 1228,41 \text{ [N]}$$

$$\bar{P}_w = \bar{m}_x + \bar{m}_z$$

$$P_w = \sqrt{\bar{m}_x^2 + \bar{m}_z^2}$$

$$\Rightarrow \underline{P_w} = \sqrt{(-1013,4)^2 + (-300)^2} = 1056,84 \text{ [N]}$$

$$\underline{P_w} = |\max|$$

$$\Rightarrow \underline{P_w} = |\max_1 + \max_2| = |-800 + 1000| = 200 \text{ [N]}$$

A)

$$\underline{P_A} = x \cdot \sigma \cdot P_p + y \cdot P_w$$

$$\begin{cases} \sigma = 1 \\ x = 1 \\ y = 0 \end{cases}$$

$$\Rightarrow \underline{P_A} = 1 \cdot 1 \cdot 1228,41 = 1228,41 \text{ [N]}$$

$$\underline{L_A} = \frac{60 \cdot n_3 \cdot L_A}{10^6} \quad [\text{ml/min}]$$

$$\begin{cases} n_3 = 500 \text{ [rpm/min]} \\ \underline{L_A} = 22000 \text{ [h]} \end{cases}$$

$$\Rightarrow \underline{L_A} = \frac{60 \cdot 500 \cdot 22000}{10^6} = \frac{660 \cdot 10^6}{10^6} = 660 \text{ [ml/min]}$$

$$\underline{C_A} = P_A \cdot (L_A)^{\frac{1}{k}}$$

$$\underline{k} = 3 \quad \Rightarrow \underline{C_A} = 1228,41 \cdot (660)^{\frac{1}{3}} = 10684,84 \text{ [N]} = 10,40 \text{ [kN]}$$

77

$$\underline{P_D = x \cdot v \cdot P_{PD} + y \cdot P_{ND}}$$

$$\begin{cases} v = 1 \\ x = 1 \\ y = 0 \end{cases}$$

$$\Rightarrow \underline{P_D} = 1 \cdot 1 \cdot 1066,84 = \underline{1066,84} \text{ [N]}$$

$$\underline{L_D} = \frac{60 \cdot 113 \cdot L_A}{106} \quad \text{[inkl. der]}$$

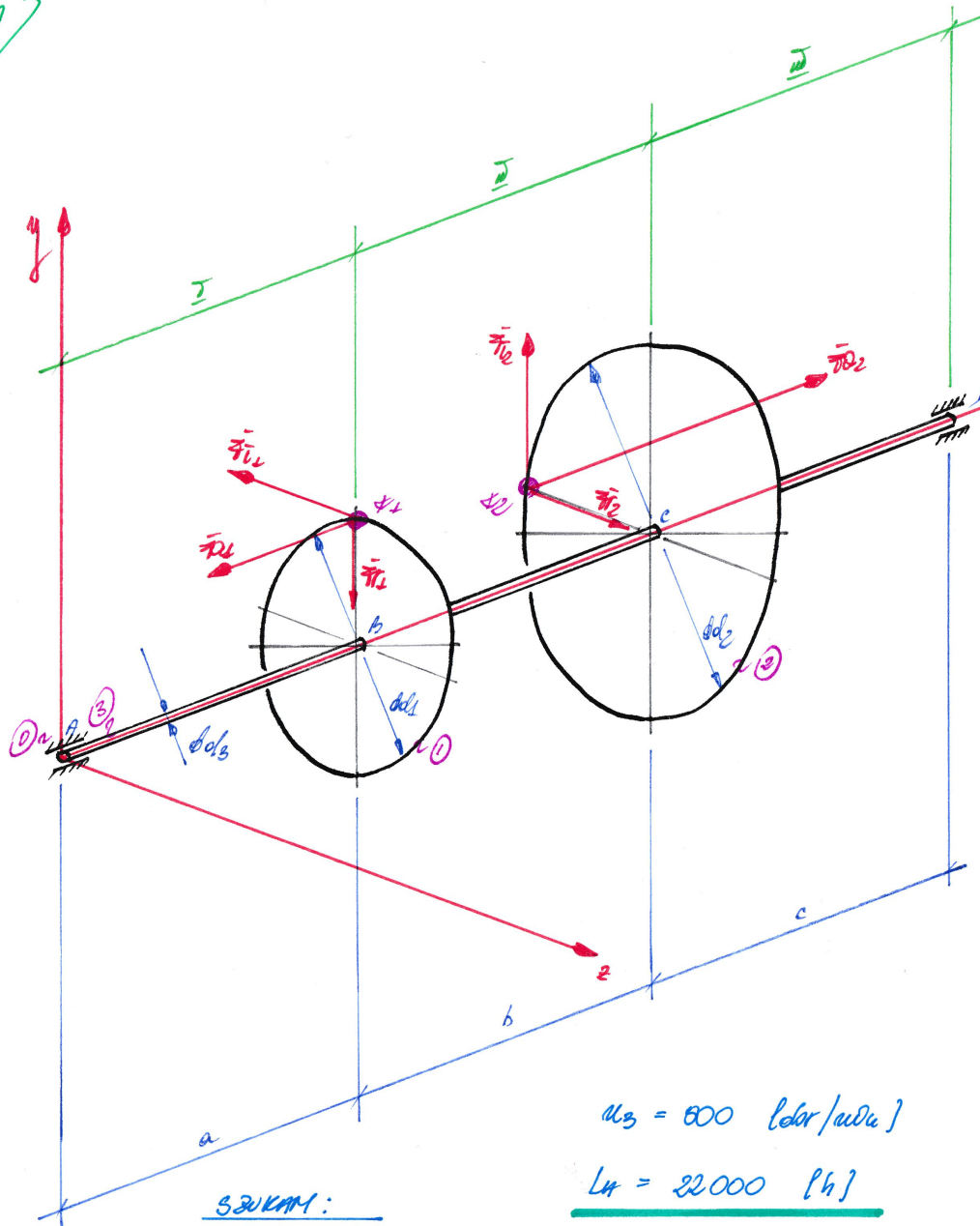
$$\Rightarrow \underline{L_D} = L_A = \underline{660} \quad \text{[inkl. der]}$$

$$\underline{C_D = P_D \cdot (L_D)^{\frac{3}{10}}}$$

$$\underline{k} = \frac{10}{3} \quad \Rightarrow \quad \underline{C_D} = 1066,84 \cdot (660)^{\frac{3}{10}} = 4411,13 \text{ [N]} = \underline{4,42} \text{ [kN]}$$

$$\Rightarrow \begin{cases} C_A = 12 \text{ [kN]} \\ C_D = 9 \end{cases}$$

9A7



DANE:

$$a = 40 \text{ (mm)} = 0,04 \text{ (m)}$$

$$l = \begin{cases} b = 80 \text{ (mm)} = 0,05 \text{ (m)} \\ c = 80 \text{ (mm)} = 0,05 \text{ (m)} \end{cases}$$

$$1) d_1 = 40 \text{ (mm)} = 0,04 \text{ (m)}$$

$$2) d_2 = 120 \text{ (mm)} = 0,12 \text{ (m)}$$

$$1) F_{t1} = 1900 \text{ (N)}$$

$$F_{r1} = 800$$

$$F_{t2} = 800$$

$$2) F_{t2} = ?$$

$$F_{r2} = 400$$

$$F_{t2} = 800$$

$$k_{g0} = 100 \text{ (MPa)} = 100 \cdot 10^6 \text{ (Pa)}$$

$$k_{sj} = 120 \text{ (MPa)} = 120 \cdot 10^6 \text{ (Pa)}$$

$$1) r_1 = \frac{1}{2} d_1 = \frac{1}{2} \cdot 40 = 20 \text{ (mm)} = 0,02 \text{ (m)}$$

$$2) r_2 = \frac{1}{2} d_2 = \frac{1}{2} \cdot 120 = 60 \text{ (mm)} = 0,06 \text{ (m)}$$

szukam:

$$d_3 = ?$$

$$n_3 = 800 \text{ (obr/min)}$$

$$L_4 = 22000 \text{ (h)}$$

$\vec{r}_2$

$\sum M_x = 0$

$=$

$$- \vec{F}_{i1} \cdot r_1 + \vec{F}_{i2} \cdot r_2 = 0$$

$$\vec{F}_{i1} \cdot r_1 = \vec{F}_{i2} \cdot r_2$$

$$\underline{\vec{F}_{i2}} = \underline{\frac{r_1}{r_2}} \underline{\vec{F}_{i1}}$$

$$\underline{\vec{F}_{i2}} = \frac{0,035}{0,06} \cdot 1900 = 0,583 \cdot 1900 = \underline{1108,33 \text{ [N]}}$$

$M_s$

$M_s = \vec{F} \cdot r$

$=$

$$M_{s1} = \vec{F}_{i1} \cdot r_1$$

$$\underline{M_{s1}} = 1900 \cdot 0,035 = \underline{66,5 \text{ [Nm]}}$$

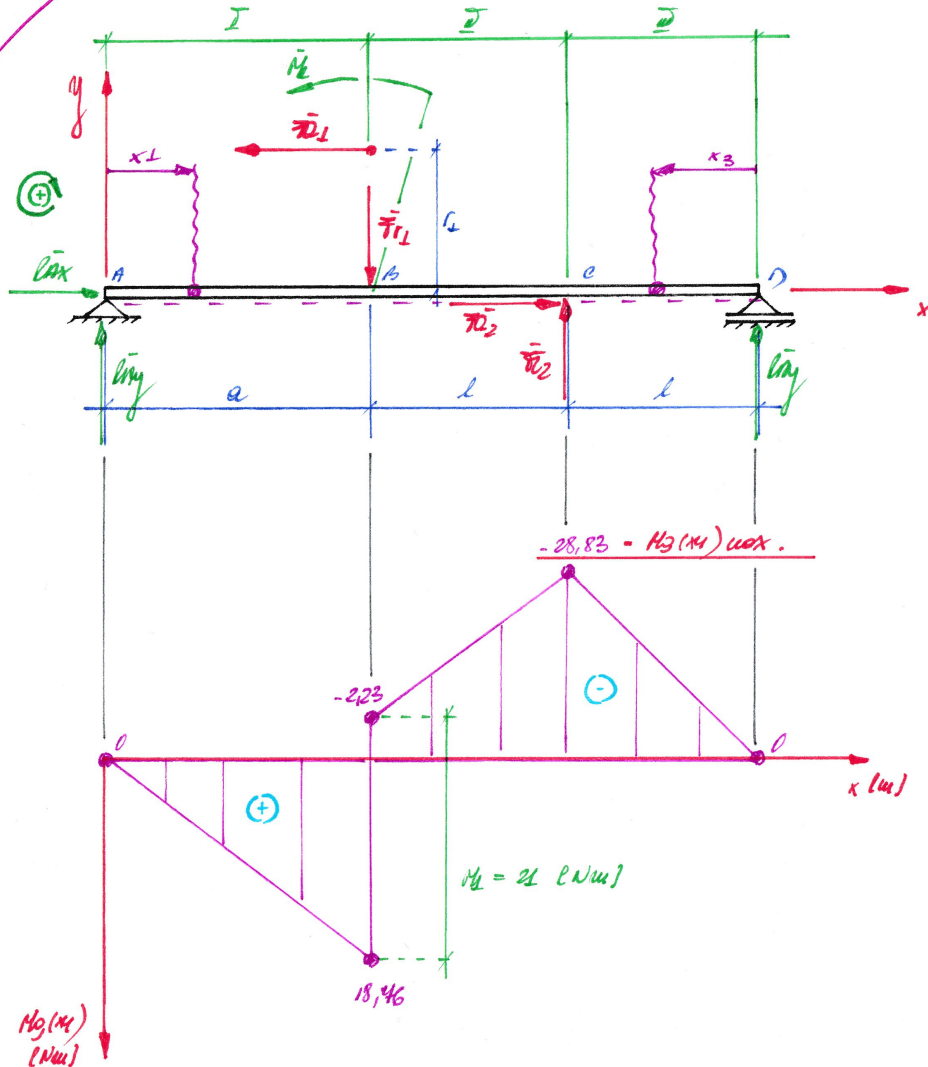
$$M_{s2} = \vec{F}_{i2} \cdot r_2$$

$$\underline{M_{s2}} = 1108,33 \cdot 0,06 = \underline{66,5 \text{ [Nm]}}$$

$$\underline{M_{s1}} = M_{s2} = M_{s3} = \underline{66,5 \text{ [Nm]}}$$



28.11



1) Решение.

$$\begin{aligned} 1) \quad & \sum \bar{F}_{ix} = 0 \\ 2) \quad & \sum \bar{F}_{iy} = 0 \\ 3) \quad & \sum \bar{M}_i = 0 \end{aligned} \quad \Rightarrow \quad \begin{aligned} 1) \quad & R_{Ax} + F_{Q2} = 0 \\ 2) \quad & R_{Ay} - F_{F1} + F_{F2} + R_{By} = 0 \\ 3) \quad & F_{F1} \cdot a - F_{F2} \cdot (a + l) - R_{By} \cdot (a + 2l) - M_1 = 0 \end{aligned}$$

$$M_1 = F_{Q2} \cdot r_{\perp}$$

$$M_1 = 600 \cdot 0,035 = 21 \text{ (Nm)}$$

$$\begin{aligned} 1) \quad & R_{Ax} = -F_{Q2} \\ & R_{Ax} = -600 \text{ (N)} \end{aligned} \quad \Rightarrow \quad \begin{aligned} R_{Ax} &= -600 \text{ (N)} \\ R_{Ay} &= 288,08 \\ R_{By} &= -546,41 \end{aligned}$$

$$\begin{aligned} 2) \quad & R_{By} = \frac{F_{F1} \cdot a - F_{F2} \cdot (a + l) - M_1}{a + 2l} \\ & R_{By} = \frac{1800 \cdot 0,04 - 1108,33 \cdot (0,04 + 0,05) - 21}{0,04 + 2 \cdot 0,05} = \frac{56 - 132,55 - 21}{0,14} = \\ & = \frac{-97,55}{0,14} = -696,41 \text{ (N)} \end{aligned}$$

$$\begin{aligned} 3) \quad & R_{Ay} = F_{F1} - F_{F2} - R_{By} \\ & R_{Ay} = 800 - 1108,33 - (-696,41) = 288,08 \text{ (N)} \end{aligned}$$

90%

$$\sum M_D = 0$$

~~100%~~

$$R_{Ay} \cdot (a + 2L) - F_{T1} \cdot 2L + F_{T2} \cdot L - M_L = 0$$

$$268,08 \cdot (0,04 + 2 \cdot 0,05) - 800 \cdot 2 \cdot 0,05 + 1108,53 \cdot 0,05 - 21 = 0$$

$$45,64 - 80 + 55,41 - 21 = 0$$

$$21 - 21 = 0$$

$$L = P$$

$$\begin{cases} R_{Ax} = - 800 \text{ [N]} \\ R_{Ay} = 268,08 \\ R_{By} = - 546,41 \end{cases}$$



2) продолжить.

1)  $0 \leq x_1 < a = 0.04 \text{ км}$

$$M_2(x_1) = \text{вы} \cdot x_1 = 268,08 x_1 \quad [\text{Нм}]$$

$$M_2(0) = 0$$

$$M_2(0.04) = 10,76$$

II)  $0.04 \leq x_2 < 0.12$

$$\begin{aligned} M_2(x_2) &= M_2^I - F_{r1}(x_2 - a) - M_1 = \\ &= 268,08 x_2 - 800(x_2 - 0.04) - 21 = \\ &= 268,08 x_2 - 800 x_2 + 66 - 21 = \\ &= -531,92 x_2 + 35 \end{aligned}$$

$$M_2(0.04) = -2,23$$

$$M_2(0.12) = -28,83$$

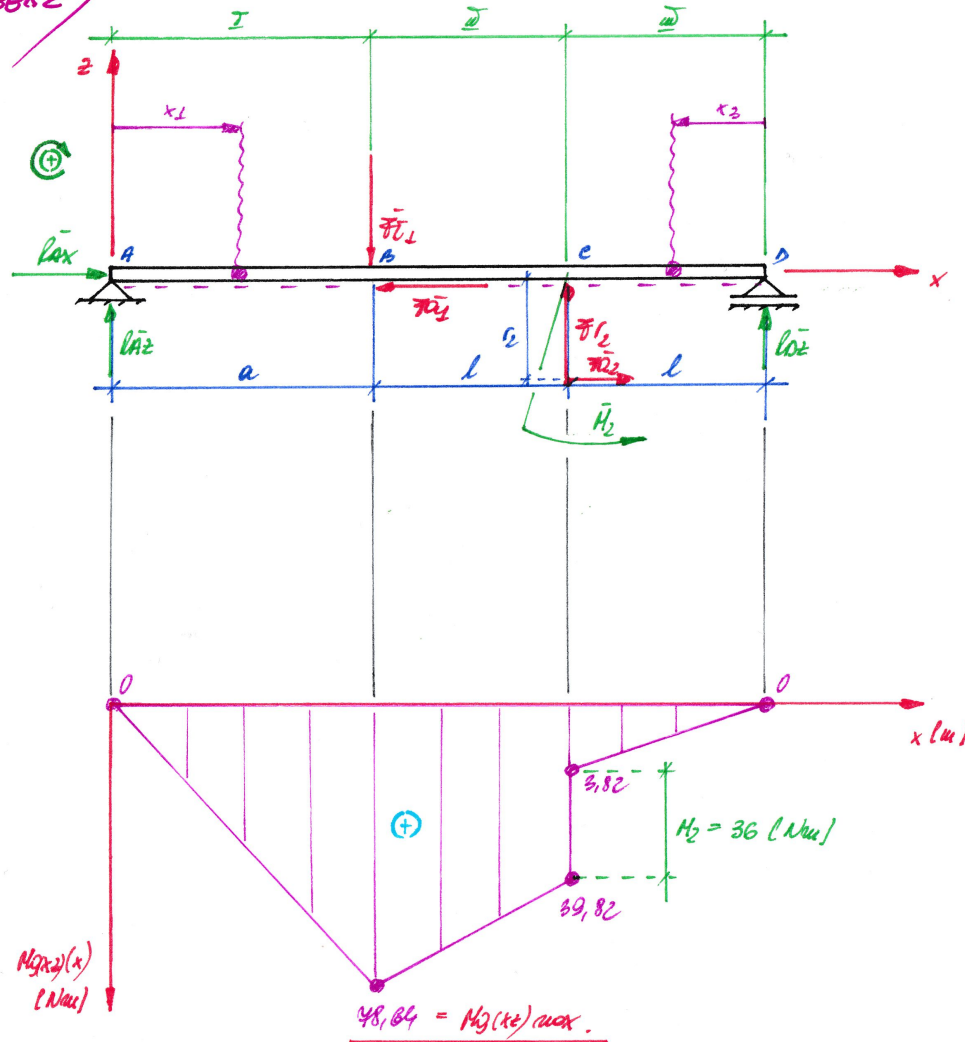
III)  $0 \leq x_3 < l - 0.05 \text{ км}$

$$M_2(x_3) = \text{вы} \cdot x_3 = -546,41 x_3$$

$$M_2(0) = 0$$

$$M_2(0.05) = -28,83$$

26x2



1) REACTIONS

$$\begin{aligned} 1) \quad \sum \vec{F}_{ix} = 0 & \quad 1) \quad R_{Ax} - F_{C1} = 0 \\ 2) \quad \sum \vec{F}_{iz} = 0 & \quad 2) \quad R_{Az} - F_{B1} + F_{C2} + R_{Dz} = 0 \\ 3) \quad \sum M_{iA} = 0 & \quad 3) \quad F_{B1} \cdot a - F_{C2} \cdot (a+l) - R_{Dz} \cdot (a+2l) - M_2 = 0 \end{aligned}$$

$$M_2 = F_{C2} \cdot l_2$$

$$M_2 = 600 \cdot 0.06 = 36 \text{ [Nm]}$$

$$\begin{aligned} 1) \quad R_{Ax} = F_{C1} & \quad \Rightarrow \quad \begin{cases} R_{Ax} = 600 \text{ [N]} \\ R_{Az} = 1123.53 \\ R_{Dz} = 96.44 \end{cases} \\ R_{Ax} = 600 \text{ [N]} & \end{aligned}$$

$$R_{Dz} = \frac{F_{B1} \cdot a - F_{C2} \cdot (a+l) - M_2}{a + 2l}$$

$$\begin{aligned} R_{Dz} &= \frac{1900 \cdot 0.04 - 400(0.04+0.05) - 36}{0.04 + 2 \cdot 0.05} = \frac{133 - 84 - 36}{0.14} = \\ &= \frac{13}{0.14} = 96.44 \text{ [N]} \end{aligned}$$

$$\begin{aligned} 1) \quad R_{Az} &= F_{B1} - F_{C2} - R_{Dz} \\ R_{Az} &= 1900 - 400 - 96.44 = 1123.53 \text{ [N]} \end{aligned}$$

408

$$\sum M_D = 0$$

$$R_{A2} \cdot (a + 2l) - F_{11} \cdot 2l + F_{12} \cdot l - M_2 = 0$$

$$1123,53 \cdot (0,04 + 2 \cdot 0,05) - 1900 \cdot 2 \cdot 0,05 + 700 \cdot 0,05 - 36 = 0$$

$$1123,53 \cdot 0,14 - 190 + 35 - 36 = 0$$

$$191 - 190 + 35 - 36 = 0$$

$$36 - 36 = 0$$

$$L = P$$

$$\Rightarrow \begin{cases} R_{Ax} = 600 \text{ [N]} \\ R_{A2} = 1123,53 \\ R_{A3} = 146,44 \end{cases}$$

c) PROBENZUG

i)  $0 \leq x_1 < a = 0,04 \text{ (m)}$

$$M_3(x_1) = R_{A2} \cdot x_1 = 1123,53 x_1 \quad [\text{Nm}]$$

$$M_3(0) = 0$$

$$M_3(0,04) = 48,64$$

ii)  $0,04 \leq x_2 < 0,12$

$$\begin{aligned} M_3(x_2) &= M_3^I - F_{G1} \cdot (x_2 - a) = \\ &= 1123,53 x_2 - 1900 (x_2 - 0,04) = \\ &= 1123,53 x_2 - 1900 x_2 + 133 = \\ &= -776,47 x_2 + 133 \end{aligned}$$

$$M_3(0,04) = 48,64$$

$$M_3(0,12) = 39,82$$

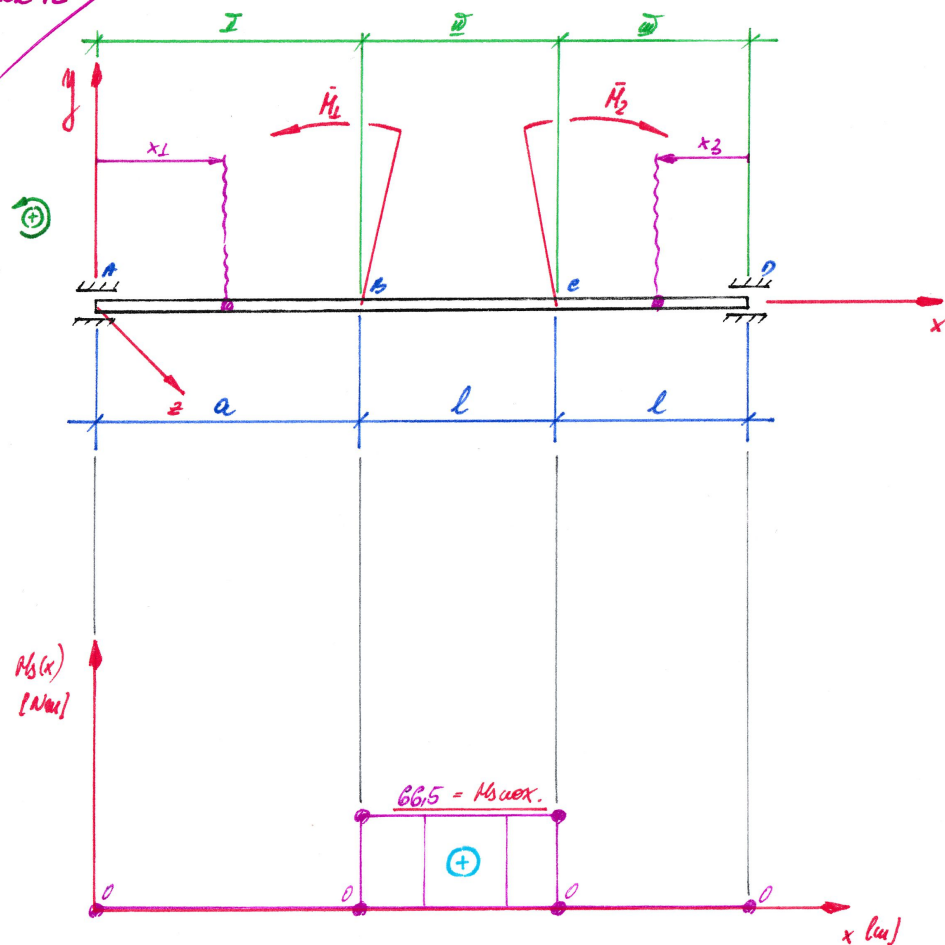
iii)  $0 \leq x_3 < l = 0,05 \text{ (m)}$

$$M_3(x_3) = R_{D2} \cdot x_3 = 746,44 x_3$$

$$M_3(0) = 0$$

$$M_3(0,05) = 3,82$$

3K242



1) PROBLEM 4.

i)  $0 \leq x_1 < a = 0.04 \text{ m}$

$M_3(x_1) = 0$  [Nm]

$M_3(0) = 0$

$M_3(0.04) = 0$

ii)  $0.04 \leq x_2 < 0.12$

$M_3(x_2) = M_3^I + M_L = 0 + 66.5 = 66.5$

$M_3(0.04) = 66.5$

$M_3(0.12) = 66.5$

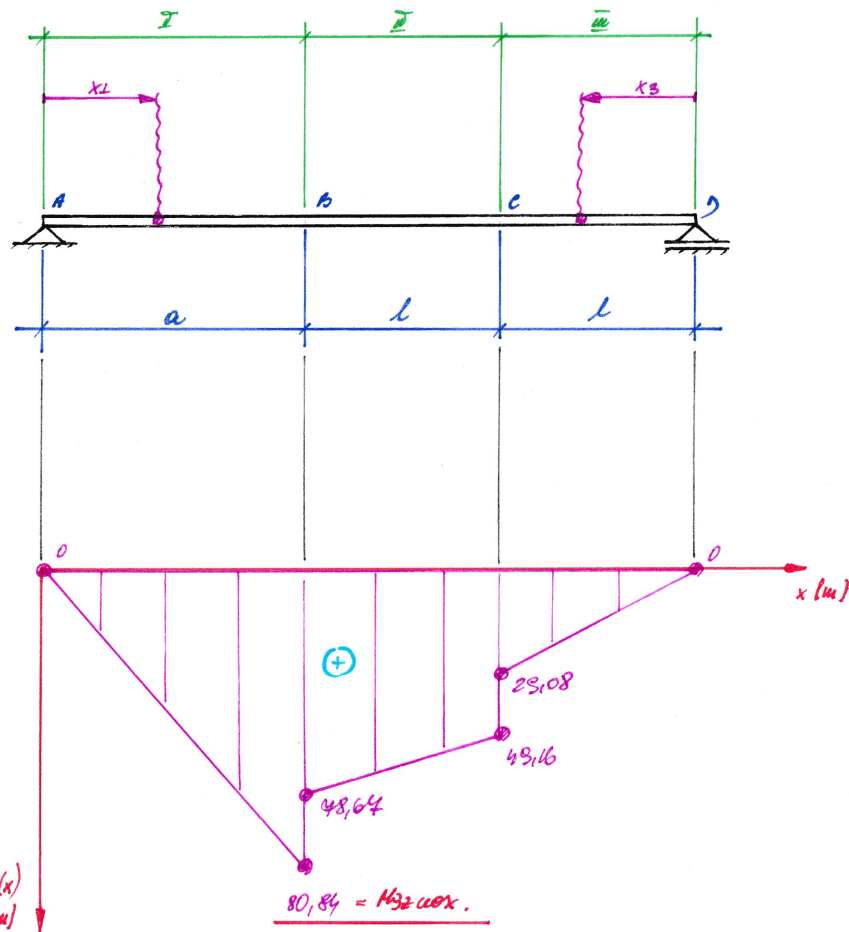
iii)  $0 \leq x_3 < l - 0.05 \text{ m}$

$M_3(x_3) = 0$

$M_3(0) = 0$

$M_3(0.05) = 0$

$M_{32}$



$$M_{32\max} = 80.84 \text{ [Nm]}$$

$$M_{3\max} = 66.5$$

$$M_{32} > M_3$$

1) РЕЗЕРВИРОВАНИЕ

$$M_{32} = M_3(x_1) + M_3(x_2)$$

$$M_{32} = \sqrt{M_3^2(x_1) + M_3^2(x_2)}$$

1)  $0 \leq x_1 < a = 0.04 \text{ [m]}$

$$M_{32}(0) = \sqrt{(0)^2 + (0)^2} = 0 \text{ [Nm]}$$

$$M_{32}(0.04) = \sqrt{(18.48)^2 + (48.64)^2} = 80.84$$

1)  $0.04 \leq x_2 < 0.12$

$$M_{32}(0.04) = \sqrt{(-2.23)^2 + (48.64)^2} = 48.64$$

$$M_{32}(0.12) = \sqrt{(-28.83)^2 + (38.82)^2} = 49.16$$

1)  $0 \leq x_3 < l = 0.05 \text{ [m]}$

$$M_{32}(0) = \sqrt{(0)^2 + (0)^2} = 0$$

$$M_{32}(0.05) = \sqrt{(-28.83)^2 + (3.82)^2} = 29.08$$

$M_2$

$$\begin{cases} M_{2\text{max}} = 80,84 \text{ [Nm]} \\ M_{2\text{min}} = 66,5 \end{cases}$$

$$\Rightarrow M_{2\text{max}} > M_2$$

$$M_2 = \sqrt{(M_{2\text{max}})^2 + \left(\frac{1}{2} \alpha M_2\right)^2} ; \quad \alpha = \frac{100}{120}$$

$$\alpha = \frac{100 \cdot 10^6}{120 \cdot 10^6} = 0,83$$

↓) продолжение.

I)  $0 \leq x_1 < 0,04 \text{ [m]}$

$$M_2(0) = \sqrt{(0)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 0\right)^2} = 0 \text{ [Nm]}$$

$$M_2(0,04) = \sqrt{(80,84)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 0\right)^2} = 80,84$$

II)  $0,04 \leq x_2 < 0,12$

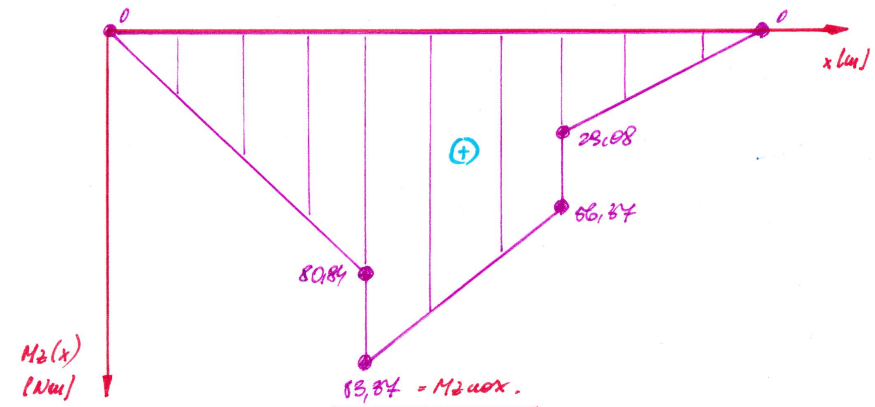
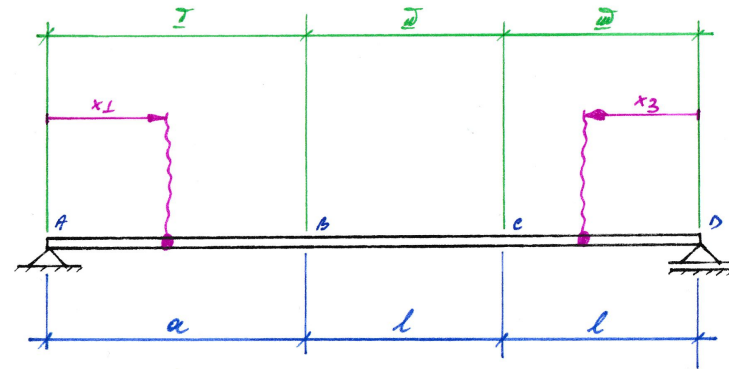
$$M_2(0,04) = \sqrt{(48,64)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 66,5\right)^2} = 83,34$$

$$M_2(0,12) = \sqrt{(49,16)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 66,5\right)^2} = 56,84$$

III)  $0 \leq x_3 < l - 0,05 \text{ [m]}$

$$M_2(0) = \sqrt{(0)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 0\right)^2} = 0$$

$$M_2(0,05) = \sqrt{(29,08)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 0\right)^2} = 29,08$$



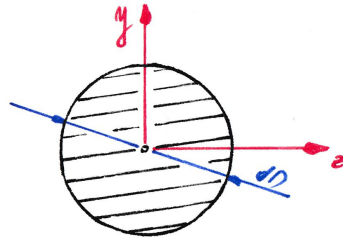


77

$$\sigma_2 = \frac{M_2}{W_2} \leq \sigma_{\text{доп}}$$

$$W_2 = \frac{I_2}{y_{\text{доп}}}$$

$$\begin{cases} I_2 = \frac{\pi D^4}{64} \\ y_{\text{доп}} = \frac{1}{2} D \end{cases}$$



$$\frac{M_2}{W_2} \leq \sigma_{\text{доп}}$$

$$\frac{\frac{M_2}{\frac{\pi D^4}{64}}}{\frac{1}{2} D} \leq \sigma_{\text{доп}}$$

$$\frac{32 M_2}{\pi D^3} \leq \sigma_{\text{доп}}$$

$$D \geq \sqrt[3]{\frac{32 M_2}{\sigma_{\text{доп}}}}$$

$$\begin{aligned} D &\geq \sqrt[3]{\frac{32 M_2}{\sigma_{\text{доп}}}} = \sqrt[3]{\frac{32 M_2}{3,14 \cdot 100 \cdot 10^6}} = \\ &= \sqrt[3]{\frac{32 M_2}{0,314} \cdot 10^{-9}} = \sqrt[3]{101,91 M_2 \cdot 10^{-9}} = \\ &= 4,64 \cdot 10^{-3} \cdot \sqrt[3]{M_2} \text{ [m]} = \\ &= 4,64 \cdot 10^{-3} \cdot \sqrt[3]{M_2} \cdot 10^3 \text{ [mm]} = \\ &= 4,64 \cdot \sqrt[3]{M_2} \end{aligned}$$

$$D \geq 4,64 \cdot \sqrt[3]{M_2}$$

1)  $0 \leq x_1 < a = 0,04 \text{ m}$

$$D(0) = 4,64 \cdot \sqrt[3]{0} = 0 \text{ [mm]}$$

$$D(0,04) = 4,64 \cdot \sqrt[3]{80,84} = 20,19$$

2)  $0,04 \leq x_2 < 0,12$

$$D(0,04) = 4,64 \cdot \sqrt[3]{83,34} = 20,40$$

$$D(0,12) = 4,64 \cdot \sqrt[3]{86,84} = 14,90$$

3)  $0 \leq x_3 < l = 0,05 \text{ m}$

$$D(0) = 4,64 \cdot \sqrt[3]{0} = 0$$

$$D(0,05) = 4,64 \cdot \sqrt[3]{28,08} = 14,36$$

1)

$$D(0) = 23 \text{ [mm]}$$

$$D(0,04) = 28$$

2)

$$D(0,04) = 28$$

$$D(0,12) = 26$$

3)

$$D(0,12) = 26$$

$$D(0,14) = 23$$



c)

$$P = x \cdot \sigma \cdot P_p + 4 \cdot P_w$$

$$\bar{P}_p = \bar{k} \bar{v}_y + \bar{k} \bar{v}_z$$

$$\bar{P}_p = \sqrt{\bar{k} v_y^2 + \bar{k} v_z^2}$$

$$\Rightarrow \bar{P}_p = \sqrt{(268,08)^2 + (1123,53)^2} = 1155,06 \text{ [N]}$$

$$\bar{P}_p = \bar{k} \bar{v}_y + \bar{k} \bar{v}_z$$

$$\bar{P}_p = \sqrt{\bar{k} v_y^2 + \bar{k} v_z^2}$$

$$\Rightarrow \bar{P}_p = \sqrt{(-646,41)^2 + (96,44)^2} = 681,46 \text{ [N]}$$

$$P_w = |R_{Ax}|$$

$$\Rightarrow \bar{P}_w = |R_{Ax1} + R_{Ax2}| = |-600 + 600| = 0 \text{ [N]}$$

d)

$$P_A = x \cdot \sigma \cdot P_p + 4 \cdot P_w$$

$$\begin{cases} \sigma = 1 \\ x = 1 \\ y = 0 \end{cases}$$

$$\Rightarrow \bar{P}_A = 1 \cdot 1 \cdot 1155,06 = 1155,06 \text{ [N]}$$

$$\bar{L}_A = \frac{60 \cdot u_3 \cdot L_A}{10^6} \quad \text{[Nucke abr]}$$

$$\begin{cases} u_3 = 800 \text{ [abr/min]} \\ L_A = 22000 \text{ [h]} \end{cases}$$

$$\Rightarrow \bar{L}_A = \frac{60 \cdot 800 \cdot 22000}{10^6} = \frac{660 \cdot 10^6}{10^6} = 660 \text{ [Nucke abr]}$$

$$\bar{L}_A = \bar{P}_A \cdot (\bar{L}_A)^{\frac{1}{k}}$$

$$\begin{aligned} k = 3 \quad \Rightarrow \quad \bar{L}_A &= 1155,06 \cdot (660)^{\frac{1}{3}} = 10086,83 \text{ [N]} = \\ &= 10,1 \text{ [kN]} \end{aligned}$$

22

$$\underline{P_D = x \cdot \vartheta \cdot P_{D0} + 4 \cdot P_{ND}}$$

$$\begin{cases} \vartheta = 1 \\ x = 1 \\ \underline{4} = \underline{0} \end{cases}$$

$$\Rightarrow \underline{P_D} = 1 \cdot 1 \cdot 581,46 = \underline{581,46} \text{ [N]}$$

$$\underline{l_D} = \frac{60 \cdot 113 \cdot l_A}{10^6} \quad \text{[mln dbr]}$$

$$\Rightarrow \underline{l_D} = l_A = \underline{660} \quad \text{[mln dbr]}$$

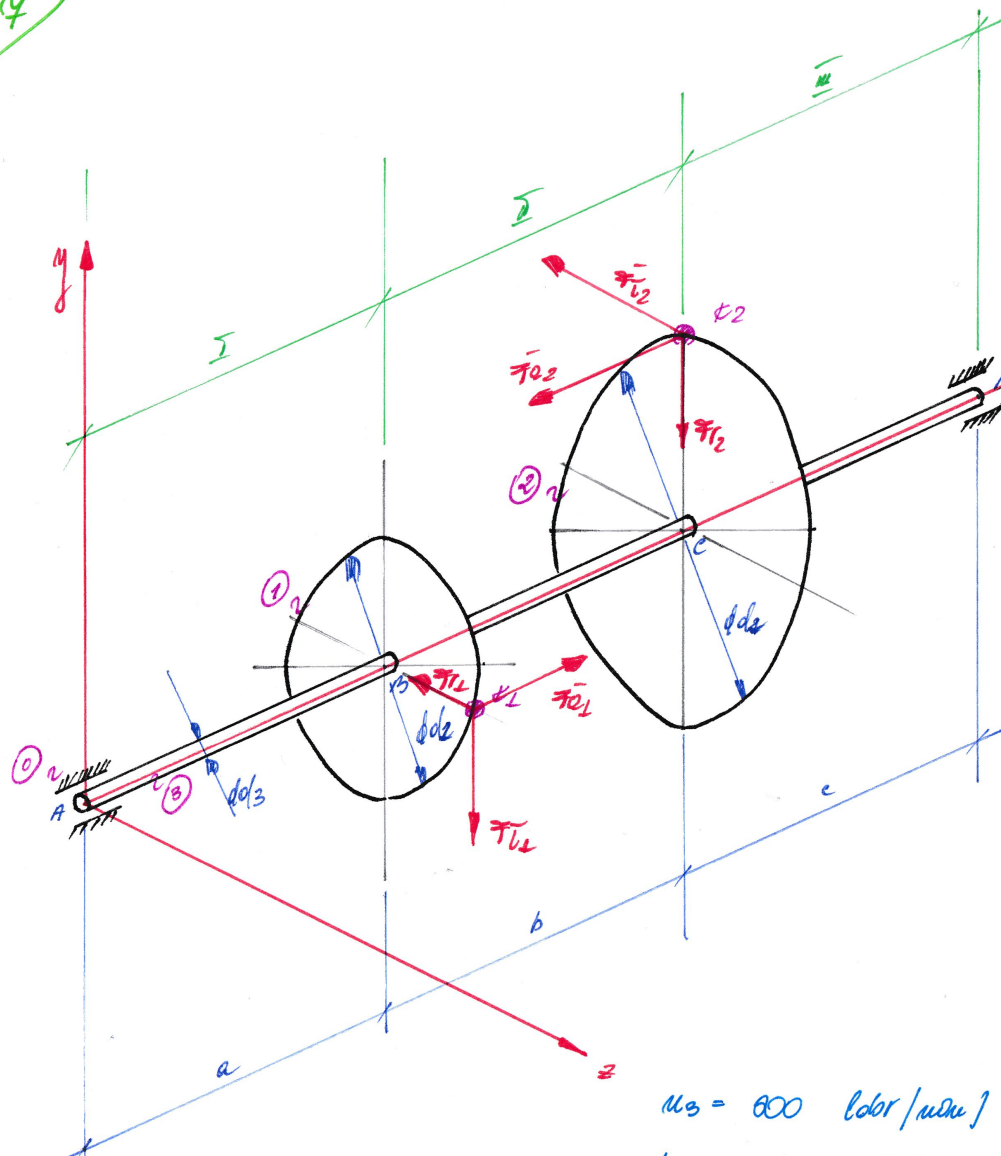
$$\underline{c_D = P_D \cdot (l_D)^{\frac{1}{k}}}$$

$$\underline{k} = \frac{10}{3} \quad \Rightarrow \quad \underline{c_D} = 581,46 \cdot (660)^{\frac{3}{10}} =$$

$$= 4044,33 \text{ [N]} = \underline{4,08} \text{ [kN]}$$

$$\Rightarrow \begin{cases} l_A = 11 \text{ [kN]} \\ \underline{c_D} = \underline{5} \end{cases}$$

C4



szukam:  
 $d_3 = ?$

$\mu_s = 600$  [obr/min]  
 $L_s = 22000$  [mm]

DANE:

$$L = \begin{cases} a = 60 \text{ [mm]} = 0,06 \text{ [m]} \\ b = 60 \text{ [mm]} = 0,06 \text{ [m]} \\ c = 60 \text{ [mm]} = 0,06 \text{ [m]} \end{cases}$$

1)  $d_1 = 60 \text{ [mm]} = 0,06 \text{ [m]}$

2)  $d_2 = 100 \text{ [mm]} = 0,1 \text{ [m]}$

1)  $F_{t1} = 1100 \text{ [N]}$

$F_{r1} = 400$

$F_{t2} = 900$

2)  $F_{r2} = ?$

$F_{t2} = 900$

$F_{r2} = 1400$

$E_s = 200 \text{ [GPa]} = 200 \cdot 10^9 \text{ [Pa]}$

$E_g = 120 \text{ [GPa]} = 120 \cdot 10^9 \text{ [Pa]}$

1)  $r_1 = \frac{1}{2} d_1 = \frac{1}{2} \cdot 60 = 30 \text{ [mm]} = 0,03 \text{ [m]}$

2)  $r_2 = \frac{1}{2} d_2 = \frac{1}{2} \cdot 100 = 50 \text{ [mm]} = 0,05 \text{ [m]}$

$F_{i2}$

$\sum M_{ix} = 0$   $\Rightarrow$

$$F_{i1} \cdot r_1 - F_{i2} \cdot r_2 = 0$$

$$F_{i1} \cdot r_1 = F_{i2} \cdot r_2$$

$$\underline{F_{i2}} = \frac{r_1}{r_2} \underline{F_{i1}}$$

$$\Rightarrow \underline{F_{i2}} = \frac{0.03}{0.05} \cdot 2200 = 0.012 \cdot 2200 = \underline{1320 \text{ (N)}}$$

$M_s$

$M_s = F \cdot r$   $\Rightarrow$

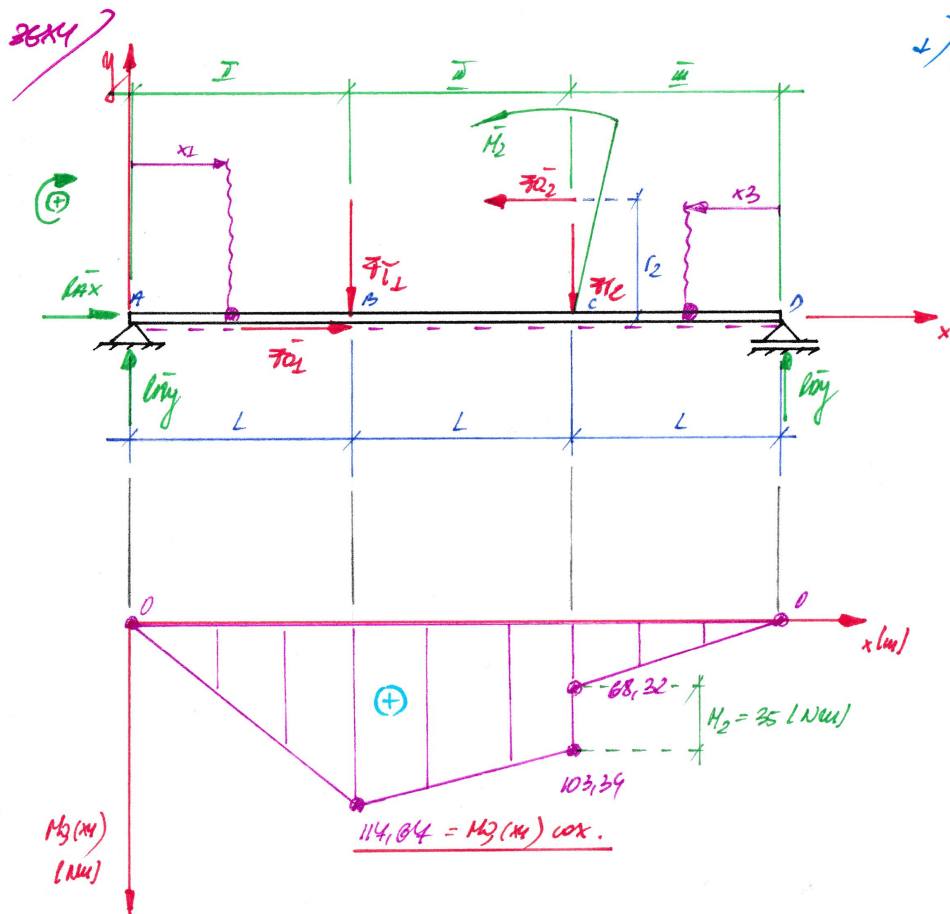
$$M_{s1} = F_{s1} \cdot r_1$$

$$\underline{M_{s1}} = 2200 \cdot 0.03 = \underline{66 \text{ (Nm)}}$$

$$M_{s2} = F_{i2} \cdot r_2$$

$$\underline{M_{s2}} = 1320 \cdot 0.05 = \underline{66 \text{ (Nm)}}$$

$$\Rightarrow \underline{M_{s1}} = M_{s2} = M_{s3} = \underline{66 \text{ (Nm)}}$$



↓) REAKT. 45.

$$\begin{aligned} \text{I)} \quad \sum \bar{F}_{ix} &= 0 & \text{I)} \quad R_{Ax} + F_{01} &= 0 \\ \text{II)} \quad \sum \bar{F}_{iy} &= 0 & \text{II)} \quad R_{Ay} - F_{01} - F_{02} + R_{Dy} &= 0 \\ \text{III)} \quad \sum M_{iA} &= 0 & \text{III)} \quad F_{01} \cdot L + F_{02} \cdot 2L - R_{Dy} \cdot 3L - M_2 &= 0 \end{aligned}$$

$$M_2 = F_{02} \cdot r_2$$

$$M_2 = 400 \cdot 0.05 = 35 \text{ (Nm)}$$

$$\begin{aligned} \text{I)} \quad R_{Ax} &= -F_{01} \\ R_{Ax} &= -400 \text{ (N)} \\ \text{II)} \quad R_{Ay} &= \frac{(F_{01}L + 2F_{02})L - M_2}{3L} \\ R_{Ay} &= \frac{(2200 + 2 \cdot 900) \cdot 0.06 - 35}{3 \cdot 0.06} = \frac{4000 \cdot 0.06 - 35}{0.18} = \\ &= \frac{240 - 35}{0.18} = \frac{205}{0.18} = 1138.80 \text{ (N)} \end{aligned}$$

$$\begin{aligned} \text{II)} \quad R_{Dy} &= F_{01} + F_{02} - R_{Ay} \\ R_{Dy} &= 2200 + 900 - 1138.80 = 1961.20 \text{ (N)} \end{aligned}$$

8/12

$$\underline{\sum M_D = 0} \Rightarrow R_{Ay} \cdot 2L - F_{r1} \cdot 2L - F_{r2} \cdot L - M_2 = 0 \quad / : L$$

$$3R_{Ay} - 2F_{r1} - F_{r2} - \frac{M_2}{L} = 0$$

$$3 \cdot 1961,20 - 2 \cdot 2200 - 900 - \frac{35}{0,06} = 0$$

$$5883,6 - 4400 - 900 - 583,33 = 0$$

$$583,60 - 583,33 = 0$$

$$\underline{L = P}$$

$$\Rightarrow \left\{ \begin{array}{l} R_{Ax} = -400 \text{ (N)} \\ R_{Ay} = 1961,20 \\ R_{By} = 1138,80 \end{array} \right.$$

2) РЕЗУЛЬТАТЫ.

I)  $0 \leq x_1 \leq L = 906$  км

$$M_3(x_1) = k_{ny} \cdot x_1 = 1961,2 x_1 \quad [N \cdot m]$$

$$M_3(0) = 0$$

$$M_3(906) = 114,64$$

II)  $906 \leq x_2 \leq 912$

$$\begin{aligned} M_3(x_2) &= M_3^I - T_{D.L}(x_2 - L) = \\ &= 1961,2 x_2 - 2200 (x_2 - 906) = \\ &= 1961,2 x_2 - 2200 x_2 + 132 = \\ &= -238,8 x_2 + 132 \end{aligned}$$

$$M_3(906) = 114,64$$

$$M_3(912) = 103,39$$

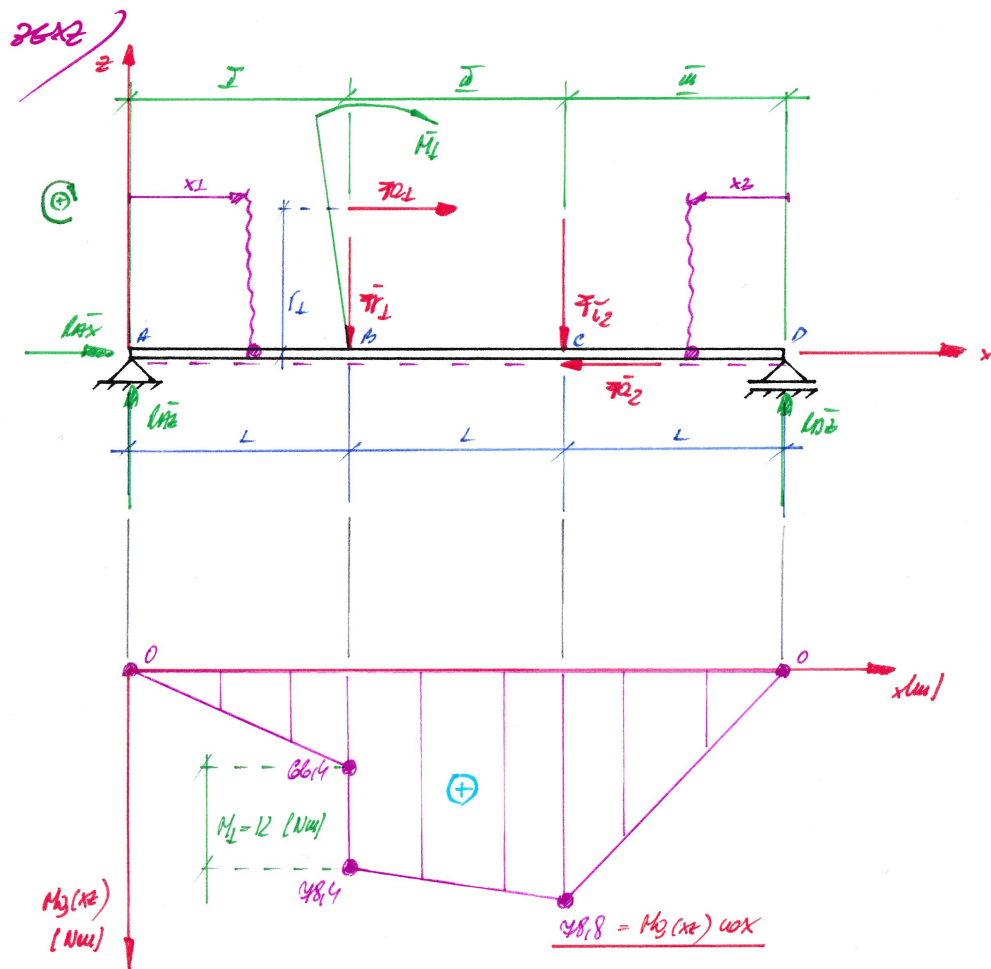
III)  $0 \leq x_3 \leq L = 906$

$$M_3(x_3) = k_{ny} \cdot x_3 = 1138,80 x_3$$

$$M_3(0) = 0$$

$$M_3(906) = 68,32$$





1) Reaktionskräfte

$$\begin{aligned} \text{I)} \quad & \sum F_{ix} = 0 \\ \text{II)} \quad & \sum F_{iz} = 0 \\ \text{III)} \quad & \sum M_{iA} = 0 \end{aligned} \quad \Rightarrow \quad \begin{aligned} \text{I)} \quad & R_{Ax} - F_{02} = 0 \\ \text{II)} \quad & R_{Az} - F_{01} - F_{02} + R_{02} = 0 \\ \text{III)} \quad & F_{01} \cdot L + F_{02} \cdot 2L - R_{02} \cdot 3L + M_1 = 0 \end{aligned}$$

$$M_1 = F_{01} \cdot L$$

$$M_1 = 400 \cdot 0.03 = 12 \text{ [Nm]}$$

$$\text{I)} \quad R_{Ax} = F_{02}$$

$$R_{Ax} = 400 \text{ [N]}$$

$$R_{Ax} = 400 \text{ [N]}$$

$$R_{Az} = 1106,67$$

$$R_{02} = 1313,33$$

$$\text{III)} \quad R_{02} = \frac{(F_{01} + 2F_{02})L + M_1}{3L}$$

$$R_{02} = \frac{(1100 + 2 \cdot 1320) \cdot 0.06 + 12}{3 \cdot 0.06} = \frac{8440 \cdot 0.06 + 12}{0.18} =$$

$$= \frac{2244 + 12}{0.18} = \frac{2256}{0.18} = 1313,33 \text{ [N]}$$

$$\text{II)} \quad R_{Az} = F_{01} + F_{02} - R_{02}$$

$$R_{Az} = 1100 + 1320 - 1313,33 = 1106,67 \text{ [N]}$$



202

$$\sum M_D = 0 \Rightarrow l_{R2} \cdot 3L - F_{R1} \cdot 2L - F_{R2} \cdot L + M_L = 0 \quad / : L$$

$$3l_{R2} - 2F_{R1} - F_{R2} + \frac{M_L}{L} = 0$$

$$3 \cdot 1106,64 - 2 \cdot 1100 - 1320 + \frac{12}{0,06} = 0$$

$$3320,01 - 2200 - 1320 + 200 = 0$$

$$- 200 + 200 = 0$$

$$\underline{L = P}$$

$$\Rightarrow \left\{ \begin{array}{l} l_{R1} = 400 \text{ (N)} \\ l_{R2} = 1106,64 \\ l_{R2} = 1313,33 \end{array} \right.$$

- 4 -

2) продолжаем.

1)  $0 \leq x_1 < L = 0,06 \text{ [m]}$

$$M_3(x_1) = k_{n2} \cdot x_1 = 1106,64 x_1 \quad [\text{Нм}]$$

$$M_3(0) = 0$$

$$M_3(0,06) = 66,4$$

II)  $0,06 \leq x_2 < 0,12$

$$\begin{aligned} M_3(x_2) &= M_3 \bar{L} - F_{TL}(x_2 - L) + M_L = \\ &= 1106,64 x_2 - 1100(x_2 - 0,06) + 12 = \\ &= 1106,64 x_2 - 1100 x_2 + 66 + 12 = \\ &= 6,64 x_2 + 78 \end{aligned}$$

$$M_3(0,06) = 78,4$$

$$M_3(0,12) = 78,8$$

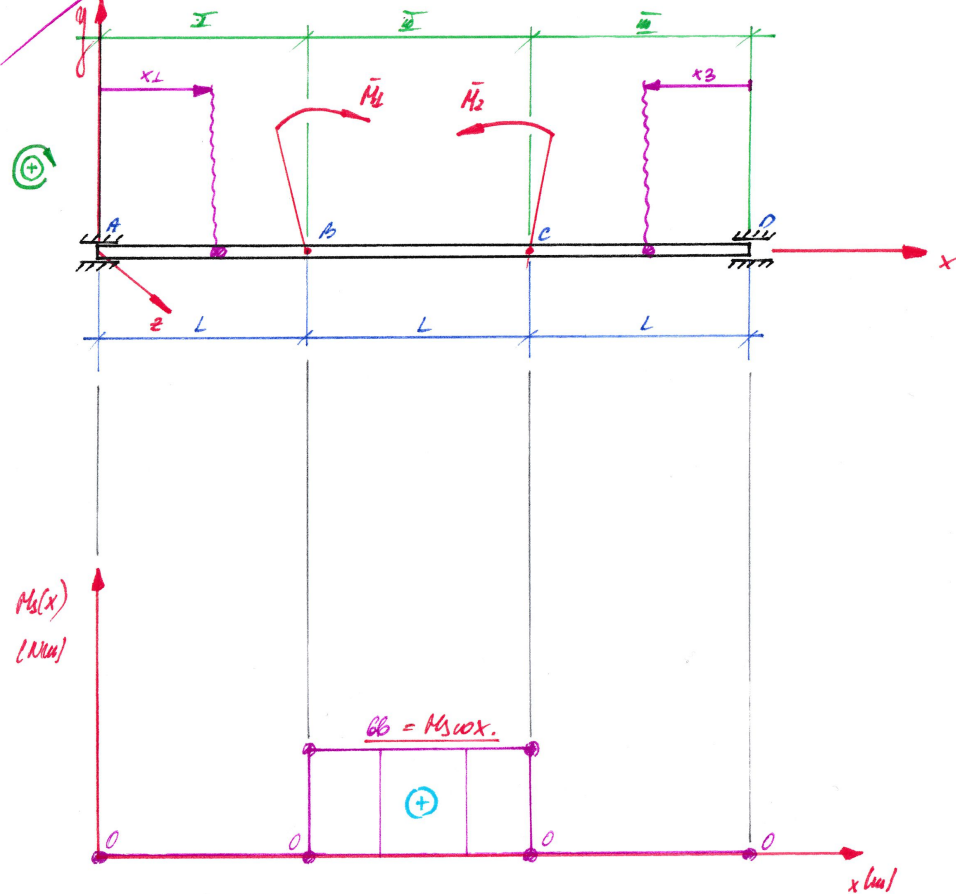
III)  $0 \leq x_3 < L = 0,06$

$$M_3(x_3) = k_{n2} \cdot x_3 = 1313,33 x_3$$

$$M_3(0) = 0$$

$$M_3(0,06) = 78,8$$

SKL 42



1) segment I.

i)  $0 \leq x_1 < L = 0.06 \text{ (m)}$

$M_s(x_1) = 0$  [Nm]

$M_s(0) = 0$

$M_s(0.06) = 0$

ii)  $0.06 \leq x_2 < 0.12$

$M_s(x_2) = M_s \bar{I} + M_L = 0 + 66 = 66$

$M_s(0.06) = 66$

$M_s(0.12) = 66$

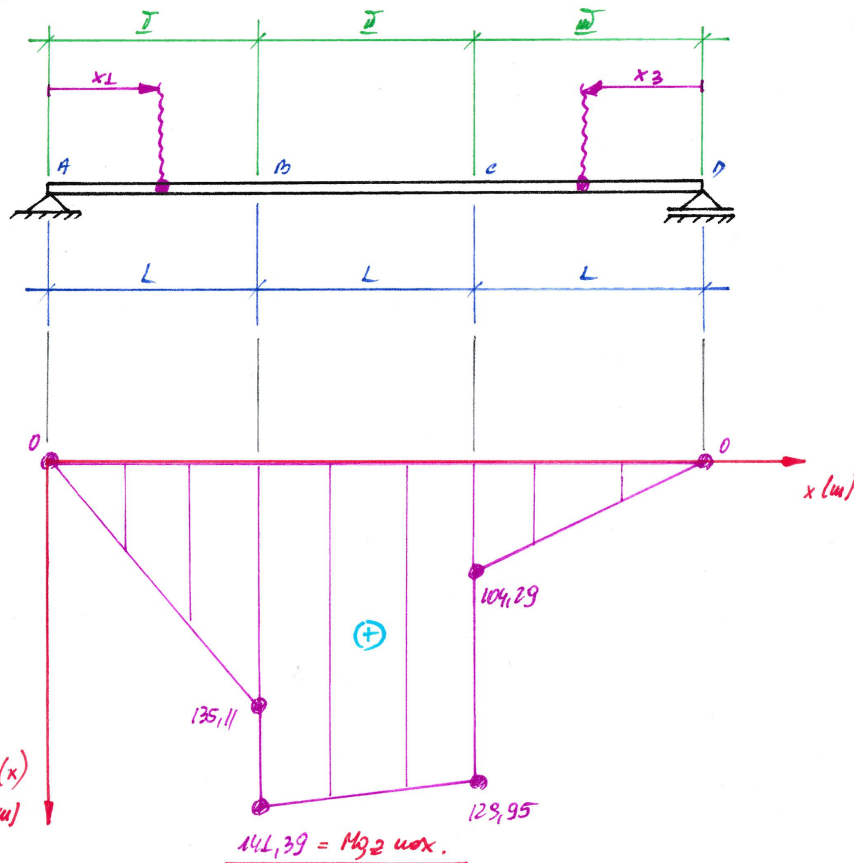
iii)  $0 \leq x_3 \leq 0.06$

$M_s(x_3) = 0$

$M_s(0) = 0$

$M_s(0.06) = 0$

M<sub>32</sub>



$$\begin{cases} M_{32 \max} = 141,39 \text{ [Nm]} \\ M_{3 \max} = 66 \end{cases}$$

$\Rightarrow M_{32} > M_3$

M<sub>32</sub>

2) результат

$$\bar{M}_{32} = \bar{M}_3(x_1) + \bar{M}_3 x_2$$

$$\underline{M_{32} = \sqrt{M_3(x_1)^2 + M_3(x_2)^2}}$$

1)  $0 \leq x_1 < L = 0,06 \text{ [m]}$

$$\underline{M_{32}(0)} = \sqrt{(0)^2 + (0)^2} = \underline{0} \text{ [Nm]}$$

$$\underline{M_{32}(0,06)} = \sqrt{(114,64)^2 + (66,4)^2} = \underline{135,11}$$

II)  $0,06 \leq x_2 < 0,12$

$$\underline{M_{32}(0,06)} = \sqrt{(114,64)^2 + (48,4)^2} = \underline{141,39}$$

$$\underline{M_{32}(0,12)} = \sqrt{(103,34)^2 + (48,8)^2} = \underline{129,95}$$

III)  $0 \leq x_3 < 0,06$

$$\underline{M_{32}(0)} = \sqrt{(0)^2 + (0)^2} = \underline{0}$$

$$\underline{M_{32}(0,06)} = \sqrt{(66,32)^2 + (48,8)^2} = \underline{104,29}$$

-10-

$$M_2 \left\{ \begin{array}{l} M_{2\max} = 141,39 \text{ [Nm]} \\ M_{2\min} = 0 \end{array} \right. \Rightarrow \underline{M_{2\max} > M_3}$$

$$\underline{M_2 = \sqrt{(M_{2\max})^2 + \left(\frac{1}{2} \alpha M_3\right)^2}}; \quad \underline{\alpha = \frac{\text{kg}}{\text{ksj}}}$$

$$\Rightarrow \underline{\alpha = \frac{100 \cdot 10^6}{120 \cdot 10^6} = 0,83}$$

1) maximally.

$$\text{I) } \underline{0 \leq x_1 \leq L = 0,06 \text{ [m]}}$$

$$\underline{M_2(0) = \sqrt{(0)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 0\right)^2} = 0 \text{ [Nm]}}$$

$$\underline{M_2(0,06) = \sqrt{(135,11)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 0\right)^2} = 135,11}$$

$$\text{II) } \underline{0,06 \leq x_2 \leq 0,12}$$

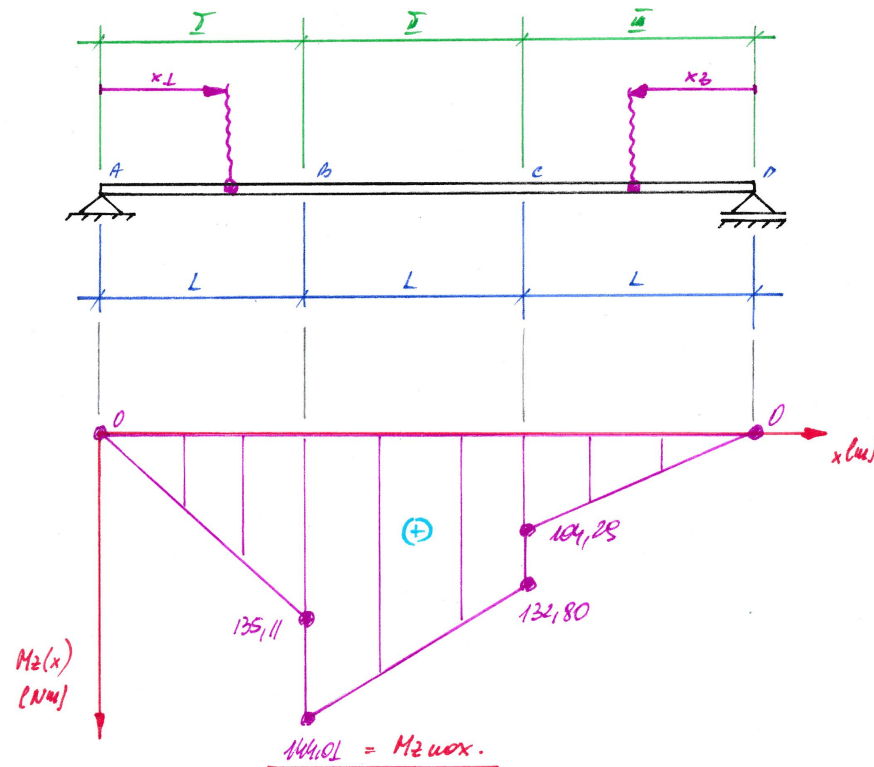
$$\underline{M_2(0,06) = \sqrt{(141,39)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 0,06\right)^2} = 144,01}$$

$$\underline{M_2(0,12) = \sqrt{(128,95)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 0,06\right)^2} = 132,80}$$

$$\text{III) } \underline{0 \leq x_3 \leq 0,06}$$

$$\underline{M_2(0) = \sqrt{(0)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 0\right)^2} = 0}$$

$$\underline{M_2(0,06) = \sqrt{(104,29)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 0\right)^2} = 104,29}$$

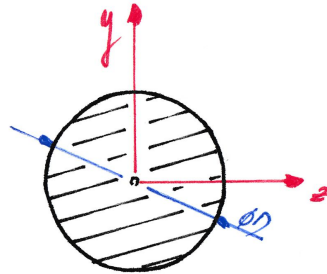


2/

$$\sigma_2 = \frac{M_2}{W_2} \leq k_2$$

$$W_2 = \frac{I_2}{y_{\max.}}$$

$$\begin{cases} I_2 = \frac{\pi D^4}{64} \\ y_{\max} = \frac{1}{2} D \end{cases}$$



$$k_2 = k_{g0}$$

$$\frac{M_2}{W_2} \leq k_2$$

$$\frac{M_2}{\frac{\pi D^4}{64} \cdot \frac{1}{2} D} \leq k_2$$

$$\frac{32 M_2}{\pi D^3} \leq k_2$$

$$D \geq \sqrt[3]{\frac{32 M_2}{\pi k_2}}$$

$$\begin{aligned} D &\geq \sqrt[3]{\frac{32 M_2}{\pi k_2}} = \sqrt[3]{\frac{32 M_2}{3,14 \cdot 100 \cdot 10^6}} = \\ &= \sqrt[3]{\frac{32 M_2}{0,314} \cdot 10^{-9}} = \sqrt[3]{101,91 M_2 \cdot 10^{-9}} = \\ &= 4,64 \cdot 10^{-3} \cdot \sqrt[3]{M_2} \text{ [m]} = \\ &= 4,64 \cdot 10^{-3} \cdot \sqrt[3]{M_2} \cdot 10^3 \text{ [mm]} = \\ &= 4,64 \cdot \sqrt[3]{M_2} \end{aligned}$$

$$D \geq 4,64 \cdot \sqrt[3]{M_2}$$

$$1) 0 \leq x_1 < L = 0,06 \text{ [m]}$$

$$D(0) = 4,64 \cdot \sqrt[3]{0} = 0 \text{ [mm]}$$

$$D(0,06) = 4,64 \cdot \sqrt[3]{135,11} = 23,86$$

$$2) 0,06 \leq x_2 < 0,12$$

$$D(0,06) = 4,64 \cdot \sqrt[3]{144,01} = 24,44$$

$$D(0,12) = 4,64 \cdot \sqrt[3]{132,80} = 23,82$$

$$3) 0 \leq x_3 < 0,06$$

$$D(0) = 4,64 \cdot \sqrt[3]{0} = 0$$

$$D(0,06) = 4,64 \cdot \sqrt[3]{104,89} = 21,88$$

$$1) A/D(0) = 24 \text{ [mm]}$$

$$B/D(0,06) = 32$$

$$2) A/D(0,06) = 32$$

$$B/D(0,12) = 30$$

$$3) A/D(0,12) = 30$$

$$B/D(0,18) = 25$$

c)

$$P = x \cdot v \cdot P_p + y \cdot P_N$$

$$\bar{P}_{PA} = \bar{L}_{Ay} + \bar{L}_{Az}$$

$$\bar{P}_{PA} = \sqrt{\bar{L}_{Ay}^2 + \bar{L}_{Az}^2}$$

$$\Rightarrow \bar{P}_{PA} = \sqrt{(1961,2)^2 + (1106,64)^2} = 2257,89 \text{ [N]}$$

$$\bar{P}_{PD} = \bar{L}_{Ay} + \bar{L}_{Az}$$

$$\bar{P}_{PD} = \sqrt{\bar{L}_{Ay}^2 + \bar{L}_{Az}^2}$$

$$\Rightarrow \bar{P}_{PD} = \sqrt{(1138,8)^2 + (1313,33)^2} = 1438,30 \text{ [N]}$$

$$P_N = |L_{Ax}|$$

$$\Rightarrow P_N = |L_{Ax1} + L_{Ax2}| = |-400 + 400| = 300 \text{ [N]}$$

a)

$$P_A = x \cdot v \cdot P_{PA} + y \cdot P_{NA}$$

$$\begin{cases} v = 1 \\ x = 1 \\ y = 0 \end{cases} \Rightarrow \bar{P}_A = 1 \cdot 1 \cdot 2257,89 = 2257,89 \text{ [N]}$$

$$L_A = \frac{60 \cdot m_3 \cdot L_H}{10^6} \quad [\text{mln dbr}]$$

$$m_3 = 600 \text{ [dbr/mkm]}$$

$$L_H = 22000 \text{ [h]}$$

$$\Rightarrow \bar{L}_A = \frac{60 \cdot 600 \cdot 22000}{10^6} = \frac{660 \cdot \cancel{10^6}}{\cancel{10^6}} = 660 \text{ [mln dbr]}$$

$$C_A = P_A \cdot (L_A)^{\frac{1}{k}}$$

$$\begin{aligned} \bar{k} = 3 \quad \Rightarrow \bar{C}_A &= 2257,89 \cdot (660)^{\frac{1}{3}} = 19666,24 \text{ [N]} = \\ &= 19,61 \text{ [kN]} \end{aligned}$$



27

$$\underline{P_D = x \cdot \varphi \cdot P_{PD} + y \cdot P_{ND}}$$

$$\begin{cases} \varphi = 1 \\ x = 1 \\ y = 0 \end{cases}$$

$$\Rightarrow \underline{P_D} = 1 \cdot 1 \cdot 1738,30 = \underline{1738,30 \text{ (N)}}$$

$$\underline{L_D} = \frac{60 \cdot 43 \cdot L_A}{10^6} \quad [\text{in cm}]$$

$$\Rightarrow \underline{L_D} = L_A = \underline{660} \quad [\text{in cm}]$$

$$\underline{C_D = P_D \cdot (L_D)^{\frac{1}{k}}}$$

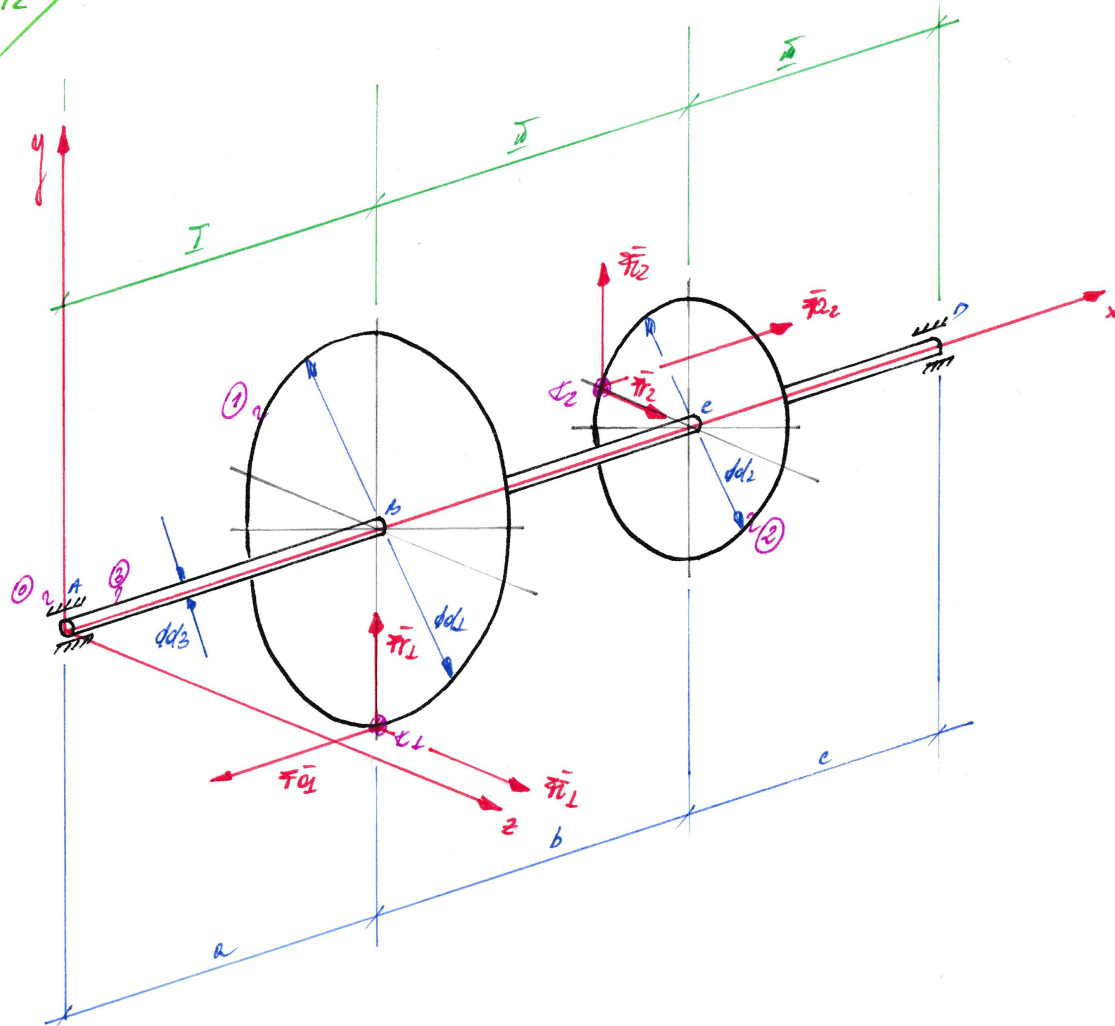
$$\underline{k} = \underline{3}$$

$$\begin{aligned} \Rightarrow \underline{C_D} &= 1738,30 \cdot (660)^{\frac{1}{3}} = \\ &= 15139,66 \text{ (N)} = \underline{15,2 \text{ (kN)}} \end{aligned}$$

$$\Rightarrow \begin{cases} C_A = 20 \text{ (kN)} \\ C_D = 16 \end{cases}$$



D12



SZUKAM:

$\phi d_3 = ?$

$$d_3 = 500 \text{ (mm)}$$

$$l_4 = 22000 \text{ (mm)}$$

DANE:

$$l = \begin{cases} a = 40 \text{ (mm)} = 0,04 \text{ (m)} \\ b = 40 \text{ (mm)} = 0,04 \text{ (m)} \\ c = 80 \text{ (mm)} = 0,08 \text{ (m)} \end{cases}$$

$$1) d_1 = 120 \text{ (mm)} = 0,12 \text{ (m)}$$

$$2) d_2 = 80 \text{ (mm)} = 0,08 \text{ (m)}$$

$$1) F_{L1} = 2300 \text{ (N)}$$

$$F_{L1} = 900$$

$$F_{L1} = 800$$

$$2) F_{L2} = ?$$

$$F_{L2} = 1400$$

$$F_{L2} = 800$$

$$k_{g0} = 100 \text{ (MPa)} = 100 \cdot 10^6 \text{ (Pa)}$$

$$k_{gj} = 120 \text{ (MPa)} = 120 \cdot 10^6 \text{ (Pa)}$$

$$1) r = \frac{1}{2} d_1 = \frac{1}{2} \cdot 120 = 60 \text{ (mm)} = 0,06 \text{ (m)}$$

$$2) r_2 = \frac{1}{2} d_2 = \frac{1}{2} \cdot 80 = 40 \text{ (mm)} = 0,04 \text{ (m)}$$

$\vec{F}_{i2}$

$\sum \vec{M}_X = 0$  - ~~177~~

$$- \vec{F}_{i1} \cdot r_1 + \vec{F}_{i2} \cdot r_2 = 0$$

$$\vec{F}_{i2} \cdot r_2 = \vec{F}_{i1} \cdot r_1$$

$$\underline{\vec{F}_{i2}} = \frac{r_1}{r_2} \underline{\vec{F}_{i1}}$$

$$\Rightarrow \underline{\vec{F}_{i2}} = \frac{0.06}{0.04} \cdot 2300 = \underline{3450 \text{ [N]}}$$

$M_3$

$M_3 = \vec{F} \cdot r$  = ~~177~~

$$M_{s1} = \vec{F}_{i1} \cdot r_1$$

$$\underline{M_{s1}} = 2300 \cdot 0.06 = \underline{138 \text{ [Nm]}}$$

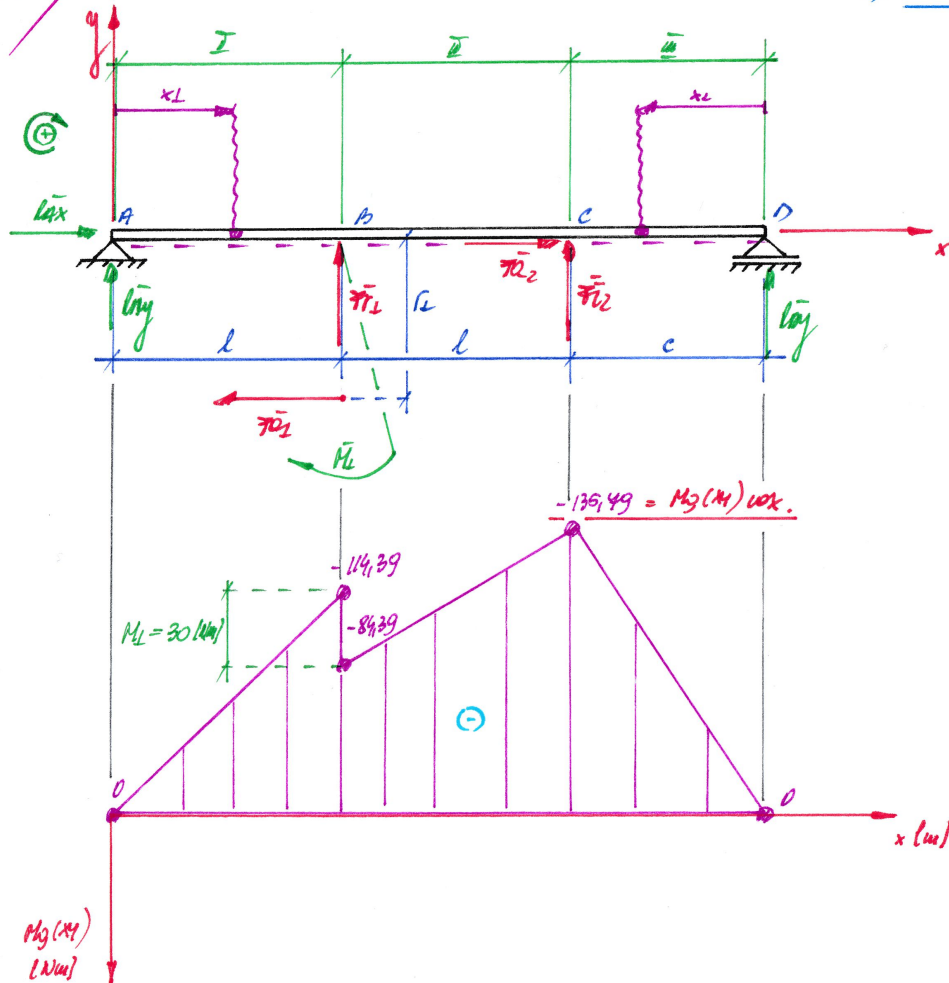
$$M_{s2} = \vec{F}_{i2} \cdot r_2$$

$$\underline{M_{s2}} = 3450 \cdot 0.04 = \underline{138 \text{ [Nm]}}$$

$$\Rightarrow \underline{M_{s1}} = M_{s2} = M_{s3} = \underline{138 \text{ [Nm]}}$$

26x4

1) REAKTOS.



$$\begin{aligned} \text{I)} \quad \sum \bar{F}_i x &= 0 & \text{I)} \quad \bar{r}_{Ax} + \bar{r}_{Dx} &= 0 \\ \text{II)} \quad \sum \bar{F}_i y &= 0 & \text{II)} \quad \bar{r}_{Ay} + \bar{F}_{1y} + \bar{F}_{2y} + \bar{r}_{Dy} &= 0 \\ \text{III)} \quad \sum M_i A &= 0 & \text{III)} \quad -\bar{F}_{1y} \cdot l - \bar{F}_{2y} \cdot 2l - \bar{r}_{Dy} (l + 2l) &+ M_1 = 0 \end{aligned}$$

$$M_1 = F_{01} \cdot r_1$$

$$M_1 = 600 \cdot 0.06 = 30 \text{ [Nm]}$$

$$\begin{aligned} \text{I)} \quad \bar{r}_{Ax} &= -\bar{F}_{02} \\ \bar{r}_{Ax} &= -600 \text{ [N]} & \begin{cases} \bar{r}_{Ax} = -600 \text{ [N]} \\ \bar{r}_{Ay} = -1634,22 \\ \bar{r}_{Dy} = -2745,48 \end{cases} \end{aligned}$$

$$\begin{aligned} \text{II)} \quad \bar{r}_{Dy} &= \frac{-(\bar{F}_{1y} + 2\bar{F}_{2y})l + M_1}{l + 2l} \\ \bar{r}_{Dy} &= \frac{-(900 + 2 \cdot 3450) \cdot 0.104 + 30}{0.105 + 2 \cdot 0.104} = \frac{-4800 \cdot 0.104 + 30}{0.118} = \\ &= \frac{-546 + 30}{0.118} = \frac{-516}{0.118} = -2745,48 \text{ [N]} \end{aligned}$$

$$\begin{aligned} \text{I)} \quad \bar{r}_{Ay} &= -\bar{F}_{1y} - \bar{F}_{2y} - \bar{r}_{Dy} \\ \bar{r}_{Ay} &= -900 - 3450 - (-2745,48) = -1634,22 \text{ [N]} \end{aligned}$$

300

$$\sum M_D = 0 \Rightarrow R_{my} \cdot (c + 2l) + F_{11} \cdot (c + l) + F_{12} \cdot c + M_1 = 0$$

$$- 1634,22 \cdot (0,05 + 2 \cdot 0,04) + 900 \cdot (0,05 + 0,04) + 8450 \cdot 0,05 + 30 = 0$$

$$- 1634,22 \cdot 0,19 + 900 \cdot 0,12 + 142,5 + 30 = 0$$

$$- 310,5 + 108 + 142,5 + 30 = 0$$

$$- 30 + 30 = 0$$

$$\underline{L = P}$$

$$\Rightarrow \begin{cases} R_{Ax} = -600 \text{ [N]} \\ R_{my} = -1634,22 \\ R_{Ay} = -2415,48 \end{cases}$$

2) результаты.

i)  $0 \leq x_1 < l = 0.04$  [м]

$$M_3(x_1) = k_{ny} \cdot x_1 = -1634,22 x_1 \text{ [Нм]}$$

$$M_3(0) = 0$$

$$M_3(0.04) = -14,39$$

ii)  $0.04 \leq x_2 < 0.14$

$$\begin{aligned} M_3(x_2) &= M_3^I + F_{rL}(x_2 - l) + M_L = \\ &= -1634,22 x_2 + 900(x_2 - 0.04) + 30 = \\ &= -1634,22 x_2 + 900 x_2 - 63 + 30 = \\ &= -734,22 x_2 - 33 \end{aligned}$$

$$M_3(0.04) = -84,39$$

$$M_3(0.14) = -135,49$$

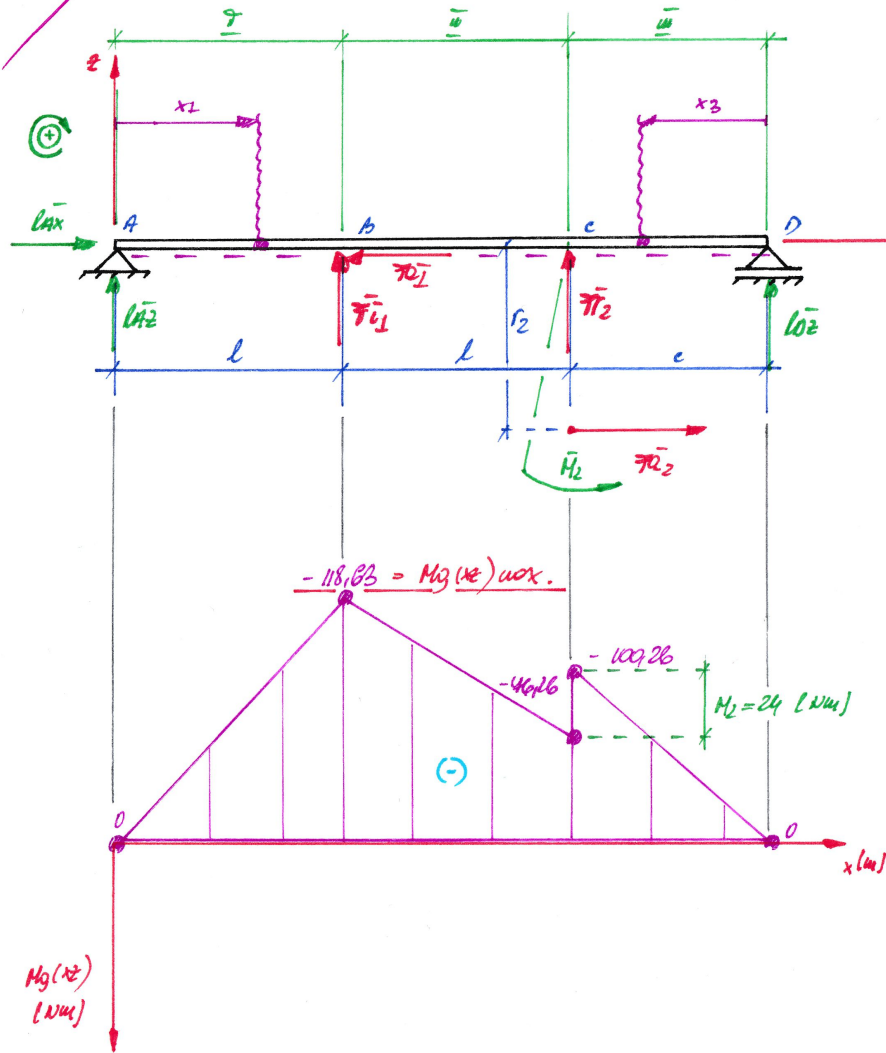
iii)  $0 \leq x_3 < c = 0.05$  [м]

$$M_3(x_3) = k_{ay} \cdot x_3 = -2415,48 x_3$$

$$M_3(0) = 0$$

$$M_3(0.05) = -135,49$$

26.12



1) REAKCJE.

$$\begin{aligned} \text{I)} \quad & \sum \bar{F}_{ix} = 0 \\ \text{II)} \quad & \sum \bar{F}_{iz} = 0 \\ \text{III)} \quad & \sum M_{iA} = 0 \end{aligned} \quad \Rightarrow \quad \begin{aligned} \text{I)} \quad & R_{Ax} - F_{Q1} = 0 \\ \text{II)} \quad & R_{Az} + \bar{F}_{1z} + \bar{F}_{2z} + R_{Dz} = 0 \\ \text{III)} \quad & -\bar{F}_{1z} \cdot l - \bar{F}_{2z} \cdot 2l - R_{Dz}(2l+c) - M_2 = 0 \end{aligned}$$

$$M_2 = F_{Q2} \cdot l_2$$

$$M_2 = 600 \cdot 0,04 = 24 \text{ [Nm]}$$

$$\begin{aligned} \text{I)} \quad & R_{Ax} = F_{Q1} \\ & R_{Ax} = 600 \text{ [N]} \end{aligned} \quad \Rightarrow \quad \begin{aligned} & R_{Ax} = 500 \text{ [N]} \\ & R_{Az} = -1694,44 \\ & R_{Dz} = -2005,26 \end{aligned}$$

$$\begin{aligned} \text{II)} \quad & R_{Dz} = \frac{-(\bar{F}_{1z} + 2\bar{F}_{2z})l - M_2}{2l + c} \\ & R_{Dz} = \frac{-(2300 + 2 \cdot 1400) \cdot 0,04 - 24}{2 \cdot 0,04 + 0,05} = \frac{-5100 \cdot 0,04 - 24}{0,13} = \\ & = \frac{-354 - 24}{0,13} = \frac{-378}{0,13} = -2907,69 \text{ [N]} \end{aligned}$$

$$\begin{aligned} \text{II)} \quad & R_{Az} = -\bar{F}_{1z} - \bar{F}_{2z} - R_{Dz} \\ & R_{Az} = -2300 - 1400 - (-2005,26) = -1694,74 \text{ [N]} \end{aligned}$$

-6-

2) проблемы.

1)  $0 \leq x_1 < l = 0,04$  км

$$M_3(x_1) = \lambda_{12} \cdot x_1 = -1684,44 x_1 \quad [\text{Нм}]$$

$$M_3(0) = 0$$

$$M_3(0,04) = -118,63$$

II)  $0,04 \leq x_2 < 0,14$

$$\begin{aligned} M_3(x_2) &= M_3^I + F_{12}(x_2 - l) = \\ &= -1684,44 x_2 + 2300(x_2 - 0,04) = \\ &= -1684,44 x_2 + 2300 x_2 - 161 = \\ &= 605,26 x_2 - 161 \end{aligned}$$

$$M_3(0,04) = -118,63$$

$$M_3(0,14) = -46,26$$

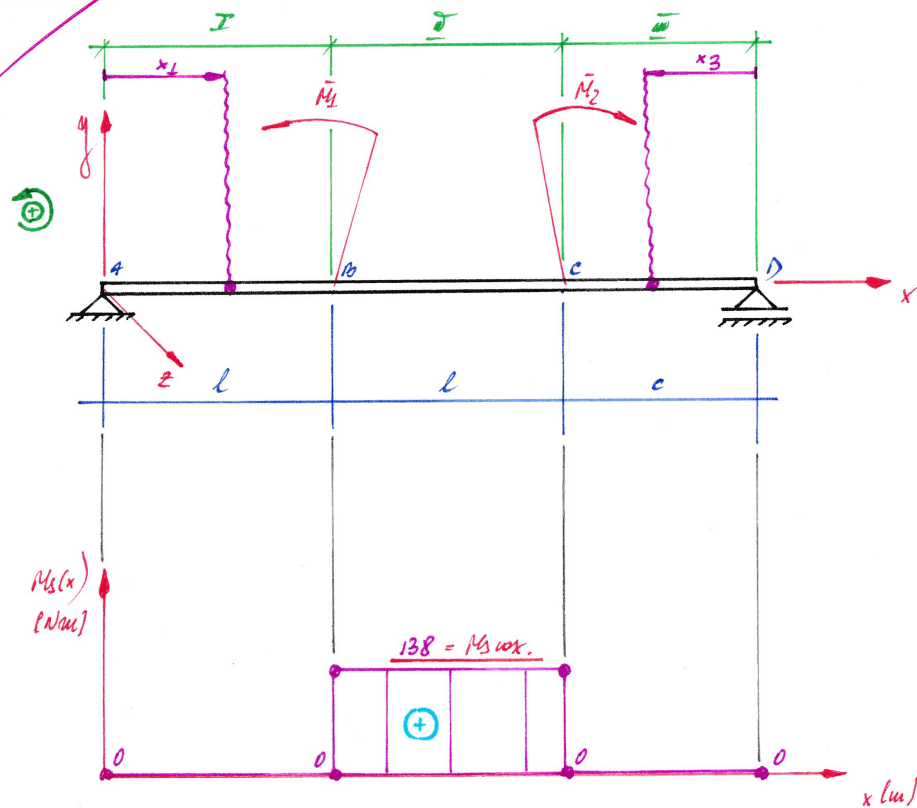
III)  $0 \leq x_3 < c = 0,05$

$$M_3(x_3) = \lambda_{02} \cdot x_3 = -2005,26 x_3$$

$$M_3(0) = 0$$

$$M_3(0,05) = -100,26$$

3KRY2



2) method 2

I)  $0 \leq x_1 < l = 0.04 \text{ m}$

$M_s(x_1) = 0$  [Nm]

$M_s(0) = 0$

$M_s(0.04) = 0$

II)  $0.04 \leq x_2 < 0.14$

$M_s(x_2) = M_s I + M_L = 0 + 138 = 138$

$M_s(0.04) = 138$

$M_s(0.14) = 138$

III)  $0 \leq x_3 < 0.05$

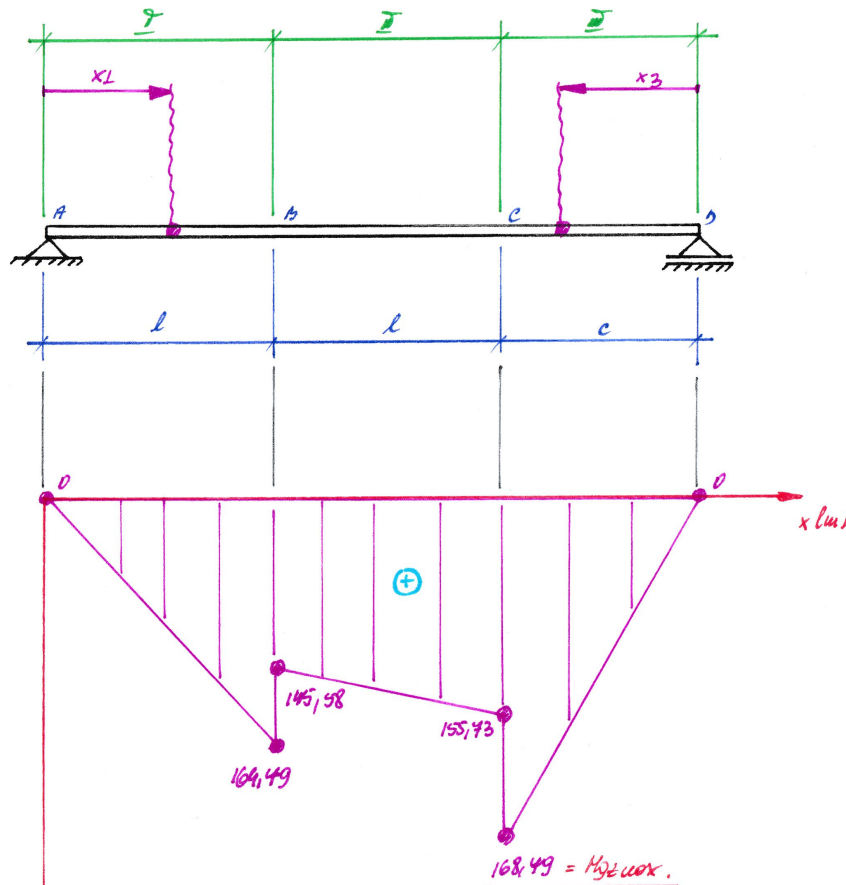
$M_s(x_3) = 0$

$M_s(0) = 0$

$M_s(0.05) = 0$



M<sub>32</sub>



M<sub>32</sub>(x)  
[Nm]

$$M_{32\max} = 168,49 \text{ [Nm]}$$

$$M_{3\max} = 138$$

$$\Rightarrow M_{32} > M_3$$

↓ ANALIZY.

$$M_{32} = M_{32}(x_1) + M_{32}(x_2)$$

$$M_{32} = \sqrt{M_{32}(x_1)^2 + M_{32}(x_2)^2}$$

I) 0 ≤ x<sub>1</sub> < l = 0.04 [m]

$$M_{32}(0) = \sqrt{(0)^2 + (0)^2} = 0 \text{ [Nm]}$$

$$M_{32}(0.04) = \sqrt{(-114,39)^2 + (-118,63)^2} = 164,49$$

II) 0.04 ≤ x<sub>2</sub> < 0.14

$$M_{32}(0.04) = \sqrt{(-84,39)^2 + (-118,63)^2} = 145,58$$

$$M_{32}(0.14) = \sqrt{(-135,49)^2 + (-94,26)^2} = 155,43$$

III) 0 ≤ x<sub>3</sub> < c = 0.05 [m]

$$M_{32}(0) = \sqrt{(0)^2 + (0)^2} = 0$$

$$M_{32}(0.05) = \sqrt{(-135,49)^2 + (-100,26)^2} = 168,49$$

M<sub>2</sub>

$$M_{2\max} = 168,49 \text{ [Nm]}$$

$$M_{3\max} = 138$$

$$M_{2} > M_{3}$$

$$M_2 = \sqrt{(M_{22})^2 + \left(\frac{1}{2} \alpha M_3\right)^2}$$

$$\alpha = \frac{k_{90}}{k_{91}}$$

$$\alpha = \frac{100 \cdot 10^6}{120 \cdot 10^6} = 0,83$$

1) пределама.

$$1) \quad 0 \leq x_1 \leq l = 0,04 \text{ [m]}$$

$$M_2(0) = \sqrt{(0)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 0\right)^2} = 0 \text{ [Nm]}$$

$$M_2(0,04) = \sqrt{(164,49)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 0\right)^2} = 164,49$$

$$2) \quad 0,04 \leq x_2 \leq 0,14$$

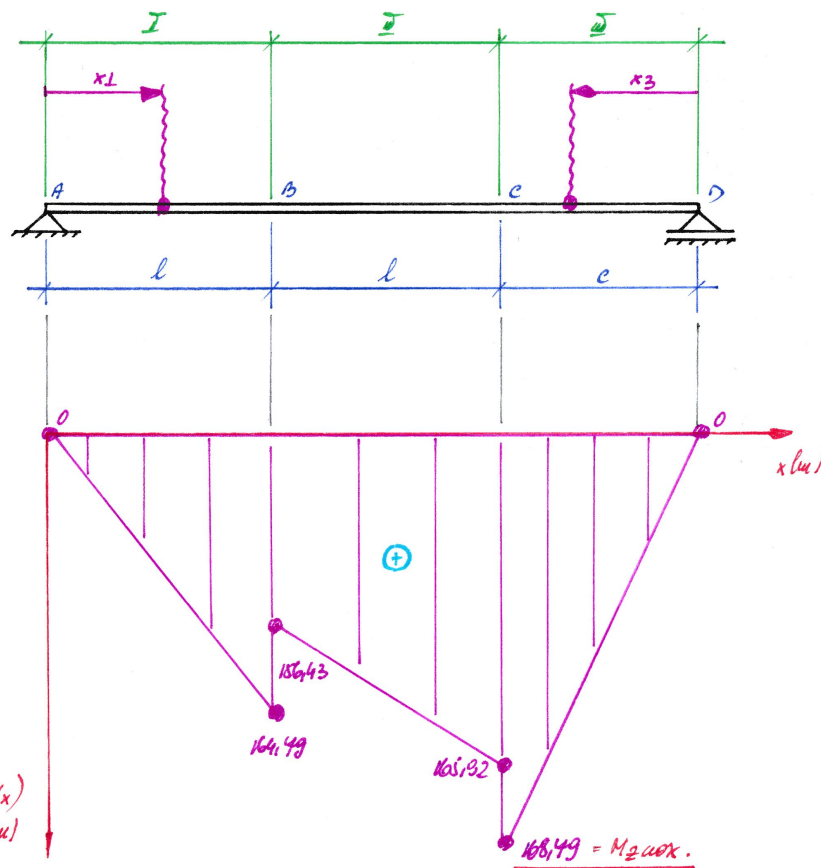
$$M_2(0,04) = \sqrt{(145,58)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 138\right)^2} = 156,43$$

$$M_2(0,14) = \sqrt{(165,43)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 138\right)^2} = 165,92$$

$$3) \quad 0 \leq x_3 \leq c = 0,05 \text{ [m]}$$

$$M_2(0) = \sqrt{(0)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 0\right)^2} = 0$$

$$M_2(0,05) = \sqrt{(168,49)^2 + \left(\frac{1}{2} \cdot 0,83 \cdot 0\right)^2} = 168,49$$

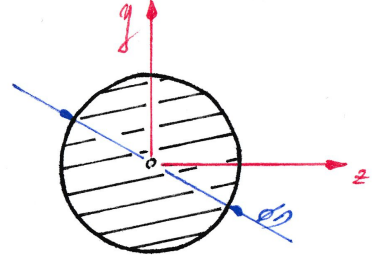


2/

$$\sigma_2 = \frac{M_2}{W_2} \leq \kappa_2$$

$$W_2 = \frac{I_2}{y_{\max}}$$

$$\left\{ \begin{array}{l} I_2 = \frac{\pi D^4}{64} \\ y_{\max} = \frac{1}{2} D \end{array} \right.$$



$$\kappa_2 = \kappa_{q0}$$

$$\frac{M_2}{W_2} \leq \kappa_2$$

$$\frac{M_2}{\frac{\pi D^4}{64} \cdot \frac{1}{2} D} \leq \kappa_2$$

$$\frac{32 M_2}{\pi D^3} \leq \kappa_2 \Rightarrow D \geq \sqrt[3]{\frac{32 M_2}{\kappa_2}}$$

$$\begin{aligned} D &\geq \sqrt[3]{\frac{32 M_2}{\kappa_2}} = \sqrt[3]{\frac{32 M_2}{3,14 \cdot 100 \cdot 10^6}} = \\ &= \sqrt[3]{\frac{32 M_2}{0,314} \cdot 10^{-9}} = \sqrt[3]{101,91 M_2 \cdot 10^{-9}} = \\ &= 4,64 \cdot 10^{-3} \cdot \sqrt[3]{M_2} \text{ [m]} = \\ &= 4,64 \cdot 10^{-3} \cdot \sqrt[3]{M_2} \cdot 10^3 = \text{[mm]} = \\ &= 4,64 \cdot \sqrt[3]{M_2} \end{aligned}$$

$$D \geq 4,64 \cdot \sqrt[3]{M_2}$$

$$\begin{aligned} 1) \quad 0 \leq x_1 < l = 0,04 \text{ [m]} \\ D(0) &= 4,64 \cdot \sqrt[3]{0} = 0 \text{ [mm]} \\ D(0,04) &= 4,64 \cdot \sqrt[3]{16,49} = 25,60 \end{aligned}$$

$$\begin{aligned} 2) \quad 0,04 \leq x_2 < 0,14 \\ D(0,04) &= 4,64 \cdot \sqrt[3]{18,43} = 25,16 \\ D(0,14) &= 4,64 \cdot \sqrt[3]{105,92} = 25,66 \end{aligned}$$

$$\begin{aligned} 3) \quad 0 \leq x_3 < 0,05 \\ D(0) &= 4,64 \cdot \sqrt[3]{0} = 0 \\ D(0,05) &= 4,64 \cdot \sqrt[3]{168,49} = 25,80 \end{aligned}$$

$$\begin{aligned} 1) \quad a) D(0) &= 28 \text{ [mm]} \\ b) D(0,04) &= 32 \end{aligned}$$

$$\begin{aligned} 2) \quad c) D(0,04) &= 32 \\ d) D(0,14) &= 34 \end{aligned}$$

$$\begin{aligned} 3) \quad e) D(0,14) &= 34 \\ f) D(0,15) &= 30 \end{aligned}$$

c)

$$P = x \cdot \vartheta \cdot P_p + y \cdot P_N$$

$$\bar{P}_p = \bar{l}_{p1} + \bar{l}_{p2}$$

$$P_p = \sqrt{l_{p1}^2 + l_{p2}^2}$$

$$\Rightarrow \underline{P_p} = \sqrt{(-1634,22)^2 + (-1694,94)^2} = \underline{2354,31} \text{ [N]}$$

$$\bar{P}_N = \bar{l}_{N1} + \bar{l}_{N2}$$

$$P_N = \sqrt{l_{N1}^2 + l_{N2}^2}$$

$$\Rightarrow \underline{P_N} = \sqrt{(-2415,48)^2 + (-2022,26)^2} = \underline{3345,84} \text{ [N]}$$

$$\underline{P_N} = |l_{N1}|$$

$$\Rightarrow \underline{P_N} = |l_{N1} + l_{N2}| = |-600 + 700| = |-100| = \underline{100} \text{ [N]}$$

d)

$$P_A = x \cdot \vartheta \cdot P_{pA} + y \cdot P_{NA}$$

$$\begin{cases} \vartheta = 1 \\ x = 1 \\ y = 0 \end{cases}$$

$$\Rightarrow \underline{P_A} = 1 \cdot 1 \cdot 2354,31 = \underline{2354,31} \text{ [N]}$$

$$\underline{L_A} = \frac{60 \cdot u_3 \cdot L_H}{10^6} \quad [\text{mln dbr}]$$

$$\begin{cases} u_3 = 600 \text{ [dbr/mdu]} \\ L_H = 22000 \text{ [h]} \end{cases}$$

$$\Rightarrow \underline{L_A} = \frac{60 \cdot 500 \cdot 22000}{10^6} = \frac{660 \cdot \cancel{10^6}}{\cancel{10^6}} = 660 \text{ [mln dbr]}$$

$$\underline{C_A} = P_A \cdot (L_A)^{\frac{1}{k}}$$

$$\underline{k} = \underline{3} \Rightarrow \underline{C_A} = 2354,31 \cdot (660)^{\frac{1}{3}} = 20438,01 \text{ [N]} = \underline{20,5} \text{ [kN]}$$

22

$$\underline{P_D = x \cdot \sigma \cdot P_{D0} + y \cdot P_{D0}}$$

$$\begin{cases} \sigma = 1 \\ x = 1 \\ y = 0 \end{cases}$$

$$\Rightarrow \underline{P_D} = 1 \cdot 1 \cdot 3345,84 = \underline{3345,84 \text{ (N)}}$$

$$\underline{l_D} = \frac{60 \cdot u_3 \cdot L_4}{10^6} \quad \text{[waku obr]}$$

$$\Rightarrow \underline{l_D} = l_A = \underline{660} \quad \text{[waku obr]}$$

$$\underline{C_D = P_D \cdot (l_D)^{\frac{1}{k}}}$$

$$\begin{aligned} \underline{k} = \underline{3} & \Rightarrow \underline{C_D} = 3345,84 \cdot (660)^{\frac{1}{3}} = \\ & = 29\,392,31 \text{ (N)} = \underline{29,4 \text{ (kN)}} \end{aligned}$$

$$\Rightarrow \begin{cases} C_A = 21 \text{ (kN)} \\ C_D = 30 \end{cases}$$

