SERWIS EDUKACYJNO - INŻYNIERSKI

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MATURA STUDIA PRAKTYKA PRACA

KOMPLEKSOWE WSPARCIE EDUKACYJNE NA KAŻDYM ETAPIE KSZTAŁCENIA INŻYNIERSKIEGO

Matematyka ; Fizyka ; Algebra z geometrią analityczną ; Analiza matematyczna I, II, III ; Mechanika I, II, III ; Mechanika płynów ; Mechanika analityczna ; Mechanika kwantowa ; Mechanika Techniczna ; Wytrzymałość materiałów I, II, III ; Równania różniczkowe ; PKM I, II ; Podstawy konstrukcji maszyn ; TMM ; Teoria mechanizmów i manipulatorów ; AiSUK ; Analiza i synteza układów kinematycznych ; PPM ; Podstawy projektowania mechanizmów (maszyn) ; PPŚT ; Podstawy projektowania środków transportu ; Manipulatory ; Automatyka i robotyka ; Synteza mechanizmów ; Modelowanie układów wieloczłonowych ; Grafika inżynierska 2D i 3D ; maszyny CNC ; konsultacje prac inżynierskich i magisterskich kierunków studiów technicznych ; współpraca z przemysłem.

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TEORIA MECHANIZMÓW I MANIPULATORÓW

ANALIZA DYNAMICZNA UKŁADÓW PŁASKICH

PROJEKT

Dla zadanego mechanizmu płaskiego, znaleźć:

1) Parametry kinematyczne:

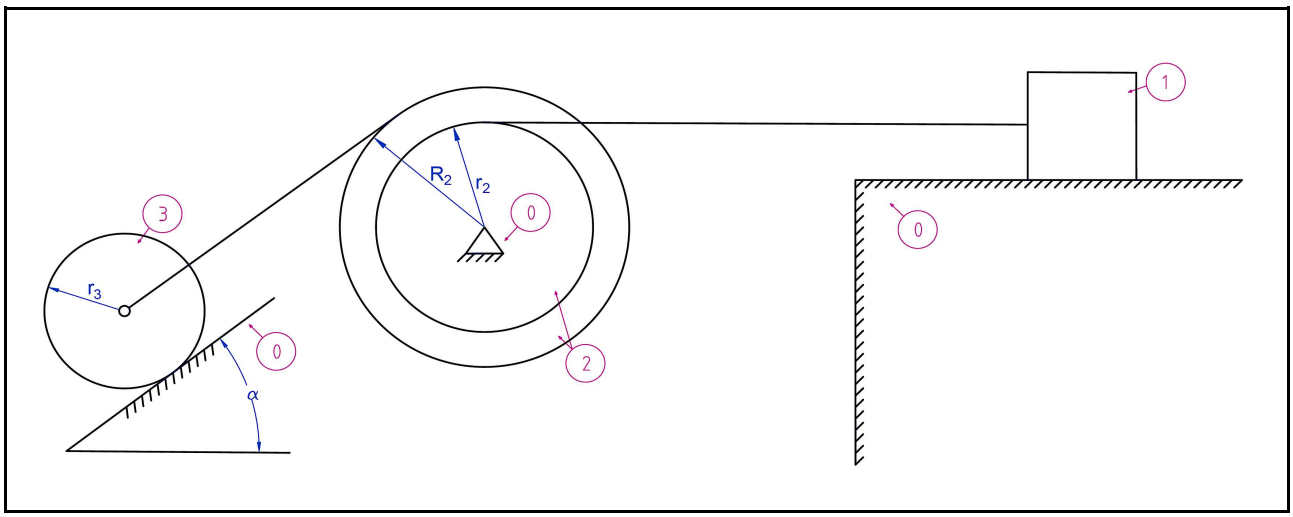
- prędkości liniowe punktów charakterystycznych.
- prędkości kątowe wszystkich członów.
- przyspieszenia liniowe punktów charakterystycznych.
- przyspieszenia kątowe wszystkich członów.

2) Parametry dynamiczne:

- reakcje we wszystkich parach kinematycznych.
- moment równoważący działanie siły, przyłożonej do suwaka.

DANE

- wymiary geometrycze wszystkich członów.
- funkcja zmiany kąta korby w czasie.
- czas położenia początkowego korby.
- prędkość kątowa korby.
- przyspieszenie kątowe korby.
- masy wszystkich członów.



Rys. 1. Dynamika układu brył sztywnych.

ZAD. 2

DANE:

$\alpha_1(t) = 0{,}1\,\bar{u}\,t^2$ [rad]

$|AB| = 0{,}5$ [m] $= 50$ [cm]

$|BC| = 1{,}4 = 140$

$|CD| = 0{,}8 = 80$

$|AD| = 1{,}0 = 100$

$|EF| = 1{,}0 = 100$

$|DE| = k \cdot |DC|$; $k = 0{,}6$

$t_1 = 2{,}8$ [s] ; $\omega_6 = 2$ [rad/s]

$\frac{l}{m} = 0{,}1$ [m/kg] $= 10$ [cm/kg]

$\bar{F} \times \bar{v}_F$

$\omega_1(t) = \alpha_1'(t) = 0{,}2\bar{u}t$ [rad/s]

$\varepsilon_1 = \omega_1'(t) = \alpha_1''(t) = 0{,}2\bar{u}$ [rad/s^2]

SZUKAM:

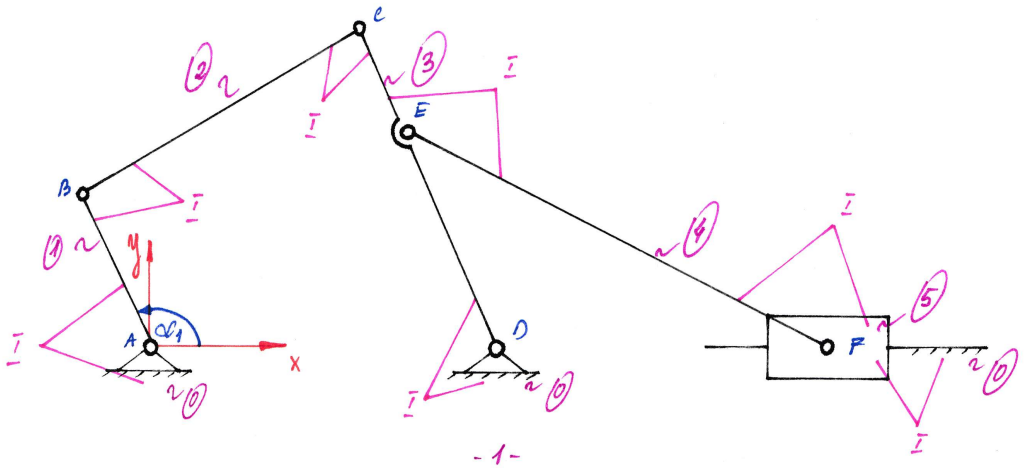
$\bar{v}, \bar{\omega} = ?$

$\bar{a}, \bar{\varepsilon} = ?$

$\bar{R} = ?$

$\bar{M} = ?$

1) SCHEMAT Z ZAZNACZENIEM WIĘZÓW:



2) Rozwiązać:

W_R:

$$W_R = W_T - W_L + W_B$$

$$W_T = 3k - 2p_1 - p_2$$

$$\begin{cases} k = 5 \\ p_1 = 7 \\ p_2 = 0 \end{cases}$$

$$\Rightarrow W_T = 3 \cdot 5 - 2 \cdot 7 - 1 \cdot 0 = 15 - 14 = 1$$

$$\Rightarrow W_T = 1$$

$$\begin{cases} W_L = 0 \\ W_B = 0 \end{cases}$$

$$\Rightarrow W_R = W_T = 1$$

jeden napęd jednoznacznie określa położenie mechanizmu.

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3) PODZIAŁKA (SKALA):

$\mathcal{K}$:)

$$K_l = \frac{\bar{l}}{(\bar{l})}$$

$$K_v = \frac{\bar{v}}{(\bar{v})}$$

$$K_a = \frac{\bar{a}}{(\bar{a})}$$

~ wielkości wektorowe przyjęte podziałce z zadania rysunk.

4) ANALIZA KINEMATYCZNA – POŁOŻENIA I TRAJEKTORIE:

α_1:)

$$\alpha_1(t) = 0{,}1\pi t^2 \qquad \{ t_1 = 2{,}8 \}$$

$$\Rightarrow \alpha_1(t_1 = 2{,}8) = 0{,}1\pi \cdot (2{,}8)^2 = 0{,}784\pi \Rightarrow \boxed{\alpha_1(t_1 = 2{,}8) = 0{,}784\pi \ [\text{rad.}]}$$

$$\left\{ \begin{aligned} \pi \ [\text{rad.}] &= 180^\circ \\ 0{,}784\pi \ [\text{rad.}] &= x^\circ \end{aligned} \right\} \Rightarrow x = \frac{0{,}784\pi \cdot 180}{\pi} = 141{,}12^\circ$$

$$\Rightarrow \boxed{\alpha_1(t_1 = 2{,}8) = 141^\circ}$$

- 3 -

$\Rightarrow |DE| = k \cdot |DC| = 0{,}6 \cdot 80 = 48 \Rightarrow \boxed{|DE| = 48 \ (cm)}$

$\Rightarrow$

$\alpha_1 = 111^\circ$
$|AB| = 50 \ (cm)$
$|BC| = 140$
$|CD| = 80$
$|EF| = 100$
$|AD| = 100$
$|DE| = 48$

$$\mathcal{H}_L = \frac{|BC|}{(|BC|)}$$

$$(|BC|) = \frac{|BC|}{\mathcal{H}_L} = \frac{140}{\mathcal{H}_L} = \left\{ \mathcal{H}_L = 20 \right\} = \frac{140}{20} = 7{,}0 \Rightarrow \boxed{(|BC|) = 7{,}0 \ (cm)}$$

$\Rightarrow$

$(|AB|) = 2{,}5 \ (cm)$
$(|BC|) = 7{,}0$
$(|CD|) = 4{,}0$
$(|EF|) = 5{,}0$
$(|AD|) = 5{,}0$
$(|DE|) = 2{,}4$

5) Analiza wektorowa - prędkości:

v_B:

$$\bar{v}_B = \bar{v}_A + \bar{v}_{BA}$$

$$\bar{v} = \bar{\omega} \cdot R$$

$$\begin{cases} \bar{v}_A = 0 \\ \bar{v}_{BA} \perp |BA| \end{cases}$$

$$\Rightarrow v_B = v_{BA} = \omega_1 \cdot |BA| = \left\{ \omega_1 = 0{,}2\pi t = 0{,}2 \cdot 3{,}14 \cdot 2{,}8 = 1{,}76 \right\} =$$

$$\Rightarrow \boxed{\omega_1 = 1{,}76 \ \left[\frac{rad}{s}\right]}$$

$$= 1{,}76 \cdot 50 = 88 \Rightarrow \boxed{\bar{v}_B = 88 \ \left[\frac{cm}{s}\right]}$$

$$\boxed{k_v = \frac{\bar{v}_B}{(\bar{v}_B)}}$$

$$\Rightarrow (\bar{v}_B) = \frac{\bar{v}_B}{k_v} = \frac{88}{k_v} = \left\{ \boxed{k_v = 20} \right\} = \frac{88}{20} = 4{,}4 \Rightarrow \boxed{\bar{v}_B = 4{,}4 \ [cm]}$$

ϑ_c:

$$\begin{cases} \bar{\vartheta}_c = \bar{\vartheta}_B + \bar{\vartheta}_{cB} \\ \bar{\vartheta}_c = \bar{\vartheta}_D^{\neq 0} + \bar{\vartheta}_{cD} \end{cases}$$

$$\bar{\vartheta}_B + \bar{\vartheta}_{cB} = \bar{\vartheta}_D^{\neq 0} + \bar{\vartheta}_{cD}$$

$$\begin{cases} \bar{\vartheta}_B = \text{const} \\ \bar{\vartheta}_{cB} \perp |cB| \\ \bar{\vartheta}_D = 0 \\ \bar{\vartheta}_{cD} \perp |cD| \end{cases}$$

odczytuję z PP:

$$\begin{cases} (\bar{\vartheta}_c) = 3{,}9 \\ (\bar{\vartheta}_{cB}) = 3{,}2 \end{cases} \quad [cm] \quad ; \quad \mu_v = 20$$

$$\Rightarrow \begin{cases} \bar{\vartheta}_c = (\bar{\vartheta}_c) \cdot \mu_v = 3{,}9 \cdot 20 = 78 \\ \bar{\vartheta}_{cB} = (\bar{\vartheta}_{cB}) \cdot \mu_v = 3{,}2 \cdot 20 = 64 \end{cases} \Rightarrow \begin{cases} \vartheta_c = 78 \\ \vartheta_{cB} = 64 \end{cases} \left[\frac{cm}{s}\right]$$

Zad. 1)

„Podobieństwo":

$$\frac{|CD|}{|cd|} = \frac{|DE|}{|de|}$$

$$|de| = \frac{|DE| \cdot |cd|}{|CD|}$$

$$|de| = \frac{|DE| \cdot |cd|}{|CD|} = \frac{48 \cdot 3,9}{80} = 2,34 \Rightarrow \boxed{|de| = 2,34 \ [cm]}$$

$$\Rightarrow \boxed{(\bar{v}_E) = 2,34 \ [cm]} \qquad \boxed{k_v = 20}$$

$$\Rightarrow \bar{v}_E = (\bar{v}_E) \cdot k_v = 2,34 \cdot 20 = 46,8 \Rightarrow \boxed{\bar{v}_E = 46,8 \ \left[\frac{cm}{s}\right]}$$

$\vec{v}_F = \vec{v}_E + \vec{v}_{FE}$

$\vec{v}_E$ = DANE

$\vec{v}_{FE}$ ⊾ |FE|

$\vec{v}_F$ = WIELKOŚĆ RZUTU

ODCZYTUJĘ Z RP:

$|(\vec{v}_F)| = 2,2$

$|(\vec{v}_{FE})| = 0,3$

[cm]

$M_v = 20$

$\Rightarrow \begin{cases} \vec{v}_F = (\vec{v}_F) \cdot M_v = 2,2 \cdot 20 = 44 \\ \vec{v}_{FE} = (\vec{v}_{FE}) \cdot M_v = 0,3 \cdot 20 = 6,0 \end{cases} \Rightarrow$

$\begin{cases} v_F = 44 \\ v_{FE} = 6,0 \end{cases}$ $\left[\frac{cm}{s}\right]$

w:

$\omega_1(t) = \alpha_1'(t) = (0{,}1\bar{1}t^2)' = 0{,}2\bar{1}t \Rightarrow$ **$\omega_1(t) = 0{,}2\bar{1}t$**

$\omega_1(t_1 = 2{,}8) = 0{,}2 \cdot 3{,}14 \cdot 2{,}8 = 1{,}76 \Rightarrow$ **$\omega_1(t_1) = 1{,}76 \ [\frac{rad}{s}]$**

$\omega_2 = \frac{\bar{v}_{cm}}{|CM|} = \frac{64}{140} = 0{,}46 \Rightarrow$ **$\omega_2 = 0{,}46$**

$\omega_3 = \frac{\bar{v}_C}{|CM|} = \frac{78}{80} = 0{,}98 \Rightarrow$ **$\omega_3 = 0{,}98$**

$\omega_4 = \frac{\bar{v}_{PE}}{|PE|} = \frac{6{,}0}{100} = 0{,}06 \Rightarrow$ **$\omega_4 = 0{,}06$**

$\omega_5 = 0 \Rightarrow$ **$\omega_5 = 0$**

6) ANALIZA KINEMATYCZNA – PRZYSPIESZENIA:

a_{B3}:

$$\bar{a}_{B3} = \bar{a}_A^{\neq 0} + \bar{a}_{BA}^{n} + \bar{a}_{BA}^{\tau}$$

$$\Downarrow$$

$$a_A = 0$$

$$a_{BA}^{n} = \omega_1^2 \cdot |BA| \quad \text{oraz} \quad \bar{a}_{BA}^{n} \parallel |BA|$$

$$a_{BA}^{\tau} = \varepsilon_1 \cdot |BA| \quad \text{oraz} \quad \bar{a}_{BA}^{\tau} \perp |BA|$$

$$\Downarrow$$

$$\Rightarrow \quad a_{BA}^{n} = \omega_1^2 \cdot |BA| = (1{,}76)^2 \cdot 50 = 154{,}88 \quad \Rightarrow \quad \boxed{a_{BA}^{n} = 154{,}88 \ \left[\frac{cm}{s^2}\right]}$$

$$a_{BA}^{\tau} = \varepsilon_1 \cdot |BA| = 0{,}63 \cdot 50 = 31{,}5 \quad \Rightarrow \quad \boxed{a_{BA}^{\tau} = 31{,}5 \ \left[\frac{cm}{s^2}\right]}$$

$$\Rightarrow \quad a_{B3} = \sqrt{(a_{BA}^{n})^2 + (a_{BA}^{\tau})^2} = \sqrt{(154{,}88)^2 + (31{,}5)^2} = 158{,}05$$

$$\Rightarrow \quad \boxed{a_{B3} = 158{,}05 \ \left[\frac{cm}{s^2}\right]}$$

$$k_a = \frac{\bar{\sigma}_{ks}}{(\bar{\sigma}_{ks})}$$

$$\Rightarrow (\bar{\sigma}_{ks}) = \frac{\bar{\sigma}_{ks}}{k_a} = \frac{158{,}05}{k_a} = \left\{ k_a = 20 \right\} = \frac{158{,}05}{20} = 7{,}9$$

$$\Rightarrow \boxed{(\bar{\sigma}_{ks}) = 7{,}9 \ (cm)}$$

$$\Rightarrow (\bar{\sigma}^{u}_{ksA}) = \frac{\bar{\sigma}^{u}_{ksA}}{k_a} = \frac{154{,}88}{20} = 7{,}74 \Rightarrow \boxed{(\bar{\sigma}^{u}_{ksA}) = 7{,}74 \ (cm)}$$

$$\Rightarrow (\bar{\sigma}^{\tau}_{ksA}) = \frac{\bar{\sigma}^{\tau}_{ksA}}{k_a} = \frac{31{,}5}{20} = 1{,}58 \Rightarrow \boxed{(\bar{\sigma}^{\tau}_{ksA}) = 1{,}58 \ (cm)}$$

a_C :)

$$\begin{cases} \bar{a}_C = \bar{a}_{OB} + \bar{a}^{n}_{CB} + \bar{a}^{\tau}_{CB} \\ \bar{a}_C = \bar{a}_{OD} \neq 0 + \bar{a}^{n}_{CD} + \bar{a}^{\tau}_{CD} \end{cases}$$

$$\Downarrow$$

$$\bar{a}_{OB} + \bar{a}^{n}_{CB} + \bar{a}^{\tau}_{CB} = \bar{a}_{OD} \neq 0 + \bar{a}^{n}_{CD} + \bar{a}^{\tau}_{CD}$$

$$\Downarrow$$

a_{OB} = DANE

$a^{n}_{CB} = \omega_2^2 \cdot |CB|$ ZWRÓT $\bar{a}^{n}_{CB} \parallel |CB|$

$a^{\tau}_{CB} = \varepsilon_2 \cdot |CB|$ ZWRÓT $a^{\tau}_{CB} \perp |CB|$

$a_D = 0$

$a^{n}_{CD} = \omega_3^2 \cdot |CD|$ ZWRÓT $a^{n}_{CD} \parallel |CD|$

$a^{\tau}_{CD} = \varepsilon_3 \cdot |CD|$ ZWRÓT $a^{\tau}_{CD} \perp |CD|$

$$\Rightarrow a^{n}_{CB} = \omega_2^2 \cdot |CB| = (0{,}46)^2 \cdot 140 = 29{,}62 \Rightarrow \boxed{a^{n}_{CB} = 29{,}62 \ \left[\frac{cm}{s^2}\right]}$$

$$\Rightarrow a^{n}_{CD} = \omega_3^2 \cdot |CD| = (0{,}98)^2 \cdot 80 = 76{,}83 \Rightarrow \boxed{a^{n}_{CD} = 76{,}83 \ \left[\frac{cm}{s^2}\right]}$$

$$\Rightarrow \begin{cases} \bar{a}_{cs}^{u} = 29,62 \\ \bar{a}_{cs}^{u} = 76,83 \end{cases} \left[\frac{cm}{s^2}\right] \qquad Ka = 20$$

$$\Rightarrow \begin{cases} (\bar{a}_{cs}^{u}) = \dfrac{\bar{a}_{cs}^{u}}{Ka} = \dfrac{29,62}{20} = 1,48 \\ (\bar{a}_{cs}^{u}) = \dfrac{\bar{a}_{cs}^{u}}{Ka} = \dfrac{76,83}{20} = 3,84 \end{cases} \Rightarrow \begin{cases} (\bar{a}_{cs}^{u}) = 1,48 \\ (\bar{a}_{cs}^{u}) = 3,84 \end{cases} [cm]$$

ODCZYTUJĘ Z WP:

$$\begin{cases} (\bar{a}_{cs}^{\tau}) = 3,2 \\ (\bar{a}_{cs}^{i}) = 2,15 \\ (\bar{a}_{c}) = 4,35 \end{cases} [cm] \qquad Ka = 20$$

$$\Rightarrow \begin{cases} \bar{a}_{cs}^{\tau} = (\bar{a}_{cs}^{\tau}) \cdot Ka = 3,2 \cdot 20 = 64 \\ \bar{a}_{cs}^{\tau} = (\bar{a}_{cs}^{i}) \cdot Ka = 2,15 \cdot 20 = 43 \\ \bar{a}_{c} = (\bar{a}_{c}) \cdot Ka = 4,35 \cdot 20 = 87 \end{cases} \Rightarrow \begin{cases} \bar{a}_{cs}^{i} = 64 \\ \bar{a}_{cs}^{i} = 43 \\ \bar{a}_{c} = 87 \end{cases} \left[\frac{cm}{s^2}\right]$$

a_E:

„Podobieństwo":

$$\frac{|CD|}{|cd|} = \frac{|DE|}{|de|}$$

$$|de| = \frac{|DE| \cdot |cd|}{|CD|}$$

$$|de| = \frac{|DE| \cdot |cd|}{|CD|} = \frac{48 \cdot 4,35}{80} = 2,61 \Rightarrow |de| = 2,61 \ (1\ cm)$$

$$\Rightarrow (\bar{a}_E) = 2,61 \ (1\ cm) \qquad n_a = 20$$

$$\Rightarrow \bar{a}_E = (\bar{a}_E) \cdot n_a = 2,61 \cdot 20 = 52,2 \Rightarrow \bar{a}_E = 52,2 \ \left[\frac{cm}{s^2}\right]$$

a_F:

$$\bar{a}_F = \bar{a}_B + \bar{a}_{FE}^n + \bar{a}_{FE}^\tau$$

a_B = dane

$a_{FE}^n = \omega_4^2 \cdot |FE|$ oraz $\bar{a}_{FE}^n \parallel |FE|$

$a_{FE}^\tau = \varepsilon_4 \cdot |FE|$ oraz $a_{FE}^\tau \perp |FE|$

a_F = wielkość szukana

$$\Rightarrow a_{FE}^n = \omega_4^2 \cdot |FE| = (0{,}06)^2 \cdot 100 = 0{,}36$$

$$\Rightarrow a_{FE}^n = 0{,}36 \ \left[\frac{cm}{s^2}\right]$$

odmierzamy z PP:

$$\begin{cases} (\bar{a}_{FE}^\tau) = 2{,}2 \\ (\bar{a}_F) = 2{,}25 \end{cases} \ [cm]$$

$$k_a = 20$$

$$\Rightarrow \begin{cases} \bar{a}_{FE}^\tau = (\bar{a}_{FE}^\tau) \cdot k_a = 2{,}2 \cdot 20 = 44 \\ \bar{a}_F = (\bar{a}_F) \cdot k_a = 2{,}25 \cdot 20 = 45 \end{cases} \Rightarrow \begin{cases} \bar{a}_{FE}^\tau = 44 \\ \bar{a}_F = 45 \end{cases} \ \left[\frac{cm}{s^2}\right]$$

-//-

ε:

$\varepsilon_1(t) = \omega_1'(t) = \alpha_1''(t) = 0{,}2\bar{\pi}$ ⇝

$\varepsilon_1(t) = 0{,}2\bar{\pi}$

$\varepsilon_1(t_1 = 2{,}8) = 0{,}2 \cdot 3{,}14 = 0{,}63$ ⇝

$\varepsilon_1(t_1 = 2{,}8) = 0{,}63 \left[\frac{\text{rad.}}{s^2}\right]$

$\varepsilon_2 = \frac{Q_{EB}^{\bar{T}}}{|CB|} = \frac{64}{140} = 0{,}46$ ⇝

$\varepsilon_2 = 0{,}46$

$\varepsilon_3 = \frac{Q_{ED}^{\bar{T}}}{|CD|} = \frac{43}{80} = 0{,}54$ ⇝

$\varepsilon_3 = 0{,}54$

$\varepsilon_4 = \frac{Q_{PE}^{\bar{T}}}{|PE|} = \frac{44}{100} = 0{,}44$ ⇝

$\varepsilon_4 = 0{,}44$

$\varepsilon_5 = 0$ ⇝

$\varepsilon_5 = 0$

4) ANALIZA OBCIĄŻENIA - MECHANIZM WOLNOBIEŻNY:

5:

$$\sum F_{i(5)} = 0$$

$$\bar{F}_5 + \bar{R}_{05} + \bar{R}_{45} = 0$$

4:

$$\sum F_{i(4)} = 0$$

$$\bar{R}_{54} + \bar{R}_{34}^{N} + \bar{R}_{34}^{T} = 0$$

5,4:

$$\bar{F}_5 + \bar{R}_{05} + \bar{R}_{45} + \bar{R}_{54} + \bar{R}_{34}^{N} + \bar{R}_{34}^{T} = 0$$

$$\Rightarrow \quad \bar{R}_{34}^{N} + \bar{R}_{34}^{T} + \bar{F}_5 + \bar{R}_{05} = 0$$

F:)

$$\sum M_{i(F)} = 0$$

$$-\bar{R}_{zu}^{\tau} \cdot |EF| = 0$$

$$\bar{R}_{zu}^{\tau} = 0$$

$$\rightarrow \quad \bar{R}_{zu}^{n} + \bar{R}_{zu}^{\tau} + \bar{F}_5 + \bar{R}_{o5} = 0$$

$$F_5 = m_5 \cdot a_5 = 2 \cdot 0{,}45 = 0{,}9 \quad \rightarrow \quad F_5 = 0{,}9 \ [N]$$

$$\gamma_F = \frac{\bar{F}_5}{(\bar{F}_5)}$$

$$(\bar{F}_5) = \frac{\bar{F}_5}{\gamma_F} = \frac{0{,}9}{\gamma_F} = \left\{ \gamma_F = 0{,}2 \right\} = \frac{0{,}9}{0{,}2} = 4{,}5 \quad \rightarrow \quad (\bar{F}_5) = 4{,}5 \ [cm]$$

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odczyt z PF:

$(\bar{R}_{o5}) = 2,55$

$(\bar{R}_{zu}^{u}) = 5,15$ (1 cm)

$\mu_F = 0,2$

$\Rightarrow \bar{R}_{o5} = (\bar{R}_{o5}) \cdot \mu_F = 2,55 \cdot 0,2 = 0,51 \Rightarrow \bar{R}_{o5} = 0,51$ (N)

$\Rightarrow \bar{R}_{zu}^{u} = (\bar{R}_{zu}^{u}) \cdot \mu_F = 5,15 \cdot 0,2 = 1,03 \Rightarrow \bar{R}_{zu}^{u} = 1,03$ (N)

3:

$\sum F_{i(3)} = 0 \Rightarrow \bar{R}_{o3}^{u} + \bar{R}_{o3}^{\tau} + \bar{R}_{13} + \bar{R}_{23} = 0$

2:

$\sum F_{i(2)} = 0 \Rightarrow \bar{R}_{12}^{u} + \bar{R}_{12}^{\tau} + \bar{R}_{32} = 0$

3,2:

$\bar{R}_{o3}^{u} + \bar{R}_{o3}^{\tau} + \bar{R}_{13} + \bar{R}_{23} + \bar{R}_{32} + \bar{R}_{12}^{u} + \bar{R}_{12}^{\tau} = 0$

$\Rightarrow \bar{R}_{o3}^{u} + \bar{R}_{o3}^{\tau} + \bar{R}_{13} + \bar{R}_{12}^{\tau} + \bar{R}_{12}^{u} = 0$

3:)

$$\sum M_{i(C)}^{3} = 0 \rightarrow R_{oz}^{\tilde{T}} \cdot |CS| - R_{43} \cdot h_1 = 0$$

odczytuję:

$$(h_1) = 1{,}3 \ (cm) \qquad \mathcal{H} = 20$$

$$h_1 = (h_1) \cdot \mathcal{H} = 1{,}3 \cdot 20 = 26 \rightarrow h_1 = 0{,}26 \ (m)$$

$$R_{oz}^{\tilde{T}} = R_{43} \cdot \frac{h_1}{|CS|}$$

$$R_{oz}^{\tilde{T}} = R_{43} \cdot \frac{h_1}{|CS|} = 1{,}03 \cdot \frac{0{,}26}{0{,}8} = 1{,}03 \cdot 0{,}325 = 0{,}335$$

$$\rightarrow R_{oz}^{\tilde{T}} = 0{,}335 \ (U)$$

2)

$$\sum M_{i(C)}^{2} = 0 \Rightarrow \quad \bar{R}_{12}^{\tau} \cdot |BC| = 0$$

$$\Downarrow$$

$$\bar{R}_{12}^{\tau} = 0$$

$$\Downarrow$$

3;2:)

$$\bar{R}_{03}^{n} + \bar{R}_{03}^{\tau} + \bar{R}_{13} + \bar{R}_{12}^{\tau} + \bar{R}_{12}^{n} = 0$$

$$\begin{cases} \bar{R}_{03}^{\tau} = 0{,}34 \\ \bar{R}_{13} = 1{,}08 \end{cases} \quad [N]$$

$$\mu_F = 0{,}2$$

$$\Rightarrow \quad (\bar{R}_{03}^{\tau}) = \frac{\bar{R}_{03}^{\tau}}{\mu_F} = \frac{0{,}34}{0{,}2} = 1{,}7 \quad \Rightarrow \quad (\bar{R}_{03}^{\tau}) = 1{,}7 \ [cm]$$

$$\Rightarrow \quad (\bar{R}_{13}) = \frac{\bar{R}_{13}}{\mu_F} = \frac{1{,}08}{0{,}2} = 5{,}15 \quad \Rightarrow \quad (\bar{R}_{13}) = 5{,}15 \ [cm]$$

odczytuję z PF:

$(\bar{R}_{12}^{u}) = 2,6$

$(\bar{R}_{03}^{u}) = 3,6$ [cm]

$(\bar{R}_{03}) = 4,0$

$M_F = 20$

$\bar{R}_{12}^{u} = (\bar{R}_{12}^{u}) \cdot M_F = 2,6 \cdot 20 = 52 \Rightarrow \bar{R}_{12}^{u} = 52$ [N]

$\bar{R}_{03}^{u} = (\bar{R}_{03}^{u}) \cdot M_F = 3,6 \cdot 20 = 72 \Rightarrow \bar{R}_{03}^{u} = 72$ [N]

$\bar{R}_{03} = (\bar{R}_{03}) \cdot M_F = 4,0 \cdot 20 = 80 \Rightarrow R_{03} = 80$ [N]

1:

$\sum F_{i(1)} = 0 \Rightarrow \bar{R}_{21} + \bar{R}_{01} = 0 \Rightarrow R_{21} = R_{01} = R_{12} = R_{12}^{u} = 52$ [N]

$\sum M_{i(1)} = 0 \Rightarrow M = F \cdot r \Rightarrow M_1 = R_{12} \cdot h_2 = 52 \cdot 0,44$

$(h_2) = 2,2$ [cm] $\quad M_L = 20$

$h_2 = (h_2) \cdot M_L = 2,2 \cdot 20 = 44 \Rightarrow h_2 = 0,44$ [m]

$\Rightarrow M_1 = 22,88$ [Nm]