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 KINEMATYCZNA MECHANIZMÓW PŁASKICH

PROJEKT

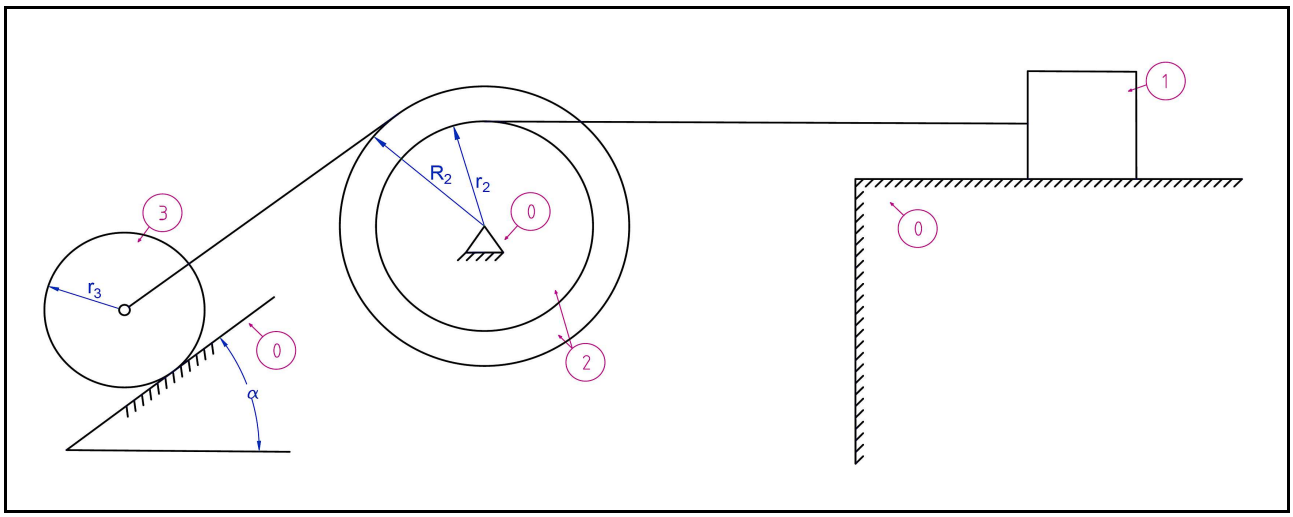
Dla zadanej struktury mechanizmu płaskiego, znaleźć:

1) Parametry kinematyczne:

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

DANE

- wymiary geometryczne wszystkich członów.
- położenie początkowe korby.
- prędkość kątowa korby.



Rys. 1. Dynamika układu brył sztywnych.

ZAD. 2

DANE:

$|O_1A| = 21$ $a = 56$ (1 cm)

$|O_2B| = 25$ $b = 10$

$|O_3F| = 20$ $c = 26$

$|AB| = 54$ $d = 16$

$|BC| = 52$ $e = 25$

$|CD| = 69$

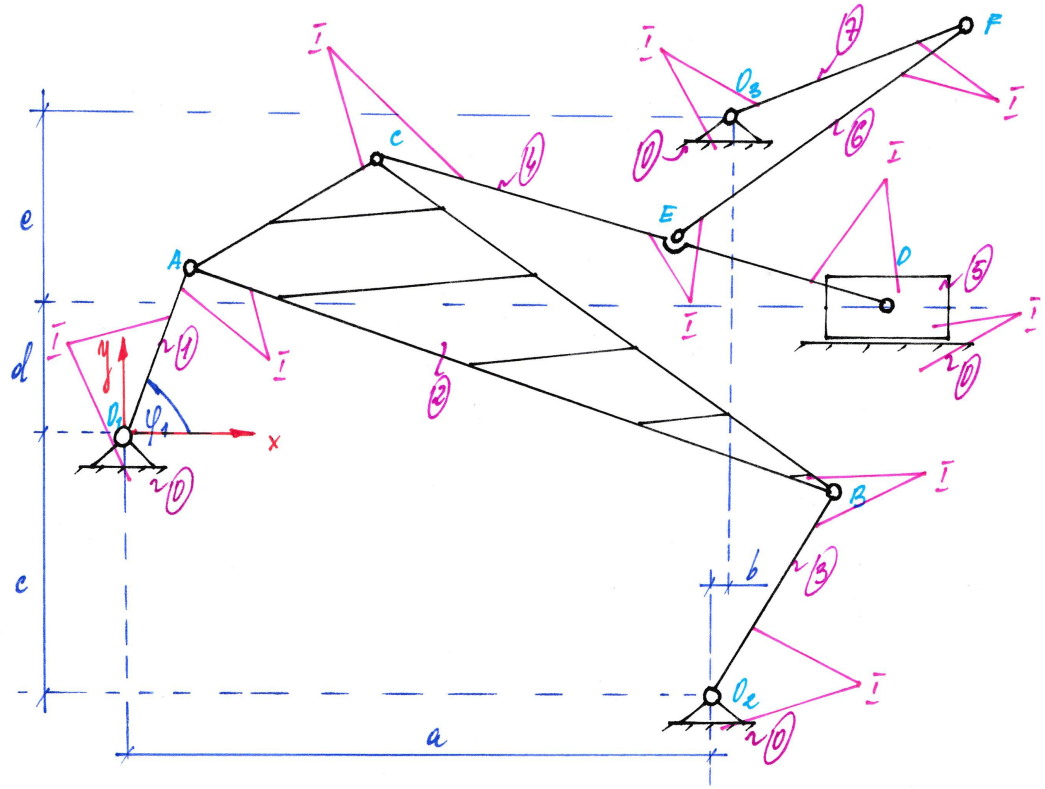
$|CE| = 35$ $\varphi_1 = 60°$; $\omega_1 = 2\ [\frac{rad}{s}]$

$|EF| = 32$ $|AC| = \frac{1}{3}|CD| = 23$

ROZWIĄZANIE:

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

1) SCHEMAT I ROZWIĄZANIE GRAFICZNE:



k) ruchliwość:

$$W_R = W_T - W_L + W_B$$

⇓

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

$$\left\{ \begin{array}{l} k = 7 \\ p_1 = 10 \\ p_2 = 0 \end{array} \right\}$$

$$\Rightarrow W_T = 3 \cdot 7 - 2 \cdot 10 = 21 - 20 = 1$$

$$\Rightarrow W_T = 1$$

$$\left\{ \begin{array}{l} W_L = 0 \\ W_B = 0 \end{array} \right\}$$

$$\Rightarrow W_R = W_T = 1$$

jeden napęd jednoznacznie określa położenie mechanizmu.

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3) PODZIAŁKA (SKALA):

$$\mathcal{H}_l = \frac{\bar{l}}{(\bar{l})}$$

$$\mathcal{H}_v = \frac{\bar{v}}{(\bar{v})}$$

$$\mathcal{H}_a = \frac{\bar{a}}{(\bar{a})}$$

- kreślę mechanizm i podaję podziałkę i przyjęte liczby.

4) ANALIZA KINEMATYCZNA - PRĘDKOŚĆ I PRZYSPIESZENIE:

$$\mathcal{H}_l = \frac{\bar{l}}{(\bar{l})}$$

$$\mathcal{H}_l = \frac{|CD|}{(|CD|)} \Rightarrow (|CD|) = \frac{|CD|}{\mathcal{H}_l} = \frac{69}{\mathcal{H}_l} = \left\{ \boxed{\mathcal{H}_l = 10} \right\} = \frac{69}{10} = 6{,}9$$

$$\Rightarrow \boxed{(|CD|) = 6{,}9 \text{ [cm]}}$$

$$\Rightarrow \quad (|O_1A|) = \frac{|O_1A|}{M_L} = \frac{21}{10} = 2{,}1 \quad \Rightarrow \quad (|O_1A|) = 21 \text{ [cm]}$$

$$(|O_2B|) = \frac{|O_2B|}{M_L} = \frac{25}{10} = 2{,}5 \quad \Rightarrow \quad (|O_2B|) = 2{,}5$$

$$(|O_3F|) = \frac{|O_3F|}{M_L} = \frac{20}{10} = 2{,}0 \quad \Rightarrow \quad (|O_3F|) = 2{,}0$$

$$(|AB|) = \frac{|AB|}{M_L} = \frac{54}{10} = 5{,}4 \quad \Rightarrow \quad (|AB|) = 5{,}4$$

$$(|BC|) = \frac{|BC|}{M_L} = \frac{52}{10} = 5{,}2 \quad \Rightarrow \quad (|BC|) = 5{,}2$$

$$(|CD|) = \frac{|CD|}{M_L} = \frac{69}{10} = 6{,}9 \quad \Rightarrow \quad (|CD|) = 6{,}9$$

$$(|CE|) = \frac{|CE|}{M_L} = \frac{35}{10} = 3{,}5 \quad \Rightarrow \quad (|CE|) = 3{,}5$$

$$(|EF|) = \frac{|EF|}{M_L} = \frac{32}{10} = 3{,}2 \quad \Rightarrow \quad (|EF|) = 3{,}2$$

$$(|AC|) = \frac{|AC|}{M_L} = \frac{23}{10} = 2{,}3 \quad \Rightarrow \quad (|AC|) = 2{,}3$$

$a = 5{,}6 \qquad b = 1{,}0 \qquad c = 2{,}6 \qquad d = 1{,}6 \qquad e = 2{,}5$

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5) ANALIZA KINEMATYCZNA – PRĘDKOŚCI:

ϑ_A:

$$\bar{\vartheta}_A = \bar{\vartheta}_{O_1} + \bar{\vartheta}_{AO_1}, \quad \bar{\vartheta}_{O_1} \neq 0$$

$$\vartheta = \omega \cdot R$$

$$\vartheta_{AO_1} \perp |AO_1|$$

$$\vartheta_A = \vartheta_{AO_1} = \omega_1 \cdot |AO_1| = 2 \cdot 21 = 42$$

$$\Rightarrow \vartheta_A = 42 \left[\frac{cm}{s}\right]$$

$$H_v = \frac{\bar{\vartheta}_A}{(\bar{\vartheta}_A)}$$

$$H_v = \frac{\bar{\vartheta}_A}{(\bar{\vartheta}_A)} \Rightarrow (\bar{\vartheta}_A) = \frac{\bar{\vartheta}_A}{H_v} = \frac{42}{H_v} = \left\{ H_v = 10 \right\} = 4{,}2$$

$$\Rightarrow (\vartheta_A) = 4{,}2 \ [cm]$$

$\vec{v}_S$; $\vec{v}_{SA}$; $\vec{v}_{SO_2}$:

$$\begin{cases} \vec{v}_S = \vec{v}_A + \vec{v}_{SA} \\ \vec{v}_S = \vec{v}_{O_2} \neq 0 + \vec{v}_{SO_2} \end{cases}$$

$$\Downarrow$$

$$\vec{v}_A + \vec{v}_{SA} = \vec{v}_{O_2} + \vec{v}_{SO_2}$$

$$\begin{cases} \vec{v}_A = \text{DANE} \\ \vec{v}_{SA} \parallel |SA| \\ \vec{v}_{O_2} = 0 \\ \vec{v}_{SO_2} \parallel |SO_2| \end{cases}$$

$$\Downarrow$$

odczytuję z rys.:

$$\begin{cases} (\vec{v}_{SA}) = 1{,}6 \\ (\vec{v}_{SO_2}) = (\vec{v}_S) = 4{,}25 \end{cases} \quad [\text{cm}]$$

$$k_v = 10$$

$$\rightarrow \begin{cases} \vec{v}_{SA} = (\vec{v}_{SA}) \cdot k_v = 1{,}6 \cdot 10 = 16 \\ \vec{v}_S = (\vec{v}_S) \cdot k_v = 4{,}25 \cdot 10 = 42{,}5 \end{cases} \rightarrow \begin{cases} v_{SA} = 16 \\ v_S = 42{,}5 \end{cases} \left[\frac{\text{cm}}{\text{s}}\right]$$

v_C; v_{CA}; v_{CB}:

$$\begin{cases} \bar{v}_C = \bar{v}_A + \bar{v}_{CA} \\ \bar{v}_C = \bar{v}_B + \bar{v}_{CB} \end{cases}$$

$$\bar{v}_A + \bar{v}_{CA} = \bar{v}_B + \bar{v}_{CB}$$

$\bar{v}_A$ = DANE

$\bar{v}_{CA} \perp |CA|$

$\bar{v}_B$ = DANE

$\bar{v}_{CB} \perp |CB|$

obrazuję zad:

$(\bar{v}_C) = 3{,}7$

$(\bar{v}_{CB}) = 1{,}5$ [cm]

$(\bar{v}_{CA}) = 0{,}6$

$k_v = 10$

$$\rightarrow \begin{cases} \bar{v}_C = (\bar{v}_C) \cdot k_v = 3{,}7 \cdot 10 = 37 \\ \bar{v}_{CB} = (\bar{v}_{CB}) \cdot k_v = 1{,}5 \cdot 10 = 15 \\ \bar{v}_{CA} = (\bar{v}_{CA}) \cdot k_v = 0{,}6 \cdot 10 = 6{,}0 \end{cases} \rightarrow \begin{cases} v_C = 37 \\ v_{CB} = 15 \\ v_{CA} = 6{,}0 \end{cases} \left[\frac{cm}{s}\right]$$

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$\vec{v_D}$:

$$\vec{v_D} = \vec{v_C} + \vec{v_{DC}}$$

$\vec{v_D}$ = WEKTOR PRĘDKOŚCI

$\vec{v_C}$ = DANE

$\vec{v_{DC}}$ ⊥ DC

odczytuję z rys:

$|(\vec{v_D})| = 3{,}8$ [cm]

$|(\vec{v_{DC}})| = 1{,}95$ [cm]

$k_v = 10$

$$\Rightarrow \begin{cases} \vec{v_D} = (\vec{v_D}) \cdot k_v = 3{,}8 \cdot 10 = 38 \\ (\vec{v_{DC}}) = (\vec{v_{DC}}) \cdot k_v = 1{,}95 \cdot 10 = 19{,}5 \end{cases} \Rightarrow \begin{cases} v_D = 38 \\ v_{DC} = 19{,}5 \end{cases} \left[\frac{cm}{s}\right]$$

$\vec{v}_E$:

$$\begin{cases} \vec{v}_E = \vec{v}_C + \vec{v}_{EC} \\ \vec{v}_E = \vec{v}_D + \vec{v}_{ED} \end{cases}$$

$$\vec{v}_C + \vec{v}_{EC} = \vec{v}_D + \vec{v}_{ED}$$

$$\begin{cases} \vec{v}_C = \text{DANE} \\ \vec{v}_{EC} \perp |EC| \\ \vec{v}_D = \text{DANE} \\ \vec{v}_{ED} \perp |ED| \end{cases}$$

ZASADA PODOBIEŃSTWA

$$\frac{|CD|}{|cd|} = \frac{|CE|}{|ce|} \Rightarrow |ce| = \frac{|CE| \cdot |cd|}{|CD|}$$

$$\begin{cases} |CE| = 35 \\ |CD| = 69 \\ |cd| = 1{,}95 \end{cases} \Rightarrow |ce| = \frac{35 \cdot 1{,}95}{69} = 0{,}99 \Rightarrow \boxed{|ce| = 0{,}99\ [cm]}$$

ODCZYT Z MP: $\Rightarrow \boxed{(\vec{v}_E) = 3{,}6\ [cm]}$; $\boxed{\vec{v}_E = (\vec{v}_E) \cdot k_v = 3{,}6 \cdot 10 = 36\ \left[\frac{cm}{s}\right]}$

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v_F:

$$\begin{cases} \bar{v}_F = \bar{v}_E + \bar{v}_{FE} \\ \bar{v}_F = \bar{v}_{O_3} + \bar{v}_{FO_3} \end{cases}$$

$$\bar{v}_E + \bar{v}_{FE} = \bar{v}_{O_3} + \bar{v}_{FO_3}$$

v_E = DANE

$v_{FE} \perp |PE|$

$v_{O_3} = 0$

$v_{FO_3} \perp |FO_3|$

odkładamy z PP.

$$\begin{cases} (\bar{v}_F) = 5{,}0 \\ (\bar{v}_{FE}) = 6{,}8 \end{cases} \quad [cm]$$

$k_v = 10$

$$\Rightarrow \begin{cases} \bar{v}_F = (\bar{v}_F) \cdot k_v = 5{,}0 \cdot 10 = 50 \\ \bar{v}_{FE} = (\bar{v}_{FE}) \cdot k_v = 6{,}8 \cdot 10 = 68 \end{cases} \Rightarrow \begin{cases} v_F = 50 \\ v_{FE} = 68 \end{cases} \left[\frac{cm}{s}\right]$$

w:

$\omega_1 = 2 \quad [\frac{rad}{s}] \Rightarrow \omega_1 = 2,0$

$\omega_2 = \frac{v_{BA}}{|BA|} = \frac{16}{54} = 0,29 \Rightarrow \omega_2 = 0,29 \quad [\frac{rad}{s}]$

$\omega_3 = \frac{v_B}{|BO_2|} = \frac{42,5}{25} = 1,7 \Rightarrow \omega_3 = 1,7$

$\omega_4 = \frac{v_{DC}}{|DC|} = \frac{19,5}{69} = 0,28 \Rightarrow \omega_4 = 0,28$

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

$\omega_6 = \frac{v_{FE}}{|FE|} = \frac{68}{32} = 2,13 \Rightarrow \omega_6 = 2,13$

$\omega_7 = \frac{v_F}{|FO_3|} = \frac{50}{20} = 2,5 \Rightarrow \omega_7 = 2,5$

6) ANALIZA KINEMATYCZNA – PRZYPADEK OGÓLNY:

a_A:

$$\bar{a}_A = \bar{a}_{O_1} + \bar{a}_{AP_1}^{n} + \bar{a}_{AP_1}^{\tau}$$

$$a_{O_1} = 0$$

$$a_{AO_1}^{n} = \omega_1^2 \cdot |AP_1| \qquad a_A : \; a_{AP_1}^{n} \parallel |AP_1|$$

$$a_{AO_1}^{\tau} = \varepsilon_1 \cdot |AP_1| \qquad a_A : \; a_{AP_1}^{\tau} \perp |AP_1|$$

$$a_{AP_1}^{n} = \omega_1^2 \cdot |AP_1| = 2^2 \cdot 21 = 81 \;\Rightarrow\; a_{AP_1}^{n} = 81 \left[\frac{cm}{s^2}\right]$$

$$a_{AP_1}^{\tau} = \varepsilon_1 \cdot |AP_1| = 0 \cdot 21 = 0 \;\Rightarrow\; a_{AP_1}^{\tau} = 0$$

$$\bar{a}_A = \bar{a}_{AO_1}^{n} + \bar{a}_{AP_1}^{\tau}$$

$$a_A = \sqrt{\left(a_{AP_1}^{n}\right)^2 + \left(a_{AP_1}^{\tau}\right)^2}$$

$$\Rightarrow \quad a_A = \sqrt{(81)^2 + 0^2} = 81 \quad \Rightarrow \quad a_A = 81 \left[\frac{cm}{s^2}\right]$$

$$\Rightarrow \quad \boxed{a_{mA} = 81 \ \left[\frac{cm}{s^2}\right]}$$

$$\boxed{k_a = \frac{\bar{a}}{(\bar{a})}}$$

$$\downarrow$$

$$k_a = \frac{\bar{a}_{mA}}{(\bar{a}_{mA})} \Rightarrow (\bar{a}_{mA}) = \frac{\bar{a}_{mA}}{k_a} = \frac{81}{k_a} = \left\{ \boxed{k_a = 20} \right\} =$$

$$= \frac{81}{20} = 4{,}05 \Rightarrow \boxed{(\bar{a}_{mA}) = 4{,}05 \ [cm]}$$

a_B; a_{BA}^{τ}; $a_{BO_2}^{\tau}$:

$$\bar{a}_B = \bar{a}_A + \bar{a}_{BA}^{n} + \bar{a}_{BA}^{\tau}$$

$$\bar{a}_B = \bar{a}_{O_2} + \bar{a}_{BO_2}^{n} + \bar{a}_{BO_2}^{\tau}$$

$$\bar{a}_A + \bar{a}_{BA}^{n} + \bar{a}_{BA}^{\tau} = \bar{a}_{O_2} \neq 0 + \bar{a}_{BO_2}^{n} + \bar{a}_{BO_2}^{\tau}$$

a_A = DANE

$a_{BA}^{n} = \omega_2^2 \cdot |BA|$ ZWROT: $a_{BA}^{n} \parallel |BA|$

$a_{BA}^{\tau} = \varepsilon_2 \cdot |BA|$ ZWROT: $a_{BA}^{\tau} \perp |BA|$

$a_{O_2} = 0$

$a_{BO_2}^{n} = \omega_3^2 \cdot |BO_2|$ ZWROT: $a_{BO_2}^{n} \parallel |BO_2|$

$a_{BO_2}^{\tau} = \varepsilon_3 \cdot |BO_2|$ ZWROT: $a_{BO_2}^{\tau} \perp |BO_2|$

$$\Rightarrow \begin{cases} a_{BA}^{n} = \omega_2^2 \cdot |BA| = (0{,}29)^2 \cdot 54 = 4{,}54 \\ a_{BO_2}^{n} = \omega_3^2 \cdot |BO_2| = (1{,}7)^2 \cdot 25 = 72{,}25 \end{cases} \Rightarrow \begin{cases} a_{BA}^{n} = 4{,}54 \ \left[\frac{cm}{s^2}\right] \\ a_{BO_2}^{n} = 72{,}25 \end{cases}$$

$$\Rightarrow \begin{cases} \sigma_{rsA}^{n} = 4{,}54 \quad [\frac{cm}{s^2}] \\ \sigma_{rsO_2}^{n} = 72{,}25 \end{cases}$$

$$k_2 = 20$$

$$\Rightarrow (\bar{\sigma}_{rsA}^{n}) = \frac{\sigma_{rsA}^{n}}{k_2} = \frac{4{,}54}{20} = 0{,}23 \Rightarrow \sigma_{rsA}^{u} = 0{,}23 \ (cm)$$

$$(\bar{\sigma}_{rsO_2}^{n}) = \frac{\sigma_{rsO_2}^{n}}{k_2} = \frac{72{,}25}{20} = 3{,}61 \Rightarrow \sigma_{rsO_2}^{n} = 3{,}61$$

odczytuję z PP:

$$\begin{cases} (\bar{\sigma}_{rsA}^{\tau}) = 0{,}1 \\ (\bar{\sigma}_{rsO_2}^{\tau}) = 1{,}65 \quad (cm) \\ (\bar{\sigma}_{rs}) = 4{,}1 \end{cases}$$

$$k_2 = 20$$

$$\Rightarrow \begin{cases} \bar{\sigma}_{rsA}^{\tau} = (\bar{\sigma}_{rsA}^{\tau}) \cdot k_2 = 0{,}1 \cdot 20 = 2{,}0 \\ \bar{\sigma}_{rsO_2}^{\tau} = (\bar{\sigma}_{rsO_2}^{\tau}) \cdot k_2 = 1{,}65 \cdot 20 = 33 \\ \bar{\sigma}_{rs} = (\bar{\sigma}_{rs}) \cdot k_2 = 4{,}1 \cdot 20 = 82 \end{cases} \Rightarrow \begin{cases} \sigma_{rsA}^{\tau} = 2{,}0 \\ \sigma_{rsO_2}^{\tau} = 33 \quad [\frac{cm}{s^2}] \\ \sigma_{rs} = 82 \end{cases}$$

a_c :)

$$\begin{cases} \bar{a}_c = \bar{a}_A + \bar{a}_{cA}^{\,n} + \bar{a}_{cA}^{\,\tau} \\ \bar{a}_c = \bar{a}_{rs} + \bar{a}_{rs}^{\,n} + \bar{a}_{rs}^{\,\tau} \end{cases}$$

$$\Downarrow$$

$$\bar{a}_A + \bar{a}_{cA}^{\,n} + \bar{a}_{cA}^{\,\tau} = \bar{a}_{rs} + \bar{a}_{rs}^{\,n} + \bar{a}_{rs}^{\,\tau}$$

„RODOWIŚNIE":

$$\Downarrow$$

$$(\bar{a}_c) = 4{,}2 \ [cm] \qquad k_a = 20$$

$$\rightarrow \quad \bar{a}_c = (\bar{a}_c) \cdot k_a = 4{,}2 \cdot 20 = 84 \quad \rightarrow \quad \bar{a}_c = 84 \ \left[\frac{cm}{s^2}\right]$$

a_D ; a_{DC}^{τ} :

$$\bar{a}_D = \bar{a}_e + \bar{a}_{DC}^{n} + \bar{a}_{DC}^{\tau}$$

a_e = DANE

$a_{DC}^{n} = \omega_4^2 \cdot |DC|$ gdzie: $a_{DC}^{n} \parallel |DC|$

$a_{DC}^{\tau} = \varepsilon_4 \cdot |DC|$ gdzie: $a_{DC}^{\tau} \perp DC$

a_D = wektor przyspieszenia punktu D.

$$a_{DC}^{n} = \omega_4^2 \cdot |DC| = (0{,}28)^2 \cdot 69 = 5{,}41 \Rightarrow \bar{a}_{DC}^{n} = 5{,}41 \ (cm)$$

$$k_a = 20$$

$$\Rightarrow (\bar{a}_{DC}^{n}) = \frac{\bar{a}_{DC}^{n}}{k_a} = \frac{5{,}41}{20} = 0{,}27 \Rightarrow (\bar{a}_{DC}^{n}) = 0{,}27 \ (cm)$$

$$\Rightarrow \begin{cases} (\bar{a}_D) = 1{,}5 \ [cm] \\ (\bar{a}_{Dc}^{\tau}) = 3{,}75 \end{cases}$$

odczytuję z PP:

$$k_2 = 20$$

$$\Rightarrow \begin{cases} \bar{a}_D = (\bar{a}_D) \cdot k_2 = 1{,}5 \cdot 20 = 30 \\ \bar{a}_{Dc}^{\tau} = (\bar{a}_{Dc}^{\tau}) \cdot k_2 = 3{,}75 \cdot 20 = 75 \end{cases} \Rightarrow \begin{cases} a_D = 30 \\ a_{Dc}^{\tau} = 75 \end{cases} \left[\frac{cm}{s^2}\right]$$

a_E:

$$\begin{cases} \bar{a}_E = \bar{a}_c + \bar{a}_{Ec}^{n} + \bar{a}_{Ec}^{\tau} \\ \bar{a}_E = \bar{a}_D + \bar{a}_{ED}^{n} + \bar{a}_{ED}^{\tau} \end{cases}$$

$$\bar{a}_c + \bar{a}_{Ec}^{n} + \bar{a}_{Ec}^{\tau} = \bar{a}_D + \bar{a}_{ED}^{n} + \bar{a}_{ED}^{\tau}$$

przekształcam 4:

$$\frac{|CD|}{|cd|} = \frac{|CE|}{|ce|}$$

$$\begin{cases} |CE| = 35 \ [cm] \\ |CD| = 69 \\ |cd| = 3{,}8 \end{cases}$$

$$|ce| = \frac{|CE| \cdot |cd|}{|CD|} = \frac{35 \cdot 3{,}8}{69} = 1{,}93 \Rightarrow |ce| = 1{,}93 \ [cm]$$

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odczytuję z PP:

$|\bar{a}_{BE}| = 2{,}7 \ [cm]$ $\quad k_a = 20$

$a_{BE} = |a_{BE}| \cdot k_a = 2{,}7 \cdot 20 = 54 \ \left[\frac{cm}{s^2}\right]$

$a_{BE} = 54 \ \left[\frac{cm}{s^2}\right]$

a_F:

$$\begin{cases} \bar{a}_F = \bar{a}_{BE} + \bar{a}_{FE}^{n} + \bar{a}_{FE}^{\tau} \\ a_F = a_{O_3}^{=0} + a_{FO_3}^{n} + a_{FO_3}^{\tau} \end{cases}$$

$$\bar{a}_{BE} + \bar{a}_{FE}^{n} + \bar{a}_{FE}^{\tau} = a_{O_3}^{=0} + \bar{a}_{FO_3}^{n} + \bar{a}_{FO_3}^{\tau}$$

$a_{BE} = DANE$

$a_{FE}^{n} = \omega_6^2 \cdot |FE|$ $\quad$ gdzie: $a_{FE}^{n} \parallel |FE|$

$a_{FE}^{\tau} = \varepsilon_6 \cdot |FE|$ $\quad$ gdzie: $a_{FE}^{\tau} \perp |FE|$

$a_{O_3} = 0$

$a_{FO_3}^{n} = \omega_7^2 \cdot |FO_3|$ $\quad$ gdzie: $a_{FO_3}^{n} \parallel |FO_3|$

$a_{FO_3}^{\tau} = \varepsilon_7 \cdot |FO_3|$ $\quad$ gdzie: $a_{FO_3}^{\tau} \perp |FO_3|$

$$\Rightarrow \begin{cases} a_{PE}^{n} = \omega_6^2 \cdot |PE| = (2{,}15)^2 \cdot 32 = 145{,}18 \\ a_{PO_3} = \omega_7^2 \cdot |PO_3| = (2{,}15)^2 \cdot 20 = 125 \end{cases}$$

$$\Rightarrow \boxed{\begin{cases} a_{PE}^{n} = 145{,}18 \\ a_{PO_3} = 125 \end{cases}} \qquad \boxed{k_a = 20}$$

$$\begin{cases} (a_{PE}^{n}) = \dfrac{a_{PE}^{n}}{k_a} = \dfrac{145{,}18}{20} = 7{,}26 \\ (a_{PO_3}^{n}) = \dfrac{a_{PO_3}^{n}}{k_a} = \dfrac{125}{20} = 6{,}25 \end{cases} \Rightarrow \boxed{\begin{cases} (\bar{a}_{PE}^{n}) = 7{,}26 \\ (a_{PO_3}^{n}) = 6{,}25 \end{cases} \; [cm]}$$

odczytuję z RP:

$$\boxed{\begin{cases} (\bar{a}_{PE}^{\tau}) = 3{,}3 \\ (\bar{a}_{PO_3}^{\tau}) = 8{,}6 \\ (\bar{a}_{P}) = 10{,}6 \end{cases} [cm]} \qquad \boxed{k_a = 20}$$

$$\Rightarrow \begin{cases} \bar{a}_{PE}^{\tau} = (\bar{a}_{PE}^{\tau}) \cdot k_a = 3{,}3 \cdot 20 = 66 \\ \bar{a}_{PO_3}^{\tau} = (\bar{a}_{PO_3}^{\tau}) \cdot k_a = 8{,}6 \cdot 20 = 172 \\ \bar{a}_{P} = (\bar{a}_{P}) \cdot k_a = 10{,}6 \cdot 20 = 212 \end{cases} \Rightarrow \boxed{\begin{cases} a_{PE}^{\tau} = 66 \\ a_{PO_3}^{\tau} = 172 \\ a_{P} = 212 \end{cases} \left[\frac{cm}{s^2}\right]}$$

ε:)

$\varepsilon_1 = 0$ ⇝ $\varepsilon_1 = 0 \quad [\frac{wod.}{1^2}]$

$\varepsilon_2 = \frac{Q_{HA}}{|HA|} = \frac{2,10}{54} = 0,04$ ⇝ $\varepsilon_2 = 0,04$

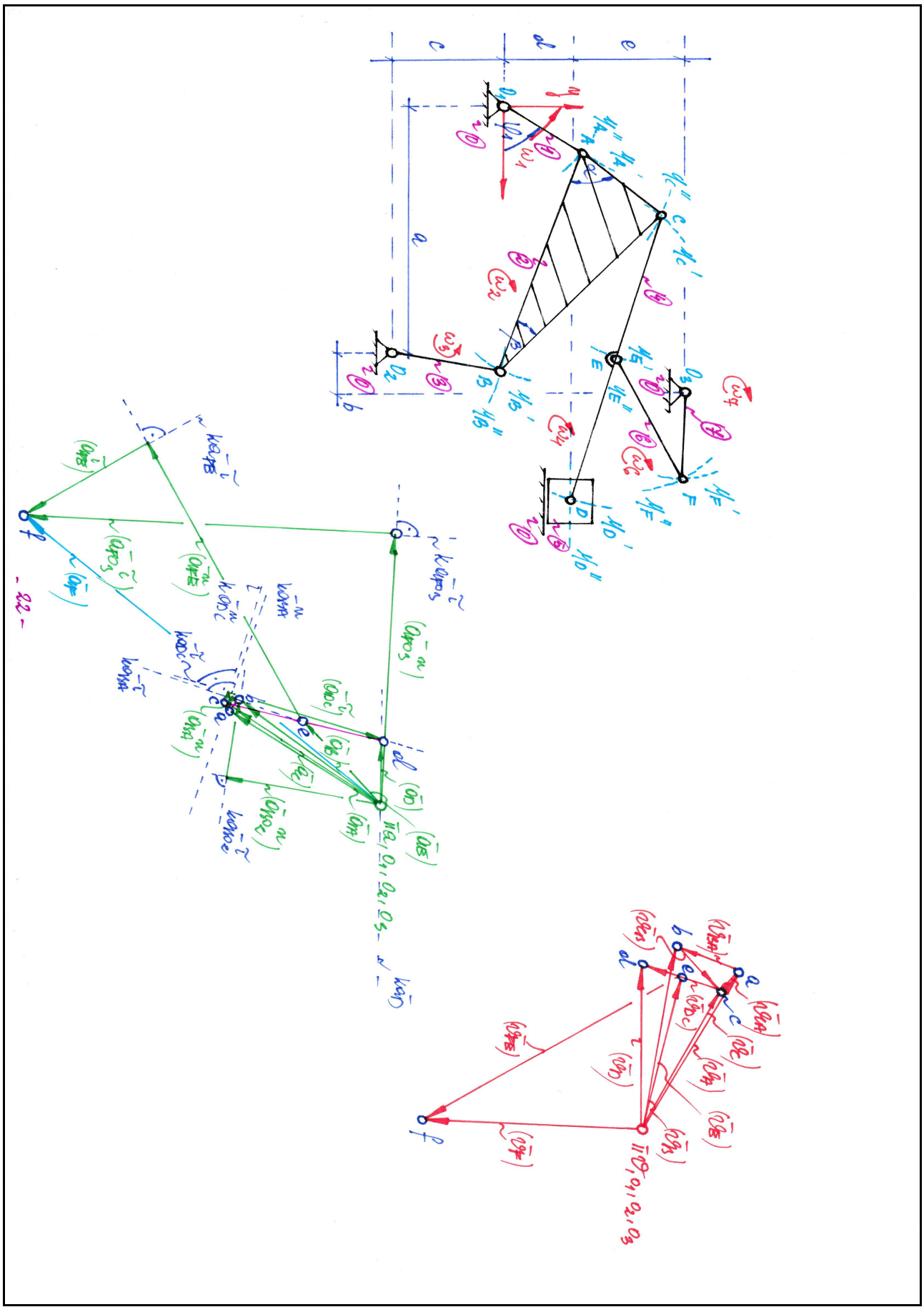
$\varepsilon_3 = \frac{Q_{NaOH}}{|NaOH|} = \frac{1,65}{25} = 0,07$ ⇝ $\varepsilon_3 = 0,07$

$\varepsilon_4 = \frac{Q_{NaCl}}{|NaCl|} = \frac{45}{69} = 1,09$ ⇝ $\varepsilon_4 = 1,09$

$\varepsilon_5 = 0$ ⇝ $\varepsilon_5 = 0$

$\varepsilon_6 = \frac{Q_{MgF_2}}{|MgF_2|} = \frac{66}{32} = 2,06$ ⇝ $\varepsilon_6 = 2,06$

$\varepsilon_7 = \frac{Q_{NaNO_3}}{|NaNO_3|} = \frac{172}{20} = 8,6$ ⇝ $\varepsilon_7 = 8,6$




inż. Szymon Flis