Dinamika 4. gyakorlat

Síkbeli mechanizmusok

Elméleti összefoglaló

$\underline{u}$ – póluvándorlás sebessége

$\underline{r}_{Ap}(t) \rightarrow$ mozgó póluspgörbe (testhez rögzített)

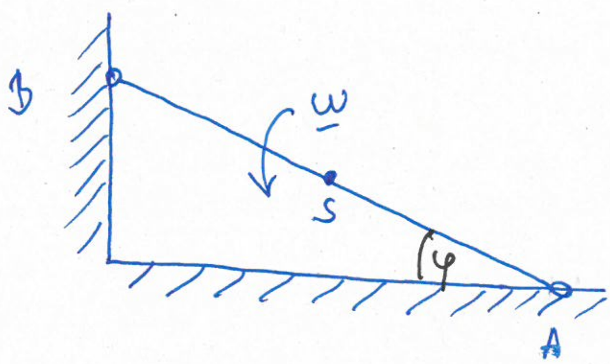
$\underline{r}_p(t) \rightarrow$ álló póluspgörbe (az álló koordináta r.-hez rögzített)

↳ Általános síkbeli mozgás elképzelhető, mint a mozgó póluspgörbe legördülése az álló póluspgörbén

$$\boxed{\underline{u} = \frac{\underline{\omega} \times \underline{a}_p}{\omega^2}}$$

1. feladat

Csúszó létra



Adatok

$\ell = 4$ [m]

$\varphi = 30$ [°]

$\omega = 0{,}6 \left[\frac{rad}{s}\right]$

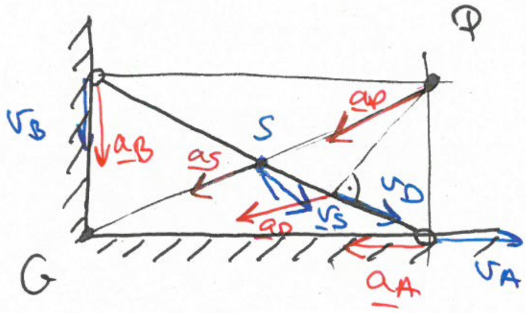
$\varepsilon = 0$

Kérdések: $\rho_A, \rho_B, \rho_S, \rho_D = ?$

Póluspgörbék

$\underline{u}$ – póluvándorlás sebessége

Előző gyakorlatról



A és B pont egy egyenesen mozog

$\underline{a}_A = \underline{a}_{At}$

$\underline{a}_B = \underline{a}_{Bt}$ $\Rightarrow$ $\underline{a}_{An} = \underline{0}$, $\underline{a}_{Bn} = \underline{0}$ $\Rightarrow$ $\boxed{\rho_A = \rho_B \to \infty}$

Súlypont görbületi sugara

$\hookrightarrow |\underline{v}_S| = 1{,}2 \left[\frac{m}{s}\right]$

$\hookrightarrow |\underline{a}_S| = 0{,}72 \left[\frac{m}{s^2}\right]$

$\Rightarrow$ $\underline{a}_S \parallel \overline{PG} \parallel \overline{PS}$, $\underline{v}_S \perp \overline{PS}$ $\Rightarrow$ $\underline{a}_S \perp \underline{v}_S$

$\underline{a}_S = \underline{a}_{S_n} \Rightarrow$ $a_{Sn} = a_S = 0{,}72 \left[\frac{m}{s^2}\right]$

$a_{Sn} = \frac{v_S^2}{\rho_S} \Rightarrow \rho_S = \frac{v_S^2}{a_{Sn}} = \underline{\underline{2\,[m]}}$

2 m sugarú körön mozog!

D pont sugara

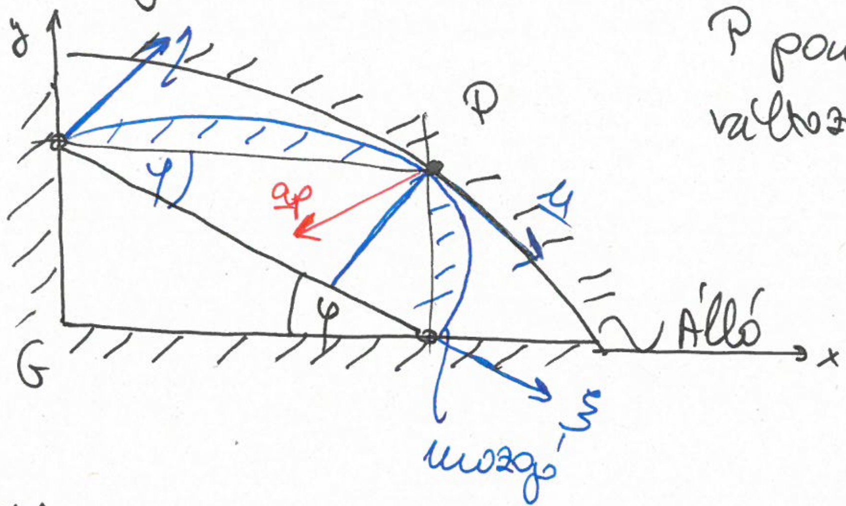
$$\underline{e}_t = \frac{\underline{v}_D}{|v_D|} = \underline{e}_{BA} = \begin{bmatrix} \frac{\sqrt{3}}{2} \\ -\frac{1}{2} \\ 0 \end{bmatrix} = \begin{bmatrix} 0{,}866 \\ -0{,}5 \\ 0 \end{bmatrix} \quad \underline{e}_n \perp \underline{e}_t$$

$$\underline{e}_n = \begin{bmatrix} 0{,}5 \\ 0{,}866 \\ 0 \end{bmatrix} \qquad v_D = 1{,}04 \left[\frac{m}{s}\right]$$

$$\underline{a}_D = \begin{bmatrix} -0{,}935 \\ -0{,}18 \\ 0 \end{bmatrix} \Rightarrow a_{Dn} = \underline{a}_D \cdot \underline{e}_n = 0{,}624 \left[\frac{m}{s^2}\right]$$

$$\rho_D = \frac{v_D^2}{a_{DN}} = 1{,}732\,[m] = \underline{\underline{\sqrt{3}\,[m]}}$$

Pólusgörbék egyenlete



P pont helye folyton változik

Álló koordinátarendszer $(\underline{O}, x, y, z)$ $\longrightarrow$ $\underline{r}_{OP} = \begin{bmatrix} l\cos\varphi \\ l\sin\varphi \\ 0 \end{bmatrix}$ $\varphi \in [0, \frac{\pi}{2}]$

Mozgó KR $(\underline{B}, \xi, \eta, z)$

Origó középpontú l sugarú negyedkör

$y(x) = ?$

$$\left.\begin{aligned} x(\varphi) &= l\cos\varphi \\ y(\varphi) &= l\sin\varphi \end{aligned}\right\} \Rightarrow \boxed{y^2 + x^2 = l^2}$$

Mozgó pólusgörbe

$$\underline{r}_{BP} = \begin{bmatrix} l\cos\varphi\cos\varphi \\ l\cos\varphi\sin\varphi \\ 0 \end{bmatrix} = \begin{bmatrix} l\,\frac{1+\cos 2\varphi}{2} \\ l\,\frac{\sin 2\varphi}{2} \\ 0 \end{bmatrix} \qquad \varphi \in [0, \frac{\pi}{2}]$$

$\xi(\eta)$ fgv. kellene

$$\left.\begin{aligned} \xi(\varphi) &= \frac{l}{2} + \frac{l\cos 2\varphi}{2} \\ \eta(\varphi) &= \frac{l}{2}\sin 2\varphi \end{aligned}\right\} \quad \underline{\left(\xi - \frac{l}{2}\right)^2 + \eta^2 = \left(\frac{l}{2}\right)^2}$$

$\frac{l}{2}$ sugarú kör

Pólusvándorlás sebessége

$$\underline{u} = \frac{\underline{\omega} \times \underline{a}_P}{\omega^2}$$

$$\underline{r}_{QP} = \begin{bmatrix} l\cos\varphi \\ l\sin\varphi \\ 0 \end{bmatrix}$$

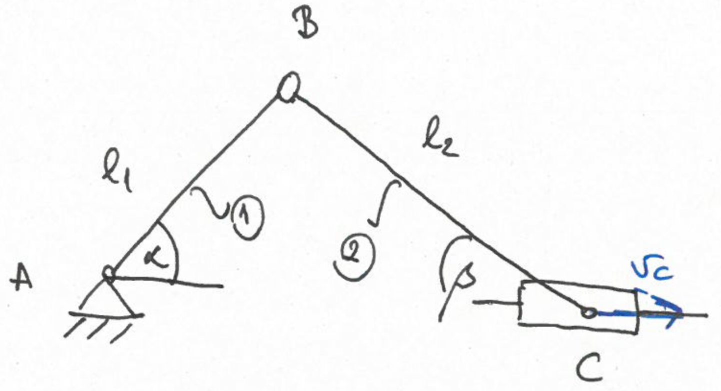
↳ $\underline{a}_P$ ismert $\rightarrow$ $\underline{a}_P = \underbrace{\underline{a}_Q}_{=\underline{0}} + \underbrace{\underline{\varepsilon}}_{=\underline{0}} \times \underline{r}_{QP} - \omega^2 \underline{r}_{QP} = \begin{bmatrix} -\omega^2 \cdot l\cos\varphi \\ -\omega^2 l\sin\varphi \\ 0 \end{bmatrix}$

$$\underline{a}_P = \begin{bmatrix} -1,247 \\ -0,72 \\ 0 \end{bmatrix} \left[\frac{m}{s^2}\right]$$

$$\underline{u} = \frac{1}{\omega^2} \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ 0 & 0 & \omega \\ -\omega^2 l\cos\varphi & -\omega^2 l\sin\varphi & 0 \end{vmatrix} = \frac{1}{\omega^2} \begin{bmatrix} \omega^3 l\sin\varphi \\ -\omega^3 l\cos\varphi \\ 0 \end{bmatrix} = \begin{bmatrix} \omega l\sin\varphi \\ -\omega l\cos\varphi \\ 0 \end{bmatrix}$$

$$\underline{u} = \begin{bmatrix} 1,2 \\ -2,078 \\ 0 \end{bmatrix} \left[\frac{m}{s}\right]$$

2. feladat Forgattyús mechanizmus



Adatok:

$v_C = \text{áll}$

$\alpha = 60^\circ$

$\beta = 30^\circ$

Feladatok: $\underline{\omega}_1$; $\underline{\omega}_2$; $\underline{\varepsilon}_1$; $\underline{\varepsilon}_2$

Látjuk, hogy

$\underline{v}_A = \underline{0} \quad \rightarrow \quad \underline{v}_B = \overset{=0}{\underline{v}_A} + \underline{\omega}_1 \times \underline{r}_{AB} = \underline{\omega}_1 \times \underline{r}_{AB}$

$$\underline{v}_C = \begin{bmatrix} v_C \\ 0 \\ 0 \end{bmatrix} \qquad \underline{v}_B = \underline{v}_C + \underline{\omega}_2 \times \underline{r}_{CB}$$

- $\underline{\omega}_1 \times \underline{r}_{AB} = \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ 0 & 0 & \omega_1 \\ l_1\cos\alpha & l_1\sin\alpha & 0 \end{vmatrix} = \begin{bmatrix} -\omega_1 l_1 \sin\alpha \\ \omega_1 l_1 \cos\alpha \\ 0 \end{bmatrix}$
- $\underline{\omega}_2 \times \underline{r}_{CB} = \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ 0 & 0 & \omega_2 \\ -l_2\cos\beta & l_2\sin\beta & 0 \end{vmatrix} = \begin{bmatrix} -\omega_2 l_2 \sin\beta \\ -\omega_2 l_2 \cos\beta \\ 0 \end{bmatrix}$

$$\begin{bmatrix} -\omega_1 l_1 \sin\alpha \\ \omega_1 l_1 \cos\alpha \\ 0 \end{bmatrix} = \begin{bmatrix} v_C - \omega_2 l_2 \sin\beta \\ -\omega_2 l_2 \cos\beta \\ 0 \end{bmatrix} \longrightarrow \omega_1 l_1 \cos\alpha = -\omega_2 l_2 \cos\beta$$

$$\omega_1 = \frac{-l_2\cos\beta}{l_1\cos\alpha}\,\omega_2$$

$$-\left(-\frac{l_2\cos\beta}{l_1\cos\alpha}\right) l_1 \sin\alpha\, \omega_2 = v_C - \omega_2 l_2 \sin\beta$$

$$\cos\beta = \frac{\sqrt{3}}{2}$$
$$\cos\alpha = \frac{1}{2}$$
$$\sin\alpha = \frac{\sqrt{3}}{2}$$
$$\sin\beta = \frac{1}{2}$$

$$\Rightarrow \quad l_2 \cdot \frac{\frac{\sqrt{3}}{2}}{\frac{1}{2}} \cdot \frac{\sqrt{3}}{2}\,\omega_2 = v_C - \omega_2 l_2 \cdot \frac{1}{2}$$

$$l_2 \omega_2 \frac{3}{2} = v_C - \omega_2 l_2 \frac{1}{2}$$

$$\hookrightarrow \omega_2 l_2 \left(\frac{3}{2} + \frac{1}{2}\right) = v_C$$

$$\boxed{\omega_2 = \frac{v_C}{l_2 \cdot 2}}$$

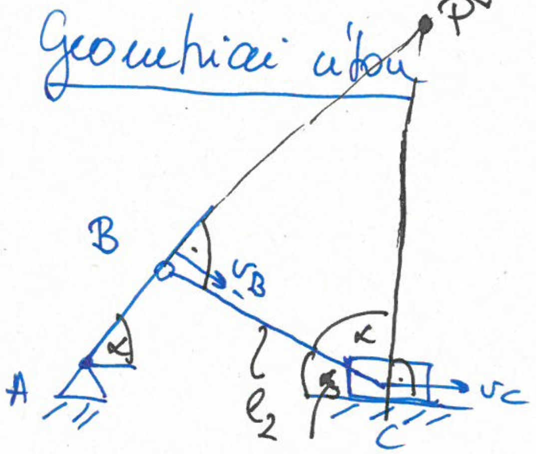
$$\underline{\omega_2} = \begin{bmatrix} 0 \\ 0 \\ \omega_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ v_C/(2l_2) \end{bmatrix}$$

$$\omega_1 = -\frac{l_2}{l_1}\frac{\cos\beta}{\cos\alpha}\,\omega_2 = \frac{-l_2}{l_1}\,\frac{\frac{\sqrt{3}}{2}}{\frac{1}{2}}\,\frac{v_C}{2l_2} \Rightarrow$$

$$\boxed{\omega_1 = -\frac{\sqrt{3}}{2}\frac{v_C}{l_1}}$$

$$\underline{\omega_1} = \begin{bmatrix} 0 \\ 0 \\ \omega_1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ -\sqrt{3}\,v_C/(2l_1) \end{bmatrix}$$

Geometriai úton



$$\overline{P_2C} \perp \underline{v_C} \quad \text{és} \quad \overline{P_2C} \perp \underline{v_B}$$

$$\boxed{P_1 = A}$$

$$\underline{v_B} \perp \overline{AB}$$

$$v_C = \overline{PC}\cdot\omega_2 = \frac{l_2}{\cos\alpha}\cdot\omega_2 \Rightarrow \omega_2 = \frac{\cos\alpha}{l_2}v_C = \underline{\underline{\frac{v_C}{2l_2}}}$$

$$v_B = \overline{PB}\cdot\omega_2 = l_2\cdot \mathrm{tg}\,\alpha\cdot\omega_2 = \frac{\cancel{l_2}\cdot \mathrm{tg}\,\alpha\cdot v_C}{2\cancel{l_2}} = \underline{\underline{\frac{\sqrt{3}}{2}v_C}}$$

$$\mathrm{tg}\,60° = \sqrt{3}$$

$$v_B = l_1\cdot\omega_1 \Rightarrow \omega_1 = \frac{v_B}{l_1} = \underline{\underline{\frac{\sqrt{3}}{2l_1}v_C}}$$

Szöggyorsulások

Hasonló úton:

$$\underline{\varepsilon_1} = \begin{bmatrix} 0 \\ 0 \\ \varepsilon_1 \end{bmatrix} \qquad \underline{\varepsilon_2} = \begin{bmatrix} 0 \\ 0 \\ \varepsilon_2 \end{bmatrix}$$

$$\left.\begin{array}{l} (1)\ \underline{a}_B = \overset{=0}{\underline{a}_A} + \underline{\varepsilon_1} \times \underline{r}_{AB} - \omega_1^2 r_{AB} \\ (2)\ \underline{a}_B = \underline{a}_C + \underline{\varepsilon_2} \times \underline{r}_{CB} - \omega_2^2 r_{CB} \end{array}\right\}$$

$$\underline{a}_C = \begin{bmatrix} a_C \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$(1):\ \underline{a}_B = \begin{vmatrix} i & j & k \\ 0 & 0 & \varepsilon_1 \\ l_1\cos\alpha & l_1\sin\alpha & 0 \end{vmatrix} - \omega_1^2 \begin{bmatrix} l_1\cos\alpha \\ l_1\sin\alpha \\ 0 \end{bmatrix} = \begin{bmatrix} -\varepsilon_1 l_1 \sin\alpha - \omega_1^2 l_1 \cos\alpha \\ \varepsilon_1 l_1 \cos\alpha - \omega_1^2 l_1 \sin\alpha \\ 0 \end{bmatrix}$$

$$(2)\ \underline{a}_B = \overset{=0}{\begin{bmatrix} a_C \\ 0 \\ 0 \end{bmatrix}} + \begin{vmatrix} i & j & k \\ 0 & 0 & \varepsilon_2 \\ -l_2\cos\beta & l_2\sin\beta & 0 \end{vmatrix} - \omega_2^2 \begin{bmatrix} -l_2\cos\beta \\ l_2\sin\beta \\ 0 \end{bmatrix} = \begin{bmatrix} -\varepsilon_2 l_2 \sin\beta + \omega_2^2 l_2 \cos\beta \\ -\varepsilon_2 l_2 \cos\beta - \omega_2^2 l_2 \sin\beta \\ 0 \end{bmatrix}$$

Egyenlővé lehet tenni:

$$-\varepsilon_1 l_1 \sin\alpha - \omega_1^2 l_1 \cos\alpha = -\varepsilon_2 l_2 \sin\beta + \omega_2^2 l_2 \cos\beta$$
$$\varepsilon_1 l_1 \cos\alpha - \omega_1^2 l_1 \sin\alpha = -\varepsilon_2 l_2 \cos\beta - \omega_2^2 l_2 \sin\beta$$

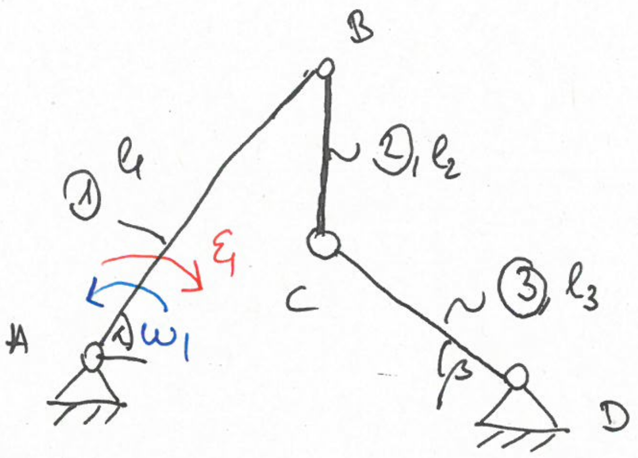
$\Downarrow$ 2 ismeretlen 2 egyenlet

$$\left.\begin{array}{l} -\dfrac{\varepsilon_1 l_1 \sqrt{3}}{2} - \dfrac{\omega_1^2 l_1}{2} = -\dfrac{\varepsilon_2 l_2}{2} + \dfrac{\omega_2^2 l_2 \sqrt{3}}{2} \\ \dfrac{\varepsilon_1 l_1}{2} - \dfrac{\omega_1 l_1 \sqrt{3}}{2} = \dfrac{-\varepsilon_2 l_2 \sqrt{3}}{2} \cancel{+} -\dfrac{\omega_2^2 l_2}{2} \end{array}\right\}$$

$$\hookrightarrow \varepsilon_2 = \frac{l_1 \omega_1^2}{l_2}$$

$$\hookrightarrow \varepsilon_{\cancel{2}1} = -\frac{l_2}{l_1}\omega_2^2$$

3. feladat Négycsuklós mechanizmus



Adatok

$l_1 = 0{,}6\ [m]$

$l_2 = 0{,}3\ [m]$

$l_3 = 0{,}3\ [m]$

$\omega_1 = 3{,}5\ \left[\frac{rad}{s}\right]$

$\varepsilon_1 = 20\ \left[\frac{rad}{s^2}\right]$

$\alpha = 60°$

$\beta = 45°$

Feladatok:

$$\left.\begin{matrix} \underline{v}_B;\ \underline{\omega}_2 \\ \underline{v}_C;\ \underline{\omega}_3 \\ P_2 = ? \end{matrix}\right\}$$ sebességáll.

$$\left.\begin{matrix} \underline{a}_B;\ \underline{\varepsilon}_2 \\ \underline{a}_C;\ \underline{\varepsilon}_3 \\ G_2 \end{matrix}\right\}$$ gyorsulásáll

Sebességállapot:

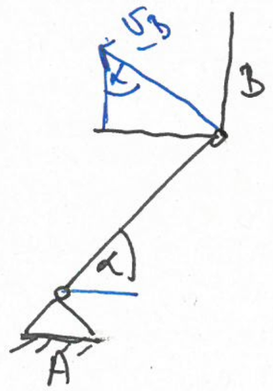
1 es rúdban: $A \equiv P_1 \equiv G_1$

3 as rúdban: $D = P_3 = G_3$

$$\underline{v}_B = \underbrace{\underline{v}_A}_{\underline{0}} + \underline{\omega}_1 \times \underline{r}_{AB}$$

$$\underline{\omega}_1 = \begin{bmatrix} 0 \\ 0 \\ \omega_1 \end{bmatrix}$$

$$\underline{v}_B = \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ 0 & 0 & \omega_1 \\ l_1 \cos\alpha & l_1 \sin\alpha & 0 \end{vmatrix} = \begin{bmatrix} -\omega_1 l_1 \sin\alpha \\ \omega_1 l_1 \cos\alpha \\ 0 \end{bmatrix} = \begin{bmatrix} -1{,}819 \\ 1{,}05 \\ 0 \end{bmatrix} \left[\frac{m}{s}\right]$$



$$v_B = l_1 \omega_1 = 2{,}1 \left[\frac{m}{s}\right]$$

$$\underline{e}_t = \begin{bmatrix} -\sin\alpha \\ \cos\alpha \\ 0 \end{bmatrix}$$

$\underline{v}_B = v_B \cdot \underline{e}_t \rightarrow$ ugyanazt kapjuk!

C-pont sebessége

$$\underline{\omega}_2 = \begin{bmatrix} 0 \\ 0 \\ \omega_2 \end{bmatrix}; \quad \underline{\omega}_3 = \begin{bmatrix} 0 \\ 0 \\ \omega_3 \end{bmatrix}$$

$$\underline{v}_C = \underline{v}_B + \underline{\omega}_2 \times \underline{r}_{BC}$$

$$\underline{v}_C = \underline{v}_D + \underline{\omega}_3 \times \underline{r}_{DC}, \quad \underline{v}_D = 0$$

$$\underline{v}_C = \begin{bmatrix} v_{Bx} \\ v_{By} \\ 0 \end{bmatrix} + \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ 0 & 0 & \omega_2 \\ 0 & -l_2 & 0 \end{vmatrix} = \begin{bmatrix} v_{Bx} + l_2\omega_2 \\ v_{By} \\ 0 \end{bmatrix}$$

$$\underline{v}_C = \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ 0 & 0 & \omega_3 \\ -l_3\cos\beta & l_3\sin\beta & 0 \end{vmatrix} = \begin{bmatrix} -l_3\sin\beta\,\omega_3 \\ -l_3\cos\beta\,\omega_3 \\ 0 \end{bmatrix}$$

Tegyük egyenlővé!

$$v_{Bx} + l_2\omega_2 = -l_3\sin\beta\,\omega_3$$

$$v_{By} = -l_3\cos\beta\,\omega_3 \rightarrow \omega_3 = \frac{-v_{By}}{l_3\cos\beta} = -4{,}95 \left[\frac{rad}{s}\right]$$

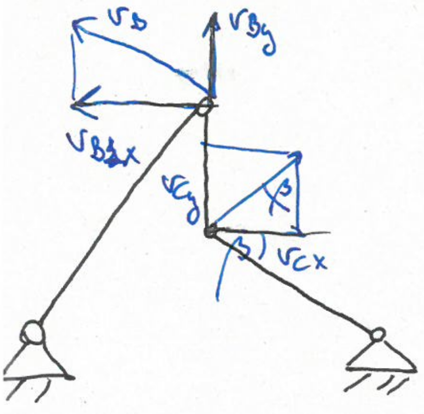
$$\omega_2 = \frac{-l_3\sin\beta\,\omega_3 - v_{Bx}}{l_2} = 9{,}56 \left[\frac{rad}{s}\right]$$

$$\underline{\omega}_3 = \begin{bmatrix} 0 \\ 0 \\ -4{,}95 \end{bmatrix} \left[\frac{rad}{s}\right]$$

$$\underline{\omega}_2 = \begin{bmatrix} 0 \\ 0 \\ 9{,}56 \end{bmatrix} \left[\frac{rad}{s}\right]$$

$$\underline{v}_C = \begin{bmatrix} v_{Bx} + l_2\omega_2 \\ v_{By} \\ 0 \end{bmatrix} = \begin{bmatrix} 1{,}05 \\ 1{,}05 \\ 0 \end{bmatrix} \left(\frac{m}{s}\right)$$

Másik út:



$$v_{C\parallel} = v_{B\parallel} = v_{By} = 1{,}05 \left(\frac{m}{s}\right)$$

vetületi tétel

rúdirányú komponens

$$v_{Cx} = \operatorname{tg}\beta \cdot v_{Cy} = 1{,}05 \left(\frac{m}{s}\right)$$

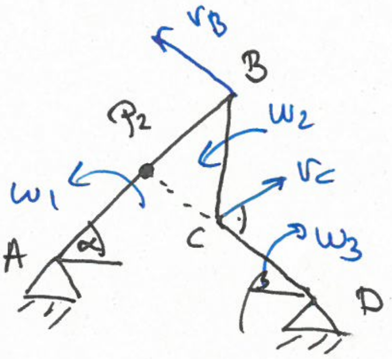
$$\omega_2 = \frac{v_{C\perp} - v_{B\perp}}{l_2} = \frac{|v_{C\perp}| + |v_{B\perp}|}{l_2} = 9{,}56 \left[\frac{rad}{s}\right]$$

ω_3 számítható a nídirányú komponensekből

$$v_{B\parallel} = v_{C\parallel}$$

$$l_1 \omega_1 \cdot \cos\alpha = \omega_3 \cdot l_3 \cdot \cos\beta$$

$$l_1 \omega_1 \cdot \frac{1}{2} = \omega_3 \; l_3 \cdot \frac{\sqrt{2}}{2} \rightarrow \omega_3 = \frac{l_1 \omega_1}{l_3 \sqrt{2}} = \underline{\underline{4{,}95 \left[\frac{rad}{s}\right]}}$$



Hol van P_2 = ?

- $\overline{P_2 C} \perp \underline{v_C} \rightarrow \underline{v_C} \perp \overline{CD}$

$\Downarrow$

$\overline{P_2 C} \parallel \overline{CD}$

- $\overline{P_2 B} \perp \underline{v_B} \rightarrow \overline{P_2 B} \parallel \overline{AD}$

Gyorsulásállapot

$$\underline{\varepsilon}_1 = \begin{bmatrix} 0 \\ 0 \\ \varepsilon_1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ -20 \end{bmatrix} \left[\frac{rad}{s^2}\right]$$

$$\underline{a}_B = \underset{\underset{\underline{0}}{\parallel}}{\underline{a}_A} + \underline{\varepsilon}_1 \times \underline{r}_{AB} - \omega_1^2 \underline{r}_{AB} = \begin{vmatrix} i & j & k \\ 0 & 0 & \varepsilon_1 \\ l_1\cos\alpha & l_1\sin\alpha & 0 \end{vmatrix} - \omega_1^2 \begin{bmatrix} l_1\cos\alpha \\ l_1\sin\alpha \\ 0 \end{bmatrix} = \begin{bmatrix} \varepsilon_1 l_1 \sin\alpha - \omega_1^2 l_1 \cos\alpha \\ \varepsilon_1 l_1 \cos\alpha - \omega_1^2 l_1 \sin\alpha \end{bmatrix}$$

$$\underline{\underline{\underline{a}_B = \begin{bmatrix} 6{,}717 \\ -12{,}365 \\ 0 \end{bmatrix} \left[\frac{m}{s^2}\right]}}$$

Szemlélettel $|\underline{a}_{Bt}| = \varepsilon_1 \cdot l_1$

körpályán mozog $\leftarrow$ $|\underline{a}_{Bn}| = l_1 \omega_1^2$

$\Longrightarrow$ $\underline{a}_B = a_{Bt} \underbrace{\begin{bmatrix} \sin\alpha \\ -\cos\alpha \\ 0 \end{bmatrix}}_{\underline{e}_t} + a_{Bn} \underbrace{\begin{bmatrix} -\cos\alpha \\ -\sin\alpha \\ 0 \end{bmatrix}}_{\underline{e}_n}$

$\hookrightarrow$ ugyanaz adódik!

C pont gyorsulása

$$\underline{\varepsilon_2} = \begin{bmatrix} 0 \\ 0 \\ \varepsilon_2 \end{bmatrix}; \quad \underline{\varepsilon_3} = \begin{bmatrix} 0 \\ 0 \\ \varepsilon_3 \end{bmatrix}$$

$$\underline{a_C} = \underline{a_B} + \underline{\varepsilon_2} \times \underline{r_{BC}} - \omega_2^2 \underline{r_{BC}}$$

$$\underline{a_C} = \underset{= \underline{0}}{\underline{a_D}} + \underline{\varepsilon_3} \times \underline{r_{DC}} - \omega_3^2 \underline{r_{DC}}$$

$$\begin{bmatrix} a_{Bx} \\ a_{By} \\ 0 \end{bmatrix} + \begin{vmatrix} i & j & k \\ 0 & 0 & \varepsilon_2 \\ 0 & -l_2 & 0 \end{vmatrix} - \omega_2^2 \begin{bmatrix} 0 \\ -l_2 \\ 0 \end{bmatrix} = \underline{a_C}$$

$$\underline{a_C} = \begin{vmatrix} i & j & k \\ 0 & 0 & \varepsilon_3 \\ -l_3\cos\beta & l_3\sin\beta & 0 \end{vmatrix} - \omega_3^2 \begin{bmatrix} -l_3\cos\beta \\ l_3\sin\beta \\ 0 \end{bmatrix}$$

$$\underline{a_C} = \begin{bmatrix} a_{Bx} + \varepsilon_2 l_2 \\ a_{By} + \omega_2^2 l_2 \\ 0 \end{bmatrix}$$

$$\underline{a_C} = \begin{bmatrix} -\varepsilon_3 l_3 \sin\beta + \omega_3^2 l_3 \cos\beta \\ -\varepsilon_3 l_3 \cos\beta - \omega_3^2 l_3 \sin\beta \\ 0 \end{bmatrix}$$

legyen egyenlő

$$a_{Bx} + \varepsilon_2 l_2 = -\varepsilon_3 l_3 \sin\beta + \omega_3^2 l_3 \cos\beta$$

$$a_{By} + \omega_2^2 l_2 = -\varepsilon_3 l_3 \cos\beta - \omega_3^2 l_3 \sin\beta$$

$$\varepsilon_3 = -\frac{a_{By} + \omega_2^2 l_2 + \omega_3^2 l_3 \sin\beta}{l_3 \cos\beta} = -95{,}46 \left[\frac{rad}{s^2}\right]$$

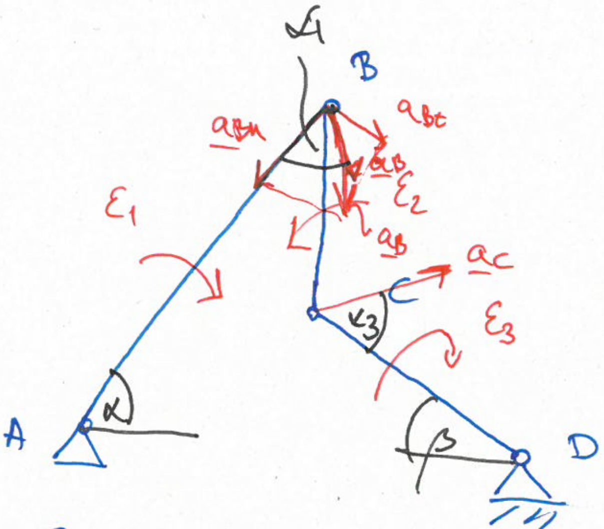
$$\varepsilon_2 = \frac{-a_{Bx} - \varepsilon_3 l_3 \sin\beta + \omega_3^2 l_3 \cos\beta}{l_2} = 62{,}43 \left[\frac{rad}{s^2}\right]$$

$$\underline{\varepsilon_3} = \begin{bmatrix} 0 \\ 0 \\ -95{,}46 \end{bmatrix} \left[\frac{rad}{s^2}\right]$$

$$\underline{\varepsilon_2} = \begin{bmatrix} 0 \\ 0 \\ 62{,}43 \end{bmatrix} \left[\frac{rad}{s^2}\right]$$

$$\underline{a_C} = \begin{bmatrix} a_{Bx} + \varepsilon_2 l_2 \\ a_{By} + \omega_2^2 l_2 \\ 0 \end{bmatrix} = \begin{bmatrix} 25{,}45 \\ 15{,}05 \\ 0 \end{bmatrix} \left[\frac{m}{s^2}\right]$$

Gyorsulások



$$\operatorname{tg}\alpha_1 = \frac{\varepsilon_1}{\omega_1^2}$$

$$\hookrightarrow \alpha_1 = \underline{\underline{58{,}51^\circ}}$$

$$\operatorname{tg}\alpha_3 = \frac{\varepsilon_3}{\omega_3^2}$$

$$\alpha_3 = \underline{\underline{75{,}6^\circ}}$$

$A \equiv G_1$

$D \equiv G_3$

G_2 gyorsuláspólus

$$\underline{a}_G = \underline{a}_B + \underline{\varepsilon}_2 \times \underline{r}_{BG} - \omega_2^2 \underline{r}_{BG} = \begin{bmatrix} a_{Bx} \\ a_{By} \\ 0 \end{bmatrix} + \begin{vmatrix} i & j & k \\ 0 & 0 & \varepsilon_2 \\ r_x & r_y & 0 \end{vmatrix} - \omega_2^2 \begin{bmatrix} r_x \\ r_y \\ 0 \end{bmatrix}$$

$\overset{\shortparallel}{\underline{0}}$

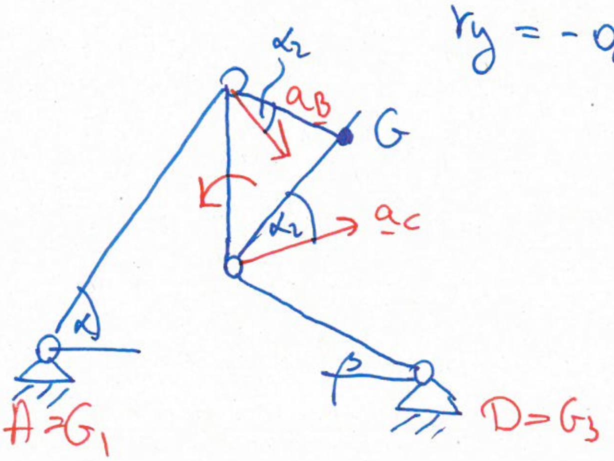
$$\underline{0} = \begin{bmatrix} a_{Bx} - \varepsilon_2 r_y - \omega_2^2 r_x \\ a_{By} + r_x \varepsilon_2 - \omega_2^2 r_y \\ 0 \end{bmatrix}$$

$\Downarrow$

Lineáris Egyenletr. r_x, r_y-ra

$r_x = 0{,}1131\ (m)$

$r_y = -0{,}058\ (m)$



$$\operatorname{tg}\alpha_2 = \frac{\varepsilon_2}{\omega_2^2}$$

$$\alpha_2 = \underline{\underline{34{,}33^\circ}}$$