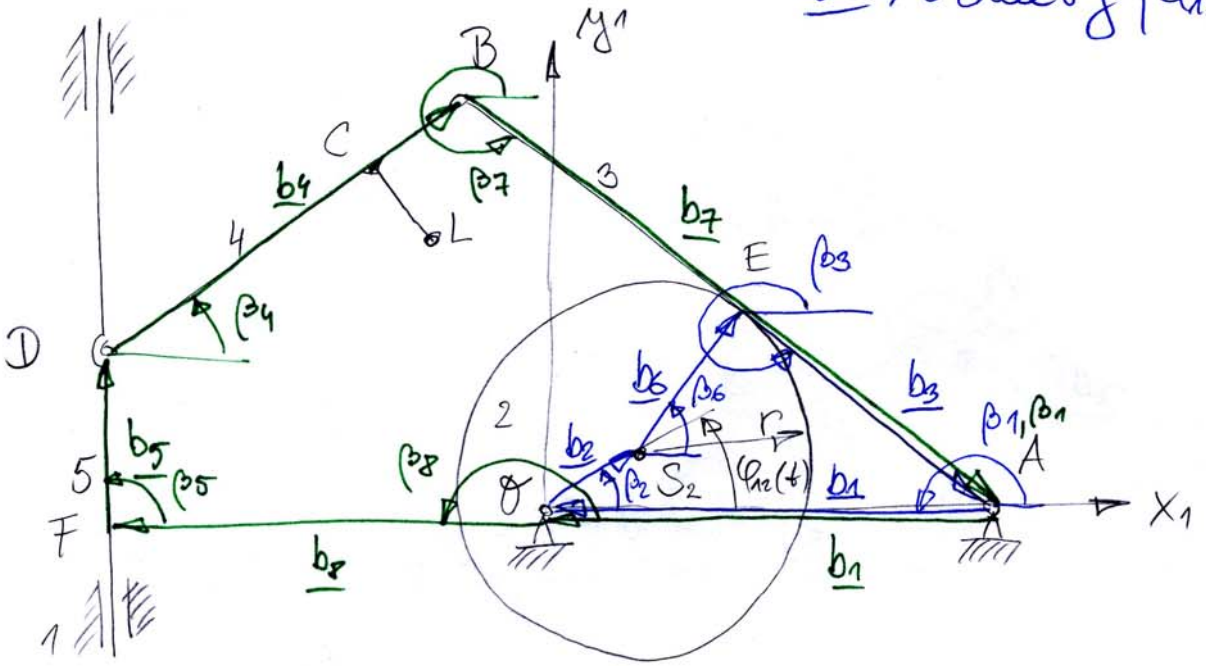
D: rozšířený $(\varphi_{12}(t))$



Počet stupňů volnosti

$i = 3(5-1) - 4_{rot}\cdot 2^\circ - 1_{pos}\cdot 2^\circ - 1_{ob}\cdot 1^\circ = 1^\circ$ volnosti

Počet nezávislých smyček

$s = d + m - n + 1 = 6 + 0 - 5 + 1 = 2$ smyčky

Nezávislé souřadnice

= počet °volnosti, $q = [\beta_2] = \varphi_{12}(t)$

Závislé souřadnice

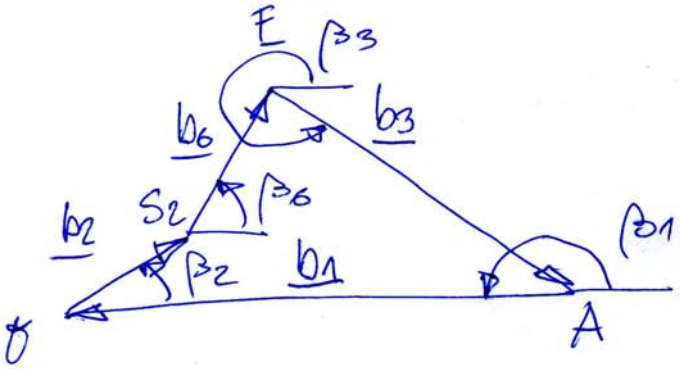
2 × počet nez. smyček $\underline{z} = \begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ z_4 \end{bmatrix}$

(1)

Smyčky

1. smyčka

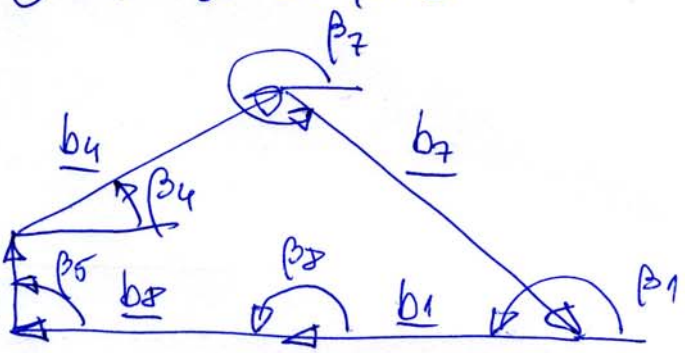
$O - S_2 - E - A - O$



$\underline{b_1} + \underline{b_2} + \underline{b_6} + \underline{b_3} = \emptyset$

2. smyčka

$O - F - D - B - A - O$



$\underline{b_1} + \underline{b_8} + \underline{b_5} + \underline{b_4} + \underline{b_7} = \emptyset$

Složkové rovnice

1. smyčka

$b_1 \cos\beta_1 + b_2 \cos\beta_2 + b_6 \cos\beta_6 + b_3 \cos\beta_3 = \emptyset$

$b_1 \sin\beta_1 + b_2 \sin\beta_2 + b_6 \sin\beta_6 + b_3 \sin\beta_3 = \emptyset$

2. smyčka

$b_1 \cos\beta_1 + b_8 \cos\beta_8 + b_5 \cos\beta_5 + b_4 \cos\beta_4 + b_7 \cos\beta_7 = \emptyset$

$b_1 \sin\beta_1 + b_8 \sin\beta_8 + b_5 \sin\beta_5 + b_4 \sin\beta_4 + b_7 \sin\beta_7 = \emptyset$

$\Rightarrow$ soustava nelineárních rovnic

Souřadnice

$b_1 = \text{konst.} = b_1$ $\quad \beta_1 = \text{konst.} = \pi$

$b_2 = \text{konst.} = b_2$ $\quad \beta_2 = q_1$

$b_3 = z_1$ $\quad \beta_3 = z_2$

$b_4 = \text{konst.} = b_4$ $\quad \beta_4 = z_3$

$b_5 = z_4$ $\quad \beta_5 = \text{konst} = \pi/2$

$b_6 = \text{konst.} = b_6$ $\quad \beta_6 = \beta_3 - 3/2\pi = z_2 - 3/2\pi$

$b_7 = \text{konst.} = b_7$ $\quad \beta_7 = \beta_3 = z_2$

$b_8 = \text{konst.} = b_8$ $\quad \beta_8 = \text{konst.} = \pi$

Derivace rovnic (1.)

1. složka

$$-b_2 \sin\beta_2 \cdot \dot{\beta}_2 - b_6 \sin\beta_6 \cdot \dot{\beta}_6 + \dot{b}_3 \cos\beta_3 - b_3 \sin\beta_3 \dot{\beta}_3 = 0$$

$$\dot{b}_2 \cos\beta_2 \cdot \dot{\beta}_2 + b_6 \cos\beta_6 \cdot \dot{\beta}_6 + \dot{b}_3 \sin\beta_3 + b_3 \cos\beta_3 \cdot \dot{\beta}_3 = 0$$

2. složka

$$\dot{b}_5 \cos\beta_5 - b_4 \sin\beta_4 \dot{\beta}_4 - b_7 \sin\beta_7 \cdot \dot{\beta}_7 = 0$$

$$\dot{b}_5 \sin\beta_5 + b_4 \cos\beta_4 \dot{\beta}_4 + b_7 \cos\beta_7 \cdot \dot{\beta}_7 = 0$$

$\Rightarrow$ soustava lin. rovnic

Maticový zápis

$$\begin{bmatrix} \cos\beta_3 & -b_3\sin\beta_3 - b_6\sin\beta_6 & \varnothing & \varnothing \\ \sin\beta_3 & b_3\cos\beta_3 + b_6\cos\beta_6 & \varnothing & \varnothing \\ \varnothing & -b_7\sin\beta_7 & -b_4\sin\beta_4 & \cos\beta_5 \\ \varnothing & b_7\cos\beta_7 & b_4\cos\beta_4 & \sin\beta_5 \end{bmatrix} \begin{bmatrix} \dot{b}_3 \\ \dot{\beta}_3 \\ \dot{\beta}_4 \\ \dot{b}_5 \end{bmatrix} + \begin{bmatrix} -b_2\sin\beta_2 \\ b_2\cos\beta_2 \\ \varnothing \\ \varnothing \end{bmatrix} \left[\dot{\beta}_2\right] = \begin{bmatrix} \varnothing \\ \varnothing \\ \varnothing \\ \varnothing \end{bmatrix}$$

$\underline{J_z}$ $\quad \underline{\dot{z}}$ $\quad \underline{J_q}$ $\quad \dot{q}$ $\quad \underline{\varnothing}$

Matice → $\underline{J_z}$

$J_z \Leftarrow \dfrac{\partial \text{složková rovnice}}{\partial \text{souřadnice (závislé)}}$

$$\underline{J_z}\cdot\underline{\dot{z}} + \underline{J_q}\cdot\dot{q} = \underline{\varnothing}$$

$$\underline{J_z}\cdot\underline{\dot{z}} = -\underline{J_q}\cdot\dot{q} \quad / \underline{J_z}^{-1}$$

$$\boxed{\underline{\dot{z}} = -\underline{J_z}^{-1}\cdot\underline{J_q}\cdot\dot{q}}$$

Derivace rovnic (2.)

1. smyčka

$$-b_2\cos\beta_2\dot\beta_2^2 - b_2\sin\beta_2\ddot\beta_2 - b_6\cos\beta_6\dot\beta_6^2 - b_6\sin\beta_6\ddot\beta_6 +$$
$$+\ddot b_3\cos\beta_3 - \dot b_3\sin\beta_3\dot\beta_3 - \dot b_3\sin\beta_3\dot\beta_3 - b_3\cos\beta_3\dot\beta_3^2 - b_3\sin\beta_3\ddot\beta_3 = 0$$
$$-b_2\sin\beta_2\dot\beta_2^2 + b_2\cos\beta_2\ddot\beta_2 - b_6\sin\beta_6\dot\beta_6^2 + b_6\cos\beta_6\ddot\beta_6 +$$
$$+\ddot b_3\sin\beta_3 + \dot b_3\cos\beta_3\dot\beta_3 + \dot b_3\cos\beta_3\dot\beta_3 - b_3\sin\beta_3\dot\beta_3^2 + b_3\cos\beta_3\ddot\beta_3 = 0$$

2. smyčka

$$\ddot b_5\cos\beta_5 - b_4\cos\beta_4\dot\beta_4^2 - b_4\sin\beta_4\ddot\beta_4 - b_7\cos\beta_7\dot\beta_7^2 - b_7\sin\beta_7\ddot\beta_7 = 0$$
$$\ddot b_5\sin\beta_5 - b_4\sin\beta_4\dot\beta_4^2 + b_4\cos\beta_4\ddot\beta_4 - b_7\sin\beta_7\dot\beta_7^2 + b_7\cos\beta_7\ddot\beta_7 = 0$$

Maticový zápis

$$\begin{bmatrix} \cos\beta_3 & -b_3\sin\beta_3 - b_6\sin\beta_6 & 0 & 0 \\ \sin\beta_3 & b_3\cos\beta_3 + b_6\cos\beta_6 & 0 & 0 \\ 0 & -b_7\sin\beta_7 & -b_4\sin\beta_4 & \cos\beta_5 \\ 0 & b_7\cos\beta_7 & b_4\cos\beta_4 & \sin\beta_5 \end{bmatrix} \begin{bmatrix} \ddot b_3 \\ \ddot\beta_3 \\ \ddot\beta_4 \\ \ddot b_5 \end{bmatrix} + \begin{bmatrix} -b_2\sin\beta_2 \\ b_2\cos\beta_2 \\ 0 \\ 0 \end{bmatrix} \ddot\beta_2 +$$

$$+ \begin{bmatrix} -b_2\cos\beta_2\dot\beta_2^2 - b_6\cos\beta_6\dot\beta_6^2 - 2\dot b_3\dot\beta_3\sin\beta_3 - b_3\cos\beta_3\dot\beta_3^2 \\ -b_2\sin\beta_2\dot\beta_2^2 - b_6\sin\beta_6\dot\beta_6^2 + 2\dot b_3\dot\beta_3\cos\beta_3 - b_3\sin\beta_3\dot\beta_3^2 \\ -b_4\cos\beta_4\dot\beta_4^2 - b_7\cos\beta_7\dot\beta_7^2 \\ -b_4\sin\beta_4\dot\beta_4^2 - b_7\sin\beta_7\dot\beta_7^2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \quad (5)$$

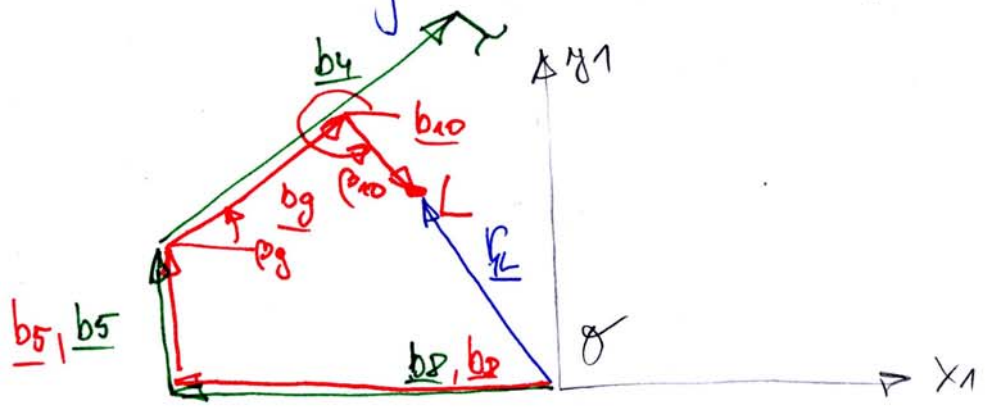
$$\underline{J_z}\cdot\ddot{\underline{z}} + \underline{J_q}\cdot\ddot{\underline{q}} + \underline{j_{qz}} = \emptyset$$

$$\underline{J_z}\cdot\ddot{\underline{z}} = -\left(\underline{J_q}\cdot\ddot{\underline{q}} + \underline{j_{qz}}\right) \Big/ \underline{J_z}^{-1}$$

$$\boxed{\ddot{\underline{z}} = -\underline{J_z}^{-1}\left(\underline{J_q}\cdot\ddot{\underline{q}} + \underline{j_{qz}}\right)}$$

Popis polohy bodu „L"

- zakreslení mový vektor k bodu „L" ($\underline{b_9}, \underline{b_{10}}$)



$\underline{r_L} = \underline{b_8} + \underline{b_5} + \underline{b_9} + \underline{b_{10}}$, kde $b_9 = \overline{DC}$, $b_{10} = \overline{CL}$,

$\beta_9 = \beta_4$, $\beta_{10} = \beta_4 + \frac{3}{2}\pi$

Složkové rovnice

$$x_{1L} = b_8\cos\beta_8 + \underline{b_5}\cos\beta_5 + b_9\cos\underline{\beta_9} + b_{10}\cos\underline{\beta_{10}}$$

$$y_{1L} = b_8\sin\beta_8 + \underline{b_5}\sin\beta_5 + b_9\sin\underline{\beta_9} + b_{10}\sin\underline{\beta_{10}}$$

$\dot{x}_{1L} =$

$\dot{y}_{1L} =$

$\ddot{x}_{1L} =$

$\ddot{y}_{1L} =$