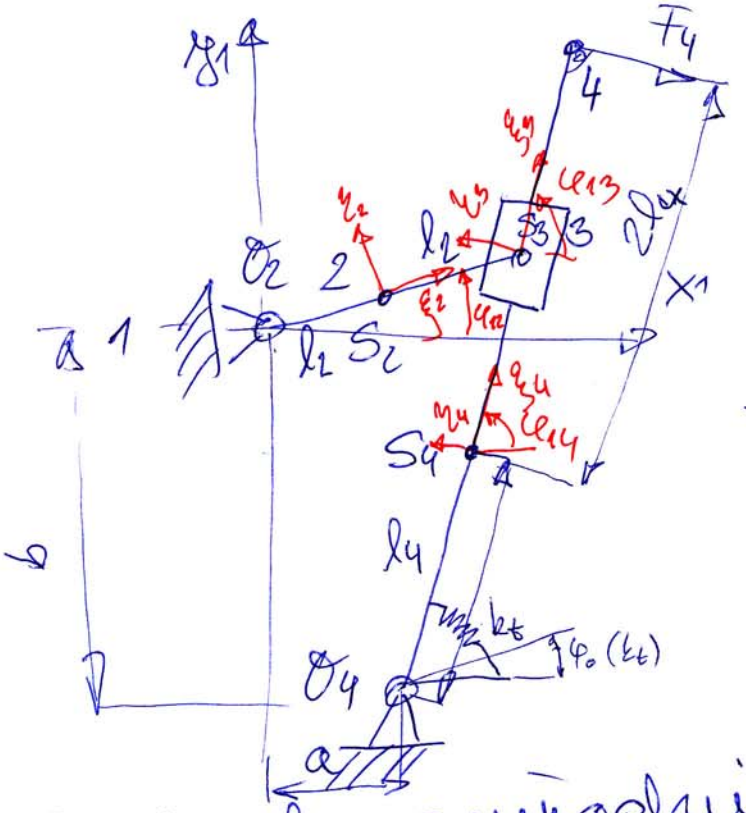


D: l_2, l_4, m_2, m_3, m_4
I_{2O2}, I_{4S4}, fyz. sou
k_t, F_4, φ_0

U: „PR" → Poh. vol.
Lagr. vol. sou. typu
LEMT (LRST)

1) Popis fyz. souřadnicemi

$s = [x_{1S2}, y_{1S2}, \varphi_{12}, x_{1S3}, y_{1S3}, \varphi_{13}, x_{1S4}, y_{1S4}, \varphi_{14}]$

⇒ 9 souřadnic

2) Stupně volnosti

$i = 3(n-1) - 2 \cdot rot - 2 \cdot pos$

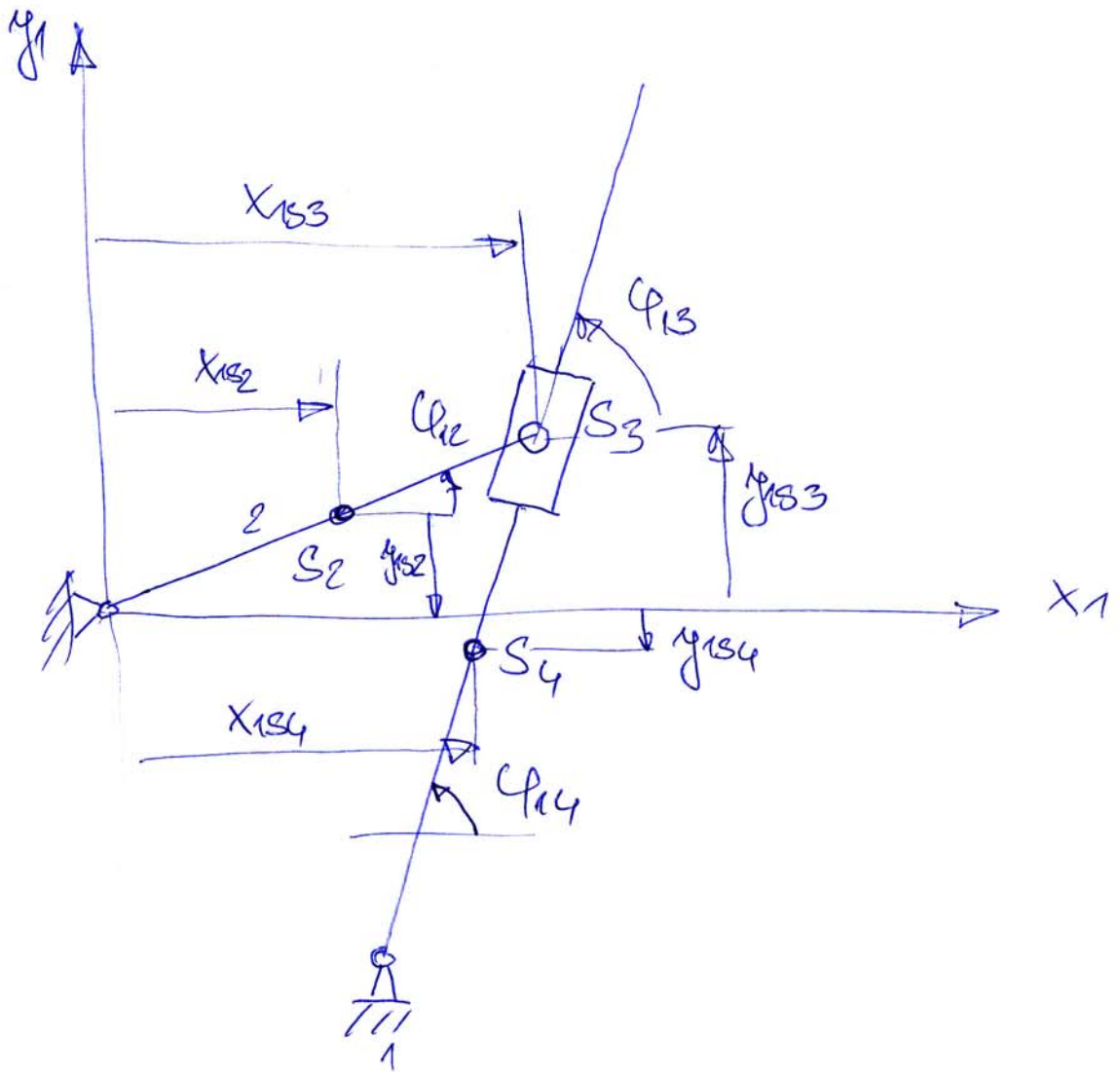
$i = 3(4-1) - 2 \cdot 3 - 2 \cdot 1 = 9 - 6 - 2 =$ 1° volnosti

3) Vazby

3x rotační (2 rovnice)
1x posuvná (2 rovnice)

⇒ 8 vazbových rovnic

Zavedení fyzikálních souřadnic



4) Kinetická energie

$$E_k(s_j) = \frac{1}{2} m_2 \left(\dot{x}_{1S2}^2 + \dot{y}_{1S2}^2\right) + \frac{1}{2} I_{2S2} \cdot \dot{\varphi}_{12}^2 +$$

$$+ \frac{1}{2} m_3 \left(\dot{x}_{1S3}^2 + \dot{y}_{1S3}^2\right) + \frac{1}{2} I_{3S3} \cdot \dot{\varphi}_{13}^2 +$$

$$+ \frac{1}{2} m_4 \left(\dot{x}_{1S4}^2 + \dot{y}_{1S4}^2\right) + \frac{1}{2} I_{4S4} \cdot \dot{\varphi}_{14}^2$$

$$I_{2S2} = I_{2O2} - m_2 \cdot l_2^2$$

$$\varphi_{14k_t} = \varphi_{14} - \varphi_0$$

$$\delta\varphi_{14k_t} = \delta\varphi_{14}$$

5) Zobecnělé síly

$$\sum Q \cdot \delta s = -G_2 \cdot \delta y_{1S2} - G_3 \delta y_{1S3} - G_4 \delta y_{1S4} - \underbrace{k_t \delta\varphi_{14k_t}}_{(\varphi_{14} - \varphi_0)} +$$

$$+ F_{40} \sin\varphi_{14} \cdot \delta x_{1S4} - F_4 \cos\varphi_{14} \delta y_{1S4} - \left\{ -k_t \cdot \delta\varphi_{14} \cdot (\varphi_{14} - \varphi_0) \right.$$

$$\left. - F_{40} 2 l_4 \cdot \delta\varphi_{14} \right.$$

6) LEMT (Lagrange's Equations of Mixed Type)

$$\frac{d}{dt}\left(\frac{\partial E_k}{\partial \dot{s}_j}\right) - \frac{\partial E_k}{\partial s_j} = Q_j + \sum_{k=1}^{r} \lambda_k \frac{\partial f_k}{\partial s_j}$$

7) Vazbové podmínky

O_2: $x_{1S2} - l_2 \cdot \cos\varphi_{12} = 0 = f_1$
$y_{1S2} - l_2 \cdot \sin\varphi_{12} = 0 = f_2$ } rotační

O_4: $x_{1S4} - l_4 \cdot \cos\varphi_{14} - a = 0 = f_3$
$y_{1S4} - l_4 \cdot \sin\varphi_{14} + b = 0 = f_4$ } rotační

S_3: $x_{1S2} + l_2 \cdot \cos\varphi_{12} - x_{1S3} = 0 = f_5$
$y_{1S2} + l_2 \cdot \sin\varphi_{12} - y_{1S3} = 0 = f_6$ } rotační

3'': $\varphi_{13} - \varphi_{14} = 0 = f_7$

$$\operatorname{tg}\varphi_{14} = \frac{y_{1S3} - y_{1S4}}{x_{1S3} - x_{1S4}} = \frac{\sin\varphi_{14}}{\cos\varphi_{14}}$$

$$(y_{1S3} - y_{1S4})\cos\varphi_{14} - (x_{1S3} - x_{1S4})\sin\varphi_{14} = 0 = f_8$$

Pozn. Pokud mají mít Lagr. multiplikátory význam reakcí, pak musí být vazbové podmínky vyjádřeny tak, že obsahují pouze tělesa na kterých působí vazba.

8) Jacobian Φ

	$\frac{\partial}{\partial x_{1S2}}$	$\frac{\partial}{\partial y_{1S2}}$	$\frac{\partial}{\partial \varphi_{12}}$	$\frac{\partial}{\partial x_{1S3}}$	$\frac{\partial}{\partial y_{1S3}}$	$\frac{\partial}{\partial \varphi_{13}}$	$\frac{\partial}{\partial x_{1S4}}$	$\frac{\partial}{\partial y_{1S4}}$	$\frac{\partial}{\partial \varphi_{14}}$
f_1	1	0	$l_2 \cdot \sin\varphi_{12}$	0	0	0	0	0	0
f_2	0	1	$-l_2\cos\varphi_{12}$	0	0	0	0	0	0
f_3	0	0	0	0	0	0	1	0	$l_4 \sin\varphi_{14}$
f_4	0	0	0	0	0	0	0	1	$-l_4\cos\varphi_{14}$
f_5	1	0	$-l_2\sin\varphi_{12}$	-1	0	0	0	0	0
f_6	0	1	$l_2\cos\varphi_{12}$	0	-1	0	0	0	0
f_7	0	0	0	0	0	1	0	0	-1
f_8	0	0	0	$-\sin\varphi_{14}$	$\cos\varphi_{14}$	0	$\sin\varphi_{14}$	$-\cos\varphi_{14}$	$-(y_{1S3}-y_{1S4})\sin\varphi_{14} - (x_{1S3}-x_{1S4})\cos\varphi_{14}$

9) Pohybové rovnice

$$m_2 \cdot \ddot{x}_{1S2} = \lambda_1 + \lambda_5$$

$$m_2 \cdot \ddot{y}_{1S2} = \lambda_2 + \lambda_6 - G_2$$

$$I_{2S2} \cdot \ddot{\varphi}_{12} = \lambda_1 l_2 \sin\varphi_{12} - \lambda_2 l_2 \cos\varphi_{12} - \lambda_5 l_2 \sin\varphi_{12} + \lambda_6 l_2 \cos\varphi_{12}$$

$$m_3 \cdot \ddot{x}_{1S3} = -\lambda_5 - \lambda_8 \sin\varphi_{14}$$

$$m_3 \ddot{y}_{1S3} = -\lambda_6 + \lambda_8 \cos\varphi_{14} - G_3$$

$$I_{3S3} \cdot \ddot{\varphi}_{13} = \lambda_7$$

$$m_4 \cdot \ddot{x}_{1S4} = \lambda_3 + \lambda_8 \cdot \sin\varphi_{14} + F_4 \sin\varphi_{14}$$

$$m_4 \cdot \ddot{y}_{1S4} = \lambda_4 - \lambda_8 \cos\varphi_{14} - G_4 - F_4 \cos\varphi_{14}$$

$$I_{4S4} \cdot \ddot{\varphi}_{14} = \lambda_3 \cdot l_4 \sin\varphi_{14} - \lambda_4 l_4 \cdot \cos\varphi_{14} - \lambda_7 - \lambda_8 \left[(y_{1S3} - y_{1S4}) \sin\varphi_{14} + (x_{1S3} - x_{1S4}) \cos\varphi_{14} \right] - k_t (\varphi_{14} - \varphi_{140}) - F_4 \cdot 2 l_4$$

Poznámka:

Pořadí byly dodrženy podmínky vazb. rov., pak bude např. λ_1 reakce v ose „x" ve vazbě (rotační) „O_2".