

## 1 Système

$$\begin{cases} m_s \ddot{z}_s + u (\dot{z}_s - \dot{z}_u) + k_s (z_s - z_u) &= -F_f \\ m_u \ddot{z}_u - u (\dot{z}_s - \dot{z}_u) - k_s (z_s - z_u) + k_t (z_u - z_r) &= F_f \\ F_f &= C_f \tanh(\gamma_f \dot{z}_s) \end{cases}$$

## 2 Sortie plate

$$S_p = m_u \dot{z}_u + m_s \dot{z}_s$$

$$S_p^{(1)} = m_u \dot{z}_u + m_s \dot{z}_s$$

$$\begin{aligned} S_p^{(2)} &= m_u \ddot{z}_u + m_s \ddot{z}_s \\ &= -k_t (z_u - z_r) \end{aligned}$$

$$S_p^{(3)} = -k_t (\dot{z}_u - \dot{z}_r)$$

$$\begin{aligned} S_p^{(4)} &= k_t \ddot{z}_r - k_t \ddot{z}_u \\ &= k_t \ddot{z}_r + \frac{k_t}{m_u} [u (\dot{z}_s - \dot{z}_u) + k_s (z_s - z_u) - k_t (z_u - z_r) + F_f] \end{aligned}$$

### 2.1 Linéarisation

$$\begin{cases} S_p^{(4)} &= v \\ v &= S_{pr}^{(4)} - \lambda_0 e_{sp} - \lambda_1 e_{sp}^{(1)} - \lambda_2 e_{sp}^{(2)} - \lambda_3 e_{sp}^{(3)} \end{cases}$$

$$e_{sp} = m_u \dot{z}_u + m_s \dot{z}_s - S_{pr}$$

$$e_{sp}^{(1)} = m_u \dot{z}_u + m_s \dot{z}_s - S_{pr}^{(1)}$$

$$e_{sp}^{(2)} = k_t \dot{z}_r - k_t \dot{z}_u - S_{pr}^{(2)}$$

$$e_{sp}^{(3)} = k_t \ddot{z}_r - k_t \ddot{z}_u - S_{pr}^{(3)}$$

On obtient la commande :

$$u (\dot{z}_s - \dot{z}_u) = \frac{m_u}{k_t} v - m_u \ddot{z}_r - k_s (z_s - z_u) + k_t (z_u - z_r) - F_f$$