

$$\dot{p}_3 = e_3 = \dot{S}_E - e_1 - e_4 = \tau_{in} - f_1 B_1 - q_5 / k_t$$

$$\dot{p}_3 = \tau_{in} - f_1 B_1 - q_5 / k_t \quad \boxed{\dot{p}_3 = \tau_{in} - \frac{p_3 B_1}{\sigma_1} - q_5 \cdot k_T}$$

$$q_5 = f_5 = f_4 - f_6 = \boxed{p_3 / J_1 - p_7 / J_2 = q_5}$$

$$\dot{p}_7 = e_7 = e_6 - e_8 = (q_5 \cdot k_t) - \tilde{m}(e_{10} + e_{11} + e_{12})$$

$$= q_5 k_t - \tilde{m}(\dot{p}_{10} + k_{11} q_{11} + b_{12} \dot{p}_{10} / m)$$

$$p_{10} = M \dot{f}_{11} = M \tilde{m} \dot{f}_7 = M \tilde{m} p_7 / J_2$$

$$\dot{p}_{10} = \frac{M \tilde{m} \dot{p}_7}{J_2}$$

$$\dot{p}_7 = q_5 k_t - \tilde{m} \left(\frac{M \tilde{m} \dot{p}_7}{J_2} + k_{11} q_{11} + b_{12} \dot{p}_{10} / m \right)$$

$$\dot{p}_7 \left(1 + \frac{M \tilde{m}^2}{J_2} \right) = q_5 k_t - \tilde{m} (k_{11} q_{11} + b_{12} \dot{p}_{10} / m)$$

$$\dot{p}_7 = \frac{q_5 k_t - \tilde{m} (k_{11} q_{11} + b_{12} \dot{p}_{10} / m)}{\left(1 + \frac{M \tilde{m}^2}{J_2} \right)} \quad \frac{M \tilde{m} p_7}{J_2}$$

\dot{p}_3	$=$	$-\frac{B_1}{J_1}$	0	$-k_T$	0	p_3	1
\dot{p}_7	$=$	0	$-\frac{\tilde{m}^2 b_{12}}{J_2 (1 + \frac{M \tilde{m}^2}{J_2})}$	$\frac{k_T}{(1 + \frac{M \tilde{m}^2}{J_2})}$	$-\frac{\tilde{m} k_{11}}{(1 + \frac{M \tilde{m}^2}{J_2})}$	p_7	0
\dot{q}_5		$1/J_1$	$-1/J_2$	0	0	q_5	0
\dot{q}_{11}		0	$\frac{\tilde{m}}{J_2}$	0	0	q_{11}	0

$\bullet \bar{U}_{in}$

5) Conceptual Question

- Add slop to the system. Imperfect gear meshing will make it so p_7 & p_{10} are not linked by derivative causality anymore.

This would make it a 6th order system as the energy stored is no longer linked between the two.

