MCT 151:
Introduction to Mechatronics

Actuators

By

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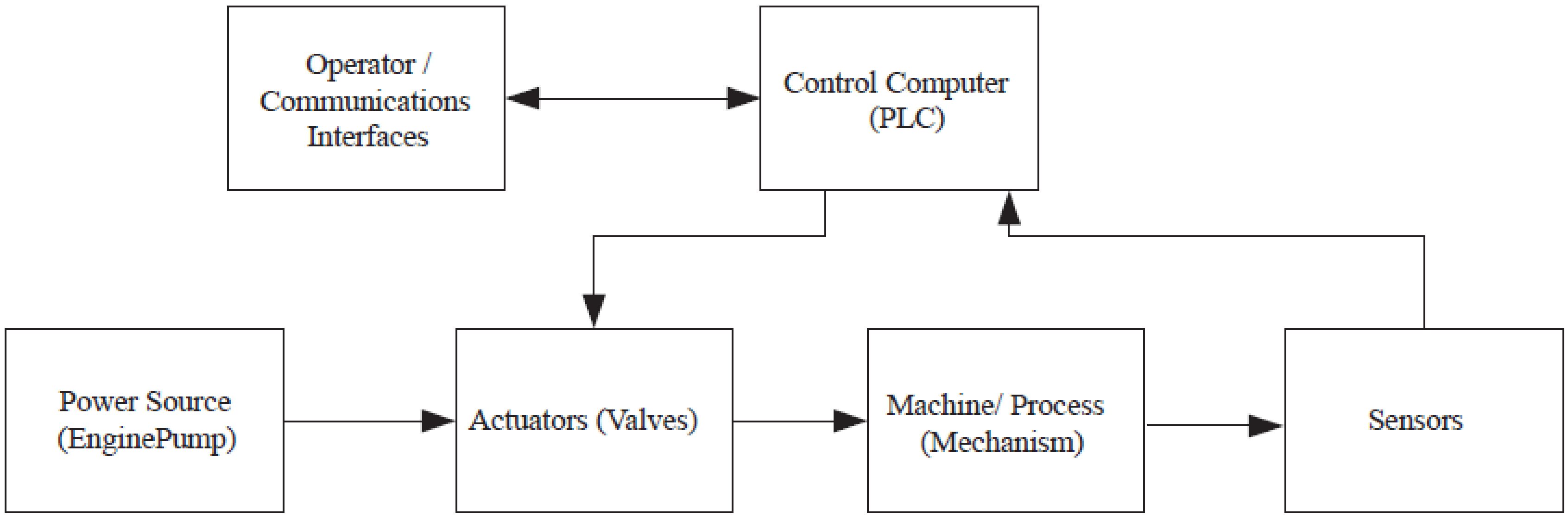
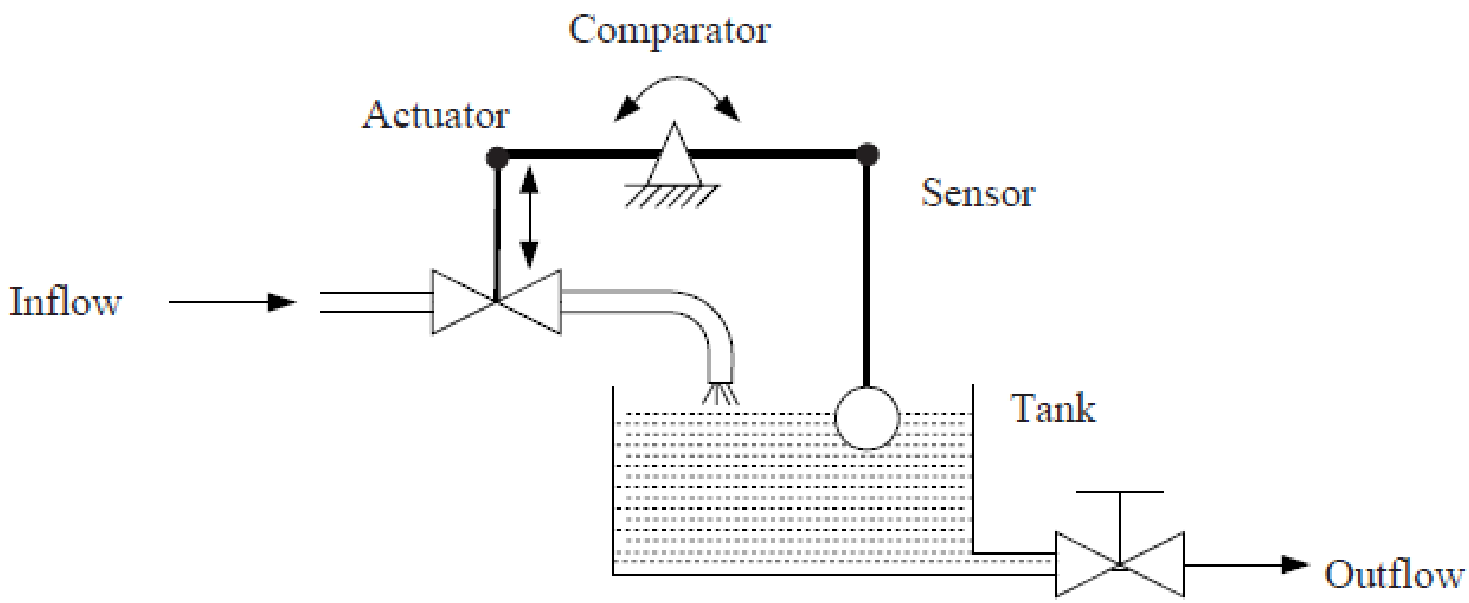
Spring 2015

Main Components of MCT System

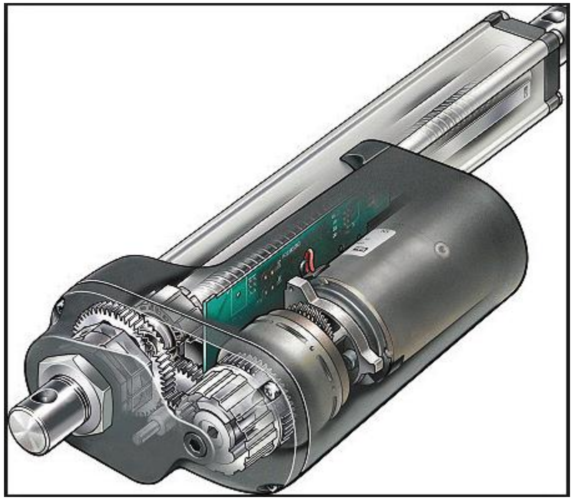


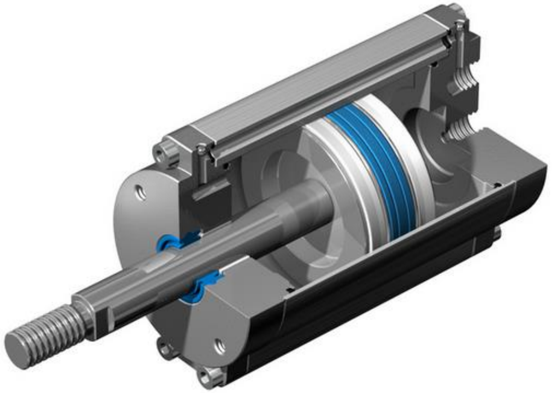
Complete Mechanical Closed Loop System

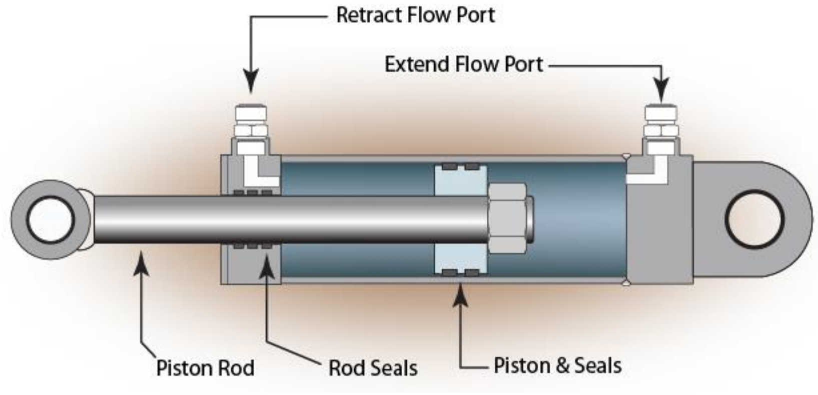


Actuators Power Based types

- Electric.
- Hydraulic.
- Pneumatic.

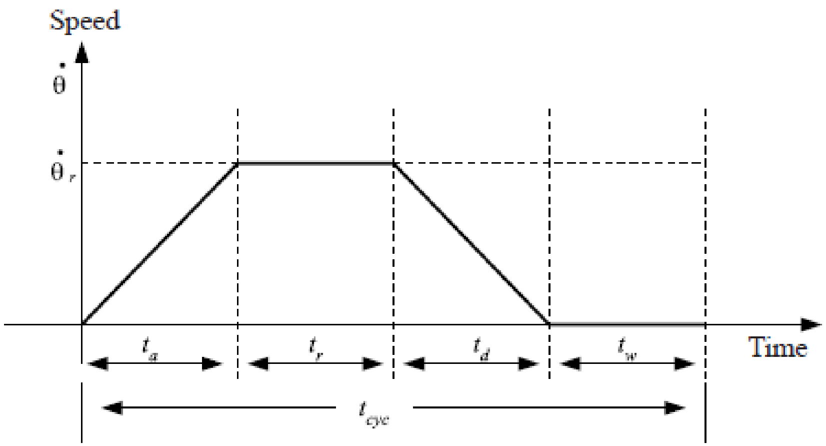






Actuators Sizing

- The size of the actuator refers to its power capacity and must be large enough to be able to move the axis under the given inertial and load force/torque conditions.
- If the actuator is undersized, the axis will not be able to deliver the desired motion, i.e. can not deliver desired acceleration or speed levels or over heats due to over loading.
- If the actuator is over sized, it will cost more and the motion axis will have slower bandwidth since as the actuator size gets larger

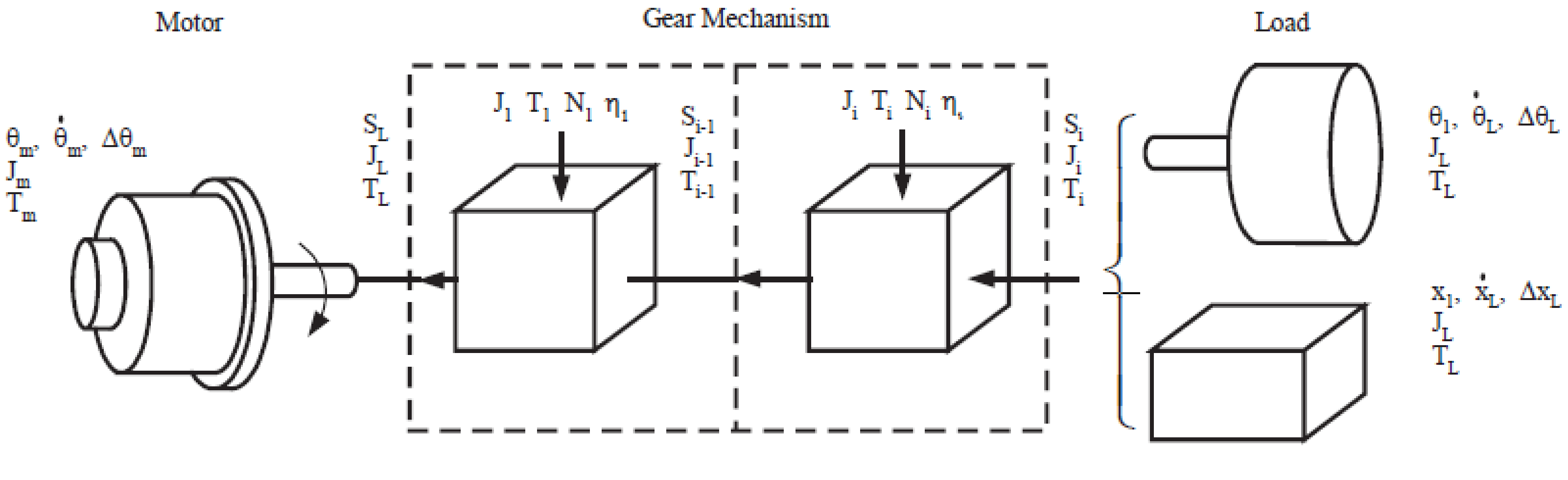


Actuator sizing requirements

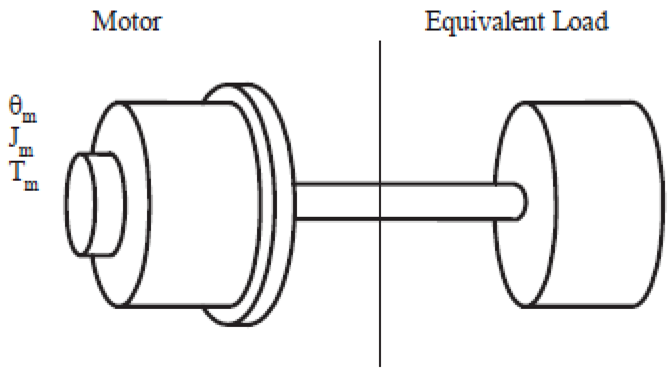
- **The following requirements for an axis under worst operating conditions (i.e. largest expected inertia and resistive load)**

1. maximum torque (also called peak torque) required, T_{max},
2. rated (continuous) torque required, T_r,
3. maximum speed required, $\dot{\theta}_{max}$,
4. positioning accuracy required, $(\Delta\theta)$,
5. gear mechanism parameters: gear ratio, its inertial and resistive load (force/torque), stiffness, backlash characteristics.

Electric actuator

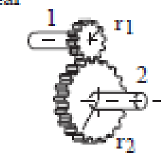
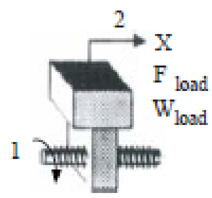
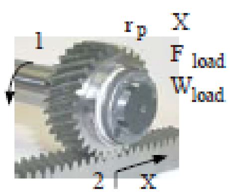
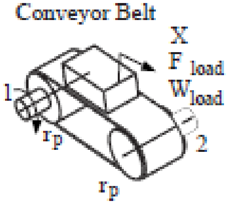


(a)



(b)

Motion Conversion Mechanisms

	Mechanism Characteristics				Input Characteristics			Output Characteristics		
Mechanism Type	n_1	η_1	J_1	T_1	S_2	J_2	T_2	S_1	J_1	T_1
Gear 	$\frac{r_2}{r_1}$	≤ 1.0	J_{r1} J_{r2}	$Tc.sgn(\dot{\theta}_1)$ $+c\,\dot{\theta}_1$	θ_2	J_2	T_2	$\theta_1 = n\,\theta_2$ $= (\frac{r_2}{r_1})\,\theta_2$	$J_{r1} + \left(\frac{J_{r2}}{n^2\eta}\right)$	$T_i + \frac{1}{n\eta} T_2$
Belt-Pulley 	$\frac{r_2}{r_1}$	≤ 1.0	J_{r1} J_{r2} W_{belt}	$Tc.sgn(\dot{\theta}_1)$ $+c\,\dot{\theta}_1$	θ_2	J_2	T_2	$\theta_1 = n\,\theta_2$ $= (\frac{r_2}{r_1})\,\theta_2$	$J_{r1} + \left(\frac{J_{r2} + J^2}{n^2\eta}\right)$ $+ \frac{1}{2}\left(\frac{W_{belt}}{g}\right)(r_1^2 + r_2^2)$	$T_i + \frac{1}{n\eta} T_2$
Ball Screw or Cam 	$2\pi p$	≤ 1.0	J_{lead} W_{load}	$Tc.sgn(\dot{\theta}_1)$ $+c\,\dot{\theta}_1$	X	W_{load}	F_{load}	$\theta_1 = n\,X$ $= (2\pi p)\,X$	$J_{load} + \left(\frac{W_{load}}{g}\right)\left(\frac{1}{n^2\eta}\right)$	$T_i + \frac{1}{n\eta} F_{load}$
Rack Pinion 	$\frac{1}{r_p}$	≤ 1.0	J_{pinion} W_{rack}	$Tc.sgn(\dot{\theta}_1)$ $+c\,\dot{\theta}_1$	X	W_{load}	F_{load}	$\theta_1 = n\,X$ $= (\frac{1}{r_p})\,X$	J_{pinion} $+ \left(\frac{W_{rack}}{g}\right)\left(\frac{1}{n^2\eta}\right)$ $+ \left(\frac{W_{load}}{g}\right)\left(\frac{1}{n^2\eta}\right)$	$T_i + \frac{1}{n^2\eta} F_{load}$
Conveyor Belt 	$\frac{1}{r_p}$	≤ 1.0	J_{p1} J_{p2} W_{belt}	$Tc.sgn(\dot{\theta}_1)$ $+c\,\dot{\theta}_1$	X	W_{load}	F_{load}	$\theta_1 = n\,X$ $= (\frac{1}{r_p})\,X$	$J_{p1} + J_{p2}$ $+ \left(\frac{W_{belt} + W_{load}}{g}\right)\left(\frac{1}{n^2\eta}\right)$	$T_i + \frac{1}{n^2\eta} F_{load}$

Torque / Force Requirements

- **The actuator needs to generate torque/force in order to move two different categories of inertia and load**

  1. load inertia and force/torque,

  2. inertia (and any resistive force) of the actuator itself. For instance, an electric motor has a rotor with finite inertia and that inertia is important on how fast the motor can accelerate and decelerate in high cycle rate automated machine applications. Similarly, a hydraulic cylinder has a piston and large rod which has non negligible mass.

$$J_T \cdot \ddot{\theta} = T_T$$

Actuators Sizing Algorithm

1. Define the geometric relationship between the actuator and load. In other words, select the type of motion transmission mechanism between the motor and the load (N).
2. Define the inertia and torque/force characteristics of the load and the transmission mechanisms, i.e. define the inertia of the tool as well as the inertia of the gear reducer mechanisms (Jl, Tl).
3. Define the desired cyclic motion profile in the form of load speed versus time ($\dot{\theta} l(t)$).

Actuators Sizing Algorithm *Cont'd*

4. Using the reflection equations developed above, calculate the reflected load inertia and torque/forces (J_{eff}, T_{eff}) that will effectively act on the actuator shaft as well as the desired motion at the actuator shaft ($\dot{\theta}_m(t) = \dot{\theta}_{in}(t)$).
5. Guess an actuator/motor inertia from an available list (or make the first calculation with zero motor inertia assumption), and calculate the torque history, $T_m(t)$, for the desired motion cycle. Then calculate the peak torque and RMS torque from $T_m(t)$.
6. Check if the actuator meets the required performance in terms of peak and RMS torque, and maximum speed capacity (T_p, T_{rms}, $\dot{\theta}_{max}$). If the above selected actuator/motor from the available list does not meet the requirements (i.e. too small or too large), repeat the previous step by selecting a different motor.

Solved Example: Page 228