Introduction to Mechatronics (MCT 151)

Actuator Sizing

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Problem 1:

The specifications of a machine that utilizes a lead screw mechanism are:
Ball screw: Diameter: 14 mm, length: 500 mm, pitch: 0.5 rev/mm, efficiency: 45%
Mechanical data: Friction coefficient (μ): 0.1, load: 6 kg, orientation: inclined by 10° relative to horizontal. Taking into consideration that inertia ratio between the machine and the motor is 4:1
Move profile: Type: 1/6- 2/3- 1/6 Trapezoid, distance: 8 mm, move time: 0.2 s, dwell time: 0.1 s.
Determine the peak and root mean square torques of a suitable motor to drive this machine.

Problem 1 (Solution):

Given: Leadscrew mechanism

$D_{ls} = 14\,mm = 0.014m$

L = $500\,mm = 0.5\,m$

Pitch = $0.5\,\frac{rev}{mm} = 500\,rev\,\frac{rev}{m}$

η = 0.45

μ = 0.1

$m_{l=6\,kg}$

$\theta\ = 10°$

$$\frac{Jmachine}{Jmotor} = \frac{4}{1}$$

Trapezoidal →(1/6 , 2/3, 1/6)

Distance = $8\,mm = 0.008\,m$

$Tmove = 0.2$

$Tdwell = 0.1sec$

Problem 1 (Solution):

$$Tm = T_R + J_T\ddot{\theta}_m$$

1. To get the inertia:

$$J_T = J_m + J_{leadscrew} + J_{load}$$

a. $J_{leadscrew} \rightarrow cylinder\ shape$

$$= \frac{1}{2}\ m\, r^2$$

$$= \frac{1}{2}\ \rho\pi r^4 L = \frac{1}{2}(7800)\pi(0.007)^4(0.5)$$

$$= 1.47\ x\ 10^{-5}\mathrm{kg}.\, m^2$$

b. $J_{loadeq} = \dfrac{m_l}{\eta(2\pi P)^2} = 1.35x\ 10^{-6}$

c. $J_{machine} = J_{loadeq} + J_{leadscrew} = 1.65\ x10^{-5}kg.\, m^2$

d. $J_{total} = 2\ x10^{-5}kg.\, m^2$

Problem 1 (Solution):

2. To get the T_R

$T_{f=} torque\ due\ to\ friction$

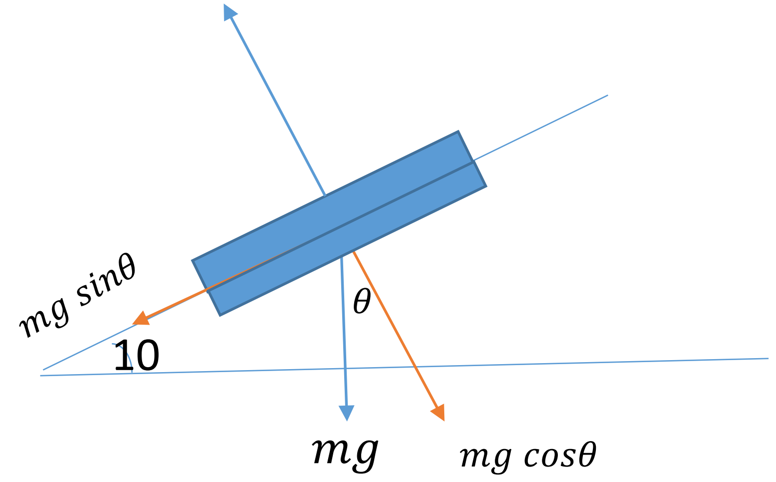
$$= \frac{\mu\, mg\ cso\theta}{\eta\ (2\pi P)} = 4.096\ x\ 10^{-3}$$

To get the T_l

$T_{l=} external\ torque\ due\ to\ the\ load$

$$= \frac{mg\ sin\theta}{\eta\ (2\pi P)} = 7.22x\ 10^{-3}$$

So $T_R = T_f + T_{l=}\ 0.0113\ N.m$

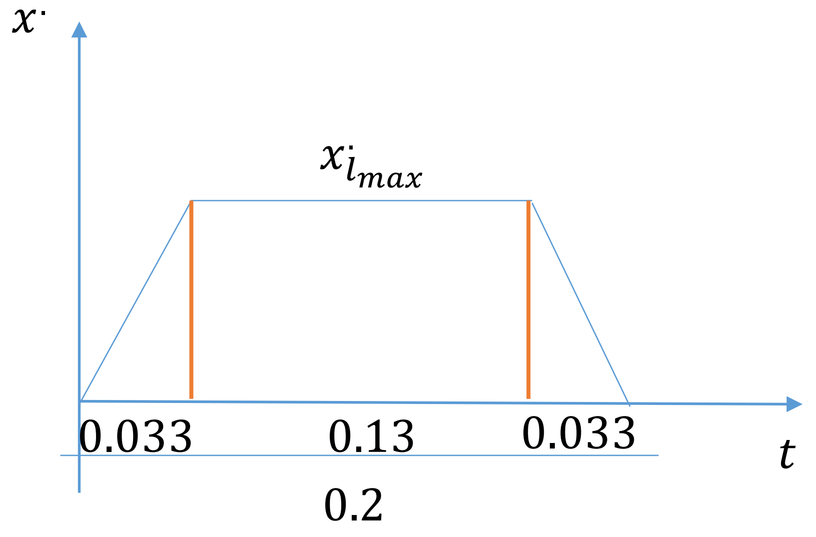


3. To get $\ddot{\theta_m}$

$x_{l_{max}} = \int_0^t x_{\dot{l}}\ dt$

$x_{l_{max}} = \frac{0.2+0.13}{2} x_{\dot{l}_{max}}$

$x_{l_{max}} = 0.008$ m



$x_{\dot{l}_{max}} = 0.008\ x\ \frac{2}{0.2+0.13} = 0.048 \frac{m}{s}\ \rightarrow linear\ spead$

$x_{\dot{l}_{max}} = \frac{\theta_{\dot{l}max}}{2\pi P} \rightarrow \theta_{\dot{l}max} = 48\ A = \pi\ rad/sec$

Problem 1 (Solution):

Now we want to see the θ_{lmax}

$$\ddot{\theta}_{acc} = \frac{d\dot{\theta}_l}{dt} = \frac{\dot{\theta}_{lmax}}{0.033} = 1460.4\pi \, rad/sec^2$$

$$\ddot{\theta}_{dec} = -1460.4\,\pi \, rad/sec^2$$

$$\ddot{\theta}_{ss} = 0$$

3. To get the motor torque

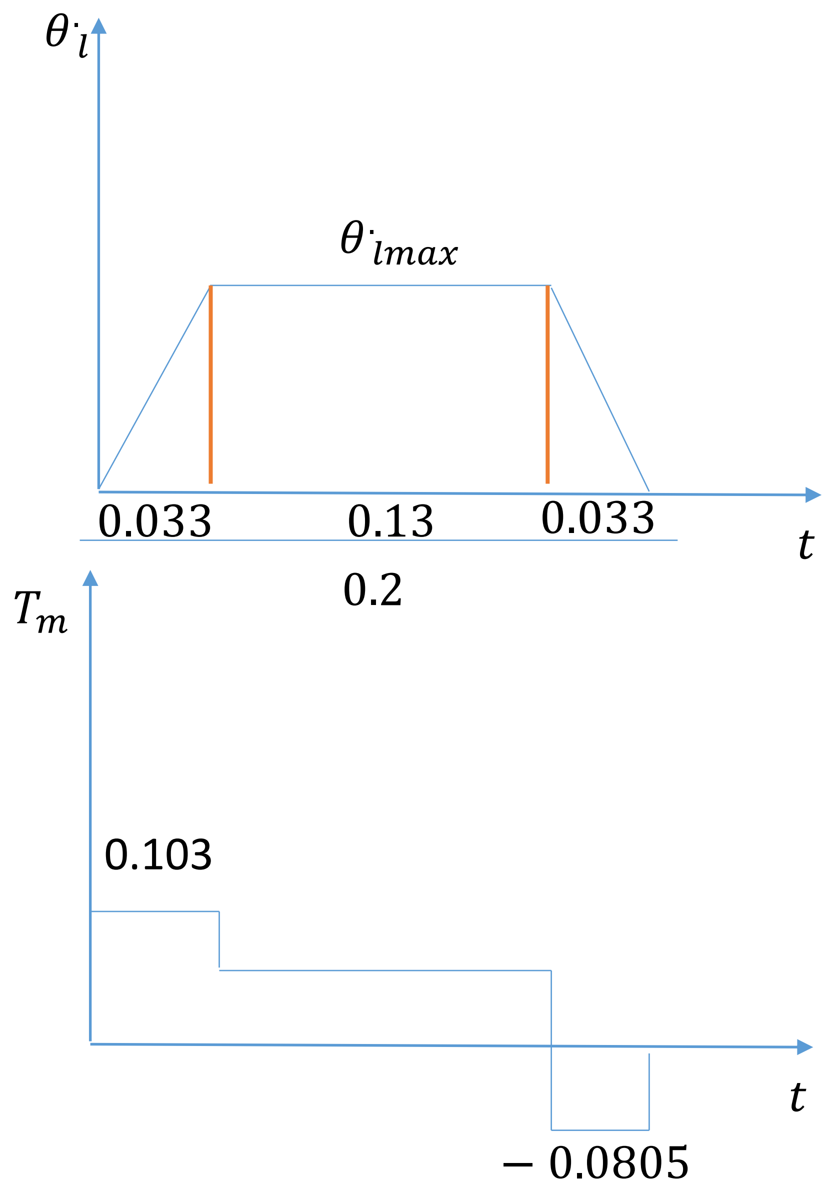
$$T_{acc} = T_R + J_T\ddot{\theta} = 0.103\ Nm$$

$$T_{dec} = T_R + J_T\ddot{\theta} = -\ 0.0805\ Nm$$

$$T_{ss} = T_R = 0.0113\ \text{Nm}$$

Peak torque = 0.103 Nm

$$T_{RMS} = \sqrt{\frac{\int_0^t T_m^2\ t\ dt}{T_{cycle}}} = \sqrt{\frac{T_{acc}^2\ t_a + T_{dec}^2 t_d + T_{ss}^2 t_{ss}}{T_{cycle}}} = 0.044 \text{ Nm}$$



Problem 2:

A conveyor; shown in Fig.; is used to transfer bags 15 kg in a production line. The conveyor main roller is connected to main servomotor through a gear box with the following specifications: Roller diameter=300mm, Roller length=1000mm, gear box reduction ratio=50:1, orientation=20° to the horizontal plane, conveyor belt weight=10 kg, working temperature=35°C, maximum number of bags on conveyor at the same time=10 bags. The motion profile: Type: 1/10 - 4/5 - 1/10 –Trapezoid, distance =500mm, move time=30s, dwell time=3s. Determine the peak and root mean square torque of the servo motor.

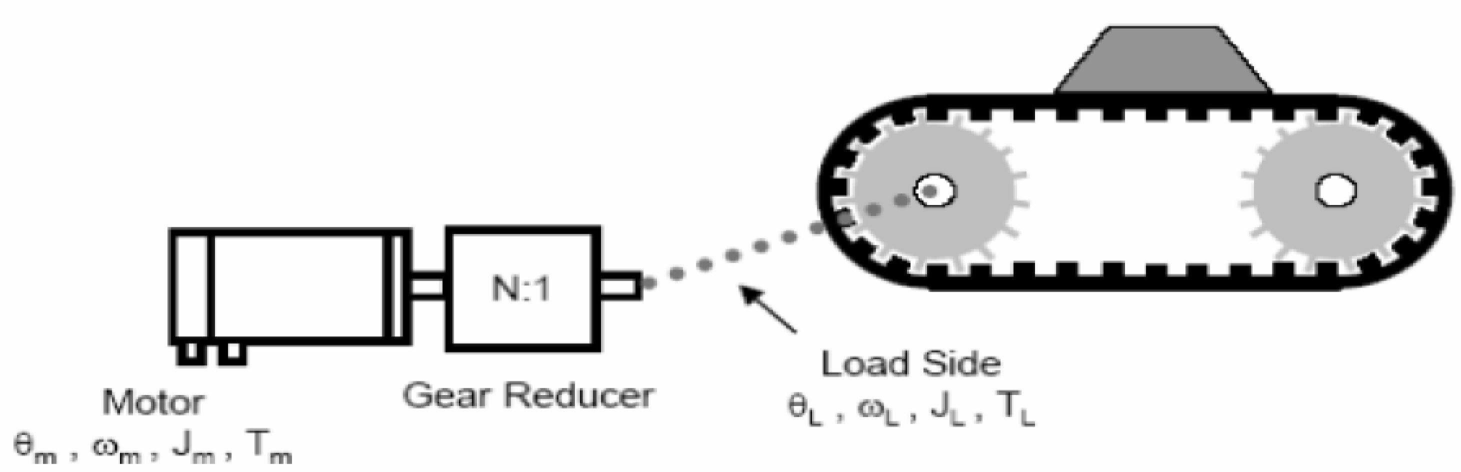


Fig. 4

Problem 2 (Solution):

Given: Convayour + Gear Box + rotary motor

working temperature=35°C

Bags = 15 kg

n = 10 bags

$D_r = 300\ mm = 0.3m$

L r= $1000mm = 1\ m$

N = 50:1 (reduction ration)

Conveyor weight = 10 kg

$\theta = 20°$

$$\frac{Jmachine}{Jmotor} = \frac{1}{1}$$

Trapezoidal →(1/10 , 4/5, 1/10)

Distance = $500mm = 0.5\ m$

$Tmove = 30\ sec$

$Tdwell = 3sec$

Problem 1 (Solution):

$$Tm = T_R + J_T \ddot{\theta_m}$$

1. To get the inertia:

$$J_T = J_m + J_{conv\,\mathrm{eff}} + J_{load_{\mathrm{eff}}} + J_{roller\ \mathrm{eff}}$$

a. $J_{roller} \rightarrow cylinder\ shape$

$$= \frac{2\,x \frac{1}{2}\, m\, r^2}{\eta N^2}$$

$$= \frac{\rho \pi r^4 L}{50^2} = (7800)\pi(0.15)^4(1)/50^2$$

$$= 4.96\ x\ 10^{-3} \mathrm{kg}.m^2$$

b. $J_{conv} = \frac{m_l\, r^2}{\eta (N)^2} = 9x10^{-5} kg.m^2$

c. $J_{load} = \frac{m_l r^2}{\eta (N)^2} = 1.35x\ 10^{-3}$

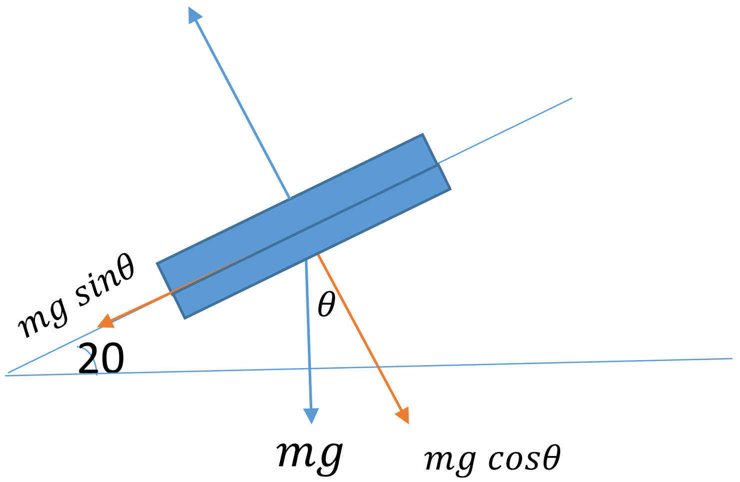
d. $J_{sys} = J_{conv} + J_{load} + J_{roller} = \ 6.4\ x10^{-3} kg.m^2$

Problem 2 (Solution):

We assume the motor inertia so

$$J_{sys} = J_{motor}$$

$$J_{total} = 2\, x\, J_{sys} = 0.0128\, kg.m^2$$



2. To get the T_R

$T_R = \ T_{l=} external\ torque\ due\ to\ the\ load$

$= \dfrac{(mg\ sin\theta) r_r}{\eta (N)} = 1.508\ Nm$

Where m=10x15

Problem 2 (Solution):

3. To get $\theta_{\ddot{m}}$

$x_{l_{max}} = \int_0^t x_{\dot{l}}\ dt$

$x_{l_{max}} = \frac{24+30}{2} x_{\dot{l}_{max}}$

$x_{l_{max}}$ = 0.5m

$x^{\cdot} l_{max} = 0.5x\ \frac{2}{24+30} = 0.0185 \frac{m}{s}\ \rightarrow linear\ spead$

$x_{\dot{l}_{max}} = \theta_{\dot{l}max}\ rr_{oller}$ → $\theta_{\dot{l}max}$ = $0.123 r/sec$ (load spead)

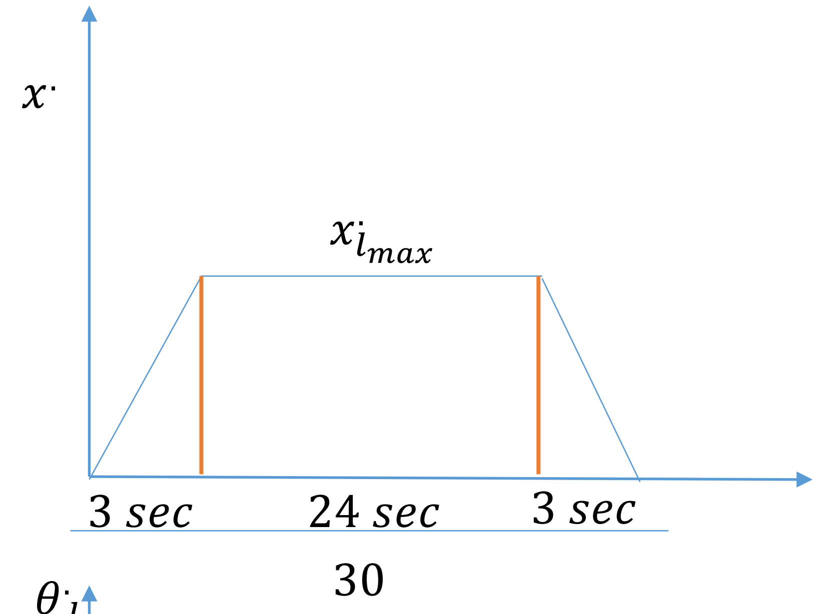
$\theta^{\cdot}_{mmax} = N\theta^{\cdot}_{lmax}$ =50x0.123= 6.173 r/sec

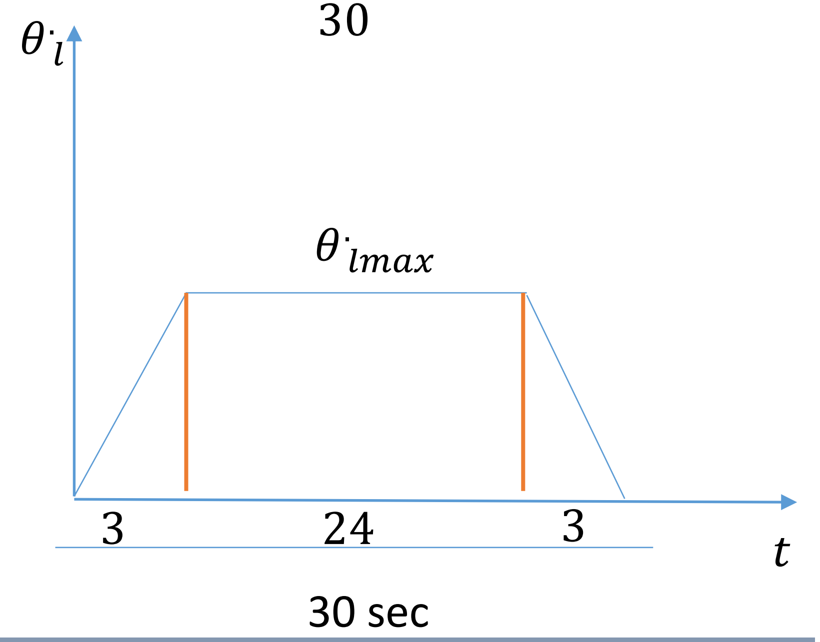
Now we want to see the angulae acceleration ($\theta^{\cdot\cdot}$)

$\theta^{\cdot\cdot}_{acc} = \frac{d\theta^{\cdot}_{l}}{dt} = \frac{\theta^{\cdot}_{lmax}}{3} = 2.058 rad/sec^2$

$\theta^{\cdot\cdot}_{dec} = -2.058 rad/sec^2$

$\theta^{\cdot\cdot}_{ss} = 0$





Problem 2 (Solution):

3. To get the motor torque

$$T_{acc} = T_R + J_T\ddot{\theta}_{acc} = 1.5343\ Nm$$

$$T_{dec} = T_R + J_T\ddot{\theta}_{dec} = 1.4816 Nm$$

$$T_{ss} = T_R = 1.508\text{Nm}$$

Peak torque = 1.5343 Nm

$$T_{RMS} = \sqrt{\frac{\int_0^t T_m^2\ t\ dt}{T_{cycle}}} = \sqrt{\frac{T_{acc}^2\ t_a + T_{dec}^2 t_d + T_{ss}^2 t_{ss}}{33}} = 0.147\ \text{Nm at } 25^0\text{C}$$

T_{RMS} @ 35^0C=0.142 Nm