$L := 1ft \quad W := 1ft$ Dimensions of Platform

$m_r := 20lbm = 9.072\,kg$ Mass of Robot

$P_s := 1in$ Pitch of screw

$\eta_s := .86$ Efficiency of screw assembly

$\rho := 8050 \frac{kg}{m^3}$ Density of steel

$\omega := 50 \frac{deg}{s}$ Angular velocity

$\mu := .16$ Coefficient of friction b/n nut and screw

$\omega_m := 3200 \frac{rev}{min}$ RPM of input power

$d_s := \frac{3}{8} in$ Diameter of screw

$R_s := \frac{d_s}{2}$ Radius of screw

$L_s := 6in$ Length of screw

$\theta := 7.5deg$ Angle to sweep up to

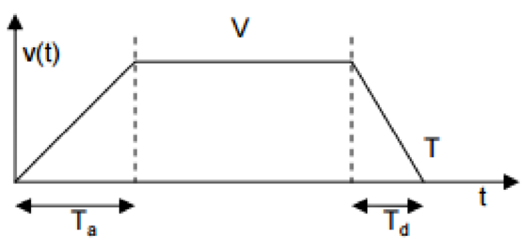
$S := \frac{L}{2} \cdot \sin(\theta) = 0.783 \cdot in$ Vertical travel distance

Estimate the power required to lift mass:

$t := \frac{\theta}{\omega} = 0.15\,s$ Time Required to sweep up to angle

$P := \frac{m_r \cdot g \cdot S}{t} = 11.798\,W$ Power required to lift mass in given time

Using a trapezoidal velocity profile calculate peak velocity and the minimum pitch required:



- Reduces peak velocity by 25% when compared to a triangular profile

$v_{pk} := \frac{3 \cdot S}{2t} = 0.199 \cdot \frac{m}{s}$ Peak velocity following a 1/3-1/3-1/3 profile

$P_{min} := \frac{v_{pk}}{\omega_m} = 0.147 \cdot in$ Minimum pitch required to sweep up to angle in given time and rpm

$$Leadscrewspeed_{pk}(Pitch) := \frac{v_{pk} \cdot 60}{Pitch}$$

$Leadscrewspeed_{pk}(P_s) = 469.894 \cdot \frac{rev}{s}$ Recalculate speed based on selected pitch screw

$$\omega_{pk} := Leadscrewspeed_{pk}(P_s) \cdot \frac{2\pi}{60} = 2952.433 \cdot \frac{rev}{min}$$

Calculate the reflected inertia from load and screw to the input power:

$m_s := \pi \cdot R_s^2 \cdot L_s \cdot \rho = 0.193 \cdot \mathrm{lbm}$ — Mass of lead screw

$J_s := m_s \cdot R_s^2 = 1.983 \times 10^{-6}\, \mathrm{m}^2 \cdot \mathrm{kg}$ — Inertia from screw

$J_L := m_r \cdot (0.063\mathrm{in})^2 = 2.323 \times 10^{-5}\, \mathrm{m}^2 \cdot \mathrm{kg}$ — Inertia from Load

$J_T := J_s + J_L = 2.521 \times 10^{-5}\, \mathrm{m}^2 \cdot \mathrm{kg}$ — Total Inertia

Calculate the acceleration of the screw based on peak velocity:

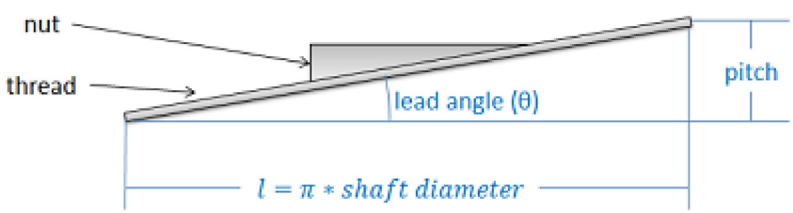
$$a := \frac{v_{pk}}{\left(\frac{1}{3} \cdot t\right)} = 3.978 \frac{\mathrm{m}}{\mathrm{s}^2}$$

Acceleration during 1/3 of the profile

$$\alpha := \frac{a \cdot 2\pi}{P_s} = 984.144 \cdot \frac{\mathrm{rad}}{\mathrm{s}^2}$$

Angular acceleration

Calculate Torques based on reflected inertia and weight being moved:



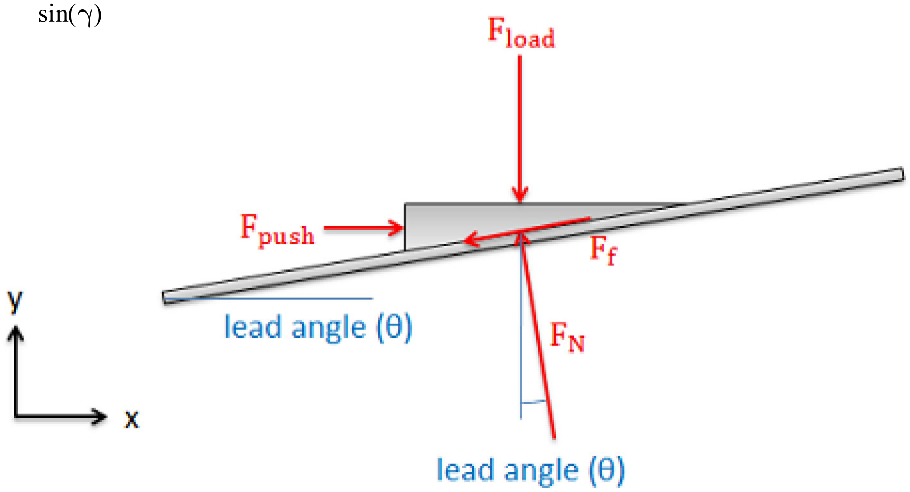
- Unwrapping the threads, the lead angle can then be calculated

$$\gamma := \operatorname{atan}\left(\frac{P_s}{\pi \cdot d_s}\right) = 40.325 \cdot \text{deg}$$

Need to check if screw is self locking later

$$x := \frac{\left(\frac{S}{P_s}\right) \cdot P_s}{\sin(\gamma)} = 1.21 \cdot \text{in}$$

Distance traveled along incline



$$T_f := \frac{m_r \cdot \mu \cdot g}{\cos(\gamma)} \cdot R_s = 0.089 \cdot \text{N} \cdot \text{m}$$

Torque to overcome friction

$$T_J := J_T \cdot \alpha = 0.025 \cdot \text{N} \cdot \text{m}$$

Torque to accelerate load

$$T_a := \frac{T_J + T_f}{\eta_s} = 0.132 \cdot \text{N} \cdot \text{m}$$

Total torque

Based on total torque, calculate the input power required:

$$P_{pk} := T_a \cdot \omega_{pk} = 6.508\, \text{W}$$

Power input required at the shaft

$$P_{avg} := \frac{\left(\frac{m_r \cdot g \cdot S}{t}\right)}{\eta_s} = 13.719\, \text{W}$$

Average Power

$$T_{rms} := \sqrt{\frac{\frac{1}{3} \cdot t \cdot T_J^{\,2} + \frac{1}{3} \cdot t \cdot T_f^{\,2} + \frac{1}{3} \cdot t \cdot T_J^{\,2}}{t}} = 0.055\, \text{J}$$

Will be used later to check heat build up

Motor-Cam Design

Linkage arm dimensions

$$d_{rod} := \frac{3}{8}in \qquad L_2 := 3in$$

Moment arm

$$y := \frac{L}{4}\cdot\sin(\theta) = 0.392\cdot in \qquad L_1 := y$$

Inertias of the linkages and platform with the robot standing on top

$$J_r := \left[\pi\cdot\left(\frac{d_{rod}}{2}\right)^2\cdot L_2\cdot\rho\right]\cdot\left(\frac{L_2^{\,2}}{3}\right) = 8.46\times 10^{-5}\,m^2\cdot kg$$

$$J_p := \frac{m_r}{12}\cdot\left[4\cdot L^2 + (W)^2\right]$$

$$J_T := J_p + J_r = 0.351\,m^2\cdot kg$$

Angular acceleration required

$$\alpha := \frac{\omega}{t} = 5.818\cdot\frac{rad}{s^2}$$

$$M := m_r\cdot\frac{g}{\cos(\theta)}\cdot L_1 = 0.892\cdot N\cdot m$$

Torque calculations

$$T_r := J_T\cdot\alpha = 2.044\cdot N\cdot m$$

$$T_t := T_r + M = 2.936\,J$$