11. A servo AC motor connected to gearbox with reduction ratio 30:1 and 80% efficiency is used to drive a steel ballscrew system to lift 20kg vertical mass/load. The mass is subjected during movement to friction coefficient (μ=0.1). If the ballscrew has 15mm diameter, 400mm length, 4mm/rev pitch, ρ= 7800 kg/m3, and 90% efficiency and taking into considerations that the inertia ratio between the effected mass/load and the motor inertia is 5:1, then:

a) Calculate the total resistance torque reflected to (affecting on) the motor shaft due the vertical load and other forces.

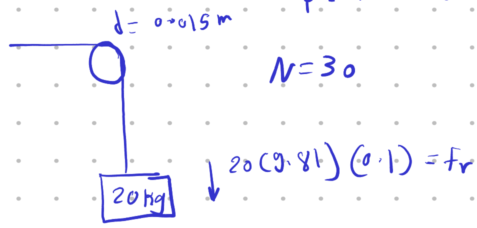
b) Calculate the reflected inertia of the vertical load/mass and the screw inertia to the motor side.

c) If the move velocity trajectory profile: Type: 1/6- 2/3- 1/6 Trapezoid, distance: 8 mm, move time: 0.4 s, dwell time: 0.5 s. Determine the required motor size including (motor speed, peak and root mean square torque) to drive this machine when the working temperature is 40°C.

d) Check the back-drivability of this system and comment on its backdrivability then suggest what do you need to add to improve the motor energy and power consumption.

e) If the ballscrew is replaced by a power screw of the same diameter and length, but with an efficiency of 40%, how will the root mean square torque be affected?

f) If vibrations occur during load movement along the previous given trajectory, what could be the cause of these vibrations, and how could they be reduced by selecting an appropriate trajectory velocity profile?



$p = 4 mm/rev$

$N = 30$

$\eta_{ball} = 0.9$

$\eta_{gb} = 0.8$

$J_m = 1/5 \, J_l$

(a)

$T_L = T_{long} + T_{fr}$

$= 20(9.81)[1+0.1]\left(\frac{0.015}{2}\right)$

$= 1.62 \text{ Nm}$

(b)

$* J_l = m_l r^2 + \frac{1}{2} m_{ps} r^2$

$= \left[20 + \frac{1}{2} 7800\times\left(\frac{\pi}{4}\times 0.015^2 \times 0.4\right)\right]\left[0.015/2\right]^2$

$= 0.00114 \text{ kg m}^2$

$* J_m = \frac{1}{5} J_l = 0.00023 \text{ kg m}^2$

$* J_{leq} = J_l\left(\frac{1}{N^2}\right) = 1.266\times10^{-6} \text{ kg m}^2$

$* J_{eq} = 1.266\times10^{-6} + 230\times10^{-6} = 231.266\times10^{-6} \text{ kg m}^2$

$\frac{1}{2} J_l \omega_l^2$

$= \frac{1}{2} J_{leq} \omega_m^2$

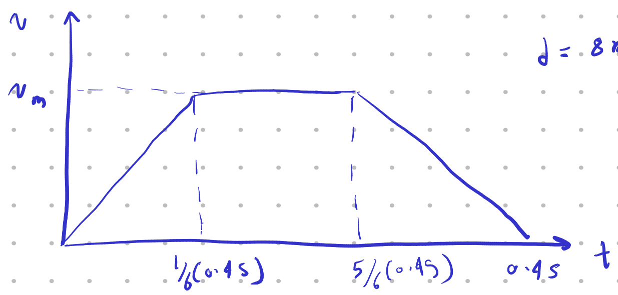
$J_{leq} = J_l\left(\frac{\omega_l}{\omega_m}\right)^2$

(c)

$d = v_m t_c + 2\times\frac{1}{2} a t_a^2 \qquad a = \frac{v}{t_a}$

$= v_m(t_c + t_a)$

$8 = v_m\left(2/3 + 1/6\right) \rightarrow v_m = \frac{48}{5} = 9.6 \text{ m/s}$



$d = 8 mm$