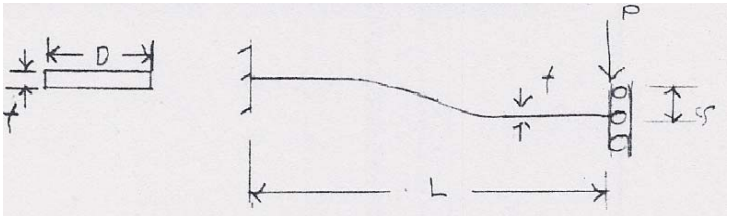
FOCUS STAGE CALCULATIONS (SPEX)

1) BENDING STRESS / DEFLECTION



$t_b := 0.5mm$ Beam Thickness

$D_b := 25mm$ Beam Depth

$L_b := 48mm$ Beam Length

$F_{stage} := 32N$ Force applied on the Focus Stage

$N_b := 8$ Number of Beans of the Focus Stage

$E_b := 71700N \cdot mm^{-2}$ Youngs Modulus: Aluminium 7075-T6

$\sigma_y := 503MPa$ Tensile Strength, Yield

$P(F_{stage}) := \frac{F_{stage}}{N_b}$ Force applied on a single Beam

$I_b := \frac{D_b \cdot t_b^3}{12} = 2.604 \times 10^{-13} \cdot m^4$ Beam Inertia

$y_b := \frac{t_b}{2}$ Distance from Neutral Axis

$M_b := P(F_{stage}) \cdot \frac{L_b}{2} = 96 \cdot N \cdot mm$ Bending Moment at the end of the Beam

$\sigma_{Bb} := \frac{M_b \cdot y_b}{I_b} = 92.16 \cdot MPa$ Bending Stress at the end of the Beam

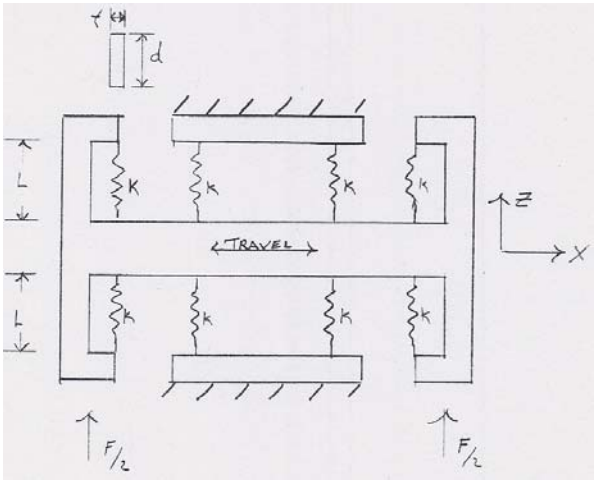
$\delta_b := \frac{P(F_{stage}) \cdot L_b^3}{12.E_b \cdot I_b} = 1.97431 \cdot mm$ Deflection at the end of the Beam

$\delta_{stage} := 2 \cdot \delta_b = 3.949 \cdot mm$ Travel of the Stage resulting from applied Force

$\frac{\sigma_y}{\sigma_{Bb}} = 5.458$

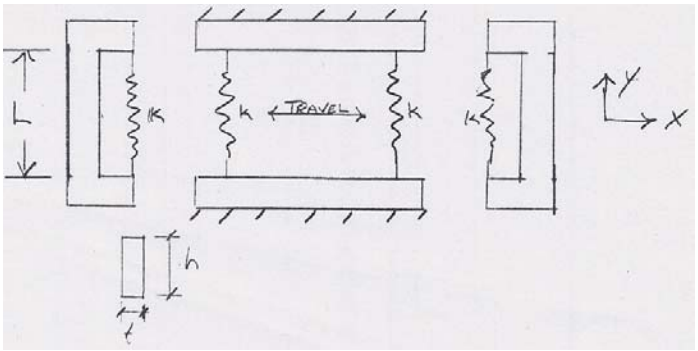
2) STIFFNESS

2.1) Perpendicular to Focus Direction (Along Z-axis):



$$K_{eq\_Z} := 8 \cdot \frac{t_b \cdot D_b \cdot E_b}{L_b} = 1.494 \times 10^5 \cdot \frac{N}{mm}$$

2.2) Perpendicular to Focus Direction (Along Y-axis):



$H_b := 38mm$ (Beam Height)

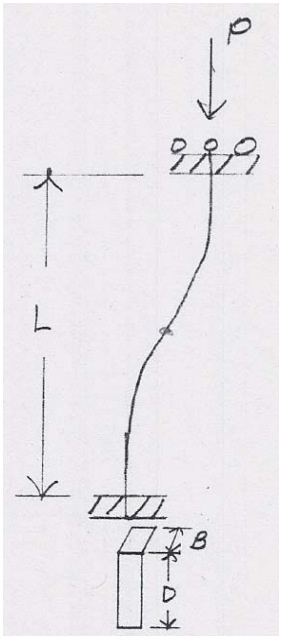
$$K_{eq\_Y} := 8 \cdot \frac{t_b \cdot H_b \cdot E_b}{L_b} = 2.271 \times 10^5 \cdot \frac{N}{mm}$$

3) BUCKLING LOAD

$A_b := D_b \cdot t_b$ Beam Section Area

$\rho_b := \sqrt{\left(\frac{I_b}{A_b}\right)} = 1.443 \times 10^{-4}\,m$ Slenderness Ratio

$F_{BL} := \frac{\left(\pi^2 \cdot E_b \cdot A_b \cdot \rho_b^{\,2}\right)}{L_b^{\,2}} = 79.984\,N$ Critical Buckling Load



4) DRIVE

$Travel := 4mm$ Total Stage travel

$s_p := -2mm, -1.9mm .. 2mm$ Stage position

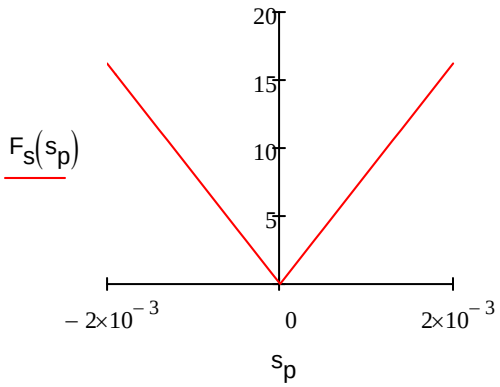
$F_s(s_p) := |s_p| \cdot \left(6 \cdot E_b \cdot I_b \cdot \frac{N_b}{L_b^{\,3}}\right)$ Force to move the Flex Stage

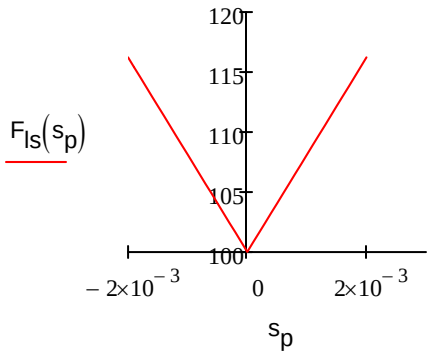
$F_{nut} := 80N$ Lead Screw Nut Preload

$F_{load} := 20N$ Load to displace

$F_{ls}(s_p) := F_{nut} + (F_{load} + F_s(s_p))$ Force applied on the lead screw thread

$F_{ls}(-2mm) = 116.208\,N$





$D_{ls} := 12.065mm$ Lead screw lead diameter

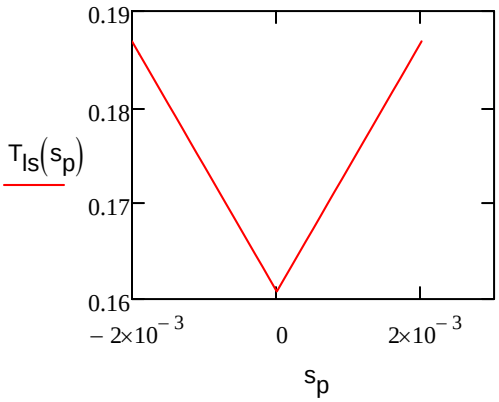
$L_{ls} := 1.27mm$ Lead srew lead

$\mu_{ls} := 0.2$ Lead screw friction coefficient (nut/screw)

$\alpha_{th} := 30deg$ ACME screw thread angle

$$T_{ls}(s_p) := \left(F_{ls}(s_p) \cdot \frac{D_{ls}}{2}\right) \cdot \left(\frac{L_{ls} + \pi \cdot \mu_{ls} \cdot \frac{D_{ls}}{\cos(\alpha_{th})}}{\pi \cdot D_{ls} - \mu_{ls} \cdot \frac{L_{ls}}{\cos(\alpha_{th})}}\right)$$

$T_{ls}(2mm) = 186.83 \cdot N \cdot mm$



$D_w := 11.4mm$ Worm Pitch Diameter

$D_{wg} := 24mm$ Worm Gear Pitch Diameter

$\gamma_w := 4.75deg$ Worm Lead Angle

$\alpha_{nw} := 14.5deg$ Pressure Angle

$\mu_w := 0.2$ Friction Coeff

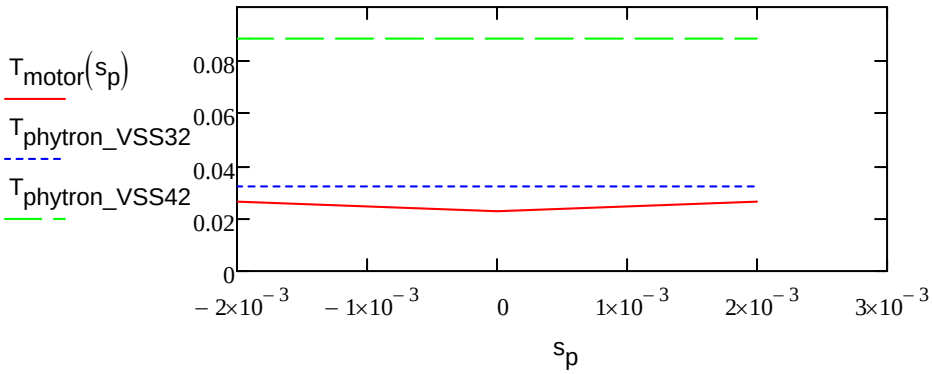
$$T_{motor}(s_p) := T_{ls}(s_p)\cdot\left(\frac{D_w}{D_{wg}}\right)\cdot\left(\frac{\cos(\alpha_{nw})\cdot\tan(\gamma_w+\mu_w)}{\cos(\alpha_{nw})-\mu_w\cdot\tan(\gamma_w)}\right)$$

Minimum necessary torque to drive the Focus Stage

$T_{motor}(2mm) = 26.248\cdot N\cdot mm$ Maximum Torque

$T_{phytron\_VSS32} := 32N\cdot mm$ Phytron VSS32 Max. Torque

$T_{phytron\_VSS42} := 88N\cdot mm$ Phytron VSS42 Max. Torque



$R_{ls} := \frac{Travel}{L_{ls}}$ Number of Lead screw revolutions for full travel

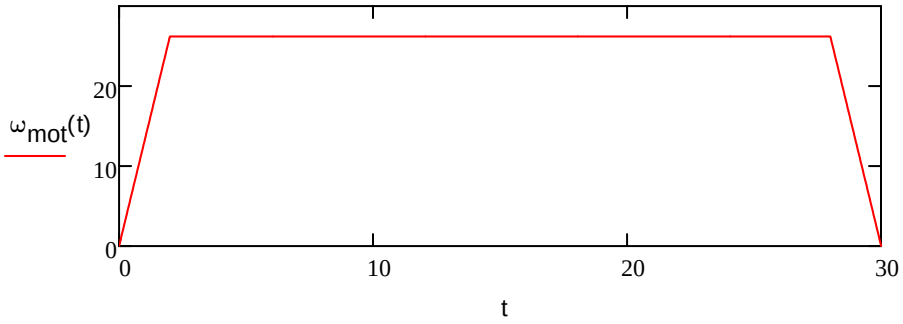
$Ratio_w := 30$ Reduction Ratio of Worm

$Travel_{rot} := Ratio_w \cdot R_{ls} = 94.488$ Number of Motor Revolutions for full travel

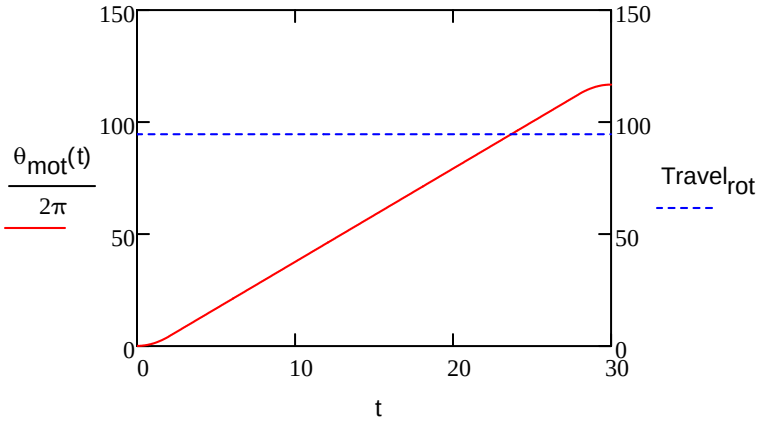
$t_{t1} := 2s \quad t_{t2} := 28s \quad t_{tt} := 30s$

$\omega_{mot\_max} := 250rpm$

$$\omega_{mot}(t) := \text{if}\left[t \le 0, 0, \text{if}\left[t < t_{t1}, \omega_{mot\_max} \cdot \frac{t}{t_{t1}}, \text{if}\left[t < t_{t2}, \omega_{mot\_max}, \text{if}\left[t < t_{tt}, \omega_{mot\_max} \cdot \frac{(t_{tt} - t)}{(t_{tt} - t_{t2})}, 0\right]\right]\right]\right]$$



$$\theta_{mot}(t) := \int_0^t \omega_{mot}(t)\, dt$$



$W_{bl} := 0.006\,in$ Typical Backlash for a Commercial Grade Worm (0.003" - 0.006")

$\alpha_{bl} := \operatorname{atan}\left(\frac{2W_{bl}}{D_{wg}}\right) = 0.728 \cdot deg$ Angular Backlash

$\varepsilon_{ls} := L_{ls} \cdot \frac{\alpha_{bl}}{2\pi} = 2.567 \cdot \mu m$ Resulting position error of Lead Screw