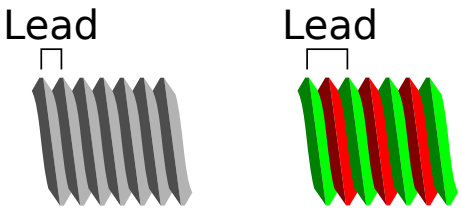
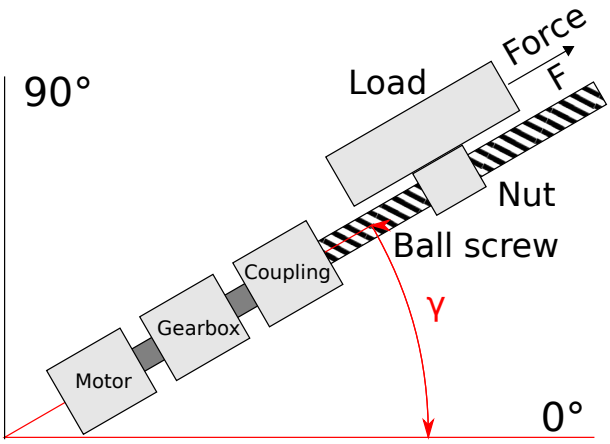
Ball Screw



Pitch Vs Lead



Ball Screw Positioner

The screw mechanism converts rotational motion into linear motion. Ball screws use circulating ball bearings to minimize friction and obtain high performance, high thrust and high precision. They are used in machinery such as injection molding machines, dosing and filling machines, simulators and test benches, machine tools, small and medium servo-presses, X-Y tables, tool bit positioning, pick & place machines, engraving machines, motorized microscope devices, etc. They are however not recommended for high cycle rates with high turning speeds, due to their high noise generation in these conditions. Do not confuse with conventional trapezoidal thread screws, such as those with acme threads, that offer much lower efficiency and performance.

Disclaimer

This tool has been created to assist engineers with the sizing of the different parts of the system. Calculations might not cover all corner cases. and results should always be checked by a qualified engineer. Under no circumstances shall we beheld responsible to any damages to persons or property due to correct or incorrect use of this tool, or to errors in it.

System Efficiency

$$\eta_t = \eta_{bs} \cdot \eta_r$$

Weight Force

$$F_w = m \cdot g \cdot \sin\left(\frac{\gamma \cdot \pi}{180}\right) \quad [N]$$

Friction Force

$$F_f = m \cdot g \cdot \mu \cdot \cos\left(\frac{\gamma \cdot \pi}{180}\right) \quad [N]$$

Acceleration Force

$$F_a = \frac{m \cdot v}{t_a} \quad [N]$$

Constants	
Pi	$\pi \simeq 3.141592654$
Acceleration of Gravity on Earth	$g = 9.80665 \ \frac{m}{s^2}$
Density of Steel	$\rho_{steel} = 7850 \ \left[\frac{kg}{m^3}\right]$

Inputs	
System Inclination	$\gamma \ [degrees]$
Ball Screw Lead	$p \ \left[\frac{mm}{rev}\right]$
Ball Screw Length	$L \ [mm]$
Ball Screw Diameter	$D \ [mm]$
Ball Screw Efficiency	η_{bs}
Friction Coefficient	μ
Service Factor	K_A
Traveling Mass	$m \ [kg]$
Linear Speed	$v \ \left[\frac{m}{s}\right]$
Acceleration Time	$t_a \ [s]$
Machining Force	$F_m \ [N]$
Max. Motor Speed During Cycle	$n_1 \ [rpm]$
Gearbox Efficiency	η_r
Gearbox Inertia	$J_R \ [kg \cdot cm^2]$
Motor Inertia	$J_M \ [kg \cdot cm^2]$

Total Force

$$F_T = F_w + F_f + F_a + F_m \ [N]$$

Traveling Mass Inertia

$$J_L = 10000 \cdot m \cdot \left(\frac{p}{2000 \cdot \pi}\right)^2 \ [kg \cdot cm^2]$$

Ball Screw Inertia

$$J_{bs} = 5 \cdot \rho_{steel} \cdot \pi \cdot L \cdot \left(\frac{D}{2000}\right)^4 \ [kg \cdot cm^2]$$

Total Inertia

$$J_T = J_L + J_{bs} \ [kg \cdot cm^2]$$

Total Inertia as seen by the motor

$$J_{T1} = \frac{J_T}{i^2} \ [kg \cdot cm^2]$$

Load to Motor Inertia Ratio

$$\Lambda = \frac{J_{T1}}{J_M + J_r}$$

Screw Rotational Acceleration

$$\alpha_{bs} = \frac{\omega_{bs}}{t_a} \ \left[\frac{rad}{s^2}\right]$$

Screw Rotational Speed

$$\omega_{bs} = \frac{2000 \cdot \pi \cdot v}{p} \ \left[\frac{rad}{s}\right]$$

Screw Rotational Speed

$$n_{bs} = \omega_{bs} \cdot \frac{30}{\pi} \ [rpm]$$

Motor Power

$$P_1 = \frac{T_2 \cdot n_{bs}}{9550 \cdot \eta_r} \ [kW]$$

Ideal Gearbox Ratio

$$i = \frac{n_1}{n_{bs}}$$

Required Gearbox Output Torque

$$T_2 = \frac{p \cdot F_T}{2000 \cdot \pi \cdot \eta_{bs}} \quad [N \cdot m]$$

Required Gearbox Output Torque, Adjusted for Service Factor

$$T_{2KA} = K_A \cdot T_2 \quad [N \cdot m]$$

Appendix: Coefficients of friction

Coefficients of friction for bearings

Anti-friction bearings	μ_L=0,005

qCoefficients of friction for linear guide units

	Friction Coefficient	
Guide Unit	**Static (μ_0)**	**Sliding (μ)**
Linear Ball Slide	0,015	0,0012
Linear Slide (without balls)	0,6	0,3
Crossed Roller Guide	0,005	0,0025
Crossed Roller Way	0,006	0,003

Coefficients of friction for various materials

Material 1	Material 2	μ_0 (Static Friction Coefficient)		μ (Sliding Friction Coefficient)	
		Dry	**Greased**	**Dry**	**Greased**
Aluminium	Aluminum	1,05 – 1,35	0,3	0,47	
Aluminum	Steel (Mild)	0,61		0,47	
Cast Iron	Cast Iron	1,1		0,15	0,07
Copper	Steel (Mild)	0,53		0,36	0,18
Glass	Glass	0,9 – 1,0	0,1 – 0,6	0,4	0,09 – 0,12
Iron	Iron	1,0		0,15 – 0,2	
Nickel	Nickel	0,7 – 1,1	0,28	0,53	0,12
Nylon	Nylon	0,15 – 0,25			
Plexiglas	Steel	0,4 – 0,5		0,4 – 0,5	
Polymer Belt	Steel	0,25 – 0,45		0,25	
Rubber	Glass	>2,0		2,0	
Rubber	Concrete	1,0		0,8	
Steel (Hard)	Polystyrene	0,3 – 0,35		0,3 – 0,35	
Steel (Hard)	Polythene	0,2		0,2	
Steel (Hard)	Steel (Hard)	0,12 - 0,6	0,12 - 0,35	0,08 - 0,5	0,04 - 0,25
Teflon	Steel	0,04	0,04		0,04
Teflon	Teflon	0,04	0,04		0,04
Wood	Steel	0,45 – 0,75		0,30 – 0,6	