Torque Requirements

The torque required to move a *LINTECH* positioning table for a specific application requires the calculation of several simple equations. These equations require you to evaluate carriage speeds, acceleration rates, and load weights. Careful torque calculations allow the proper selection of an electronic motor/drive system.

The maximum torque demand from any motor is usually during the acceleration portion of a move profile and consists of several parts - Acceleration Torque, Friction Torque, Breakaway Torque, and for vertical applications the Torque to overcome Gravity.

The torque required from a motor varies as the move profile changes from acceleration to constant velocity to deceleration. Constant velocity torque and deceleration torque become important when sizing for a servo motor system. Torque to overcome gravity becomes extremely important in vertical applications. The upward move places the highest torque demand on the motor, while the downward move sometimes requires the motor/drive system to act as a brake.

Step Motors

When sizing for a step motor system, calculate the maximum torque demand for the application. This will usually be the total torque required during the acceleration portion of a move profile. Select an electronic motor/drive system which will deliver more torque than is absolutely required. This torque margin accommodates mechanical wear, extra loads, lubricant hardening, and other unexpected factors. Consult the individual motor manufacturer for details on their required torque margin and inertia matching.

Servo Motors

When sizing for a servo motor system, two calculations must be performed - maximum (peak) torque and RMS (continuous) torque. The maximum torque demand for the application will usually occur during the acceleration portion of a move profile. The RMS torque calculation will require values for acceleration torque, constant velocity torque, deceleration torque, and the time between move profiles. All servo motor systems have a peak and continuous torque rating. Select an electronic motor/drive system which will deliver more peak torque than the calculated maximum torque value and more continuous torque than the RMS calculated value. This torque margin accommodates mechanical wear, extra loads, lubricant hardening, and other unexpected factors. Consult the individual motor manufacturer for details on their torque margin and inertia matching.

Torque Equations - (servo or step motor)

Horizontal Applications

$$T_{Total\text{-}Accel} = T_{Acc} + T_{Breakaway} + T_{Friction} + T_{Gravity}$$

$$T_{Total\text{-}Constant} = T_{Breakaway} + T_{Friction} + T_{Gravity}$$

$$T_{Total\text{-}Decel} = T_{Acc} - T_{Breakaway} - T_{Friction} - T_{Gravity}$$

Vertical Applications
Upward Move

$$T_{Total\text{-}Accel} = T_{Acc} + T_{Breakaway} + T_{Friction} + T_{Gravity}$$

$$T_{Total\text{-}Constant} = T_{Breakaway} + T_{Friction} + T_{Gravity}$$

$$T_{Total\text{-}Decel} = T_{Acc} - T_{Breakaway} - T_{Friction} - T_{Gravity}$$

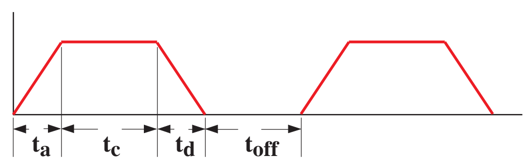
Vertical Applications
Downward Move

$$T_{Total\text{-}Accel} = T_{Acc} + T_{Breakaway} + T_{Friction} - T_{Gravity}$$

$$T_{Total\text{-}Constant} = T_{Breakaway} + T_{Friction} - T_{Gravity}$$

$$T_{Total\text{-}Decel} = T_{Acc} - T_{Breakaway} - T_{Friction} - T_{Gravity}$$

Servo motor RMS calculation



$$T_{RMS} = \sqrt{\frac{(T_a)^2 t_a + (T_c)^2 t_c + (T_d)^2 t_d + (T_{off})^2 t_{off}}{t_a + t_c + t_d + t_{off}}}$$

$T_{Total\text{-}Accel}$ = T_a = *acceleration torque*

$T_{Total\text{-}Constant}$ = T_c = *constant velocity torque*

$T_{Total\text{-}Decel}$ = T_d = *deceleration torque*

T_{off} = *torque at standstill - usually a 0 value*

T_{RMS} = *RMS (continuous) torque*

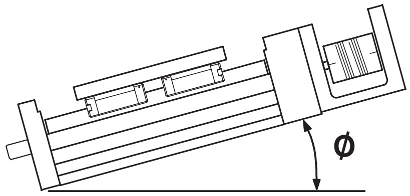
t_a = *acceleration time in seconds*

t_c = *constant velocity time in seconds*

t_d = *deceleration time in seconds*

t_{off} = *dwell time in seconds between moves*

Torque Equations - Screw Driven (Linear Motion)



$$T_{Total} = \left[T_{Acc} + T_{Breakaway} + T_{Friction} + T_{Gravity} \right] SF \quad \text{(oz-in)}$$

$$T_{Acc} = \frac{1}{386}\left[\frac{J_{Load}}{e} + J_{Screw} + J_{Motor} \right] \frac{\omega}{t_a} \quad \text{(oz-in)}$$

$$J_{Load} = \frac{d^2 \left(W_{Load} + W_{Other} \right)}{(2\pi)^2} \; \frac{(16 \text{ oz})}{\text{lb}} \quad \text{(oz-in}^2\text{)}$$

$$J_{Screw} = \frac{\pi \rho L R^4}{2} \quad \text{(oz-in}^2\text{)}$$

J_{Motor} = See Motor Data (*not included in this catalog*) (oz-in^2)

$$\omega = \frac{2\pi V_M}{d} \quad \text{(rad/sec)}$$

$T_{Breakaway}$ = See values in individual screw technical sections (oz-in)

$$T_{Friction} = \frac{d F_T \cos \phi}{2\pi e} \; \frac{(16 \text{ oz})}{\text{lb}} \quad \text{(oz-in)}$$

$$F_T = \mu \left(W_{Load} + W_{Other} \right) \quad \text{(lbs)}$$

$$T_{Gravity} = \frac{d \left(W_{Load} + W_{Other} \right) \sin \phi}{2\pi e} \; \frac{(16 \text{ oz})}{\text{lb}} \quad \text{(oz-in)}$$

Notes:

1) T_{Total} is the maximum torque required from a motor during a move. This usually occurs during the acceleration portion of a move profile for horizontal applications and an upward move for vertical applications. During the deceleration portion of a move profile, $T_{Friction}$ and $T_{Breakaway}$ are subtractions from T_{Total}. For horizontal applications $T_{Gravity}$ has a zero value.

2) The factor 386 in the denominator for the T_{Acc} equation represents acceleration due to gravity (386 in/sec^2 or 32.2 ft/sec^2) and converts inertia from units of oz-in^2 to oz-in-sec^2.

3) The safety factor (SF) should be between 1.4 to 1.6 for step motor systems and between 1.1 to 1.2 for servo motor systems.

Thrust Force Equation

$$C_T = \frac{2\pi e \left(T_{Motor} - T_{Total} \right)}{d} \; \frac{\text{lb}}{(16 \text{ oz})} \quad \text{(lbs)}$$

Terms

C_T = potential thrust force (lbs)

d = lead of screw (in/rev)

e = screw efficiency (90% =.9)

F_T = total frictional force (lbs)

J_{Load} = load inertia (oz-in^2)

J_{Screw} = screw inertia (oz-in^2)

J_{Motor} = motor inertia (oz-in^2)

L = screw length (in)

ϕ = angle of load from horizontal (degrees)

ρ = density of steel screw (4.48 oz/in^3)

R = radius of screw (in)

SF = safety factor (see note #3)

t_a = acceleration time (sec)

T_{Acc} = required torque to accel the load (oz-in)

$T_{Breakaway}$ = breakaway torque (oz-in)

$T_{Friction}$ = required torque to overcome system friction (oz-in)

$T_{Gravity}$ = required torque to overcome gravity (oz-in)

T_{Motor} = motor output torque at calculated speed (oz-in)

T_{Total} = required torque to move the load (oz-in)

μ = coefficient of friction for linear bearing system (.01)

V_M = max linear velocity (in/sec)

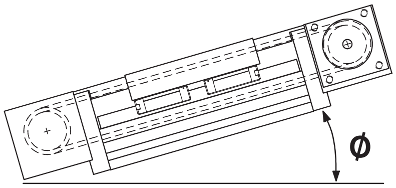
ω = angular velocity (rad/sec)

W_{Load} = weight of load (lbs)

W_{Other} = weight of carriage or weight of mounting hardware (lbs)

π = 3.1416

Torque Equations - Belt Driven (Linear Motion)



$$T_{Total} = \left[T_{Acc} + T_{Breakaway} + T_{Friction} + T_{Gravity} \right] SF \qquad \text{(oz-in)}$$

$$T_{Acc} = \frac{1}{386} \left[\frac{J_{Load}}{e} + \frac{J_{Pulley}}{e} + \frac{J_{Belt}}{e} + J_{Motor} \right] \frac{\omega}{t_a} \qquad \text{(oz-in)}$$

$$J_{Load} = \frac{(W_{Load} + W_{Other})\, r^2}{g^2} \; \frac{(16 \text{ oz})}{\text{lb}} \qquad (\text{oz-in}^2)$$

$$J_{Pulley} = \frac{(W_{Pulley})\, r^2}{2\, g^2} \; \frac{2 \;\; (\textit{for 2 pulleys})}{} \qquad (\text{oz-in}^2)$$

$$J_{Belt} = \frac{(W_{Belt})\, r^2}{g^2} \qquad (\text{oz-in}^2)$$

J_{Motor} = See Motor Data (*not included in this catalog*) (oz-in^2)

$$\omega = \frac{V_M}{r} \qquad \text{(rad/sec)}$$

$$T_{Breakaway} = \frac{\text{See values in individual belt technical sections}}{g\, e} \qquad \text{(oz-in)}$$

$$T_{Friction} = \frac{(W_{Load} + W_{Other})\, r\, \mu \cos\phi}{g\, e} \; \frac{(16 \text{ oz})}{\text{lb}} \qquad \text{(oz-in)}$$

$$T_{Gravity} = \frac{(W_{Load} + W_{Other})\, r \sin\phi}{g\, e} \; \frac{(16 \text{ oz})}{\text{lb}} \qquad \text{(oz-in)}$$

Notes:

1) T_{Total} is the maximum torque required from a motor during a move. This usually occurs during the acceleration portion of a move profile for horizontal applications and an upward move for vertical applications. During the deceleration portion of a move profile, $T_{Friction}$ and $T_{Breakaway}$ are subtractions from T_{Total}. For horizontal applications $T_{Gravity}$ has a zero value.

2) The factor 386 in the denominator for the T_{Acc} equation represents acceleration due to gravity (386 in/sec^2 or 32.2 ft/sec^2) and converts inertia from units of oz-in^2 to oz-in-sec^2.

3) The safety factor (SF) should be between 1.4 to 1.6 for step motor systems and between 1.1 to 1.2 for servo motor systems.

Thrust Force Equation

$$C_T = \frac{(T_{Motor} - T_{Total})\, g\, e}{r} \; \frac{\text{lb}}{(16 \text{ oz})} \qquad \text{(lbs)}$$

Terms

C_T = potential thrust force (lbs)

e = gearhead efficiency (90% = .9)

g = gearhead ratio (5:1 = 5)

J_{Belt} = belt inertia (oz-in^2)

J_{Load} = load inertia (oz-in^2)

J_{Motor} = motor inertia (oz-in^2)

J_{Pulley} = pulley inertia (oz-in^2)

ϕ = angle of load from horizontal (degrees)

r = radius of drive pulley (in)

SF = safety factor (see note #3)

t_a = acceleration time (sec)

T_{Acc} = required torque to accel the load (oz-in)

$T_{Breakaway}$ = breakaway torque (oz-in)

$T_{Friction}$ = required torque to overcome system friction (oz-in)

$T_{Gravity}$ = required torque to overcome gravity (oz-in)

T_{Motor} = motor output torque at calculated speed (oz-in)

T_{Total} = required torque to move the load (oz-in)

μ = coefficient of friction for linear bearing system (.01)

V_M = max linear velocity (in/sec)

ω = angular velocity (rad/sec)

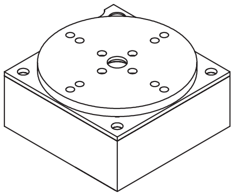
W_{Belt} = weight of belt (oz)

W_{Load} = weight of load (lbs)

W_{Other} = weight of carriage or weight of mounting hardware (lbs)

W_{Pulley} = weight of pulley (oz)

Torque Equations - Worm Gear Driven (Rotary Motion)



$$T_{Total} = \left[T_{Acc} + T_{Breakaway} \right] SF \qquad \text{(oz-in)}$$

$$T_{Acc} = \frac{1}{386} \left[\frac{J_{Load}}{e} + J_{Worm} + J_{Motor} \right] \frac{\omega}{t_a} \qquad \text{(oz-in)}$$

$$J_{Load} = \frac{(W_{Load} + W_{Table\ Top})\ R^2}{2\ N^2} \ \frac{(16\ oz)}{lb} \qquad \text{(oz-in}^2\text{)}$$

J_{Worm} = See values in individual rotary table technical sections (oz-in^2)

J_{Motor} = See Motor Data (*not included in this catalog*) (oz-in^2)

$$\omega = 2\ \pi\ N\ V_M \qquad \text{(rad/sec)}$$

$T_{Breakaway}$ = See values in individual rotary table technical sections (oz-in)

Notes:

1) T_{Total} is the maximum torque required from a motor during a move. This usually occurs during the acceleration portion of a move profile for horizontal applications and an upward move for vertical applications. During the deceleration portion of a move profile, $T_{Friction}$ and $T_{Breakaway}$ are subtractions from T_{Total}. For horizontal applications $T_{Gravity}$ has a zero value.

2) The factor 386 in the denominator for the T_{Acc} equation represents acceleration due to gravity (386 in/sec^2 or 32.2 ft/sec^2) and converts inertia from units of oz-in^2 to oz-in-sec^2.

3) The safety factor (SF) should be between 1.4 to 1.6 for step motor systems and between 1.1 to 1.2 for servo motor systems.

4) The frictional torque value is so small, it can be ignored for rotary table torque equations.

Terms

- e = worm gear assembly efficiency (90% =.9)
- J_{Load} = load inertia (oz-in^2)
- J_{Motor} = motor inertia (oz-in^2)
- J_{Worm} = worm gear assembly inertia (oz-in^2)
- N = worm gear reduction (45:1 = 45)
- R = radius of table top (in)
- SF = safety factor (see note #3)
- t_a = acceleration time (sec)
- T_{Acc} = required torque to accel the load (oz-in)
- $T_{Breakaway}$ = breakaway torque (oz-in)
- T_{Total} = required torque to move the load (oz-in)
- V_M = max table top velocity (revs/sec)
- ω = angular velocity (rad/sec)
- W_{Load} = weight of load (lbs)
- $W_{Table\ Top}$ = weight of table top or weight of mounting hardware (lbs)
- π = 3.1416

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