

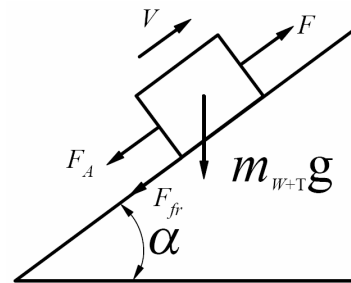
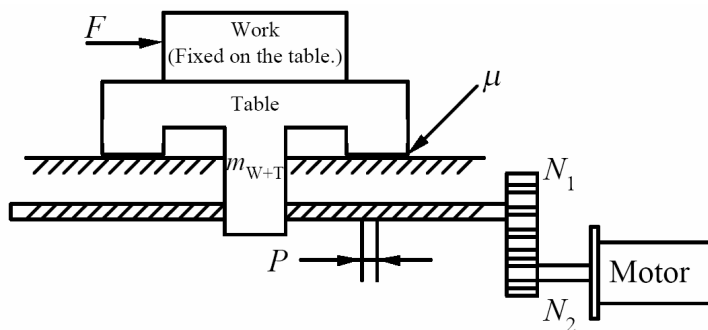
## Motor Torque Calculation

Selecting the proper motor and driver to meet a specific application needs motor torque calculation. Generally speaking, the user can follow the below steps to choose the proper motor and driver.

1. Determine the motion profile and calculate acceleration, deceleration and maximum velocity required to make the desired move.
2. Select mechanical drive mechanism to be used and calculated inertia, friction and load torque using formulas provided in this document.
3. Determine required motor torque for the specific application.
4. Select proper motor and driver based on their speed-torque characteristics.

### ◆ Lead Screw Drive Loads

Lead screw drives are widely used in many applications, such as XY tables, slides, tool bit positioning, pick-and-place machines, engraving machines, microscope drives, and etc.



Inertia:

$$J_L = m_{W+T} \left( \frac{P}{2\pi} \cdot \frac{N_1}{N_2} \right)^2 \quad [kg \cdot m^2]$$

$$J_{G1} = \frac{1}{8} m_{G1} D_{G1}^2 \left( \frac{N_2}{N_1} \right)^2 \quad [kg \cdot m^2]$$

$$J_{G2} = \frac{1}{8} m_{G2} D_{G2}^2 \quad [kg \cdot m^2]$$

$$J_T = J_L + J_{G1} + J_{G2} + J_S \left( \frac{N_2}{N_1} \right)^2 + J_M \quad [kg \cdot m^2]$$

Torque:

$$T_a = J_T a = (J_L + J_{G1} + J_{G2} + J_S \left( \frac{N_2}{N_1} \right)^2 + J_M) \frac{\omega_1 - \omega_0}{t} \quad [N \cdot m]^*$$

$$T_L = \frac{m_{W+T} g P (\sin \alpha + \mu \cos \alpha)}{2\pi \eta} \quad [N \cdot m]$$

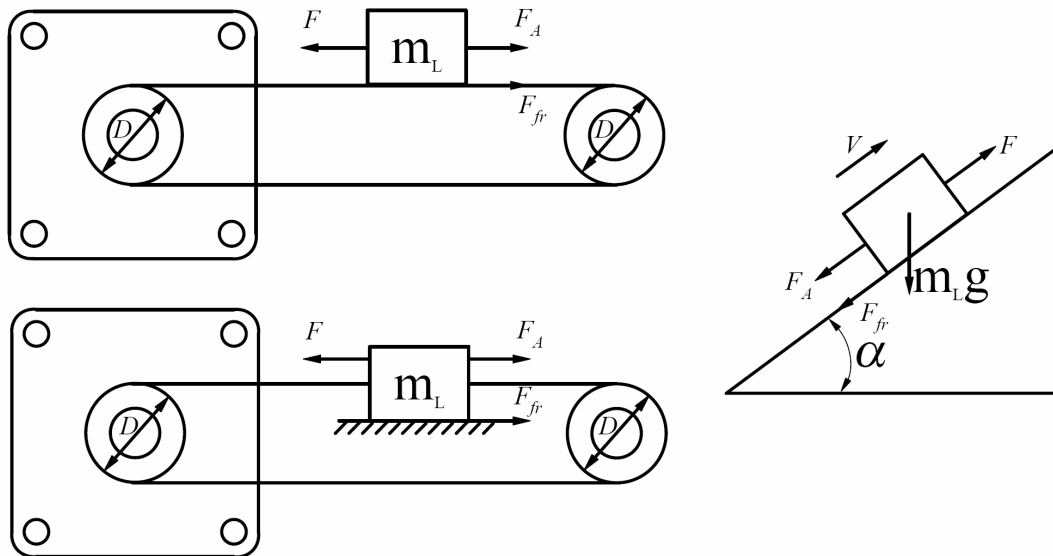
$$T_T = T_L + T_a \quad [N \cdot m]$$

$$T_M = K_S T_T \quad [N \cdot m]$$

$J_L$  – Inertia of the load [kg·m<sup>2</sup>]  
 $J_{G1}$  – Inertia of the Gear 1 [kg·m<sup>2</sup>]  
 $J_{G2}$  – Inertia of the Gear 2 [kg·m<sup>2</sup>]  
 $J_S$  – Inertia of the lead screw [kg·m<sup>2</sup>]  
 $J_M$  – Inertia of the motor [kg·m<sup>2</sup>]  
 $J_T$  – Inertia of the system [kg·m<sup>2</sup>]  
 $m_{W+T}$  – Weight of the work and the table [kg]  
 $\omega_0$  – Initial velocity of the motor [rad/s]  
 $\omega_1$  – Final velocity of the motor [rad/s]  
 $t$  – Time for velocity change [s]  
 $T_a$  – Acceleration torque [N·m]  
 $T_L$  – Load torque [N·m]  
 $T_T$  – Total calculation torque [N·m],  $T_T = T_L + T_a$   
 $T_M$  – Required motor torque [N·m],  $T_M = K_S \cdot T_T$   
 $K_S$  – Safety factor (Reference Value is 1.5 to 2.0.)  
 $\alpha$  – Angle of inclination [°]  
 $\mu$  – Frictional coefficient of sliding surfaces  
 $\eta$  – Efficiency (Reference Value is 0.85 to 0.95.)  
 $g$  – Gravity constant (9.8 m/s<sup>2</sup>)  
 \*Please use the max acceleration of the specific application.

◆ Wire Belt Drive Loads

Wire belt drives are usually adopted by relatively long distance drives, such as conveyors, jet-ink machines, plotters, assembly lines, and etc.



Inertia:

$$J_L = \frac{1}{4} m_L D^2 \quad [kg \cdot m^2]$$

$$J_P = \frac{1}{8} m_P D^2 \quad [kg \cdot m^2] \text{ * (Remember to multiply by 2 if there 2 pulleys.)}$$

$$J_B = \frac{1}{4} m_B D^2 \quad [kg \cdot m^2]$$

$$J_T = J_L + J_P + J_B + J_M \quad [kg \cdot m^2]$$

Torque:

$$T_a = J_T a = (J_L + J_P + J_B + J_M) \frac{\omega_1 - \omega_0}{t} \quad [N \cdot m]^{**}$$

$$T_L = \frac{m_L g D (\sin \alpha + \mu \cos \alpha)}{2\eta} \quad [N \cdot m]^{**}$$

$$T_T = T_L + T_a \quad [N \cdot m]$$

$$T_M = K_S T_T \quad [N \cdot m]$$

$J_L$  – Inertia of the load [kg·m<sup>2</sup>]

$J_P$  – Inertia of the pulley(s) [kg·m<sup>2</sup>]

$J_B$  – Inertia of the belt [kg·m<sup>2</sup>]

$J_M$  – Inertia of the motor [kg·m<sup>2</sup>]

$J_T$  – Inertia of the system [kg·m<sup>2</sup>]

$m_L$  – Weight of the load [kg]

$m_P$  – Weight of the pulley [kg]

$m_B$  – Weight of the belt [kg]

$D$  – Diameter [m]

$\omega_0$  – Initial velocity of the motor [rad/s]

$\omega_1$  – Final velocity of the motor [rad/s]

$t$  – Time for velocity change [s]

$T_a$  – Acceleration torque [N·m]

$T_L$  – Load torque [N·m]

$T_T$  – Total calculation torque [N·m],  $T_T = T_L + T_a$

$T_M$  – Required motor torque [N·m],  $T_M = K_S T_T$

$K_S$  – Safety factor (Reference Value is 1.5 to 2.0.)

$\alpha$  – Angle of inclination [°]

$\mu$  – Frictional coefficient of sliding surfaces

$\eta$  – Efficiency (Reference Value is 0.85 to 0.95.)

$g$  – Gravity constant (9.8 m/s<sup>2</sup>)

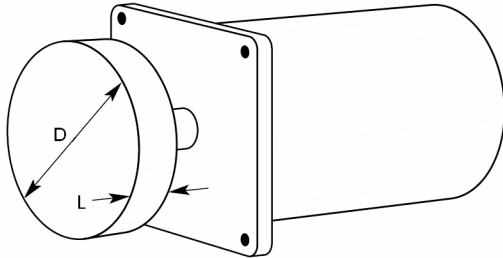
\* This is for solid cylinder, and see page 1 for hollow cylinder.

\*\*Please use the max value(s) of the specific application.

◆ **Direct Drive Loads**

There are many direct drive applications, such as index tables, feeding materials, and etc. A motor is typically connected to the load through a flexible or compliant coupling. This coupling provides a small amount of damping and helps correct for any mechanical misalignment. Direct drive is attractive when mechanical simplicity is desirable and the load being driven is of moderate inertia.

➤ **Solid Cylinder**



Inertia:

$$J_L = \frac{1}{8}mD^2 = \frac{\pi}{32}\rho LD^4 \quad [kg \cdot m^2]$$

$$J_T = J_L + J_M \quad [kg \cdot m^2]$$

Torque:

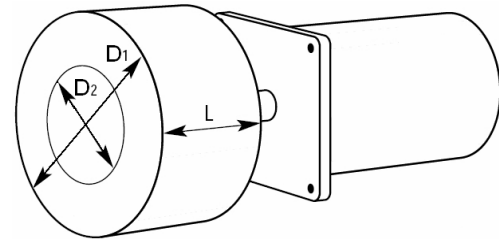
$$T_a = J_T a = (J_L + J_M) \frac{\omega_1 - \omega_0}{t} \quad [N \cdot m]^*$$

$$T_T = T_L + T_a \quad [N \cdot m]^*$$

$$T_M = K_S T_T \quad [N \cdot m]$$

- $J_L$  – Inertia of the load [kg·m<sup>2</sup>]
  - $J_M$  – Inertia of the motor [kg·m<sup>2</sup>]
  - $J_T$  – Inertia of the system [kg·m<sup>2</sup>]
  - $m$  – Weight [kg]
  - $D$  – Diameter [m]
  - $\rho$  – Density of the load [kg/m<sup>3</sup>]
  - $L$  – Length of the load [m]
  - $\omega_0$  – Initial velocity [rad/s]
  - $\omega_1$  – Final velocity [rad/s]
  - $t$  – Time for velocity change [s]
  - $T_a$  – Acceleration torque [N·m]
  - $T_L$  – Load torque [N·m], see Load Torque Calculation.
  - $T_T$  – Total calculation torque [N·m],  $T_T = T_L + T_a$
  - $T_M$  – Required motor torque [N·m],  $T_M = K_S \cdot T_T$
  - $K_S$  – Safety factor (Reference Value is 1.5 to 2.0.)
- \*Please use the max value(s) of the specific application.

➤ **Hollow Cylinder**



Inertia:

$$J_L = \frac{1}{8}m(D_1^2 + D_2^2) = \frac{\pi}{32}\rho L(D_1^4 - D_2^4) \quad [kg \cdot m^2]$$

$$J_T = J_L + J_M \quad [kg \cdot m^2]$$

Torque:

$$T_a = J_T a = (J_L + J_M) \frac{\omega_1 - \omega_0}{t} \quad [N \cdot m]^*$$

$$T_T = T_L + T_a \quad [N \cdot m]^*$$

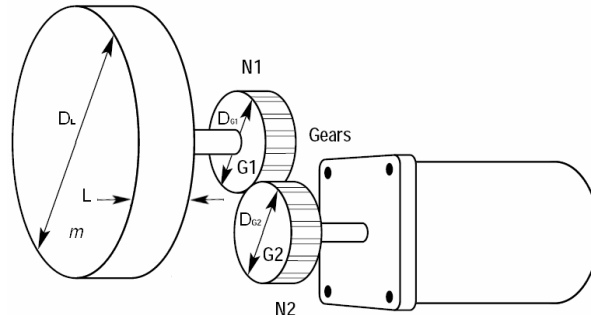
$$T_M = K_S T_T \quad [N \cdot m]$$

- $J_L$  – Inertia of the load [kg·m<sup>2</sup>]
  - $J_M$  – Inertia of the motor [kg·m<sup>2</sup>]
  - $J_T$  – Inertia of the system [kg·m<sup>2</sup>]
  - $m$  – Weight of load [kg]
  - $D_1$  – External diameter of the disc [m]
  - $D_2$  – Internal diameter of the disc [m]
  - $\rho$  – Density of the load [kg/m<sup>3</sup>]
  - $L$  – Length of the load [m]
  - $\omega_0$  – Initial velocity [rad/s]
  - $\omega_1$  – Final velocity [rad/s]
  - $t$  – Time for velocity change [s]
  - $T_a$  – Acceleration torque [N·m]
  - $T_L$  – Load torque [N·m], see Load Torque Calculation.
  - $T_T$  – Total calculation torque [N·m],  $T_T = T_L + T_a$
  - $T_M$  – Required motor torque [N·m],  $T_M = K_S \cdot T_T$
  - $K_S$  – Safety factor (Reference Value is 1.5 to 2.0.)
- \*Please use the max value(s) of the specific application.

◆ **Gear Drive Loads**

Traditional gear drives are more commonly used with stepping motors. The fine resolution of a microstepping motor can

make gearing unnecessary in many applications, where gears are used only for increase system precision. Gears generally have undesirable efficiency, wear characteristics, backlash, and can be noisy. Gears are useful; however, when very large inertias must be moved because the inertia of the load reflected back to the motor through the gearing is divided by the square of the gear ratio. In this manner, large inertial loads can be moved while maintaining a good load-inertia to rotor-inertia ratio (less than 10:1).



Inertia:

$$J_L = \frac{1}{8} m D_L^2 \left(\frac{N_2}{N_1}\right)^2 = \frac{\pi}{32} \rho L D_L^4 \left(\frac{N_2}{N_1}\right)^2 \quad [\text{kg} \cdot \text{m}^2]^*$$

$$J_{G1} = \frac{1}{8} m_{G1} D_{G1}^2 \left(\frac{N_2}{N_1}\right)^2 \quad [\text{kg} \cdot \text{m}^2]$$

$$J_{G2} = \frac{1}{8} m_{G2} D_{G2}^2 \quad [\text{kg} \cdot \text{m}^2]$$

$$J_T = J_L + J_{G1} + J_{G2} + J_M \quad [\text{kg} \cdot \text{m}^2]$$

Torque:

$$T_a = J_T a = (J_L + J_{G1} + J_{G2} + J_M) \frac{\omega_1 - \omega_0}{t} \quad [\text{N} \cdot \text{m}]^{**}$$

$$T_T = T_L + T_a \quad [\text{N} \cdot \text{m}]^{**}$$

$$T_M = K_S T_T \quad [\text{N} \cdot \text{m}]$$

$J_L$  – Inertia of the load [ $\text{kg} \cdot \text{m}^2$ ]

$J_{G1}$  – Inertia of the Gear 1 [ $\text{kg} \cdot \text{m}^2$ ]

$J_{G2}$  – Inertia of the Gear 2 [ $\text{kg} \cdot \text{m}^2$ ]

$J_M$  – Inertia of the motor [ $\text{kg} \cdot \text{m}^2$ ]

$J_T$  – Inertia of the system [ $\text{kg} \cdot \text{m}^2$ ]

$N_1$  – Number of gear teeth of the Gear 1 [constant]

$N_2$  – Number of gear teeth of the Gear 2 [constant]

$m$  – Weight of the load [kg]

$m_{G1}$  – Weight of the Gear 1 [kg]

$m_{G2}$  – Weight of the Gear 2 [kg]

$D_L$  – Diameter [m]

$\rho$  – Density of the load [ $\text{kg}/\text{m}^3$ ]

$L$  – Length of the load [m]

$\omega_0$  – Initial velocity of the motor [rad/s]

$\omega_1$  – Final velocity of the motor [rad/s]

$t$  – Time for velocity change [s]

$T_a$  – Acceleration torque [ $\text{N} \cdot \text{m}$ ]

$T_L$  – Load torque [ $\text{N} \cdot \text{m}$ ], see Load Torque Calculation.

$T_T$  – Total calculation torque [ $\text{N} \cdot \text{m}$ ],  $T_T = T_L + T_a$

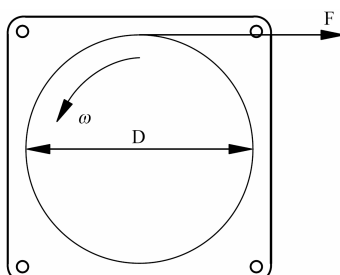
$T_M$  – Required motor torque [ $\text{N} \cdot \text{m}$ ],  $T_M = K_S T_T$

$K_S$  – Safety factor (Reference Value is 1.5 to 2.0.)

\* This is for solid cylinder, and see page 1 for hollow cylinder.

\*\*Please use the max value(s) of the specific application.

#### ❖ Load Torque Calculation



$$T_L = \frac{FD}{2} + T_F \quad [\text{N} \cdot \text{m}]^*$$

$F$  – Force to rotate the load [N]

$D$  – Diameter [m]

$T_L$  – Load torque [ $\text{N} \cdot \text{m}$ ]

$T_F$  – Load torque due to friction [ $\text{N} \cdot \text{m}$ ], here  $\approx 0$  [ $\text{N} \cdot \text{m}$ ]

\*Please use the max value of the specific application.

◆ **Checking the Required Motor Torque**

Select a motor and check that the required motor torque falls within the pull-out torque of the speed-torque characteristics.

