Considering the Rotational Torque

The rotational torque required to convert rotational motion of the ball screw into straight motion is obtained using equation (45) below.

During Uniform Motion

$$T_t = (T_1 + T_2 + T_4) \cdot A \quad \cdots\cdots\cdots (45)$$

T_t : Rotation torque required during uniform motion (N·mm)
T_1 : Friction torque due to an external load (N·mm)
T_2 : Preload torque of the ball screw (N·mm)
T_4 : Other torque (N·mm)
(frictional torque of the support bearing and oil seal)
A : Reduction ratio

During Acceleration

$$T_K = T_t + T_3 \quad \cdots\cdots\cdots (46)$$

T_K : Rotation torque required during acceleration (N·mm)
T_3 : Torque required for acceleration (N·mm)

During Deceleration

$$T_g = T_t - T_3 \quad \cdots\cdots\cdots (47)$$

T_g : Rotational torque required for deceleration (N·mm)

Frictional Torque Due to an External Load

Of the turning forces required for the ball screw, the rotational torque needed for an external load (guide surface resistance or external force) is obtained using equation (48) below.

$$T_1 = \frac{Fa \cdot Ph}{2\pi \cdot \eta} \quad \cdots\cdots\cdots (48)$$

T_1 : Friction torque due to an external load (N·mm)
Fa : Applied load (N)
Ph : Ball screw lead (mm)
η : Ball screw efficiency (0.9 to 0.95)

Torque Due to a Preload on the Ball Screw

For a preload on the ball screw, see “Preload Torque” on A15-22.

Torque Required for Acceleration

$$T_3 = J \times \omega' \times 10^3 \quad \cdots\cdots\cdots (49)$$

T_3 : Torque required for acceleration (N·mm)
J : Inertial moment ($kg \cdot m^2$)
ω' : Angular acceleration (rad/s^2)

$$J = m\left(\frac{Ph}{2\pi}\right)^2 \cdot A^2 \cdot 10^{-6} + J_S \cdot A^2 + J_A \cdot A^2 + J_B$$

m : Transferred mass (kg)
Ph : Ball screw lead (mm)
J_S : Inertial moment of the screw shaft ($kg \cdot m^2$)
(indicated in the dimensional tables of the respective model number)
A : Reduction ratio
J_A : Inertial moment of gears, etc. attached to the screw shaft side ($kg \cdot m^2$)
J_B : Inertial moment of gears, etc. attached to the motor side ($kg \cdot m^2$)

$$\omega' = \frac{2\pi \cdot Nm}{60t}$$

Nm : Motor revolutions per minute (min^{-1})
t : Acceleration time (s)

Reference: Inertial moment of a round object

$$J = \frac{m \cdot D^2}{8 \cdot 10^6}$$

J : Inertial moment ($kg \cdot m^2$)
m : Mass of the round object (kg)
D : Screw shaft outer diameter (mm)

Considering the Strength of Ball Screw Shaft Ends

When torque is conveyed through the screw shaft in a ball screw, the strength of the screw shaft must be taken into consideration since it experiences both torsion load and bending load.

Screw Shaft Subjected to Torsion

When torsion load is applied to the end of a ball screw shaft, use equation (50) to obtain the end diameter of the screw shaft.

$$T = \tau_a \cdot Z_P \quad \text{and} \quad Z_P = \frac{T}{\tau_a} \quad \cdots\cdots\cdots(50)$$

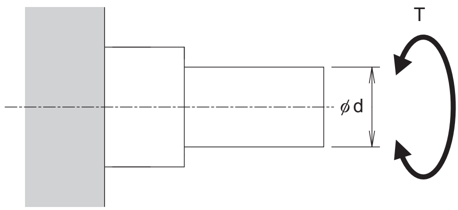
T : Maximum torsion moment (N·mm)

τ_a : Permissible torsion stress of the screw shaft (49 N/mm²)

Z_P : Section modulus (mm³)

$$Z_P = \frac{\pi \cdot d^3}{16}$$

T: Torsion moment



Screw Shaft Subjected to Bending

When a bending load is applied to the end of a ball screw shaft, use equation (51) to obtain the end diameter of the screw shaft.

$$M = \sigma \cdot Z \quad \text{and} \quad Z = \frac{M}{\sigma} \quad \cdots\cdots\cdots(51)$$

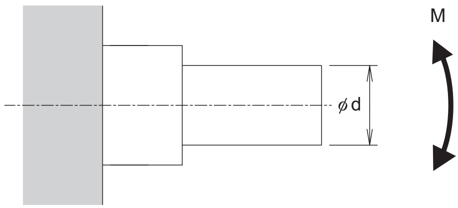
M : Maximum bending moment (N·mm)

σ : Permissible bending stress of the screw shaft (98 N/mm²)

Z : Section modulus (mm³)

$$Z = \frac{\pi \cdot d^3}{32}$$

M: Bending moment



Screw Shaft Subjected to Both Torsion and Bending

When torsion load and bending load are both applied simultaneously to the end of a ball screw shaft, calculate the diameter of the screw shaft separately for each, taking into consideration the corresponding bending moment (M_e) and the corresponding torsion moment (T_e). Then calculate the thickness of the screw shaft and use the largest of the values.

Equivalent bending moment

$$M_e = \frac{M + \sqrt{M^2 + T^2}}{2} = \frac{M}{2}\left\{1 + \sqrt{1 + \left(\frac{T}{M}\right)^2}\right\}$$

$M_e = \sigma \cdot Z$

Equivalent torsion moment

$$T_e = \sqrt{M^2 + T^2} = M \cdot \sqrt{1 + \left(\frac{T}{M}\right)^2}$$

$T_e = \tau_a \cdot Z_P$