Selecting a Model Number

Calculating the Axial Load

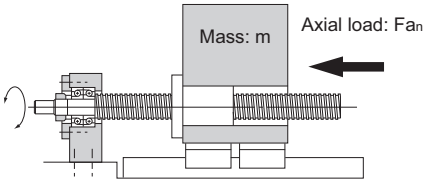
Mounted Horizontally

With ordinary conveyance systems, the axial load (Fa_n) applied when horizontally reciprocating the work is obtained by the equations below.

$$Fa_1 = \mu \cdot mg + f + m\alpha \quad \cdots\cdots (18)$$
$$Fa_2 = \mu \cdot mg + f \quad \cdots\cdots (19)$$
$$Fa_3 = \mu \cdot mg + f - m\alpha \quad \cdots\cdots (20)$$
$$Fa_4 = -\mu \cdot mg - f - m\alpha \quad \cdots\cdots (21)$$
$$Fa_5 = -\mu \cdot mg - f \quad \cdots\cdots (22)$$
$$Fa_6 = -\mu \cdot mg - f + m\alpha \quad \cdots\cdots (23)$$

V_{max} : Maximum speed (m/s)
t_1 : Acceleration time (s)

$$\alpha = \frac{V_{max}}{t_1} : \text{Acceleration} \quad (m/s^2)$$



Guide surface
Friction coefficient : μ
Resistance without load : f
Gravitational acceleration: g

Fa_1 : Axial load during forward acceleration (N)
Fa_2 : Axial load during uniform forward motion (N)
Fa_3 : Axial load during forward deceleration (N)
Fa_4 : Axial load during backward acceleration (N)
Fa_5 : Axial load during uniform backward motion (N)
Fa_6 : Axial load during backward deceleration (N)
m : Transferred mass (kg)
μ : Frictional coefficient of the guide surface (–)
f : Guide surface resistance (without load) (N)

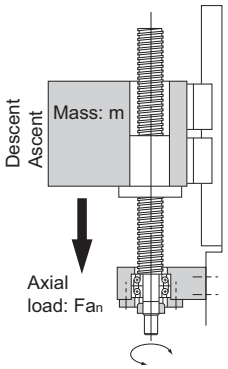
Mounted Vertically

With ordinary conveyance systems, the axial load (Fa_n) applied when vertically reciprocating the work is obtained by the equations below.

$$Fa_1 = mg + f + m\alpha \quad \cdots\cdots (24)$$
$$Fa_2 = mg + f \quad \cdots\cdots (25)$$
$$Fa_3 = mg + f - m\alpha \quad \cdots\cdots (26)$$
$$Fa_4 = mg - f - m\alpha \quad \cdots\cdots (27)$$
$$Fa_5 = mg - f \quad \cdots\cdots (28)$$
$$Fa_6 = mg - f + m\alpha \quad \cdots\cdots (29)$$

V_{max} : Maximum speed (m/s)
t_1 : Acceleration time (s)

$$\alpha = \frac{V_{max}}{t_1} : \text{Acceleration} \quad (m/s^2)$$



Guide surface
Friction coefficient : μ
Resistance without load: f

Fa_1 : Axial load during upward acceleration (N)
Fa_2 : Axial load during uniform upward motion (N)
Fa_3 : Axial load during upward deceleration (N)
Fa_4 : Axial load during downward acceleration (N)
Fa_5 : Axial load during uniform downward motion (N)
Fa_6 : Axial load during downward deceleration (N)
m : Transferred mass (kg)
f : Guide surface resistance (without load) (N)

Static Safety Factor

Static Safety Factor per Basic Static Load Rating (Excluding Models HBN-V, HBN-K (KA), HBN, and SBKH)

For ball screws, a static safety factor as defined by formula 30 based on the calculated maximum axial load and static load rating must be considered. Vibrations, impacts, or inertia due to starting and stopping may result in an unexpectedly large load. Therefore, please confirm that a sufficient static safety factor has been ensured when selecting a model. Table 1 shows guideline values for the static safety factor.

$$f_s = \frac{C_0a}{Fa_{max}} \quad \cdots\cdots\cdots (30)$$

f_s : Static safety factor (see Table 1)
C_0a : Basic static load rating[1] (kN)
Fa_{max} : Maximum axial load[2] (kN)

Table 1: Guideline for the Static Safety Factor (f_s)

Load conditions[3]	Lower Limit of f_s
Without vibrations or impacts	2
With vibrations or impacts	5

Permissible Load Safety Margin (Models HBN-V, HBN-K (KA), HBN, and SBKH)

The permissible load Fp in the axial direction is fixed for high-load ball screw models HBN-V, HBN-K (KA), HBN, and SBKH. Therefore, please select a model with a calculated maximum axial load (Fa_{max}) that does not exceed the permissible load (Fp). Permissible load (Fp) indicates the maximum axial load that the high-load ball screw can receive, and this range should not be exceeded.

$$\frac{Fp}{Fa_{max}} > 1 \quad \cdots\cdots\cdots (31)$$

Fp : Permissible axial load (kN)
Fa_{max} : Maximum axial load[2] (kN)

[1] The basic static load rating (C_0a) is a static load with a constant direction and magnitude whereby the sum of the permanent deformation of the rolling element and that of the raceway on the contact area under the maximum stress is 0.0001 times the rolling element diameter. With the ball screw, it is defined as the axial load. (Specific values for each ball screw model are indicated in the dimensional tables for the corresponding model.)
[2] The maximum load in the axial direction calculated on B15-46 is applied to the maximum axial load (Fa_{max}).
[3] Vibrations and impacts are typically caused by factors such as acceleration and deceleration, sudden starting and stopping, vibrations and impacts from an external machine, and changes in processing power over time.

Considering the Service Life

Service Life of the Ball Screw

A ball screw in motion under an external load receives repeated stress on its raceways and balls. When the stress reaches the limit, the raceways break from fatigue, and their surfaces flake like scales. This phenomenon is called flaking. The service life of the ball screw is the total number of revolutions until the first flaking occurs on any of the raceways or the balls as a result of rolling fatigue of the material.

The nominal life defined below is used as a guideline for the service life of a ball screw.

Nominal life is the total number of revolutions that 90% of a group of identical ball screws independently operating under the same conditions can achieve without flaking.

Calculating the Rated Life

The service life of the ball screw is calculated from formula (32) below using the basic dynamic load rating (Ca) and the applied axial load.

● Calculating the Nominal Life

The nominal life (L_{10}) is obtained from the following formula using the basic dynamic load rating (Ca) and the applied load in the axial direction (Fa).

$$L_{10} = \left(\frac{Ca}{Fa}\right)^3 \times 10^6 \quad \cdots\cdots\cdots\cdots\cdots\cdots (32\text{-}1)$$

L_{10}	: Nominal life	(rev.)
Ca	: Basic dynamic load rating	(N)
Fa	: Applied axial load	(N)

● Calculating the Modified Nominal Life

During use, a ball screw may be subjected to vibrations and shocks as well as fluctuating loads, which are difficult to detect. Taking these factors into account, the modified nominal life (L_{10m}) can be calculated by formula (32-2) below.

•Modified factor α

$$\alpha = \frac{1}{f_w}$$

α	: Modified factor	
f_w	: Load factor	(see Table 2)

•Modified nominal life L_{10m}

$$L_{10m} = \left(\alpha \times \frac{Ca}{Fa}\right)^3 \times 10^6 \quad \cdots\cdots\cdots (32\text{-}2)$$

L_{10m}	: Modified nominal life	(rev.)
Ca	: Basic dynamic load rating	(N)
Fa	: Applied axial load	(N)

Table 2: Load Factor (f_w)

Vibrations and impacts	Speed (V)	f_w
Faint	Very low V ≦ 0.25 m/s	1 to 1.2
Weak	Slow 0.25 < V ≦ 1 m/s	1.2 to 1.5
Medium	Medium 1 < V ≦ 2 m/s	1.5 to 2
Strong	High V > 2 m/s	2 to 3.5

Notes: The basic dynamic load rating (Ca) is used in calculations of service life when the ball screw is under an axial load. The basic dynamic load rating is defined as a load rating based on the movement of a set of identical ball screws with a rated life (L) of 10^6 revolutions, using a load applied in the axial direction that does not vary in either magnitude or direction. (The basic dynamic load ratings (Ca) for each model number are indicated in the dimensional tables.)
The rated service life is estimated by calculating the load on the premise that the product is set up in ideal mounting conditions with the assurance of good lubrication. The service life can be affected by the precision of the mounting materials used and any distortion.

● Service Life Time

If the revolutions per minute is determined, the service life time can be calculated from equation (33) below using the nominal life (L_{10}).

$$L_h = \frac{L_{10}}{60 \times N} = \frac{L_{10} \times Ph}{2 \times 60 \times n \times \ell_s} \quad \cdots\cdots\cdots(33)$$

L_h : Service life time (h)
N : Revolutions per minute (min^{-1})
n : Number of reciprocations per minute (min^{-1})
Ph : Ball screw lead (mm)
ℓ_s : Stroke length (mm)

● Service Life in Travel Distance

The service life in travel distance can be calculated from equation (34) below using the nominal life (L_{10}) and the ball screw lead.

$$L_s = \frac{L_{10} \times Ph}{10^6} \quad \cdots\cdots\cdots(34)$$

L_s : Service life in travel distance (km)
Ph : Ball screw lead (mm)

● Applied Load and Service Life with a Preload Taken into Account

If the ball screw is used under a preload (medium preload), it is necessary to consider the applied preload in calculating the service life since the ball screw nut already receives an internal load. For details on applied preload for a specific model number, contact THK.

● Average Axial Load

If the axial load acting on the ball screw fluctuates, it is necessary to calculate the service life by determining the average axial load.
The average axial load (F_m) refers to a constant load that results in a service life equal to the service life under fluctuating load conditions.
If the load changes in steps, the average axial load can be obtained from the equation below.

$$F_m = \sqrt[3]{\frac{1}{\ell}(Fa_1^3\ell_1 + Fa_2^3\ell_2 + \cdots + Fa_n^3\ell_n)} \quad \cdots\cdots\cdots(35)$$

F_m : Average axial load (N)
Fa_n : Varying load (N)
ℓ_n : Distance traveled under load (F_n)
ℓ : Total travel distance

To determine the average axial load using rotational speed and time instead of distance, calculate the average axial load by determining the distance in the equation below.

$\ell = \ell_1 + \ell_2 + \cdots \ell_n$

$\ell_1 = N_1 \cdot t_1$

$\ell_2 = N_2 \cdot t_2$

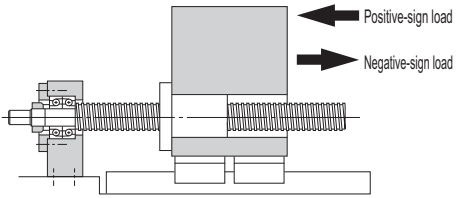
$\ell_n = N_n \cdot t_n$

N: Rotational speed

t: Time

■When the Applied Load Sign Changes

If the sign (positive or negative) used for variable load is always the same, there are no problems with formula (35). However, if the variable load sign changes depending on the type of operation, calculate the average axial load for either positive or negative load, allowing for the load direction. (If the average axial load for positive load is calculated, the negative load is taken to be zero.) The larger of the two average axial loads is taken as the average axial load when the service life is calculated.



Example: Calculate the average axial load with the following load conditions.

Operation No.	Varying load Fa_n (N)	Travel distance ℓ_n (mm)
No. 1	10	10
No. 2	50	50
No. 3	–40	10
No. 4	–10	70

Note: The subscripts of the fluctuating load symbol and the travel distance symbol indicate operation numbers.

- Average axial load of positive-sign load

$$Fm_1 = \sqrt[3]{\frac{Fa_1^3 \times \ell_1 + Fa_2^3 \times \ell_2}{\ell_1 + \ell_2 + \ell_3 + \ell_4}} = 35.5 \text{ N}$$

Note: To calculate the average axial load of the positive-sign load, assume Fa_3 and Fa_4 to be zero.

- Average axial load of negative-sign load

$$Fm_2 = \sqrt[3]{\frac{|Fa_3|^3 \times \ell_3 + |Fa_4|^3 \times \ell_4}{\ell_1 + \ell_2 + \ell_3 + \ell_4}} = 17.2 \text{ N}$$

Note: To calculate the average axial load of the negative-sign load, assume Fa_1 and Fa_2 to be zero.

Accordingly, the average axial load of the positive-sign load (F_{m1}) is adopted as the average axial load (F_m) for calculating the service life.