# Selecting a Model Number

## Calculating the Axial Load

### [In Horizontal Mount]

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

$$Fa_1 = \mu \cdot mg + f + m\alpha \quad \cdots (18)$$

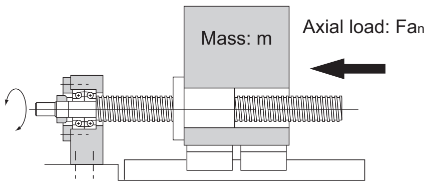
$$Fa_2 = \mu \cdot mg + f \quad \cdots (19)$$

$$Fa_3 = \mu \cdot mg + f - m\alpha \quad \cdots (20)$$

$$Fa_4 = -\mu \cdot mg - f - m\alpha \quad \cdots (21)$$

$$Fa_5 = -\mu \cdot mg - f \quad \cdots (22)$$

$$Fa_6 = -\mu \cdot mg - f + m\alpha \quad \cdots (23)$$




Guide surface
Friction coefficient : $\mu$
Resistance without load : f
Gravitational acceleration: g

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

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

$Fa_1$ : Axial load during forward acceleration (N)
$Fa_2$ : Axial load during forward uniform 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)
$\mu$ : Frictional coefficient of the guide surface (–)
f : Guide surface resistance (without load) (N)

### [In Vertical Mount]

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

$$Fa_1 = mg + f + m\alpha \quad \cdots (24)$$

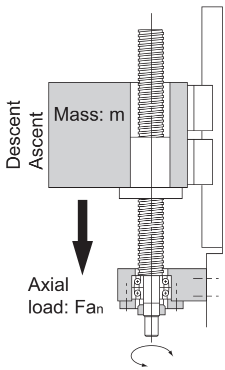
$$Fa_2 = mg + f \quad \cdots (25)$$

$$Fa_3 = mg + f - m\alpha \quad \cdots (26)$$

$$Fa_4 = mg - f - m\alpha \quad \cdots (27)$$

$$Fa_5 = mg - f \quad \cdots (28)$$

$$Fa_6 = mg - f + m\alpha \quad \cdots (29)$$




Guide surface
Friction coefficient : $\mu$
Resistance without load: f

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

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

$Fa_1$ : 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

The basic static load rating ($C_0a$) generally equals to the permissible axial load of a Ball Screw. Depending on the conditions, it is necessary to take into account the following static safety factor against the calculated load. When the Ball Screw is stationary or in motion, unexpected external force may be applied through an inertia caused by the impact or the start and stop.

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

$Fa_{max}$ : Allowable Axial Load (kN)
$C_0a$ : Basic static load rating* (kN)
$f_S$ : Static safety factor (see Table21)

Table21 Static Safety Factor ($f_S$)

| Machine using the LM system | Load conditions | Lower limit of $f_S$ |
|---|---|---|
| General industrial machinery | Without vibration or impact | 1.0 to 3.5 |
| | With vibration or impact | 2.0 to 5.0 |
| Machine tool | Without vibration or impact | 1.0 to 4.0 |
| | With vibration or impact | 2.5 to 7.0 |

*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 of each Ball Screw model are indicated in the specification tables for the corresponding model number.)

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

In comparison to previous ball screws, high-load ball screw models HBN-V, HBN-K (KA), HBN, and SBKH are designed to achieve longer service lives under high load conditions, and it is necessary to consider the permissible load Fp for the axial load. Permissible load Fp indicates the maximum axial load that the high-load ball screw can support, and this range should not be exceeded.

Permissible load Fp indicates the maxim axial load that the high load Ball Screw can receive, and this range should not be exceeded.

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

Fp : Permissible Axial Load (kN)
Fa : Applied Axial Load (kN)

Ball Screw

# Studying 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 service life of the Ball Screw varies from unit to unit even if they are manufactured in the same process and used in the same operating conditions. For this reason, when determining the service life of a Ball Screw unit, the nominal life as defined below is used as a guideline.

The nominal life is the total number of revolutions that 90% of identical Ball Screw units in a group achieve without flaking after they independently operate in the same conditions.

## [Calculating the Rated Life]

The service life of the Ball Screw is calculated from the 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).

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

$L_{10}$ : 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 according to the following formula (32-2).

•Modified factor $\alpha$

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

$\alpha$ : Modified factor
$f_w$ : Load factor (see Table22)

•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)

Table22 Load Factor ($f_w$)

| Vibrations/impact | Speed (V) | $f_w$ |
|---|---|---|
| Faint | Very low<br>V≦0.25 m/s | 1 to 1.2 |
| Weak | Slow<br>0.25<V≦1 m/s | 1.2 to 1.5 |
| Medium | Medium<br>1<V≦2 m/s | 1.5 to 2 |
| Strong | High<br>V>2 m/s | 2 to 3.5 |

*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 specification 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 the 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)
$\ell_s$ : Stroke length (mm)

## ● Service Life in Travel Distance

The service life in travel distance can be calculated from the 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 an axial load acting on the Ball Screw is present, it is necessary to calculate the service life by determining the average axial load.

The average axial load ($F_m$) is a constant load that equals to the service life in fluctuating the load conditions.

If the load changes in steps, the average axial load can be obtained from the equation below.

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

$F_m$ : Average Axial Load (N)
$Fa_n$ : Varying load (N)
$\ell_n$ : Distance traveled under load ($F_n$)
$\ell$ : Total travel distance

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

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

$\ell_1 = N_1 \cdot t_1$

$\ell_2 = N_2 \cdot t_2$

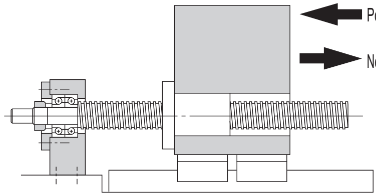
$\ell_n = N_n \cdot t_n$

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 $\ell_n$(mm) |
|---|---|---|
| No.1 | 10 | 10 |
| No.2 | 50 | 50 |
| No.3 | –40 | 10 |
| No.4 | –10 | 70 |

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

● Average axial load of positive-sign load

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

$$F_{m1} = \sqrt[3]{\frac{Fa_1^{3} \times \ell_1 + Fa_2^{3} \times \ell_2}{\ell_1 + \ell_2 + \ell_3 + \ell_4}} = 35.5\ \text{N}$$

● Average axial load of negative-sign load

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

$$F_{m2} = \sqrt[3]{\frac{|Fa_3|^{3} \times \ell_3 + |Fa_4|^{3} \times \ell_4}{\ell_1 + \ell_2 + \ell_3 + \ell_4}} = 17.2\ \text{N}$$

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.