Selecting a Model Number

Calculating the Axial Load

Mounted Horizontally

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

$\mathbf{Fa}_1 = \boldsymbol{\mu} \cdot \mathbf{mg} + \mathbf{f} + \mathbf{m}\boldsymbol{\alpha}$	(18)
Fa₂ = μ · mg + f	(19)
Fa₃ = μ · mg + f − mα	(20)
$\mathbf{Fa}_4 = -\mathbf{\mu} \cdot \mathbf{mg} - \mathbf{f} - \mathbf{m}\alpha$	(21)
Fa₅= -µ · mg - f	(22)
$Fa_6 = -\mu \cdot mg - f + m\alpha$	(23)
V _{max} : Maximum speed	(m/s)
t ₁ : Acceleration time	(s)
$\alpha = \frac{V_{max}}{t_1}$: Acceleration	(m/s²)

- Fa1 : Axial load during forward acceleration (N)
- : Axial load during uniform forward motion (N) Fa₂
- Fa : Axial load during forward deceleration (N)
- : Axial load during backward acceleration (N) Fa₄
- : Axial load during uniform backward motion (N) Fa₅



- : Transferred mass m (kg)
- : Frictional coefficient of the guide surface (-) μ
- f : Guide surface resistance (without load) (N)

Mounted Vertically

A15-46

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

Fa₁= mg	+ f + m α ······	(24)
Fa₂= mg	+f	(25)
Fa₃= mg	+ f – mα	(26)
Fa₄= mg	- f - m α ······	
Fa₅= mg	- f	
Fa₀= mg	- f + m α ······	
V _{max} : Maxin t ₁ : Acce	mum speed leration time	(m/s) (s)
$\alpha = \frac{V_{max}}{t_1} : Ac$	cceleration	(m/s²)
Fa₁ : Axial Fa₂ : Axial	load during upward ac load during uniform upw	celeration (N) vard motion (N)



- Fa₃ : Axial load during upward deceleration (N)
- Fa₄ : Axial load during downward acceleration (N)
- Fa₅ : Axial load during uniform downward motion (N)

TOHK



- Fa₀ : Axial load during downward deceleration (N)
- : Transferred mass m (kg)
- f : Guide surface resistance (without load) (N)

Static Safety Factor

The basic static load rating (C_0a) generally equals the permissible axial load of a ball screw. Depending on the operating conditions, it is necessary to take into account the following static safety factor with regard to the calculated load. When the ball screw is stationary or in motion, an unexpected external force may be applied due to inertia caused by an impact or starting and stopping.

$$Fa_{max} = \frac{C_0 a}{f_s} \dots \dots \dots (30)$$

fs

- C_0a : Basic static load rating (kN)
 - : Static safety factor (see Table 21)

Table 21: Static Safety Factor (fs)

Machine using the LM System	Load conditions	Lower limit of fs
General industrial	Without vibrations or impacts	1.0 to 3.5
machinery	With vibrations or impacts	2.0 to 5.0
Machina taal	Without vibrations or impacts	1.0 to 4.0
wachine tool	With vibrations or impacts	2.5 to 7.0

Note: The basic static load rating (C₀a) 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 dimensional tables for the corresponding model number.)

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

High-load ball screw Model HBN and high-load high-speed ball screw Model SBKH, in comparison to previous ball screws, are designed to achieve longer service lives under high-load conditions, and for axial load it is necessary to consider 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.



Fp	: Permissible axial load	(kN)
Fa	: Applied axial load	(kN)

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 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 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).

$$\mathbf{L}_{10} = \left(\frac{\mathbf{Ca}}{\mathbf{Fa}}\right)^3 \times \mathbf{10}^6 \dots (32-1)$$

L10	: Nominal life	(rev.)
Ca	: Basic dynamic load rating	(N)
-	A 12 1 2 1 1	

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 $\boldsymbol{\alpha}$

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

•Modified nominal life L10m

$$\mathbf{L}_{10m} = \left(\alpha \times \frac{\mathbf{Ca}}{\mathbf{Fa}} \right)^3 \times \mathbf{10}^6 \quad \dots \dots \quad (32-2)$$

Table 22:	Load	Factor	(f _w)	1
-----------	------	--------	-------------------	---

Vibrations and impacts	Speed (V)	fw
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

α	: Modified factor	
fw	: Load factor	(see Table 22)

L _{10m}	: Modified nominal life	(rev.)
------------------	-------------------------	--------

- Ca : Basic dynamic load rating (N)
- Fa : Applied axial load (N)

*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° 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.



Selecting a Model Number

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. =	$\frac{L_{10}}{60 \times N} =$	$\frac{\mathbf{L}_{10} \times \mathbf{Ph}}{2 \times 60 \times \mathbf{n} \times \boldsymbol{\ell}_{\mathbf{s}}}$	(33)
Ln	: Service life	time	(h)
Ν	: Revolutions	per minute	(min⁻¹)
n	: Number of	reciprocations per mir	ute
			(min⁻¹)
Ph	: Ball screw I	ead	(mm)
ls	: Stroke leng	th	(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.

$$\mathbf{L}_{\mathbf{s}} = \frac{\mathbf{L}_{10} \times \mathbf{Ph}}{\mathbf{10}^{6}} \dots \dots \dots (34)$$

Ls : 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.

(N)

(N)

- F_m : Average axial load
- Fan : Varying load
- 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.

$$\begin{split} \ell &= \ell_1 + \ell_2 + \cdots \cdot \ell_n \\ \ell_1 &= N_1 \cdot t_1 \\ \ell_2 &= N_2 \cdot t_2 \\ \ell_n &= N_n \cdot t_n \\ N: \text{ Rotational speed} \\ t: \text{ Time} \end{split}$$

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)	Travel distance ℓ₁(mm)
No. 1	10	10
No. 2	50	50
No. 3	-40	10
No. 4	-10	70



• Average axial load of positive-sign load

*To calculate the average axial load of the positive-sign load, assume Fa₃ and Fa₄ to be zero.

$$F_{m_1} = \sqrt[3]{\frac{Fa_1^3 \times \ell_1 + Fa_2^3 \times \ell_2}{\ell_1 + \ell_2 + \ell_3 + \ell_4}} = 35.5 \text{ N}$$

• 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.

$$Fm_{2} = \sqrt[3]{\frac{|Fa_{3}|^{3} \times \ell_{3} + |Fa_{4}|^{3} \times \ell_{4}}{\ell_{1} + \ell_{2} + \ell_{3} + \ell_{4}}} = 17.2 \text{ N}$$

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.



A15-50 冗出K