7.4. Studying the Service Life

7.4.1. Service Life of the Ball Screw

The 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 partially exfoliate in flakes. 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 rated life as defined below is used as a guideline.
The rated life is the total number of revolutions that 90% of identical Ball Screw units in a group achieve without developing flaking (scale-like exfoliation of a metallic surface) after they independently operate in the same conditions.

7.4.2. Calculating the Rated Life

The service life of the Ball Screw is calculated from the equation (27) below using the basic dynamic load rating (Ca) and the applied axial load.

Rated Life (Total Number of Revolutions)

$$L = \left(\frac{Ca}{f_W \cdot Fa}\right)^3 \times 10^6 \quad \cdots\cdots\cdots (27)$$

where

L : Rated life (total number of revolutions) (rev)
Ca : Basic dynamic load rating* (N)
Fa : Applied axial load (N)
f_W : Load factor (see table 2)

Table 2 Load Factor (f_W)

Vibrations/impact	Speed (V)	f_W
Faint	Very low V≦0.25m/s	1 to 1.2
Weak	Low 0.25<V≦1m/s	1.2 to 1.5
Medium	Moderate 1<V≦2m/s	1.5 to 2
Strong	High V>2m/s	2 to 3.5

* The basic dynamic load rating (Ca) is used in calculating the service life when a Ball Screw operates under a load.
The basic dynamic load rating is a load with constant direction and magnitude under which the rated life (L) equals to 10^6rev. when a group of the same Ball Screw units independently operate. (Specific basic dynamic load ratings (Ca) are indicated in the dimensional tables of the corresponding model numbers in the "THK General Catalog - Product Specifications," provided separately.)

Service Life Time

If the rotation speed per minute is determined, the service life time can be calculated from the equation (28) below using the rated life (L).

$$L_h = \frac{L}{60 \times N} = \frac{L \times \ell}{2 \times 60 \times n \times \ell_S} \quad \cdots\cdots\cdots(28)$$

where

L_h : Service life time (h)

N : Rotation speed per minute (min^{-1})

n : Reciprocations per minute (min^{-1})

ℓ : Lead of the Ball Screw (mm)

ℓ_S : Stroke length (mm)

Service Life in Travel Distance

The service life in travel distance can be calculated from the equation (29) below using the rated life (L) and the Ball Screw lead.

$$L_S = \frac{L \times \ell}{10^6} \quad \cdots\cdots\cdots(29)$$

where

L_S : Service life in travel distance (km)

ℓ : 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 load), 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 load conditions.

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

$$F_m = \sqrt[3]{\frac{1}{L}(Fa_1^3 \ell_1 + Fa_2^3 \ell_2 + \cdots\cdots + Fa_n^3 \ell_n)} \quad \cdots\cdots\cdots(30)$$

where

F_m : Average axial load (N)

Fa_n : Fluctuating load (N)

ℓ_n : Distance traveled under a load (F_n)

ℓ : Total travel distance

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

where

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

$\ell_1 = N_1 \cdot t_1$

$\ell_2 = N_2 \cdot t_2$

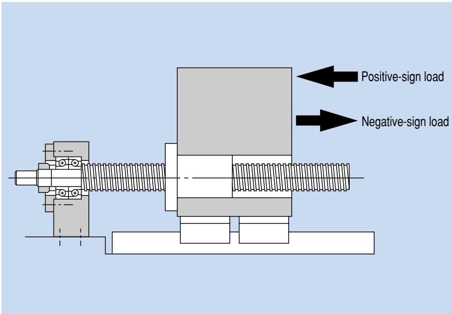
$\ell_n = N_n \cdot t_n$

N : Rotation speed

t : Time

When the Applied Load Sign Changes

When all signs for fluctuating loads are the same, the equation (30) applies without problem. However, if the sign for the fluctuating load changes according to the operation, it is necessary to calculate both the average axial load of the positive-sign load and that of the negative-sign load while taking in to account the load direction (when calculating the average axial load of the positive-sign load, assume the negative-sign load to be zero). Of the two average axial loads, the greater value is regarded as the average axial load for calculating the service life.



Example:

Calculate the average axial load with the following load conditions.

Operation No.	Fluctuating 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

* 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.