

LIFE TIME CALCULATION

•LIFE TIME OF BALL SCREWS

The life time of a ball screw is defined as a total number of revolutions which, when a group of balls run under the same conditions, they can perform without causing any fatigue failure (flaking) to the thread groove and/or balls. The flaking is caused by metal fatigue due to constant stress.

The life of a ball screw is determined by the basic dynamic load rating.

•LIFE TIME

The life time of a ball screw (Fatigue life) is calculated by the following formula:

$$L_h = \frac{10^6}{60N_m} \left(\frac{C}{P_m f_w} \right)^3 \quad (\text{hours}) \dots\dots\dots ⑤$$

Where,

L_h :Life time (hours)

C :Basic dynamic load rating (N)

P_m :Average axial load (N)

N_m :Average number of revolutions (min⁻¹)

f_w :Load factor (Coefficient by operating condition)

- Smooth operation without impact $f_w=1.0-1.2$
- Normal operation $f_w=1.2-1.5$
- Operation associated with shock or vibration $f_w=1.5-2.0$

The basic dynamic load rating that satisfies the intended life time is obtained from the following formula:

$$C = \left(\frac{60L_h N_m}{10^6} \right)^{\frac{1}{3}} P_m f_w \quad (\text{N})$$

If the life time of a ball screw is set too longer, it is necessary to increase both size and cost of the ball screw. Some case examples of standard life requirements are given below for reference.

Machine tools	20,000hrs.
Industrial machinery	10,000hrs.
Automated control equipment	15,000hrs.
Measuring instruments	15,000hrs.

•Basic dynamic load rating“C”

The basic dynamic load rating (C) is an axial load that permits the rated life of 1,000,000 revolutions (10⁶ revolutions) during which 90% or more of a group of the same ball screws can perform without causing a flaking. For basic dynamic load ratings, refer to the dimension tables.

•Average axial load“P_m”and average number of revolutions“N_m”

To select a ball screw suitable for your use, determine the following values. It may be difficult to accurately determine these operating conditions. However, it is recommendable to gather correct data, because the life time is inversely proportional to the cube of load. When these values are properly determined, the range of choice will surely broaden.

(t₁+t₂+t₃=100%)

Axial load	No. of revolutions	Operating time ratio
P ₁ N (Maximum)	N ₁ min ⁻¹	t ₁ %
P ₂ N (Normal)	N ₂ min ⁻¹	t ₂ %
P ₃ N (Minimum)	N ₃ min ⁻¹	t ₃ %

Considering the operating conditions of a machine tool, the maximum load (P₁) is a load applied at the time of heaviest cutting, the normal load (P₂) is a load applied during general cutting and the minimum load (P₃) is a load applied at the time of rapid traverse of the cutting tool before starting cutting and at the time of quick return after completion of cutting. Once the above-mentioned values are determined, the average axial load (P_m) and the average number of revolutions (N_m) can be obtained from the following formulae:

$$P_m = \left(\frac{P_1^3 N_1 t_1 + P_2^3 N_2 t_2 + P_3^3 N_3 t_3}{N_1 t_1 + N_2 t_2 + N_3 t_3} \right)^{\frac{1}{3}} \quad (\text{N}) \dots\dots ⑥$$

$$N_m = \frac{N_1 t_1 + N_2 t_2 + N_3 t_3}{t_1 + t_2 + t_3} \quad (\text{min}^{-1}) \dots\dots\dots ⑦$$

When the difference between the maximum axial load (P₁) and the minimum axial load (P₃) is small, or when the load changes linearly, an approximate value can be calculated from the following formula:

$$P_m \approx \frac{2P_1 + P_3}{3} \quad (\text{N}) \dots\dots\dots ⑧$$

TECHNICAL DATA OF BALL SCREWS

•LIFE TIME IN CASE OF LOW SPEED REVOLUTION

In the case of low speed revolution lower than 10min⁻¹, the life time can be satisfied with a value smaller than basic dynamic load rating (C).

In such a case, select a ball screw whose basic static load rating (C₀) satisfies the value obtained from the following formula:

$$C_0 = f_a P_{\max} \quad (\text{N}) \dots\dots\dots \textcircled{9}$$

Where,
 P_{max}: Maximum axial load (N)
 f_a: Safety factor

{	Normal operation	f _a =1-2
	Operation associated with impacts and shocks	f _a =2-3
	When smooth operation is required	f _a =3 or more

•Basic static load rating “C₀”

The basic static load rating (C₀) is an axial load where the sum of permanent deformation of the steel balls and that of the thread groove surface by a certain amount of static load becomes 0.0001 time as much as the steel ball diameter.

In many cases, no problem will be caused by the permanent deformation during operation. However, when high accuracy or very smooth revolutions are required, select a ball screw a (C₀) value which is largely over the static load.

For basic static load ratings, refer to dimension tables.

•HARDNESS AND LIFE TIME

When special material is used in the thread groove because corrosion resistance or other characteristics are required, the thread groove cannot be hardened to HRC58-62. In such a case, the basic dynamic load rating and the basic static load rating decrease according as the hardness lowers. When the hardness is low, the basic dynamic load rating (C') and the basic static load rating (C₀') are expressed by the following formulae, assuming that the respective hardness factors are (f_H) and (f_H').

$$C' = f_H C \quad (\text{N}) \dots\dots\dots \textcircled{10}$$

$$C_0' = f_H' C_0 \quad (\text{N}) \dots\dots\dots \textcircled{11}$$

Table 19 Hardness factors

Hardness HRC	58 or more	56	54	52	50	40	30	20	10
f _H	1.0	0.88	0.72	0.58	0.47	0.27	0.16	0.10	0.07
f _H '	1.0	0.83	0.61	0.45	0.32	0.14	0.07	0.03	0.02

•TEMPERATURE AND LIFE TIME

When operating a ball screw made of standard material (See Table 1 on Page 20) at a temperature of over 100°C at all times or when operating it at a extremely high temperature for a short period of time, the composition of the material changes; thus, the basic dynamic load rating and the basic static load rating decrease according as the temperature rises. In this case, however, the temperature of up to 100°C, will not adversely affect the operation. When the ball screw is operated at a temperature over 100°C, the basic dynamic load rating (C'') and the basic static load rating (C₀'') are expressed by the following formulae, assuming that the respective temperature factors are (f_t) and (f_t').

$$C'' = f_t C \quad (\text{N}) \dots\dots\dots \textcircled{12}$$

$$C_0'' = f_t' C_0 \quad (\text{N}) \dots\dots\dots \textcircled{13}$$

Table 20 Temperature factors

Temperature °C	100 or less	125	150	175	200	225	250	350
f _t	1.0	0.95	0.90	0.85	0.75	0.65	0.60	0.50
f _t '	1.0	0.93	0.85	0.78	0.65	0.52	0.46	0.35