4.4. Preload

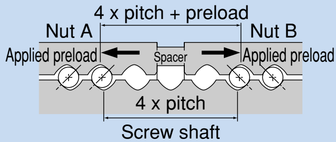
A preload is provided in order to eliminate axial clearance and minimize the displacement under an axial load.
When performing highly accurate positioning, a preload is generally provided.

4.4.1. Method for Providing a Preload

Fixed-point Preloading

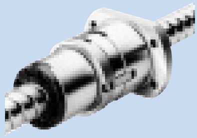
●Double-nut method (models BNFN, DKN and BLW)

This method provides a preload by inserting a spacer between two nuts.



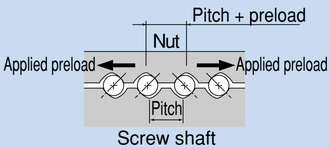

Model BNFN

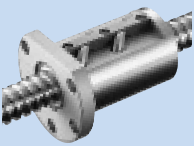

Model DKN

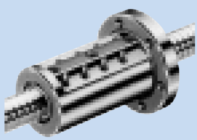

Model BLW

●Offset preloading (models SBN, BIF, DIK, SBK and DIR)

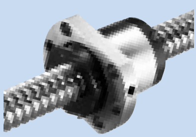
More compact than the double-nut method, the offset preloading provides a preload by changing the groove pitch in the middle of the nut without using a spacer.

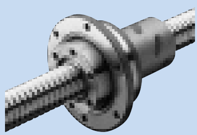



Model SBN


Model BIF

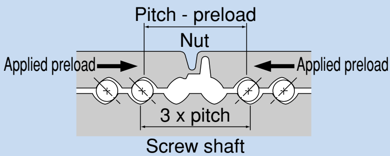

Model DIK


Model SBK


Model DIR

Constant-pressure Preloading Model JPF

A spring structure is established almost in the middle of the nut, and the groove pitch is changed in the middle of the nut to provide a preload.



Model JPF

4.4.2. Rigidity of the Ball Screw under a Preload

When a preload is provided to the Ball Screw, the rigidity of the nut is increased.
Fig. 4 shows elastic displacement curbs of the Ball Screw under a preload and without a preload.

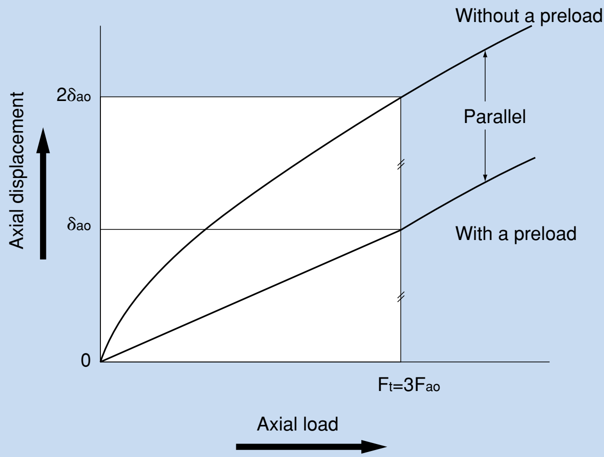


Fig. 4 Elastic Displacement of the Ball Screw

Fig. 5 shows a double-nut type of Ball Screw.

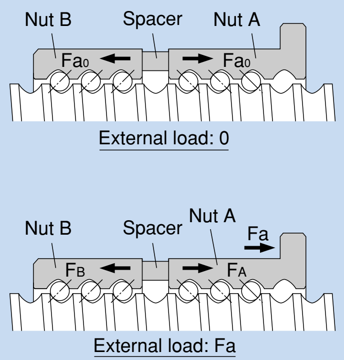


Fig. 5

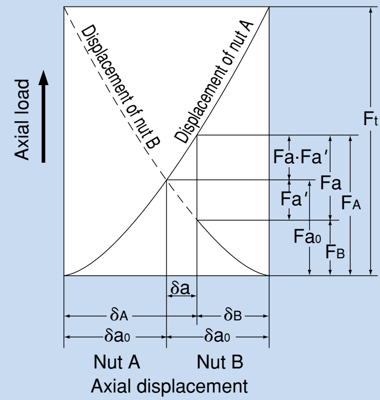


Fig. 6

Nuts A and B are provided with preload Fa_0 from the spacer. Because of the preload, nuts A and B are elastically displaced by δa_0 each. If an axial load (Fa) is applied from outside in this state, the displacement of nuts A and B is calculated as follows.

$\delta_A = \delta a_0 + \delta a$ $\quad$ $\delta_B = \delta a_0 - \delta a$

In other words, the loads on nut A and B are expressed as follows:

$F_A = Fa_0 + (Fa - Fa')$ $\quad$ $F_B = Fa_0 - Fa'$

Therefore, under a preload, the load that nut A receives equals to Fa - Fa'. This means that since load Fa', which is applied when nut A receives no preload, is deducted from Fa, the displacement of nut A is smaller.

This effect extends to the point where the displacement (δa_0) caused by the preload applied on nut B reaches zero.

To what extent is elastic displacement reduced? The relationship between the axial load on the Ball Screw under no preload and the elastic displacement can be expressed by $\delta a \propto Fa^{2/3}$. From Fig. 6, the following equations are established.

$$\delta a_0 = KFa_0^{2/3} \quad \text{(K: constant)}$$

$$2\delta a_0 = KF_t^{2/3}$$

$$\left(\frac{F_t}{Fa_0}\right)^{\frac{2}{3}} = 2 \quad F_t = 2^{3/2} \times Fa_0 = 2.8Fa_0 \fallingdotseq 3Fa_0$$

Thus, the Ball Screw under a preload is displaced by δa_0 when an axial load (F_t) approximately three times greater than the preload is provided from outside. As a result, the displacement of the Ball Screw under a preload is half the displacement ($2\delta a_0$) of the Ball Screw without a preload.

As stated above, since the preloading is effective up to approximately three times the applied preload, the optimum preload is one third of the maximum axial load.

Note, however, that an excessive preload adversely affects the service life and heat generation. As a guideline, the maximum preload should be set at 10% of the basic dynamic load rating (Ca) at a maximum.

4.4.3. Preload Torque

The preload torque of the Ball Screw in lead is controlled in accordance with JIS standard (JIS B 1192).

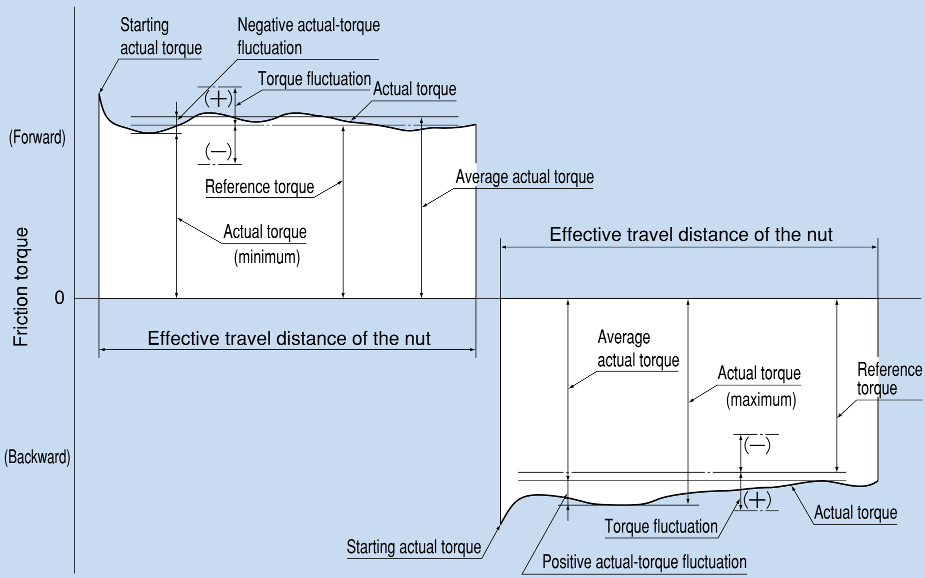


Fig. 7 Terms on Preload Torque

●Dynamic preload torque

A torque required to continuously rotate the screw shaft of a Ball Screw under a given preload without an external load applied.

●Actual torque

A dynamic preload torque measured with an actual Ball Screw.

●Torque fluctuation

Variation in a dynamic preload torque set at a target value. It can be positive or negative in relation to the reference torque.

●Coefficient of torque fluctuation

Ratio of torque fluctuation to the reference torque.

●Reference torque

A dynamic preload torque set as a target.

●Calculating the reference torque

The reference torque of a Ball Screw provided with a preload is obtained in the following equation (5).

$$T_p = 0.05\,(\tan\beta)^{-0.5}\,\frac{Fa_0 \cdot \ell}{2\pi} \quad \cdots\cdots\cdots(5)$$

where

T_p	: Reference torque	(N·mm)
β	: Lead angle	
Fa_0	: Applied preload	(N)
ℓ	: Lead	(mm)

Table 12 Tolerance Range in Torque Fluctuation

Reference torque N·mm		Effective thread length									
		4,000 mm or less								Above 4,000 mm and 10,000 mm or less	
		$\frac{\text{Thread length}}{\text{screw shaft outer diameter}} \leqq 40$				$40 < \frac{\text{Thread length}}{\text{screw shaft outer diameter}} < 60$				—	
		Accuracy grade				Accuracy grade				Accuracy grade	
Above	Or less	C0	C1	C2, C3	C5	C0	C1	C2, C3	C5	C2, C3	C5
200	400	±35%	±40%	±45%	±55%	±45%	±45%	±55%	±65%	—	—
400	600	±25%	±30%	±35%	±45%	±38%	±38%	±45%	±50%	—	—
600	1000	±20%	±25%	±30%	±35%	±30%	±30%	±35%	±40%	±40%	±45%
1000	2500	±15%	±20%	±25%	±30%	±25%	±25%	±30%	±35%	±35%	±40%
2500	6300	±10%	±15%	±20%	±25%	±20%	±20%	±25%	±30%	±30%	±35%
6300	10000	—	—	±15%	±20%	—	—	±20%	±25%	±25%	±30%

Example: When a preload of 3,000 N is provided to Ball Screw model BNFN4010-5G0 + 1500LC3 with a thread length of 1,300 mm (shaft diameter: 40 mm; ball center diameter: 41.75 mm; lead: 10 mm), the preload torque of the Ball Screw is calculated in the steps below.

Calculating the Reference Torque

β : Lead angle

$$\tan\beta = \frac{\text{lead}}{\pi \times \text{ball center diameter}} = \frac{10}{\pi \times 41.75} = 0.0762$$

Fa_0 : Applied preload = 3000N

ℓ : Lead = 10mm

$$T_p = 0.05\,(\tan\beta)^{-0.5}\,\frac{Fa_0 \cdot \ell}{2\pi} = 0.05\,(0.0762)^{-0.5}\,\frac{3000 \times 10}{2\pi} = 865\text{N} \cdot \text{mm}$$

Calculating the Torque Fluctuation

$$\frac{\text{thread length}}{\text{screw shaft outer diameter}} = \frac{1300}{40} = 32.5 \leqq 40$$

Thus, with the reference torque in table 12 being between 600 and 1,000 N-mm, effective thread length 4,000 mm or less and accuracy grade C3, the coefficient of torque fluctuation is obtained as ±30%.

As a result, the torque fluctuation is calculated as follows,

$865 \times (1 \pm 0.3) = 606\ \text{N} \cdot \text{mm}$ to $1125\ \text{N} \cdot \text{mm}$

Result

Reference torque: 865 N-mn

Torque fluctuation: 606 N-mm to 1,125 N-mm