Axial Clearance

Axial Clearance of Precision Ball Screws

Table 10 shows the axial clearance of the precision ball screw. If the manufacturing length exceeds the value in Table 11, the resultant clearance may partially be negative (preload applied).
The manufacturing limit lengths of the ball screws compliant with the DIN standard are provided in Table 12.
For the axial clearance of precision Caged Ball ball screws, see **A15-76** to **A15-93**, **A15-112** to **A15-119**, **A15-244** to **A15-255**.

Table 10: Axial Clearance of the Precision Ball Screw

Unit: mm

Clearance symbol	G0	GT	G1	G2	G3
Axial clearance	0 or less	0 to 0.005	0 to 0.01	0 to 0.02	0 to 0.05

Table 11: Maximum Manufacturing Length of Precision Ball Screws by Axial Clearance and Accuracy Grade

Unit: mm

Screw shaft outer diameter	GT clearance				G1 clearance				G2 clearance					
	C0	C1	C2, C3	C5	C0	C1	C2, C3	C5	C0	C1	C2	C3	C5	C7
4, 6	80	80	80	100	80	80	80	100	80	80	80	80	100	120
8	230	250	250	200	230	250	250	250	230	250	250	250	300	300
10	250	250	250	200	250	250	250	250	250	250	250	250	300	300
12, 13	440	500	500	400	440	500	500	500	440	500	630	680	600	500
14	500	500	500	400	500	500	500	500	530	620	700	700	600	500
15	500	500	500	400	500	500	500	500	570	670	700	700	600	500
16	500	500	500	400	500	500	500	500	620	700	700	700	600	500
18	720	800	800	700	720	800	800	700	720	840	1,000	1,000	1,000	1,000
20	800	800	800	700	800	800	800	700	820	950	1,000	1,000	1,000	1,000
25	800	800	800	700	800	800	800	700	1,000	1,000	1,000	1,000	1,000	1,000
28	900	900	900	800	1,100	1,100	1,100	900	1,300	1,400	1,400	1,400	1,200	1,200
30, 32	900	900	900	800	1,100	1,100	1,100	900	1,400	1,400	1,400	1,400	1,200	1,200
36, 40, 45	1,000	1,000	1,000	800	1,300	1,300	1,300	1,000	2,000	2,000	2,000	2,000	1,500	1,500
50, 55, 63, 70	1,200	1,200	1,200	1,000	1,600	1,600	1,600	1,300	2,000	2,500	2,500	2,500	2,000	2,000
80, 100	—	—	—	—	1,800	1,800	1,800	1,500	2,000	4,000	4,000	4,000	3,000	3,000

* When manufacturing a ball screw of accuracy grade C7 with clearance GT or G1, the resultant clearance is partially negative.
G0 clearance is not available for models HBN-V, HBN-K (KA), HBN, and SBKH.
Accuracy grade C7 is not available when manufacturing a miniature ball screw (screw shaft outer diameter ϕ14 mm or less) with a G0 clearance.

Table 12: Manufacturing Limit Lengths of Precision Ball Screws with Axial Clearances (DIN Standard-Compliant Ball Screws)

Unit: mm

Shaft diameter	GT clearance		G1 clearance		G2 clearance		
	C3, Cp3	C5, Cp5, Ct5	C3, Cp3	C5, Cp5, Ct5	C3, Cp3	C5, Cp5, Ct5	C7, Cp7
16	500	400	500	500	700	600	500
20, 25	800	700	800	700	1,000	1,000	1,000
32	900	800	1,100	900	1,400	1,200	1,200
40	1,000	800	1,300	1,000	2,000	1,500	1,500
50, 63	1,200	1,000	1,600	1,300	2,500	2,000	2,000

* When manufacturing a ball screw of accuracy grade C7 (Ct7) with clearance GT or G1, the resultant clearance is partially negative.

Axial Clearance of Rolled Ball Screws

Table 13 shows axial clearance of rolled ball screws.

Table 13: Axial Clearance of Rolled Ball Screws

Unit: mm

Screw shaft outer diameter	Axial clearance (maximum)
6 to 12	0.05
14 to 28	0.1
30 to 32	0.14
36 to 45	0.17
50	0.2

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Preload

A preload is applied in order to eliminate the axial clearance and minimize the displacement under an axial load.
A preload is generally used in applications requiring highly accurate positioning.

Rigidity of the Ball Screw under a Preload

When a preload is applied to a ball screw, the rigidity of the nut is increased.
Fig. 4 shows elastic displacement curves of a ball screw under a preload and without a preload.

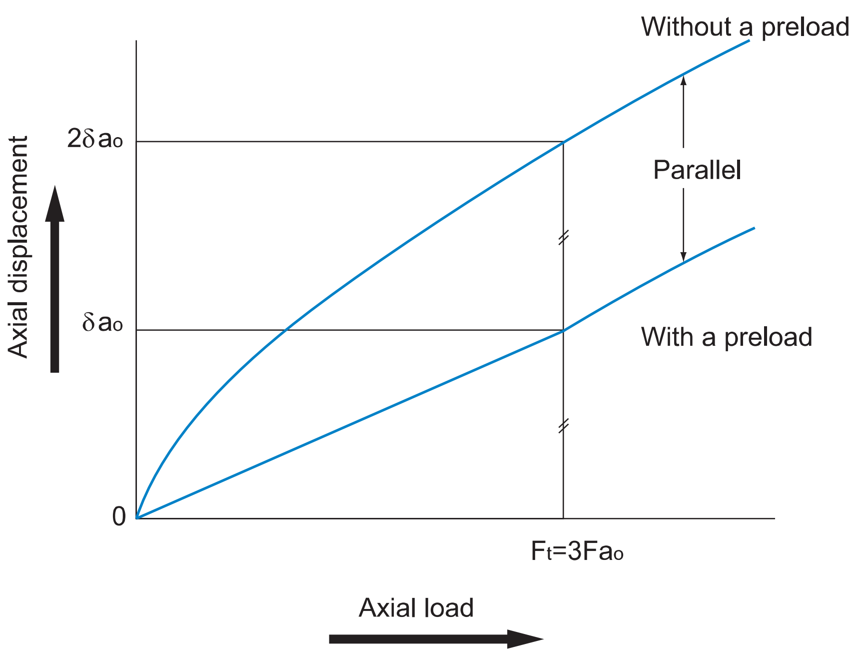

Fig. 4: Elastic Displacement Curve of the Ball Screw

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Fig. 5 shows a single-nut type of the ball screw.

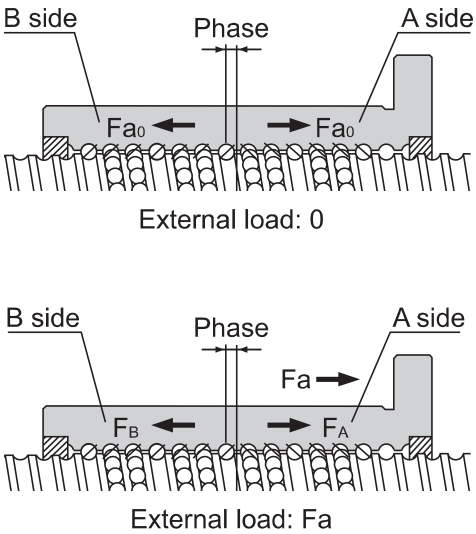

Fig. 5

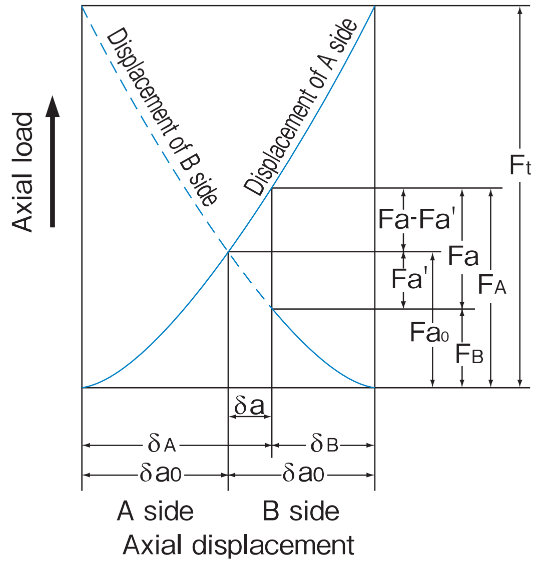

Fig. 6

The A and B sides are provided with preload Fa_0 by changing the groove pitch in the center of the nut to create a phase. Because of the preload, the A and B sides are elastically displaced by δa_0 each. If an axial load (Fa) is applied from outside in this state, the displacement of the A and B sides is calculated as follows:

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

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

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

Therefore, under a preload, the load that the A side receives equals Fa–Fa'. This means that the displacement of the A side is smaller because load Fa', which is applied when the A side receives no preload, is deducted from Fa.
This effect extends to the point where the displacement (δa_0) caused by the preload applied on the B side reaches zero.
To what extent is the 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.

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

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

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

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 that an excessive preload adversely affects the service life and heat generation. The maximum preload should be set at 10% of the basic dynamic load rating (Ca) in the axial direction.

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Preload Torque

The preload torque of the ball screw is controlled in accordance with the JIS standard JIS B 1192 (ISO 3408).

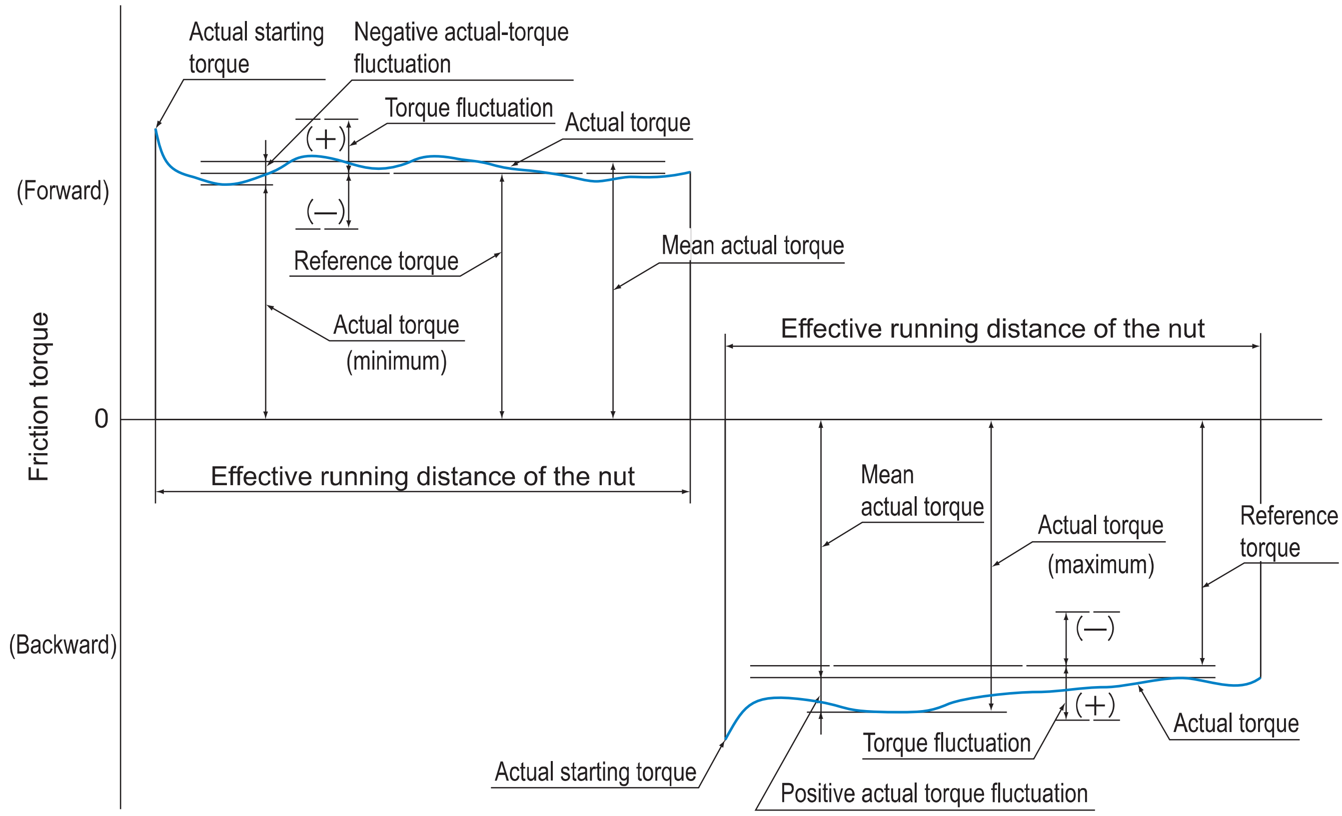

Fig. 7: Preload Torque Terminology

● 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 (4).

$$T_p = 0.05\,(\tan\beta)^{-0.5}\,\frac{Fa_0 \cdot Ph}{2\pi} \quad \cdots\cdots\cdots(4)$$

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

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Example: When a preload of 3,000 N is provided to the Ball Screw Model BIF4010-10G0 + 1500LC3 with a thread length of 1,300 mm (shaft diameter: 40 mm; ball center-to-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

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

Fa_0 : Applied preload = 3,000 N

Ph : Lead = 10 mm

$$T_p = 0.05\,(\tan\beta)^{-0.5}\,\frac{Fa_0 \cdot Ph}{2\pi} = 0.05\,(0.0762)^{-0.5}\,\frac{3{,}000 \times 10}{2\pi} = 865\ \text{N}\cdot\text{mm}$$

■Calculating the Torque Fluctuation

$$\frac{\text{thread length}}{\text{screw shaft outer diameter}} = \frac{1{,}300}{40} = 32.5 \leqq 40$$

Thus, with the reference torque in Table 14 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×(1±0.3) = 606 N·mm to 1,125 N·mm

■Result

Reference torque : 865 N·mm

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

Table 14: Tolerance Range in Torque Fluctuation

Reference torque N·mm		Effective thread length												
		4,000 mm or less										Above 4,000 mm and up to 10,000 mm		
		thread length / screw shaft outer diameter ≦40					40< thread length / screw shaft outer diameter <60					—		
		Accuracy grades					Accuracy grades					Accuracy grades		
Above	Up to	C0	C1	C3	C5	C7	C0	C1	C3	C5	C7	C3	C5	C7
200	400	±30%	±35%	±40%	±50%	—	±40%	±40%	±50%	±60%	—	—	—	—
400	600	±25%	±30%	±35%	±40%	—	±35%	±35%	±40%	±45%	—	—	—	—
600	1,000	±20%	±25%	±30%	±35%	±40%	±30%	±30%	±35%	±40%	±45%	±40%	±45%	±50%
1,000	2,500	±15%	±20%	±25%	±30%	±35%	±25%	±25%	±30%	±35%	±40%	±35%	±40%	±45%
2,500	6,300	±10%	±15%	±20%	±25%	±30%	±20%	±20%	±25%	±30%	±35%	±30%	±35%	±40%
6,300	10,000	—	—	±15%	±20%	±30%	—	—	±20%	±25%	±35%	±25%	±30%	±35%

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