



Ball Screw

THK General Catalog

Ball Screw

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* Please see the separate "B Product Specifications".

Features of the Ball Screw

Driving Torque One Third of the Sliding Screw

With the Ball Screw, balls roll between the screw shaft and the nut to achieve high efficiency. Its required driving torque is only one third of the conventional sliding screw. (See Fig.1 and Fig.2.) As a result, it is capable of not only converting rotational motion to straight motion, but also converting straight motion to rotational motion.

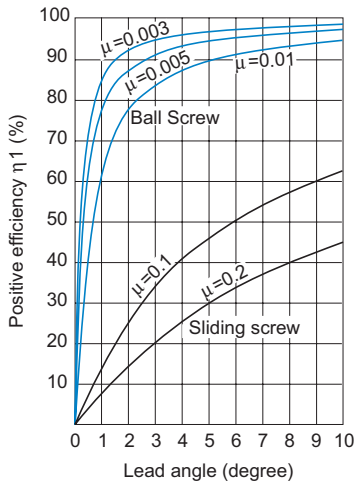


Fig.1 Positive Efficiency (Rotational to Linear)

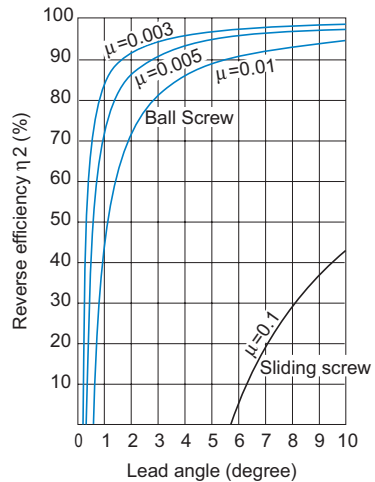


Fig.2 Reverse Efficiency (Linear to Rotational)

[Calculating the Lead Angle]

$$\tan\beta = \frac{Ph}{\pi \cdot d_p} \dots\dots\dots (1)$$

- β : Lead angle (°)
- d_p : Ball center-to-center diameter (mm)
- Ph : Feed screw lead (mm)

[Relationship between Thrust and Torque]

The torque or the thrust generated when thrust or torque is applied is obtained from equations (2) to (4).

● **Driving Torque Required to Gain Thrust**

$$T = \frac{F_a \cdot Ph}{2\pi \cdot \eta_1} \dots\dots\dots(2)$$

T : Driving torque (N-mm)

F_a : Frictional resistance on the guide surface (N)

F_a=μ × mg

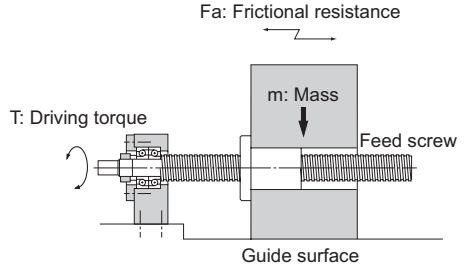
μ : Frictional coefficient of the guide surface

g : Gravitational acceleration (9.8 m/s²)

m : Mass of the transferred object (kg)

Ph : Feed screw lead (mm)

η₁ : Positive efficiency of feed screw
(see Fig.1 on A-682)



● **Thrust Generated When Torque is Applied**

$$F_a = \frac{2\pi \cdot \eta_1 \cdot T}{Ph} \dots\dots\dots(3)$$

F_a : Thrust generated (N)

T : Driving torque (N-mm)

Ph : Feed screw lead (mm)

η₁ : Positive efficiency of feed screw
(see Fig.1 on A-682)

● **Torque Generated When Thrust is Applied**

$$T = \frac{Ph \cdot \eta_2 \cdot F_a}{2\pi} \dots\dots\dots(4)$$

T : Torque generated (N-m)

F_a : Thrust generated (N)

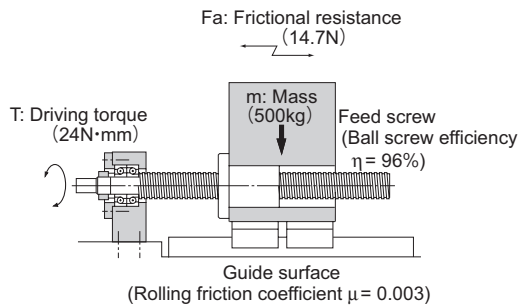
Ph : Feed screw lead (mm)

η₂ : Reverse efficiency of feed screw
(see Fig.2 on A-682)

[Examples of Calculating Driving Torque]

When moving an object with a mass of 500 kg using a screw with an effective diameter of 33 mm and a lead length of 10 mm (lead angle: 5°30'), the required torque is obtained as follows.

Rolling guide ($\mu = 0.003$)
Ball Screw (from $\mu = 0.003$, $\eta = 0.96$)



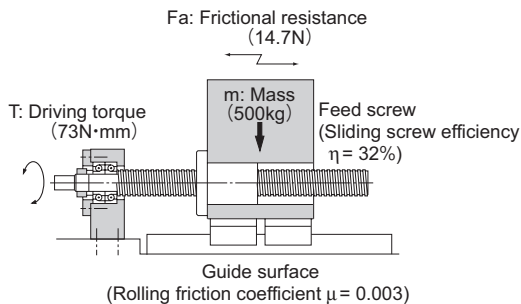
Frictional resistance on the guide surface

$$F_a = 0.003 \times 500 \times 9.8 = 14.7 \text{ N}$$

Driving torque

$$T = \frac{14.7 \times 10}{2\pi \times 0.96} = 24 \text{ N} \cdot \text{mm}$$

Rolling guide ($\mu = 0.003$)
Ball Screw (from $\mu = 0.2$, $\eta = 0.32$)



Frictional resistance on the guide surface

$$F_a = 0.003 \times 500 \times 9.8 = 14.7 \text{ N}$$

Driving torque

$$T = \frac{14.7 \times 10}{2\pi \times 0.32} = 73 \text{ N} \cdot \text{mm}$$

Ensuring High Accuracy

The Ball Screw is ground with the highest-level facilities and equipment at a strictly temperature-controlled factory. Its accuracy is assured under a thorough quality control system that covers assembly to inspection.



Automatic lead-measuring machine using laser

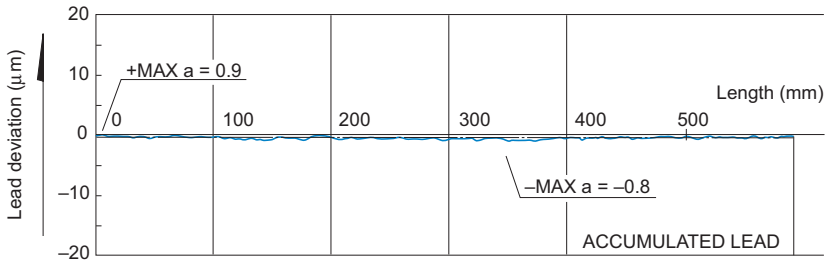


Fig.3 Lead Accuracy Measurement

[Conditions]

Model No.: BIF3205-10RRG0+903LC2

Table1 Lead Accuracy Measurement Unit: mm

Item	Standard value	Actual measurement
Directional target point	0	—
Representative travel distance error	± 0.011	-0.0012
Fluctuation	0.008	0.0017

Capable of Micro Feeding

The Ball Screw requires a minimal starting torque due to its rolling motion, and does not cause a slip, which is inevitable with a sliding motion. Therefore, it is capable of an accurate micro feeding. Fig.4 shows a travel distance of the Ball Screw in one-pulse, 0.1- μm feeding. (LM Guide is used for the guide surface.)

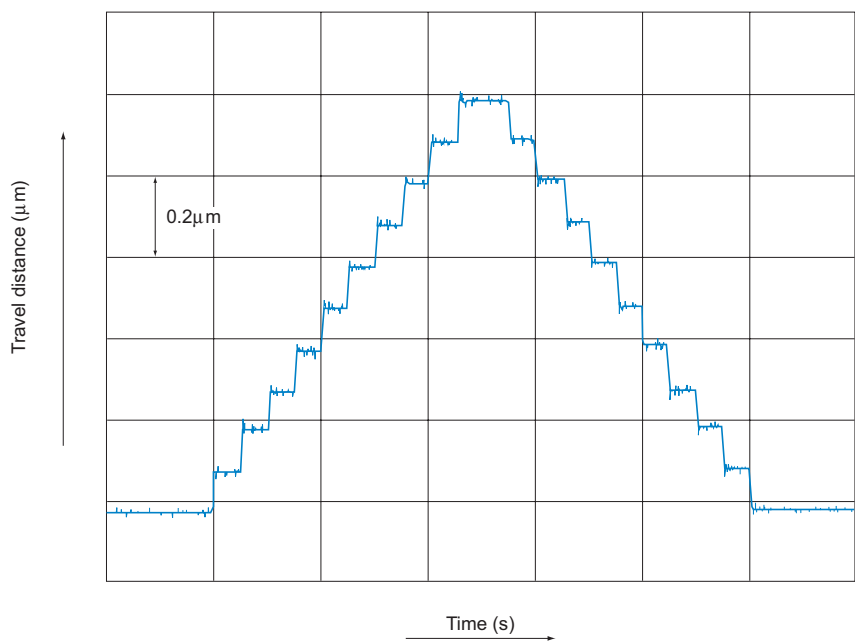


Fig.4 Data on Travel in 0.1- μm Feeding

High Rigidity without Backlash

Since the Ball Screw is capable of receiving a preload, the axial clearance can be reduced to below zero and the high rigidity is achieved because of the preload. In Fig.5, when an axial load is applied in the positive (+) direction, the table is displaced in the same (+) direction. When an axial load is provided in the reverse (-) direction, the table is displaced in the same (-) direction. Fig.6 shows the relationship between the axial load and the axial displacement. As indicated in Fig.6, as the direction of the axial load changes, the axial clearance occurs as a displacement. Additionally, when the Ball Screw is provided with a preload, it gains a higher rigidity and a smaller axial displacement than a zero clearance in the axial direction.

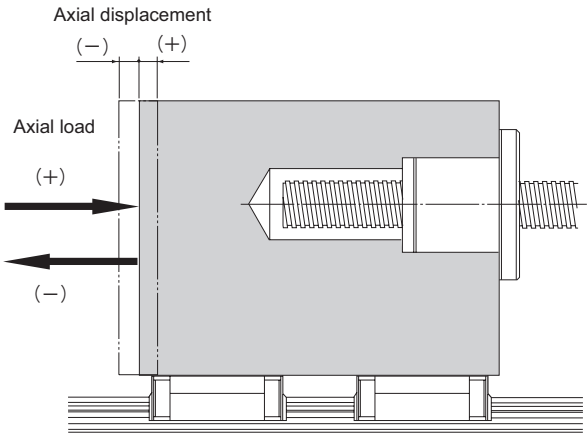


Fig.5

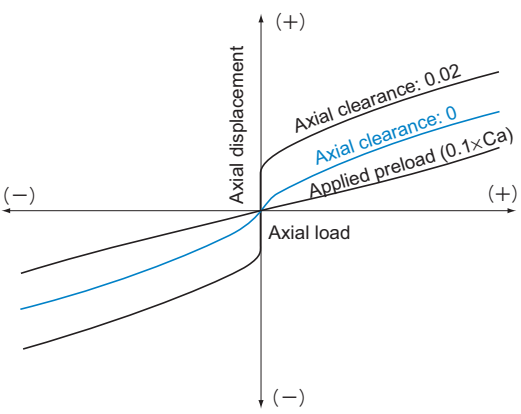


Fig.6 Axial Displacement in Relation to Axial Load

Capable of Fast Feed

Since the Ball Screw is highly efficient and generates little heat, it is capable of a fast feed.

[Example of High Speed]

Fig.7 shows a speed diagram for a large lead rolled Ball Screw operating at 2 m/s.

[Conditions]

Item	Description
Sample	Large Lead Rolled Ball Screw WTF3060 (Shaft diameter: 30mm; lead: 60mm)
Maximum speed	2m/s (Ball Screw rotational speed: 2,000 min ⁻¹)
Guide surface	LM Guide model SR25W

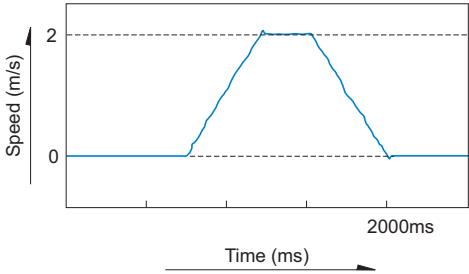


Fig.7 Velocity diagram

[Example of Heat Generation]

Fig.8 shows data on heat generation from the screw shaft when a Ball Screw is used in an operating pattern indicated in Fig.9

[Conditions]

Item	Description
Sample	Double-nut precision Ball Screw BNFN4010-5 (Shaft diameter: 40 mm; lead: 10 mm; applied preload: 2,700 N)
Maximum speed	0.217m/s (13m/min) (Ball Screw rotational speed: 1300 min ⁻¹)
Low speed	0.0042m/s (0.25m/min) (Ball Screw rotational speed: 25 min ⁻¹)
Guide surface	LM Guide model HSR35CA
Lubricant	Lithium-based grease (No. 2)

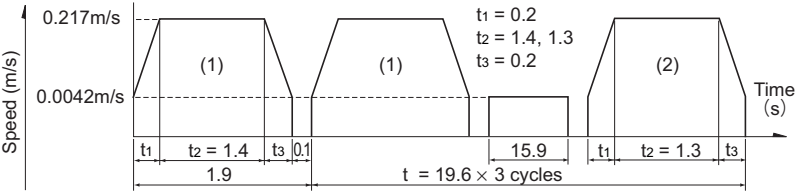


Fig.8 Operating Pattern

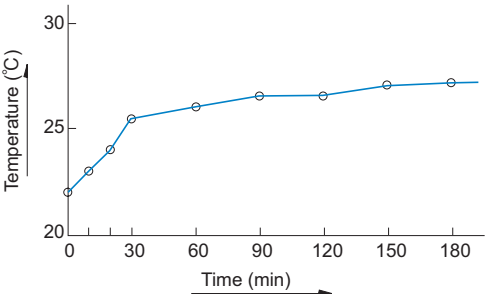
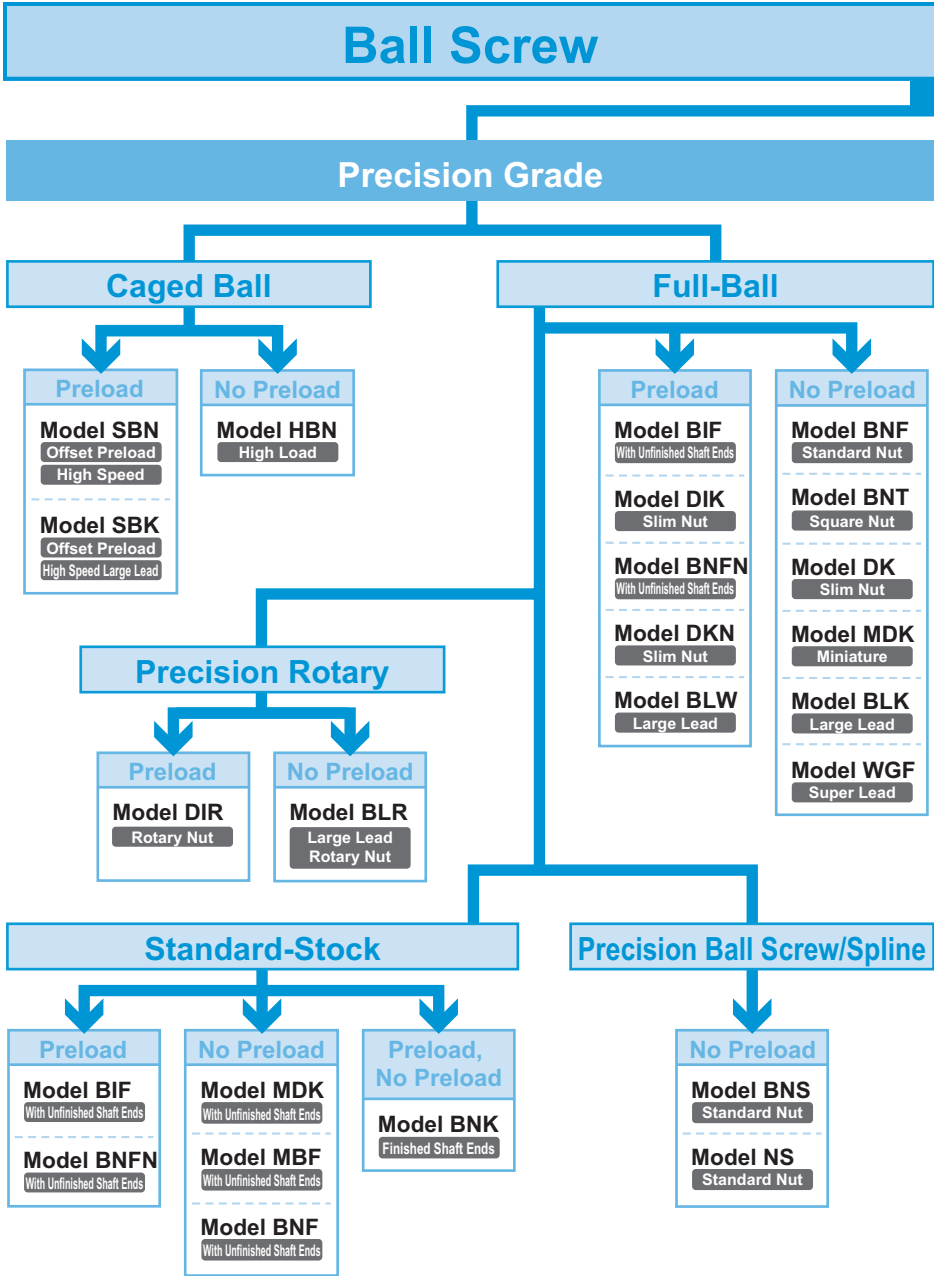
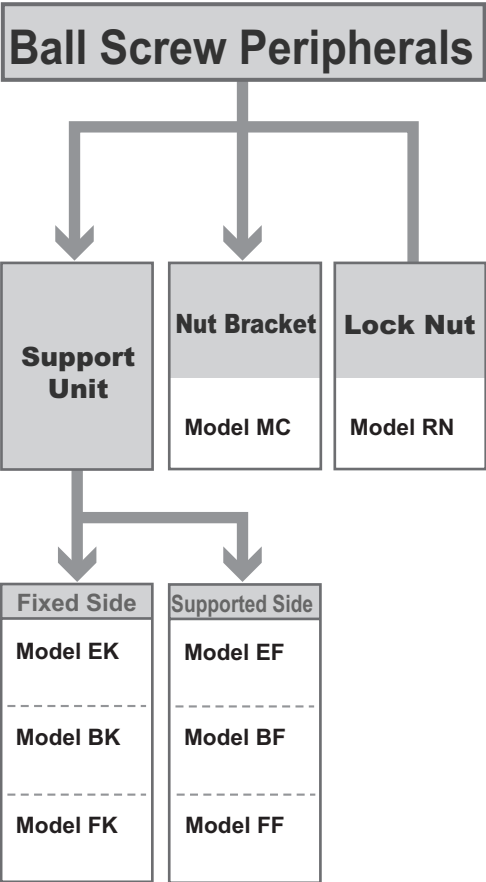
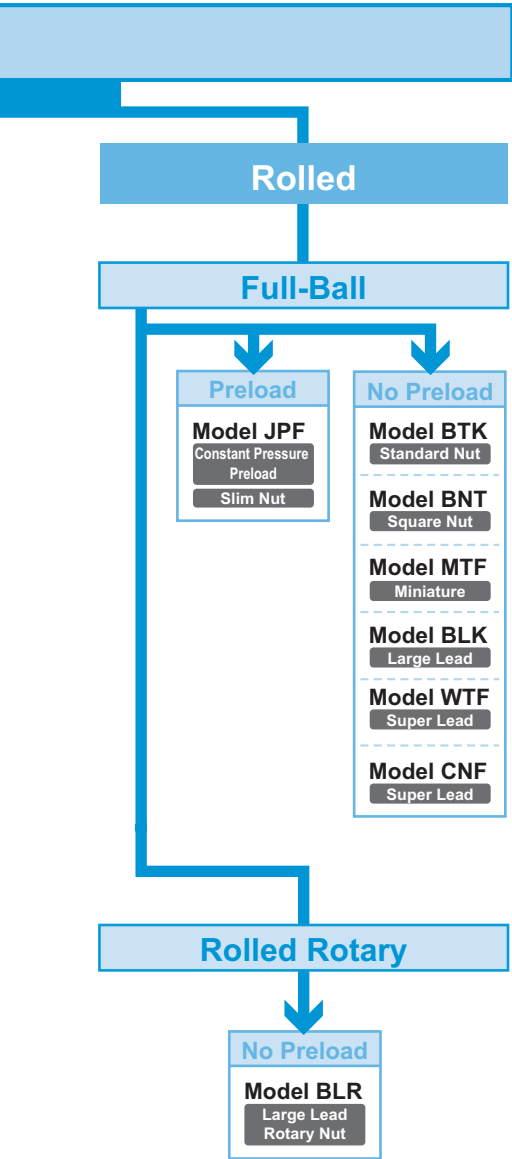


Fig.9 Ball Screw Heat Generation Data

Types of Ball Screws



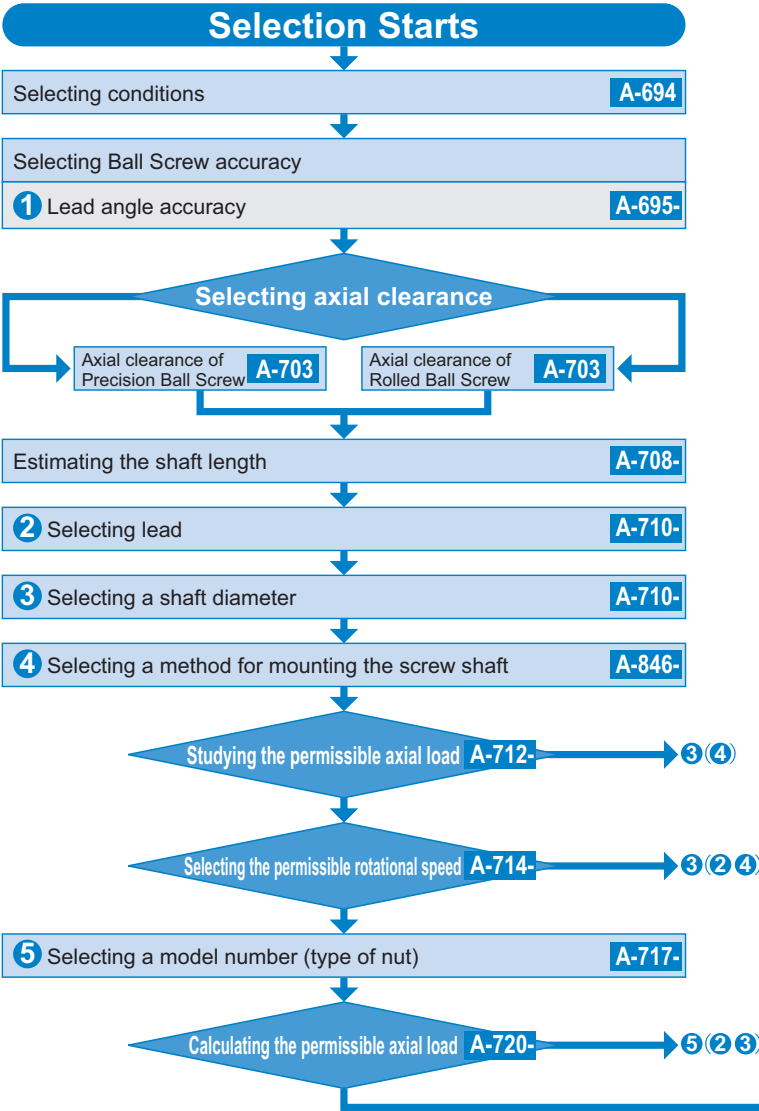


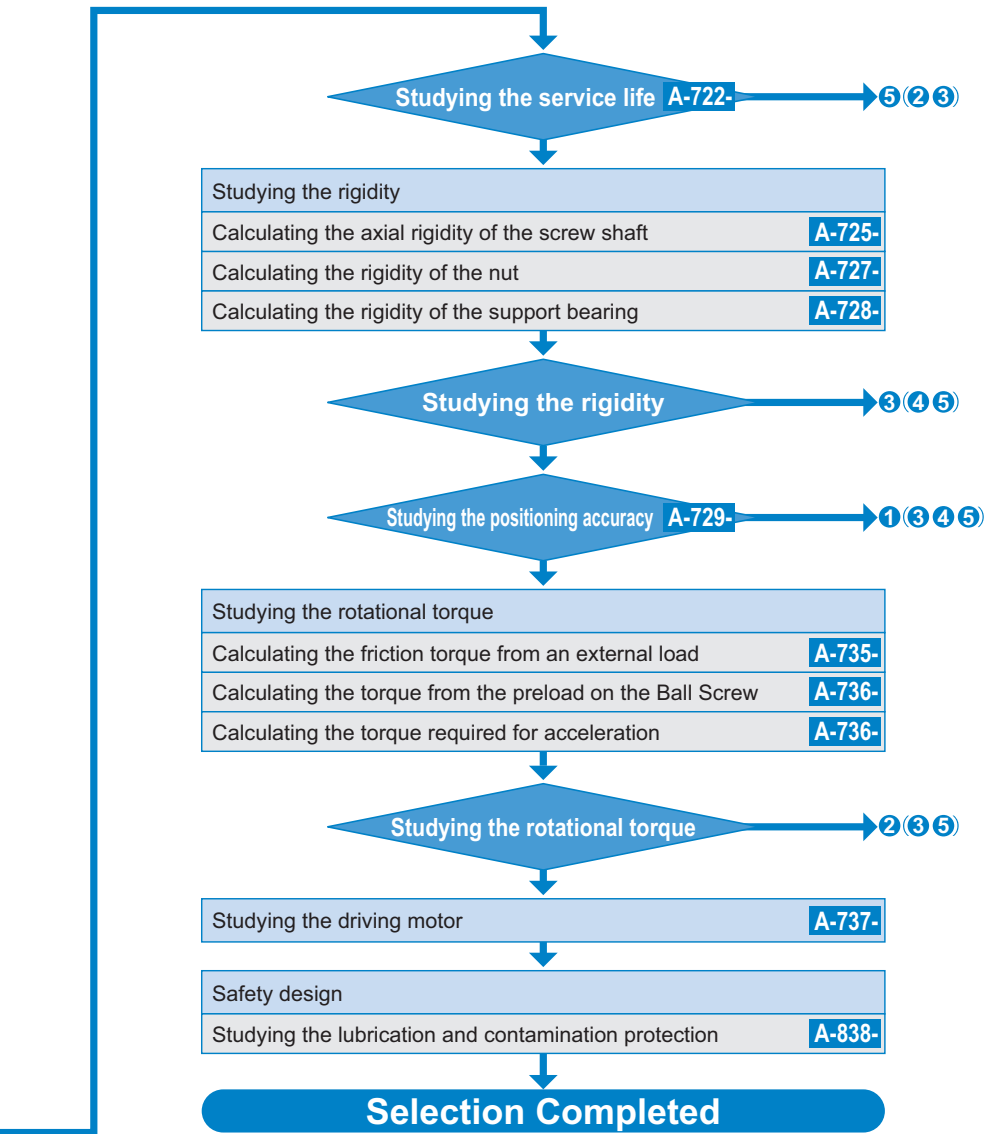
Ball Screw

Flowchart for Selecting a Ball Screw

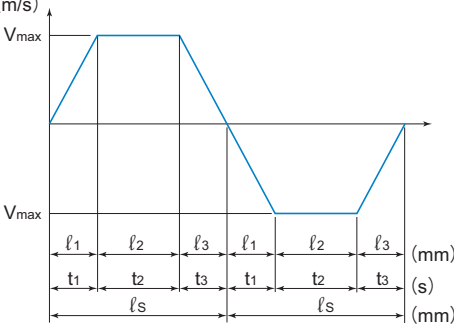
[Ball Screw Selection Procedure]

When selecting a Ball Screw, it is necessary to make a selection while considering various parameters. The following is a flowchart for selecting a Ball Screw.





[Conditions of the Ball Screw]

The following conditions are required when selecting a Ball Screw.		
Transfer orientation	(horizontal, vertical, etc.)	
Transferred mass	m (kg)	
Table guide method	(sliding, rolling)	
Frictional coefficient of the guide surface	μ (-)	
Guide surface resistance	f (N)	
External load in the axial direction	F (N)	
Desired service life time	L_h (h)	
Stroke length	l_s (mm)	
Operating speed	V_{max} (m/s)	
Acceleration time	t_1 (s)	
Even speed time	t_2 (s)	
Deceleration time	t_3 (s)	
Acceleration	$\alpha = \frac{V_{max}}{t_1}$	(m/s ²)
Acceleration distance	$l_1 = V_{max} \times t_1 \times 1000/2$	(mm)
Even speed distance	$l_2 = V_{max} \times t_2 \times 1000$	(mm)
Deceleration distance	$l_3 = V_{max} \times t_3 \times 1000/2$	(mm)
Number of reciprocations per minute	n (min ⁻¹)	
Positioning accuracy	(mm)	
Positioning accuracy repeatability	(mm)	
Backlash	(mm)	
Minimum feed amount	s (mm/pulse)	
Driving motor (AC servomotor, stepping motor, etc.)		
The rated rotational speed of the motor	N_{MO} (min ⁻¹)	
Inertial moment of the motor	J_M (kg · m ²)	
Motor resolution	(pulse/rev)	
Reduction ratio	A (-)	

Accuracy of the Ball Screw

Lead Angle Accuracy

The accuracy of the Ball Screw in the lead angle is controlled in accordance with the JIS standards (JIS B 1192 - 1997).

Accuracy grades C0 to C5 are defined in the linearity and the directional property, and C7 to C10 in the travel distance error in relation to 300 mm.

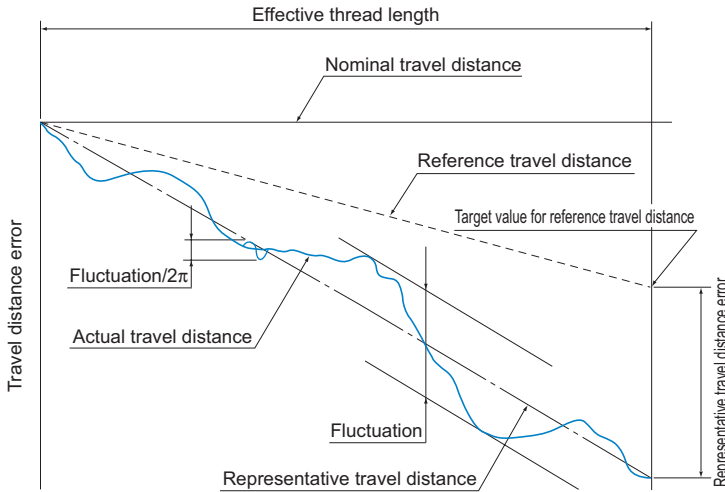


Fig.1 Terms on Lead Angle Accuracy

[Actual Travel Distance]

An error in the travel distance measured with an actual Ball Screw.

[Reference Travel Distance]

Generally, it is the same as nominal travel distance, but can be an intentionally corrected value of the nominal travel distance according to the intended use.

[Target Value for Reference Travel Distance]

You may provide some tension in order to prevent the screw shaft from runout, or set the reference travel distance in "negative" or "positive" value in advance given the possible expansion/contraction from external load or temperature. In such cases, indicate a target value for the reference travel distance.

[Representative Travel Distance]

It is a straight line representing the tendency in the actual travel distance, and obtained with the least squares method from the curve that indicates the actual travel distance.

[Representative Travel Distance Error (in $\pm$)]

Difference between the representative travel distance and the reference travel distance.

[Fluctuation]

The maximum width of the actual travel distance between two straight lines drawn in parallel with the representative travel distance.

[Fluctuation/300]

Indicates a fluctuation against a given thread length of 300 mm.

[Fluctuation/2 π]

A fluctuation in one revolution of the screw shaft.

Table1 Lead Angle Accuracy (Permissible Value)

Unit: μm

		Precision Ball Screw												
												Rolled Ball Screw		
Accuracy grades		C0		C1		C2		C3		C5		C7	C8	C10
Effective thread length		Representative travel distance error	Fluctuation	Representative travel distance error	Fluctuation	Representative travel distance error	Fluctuation	Representative travel distance error	Fluctuation	Representative travel distance error	Fluctuation	Travel distance error	Travel distance error	Travel distance error
Above	Or less													
—	100	3	3	3.5	5	5	7	8	8	18	18	$\pm 50/$ 300mm	$\pm 100/$ 300mm	$\pm 210/$ 300mm
100	200	3.5	3	4.5	5	7	7	10	8	20	18			
200	315	4	3.5	6	5	8	7	12	8	23	20			
315	400	5	3.5	7	5	9	7	13	10	25	20			
400	500	6	4	8	5	10	7	15	10	27	20			
500	630	6	4	9	6	11	8	16	12	30	23			
630	800	7	5	10	7	13	9	18	13	35	25			
800	1000	8	6	11	8	15	10	21	15	40	27			
1000	1250	9	6	13	9	18	11	24	16	46	30			
1250	1600	11	7	15	10	21	13	29	18	54	35			
1600	2000	—	—	18	11	25	15	35	21	65	40			
2000	2500	—	—	22	13	30	18	41	24	77	46			
2500	3150	—	—	26	15	36	21	50	29	93	54			
3150	4000	—	—	30	18	44	25	60	35	115	65			
4000	5000	—	—	—	—	52	30	72	41	140	77			
5000	6300	—	—	—	—	65	36	90	50	170	93			
6300	8000	—	—	—	—	—	—	110	60	210	115			
8000	10000	—	—	—	—	—	—	—	—	260	140			

Note) Unit of effective thread length: mm

Table2 Fluctuation in Thread Length of 300 mm and in One Revolution (permissible value)

Unit: μm

Accuracy grades	C0	C1	C2	C3	C5	C7	C8	C10
Fluctuation/300	3.5	5	7	8	18	—	—	—
Fluctuation/ 2π	3	4	5	6	8	—	—	—

Table3 Types and Grades

Type	Series symbol	Grade	Remarks
For positioning	Cp	1, 3, 5	ISO compliant
For conveyance	Ct	1, 3, 5, 7, 10	

Note) Accuracy grades apply also to the Cp series and Ct series. Contact THK for details.

Example: When the lead of a Ball Screw manufactured is measured with a target value for the reference travel distance of $-9\text{ }\mu\text{m}/500\text{ mm}$, the following data are obtained.

Table4 Measurement Data on Travel Distance Error

Unit: mm

Command position (A)	0	50	100	150
Travel distance (B)	0	49.998	100.001	149.996
Travel distance error (A-B)	0	-0.002	+0.001	-0.004

Command position (A)	200	250	300	350
Travel distance (B)	199.995	249.993	299.989	349.885
Travel distance error (A-B)	-0.005	-0.007	-0.011	-0.015

Command position (A)	400	450	500
Travel distance (B)	399.983	449.981	499.984
Travel distance error (A-B)	-0.017	-0.019	-0.016

The measurement data are expressed in a graph as shown in Fig.2.

The positioning error (A-B) is indicated as the actual travel distance while the straight line representing the tendency of the (A-B) graph refers to the representative travel distance.

The difference between the reference travel distance and the representative travel distance appears as the representative travel distance error.

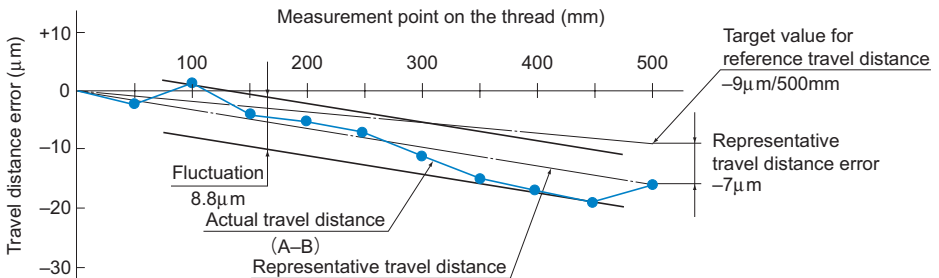


Fig.2 Measurement Data on Travel Distance Error

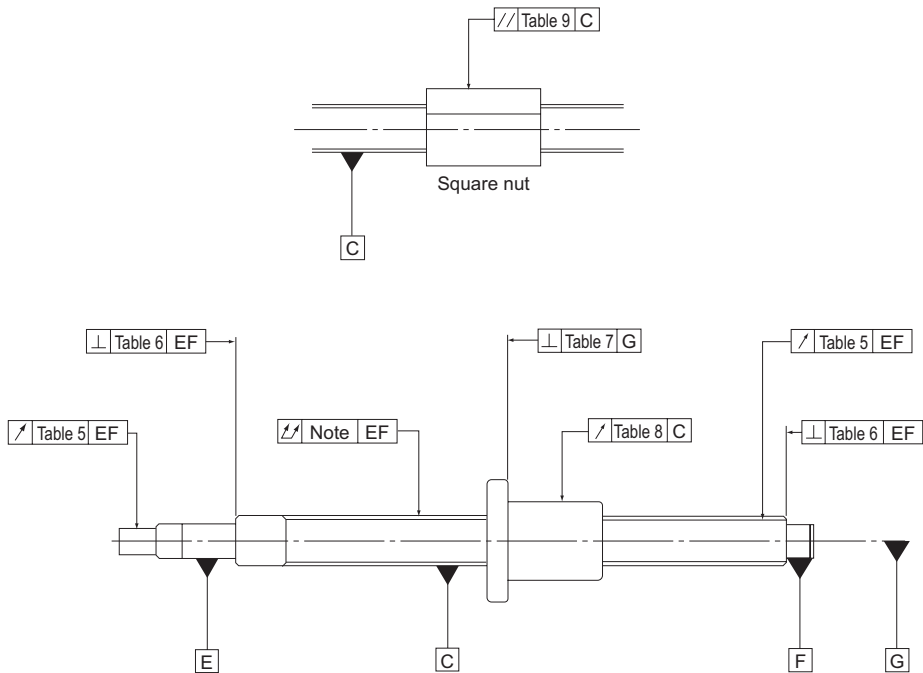
[Measurements]

Representative travel distance error: $-7\mu\text{m}$

Fluctuation: $8.8\mu\text{m}$

Accuracy of the Mounting Surface

The accuracy of the Ball Screw mounting surface complies with the JIS standard (JIS B 1192-1997).



Note) For the overall radial runout of the screw shaft axis, refer to JIS B 1192-1997.

Fig.3 Accuracy of the Mounting Surface of the Ball Screw

[Accuracy Standards for the Mounting Surface]

Table5 to Table9 show accuracy standards for the mounting surfaces of the precision Ball Screw.

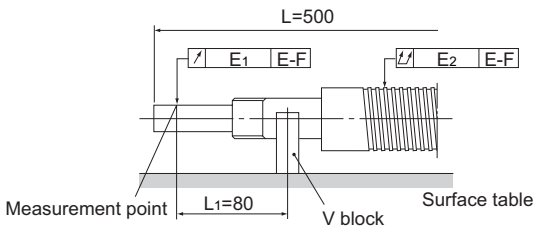
Table5 Radial Runout of the Circumference of the Thread Root
in Relation to the Supporting Portion Axis of the Screw Shaft

Unit: μm

Screw shaft outer diameter (mm)		Runout (maximum)					
Above	Or less	C0	C1	C2	C3	C5	C7
—	8	3	5	7	8	10	14
8	12	4	5	7	8	11	14
12	20	4	6	8	9	12	14
20	32	5	7	9	10	13	20
32	50	6	8	10	12	15	20
50	80	7	9	11	13	17	20
80	100	—	10	12	15	20	30

Note) The measurements on these items include the effect of the runout of the screw shaft diameter. Therefore, it is necessary to obtain the correction value from the overall runout of the screw shaft axis, using the ratio of the distance between the fulcrum and measurement point to the overall screw shaft length, and add the obtained value to the table above.

Example: model No. DIK2005-6RRGO+500LC5



$$E_1 = e + \Delta e$$

e : Standard value in Table5 (0.012)

Δe : Correction value

$$\Delta e = \frac{L_1}{L} \times E_2$$

$$= \frac{80}{500} \times 0.06$$

$$= 0.01$$

E_2 : Overall radial runout of the screw shaft axis (0.06)

$$E_1 = 0.012 + 0.01$$

$$= 0.022$$

Table6 Perpendicularity of the Supporting Portion End of the Screw Shaft to the Supporting Portion Axis

Unit: μm

Screw shaft outer diameter (mm)		Perpendicularity (maximum)					
Above	Or less	C0	C1	C2	C3	C5	C7
—	8	2	3	3	4	5	7
8	12	2	3	3	4	5	7
12	20	2	3	3	4	5	7
20	32	2	3	3	4	5	7
32	50	2	3	3	4	5	8
50	80	3	4	4	5	7	10
80	100	—	4	5	6	8	11

Table7 Perpendicularity of the Flange Mounting Surface of the Screw Shaft to the Screw Shaft Axis

Unit: μm

Nut diameter (mm)		Perpendicularity (maximum)					
Above	Or less	C0	C1	C2	C3	C5	C7
—	20	5	6	7	8	10	14
20	32	5	6	7	8	10	14
32	50	6	7	8	8	11	18
50	80	7	8	9	10	13	18
80	125	7	9	10	12	15	20
125	160	8	10	11	13	17	20
160	200	—	11	12	14	18	25

Table8 Radial Runout of the Nut Circumference in Relation to the Screw Shaft Axis

Unit: μm

Nut diameter (mm)		Runout (maximum)					
Above	Or less	C0	C1	C2	C3	C5	C7
—	20	5	6	7	9	12	20
20	32	6	7	8	10	12	20
32	50	7	8	10	12	15	30
50	80	8	10	12	15	19	30
80	125	9	12	16	20	27	40
125	160	10	13	17	22	30	40
160	200	—	16	20	25	34	50

Table9 Parallelism of the Nut Circumference (Flat Mounting Surface) to the Screw Shaft Axis

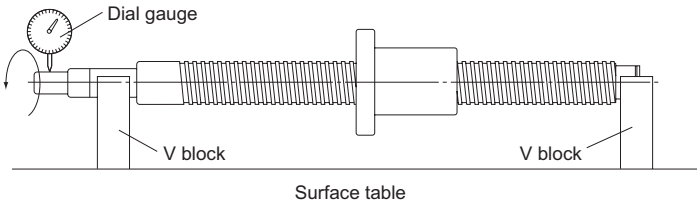
Unit: μm

Mounting reference length (mm)		Parallelism (maximum)					
Above	Or less	C0	C1	C2	C3	C5	C7
—	50	5	6	7	8	10	17
50	100	7	8	9	10	13	17
100	200	—	10	11	13	17	30

[Method for Measuring Accuracy of the Mounting Surface]

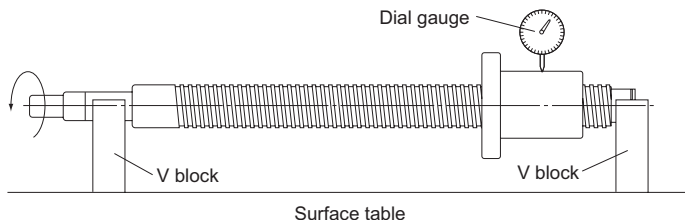
● Radial Runout of the Circumference of the Part Mounting Section in Relation to the Supporting Portion Axis of the Screw Shaft (see Table5 on A-699)

Support the supporting portion of the screw shaft with V blocks. Place a probe on the circumference of the part mounting section, and read the largest difference on the dial gauge as a measurement when turning the screw shaft by one revolution.



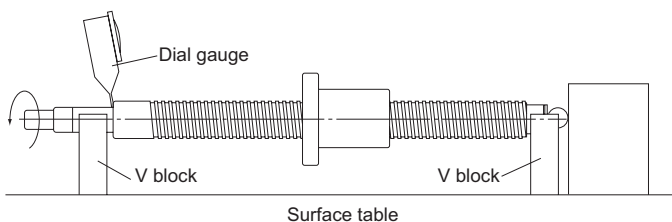
● **Radial Runout of the Circumference of the Thread Root in Relation to the Supporting Portion Axis of the Screw Shaft (see Table5 on A-699)**

Support the supporting portion of the screw shaft with V blocks. Place a probe on the circumference of the nut, and read the largest difference on the dial gauge as a measurement when turning the screw shaft by one revolution without turning the nut.



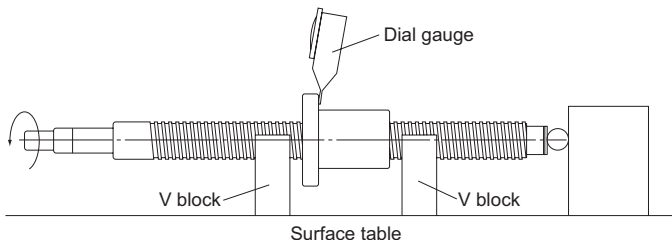
● **Perpendicularity of the Supporting Portion End of the Screw Shaft to the Supporting Portion Axis (see Table6 on A-700)**

Support the supporting portion of the screw shaft with V blocks. Place a probe on the screw shaft's supporting portion end, and read the largest difference on the dial gauge as a measurement when turning the screw shaft by one revolution.



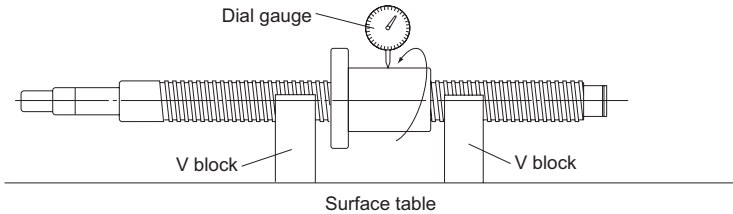
● **Perpendicularity of the Flange Mounting Surface of the Screw Shaft to the Screw Shaft Axis (see Table7 on A-700)**

Support the thread of the screw shaft with V blocks near the nut. Place a probe on the flange end, and read the largest difference on the dial gauge as a measurement when simultaneously turning the screw shaft and the nut by one revolution.



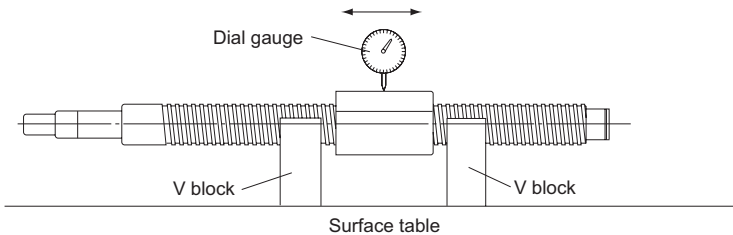
● **Radial Runout of the Nut Circumference in Relation to the Screw Shaft Axis (see Table8 on A-700)**

Support the thread of the screw shaft with V blocks near the nut. Place a probe on the circumference of the nut, and read the largest difference on the dial gauge as a measurement when turning the nut by one revolution without turning the screw shaft.



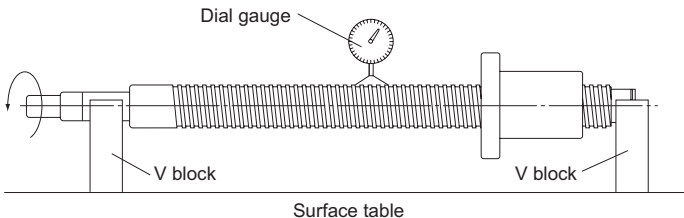
● **Parallelism of the Nut Circumference (Flat Mounting Surface) to the Screw Shaft Axis (see Table9 on A-700)**

Support the thread of the screw shaft with V blocks near the nut. Place a probe on the circumference of the nut (flat mounting surface), and read the largest difference on the dial gauge as a measurement when moving the dial gauge in parallel with the screw shaft.



● **Overall Radial Runout of the Screw Shaft Axis**

Support the supporting portion of the screw shaft with V blocks. Place a probe on the circumference of the screw shaft, and read the largest difference on the dial gauge at several points in the axial directions as a measurement when turning the screw shaft by one revolution.



Note) For the overall radial runout of the screw shaft axis, refer to JIS B 1192-1997.

Axial Clearance

[Axial Clearance of the Precision Ball Screw]

Table10 shows the axial clearance of the precision Screw Ball. If the manufacturing length exceeds the value in Table11, 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 Table12.

Table10 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

Table11 Maximum Length of the Precision Ball Screw in Axial Clearance

Unit: mm

Screw shaft outer diameter	Overall thread length						
	Clearance GT		Clearance G1		Clearance G2		
	C0 to C3	C5	C0 to C3	C5	C0 to C3	C5	C7
4 to 6	80	100	80	100	80	100	120
8 to 10	250	200	250	250	250	300	300
12 to 16	500	400	500	500	700	600	500
18 to 25	800	700	800	700	1000	1000	1000
28 to 32	900	800	1100	900	1400	1200	1200
36 to 45	1000	800	1300	1000	2000	1500	1500
50 to 70	1200	1000	1600	1300	2500	2000	2000
80 to 100	—	—	1800	1500	4000	3000	3000

* When manufacturing the Ball Screw of precision-grade accuracy C7 with clearance GT or G1, the resultant clearance is partially negative.

Table12 Manufacturing limit lengths of precision Ball Screws with axial clearances (DIN standard compliant Ball Screws)

Unit: mm

Shaft diameter	Clearance GT		Clearance G1		Clearance G2		
	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	1000	1000	1000
32	900	800	1100	900	1400	1200	1200
40	1000	800	1300	1000	2000	1500	1500
50, 63	1200	1000	1600	1300	2500	2000	2000

* When manufacturing the Ball Screw of precision-grade accuracy C7 (Ct7) with clearance GT or G1, the resultant clearance is partially negative.

[Axial Clearance of the Rolled Ball Screw]

Table13 shows axial clearance of the rolled Ball Screw.

Table13 Axial Clearance of the Rolled Ball Screw

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

Preload

A preload is provided in order to eliminate the axial clearance and minimize the displacement under an axial load.

When performing a highly accurate positioning, a preload is generally provided.

[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 curves of the Ball Screw under a preload and without a preload.

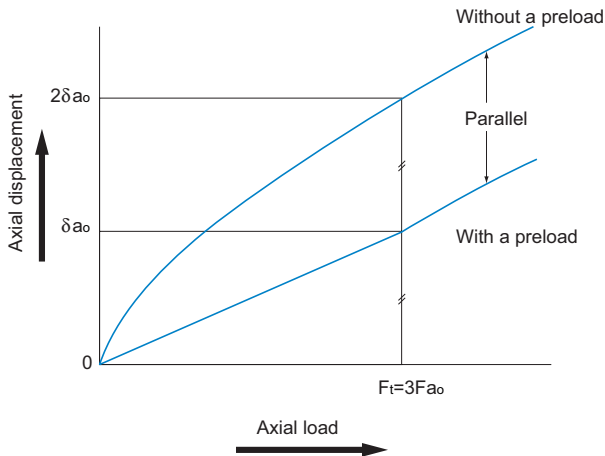


Fig.4 Elastic Displacement Curve of the Ball Screw

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

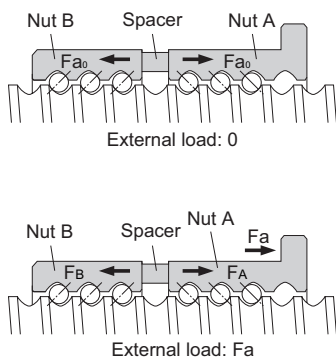


Fig.5

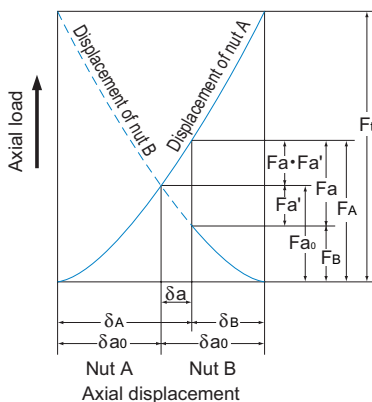


Fig.6

Nuts A and B are provided with preload F_{a0} from the spacer. Because of the preload, nuts A and B are elastically displaced by δa_0 each. If an axial load (F_a) 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:

$$F_A = F_{a0} + (F_a - F_{a'}) \quad F_B = F_{a0} - F_{a'}$$

Therefore, under a preload, the load that nut A receives equals to $F_a - F_{a'}$. This means that since load $F_{a'}$, which is applied when nut A receives no preload, is deducted from F_a , 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 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 $\delta a \propto F_a^{2/3}$. From Fig.6, the following equations are established.

$$\delta a_0 = K F_{a0}^{2/3} \quad (K : \text{constant})$$

$$2\delta a_0 = K F_t^{2/3}$$

$$\left(\frac{F_t}{F_{a0}} \right)^{2/3} = 2 \quad F_t = 2^{3/2} \times F_{a0} = 2.8 F_{a0} \approx 3 F_{a0}$$

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 (C_a) at a maximum.

[Preload Torque]

The preload torque of the Ball Screw in lead is controlled in accordance with the JIS standard (JIS B 1192-1997).

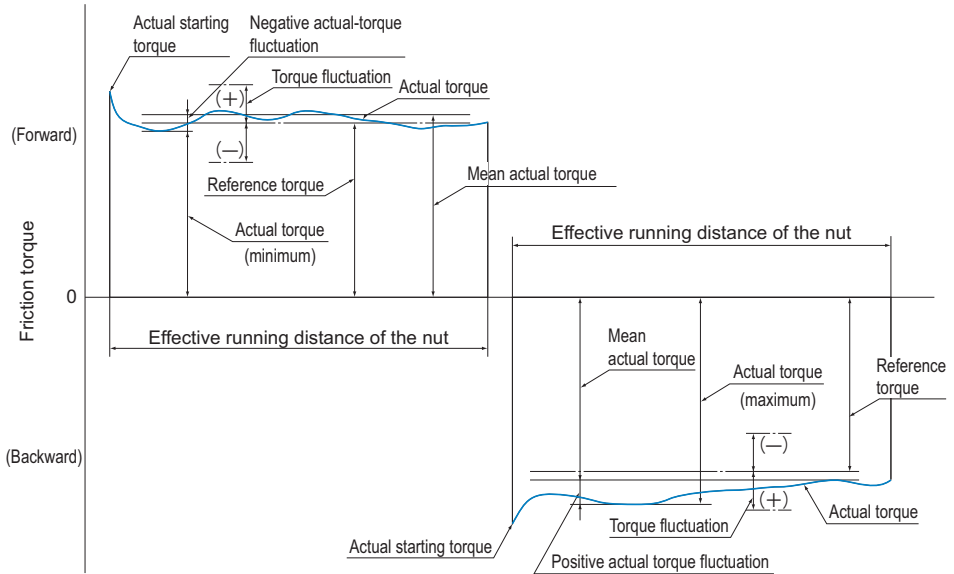


Fig.7 Terms on Preload Torque

● 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).

$$T_p = 0.05 (\tan \beta)^{-0.5} \frac{F_{a0} \cdot Ph}{2\pi} \dots\dots\dots (5)$$

T_p	: Reference torque	(N·mm)
β	: Lead angle	
F_{a0}	: Applied preload	(N)
Ph	: Lead	(mm)

Example: When a preload of 3,000 N is provided to the Ball Screw model BNFN4010-5G0 + 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

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

F_{a0} : Applied preload=3000N

P_h : Lead = 10mm

$$T_p = 0.05 (\tan\beta)^{-0.5} \frac{F_{a0} \cdot P_h}{2\pi} = 0.05 (0.0762)^{-0.5} \frac{3000 \times 10}{2\pi} = 865 \text{ N} \cdot \text{mm}$$

■Calculating the Torque Fluctuation

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

Thus, with the reference torque in Table14 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 $\pm 30\%$.

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·mm

Torque fluctuation : 606 N·mm to 1125 N·mm

Table14 Tolerance Range in Torque Fluctuation

Reference torque N•mm		Effective thread length									
		4000mm or less								Above 4,000 mm and 10,000 mm or less	
		$\frac{\text{thread length}}{\text{screw shaft outer diameter}} \leq 40$				$40 < \frac{\text{thread length}}{\text{screw shaft outer diameter}} < 60$				—	
		Accuracy grades				Accuracy grades				Accuracy grades	
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%

Selecting a Screw Shaft

Maximum Length of the Screw Shaft

Table15 shows the manufacturing limit lengths of precision Ball Screws by accuracy grades, Table16 shows the manufacturing limit lengths of precision Ball Screws compliant with DIN standard by accuracy grades, and Table17 shows the manufacturing limit lengths of rolled Ball Screws by accuracy grades.

If the shaft dimensions exceed the manufacturing limit in Table15,Table16 or Table17, contact THK.

Table15 Maximum Length of the Precision Ball Screw by Accuracy Grade Unit: mm

Screw shaft outer diameter	Overall screw shaft length					
	C0	C1	C2	C3	C5	C7
4	90	110	120	120	120	120
6	150	170	210	210	210	210
8	230	270	340	340	340	340
10	350	400	500	500	500	500
12	440	500	630	680	680	680
13	440	500	630	680	680	680
14	530	620	770	870	890	890
15	570	670	830	950	980	1100
16	620	730	900	1050	1100	1400
18	720	840	1050	1220	1350	1600
20	820	950	1200	1400	1600	1800
25	1100	1400	1600	1800	2000	2400
28	1300	1600	1900	2100	2350	2700
30	1450	1700	2050	2300	2570	2950
32	1600	1800	2200	2500	2800	3200
36	2000	2100	2550	2950	3250	3650
40		2400	2900	3400	3700	4300
45		2750	3350	3950	4350	5050
50		3100	3800	4500	5000	5800
55		3450	4150	5300	6050	6500
63		4000	5200	5800	6700	7700
70			6300	6450	7650	9000
80				7900	9000	10000
100				10000	10000	

Table16 Manufacturing limit lengths of precision Ball Screws (DIN standard compliant Ball Screws)

Unit: mm

Shaft diameter	Ground shaft			CES shaft			
	C3	C5	C7	Cp3	Cp5	Ct5	Ct7
16	1050	1100	1400	1050	1100	1100	1400
20	1400	1600	1800	1400	1600	1600	1800
25	1800	2000	2400	1800	2000	2000	2400
32	2500	2800	3200	2500	2800	2800	3200
40	3400	3700	4300	3400	3700	3700	4300
50	4500	5000	5800	—	—	—	—
63	5800	6700	7700	—	—	—	—

Table17 Maximum Length of the Rolled Ball Screw
by Accuracy Grade

Unit: mm

Screw shaft outer diameter	Overall screw shaft length		
	C7	C8	C10
6 to 8	320	320	—
10 to 12	500	1000	—
14 to 15	1500	1500	1500
16 to 18	1500	1800	1800
20	2000	2200	2200
25	2000	3000	3000
28	3000	3000	3000
30	3000	3000	4000
32 to 36	3000	4000	4000
40	3000	5000	5000
45	3000	5500	5500
50	3000	6000	6000

Standard Combinations of Shaft Diameter and Lead for the Precision Ball Screw

Table18 shows standard combinations of shaft diameters and leads of precision Ball Screws, and Table19 shows standard combinations of shaft diameters and leads of precision Ball Screws compliant with DIN standard.
If a Ball Screw not covered by the table is required,contact THK.

Table18 Standard Combinations of Screw Shaft and Lead (Precision Ball Screw) Unit: mm

Screw shaft outer diameter	Lead																			
	1	2	4	5	6	8	10	12	15	16	20	24	25	30	32	36	40	50	60	80
4	●																			
5	●																			
6	●																			
8	●	●					●	○												
10		●	●				●		○											
12		●		●		●														
13											○									
14		●	●	●		●														
15							●			●			○				○			
16			○	●	○		○			●										
18							●													
20			○	●	○	○	●	○		●							○		○	
25			○	●	○	○	●	○		○	●		○					○		
28				○	●	○	○													
30																		○		○
32			○	●	●	○	●	○			○				○					
36					○	○	●	○		○	○	○				○				
40				○	○	○	●	●		○	○			○			○			○
45					○	○	○	○		○	○									
50				○		○	●	○		○	○			○		○		○		○
55							○	○		○	○			○		○				
63							○	○		○	○									
70							○	○			○									
80							○	○			○									
100											○									

- : off-the-shelf products [standard-stock products equipped with the standardized screw shafts (with unfinished shaft ends/finished shaft ends)]
- : Semi-standard stock

Table19 Standard combinations of outer diameters and leads of the screw shafts (DIN standard compliant Ball Screws) Unit: mm

Shaft diameter	Lead		
	5	10	20
16	●	—	—
20	●	—	—
25	●	●	—
32	●	●	—
40	○	●	○*
50	—	○	○*
63	—	○	○*

- : Ground shaft, CES shaft
- : Ground shaft only
- *: Model EB (no preload) only

Standard Combinations of Shaft Diameter and Lead for the Rolled Ball Screw

Table20 shows the standard combinations of shaft diameter and lead for the rolled Ball Screw.

Table20 Standard Combinations of Screw Shaft and Lead (Rolled Ball Screw) Unit: mm

Screw shaft outer diameter	Lead																			
	1	2	4	5	6	8	10	12	16	20	24	25	30	32	36	40	50	60	80	100
6	●																			
8		●																		
10		●			○															
12		●				○														
14			●	●																
15							●			●			●							
16				●					●											
18						●														
20				●			●			●						●				
25				●			●					●					●			
28					●															
30																		●		
32							●							●						
36							●			●	●				●					
40							●									●			●	
45								●												
50									●								●			●

●: Standard stock
○: Semi-standard stock

Ball Screw

Permissible Axial Load

[Buckling Load on the Screw Shaft]

With the Ball Screw, it is necessary to select a screw shaft so that it will not buckle when the maximum compressive load is applied in the axial direction.

Fig.8 on A-713 shows the relationship between the screw shaft diameter and a buckling load.

If determining a buckling load by calculation, it can be obtained from the equation (6) below. Note that in this equation, a safety factor of 0.5 is multiplied to the result.

$$P_1 = \frac{\eta_1 \cdot \pi^2 \cdot E \cdot I}{\ell_a^2} \cdot 0.5 = \eta_2 \frac{d_1^4}{\ell_a^2} \cdot 10^4 \quad \dots\dots\dots (6)$$

P_1 : Buckling load (N)

ℓ_a : Distance between two mounting surfaces (mm)

E : Young's modulus (2.06×10^5 N/mm²)

I : Minimum geometrical moment of inertia of the shaft (mm⁴)

$$I = \frac{\pi}{64} d_1^4 \quad d_1: \text{screw-shaft thread minor diameter (mm)}$$

η_1, η_2 = Factor according to the mounting method

Fixed - free $\eta_1=0.25$ $\eta_2=1.3$

Fixed - supported $\eta_1=2$ $\eta_2=10$

Fixed - fixed $\eta_1=4$ $\eta_2=20$

[Permissible Tensile Compressive Load on the Screw Shaft]

If an axial load is applied to the Ball Screw, it is necessary to take into account not only the buckling load but also the permissible tensile compressive load in relation to the yielding stress on the screw shaft.

The permissible tensile compressive load is obtained from the equation (7).

$$P_2 = \sigma \frac{\pi}{4} d_1^2 = 116 d_1^2 \quad \dots\dots\dots (7)$$

P_2 : Permissible tensile compressive load (N)

σ : Permissible tensile compressive stress (147 MPa)

d_1 : Screw-shaft thread minor diameter (mm)

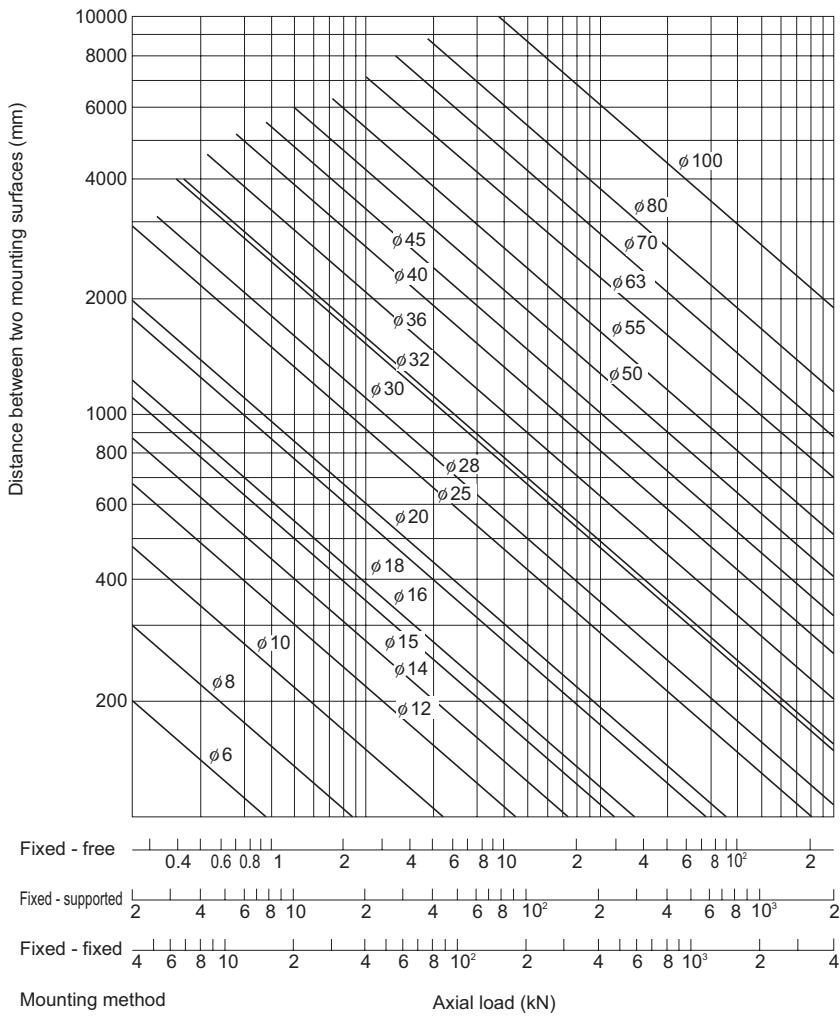


Fig.8 Permissible Tensile Compressive Load Diagram

Permissible Rotational Speed

[Dangerous Speed of the Screw Shaft]

When the rotational speed reaches a high magnitude, the Ball Screw may resonate and eventually become unable to operate due to the screw shaft's natural frequency. Therefore, it is necessary to select a model so that it is used below the resonance point (dangerous speed).

Fig.9 on A-716 shows the relationship between the screw shaft diameter and a dangerous speed.

If determining a dangerous speed by calculation, it can be obtained from the equation (8) below. Note that in this equation, a safety factor of 0.8 is multiplied to the result.

$$N_1 = \frac{60 \cdot \lambda_1^2}{2\pi \cdot \ell_b^2} \times \sqrt{\frac{E \times 10^3 \cdot I}{\gamma \cdot A}} \times 0.8 = \lambda_2 \cdot \frac{d_1}{\ell_b^2} \cdot 10^7 \quad \dots\dots\dots(8)$$

N_1 : Permissible rotational speed determined
by dangerous speed (min⁻¹)

ℓ_b : Distance between two mounting
surfaces (mm)

E : Young's modulus (2.06 × 10⁵ N/mm²)

I : Minimum geometrical moment of inertia
of the shaft (mm⁴)

$I = \frac{\pi}{64} d_1^4$ d_1 : screw-shaft thread minor diameter (mm)

γ : Density (specific gravity)
(7.85 × 10⁻⁶ kg/mm³)

A : Screw shaft cross-sectional area (mm²)

$$A = \frac{\pi}{4} d_1^2$$

λ_1, λ_2 : Factor according to the mounting method

Fixed - free $\lambda_1=1.875$ $\lambda_2=3.4$

Supported - supported $\lambda_1=3.142$ $\lambda_2=9.7$

Fixed - supported $\lambda_1=3.927$ $\lambda_2=15.1$

Fixed - fixed $\lambda_1=4.73$ $\lambda_2=21.9$

[DN Value]

The permissible rotational speed of the Ball Screw must be obtained from the dangerous speed of the screw shaft and the DN value.

The permissible rotational speed determined by the DN value is obtained using the equations (9) to (14) below.

● **Ball Screw with Ball Cage**

■ **Models SBN and HBN**

$$N_2 = \frac{130000}{D} \dots\dots\dots(9)$$

N_2 : Permissible rotational speed determined by the DN value ($\text{min}^{-1}(\text{rpm})$)

D : Ball center-to-center diameter
(indicated in the specification tables of the respective model number)

■ **Model SBK**

$$N_2 = \frac{160000}{D} \dots\dots\dots(10)$$

● **Precision Ball Screw (DIN Standard Compliant Ball Screw)**

$$N_2 = \frac{100000}{D} \dots\dots\dots(11)$$

● **Precision Ball Screw**

$$N_2 = \frac{70000}{D} \dots\dots\dots(12)$$

● **Rolled Ball Screw**

(excluding large lead type)

$$N_2 = \frac{50000}{D} \dots\dots\dots(13)$$

● **Large-Lead Rolled Ball Screw**

$$N_2 = \frac{70000}{D} \dots\dots\dots(14)$$

Of the permissible rotational speed determined by dangerous speed (N_1) and the permissible rotational speed determined by DN value (N_2), the lower rotational speed is regarded as the permissible rotational speed.

If the working rotational speed exceeds N_2 , a high-speed type Ball Screw is available. Contact THK for details.

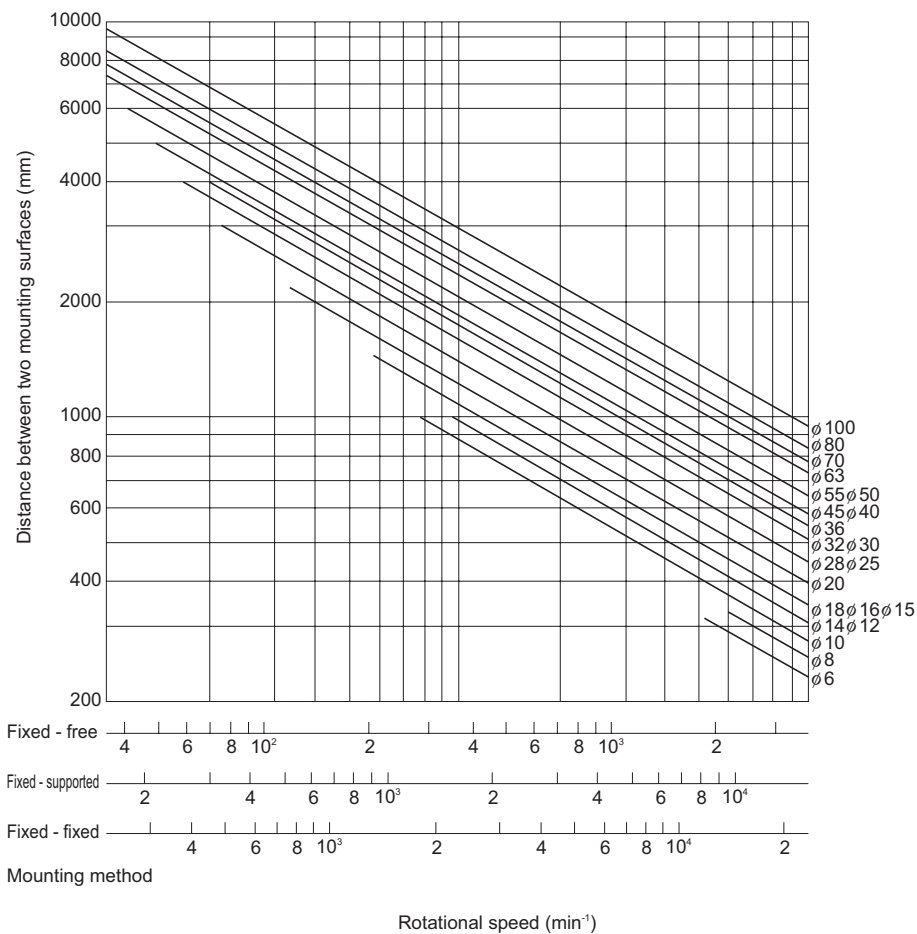


Fig.9 Permissible Rotational Speed Diagram

Selecting a Nut

Types of Nuts

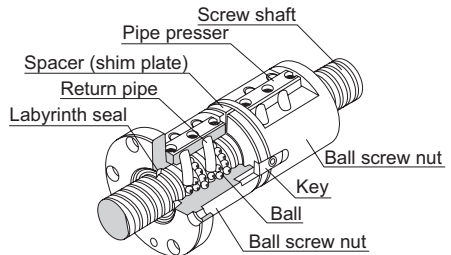
The nuts of the Ball Screws are categorized by the ball circulation method into the return-pipe type, the deflector type and end the cap type. These three nut types are described as follows. In addition to the circulation methods, the Ball Screws are categorized also by the preloading method.

[Types by Ball Circulation Method]

● Return-pipe Type (Models SBN, BNF, BNT, BNFN, BIF and BTK)

Return-piece Type (Model HBN)

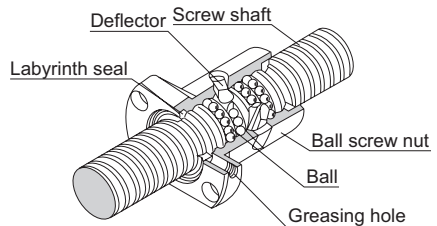
These are most common types of nuts that use a return pipe for ball circulation. The return pipe allows balls to be picked up, pass through the pipe, and return to their original positions to complete infinite motion.



Example of Structure of Return-Pipe Nut

● Deflector Type (Models DK, DKN, DIK, JPF and DIR)

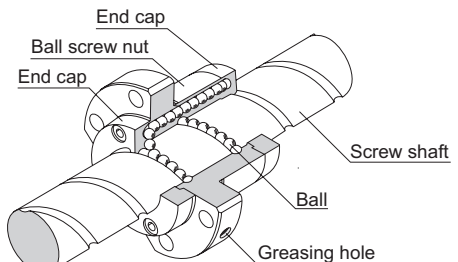
These are the most compact type of nut. The balls change their traveling direction with a deflector, pass over the circumference of the screw shaft, and return to their original positions to complete an infinite motion.



Example of Structure of Simple Nut

● End-cap Type: Large lead Nut (Models SBK, BLK, WGF, BLW, WTF, CNF and BLR)

These nuts are most suitable for the fast feed. The balls are picked up with an end cap, pass through the through hole of the nut, and return to their original positions to complete an infinite motion.



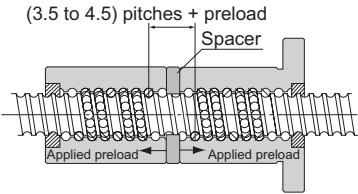
Example of Structure of Large lead Nut

[Types by Preloading Method]

● Fixed-point Preloading

■ Double-nut Preload (Models BNFN, DKN and BLW)

A spacer is inserted between two nuts to provide a preload.



Model BNFN



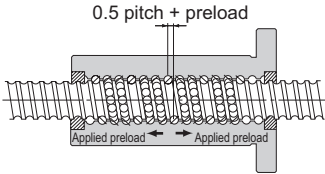
Model DKN



Model BLW

■ Offset Preload (Models SBN, BIF, DIK, SBK and DIR)

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



Model SBN



Model BIF



Model DIK



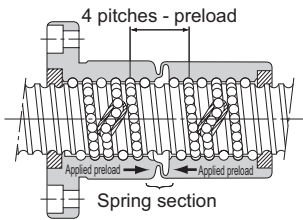
Model SBK



Model DIR

● Constant Pressure Preloading (Model JPF)

With this method, a spring structure is installed almost in the middle of the nut, and it provides a preload by changing the groove pitch in the middle of the nut.



Model JPF

Selecting a Model Number

Calculating the Axial Load

[In Horizontal Mount]

With ordinary conveyance systems, the axial load (F_{a_n}) applied when horizontally reciprocating the work is obtained in the equation below.

$$Fa_1 = \mu \cdot mg + f + m\alpha \quad (14)$$

$$Fa_2 = \mu \cdot mg + f \quad (15)$$

$$Fa_3 = \mu \cdot mg + f - m\alpha \quad (16)$$

$$Fa_4 = -\mu \cdot mg - f - m\alpha \quad (17)$$

$$Fa_5 = -\mu \cdot mg - f \quad (18)$$

$$Fa_6 = -\mu \cdot mg - f + m\alpha \quad (19)$$

$V_{\max}$: Maximum speed (m/s)

t_1 : Acceleration time (m/s)

$$\alpha = \frac{V_{\max}}{t_1} : \text{Acceleration} \quad (m/s^2)$$

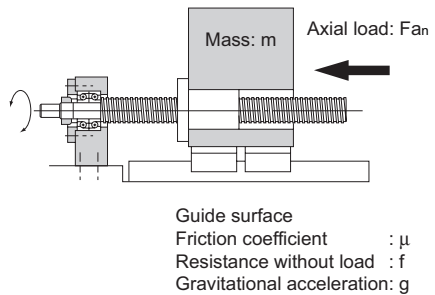
Fa_1 : Axial load during forward acceleration (N)

Fa_2 : Axial load during forward uniform motion (N)

Fa_3 : Axial load during forward deceleration (N)

Fa_4 : Axial load during backward acceleration (N)

Fa_5 : Axial load during uniform backward motion (N)



Fa_6 : Axial load during backward deceleration (N)

m : Transferred mass (kg)

μ : Frictional coefficient of the guide surface (-)

f : Guide surface resistance (without load) (N)

[In Vertical Mount]

With ordinary conveyance systems, the axial load (F_{a_n}) applied when vertically reciprocating the work is obtained in the equation below.

$$Fa_1 = mg + f + m\alpha \quad (20)$$

$$Fa_2 = mg + f \quad (21)$$

$$Fa_3 = mg + f - m\alpha \quad (22)$$

$$Fa_4 = mg - f - m\alpha \quad (23)$$

$$Fa_5 = mg - f \quad (24)$$

$$Fa_6 = mg - f + m\alpha \quad (25)$$

$V_{\max}$: Maximum speed (m/s)

t_1 : Acceleration time (m/s)

$$\alpha = \frac{V_{\max}}{t_1} : \text{Acceleration} \quad (m/s^2)$$

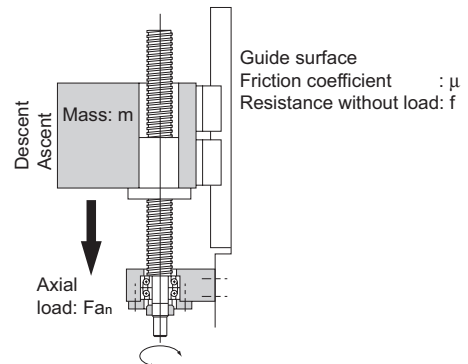
Fa_1 : Axial load during upward acceleration (N)

Fa_2 : Axial load during uniform upward motion (N)

Fa_3 : Axial load during upward deceleration (N)

Fa_4 : Axial load during downward acceleration (N)

Fa_5 : Axial load during uniform downward motion (N)



Fa_6 : Axial load during downward deceleration (N)

m : Transferred mass (kg)

f : Guide surface resistance (without load) (N)

Static Safety Factor

The basic static load rating (C_{0a}) generally equals to the permissible axial load of a Ball Screw. Depending on the conditions, it is necessary to take into account the following static safety factor against the calculated load. When the Ball Screw is stationary or in motion, unexpected external force may be applied through an inertia caused by the impact or the start and stop.

$$F_{a_{\max}} = \frac{C_{0a}}{f_s} \dots\dots\dots (26)$$

- $F_{a_{\max}}$: Permissible Axial Load (kN)
 C_{0a} : Basic static load rating* (kN)
 f_s : Static safety factor (see Table21)

Table21 Static Safety Factor (f_s)

Machine using the LM system	Load conditions	Lower limit of f_s
General industrial machinery	Without vibration or impact	1 to 1.3
	With vibration or impact	2 to 3
Machine tool	Without vibration or impact	1 to 1.5
	With vibration or impact	2.5 to 7

The basic static load rating (C_{0a}) 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 specification tables for the corresponding model number.)

Studying the Service Life

[Service Life of the Ball Screw]

The Ball Screw in motion under an external load receives the continuous stress on its raceways and balls. When the stress reaches the limit, the raceways break from the fatigue and their surfaces partially disintegrate in scale-like pieces. 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 the 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 developing flaking (scale-like pieces of a metal surface) after they independently operate in the same conditions.

[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.

● Nominal Life (Total Number of Revolutions)

$$L = \left(\frac{C_a}{f_w \cdot F_a} \right)^3 \times 10^6 \dots\dots\dots(27)$$

- L : Nominal life (rev)
(total number of revolutions)
- Ca : Basic dynamic load rating* (N)
- Fa : Applied axial load (N)
- fw : Load factor (see Table22)

Table22 Load Factor (fw)

Vibrations/ impact	Speed(V)	fw
Faint	Very low V ≤ 0.25m/s	1 to 1.2
Weak	Slow 0.25 < V ≤ 1m/s	1.2 to 1.5
Medium	Medium 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 interlocked direction and magnitude under which the nominal life (L) equals to 10⁶rev. when a group of the same Ball Screw units independently operate. (Specific basic dynamic load ratings (Ca) are indicated in the specification tables of the corresponding model numbers.)

● Service Life Time

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

$$L_h = \frac{L}{60 \times N} = \frac{L \times Ph}{2 \times 60 \times n \times \ell_s} \dots\dots\dots(28)$$

- L_h : Service life time (h)
- N : Revolutions per minute (min^{-1})
- n : Number of reciprocations per minute (min^{-1})
- Ph : Ball Screw lead (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 nominal life (L) and the Ball Screw lead.

$$L_s = \frac{L \times Ph}{10^6} \dots\dots\dots(29)$$

- L_s : 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 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 the load conditions.

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

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

- F_m : Average Axial Load (N)
- Fa_n : Varying load (N)
- ℓ_n : Distance traveled under load (F_n)
- ℓ : Total travel distance

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

$$l = l_1 + l_2 + \dots + l_n$$

$$l_1 = N_1 \cdot t_1$$

$$l_2 = N_2 \cdot t_2$$

$$l_n = N_n \cdot t_n$$

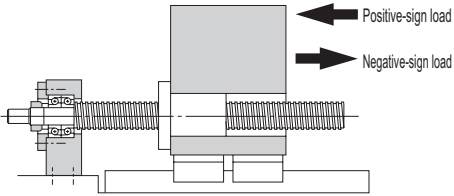
N: Rotational speed

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.	Varying load $F_{a_i}(N)$	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 F_{a_3} and F_{a_4} to be zero.

$$F_{m1} = \sqrt[3]{\frac{F_{a1}^3 \times l_1 + F_{a2}^3 \times l_2}{l_1 + l_2 + l_3 + l_4}} = 35.5N$$

● Average axial load of negative-sign load

To calculate the average axial load of the negative-sign load, assume F_{a1} and F_{a2} to be zero.

$$F_{m2} = \sqrt[3]{\frac{|F_{a3}|^3 \times l_3 + |F_{a4}|^3 \times l_4}{l_1 + l_2 + l_3 + l_4}} = 17.2N$$

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.

Studying the Rigidity

To increase the positioning accuracy of feed screws in NC machine tools or the precision machines, or to reduce the displacement caused by the cutting force, it is necessary to design the rigidity of the components in a well-balanced manner.

Axial Rigidity of the Feed Screw System

When the axial rigidity of a feed screw system is K, the elastic displacement in the axial direction can be obtained using the equation (31) below.

$\delta = \frac{F_a}{K}$ (31)

- δ : Elastic displacement of a feed screw system in the axial direction (μm)
- F_a : Applied axial load (N)

The axial rigidity (K) of the feed screw system is obtained using the equation (32) below.

$\frac{1}{K} = \frac{1}{K_s} + \frac{1}{K_N} + \frac{1}{K_B} + \frac{1}{K_H}$ (32)

- K : Axial Rigidity of the Feed Screw System (N/μm)
- K_s : Axial rigidity of the screw shaft (N/μm)
- K_N : Axial rigidity of the nut (N/μm)
- K_B : Axial rigidity of the support bearing(N/μm)
- K_H : Rigidity of the nut bracket and the support bearing bracket (N/μm)

[Axial rigidity of the screw shaft]

The axial rigidity of a screw shaft varies depending on the method for mounting the shaft.

● For Fixed-Supported (or -Free) Configuration

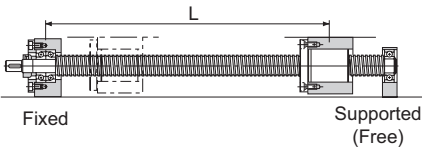
$K_s = \frac{A \cdot E}{1000 \cdot L}$ (33)

- A : Screw shaft cross-sectional area (mm²)

$A = \frac{\pi}{4} d_1^2$

- d_1 : Screw-shaft thread minor diameter (mm)
- E : Young's modulus (2.06 × 10⁵ N/mm²)
- L : Distance between two mounting surfaces (mm)

Fig.10 onA-726 shows an axial rigidity diagram for the screw shaft.



● For Fixed-Fixed Configuration

$$K_s = \frac{A \cdot E \cdot L}{1000 \cdot a \cdot b} \dots\dots\dots (34)$$

K_s becomes the lowest and the elastic displacement in the axial direction is the greatest at the position of $a = b = \frac{L}{2}$.

$$K_s = \frac{4A \cdot E}{1000L}$$

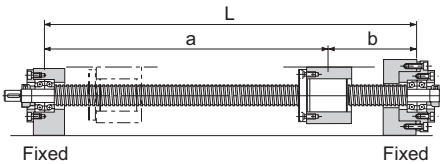


Fig.11 on A-727 shows an axial rigidity diagram of the screw shaft in this configuration.

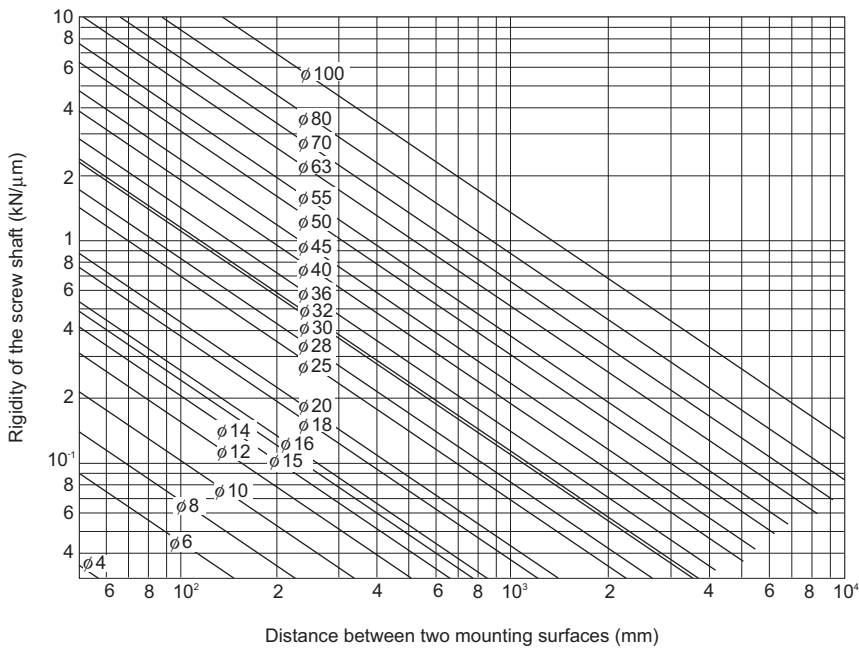


Fig.10 Axial Rigidity of the Screw Shaft (Fixed-Free, Fixed-Supported)

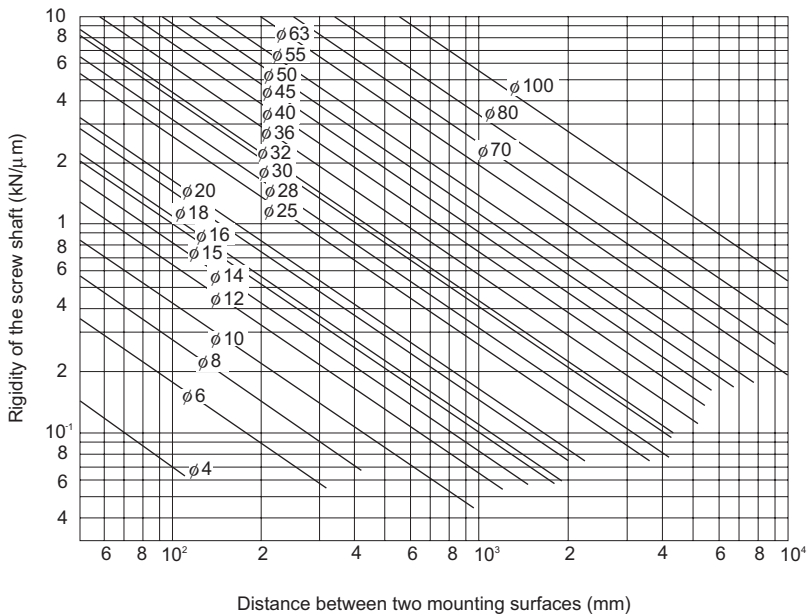


Fig.11 Axial Rigidity of the Screw Shaft (Fixed-Fixed)

Ball Screw

[Axial rigidity of the nut]

The axial rigidity of the nut varies widely with preloads.

● No Preload Type

The logical rigidity in the axial direction when an axial load accounting for 30% of the basic dynamic load rating (Ca) is applied is indicated in the specification tables of the corresponding model number. This value does not include the rigidity of the components related to the nut-mounting bracket. In general, set the rigidity at roughly 80% of the value in the table.

The rigidity when the applied axial load is not 30% of the basic dynamic load rating (Ca) is calculated using the equation (35) below.

$$K_N = K \left(\frac{F_a}{0.3C_a} \right)^{\frac{1}{3}} \times 0.8 \dots\dots\dots (35)$$

- K_N : Axial rigidity of the nut (N/μm)
- K : Rigidity value in the specification tables (N/μm)
- F_a : Applied axial load (N)
- C_a : Basic dynamic load rating (N)

● Preload Type

The logical rigidity in the axial direction when an axial load accounting for 10% of the basic dynamic load rating (Ca) is applied is indicated in the dimensional table of the corresponding model number. This value does not include the rigidity of the components related to the nut-mounting bracket. In general, generally set the rigidity at roughly 80% of the value in the table.

The rigidity when the applied preload is not 10% of the basic dynamic load rating (Ca) is calculated using the equation (36) below.

$$K_N = K \left(\frac{Fa_0}{0.1Ca} \right)^{\frac{1}{3}} \times 0.8 \quad \dots\dots\dots (36)$$

K_N : Axial rigidity of the nut (N/μm)

K : Rigidity value in the specification tables (N/μm)

Fa_0 : Applied preload (N)

Ca : Basic dynamic load rating (N)

[Axial rigidity of the support bearing]

The rigidity of the Ball Screw support bearing varies depending on the support bearing used.

The calculation of the rigidity with a representative angular ball bearing is shown in the equation (37) below.

$$K_B \div \frac{3Fa_0}{\delta a_0} \quad \dots\dots\dots (37)$$

K_B : Axial rigidity of the support bearing (N/μm)

Fa_0 : Applied preload of the support bearing (N)

δa_0 : Axial displacements (μm)

$$\delta a_0 = \frac{0.45}{\sin \alpha} \left(\frac{Q^2}{Da} \right)^{\frac{1}{3}}$$

$$Q = \frac{Fa_0}{Z \sin \alpha}$$

Q : Axial load (N)

Da : Ball diameter of the support bearing (mm)

α : Initial contact angle of the support bearing (°)

Z : Number of balls

For details of a specific support bearing, contact its manufacturer.

[Axial Rigidity of the Nut Bracket and the Support Bearing Bracket]

Take this factor into consideration when designing your machine. Set the rigidity as high as possible.

Studying the Positioning Accuracy

Causes of Error in the Positioning Accuracy

The causes of error in the positioning accuracy include the lead angle accuracy, the axial clearance and the axial rigidity of the feed screw system. Other important factors include the thermal displacement from heat and the orientation change of the guide system during traveling.

Studying the Lead Angle Accuracy

It is necessary to select the correct accuracy grade of the Ball Screw that satisfies the required positioning accuracy from the Ball Screw accuracies (Table1 on A-696). Table23 on A-730 shows examples of selecting the accuracy grades by the application.

Studying the Axial Clearance

The axial clearance is not a factor of positioning accuracy in single-directional feed. However, it will cause a backlash when the feed direction is inversed or the axial load is inversed. Select an axial clearance that meets the required backlash from Table10 and Table13 on A-703.

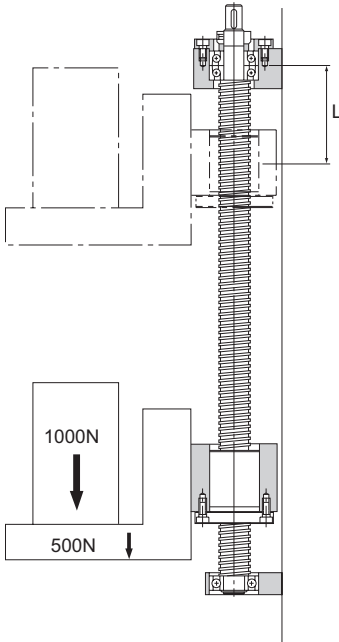
Table23 Examples of Selecting Accuracy Grades by Application

Applications			Shaft	Accuracy grades						
				C0	C1	C2	C3	C5	C7	C8
NC machine tools	Lathe	X		●	●	●	●			
		Z				●	●			
	Machining center	XY			●	●	●			
		Z			●	●	●			
	Drilling machine	XY				●	●			
		Z					●	●		
	Jig borer	XY	●	●						
		Z	●	●						
	Surface grinder	X				●	●			
		Y		●	●	●	●			
		Z		●	●	●	●			
	Cylindrical grinder	X	●	●	●					
		Z		●	●	●				
	Electric discharge machine	XY	●	●	●					
		Z		●	●	●	●			
	Electric discharge machine	XY	●	●	●					
		Z	●	●	●	●				
	Wire cutting machine	UV		●	●	●				
	Punching press	XY				●	●	●		
	Laser beam machine	X				●	●	●		
Z					●	●	●			
Woodworking machine							●	●	●	●
General-purpose machine; dedicated machine						●	●	●	●	●
Industrial robot	Cartesian coordinate	Assembly				●	●	●	●	
		Other					●	●	●	●
	Vertical articulated type	Assembly					●	●	●	
		Other						●	●	
Cylindrical coordinate						●	●	●		
Semiconductor manufacturing machine	Photolithography machine		●	●						
	Chemical treatment machine				●	●	●	●	●	●
	Wire bonding machine			●	●					
	Prober		●	●	●	●				
	Printed circuit board drilling machine			●	●	●	●	●		
	Electronic component inserter				●	●	●	●		
3D measuring instrument			●	●	●					
Image processing machine			●	●	●					
Injection molding machine							●	●	●	
Office equipment							●	●	●	●

Studying the Axial Clearance of the Feed Screw System

Of the axial rigidities of the feed screw system, the axial rigidity of the screw shaft fluctuates according to the stroke position. When the axial rigidity is large, such change in the axial rigidity of the screw shaft will affect the positioning accuracy. Therefore, it is necessary to take into account the rigidity of the feed screw system (A-725 to A-728).

Example: Positioning error due to the axial rigidity of the feed screw system during a vertical transfer



[Conditions]

Transferred weight: 1,000 N; table weight: 500 N

Ball Screw used: model BNF2512-2.5 (screw-shaft thread minor diameter $d_1 = 21.9$ mm)

Stroke length: 600 mm ($L=100$ mm to 700 mm)

Screw shaft mounting type: fixed-supported

[Consideration]

The difference in axial rigidity between $L = 100$ mm and $L = 700$ mm applied only to the axial rigidity of the screw shaft.

Therefore, positioning error due to the axial rigidity of the feed screw system equals to the difference in the axial displacement of the screw shaft between $L = 100$ mm and $L = 700$ mm.

[Axial Rigidity of the Screw Shaft (see A-725 and A-726)]

$$K_s = \frac{A \cdot E}{1000L} = \frac{376.5 \times 2.06 \times 10^5}{1000 \times L} = \frac{77.6 \times 10^3}{L}$$

$$A = \frac{\pi}{4} d_1^2 = \frac{\pi}{4} \times 21.9^2 = 376.5 \text{ mm}^2$$

$$E = 2.06 \times 10^5 \text{ N/mm}^2$$

(1) When $L = 100 \text{ mm}$

$$K_{s1} = \frac{77.6 \times 10^3}{100} = 776 \text{ N/}\mu\text{m}$$

(2) When $L = 700 \text{ mm}$

$$K_{s2} = \frac{77.6 \times 10^3}{700} = 111 \text{ N/}\mu\text{m}$$

[Axial Displacement due to Axial Rigidity of the Screw Shaft]

(1) When $L = 100 \text{ mm}$

$$\delta_1 = \frac{Fa}{K_{s1}} = \frac{1000+500}{776} = 1.9 \mu\text{m}$$

(2) When $L = 700 \text{ mm}$

$$\delta_2 = \frac{Fa}{K_{s2}} = \frac{1000+500}{111} = 13.5 \mu\text{m}$$

[Positioning Error due to Axial Rigidity of the Feed Screw System]

Positioning accuracy $= \delta_1 - \delta_2 = 1.9 - 13.5$
 $= -11.6 \mu\text{m}$

Therefore, the positioning error due to the axial rigidity of the feed screw system is $11.6 \mu\text{m}$.

Studying the Thermal Displacement through Heat Generation

If the temperature of the screw shaft increases during operation, the screw shaft is elongated due to heat thereby to lowering the positioning accuracy. The expansion and contraction of the screw shaft is calculated using the equation (38) below.

$$\Delta \ell = \rho \times \Delta t \times \ell \quad \cdots \cdots \cdots (38)$$

- $\Delta \ell$: Axial expansion/contraction of
the screw shaft (mm)
 ρ : Thermal expansion coefficient ($12 \times 10^{-6}/^{\circ}\text{C}$)
 Δt : Temperature change in
the screw shaft ($^{\circ}\text{C}$)
 ℓ : Effective thread length (mm)

Thus, if the temperature of the screw shaft increases by 1°C , the screw shaft is elongated by $12 \mu\text{m}$ per meter. Therefore, as the Ball Screw travels faster, the more heat is generated. So, as the temperature increases, the positioning accuracy lowers. Accordingly, if high accuracy is required, it is necessary to take measures to cope with the temperature increase.

[Measures to Cope with the Temperature Rise]

● Minimize the Heat Generation

- Minimize the preloads on the Ball Screw and the support bearing.
- Increase the Ball Screw lead and reduce the rotational speed.
- Select a correct lubricant. (See Accessories for Lubrication on A-976.)
- Cool the circumference of the screw shaft with a lubricant or air.

● Avoid Effect of Temperature Rise through Heat Generation

- Set a negative target value for the reference travel distance of the Ball Screw.
Generally, set a negative target value for the reference travel distance assuming a temperature increase of 2°C to 5°C by heat.
(-0.02mm to -0.06 mm/m)
- Preload the shaft screw with tension. (See Fig.3 of the structure on A-847.)

Studying the Orientation Change during Traveling

The lead angle accuracy of the Ball Screw equals the positioning accuracy of the shaft center of the Ball Screw. Normally, the point where the highest positioning accuracy is required changes according to the ball screw center and the vertical or horizontal direction. Therefore, the orientation change during traveling affects the positioning accuracy.

The largest factor of orientation change affecting the positioning accuracy is pitching if the change occurs in the ball screw center and the vertical direction, and yawing if the change occurs in the horizontal direction.

Accordingly, it is necessary to study the orientation change (accuracy in pitching, yawing, etc.) during the traveling on the basis of the distance from the ball screw center to the location where positioning accuracy is required.

Positioning error due to pitching and yawing is obtained using the equation (39) below.

$$A = \ell \times \sin\theta \dots\dots\dots(39)$$

- A: Positioning accuracy due to pitching (or yawing) (mm)
- ℓ : Vertical (or horizontal) distance from the ball screw center (mm) (see Fig.12)
- θ : Pitching (or yawing) (°)

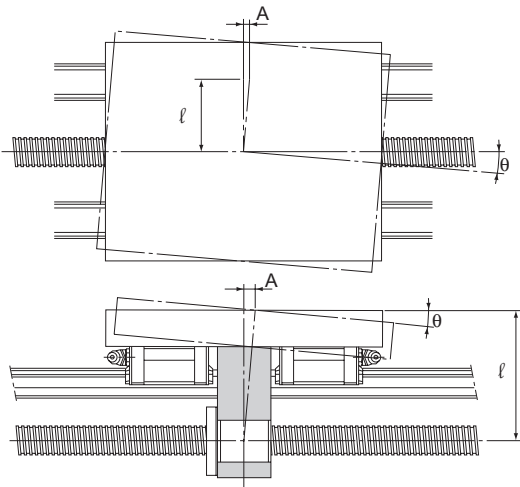


Fig.12

Studying the Rotational Torque

The rotational torque required to convert rotational motion of the Ball Screw into straight motion is obtained using the equation (40) below.

[During Uniform Motion]

$$T_t = T_1 + T_2 + T_4 \dots\dots\dots(40)$$

- T_t : Rotational torque required during uniform motion (N-mm)
- T_1 : Frictional torque due to an external load (N-mm)
- T_2 : Preload torque of the Ball Screw (N-mm)
- T_4 : Other torque (N-mm)
(frictional torque of the support bearing and oil seal)

[During Acceleration]

$$T_k = T_t + T_3 \dots\dots\dots(41)$$

- T_k : Rotational torque required during acceleration (N-mm)
- T_3 : Torque required for acceleration (N-mm)

[During Deceleration]

$$T_g = T_t - T_3 \dots\dots\dots(42)$$

- T_g : Rotational torque required for deceleration (N-mm)

Frictional Torque Due to an External Load

Of the turning forces required for the Ball Screw, the rotational torque needed for an external load (guide surface resistance or external force) is obtained using the equation (43) below

$$T_1 = \frac{F_a \cdot Ph}{2\pi \cdot \eta} \cdot A \dots\dots\dots(43)$$

- T_1 : Frictional torque due to an external load (N-mm)
- F_a : Applied axial load (N)
- Ph : Ball Screw lead (mm)
- η : Ball Screw efficiency (0.9 to 0.95)
- A : Reduction ratio

Torque Due to a Preload on the Ball Screw

For a preload on the Ball Screw, see "Preload Torque" on A-706.

$$T_2 = T_d \cdot A \quad \dots\dots\dots(44)$$

T_2 : Preload torque of the Ball Screw (N-mm)

T_d : Preload torque of the Ball Screw (N-mm)

A : Reduction ratio

Torque Required for Acceleration

$$T_3 = J \times \omega' \times 10^3 \quad \dots\dots\dots(45)$$

T_3 : Torque required for acceleration (N-mm)

J : Inertial moment (kg·m²)

ω' : Angular acceleration (rad/s²)

$$J = m \left(\frac{Ph}{2\pi} \right)^2 \cdot A^2 \cdot 10^{-6} + J_s \cdot A^2 + J_A \cdot A^2 + J_B$$

m : Transferred mass (kg)

Ph : Ball Screw lead (mm)

J_s : Inertial moment of the screw shaft (kg·m²)

(indicated in the specification tables of the respective model number)

A : Reduction ratio

J_A : Inertial moment of gears, etc. attached to the screw shaft side (kg·m²)

J_B : Inertial moment of gears, etc. attached to the motor side (kg·m²)

$$\omega' = \frac{2\pi \cdot Nm}{60t}$$

Nm : Motor revolutions per minute (min⁻¹)

t : Acceleration time (s)

[Ref.] Inertial moment of a round object

$$J = \frac{m \cdot D^2}{8 \cdot 10^6}$$

J : Inertial moment (kg·m²)

m : Mass of a round object (kg)

D : Screw shaft outer diameter (mm)

Studying the Driving Motor

When selecting a driving motor required to rotate the Ball Screw, normally take into account the rotational speed, rotational torque and minimum feed amount.

When Using a Servomotor

[Rotational Speed]

The rotational speed required for the motor is obtained using the equation (46) based on the feed speed, Ball Screw lead and reduction ratio.

$$N_M = \frac{V \times 1000 \times 60}{Ph} \times \frac{1}{A} \dots\dots\dots(46)$$

- N_M : Required rotational speed
of the motor (min⁻¹)
- V : Feeding speed (m/s)
- Ph : Ball Screw lead (mm)
- A : Reduction ratio

The rated rotational speed of the motor must be equal to or above the calculated value (N_M) above.

$$N_M \leq N_R$$

- N_R : The rated rotational speed
of the motor (min⁻¹)

[Required Resolution]

Resolutions required for the encoder and the driver are obtained using the equation (47) based on the minimum feed amount, Ball Screw lead and reduction ratio.

$$B = \frac{Ph \cdot A}{S} \dots\dots\dots(47)$$

- B : Resolution required for the encoder
and the driver (p/rev)
- Ph : Ball Screw lead (mm)
- A : Reduction ratio
- S : Minimum feed amount (mm)

[Motor Torque]

The torque required for the motor differs between uniform motion, acceleration and deceleration. To calculate the rotational torque, see "Studying the Rotational Torque" on A-735.

a. Maximum torque

The maximum torque required for the motor must be equal to or below the maximum peak torque of the motor.

$$T_{\max} \leq T_{p\max}$$

$T_{\max}$: Maximum torque acting on the motor

$T_{p\max}$: Maximum peak torque of the motor

b. Effective torque value

The effective value of the torque required for the motor must be calculated. The effective value of the torque is obtained using the equation (48) below.

$$T_{rms} = \sqrt{\frac{T_1^2 \times t_1 + T_2^2 \times t_2 + T_3^2 \times t_3}{t}} \dots\dots\dots(48)$$

T_{rms} : Effective torque value (N-mm)

T_n : Fluctuating torque (N-mm)

t_n : Time during which the torque
 T_n is applied (s)

t : Cycle time (s)
 ($t=t_1+t_2+t_3$)

The calculated effective value of the torque must be equal to or below the rated torque of the motor.

$$T_{rms} \leq T_R$$

T_R : Rated torque of the motor (N-mm)

[Inertial Moment]

The inertial moment required for the motor is obtained using the equation (49) below.

$$J_M = \frac{J}{C} \dots\dots\dots(49)$$

J_M : Inertial moment required for the motor ($\text{kg} \cdot \text{m}^2$)

C : Factor determined by the motor and the driver

(It is normally between 3 to 10. However, it varies depending on the motor and the driver. Check the specific value in the catalog by the motor manufacturer.)

The inertial moment of the motor must be equal to or above the calculated J_M value.

When Using a Stepping Motor (Pulse Motor)

[Minimal Feed Amount(per Step)]

The step angle required for the motor and the driver is obtained using the equation (50) below based on the minimum feed amount, the Ball Screw lead and the reduction ratio.

$$E = \frac{360S}{Ph \cdot A} \dots\dots\dots(50)$$

- E : Step angle required for the motor and the driver (°)
S : Minimum feed amount (mm)
(per step)
Ph : Ball Screw lead (mm)
A : Reduction ratio

[Pulse Speed and Motor Torque]

a. Pulse speed

The pulse speed is obtained using the equation (51) below based on the feed speed and the minimum feed amount.

$$f = \frac{V \times 1000}{S} \dots\dots\dots(51)$$

- f : Pulse speed (Hz)
V : Feeding speed (m/s)
S : Minimum feed amount (mm)

b. Torque required for the motor

The torque required for the motor differs between the uniform motion, the acceleration and the deceleration. To calculate the rotational torque, see "Studying the Rotational Torque" on A-735.

Thus, the pulse speed required for the motor and the required torque can be calculated in the manner described above.

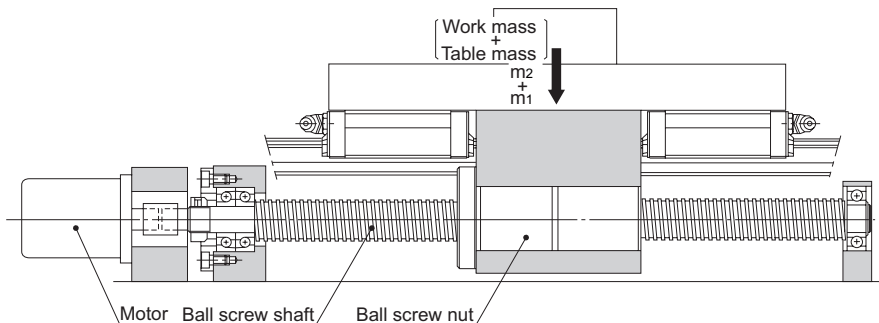
Although the torque varies depending on the motors, normally the calculated torque should be doubled to ensure safety. Check if the torque can be used in the motor's speed-torque curve.

Examples of Selecting a Ball Screw

High-speed Transfer Equipment (Horizontal Use)

[Selection Conditions]

Table Mass	$m_1 = 60\text{kg}$	Positioning Repeatability	$\pm 0.1\text{ mm}$
Work Mass	$m_2 = 20\text{kg}$	Minimum feed amount	$s = 0.02\text{mm/pulse}$
Stroke length	$\ell_s = 1000\text{mm}$	Desired service life time	30000h
Maximum speed	$V_{\max} = 1\text{m/s}$	Driving motor	AC servo motor
Acceleration time	$t_1 = 0.15\text{s}$		Rated rotational speed:
Deceleration time	$t_3 = 0.15\text{s}$		$3,000\text{ min}^{-1}$
Number of reciprocations per minute	$n = 8\text{min}^{-1}$	Inertial moment of the motor	$J_m = 1 \times 10^{-3}\text{ kg} \cdot \text{m}^2$
Backlash	0.15mm	Reduction gear	None (direct coupling)
Positioning accuracy	$\pm 0.3\text{ mm/1000 mm}$ (Perform positioning from the negative direction)		$A=1$
		Frictional coefficient of the guide surface	$\mu = 0.003\text{ (rolling)}$
		Guide surface resistance	$f = 15\text{ N (without load)}$



[Selection Items]

Screw shaft diameter
 Lead
 Nut model No.
 Accuracy
 Axial clearance
 Screw shaft support method
 Driving motor

[Selecting Lead Angle Accuracy and Axial Clearance]

● **Selecting Lead Angle Accuracy**

To achieve positioning accuracy of ± 0.3 mm/1,000 mm:

$$\frac{\pm 0.3}{1000} = \frac{\pm 0.09}{300}$$

The lead angle accuracy must be ± 0.09 mm/300 mm or higher.

Therefore, select the following as the accuracy grade of the Ball Screw (see Table1 on A-696).

C7 (travel distance error: ± 0.05 mm/300mm)

Accuracy grade C7 is available for both the Rolled and the Precision Ball Screws. Assume that a Rolled Ball Screw is selected here because it is less costly.

● **Selecting Axial Clearance**

To satisfy the backlash of 0.15 mm, it is necessary to select a Ball Screw with an axial clearance of 0.15 mm or less.

Therefore, a Rolled Ball Screw model with a screw shaft diameter of 32 mm or less that meets the axial clearance of 0.15 mm or less (see Table13 on A-703) meets the requirements.

Thus, a Rolled Ball Screw model with a screw shaft diameter of 32 mm or less and an accuracy grade of C7 is selected.

[Selecting a Screw Shaft]

● **Assuming the Screw Shaft Length**

Assume the overall nut length to be 100 mm and the screw shaft end length to be 100 mm.

Therefore, the overall length is determined as follows based on the stroke length of 1,000 mm.

$$1000 + 200 = 1200 \text{ mm}$$

Thus, the screw shaft length is assumed to be 1,200 mm.

● **Selecting a Lead**

With the driving motor's rated rotational speed being 3,000 min⁻¹ and the maximum speed 1 m/s, the Ball Screw lead is obtained as follows:

$$\frac{1 \times 1000 \times 60}{3000} = 20 \text{ mm}$$

Therefore, it is necessary to select a type with a lead of 20 mm or longer.

In addition, the Ball Screw and the motor can be mounted in direct coupling without using a reduction gear. The minimum resolution per revolution of an AC servomotor is obtained based on the resolution of the encoder (1,000 p/rev; 1,500 p/rev) provided as a standard accessory for the AC servomotor, as indicated below.

- 1000 p/rev(without multiplication)
- 1500 p/rev(without multiplication)
- 2000 p/rev(doubled)
- 3000 p/rev(doubled)
- 4000 p/rev(quadupled)
- 6000 p/rev(quadupled)

To meet the minimum feed amount of 0.02 mm/pulse, which is the selection requirement, the following should apply.

Lead	20mm — 1000 p/rev
	30mm — 1500 p/rev
	40mm — 2000 p/rev
	60mm — 3000 p/rev
	80mm — 4000 p/rev

● Selecting a Screw Shaft Diameter

Those Ball Screw models that meet the requirements defined in Section [Selecting Lead Angle Accuracy and Axial Clearance] on A-741: a rolled Ball Screw with a screw shaft diameter of 32 mm or less; and the requirement defined in Section [Selecting a Screw Shaft] on A-741: a lead of 20, 30, 40, 60 or 80 mm (see Table20 on A-711) are as follows.

Shaft diameter	Lead
15mm —	20mm
15mm —	30mm
20mm —	20mm
20mm —	40mm
30mm —	60mm

Since the screw shaft length has to be 1,200 mm as indicated in Section [Selecting a Screw Shaft] on A-741, the shaft diameter of 15 mm is insufficient. Therefore, the Ball Screw should have a screw shaft diameter of 20 mm or greater.

Accordingly, there are three combinations of screw shaft diameters and leads that meet the requirements: screw shaft diameter of 20 mm/lead of 20 mm; 20 mm/40 mm; and 30 mm/60 mm.

● Selecting a Screw Shaft Support Method

Since the assumed type has a long stroke length of 1,000 mm and operates at high speed of 1 m/s, select either the fixed-supported or fixed-fixed configuration for the screw shaft support.

However, the fixed-fixed configuration requires a complicated structure, needs high accuracy in the installation.

Accordingly, the fixed-supported configuration is selected as the screw shaft support method.

● Studying the Permissible Axial Load

■ Calculating the Maximum Axial Load

Guide surface resistance	$f=15 \text{ N (without load)}$
Table Mass	$m_1=60 \text{ kg}$
Work Mass	$m_2=20 \text{ kg}$
Frictional coefficient of the guide surface	$\mu=0.003$
Maximum speed	$V_{\max}=1 \text{ m/s}$
Gravitational acceleration	$g=9.807 \text{ m/s}^2$
Acceleration time	$t_1=0.15 \text{ s}$

Accordingly, the required values are obtained as follows.

Acceleration:

$$\alpha = \frac{V_{\max}}{t_1} = 6.67 \text{ m/s}^2$$

During forward acceleration:

$$Fa_1 = \mu \cdot (m_1 + m_2) g + f + (m_1 + m_2) \cdot \alpha = 550 \text{ N}$$

During forward uniform motion:

$$Fa_2 = \mu \cdot (m_1 + m_2) g + f = 17 \text{ N}$$

During forward deceleration:

$$Fa_3 = \mu \cdot (m_1 + m_2) g + f - (m_1 + m_2) \cdot \alpha = -516 \text{ N}$$

During backward acceleration:

$$Fa_4 = -\mu \cdot (m_1 + m_2) g - f - (m_1 + m_2) \cdot \alpha = -550 \text{ N}$$

During uniform backward motion:

$$Fa_5 = -\mu \cdot (m_1 + m_2) g - f = -17 \text{ N}$$

During backward deceleration:

$$Fa_6 = -\mu \cdot (m_1 + m_2) g - f + (m_1 + m_2) \cdot \alpha = 516 \text{ N}$$

Thus, the maximum axial load applied on the Ball Screw is as follows:

$$Fa_{\max} = Fa_1 = 550 \text{ N}$$

Therefore, if there is no problem with a shaft diameter of 20 mm and a lead of 20 mm (smallest thread minor diameter of 17.5 mm), then the screw shaft diameter of 30 mm should meet the requirements. Thus, the following calculations for the buckling load and the permissible compressive and tensile load of the screw shaft are performed while assuming a screw shaft diameter of 20 mm and a lead of 20 mm.

■ Buckling Load on the Screw Shaft

Factor according to the mounting method $\eta_2=20$ (see A-712)

Since the mounting method for the section between the nut and the bearing, where buckling is to be considered, is "fixed-fixed: "

Distance between two mounting surfaces $\ell_a=1100$ mm (estimate)

Screw-shaft thread minor diameter $d_1=17.5$ mm

$$P_1 = \eta_2 \cdot \frac{d_1^4}{\ell_a^2} \times 10^4 = 20 \times \frac{17.5^4}{1100^2} \times 10^4 = 15500 \text{ N}$$

■ Permissible Compressive and Tensile Load of the Screw Shaft

$$P_2 = 116 \times d_1^2 = 116 \times 17.5^2 = 35500 \text{ N}$$

Thus, the buckling load and the permissible compressive and the tensile load of the screw shaft are at least equal to the maximum axial load. Therefore, a Ball Screw that meets these requirements can be used without a problem.

● Studying the Permissible Rotational Speed

■ Maximum Rotational Speed

- Screw shaft diameter: 20 mm; lead: 20 mm

Maximum speed $V_{\max}=1$ m/s

Lead $Ph=20$ mm

$$N_{\max} = \frac{V_{\max} \times 60 \times 10^3}{Ph} = 3000 \text{ min}^{-1}$$

- Screw shaft diameter: 20 mm; lead: 40mm

Maximum speed $V_{\max}=1$ m/s

Lead $Ph=40$ mm

$$N_{\max} = \frac{V_{\max} \times 60 \times 10^3}{Ph} = 1500 \text{ min}^{-1}$$

- Screw shaft diameter: 30mm; lead: 60mm

Maximum speed $V_{\max}=1$ m/s

Lead $Ph=60$ mm

$$N_{\max} = \frac{V_{\max} \times 60 \times 10^3}{Ph} = 1000 \text{ min}^{-1}$$

■ **Permissible Rotational Speed Determined by the Dangerous Speed of the Screw Shaft**

Factor according to the mounting method $\lambda_2=15.1$ (see A-714)

Since the mounting method for the section between the nut and the bearing, where dangerous speed is to be considered, is "fixed-supported: "

Distance between two mounting surfaces $\ell_b=1100$ mm (estimate)

- Screw shaft diameter: 20 mm; lead: 20 mm and 40 mm

Screw-shaft thread minor diameter $d_1=17.5$ mm

$$N_1 = \lambda_2 \times \frac{d_1}{\ell_b^2} 10^7 = 15.1 \times \frac{17.5}{1100^2} \times 10^7 = 2180 \text{ min}^{-1}$$

- Screw shaft diameter: 30mm; lead: 60mm

Screw-shaft thread minor diameter $d_1=26.4$ mm

$$N_1 = \lambda_2 \times \frac{d_1}{\ell_b^2} 10^7 = 15.1 \times \frac{26.4}{1100^2} \times 10^7 = 3294 \text{ min}^{-1}$$

■ **Permissible Rotational Speed Determined by the DN Value**

- Screw shaft diameter: 20 mm; lead: 20 mm and 40mm (large lead Ball Screw)

Ball center-to-center diameter $D=20.75$ mm

$$N_2 = \frac{70000}{D} = \frac{70000}{20.75} = 3370 \text{ min}^{-1}$$

- Screw shaft diameter: 30 mm; lead: 60 mm (large lead Ball Screw)

Ball center-to-center diameter $D=31.25$ mm

$$N_2 = \frac{70000}{D} = \frac{70000}{31.25} = 2240 \text{ min}^{-1}$$

Thus, with a Ball Screw having a screw shaft diameter of 20 mm and a lead of 20 mm, the maximum rotational speed exceeds the dangerous speed.

In contrast, a combination of a screw shaft diameter of 20 mm and a lead of 40 mm, and another of a screw shaft diameter of 30 mm and a lead of 60 mm, meet the dangerous speed and the DN value. Accordingly, a Ball Screw with a screw shaft diameter of 20 mm and a lead of 40 mm, or with a screw shaft diameter of 30 mm and a lead of 60 mm, is selected.

[Selecting a Nut]

● **Selecting a Nut Model Number**

Rolled Ball Screw models with a screw shaft diameter of 20 mm and a lead of 40 mm, or with a screw shaft diameter of 30 mm and a lead of 60 mm, are large lead Rolled Ball Screw model WTF variations.

- WTF2040-2
(Ca=5.4 kN, C₀a=13.6 kN)
- WTF2040-3
(Ca=6.6 kN, C₀a=17.2 kN)
- WTF3060-2
(Ca=11.8 kN, C₀a=30.6 kN)
- WTF3060-3
(Ca=14.5 kN, C₀a=38.9 kN)

● **Studying the Permissible Axial Load**

Study the permissible axial load of model WTF2040-2 ($C_0a = 13.6$ kN).

Assuming that this model is used in high-speed transfer equipment and an impact load is applied during deceleration, set the static safety factor (f_s) at 2.5 (see Table21 on A-721).

$$\frac{C_0a}{f_s} = \frac{13.6}{2.5} = 5.44 \text{ kN} = 5440 \text{ N}$$

The obtained permissible axial load is greater than the maximum axial load of 550 N, and therefore, there will be no problem with this model.

■ **Calculating the Travel Distance**

Maximum speed $V_{\max} = 1$ m/s

Acceleration time $t_1 = 0.15$ s

Deceleration time $t_3 = 0.15$ s

● Travel distance during acceleration

$$\ell_{1,4} = \frac{V_{\max} \cdot t_1}{2} \times 10^3 = \frac{1 \times 0.15}{2} \times 10^3 = 75 \text{ mm}$$

● Travel distance during uniform motion

$$\ell_{2,5} = \ell_s - \frac{V_{\max} \cdot t_1 + V_{\max} \cdot t_3}{2} \times 10^3 = 1000 - \frac{1 \times 0.15 + 1 \times 0.15}{2} \times 10^3 = 850 \text{ mm}$$

● Travel distance during deceleration

$$\ell_{3,6} = \frac{V_{\max} \cdot t_3}{2} \times 10^3 = \frac{1 \times 0.15}{2} \times 10^3 = 75 \text{ mm}$$

Based on the conditions above, the relationship between the applied axial load and the travel distance is shown in the table below.

Motion	Applied axial load $F_{a(N)}$	Travel distance $\ell_N(\text{mm})$
No.1: During forward acceleration	550	75
No.2: During forward uniform motion	17	850
No.3: During forward deceleration	-516	75
No.4: During backward acceleration	-550	75
No.5: During uniform backward motion	-17	850
No.6: During backward deceleration	516	75

* The subscript (N) indicates a motion number.

Since the load direction (as expressed in positive or negative sign) is reversed with F_{a3} , F_{a4} and F_{a5} , calculate the average axial load in the two directions.

■Average Axial Load

- Average axial load in the positive direction
Since the load direction varies, calculate the average axial load while assuming $F_{a_{3,4,5}} = 0\text{N}$.

$$F_{m1} = \sqrt[3]{\frac{F_{a1}^3 \times l_1 + F_{a2}^3 \times l_2 + F_{a6}^3 \times l_6}{l_1 + l_2 + l_3 + l_4 + l_5 + l_6}} = 225 \text{ N}$$

- Average axial load in the negative direction
Since the load direction varies, calculate the average axial load while assuming $F_{a_{1,2,6}} = 0\text{N}$.

$$F_{m2} = \sqrt[3]{\frac{|F_{a3}|^3 \times l_3 + |F_{a4}|^3 \times l_4 + |F_{a5}|^3 \times l_5}{l_1 + l_2 + l_3 + l_4 + l_5 + l_6}} = 225 \text{ N}$$

Since $F_{m1} = F_{m2}$, assume the average axial load to be $F_m = F_{m1} = F_{m2} = 225 \text{ N}$.

■Nominal Life

- Load factor $f_w = 1.5$ (see Table22 on A-722)
Average load $F_m = 225 \text{ N}$
Nominal life L (rev)

$$L = \left(\frac{C_a}{f_w \cdot F_m} \right)^3 \times 10^6$$

Assumed model number	Dynamic load rating $C_a(\text{N})$	Nominal life $L(\text{rev})$
WTF 2040-2	5400	4.1×10^9
WTF 2040-3	6600	7.47×10^9
WTF 3060-2	11800	4.27×10^{10}
WTF 3060-3	14500	7.93×10^{10}

■Average Revolutions per Minute

Number of reciprocations per minute $n = 8 \text{ min}^{-1}$
Stroke $\ell_s = 1000 \text{ mm}$

- Lead: $Ph = 40 \text{ mm}$

$$N_m = \frac{2 \times n \times \ell_s}{Ph} = \frac{2 \times 8 \times 1000}{40} = 400 \text{ min}^{-1}$$

- Lead: $Ph = 60 \text{ mm}$

$$N_m = \frac{2 \times n \times \ell_s}{Ph} = \frac{2 \times 8 \times 1000}{60} = 267 \text{ min}^{-1}$$

■Calculating the Service Life Time on the Basis of the Nominal Life

- WTF2040-2

Nominal life $L = 4.1 \times 10^9 \text{ rev}$
Average revolutions per minute $N_m = 400 \text{ min}^{-1}$

$$L_h = \frac{L}{60 \times N_m} = \frac{4.1 \times 10^9}{60 \times 400} = 171000 \text{ h}$$

- WTF2040-3

Nominal life $L = 7.47 \times 10^9 \text{ rev}$
Average revolutions per minute $N_m = 400 \text{ min}^{-1}$

$$L_h = \frac{L}{60 \times N_m} = \frac{7.47 \times 10^9}{60 \times 400} = 311000 \text{ h}$$

- WTF3060-2

Nominal life $L = 4.27 \times 10^{10} \text{ rev}$
Average revolutions per minute $N_m = 267 \text{ min}^{-1}$

$$L_h = \frac{L}{60 \times N_m} = \frac{4.27 \times 10^{10}}{60 \times 267} = 2670000 \text{ h}$$

- WTF3060-3

Nominal life $L = 7.93 \times 10^{10} \text{ rev}$
Average revolutions per minute $N_m = 267 \text{ min}^{-1}$

$$L_h = \frac{L}{60 \times N_m} = \frac{7.93 \times 10^{10}}{60 \times 267} = 4950000 \text{ h}$$

■Calculating the Service Life in Travel Distance on the Basis of the Nominal Life

● WTF2040-2

Nominal life $L=4.1 \times 10^9$ rev

Lead $Ph=40$ mm

$$L_s = L \times Ph \times 10^{-6} = 164000 \text{ km}$$

● WTF2040-3

Nominal life $L=7.47 \times 10^9$ rev

Lead $Ph=40$ mm

$$L_s = L \times Ph \times 10^{-6} = 298800 \text{ km}$$

● WTF3060-2

Nominal life $L=4.27 \times 10^{10}$ rev

Lead $Ph=60$ mm

$$L_s = L \times Ph \times 10^{-6} = 2562000 \text{ km}$$

● WTF3060-3

Nominal life $L=7.93 \times 10^{10}$ rev

Lead $Ph=60$ mm

$$L_s = L \times Ph \times 10^{-6} = 4758000 \text{ km}$$

With all the conditions stated above, the following models satisfying the desired service life time of 30,000 hours are selected.

WTF 2040-2

WTF 2040-3

WTF 3060-2

WTF 3060-3

[Studying the Rigidity]

Since the conditions for selection do not include rigidity and this element is not particularly necessary, it is not described here.

[Studying the Positioning Accuracy]

● Studying the Lead Angle Accuracy

Accuracy grade C7 was selected in Section [Selecting Lead Angle Accuracy and Axial Clearance] on A-741.

C7 (travel distance error: $\pm 0.05\text{mm}/300\text{mm}$)

● Studying the Axial Clearance

Since positioning is performed in a given direction only, axial clearance is not included in the positioning accuracy. As a result, there is no need to study the axial clearance.

WTF2040: axial clearance: 0.1 mm

WTF3060: axial clearance: 0.14 mm

● Studying the Axial Rigidity

Since the load direction does not change, it is unnecessary to study the positioning accuracy on the basis of the axial rigidity.

● Studying the Thermal Displacement through Heat Generation

Assume the temperature rise during operation to be 5°C .

The positioning accuracy based on the temperature rise is obtained as follows:

$$\begin{aligned}\Delta l &= \rho \times \Delta t \times l \\ &= 12 \times 10^{-6} \times 5 \times 1000 \\ &= 0.06 \text{ mm}\end{aligned}$$

● Studying the Orientation Change during Traveling

Since the ball screw center is 150 mm away from the point where the highest accuracy is required, it is necessary to study the orientation change during traveling.

Assume that pitching can be done within ± 10 seconds because of the structure. The positioning error due to the pitching is obtained as follows:

$$\begin{aligned}\Delta a &= l \times \sin\theta \\ &= 150 \times \sin(\pm 10'') \\ &= \pm 0.007 \text{ mm}\end{aligned}$$

Thus, the positioning accuracy (Δp) is obtained as follows:

$$\Delta p = \frac{\pm 0.05 \times 1000}{300} \pm 0.007 + 0.06 = 0.234 \text{ mm}$$

Since models WTF2040-2, WTF2040-3, WTF3060-2 and WTF3060-3 meet the selection requirements throughout the studying process in Section [Selecting Lead Angle Accuracy and Axial Clearance] on A-741 to Section [Studying the Positioning Accuracy] on A-750, the most compact model WTF2040-2 is selected.

[Studying the Rotational Torque]

● **Friction Torque Due to an External Load**

The friction torque is obtained as follows:

$$T_1 = \frac{F_a \cdot Ph}{2\pi \cdot \eta} \cdot A = \frac{17 \times 40}{2 \times \pi \times 0.9} \times 1 = 120 \text{ N} \cdot \text{mm}$$

● **Torque Due to a Preload on the Ball Screw**

The Ball Screw is not provided with a preload.

● **Torque Required for Acceleration**

Inertial Moment

Since the inertial moment per unit length of the screw shaft is $1.23 \times 10^{-3} \text{ kg} \cdot \text{cm}^2/\text{mm}$ (see the specification table), the inertial moment of the screw shaft with an overall length of 1200 mm is obtained as follows.

$$\begin{aligned} J_s &= 1.23 \times 10^{-3} \times 1200 = 1.48 \text{ kg} \cdot \text{cm}^2 \\ &= 1.48 \times 10^{-4} \text{ kg} \cdot \text{m}^2 \end{aligned}$$

$$\begin{aligned} J &= (m_1 + m_2) \left(\frac{Ph}{2 \times \pi} \right)^2 \cdot A^2 \times 10^{-6} + J_s \cdot A^2 = (60 + 20) \left(\frac{40}{2 \times \pi} \right)^2 \times 1^2 \times 10^{-6} + 1.48 \times 10^{-4} \times 1^2 \\ &= 3.39 \times 10^{-3} \text{ kg} \cdot \text{m}^2 \end{aligned}$$

Angular acceleration:

$$\omega' = \frac{2\pi \cdot \text{Nm}}{60 \cdot t_1} = \frac{2\pi \times 1500}{60 \times 0.15} = 1050 \text{ rad/s}^2$$

Based on the above, the torque required for acceleration is obtained as follows.

$$\begin{aligned} T_2 &= (J + J_m) \times \omega' = (3.39 \times 10^{-3} + 1 \times 10^{-3}) \times 1050 = 4.61 \text{ N} \cdot \text{m} \\ &= 4.61 \times 10^3 \text{ N} \cdot \text{mm} \end{aligned}$$

Therefore, the required torque is specified as follows.

During acceleration

$$T_k = T_1 + T_2 = 120 + 4.61 \times 10^3 = 4730 \text{ N} \cdot \text{mm}$$

During uniform motion

$$T_i = T_1 = 120 \text{ N} \cdot \text{mm}$$

During deceleration

$$T_g = T_i - T_2 = 120 - 4.61 \times 10^3 = -4490 \text{ N} \cdot \text{mm}$$

[Studying the Driving Motor]

● Rotational Speed

Since the Ball Screw lead is selected based on the rated rotational speed of the motor, it is unnecessary to study the rotational speed of the motor.

Maximum working rotational speed: 1500 min^{-1}

Rated rotational speed of the motor: 3000 min^{-1}

● Minimum Feed Amount

As with the rotational speed, the Ball Screw lead is selected based on the encoder normally used for an AC servomotor. Therefore, it is unnecessary to study this factor.

Encoder resolution : 1000 p/rev .

Doubled : 2000 p/rev

● Motor Torque

The torque during acceleration calculated in Section [Studying the Rotational Torque] on A-751 is the required maximum torque.

$$T_{\text{max}} = 4730 \text{ N} \cdot \text{mm}$$

Therefore, the instantaneous maximum torque of the AC servomotor needs to be at least $4,730 \text{ N} \cdot \text{mm}$.

● Effective Torque Value

The selection requirements and the torque calculated in Section [Studying the Rotational Torque] on A-751 can be expressed as follows.

During acceleration:

$$T_k = 4730 \text{ N} \cdot \text{mm}$$

$$t_1 = 0.15 \text{ s}$$

During uniform motion:

$$T_t = 120 \text{ N} \cdot \text{mm}$$

$$t_2 = 0.85 \text{ s}$$

During deceleration:

$$T_g = 4490 \text{ N} \cdot \text{mm}$$

$$t_3 = 0.15 \text{ s}$$

When stationary:

$$T_s = 0$$

$$t_4 = 2.6 \text{ s}$$

The effective torque is obtained as follows, and the rated torque of the motor must be $1305 \text{ N} \cdot \text{mm}$ or greater.

$$\begin{aligned} T_{\text{rms}} &= \sqrt{\frac{T_k^2 \cdot t_1 + T_t^2 \cdot t_2 + T_g^2 \cdot t_3 + T_s^2 \cdot t_4}{t_1 + t_2 + t_3 + t_4}} = \sqrt{\frac{4730^2 \times 0.15 + 120^2 \times 0.85 + 4490^2 \times 0.15 + 0}{0.15 + 0.85 + 0.15 + 2.6}} \\ &= 1305 \text{ N} \cdot \text{mm} \end{aligned}$$

● Inertial Moment

The inertial moment applied to the motor equals to the inertial moment calculated in Section [Studying the Rotational Torque] on A-751.

$$J = 3.39 \times 10^{-3} \text{ kg} \cdot \text{m}^2$$

Normally, the motor needs to have an inertial moment at least one tenth of the inertial moment applied to the motor, although the specific value varies depending on the motor manufacturer.

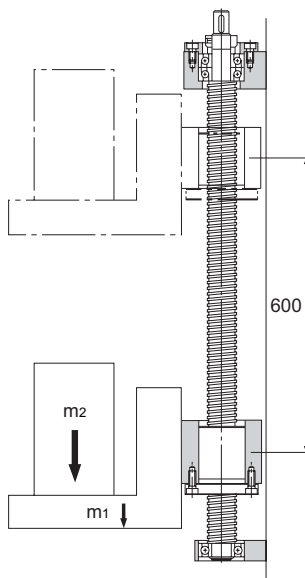
Therefore, the inertial moment of the AC servomotor must be $3.39 \times 10^{-4} \text{ kg} \cdot \text{m}^2$ or greater.

The selection has been completed.

Vertical Conveyance System

[Selection Conditions]

Table Mass	$m_1 = 40\text{kg}$
Work Mass	$m_2 = 10\text{kg}$
Stroke length	$l_s = 600\text{mm}$
Maximum speed	$V_{\max} = 0.3\text{m/s}$
Acceleration time	$t_a = 0.2\text{s}$
Deceleration time	$t_d = 0.2\text{s}$
Number of reciprocations per minute	$n = 5\text{min}^{-1}$
Backlash	0.1mm
Positioning accuracy	$\pm 0.7\text{mm}/600\text{mm}$
Positioning Repeatability	$\pm 0.05\text{mm}$
Minimum feed amount	$s = 0.01\text{mm/pulse}$
Service life time	20000h
Driving motor	AC servo motor
	Rated rotational speed: $3,000\text{ min}^{-1}$
Inertial moment of the motor	$J_m = 5 \times 10^{-5} \text{ kg} \cdot \text{m}^2$
Reduction gear	None (direct coupling)
Frictional coefficient of the guide surface	$\mu = 0.003$ (rolling)
Guide surface resistance	$f = 20 \text{ N}$ (without load)



[Selection Items]

Screw shaft diameter
Lead
Nut model No.
Accuracy
Axial clearance
Screw shaft support method
Driving motor

[Selecting Lead Angle Accuracy and Axial Clearance]

● **Selecting the Lead Angle Accuracy**

To achieve positioning accuracy of $\pm 0.7\text{mm}/600\text{mm}$:

$$\frac{\pm 0.7}{600} = \frac{\pm 0.35}{300}$$

The lead angle accuracy must be $\pm 0.35\text{mm}/300\text{ mm}$ or higher.

Therefore, the accuracy grade of the Ball Screw (see Table1 on A-696) needs to be C10 (travel distance error: $\pm 0.21\text{ mm}/300\text{ mm}$).

Accuracy grade C10 is available for low priced, Rolled Ball Screws. Assume that a Rolled Ball Screw is selected.

● **Selecting the Axial Clearance**

The required backlashes is 0.1 mm or less. However, since an axial load is constantly applied in a single direction with vertical mount, the axial load does not serve as a backlash no matter how large it is.

Therefore, a low price, rolled Ball Screw is selected since there will not be a problem in axial clearance.

[Selecting a Screw Shaft]

● **Assuming the Screw Shaft Length**

Assume the overall nut length to be 100 mm and the screw shaft end length to be 100 mm.

Therefore, the overall length is determined as follows based on the stroke length of 600mm.

$$600 + 200 = 800\text{ mm}$$

Thus, the screw shaft length is assumed to be 800 mm.

● **Selecting the Lead**

With the driving motor's rated rotational speed being $3,000\text{ min}^{-1}$ and the maximum speed 0.3 m/s , the Ball Screw lead is obtained as follows:

$$\frac{0.3 \times 60 \times 1000}{3000} = 6\text{ mm}$$

Therefore, it is necessary to select a type with a lead of 6mm or longer.

In addition, the Ball Screw and the motor can be mounted in direct coupling without using a reduction gear. The minimum resolution per revolution of an AC servomotor is obtained based on the resolution of the encoder (1,000 p/rev; 1,500 p/rev) provided as a standard accessory for the AC servomotor, as indicated below.

- 1000 p/rev(without multiplication)
- 1500 p/rev(without multiplication)
- 2000 p/rev(doubled)
- 3000 p/rev(doubled)
- 4000 p/rev(quadupled)
- 6000 p/rev(quadupled)

To meet the minimum feed amount of 0.010mm/pulse, which is the selection requirement, the following should apply.

Lead	6mm	—	3000 p/rev
	8mm	—	4000 p/rev
	10mm	—	1000 p/rev
	20mm	—	2000 p/rev
	40mm	—	2000 p/rev

However, with the lead being 6 mm or 8 mm, the feed distance is 0.002 mm/pulse, and the starting pulse of the controller that issues commands to the motor driver needs to be at least 150 kpps, and the cost of the controller may be higher.

In addition, if the lead of the Ball Screw is greater, the torque required for the motor is also greater, and thus the cost will be higher.

Therefore, select 10 mm for the Ball Screw lead.

● **Selecting the Screw Shaft Diameter**

Those Ball Screw models that meet the lead being 10 mm as described in Section [Selecting Lead Angle Accuracy and Axial Clearance] on A-755 and Section [Selecting a Screw Shaft] on A-755 (see Table20 on A-711) are as follows.

Shaft diameter	Lead
15mm	— 10mm
20mm	— 10mm
25mm	— 10mm

Accordingly, the combination of a screw shaft diameter of 15 mm and a lead 10 mm is selected.

● **Selecting the Screw Shaft Support Method**

Since the assumed Ball Screw has a stroke length of 600 mm and operates at a maximum speed of 0.3 m/s (Ball Screw rotational speed: 1,800 min⁻¹), select the fixed-supported configuration for the screw shaft support.

● Studying the Permissible Axial Load

■ Calculating the Maximum Axial Load

Guide surface resistance	$f=20$ N (without load)
Table Mass	$m_1=40$ kg
Work Mass	$m_2=10$ kg
Maximum speed	$V_{\max}=0.3$ m/s
Acceleration time	$t_1=0.2$ s

Accordingly, the required values are obtained as follows.

Acceleration

$$\alpha = \frac{V_{\max}}{t_1} = 1.5 \text{ m/s}^2$$

During upward acceleration:

$$Fa_1 = (m_1 + m_2) \cdot g + f + (m_1 + m_2) \cdot \alpha = 585 \text{ N}$$

During upward uniform motion:

$$Fa_2 = (m_1 + m_2) \cdot g + f = 510 \text{ N}$$

During upward deceleration:

$$Fa_3 = (m_1 + m_2) \cdot g + f - (m_1 + m_2) \cdot \alpha = 435 \text{ N}$$

During downward acceleration:

$$Fa_4 = (m_1 + m_2) \cdot g - f - (m_1 + m_2) \cdot \alpha = 395 \text{ N}$$

During downward uniform motion:

$$Fa_5 = (m_1 + m_2) \cdot g - f = 470 \text{ N}$$

During downward deceleration:

$$Fa_6 = (m_1 + m_2) \cdot g - f + (m_1 + m_2) \cdot \alpha = 545 \text{ N}$$

Thus, the maximum axial load applied on the Ball Screw is as follows:

$$Fa_{\max} = Fa_1 = 585 \text{ N}$$

■ Buckling Load of the Screw Shaft

Factor according to the mounting method $\eta_2=20$ (see A-712)

Since the mounting method for the section between the nut and the bearing, where buckling is to be considered, is "fixed-fixed: "

Distance between two mounting surfaces $\ell_a=700$ mm (estimate)

Screw-shaft thread minor diameter $d_i=12.5$ mm

$$P_1 = \eta_2 \cdot \frac{d_i^4}{\ell_a^2} \times 10^4 = 20 \times \frac{12.5^4}{700^2} \times 10^4 = 9960 \text{ N}$$

■ Permissible Compressive and Tensile Load of the Screw Shaft

$$P_2 = 116d_i^2 = 116 \times 12.5^2 = 18100 \text{ N}$$

Thus, the buckling load and the permissible compressive and tensile load of the screw shaft are at least equal to the maximum axial load. Therefore, a Ball Screw that meets these requirements can be used without a problem.

● Studying the Permissible Rotational Speed

■ Maximum Rotational Speed

- Screw shaft diameter: 15mm; lead: 10mm

Maximum speed $V_{\max}=0.3 \text{ m/s}$

Lead $Ph=10 \text{ mm}$

$$N_{\max} = \frac{V_{\max} \times 60 \times 10^3}{Ph} = 1800 \text{ min}^{-1}$$

■ Permissible Rotational Speed Determined by the Dangerous Speed of the Screw Shaft

Factor according to the mounting method $\lambda_2=15.1$ (see A-714)

Since the mounting method for the section between the nut and the bearing, where dangerous speed is to be considered, is "fixed-supported: "

Distance between two mounting surfaces $\ell_b=700 \text{ mm}$ (estimate)

- Screw shaft diameter: 15mm; lead: 10mm

Screw-shaft thread minor diameter $d_i=12.5 \text{ mm}$

$$N_1 = \lambda_2 \times \frac{d_i}{\ell_b^2} 10^7 = 15.1 \times \frac{12.5}{700^2} \times 10^7 = 3852 \text{ min}^{-1}$$

■ Permissible Rotational Speed Determined by the DN Value

- Screw shaft diameter: 15mm; lead: 10mm (large lead Ball Screw)

Ball center-to-center diameter $D=15.75 \text{ mm}$

$$N_2 = \frac{70000}{D} = \frac{70000}{15.75} = 4444 \text{ min}^{-1}$$

Thus, the dangerous speed and the DN value of the screw shaft are met.

[Selecting a Nut]

● **Selecting a Nut Model Number**

The Rolled Ball Screw with a screw shaft diameter of 15 mm and a lead of 10 mm is the following large-lead Rolled Ball Screw model.

BLK1510-5.6
(Ca=9.8 kN, C₀a=25.2 kN)

● **Studying the Permissible Axial Load**

Assuming that an impact load is applied during an acceleration and a deceleration, set the static safety factor (f_s) at 2 (see Table 21 on A-721).

$$F_{a_{max}} = \frac{C_0 a}{f_s} = \frac{25.2}{2} = 12.6 \text{ kN} = 12600 \text{ N}$$

The obtained permissible axial load is greater than the maximum axial load of 585 N, and therefore, there will be no problem with this model.

● **Studying the Service Life**

■ **Calculating the Travel Distance**

Maximum speed V_{max}=0.3 m/s
Acceleration time t₁ = 0.2s
Deceleration time t₃ = 0.2s

● Travel distance during acceleration

$$\ell_{1,4} = \frac{V_{max} \cdot t_1}{2} \times 10^3 = \frac{1.3 \times 0.2}{2} \times 10^3 = 30 \text{ mm}$$

● Travel distance during uniform motion

$$\ell_{2,5} = \ell_s - \frac{V_{max} \cdot t_1 + V_{max} \cdot t_3}{2} \times 10^3 = 600 - \frac{0.3 \times 0.2 + 0.3 \times 0.2}{2} \times 10^3 = 540 \text{ mm}$$

● Travel distance during deceleration

$$\ell_{3,6} = \frac{V_{max} \cdot t_3}{2} \times 10^3 = \frac{0.3 \times 0.2}{2} \times 10^3 = 30 \text{ mm}$$

Based on the conditions above, the relationship between the applied axial load and the travel distance is shown in the table below.

Motion	Applied axial load F _a (N)	Travel distance ℓ _N (mm)
No1: During upward acceleration	585	30
No2: During upward uniform motion	510	540
No3: During upward deceleration	435	30
No4: During downward acceleration	395	30
No5: During downward uniform motion	470	540
No6: During downward deceleration	545	30

* The subscript (N) indicates a motion number.

■Average Axial Load

$$F_m = \sqrt[3]{\frac{1}{2 \times \ell_s} (F_{a_1}^3 \cdot \ell_1 + F_{a_2}^3 \cdot \ell_2 + F_{a_3}^3 \cdot \ell_3 + F_{a_4}^3 \cdot \ell_4 + F_{a_5}^3 \cdot \ell_5 + F_{a_6}^3 \cdot \ell_6)} = 225 \text{ N}$$

■Nominal Life

Dynamic load rating	Ca= 9800 N
Load factor	f _w = 1.5 (see Table 22 on A-722)
Average load	F _m = 492 N
Nominal life	L (rev)

$$L = \left(\frac{C_a}{f_w \cdot F_m} \right)^3 \times 10^6 = \left(\frac{9800}{1.5 \times 492} \right)^3 \times 10^6 = 2.34 \times 10^9 \text{ rev}$$

■Average Revolutions per Minute

Number of reciprocations per minute	n = 5 min ⁻¹
Stroke	ℓ _s =600 mm
Lead	Ph= 10 mm

$$N_m = \frac{2 \times n \times \ell_s}{Ph} = \frac{2 \times 5 \times 600}{10} = 600 \text{ min}^{-1}$$

■Calculating the Service Life Time on the Basis of the Nominal Life

Nominal life	L=2.34 × 10 ⁹ rev
Average revolutions per minute	N _m = 600 min ⁻¹

$$L_h = \frac{L}{60 \cdot N_m} = \frac{2.34 \times 10^9}{60 \times 600} = 65000 \text{ h}$$

■Calculating the Service Life in Travel Distance on the Basis of the Nominal Life

Nominal life	L=2.34 × 10 ⁹ rev
Lead	Ph= 10 mm
L _s = L × Ph × 10 ⁻⁶	= 23400 km

With all the conditions stated above, model BLK1510-5.6 satisfies the desired service life time of 20,000 hours.

[Studying the Rigidity]

Since the conditions for selection do not include rigidity and this element is not particularly necessary, it is not described here.

[Studying the Positioning Accuracy]

● **Studying the Lead Angle Accuracy**

Accuracy grade C10 was selected in Section [Selecting Lead Angle Accuracy and Axial Clearance] on A-755.

C10 (travel distance error: $\pm 0.21\text{mm}/300\text{mm}$)

● **Studying the Axial Clearance**

Since the axial load is constantly present in a given direction only because of vertical mount, there is no need to study the axial clearance.

● **Studying the Axial Rigidity**

Since the lead angle accuracy is achieved beyond the required positioning accuracy, there is no need to study the positioning accuracy determined by axial rigidity.

● **Studying the Thermal Displacement through Heat Generation**

Since the lead angle accuracy is achieved beyond the required positioning accuracy, there is no need to study the positioning accuracy determined by the heat generation.

● **Studying the Orientation Change during Traveling**

Since the lead angle accuracy is achieved at a much higher degree than the required positioning accuracy, there is no need to study the positioning accuracy.

[Studying the Rotational Torque]

● **Frictional Torque Due to an External Load**

During upward uniform motion:

$$T_1 = \frac{F_{a2} \cdot Ph}{2 \times \pi \times \eta} = \frac{510 \times 10}{2 \times \pi \times 0.9} = 900 \text{ N} \cdot \text{mm}$$

During downward uniform motion:

$$T_2 = \frac{F_{a5} \cdot Ph}{2 \times \pi \times \eta} = \frac{470 \times 10}{2 \times \pi \times 0.9} = 830 \text{ N} \cdot \text{mm}$$

● **Torque Due to a Preload on the Ball Screw**

The Ball Screw is not provided with a preload.

● Torque Required for Acceleration

Inertial Moment:

Since the inertial moment per unit length of the screw shaft is $3.9 \times 10^{-4} \text{ kg} \cdot \text{cm}^2/\text{mm}$ (see the specification table), the inertial moment of the screw shaft with an overall length of 800mm is obtained as follows.

$$\begin{aligned} J_s &= 3.9 \times 10^{-4} \times 800 = 0.31 \text{ kg} \cdot \text{cm}^2 \\ &= 0.31 \times 10^{-4} \text{ kg} \cdot \text{m}^2 \end{aligned}$$

$$\begin{aligned} J &= (m_1 + m_2) \left(\frac{Ph}{2 \times \pi} \right)^2 \cdot A^2 \times 10^{-6} + J_s \cdot A^2 = (40 + 10) \left(\frac{10}{2 \times \pi} \right)^2 \times 1^2 \times 10^{-6} + 0.31 \times 10^{-4} \times 1^2 \\ &= 1.58 \times 10^{-4} \text{ kg} \cdot \text{m}^2 \end{aligned}$$

Angular acceleration:

$$\omega' = \frac{2\pi \cdot \text{Nm}}{60 \cdot t} = \frac{2\pi \times 1800}{60 \times 0.2} = 942 \text{ rad/s}^2$$

Based on the above, the torque required for acceleration is obtained as follows.

$$T_3 = (J + J_m) \cdot \omega' = (1.58 \times 10^{-4} + 5 \times 10^{-6}) \times 942 = 0.2 \text{ N} \cdot \text{m} = 200 \text{ N} \cdot \text{mm}$$

Therefore, the required torque is specified as follows.

During upward acceleration:

$$T_{K1} = T_1 + T_3 = 900 + 200 = 1100 \text{ N} \cdot \text{mm}$$

During upward uniform motion:

$$T_{I1} = T_1 = 900 \text{ N} \cdot \text{mm}$$

During upward deceleration:

$$T_{g1} = T_1 - T_3 = 900 - 200 = 700 \text{ N} \cdot \text{mm}$$

During downward acceleration:

$$T_{K2} = 630 \text{ N} \cdot \text{mm}$$

During downward uniform motion:

$$T_{I2} = 830 \text{ N} \cdot \text{mm}$$

During downward deceleration:

$$T_{g2} = 1030 \text{ N} \cdot \text{mm}$$

[Studying the Driving Motor]

● **Rotational Speed**

Since the Ball Screw lead is selected based on the rated rotational speed of the motor, it is unnecessary to study the rotational speed of the motor.

Maximum working rotational speed: 1800 min^{-1}

Rated rotational speed of the motor: 3000 min^{-1}

● **Minimum Feed Amount**

As with the rotational speed, the Ball Screw lead is selected based on the encoder normally used for an AC servomotor. Therefore, it is unnecessary to study this factor.

Encoder resolution: 1000 p/rev .

● **Motor Torque**

The torque during acceleration calculated in Section [Studying the Rotational Torque] on A-761 is the required maximum torque.

$$T_{\max} = T_{k1} = 1100 \text{ N} \cdot \text{mm}$$

Therefore, the maximum peak torque of the AC servomotor needs to be at least $1100 \text{ N} \cdot \text{mm}$.

● **Effective Torque Value**

The selection requirements and the torque calculated in Section [Studying the Rotational Torque] on A-761 can be expressed as follows.

During upward acceleration:

$$T_{k1} = 1100 \text{ N} \cdot \text{mm}$$

$$t_1 = 0.2 \text{ s}$$

During upward uniform motion:

$$T_{t1} = 900 \text{ N} \cdot \text{mm}$$

$$t_2 = 1.8 \text{ s}$$

During upward deceleration:

$$T_{g1} = 700 \text{ N} \cdot \text{mm}$$

$$t_3 = 0.2 \text{ s}$$

During downward acceleration:

$$T_{k2} = 630 \text{ N} \cdot \text{mm}$$

$$t_1 = 0.2 \text{ s}$$

During downward uniform motion:

$$T_{t2} = 830 \text{ N} \cdot \text{mm}$$

$$t_2 = 1.8 \text{ s}$$

During downward deceleration:

$$T_{g2} = 1030 \text{ N} \cdot \text{mm}$$

$$t_3 = 0.2 \text{ s}$$

When stationary ($m_2=0$):

$$T_s = 658 \text{ N} \cdot \text{mm}$$

$$t_4 = 7.6 \text{ s}$$

The effective torque is obtained as follows, and the rated torque of the motor must be 743 N•mm or greater.

$$T_{rms} = \sqrt{\frac{T_{k1}^2 \cdot t_1 + T_{t1}^2 \cdot t_2 + T_{g1}^2 \cdot t_3 + T_{k2}^2 \cdot t_1 + T_{t2}^2 \cdot t_2 + T_{g2}^2 \cdot t_3 + T_s^2 \cdot t_4}{t_1 + t_2 + t_3 + t_1 + t_2 + t_3 + t_4}}$$

$$= \sqrt{\frac{1100^2 \times 0.2 + 900^2 \times 1.8 + 700^2 \times 0.2 + 630^2 \times 0.2 + 830^2 \times 1.8 + 1030^2 \times 0.2 + 658^2 \times 7.6}{0.2 + 1.8 + 0.2 + 0.2 + 1.8 + 0.2 + 7.6}}$$

$$= 743 \text{ N} \cdot \text{mm}$$

● Inertial Moment

The inertial moment applied to the motor equals to the inertial moment calculated in Section [Studying the Rotational Torque] on A-761.

$$J = 1.58 \times 10^{-4} \text{ kg} \cdot \text{m}^2$$

Normally, the motor needs to have an inertial moment at least one tenth of the inertial moment applied to the motor, although the specific value varies depending on the motor manufacturer.

Therefore, the inertial moment of the AC servomotor must be $1.58 \times 10^{-5} \text{ kg} \cdot \text{m}^2$ or greater.

The selection has been completed.

Ball Screw

Accuracy of Each Model

DIN Standard Compliant Ball Screw

Models EBA, EBB, EBC, EPA, EPB and EPC

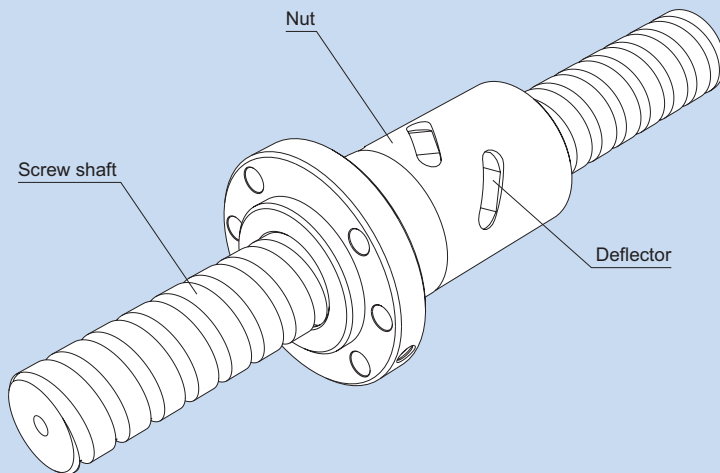


Fig.1 DIN Standard (DIN69051-1989) Compliant Precision Ball Screw

Structure and Features	▶▶▶ A-767
Types and Features	▶▶▶ A-768
Service Life	▶▶▶ A-722
Axial Clearance	▶▶▶ A-703
Accuracy Standards	▶▶▶ A-769
Dimensional Drawing, Dimensional Table, Example of Model Number Coding	▶▶▶ B-602

Structure and Features

In the DIN standard compliant Ball Screw, balls under a load roll in the raceway cut between the screw shaft and the nut while receiving the axial load, travel along the groove of a deflector embedded inside the nut to the adjacent raceway, and then circulate back to the loaded area. Thus, the balls perform infinite rolling motion.

Two types of nuts are available: model EB of over-ball preloaded type or non-preloaded type, and model EP of offset preloaded type.

[Compact]

This Ball Screw is compactly built. Because of an internal circulation system using deflectors, the outer diameter of the nut is 70 to 80% of the conventional double nut and the overall nut length is only 60 to 80% of the return pipe nut.

[Compliant with a DIN standard]

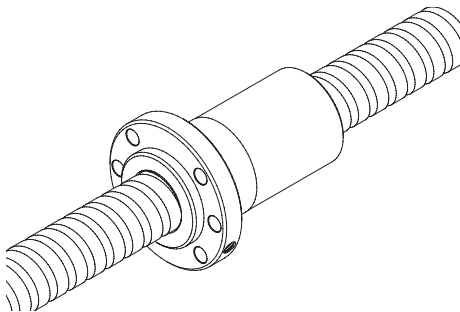
The nut flange shape, mounting holes and rated load are compliant with DIN69051.

Types and Features

Models EPA/EBA

Specification Table⇒B-608/B-602

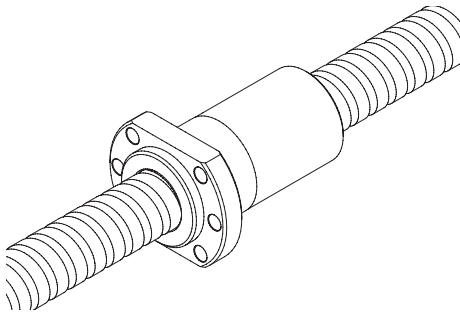
[Flange shape: round-flange type]



Models EPB/EBB

Specification Table⇒B-610/B-604

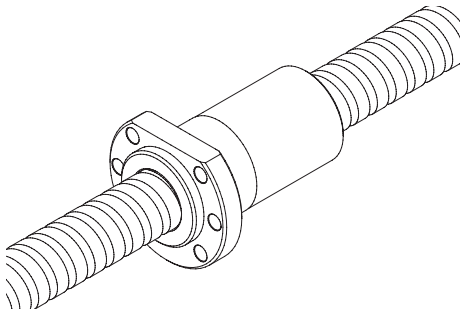
[Flange shape: type with two cut faces]



Models EPC/EBC

Specification Table⇒B-612/B-606

[Flange shape: type with one cut face]



Service Life

For details, see A-722.

Axial Clearance

For details, see A-703.

Accuracy Standards

The accuracy of the DIN standard compliant Ball Screw is controlled in accordance with an ISO standard (ISO3408-3) and a JIS standard (JIS B1192-1997), and Cp and Ct grades are defined for this Ball Screw series.

Precision, Caged Ball Screw



Models SBN, SBK and HBN

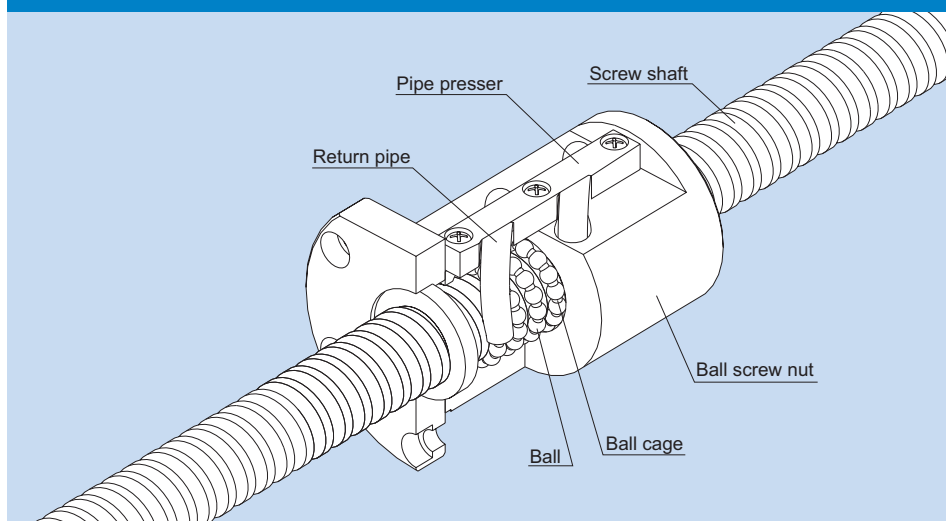


Fig.1 Structure of High-Speed Ball Screw with Ball Cage Model SBN

Structure and Features	▶▶▶ A-771
Ball Cage Effect	▶▶▶ A-771
Types and Features	▶▶▶ A-774
Service Life	▶▶▶ A-722
Axial Clearance	▶▶▶ A-703
Accuracy Standards	▶▶▶ A-696
Dimensional Drawing, Dimensional Table, Example of Model Number Coding	▶▶▶ B-616

Structure and Features

The use of a ball cage in the Ball Screw with the Ball Cage eliminates collision and friction between balls and increases the grease retention. This makes it possible to achieve a low noise, a low torque fluctuation and a long-term maintenance-free operation.

In addition, this Ball Screw is superbly capable of responding to the high speed because of an ideal ball recirculation structure, a strengthened circulation path and an adoption of the ball cage.

Ball Cage Effect

[Low Noise, Acceptable Running Sound]

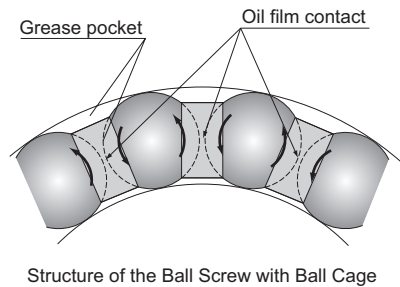
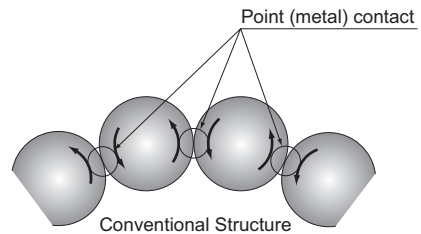
The use of the ball cage eliminates the collision noise between the balls. Additionally, as balls are picked up in the tangential direction, the collision noise from the ball circulation has also been eliminated.

[Long-term Maintenance-free Operation]

The friction between the balls has been eliminated, and the grease retention has been improved through the provision of grease pockets. As a result, the long-term maintenance-free operation (i.e., lubrication is unnecessary over a long period) is achieved.

[Smooth Motion]

The use of a ball cage eliminates the friction between the balls and minimizes the torque fluctuation, thus allowing the smooth motion to be achieved.



[Low Noise]

● Noise Level Data

Since the balls in the Ball Screw with the Ball Cage do not collide with each other, they do not produce a metallic sound and a low noise level is achieved.

■ Noise Measurement

[Conditions]

Item	Description
Sample	High load ball screw with ball cage HBN3210-5 Conventional type: model BNF3210-5
Stroke	600mm
Lubrication	Grease lubrication (lithium-based grease containing extreme pressure agent)

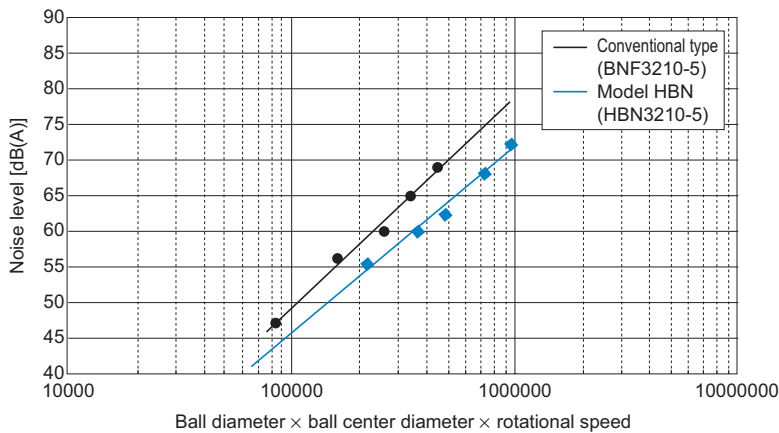
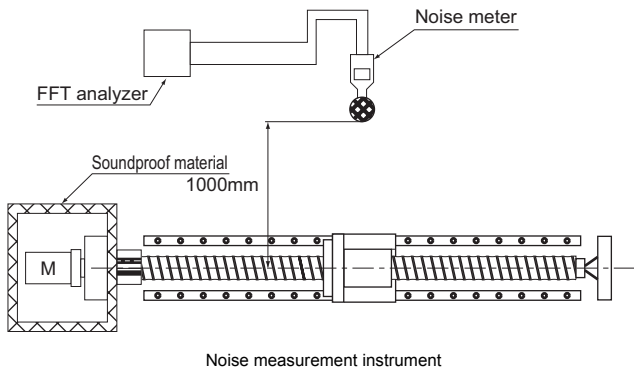


Fig.2 Ball Screw Noise Level

[Long-term Maintenance-free Operation]

● High speed, Load-bearing Capacity

Thanks to the ball circulating method supporting high speed and the caged ball technology, the Ball Screw with Ball Cage excels in high speed and load-bearing capacity.

■High Speed Durability Test

[Test conditions]

Item	Description
Sample	High Speed Ball Screw with Ball Cage SBN3210-7
Speed	3900(min ⁻¹)(DN value*: 130,000)
Stroke	400mm
Lubricant	THK AFG Grease
Quantity	12cm ³ (lubricated every 1000km)
Applied load	1.73kN
Acceleration	1G

* DN value: Ball center-to-center diameter x revolutions per minute

[Test result]

Shows no deviation after running 10,000 km.

■Load Bearing Test

[Test conditions]

Item	Description
Sample	High Speed Ball Screw with Ball Cage SBN3210-7
Speed	1500(min ⁻¹)(DN value*: 50,000)
Stroke	300mm
Lubricant	THK AFG Grease
Quantity	12cm ³
Applied load	17.3kN(0.5Ca)
Acceleration	0.5G

[Test result]

Shows no deviation after running a distance 2.5 times the calculated service life.

[Smooth Motion]

● Low Torque Fluctuation

The caged ball technology allows smoother motion than the conventional type to be achieved, thus to reduce torque fluctuation.

[Conditions]

Item	Description
Shaft diameter/ lead	32/10mm
Shaft rotational speed	60min ⁻¹

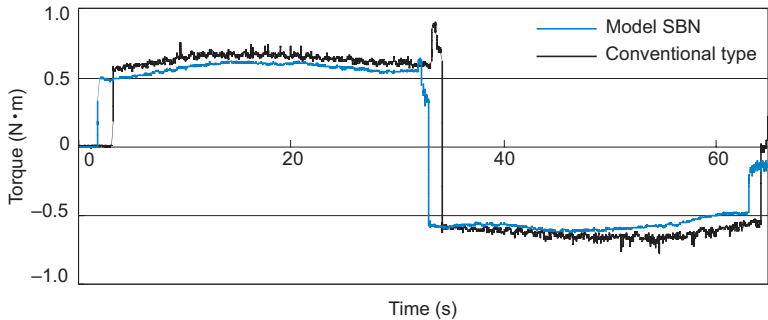


Fig.3 Torque Fluctuation Data

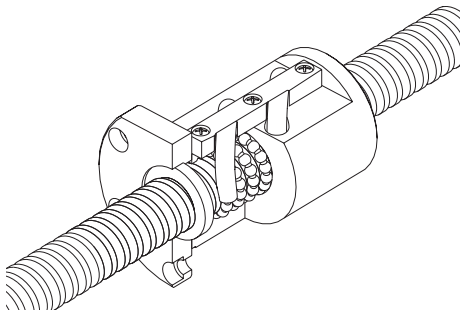
Types and Features

[Preload Type]

Model SBN

Specification Table⇒B-616

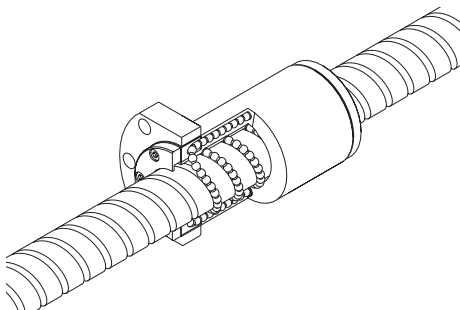
Model SBN has a circulation structure where balls are picked up in the tangential direction and is provided with a strengthened circulation path, thus to achieve a DN value of 130,000.



Model SBK

Specification Table⇒B-618

As a result of adopting the offset preloading method, which shifts two rows of grooves of the ball screw nut, a compact structure is achieved.

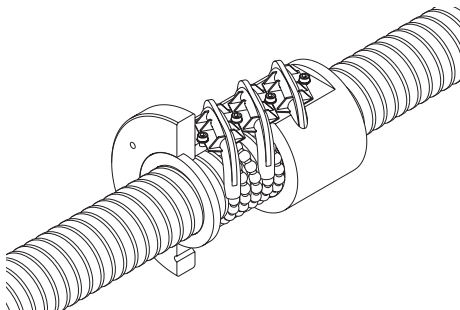


[No Preload Type]

Model HBN

Specification Table⇒B-620

With the optimal design for high loads, this Ball Screw model achieves a rated load more than twice the conventional type.



Service Life

For details,see A-722.

Axial Clearance

For details,see A-703.

Accuracy Standards

For details,see A-696.

Standard-Stock Precision Ball Screw

Unfinished Shaft Ends
Models BIF, BNFN, MDK, MBF and BNF



Structure and Features	▶▶▶ A-777
Types and Features	▶▶▶ A-778
Service Life	▶▶▶ A-722
Nut Types and Axial Clearance	▶▶▶ A-780
<u>Dimensional Drawing, Dimensional Table, Example of Model Number Coding</u>	▶▶▶ B-624

Structure and Features

This type of Ball Screw is mass manufactured by cutting the standardized screw shafts of Precision Ball Screws to regular lengths. Additional machining of the shaft ends can easily be performed. To meet various intended purposes, THK offers several Ball Screw models with different types of nuts: the double-nut type (model BNFN), the single-nut type (model BNF), the offset preload-nut type (model BIF) and the miniature Ball Screw (models MDK and MBF).

[Contamination Protection]

Nuts of the following model numbers are attached with a labyrinth seal.

- All variations of models BNFN, BNF and BIF
- Model MDK0802/1002/1202/1402/1404/1405

When dust or other foreign materials may enter the Ball Screw, it is necessary to use a contamination protection device (e.g., bellows) to completely protect the screw shaft.

[Lubrication]

The ball screw nuts are supplied with lithium soap-group grease with shipments.

(Models MDK and MBF are applied only with an anti-rust oil.)

[Additional Machining of the Shaft End]

Since only the effective thread of the screw shaft is surface treated with induction-hardening (all variations of models BNFN, BNF and BIF; model MDK 1405) or carburizing (all variations of model MBF; model MDK0401 to 1404), the shaft ends can additionally be machined easily either by grinding or milling.

In addition, since both ends of the screw shaft have a center hole, they can be cylindrically ground.

Surface hardness of the effect thread : HRC58 to 64

Hardness of the screw shaft ends

All variation of models BNFN, BNF and BIF; model MDK 1405 : HRC22 to 27

All variations of model MBF; model MDK0401 to 1404 : HRC35 or below

THK has standardized the shapes of the screw shaft ends in order to allow speedy estimation and manufacturing of the Ball Screws.

The shapes of shaft ends are divided into those allowing the standard support units to be used (symbols H, K and J) and those compliant with JIS B 1192-1997 (symbols A, B and C). See A-832 for details.

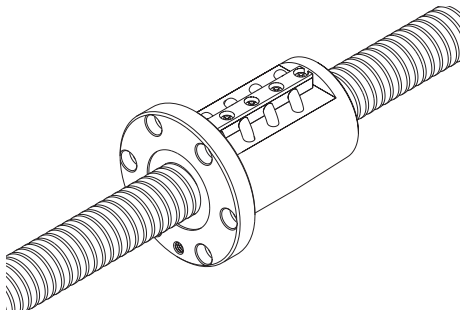
Types and Features

[Preload Type]

Model BIF

The right and left screws are provided with a phase in the middle of the ball screw nut, and an axial clearance is set at a below-zero value (under a preload). This compact model is capable of a smooth motion.

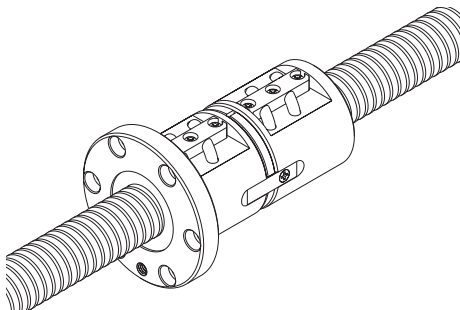
Specification Table⇒B-634



Model BNFN

The most common type with a preload provided via a spacer between the two combined ball screw nuts to eliminate backlash. It can be mounted using the bolt holes drilled on the flange.

Specification Table⇒B-634

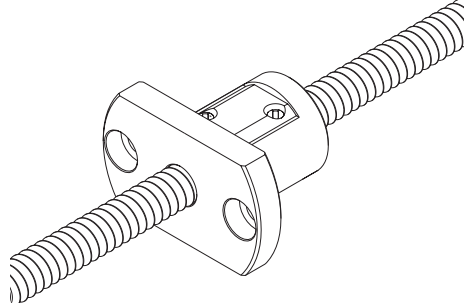


[No Preload Type]

Models MDK and MBF

Specification Table⇒B-624

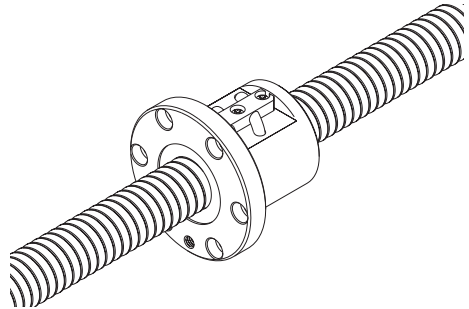
A miniature type with a screw shaft diameter of $\phi 4$ to $\phi 14$ mm and a lead of 1 to 5mm.



Model BNF

Specification Table⇒B-634

The simplest type with a single ball screw nut. It is designed to be mounted using the bolt holes drilled on the flange.



Service Life

For details,see A-722.

Nut Types and Axial Clearance

Screw shaft out diameter (mm)	φ 4 to 14			
Nut type	Model MDK		Model MBF	
	 No preload type		 No preload type	
Accuracy grades	C3, C5	C7	C3, C5	C7
Axial clearance (mm)	0.005 or less (GT)	0.02 or less (G2)	0.005 or less (GT)	0.02 or less (G2)
Preload	—		—	

Note) The symbols in the parentheses indicate axial clearance symbols.

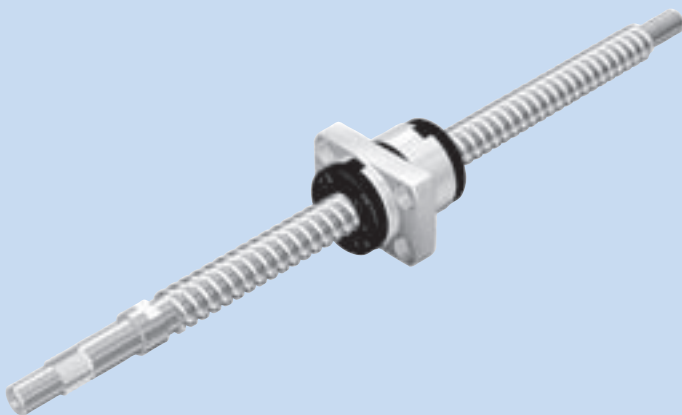
Screw shaft out diameter (mm)	φ16 to 50					
Nut type	Model BIF		Model BNFN		Model BNF	
	 Preload Type		 Preload Type		 No preload type	
Accuracy grades	C5	C7	C5	C7	C5	C7
Axial clearance (mm)	0 or less (G0)	0 or less (G0)	0 or less (G0)	0 or less (G0)	0.01 or less (G1)	0.02 or less (G2)
Preload	0.05Ca	0.05Ca	0.05Ca	0.05Ca	—	—

Note1) The symbols in the parentheses indicate axial clearance symbols.

Note2) Symbol "Ca" for preload indicates the basic dynamic load rating.

Standard-Stock Precision Ball Screw

Finished Shaft Ends
Model BNK



Features

▶▶▶ **A-783**

Types and Features

▶▶▶ **A-783**

Table of Ball Screw Types with Finished Shaft Ends and the Corresponding Support Units and Nut Brackets

▶▶▶ **A-784**

Dimensional Drawing, Dimensional Table

▶▶▶ **B-648**

Features

To meet the space-saving requirement, this type of Ball Screw has a standardized screw shaft and a ball screw nut. The ends of the screw shaft are standardized to fit the corresponding support unit. The shaft support method with models BNK0401, 0501 and 0601 is "fixed-free," while other models use the "fixed-supported" method with the shaft directly coupled with the motor.

Screw shafts and nuts are compactly designed. When a support unit and a nut bracket are combined with a Ball Screw, the assembly can be mounted on your machine as it is. Thus, a high-accuracy feed mechanism can easily be achieved.

[Contamination Protection and Lubrication]

Each ball screw nut contains a right amount of grease. In addition, the ball nuts of model BNK0802 or higher contain a labyrinth seal (with models BNK1510, BNK1520, BNK1616, BNK2020 and BNK2520, the end cap also serves as a labyrinth seal).

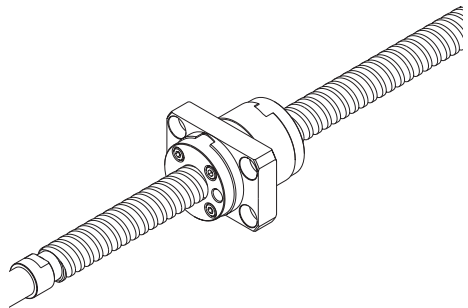
When foreign materials may enter the screw nut, it is necessary to use a dust-prevention device (e.g., bellows) to completely protect the screw shaft.

Types and Features

Model BNK

Specification Table⇒B-648

For this model, screw shafts with a diameter $\phi 4$ to $\phi 25$ mm and a lead 1 to 20 mm are available as the standard.



Ball Screw

Table of Ball Screw Types with Finished Shaft Ends and the Corresponding

Support Units and Nut Brackets

Model No.		BNK																										
		0401			0501			0601			0801			0802			0810			1002			1004			1010		
Accuracy grades		C3, C5, C7			C3, C5, C7			C3, C5, C7			C3, C5, C7			C5, C7			C3, C5, C7			C3, C5, C7			C5, C7					
Axial clearance ^{Note}		G0	GT	G2	G0	GT	G2	G0	GT	G2	G0	GT	G2	G0	GT	G2	—	GT	G2	G0	GT	G2	G0	GT	G2	G0	GT	G2
Stroke (mm)	20	●			●																							
	30																											
	40	●			●			●			●			●														
	50																●			●								
	60																											
	70	●			●			●			●			●														
	100							●			●			●			●			●			●			●		
	120																											
	150										●			●			●			●			●			●		
	170																											
	200																●			●			●			●		
	250																●						●			●		
	300																●									●		
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	900																											
	1000																											
1100																												
1200																												
1400																												
1600																												
Support unit: square on fixed side		EK4			EK4			EK5			EK6			EK6			EK6			EK8			EK10			EK10		
Support unit: round on fixed side		FK4			FK4			FK5			FK6			FK6			FK6			FK8			FK10			FK10		
Support unit: square on supported side		—			—			—			EF6			EF6			EF6			EF8			EF10			EF10		
Support unit: round on supported side		—			—			—			FF6			FF6			FF6			FF8			FF10			FF10		
Nut bracket		—			—			—			—			—			—			—			MC1004			MC1004		

Note) Axial clearance: G0: 0 or less

GT: 0.005 mm or less

G2: 0.02 mm or less

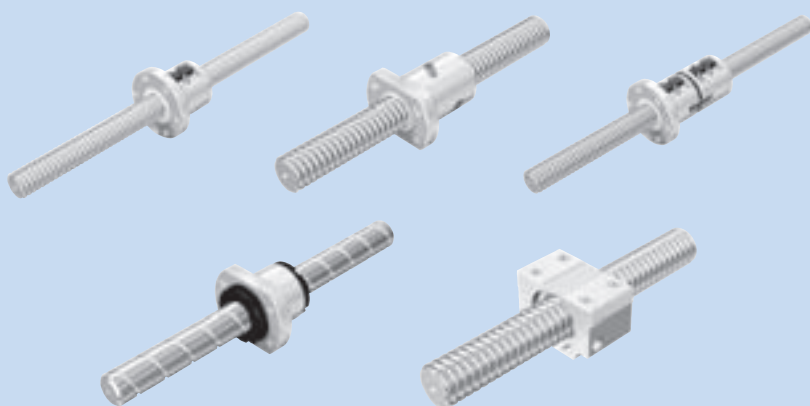
For details of the support unit and the nut bracket, see A-824 onward and A-834 onward, respectively.

BNK												
	1202	1205	1208	1402	1404	1408	1510	1520	1616	2010	2020	2520
	C3, C5, C7	C3, C5, C7	C7	C3, C5, C7	C3, C5, C7	C5, C7	C5, C7	C5, C7	C5, C7	C5, C7	C5, C7	C5, C7
	G0 GT G2	G0 GT G2	— — G2	G0 GT G2	G0 GT G2	G0 GT G2	G0 GT G2	G0 GT G2	G0 GT G2	G0 GT G2	G0 GT G2	G0 GT G2
	●	●	●	●								
	●	●	●	●	●							
	●	●	●	●	●	●	●	●	●			
	●	●	●	●	●	●	●	●	●			
	●	●	●	●	●	●	●	●	●			
	●	●	●			●	●	●	●			
				●	●	●	●	●	●	●	●	
					●	●	●	●	●	●	●	
						●	●	●	●	●	●	●
						●	●	●	●	●	●	●
						●	●	●	●	●	●	●
							●	●	●	●	●	●
										●	●	●
										●	●	●
												●
												●
												●
	EK10	EK10	EK10	EK12	EK12	EK12	EK12	EK12	EK12	EK15	EK15	EK20
	FK10	FK10	FK10	FK12	FK12	FK12	FK12	FK12	FK12	FK15	FK15	FK20
	EF10	EF10	EF10	EF12	EF12	EF12	EF12	EF12	EF12	EF15	EF15	EF20
	FF10	FF10	FF10	FF12	FF12	FF12	FF12	FF12	FF12	FF15	FF15	FF20
	—	MC1205	MC1205	—	—	MC1408	MC1408	MC1408	MC1408	MC2010	MC2020	—

Ball Screw

Precision Ball Screw

Models BIF, DIK, BNFN, DKN, BLW, BNF, DK, MDK, BLK/WGF and BNT



Structure and Features	▶▶▶ A-787
Types and Features	▶▶▶ A-791
Service Life	▶▶▶ A-722
Axial Clearance	▶▶▶ A-703
Accuracy Standards	▶▶▶ A-696
Dimensional Drawing, Dimensional Table (Preload Type)	▶▶▶ B-692
Dimensional Drawing, Dimensional Table (No Preload Type)	▶▶▶ B-726
Model number coding	▶▶▶ B-758

For THK Precision Ball Screws, a wide array of precision-ground screw shafts and ball screw nuts are available as standard to meet diversified applications.

Structure and Features

[Combinations of Various shaft Diameters and Leads]

You can select the combination of a shaft diameter and a lead that meet the intended use from the various nut types and the screw shaft leads. Those nut types include the return-pipe nuts, which represent the most extensive variations among the series, the compact simple nuts and the large-lead end-cap nuts.

[Standard-stock Types (with Unfinished Shaft Ends/Finished Shaft Ends) are Available]

The unfinished shaft end types, which are mass manufactured by cutting the standardized screw shafts to the standard lengths, and those with finished shaft ends, for which the screw shaft ends are machined to match the corresponding the support units, are available as the standard.

[Accuracy Standards Compliant with JIS (ISO)]

The accuracy of the Ball Screw is controlled in accordance with the JIS standards (JIS B1192-1997).

	Precision Ball Screw						Rolled Ball Screw	
Accuracy grades	C0	C1	C2	C3	C5	C7	C8	C10

Type	Series symbol	Grade	Remarks
For positioning	C	0, 1, 3, 5	JIS series
	Cp	1, 3, 5	ISO compliant
For conveyance	Ct	1, 3, 5, 7, 10	

[Options that Meet the Environment are Available]

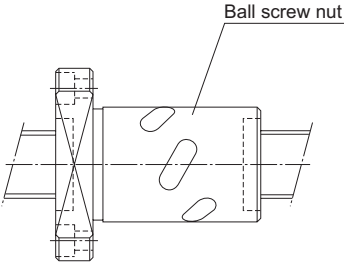
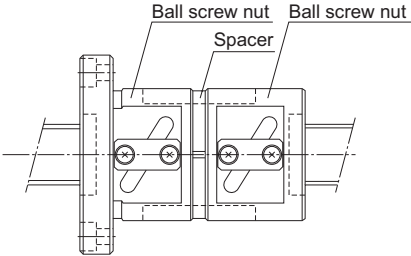
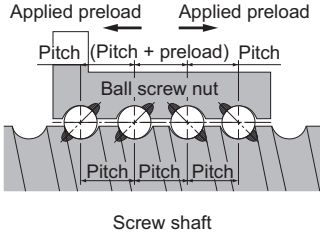
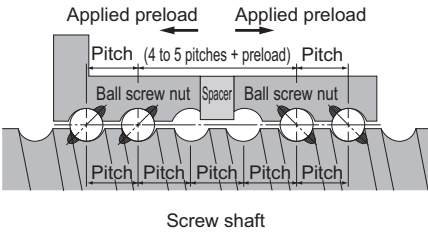
Options are available consisting of a lubricator (QZ), which enables the maintenance interval to be significantly extended, and a wiper ring (W), which improves the ability to remove foreign materials in adverse environments.

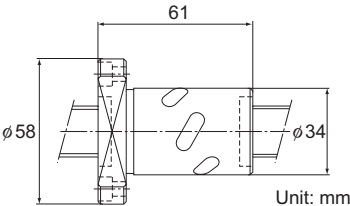
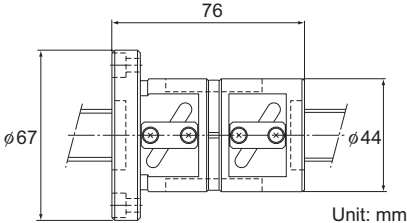
[Structure and Features of Offset Preload Type Simple-Nut Ball Screw Model DIK]

The Simple-Nut Ball Screw model DIK is an offset preload type in which a phase is provided in the middle of a single ball screw nut, and an axial clearance is set at a below-zero value (under a preload).

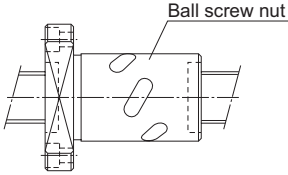
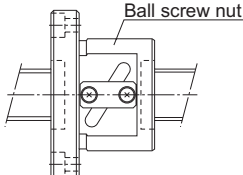
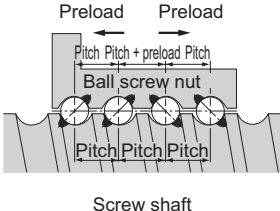
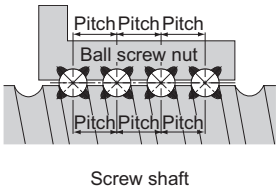
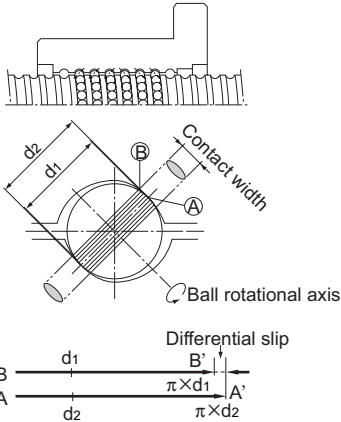
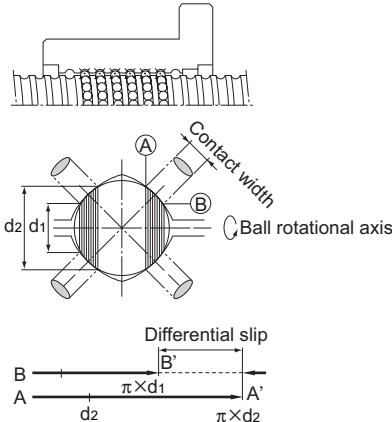
Model DIK has a more compact structure and allows smoother motion than the conventional double-nut type (spacer inserted between two nuts).

[Comparison between the Simple Nut and the Double-Nuts]

Simple-Nut Ball Screw Model DIK	Conventional Double-Nut Type Ball Screw Model BNFN
	
Preloading Structure	
	

Simple-Nut Ball Screw Model DIK	Conventional Double-Nut Type Ball Screw Model BNFN
Rotational Performance	
The preload adjustment with Simple Nut Ball Screw model DIK is performed according to the ball diameter. This eliminates the inconsistency in the contact angle, which is the most important factor of the Ball Screw performance. It also ensures the high rigidity, the smooth motion and the high wobbling accuracy.	The use of a spacer in the double-nuts tends to cause inconsistency in the contact angle due to inaccurate flatness of the spacer surface and an inaccurate perpendicularity of the nut. This results in a non-uniform ball contact, an inferior rotational performance and a low wobbling accuracy.
Dimensions	
Since Simple-Nut Ball Screw model DIK is based on a preloading mechanism that does not require a spacer, the overall nut length can be kept short. As a result, the whole nut can be lightly and compactly designed.	
 Unit: mm Model DIK 2005-6	 Unit: mm Model BNFN 2005-2.5

[Comparison between the Offset Preload Type of Simple-Nut Ball Screw and the Oversize Preload Nut Ball Screw]

Simple-Nut Ball Screw Model DIK	Conventional Oversize Preload Nut Ball Screw Model BNF
	
Preloading Structure	
	
Accuracy Life	
Simple-Nut Ball Screw model DIK has a similar preloading structure to that of the double-nut type although the former only has one ball screw shaft. As a result, no differential slip or spin occurs, thus to minimize the increase in the rotational torque and the generation of heat. Accordingly, a high level of accuracy can be maintained over a long period. 2 point contact structure  Differential slip B ——— d1 ——— B' ——— A ——— d2 ——— A' ——— $\pi \times d_1$ $\pi \times d_2$	With the oversize preload nut Ball Screw, a preload is provided through the balls each in contact with the raceway at four points. This causes differential slip and spin to increase the rotational torque, resulting in an accelerated wear and a heat generation. Therefore, the accuracy deteriorates in a short period. 4 point contact structure  Differential slip B ——— d1 ——— B' ——— A ——— d2 ——— A' ——— $\pi \times d_1$ $\pi \times d_2$

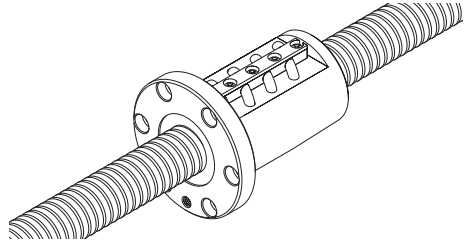
Types and Features

[Preload Type]

Model BIF

The right and the left screws are provided with a phase in the middle of the ball screw nut, and an axial clearance is set at a below-zero value (under a preload). This compact model is capable of a smooth motion.

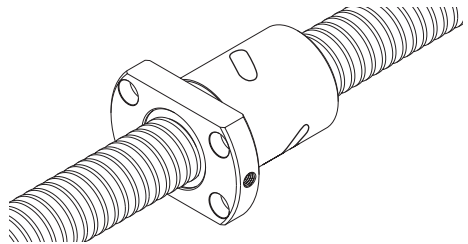
Specification Table⇒B-692



Model DIK

The right and the left screws are provided with a phase in the middle of the ball screw nut, and an axial clearance is set at a below-zero value (under a preload). This compact model is capable of a smooth motion.

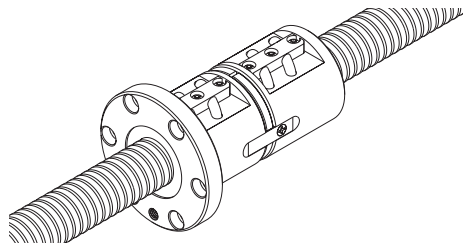
Specification Table⇒B-692



Model BNFN

The most common type with a preload provided via a spacer between the two combined ball screw nuts to eliminate the backlash. It can be mounted using the bolt holes drilled on the flange.

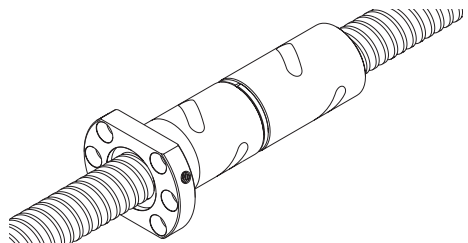
Specification Table⇒B-692



Model DKN

A preload is provided via a spacer between the two combined ball screw nuts to achieve a below-zero axial clearance (under a preload).

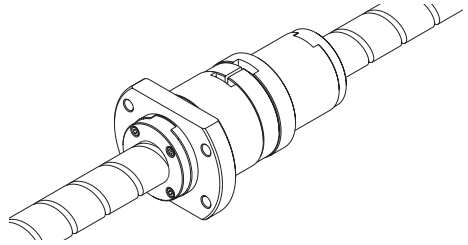
Specification Table⇒B-712



Model BLW

Specification Table⇒B-692

Since a preload is provided through a spacer between two large lead nuts, high-speed feed without backlash is ensured.

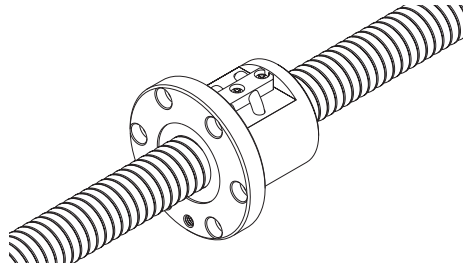


[No Preload Type]

Model BNF

Specification Table⇒B-726

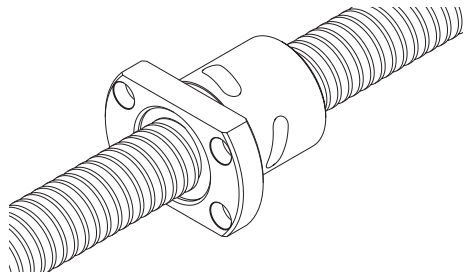
The simplest type with a single ball screw nut. It is designed to be mounted using the bolt holes drilled on the flange.



Model DK

Specification Table⇒B-726

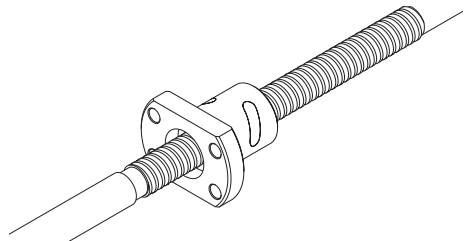
The most compact type, with a ball screw nut diameter 70 to 80% of that of the return-pipe nut.



Model MDK

Specification Table⇒B-726

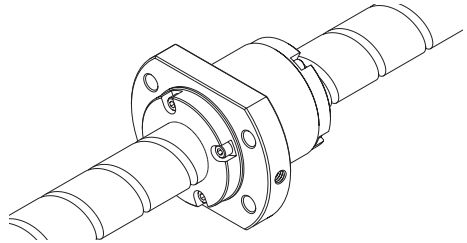
This model is a miniature nut with a screw shaft diameter of $\phi 4$ to 14 mm and a lead of 1 to 5 mm.



Models BLK/WGF

Specification Table⇒B-726

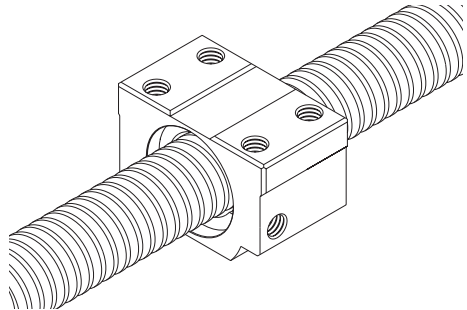
With model BLK, the shaft diameter is equal to the lead dimension. Model WGF has a lead dimension 1.5 to 3 times longer than the shaft diameter.



Square Ball Screw Nut Model BNT

Specification Table⇒B-756

Since mounting screw holes are machined on the square ball screw nut, this model can compactly be mounted on the machine without a housing.



Service Life

For details, see A-722.

Axial Clearance

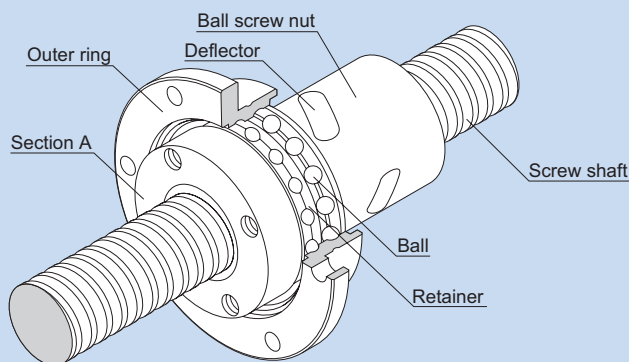
For details, see A-703.

Accuracy Standards

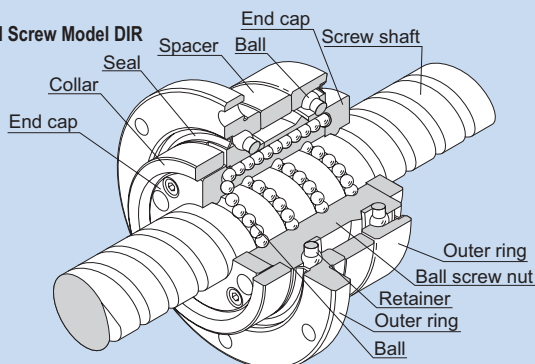
For details, see A-696.

Precision Rotary Ball Screw

Models DIR and BLR



Structure of Standard-Lead Rotary Nut Ball Screw Model DIR



Structure of Large Lead Rotary Nut Ball Screw Model BLR

Structure and Features

▶▶▶ A-795

Type

▶▶▶ A-797

Service Life

▶▶▶ A-722

Axial Clearance

▶▶▶ A-703

Accuracy Standards

▶▶▶ A-798

Example of Assembly

▶▶▶ A-800

Dimensional Drawing, Dimensional Table, Example of Model Number Coding

▶▶▶ B-760

Structure and Features

[Model DIR]

Standard-Lead Rotary-Nut Ball Screw model DIR is a rotary-nut Ball Screw that has a structure where a simple-nut Ball Screw is integrated with a support bearing.

Its ball screw nut serves as a ball recirculation structure using deflectors. Balls travel along the groove of the deflector mounted in the ball screw nut to the adjacent raceway, and then circulate back to the loaded area to complete an infinite rolling motion.

Being an offset preload nut, the single ball screw nut provides different phases to the right and left thread in the middle of the nut, thus to set the axial clearance below zero (a preload is provided). This allows more compact, smoother motion to be achieved than the conventional double-nut type (a spacer is inserted between two nuts).

The support bearing comprises of two rows of DB type angular bearings with a contact angle of 45° to provide a preload. The collar, previously used to mount a pulley, is integrated with the ball screw nut. (See the A section.)

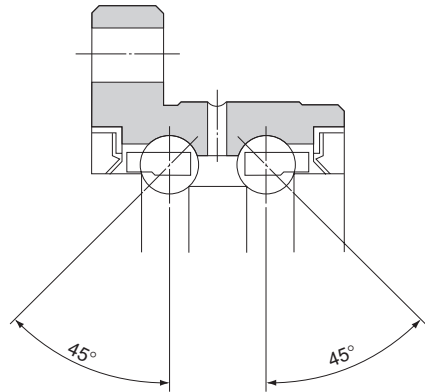


Fig.1 Structure of the Support Bearing

● Compact

Because of the internal circulation mechanism using a deflector, the outer diameter is only 70 to 80%, and the overall length is 60 to 80%, of that of the return-pipe nut, thus to reduce the weight and decrease the inertia during acceleration.

Since the nut and the support bearing are integrated, a highly accurate, and a compact design is achieved.

In addition, small inertia due to the lightweight ball screw nut ensures high responsiveness.

● Capable of Fine Positioning

Being a Standard-Lead Ball Screw, it is capable of fine positioning despite that the ball screw nut rotates.

● Accuracy can Easily be Established

As the support bearing is integrated with the outer ring, the bearing can be assembled with the nut housing on the end face of the outer ring flange. This makes it easy to center the ball screw nut and establish accuracy.

● Well Balanced

Since the deflector is evenly placed along the circumference, a superb balance is ensured while the ball screw nut is rotating.

● **Stability in the Low-speed Range**

Traditionally, motors tend to have an uneven torque and a speed in the low-speed range due to the external causes. With model DIR, the motor can be connected independently with the screw shaft and the ball screw nut, thus to allow micro feeding within the motor's stable rotation range.

[Model BLR]

The Rotary Ball Screw is a rotary-nut ball screw unit that has an integrated structure consisting of a ball screw nut and a support bearing. The support bearing is an angular bearing that has a contact angle of 60°, contains an increased number of balls and achieves large axial rigidity.

Model BLR is divided into two types: Precision Ball Screw and Rolled Screw Ball.

● **Smooth Motion**

It achieves smoother motion than rack-and-pinion based straight motion. Also, since the screw shaft does not rotate because of the ball screw nut drive, this model does not show skipping, produces low noise and generates little heat.

● **Low Noise even in High-speed Rotation**

Model BLR produces very low noise when the balls are picked up along the end cap. In addition, the balls circulate by passing through the ball screw nut, allowing this model to be used at high speed.

● **High Rigidity**

The support bearing of this model is larger than that of the screw shaft rotational type. Thus, its axial rigidity is significantly increased.

● **Compact**

Since the nut and the support bearing are integrated, a highly accurate, and a compact design is achieved.

● **Easy Installation**

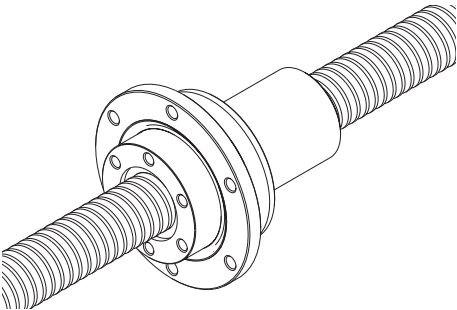
By simply mounting this model to the housing with bolts, a ball screw nut rotating mechanism can be obtained. (For the housing's inner-diameter tolerance, H7 is recommended.)

Type

[Preload Type]

Model DIR

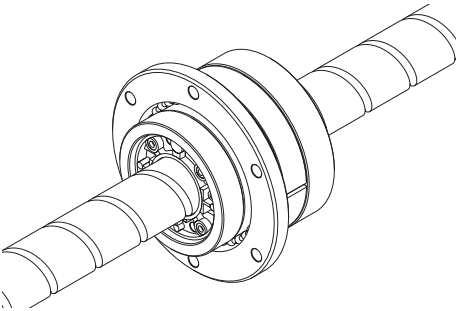
Specification Table⇒B-760



[No Preload Type]

Model BLR

Specification Table⇒B-762



Ball Screw

Service Life

For details, see A-722.

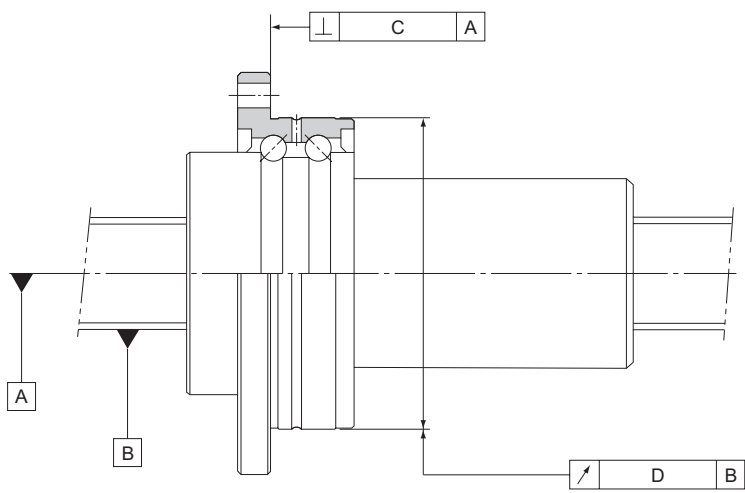
Axial Clearance

For details, see A-703.

Accuracy Standards

[Model DIR]

The accuracy of model DIR is compliant with a the JIS standard (JIS B 1192-1997) except for the radial runout of the circumference of the ball screw nut from the screw axis (D) and the perpendicularity of the flange-mounting surface against the screw axis (C).

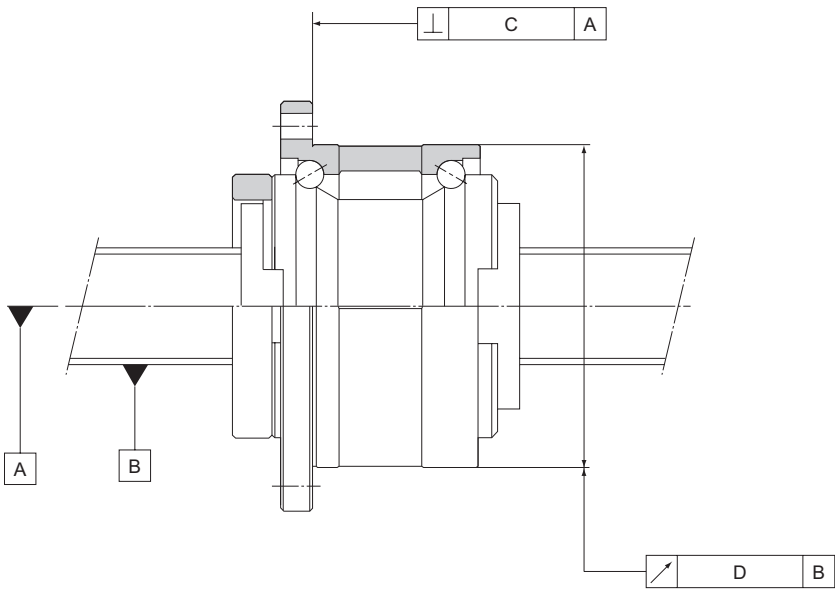


Unit: mm

Accuracy grades	C3		C5		C7	
Model No.	C	D	C	D	C	D
DIR 16□□	0.013	0.017	0.016	0.020	0.023	0.035
DIR 20□□	0.013	0.017	0.016	0.020	0.023	0.035
DIR 25□□	0.015	0.020	0.018	0.024	0.023	0.035
DIR 32□□	0.015	0.020	0.018	0.024	0.023	0.035
DIR 36□□	0.016	0.021	0.019	0.025	0.024	0.036
DIR 40□□	0.018	0.026	0.021	0.033	0.026	0.036

[Model BLR]

The accuracy of model BLR is compliant with a the JIS standard (JIS B 1192-1997) except for the radial runout of the circumference of the ball screw nut from the screw axis (D) and the perpendicularity of the flange-mounting surface against the screw axis (C).



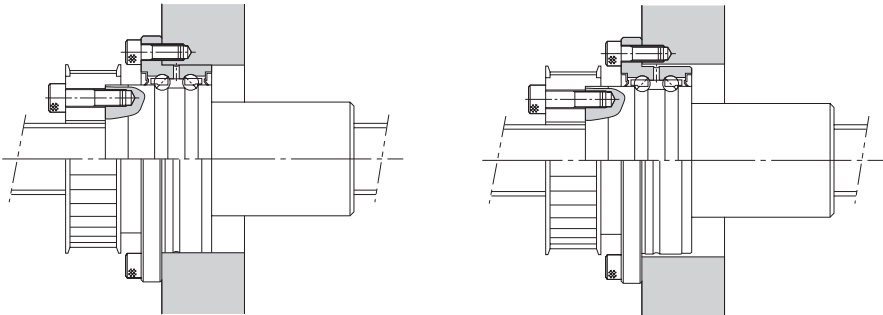
Ball Screw

Unit: mm

Lead angle accuracy	C3		C5		C7	
Accuracy grades	C3		C5		C7	
Model No.	C	D	C	D	C	D
BLR 1616	0.013	0.017	0.016	0.020	0.023	0.035
BLR 2020	0.013	0.017	0.016	0.020	0.023	0.035
BLR 2525	0.015	0.020	0.018	0.024	0.023	0.035
BLR 3232	0.015	0.020	0.018	0.024	0.023	0.035
BLR 3636	0.016	0.021	0.019	0.025	0.024	0.036
BLR 4040	0.018	0.026	0.021	0.033	0.026	0.046
BLR 5050	0.018	0.026	0.021	0.033	0.026	0.046

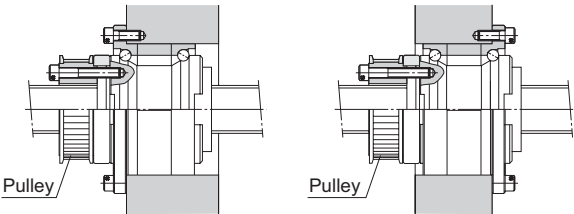
Example of Assembly

[Example of Mounting Ball Screw Nut Model DIR]



Installation to the housing can be performed on the end face of the outer ring flange.

[Example of Mounting Ball Screw Nut Model BLR]



Standard installation method

Inverted flange

Note) If the flange is to be inverted, indicate "K" in the model number. (applicable only to model BLR)

Example: BLR 2020-3.6 K UU

Symbol for inverted flange (No symbol for standard flange orientation)

[Example of Mounting Model BLR on the Table]

- (1) Screw shaft free, ball screw nut fixed
(Suitable for a long table)

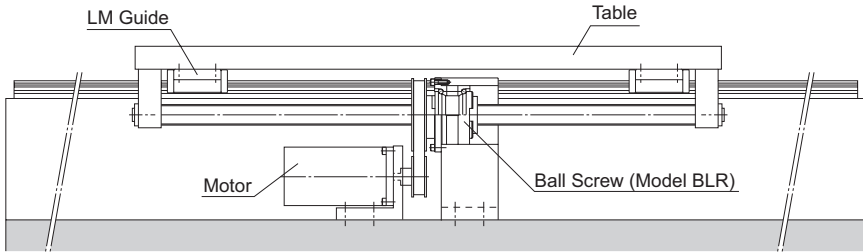


Fig.2 Example of Installation on the Table (Ball Screw Nut Fixed)

- (2) Ball screw nut free, screw shaft fixed
(Suitable for a short table and a long stroke)

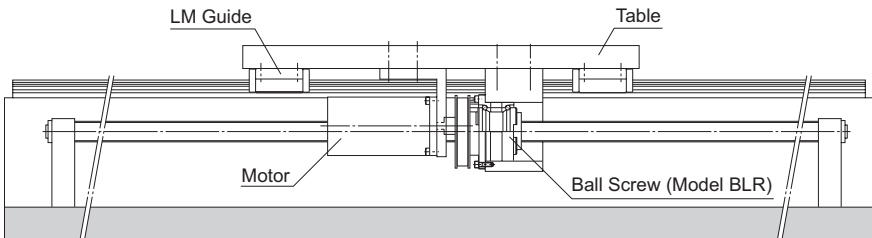
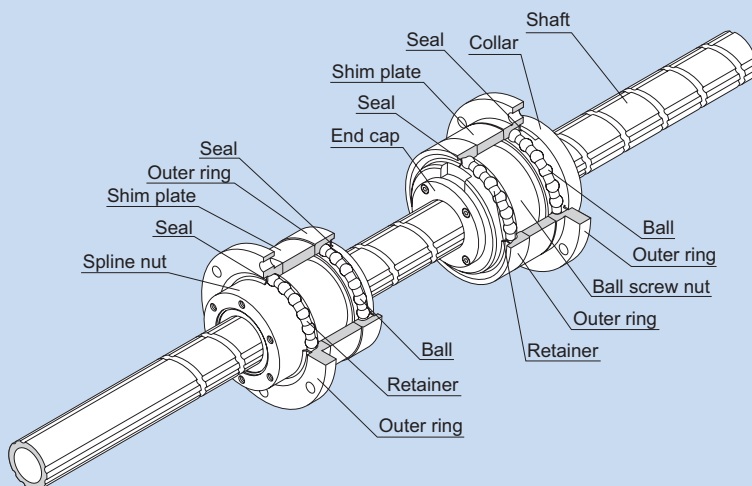


Fig.3 Example of Installation on the Table (Screw Shaft Fixed)

Precision Ball Screw/Spline

Models BNS-A, BNS, NS-A and NS



Structure and Features

Type	▶▶▶ A-803
Service Life	▶▶▶ A-804
Axial Clearance	▶▶▶ A-722
Accuracy Standards	▶▶▶ A-703
Action Patterns	▶▶▶ A-805
Example of Assembly	▶▶▶ A-806
Example of Using the Spring Pad	▶▶▶ A-809
Precautions on Use	▶▶▶ A-810
Dimensional Drawing, Dimensional Table, Example of Model Number Coding	▶▶▶ A-811
	▶▶▶ B-766

Structure and Features

The Ball Screw/Spline contains the Ball Screw grooves and the Ball Spline groove crossing one another. The nuts of the Ball Screw and the Ball Spline have dedicated support bearings directly embedded on the circumference of the nuts.

The Ball Screw/Spline is capable of performing three (rotational, linear and spiral) modes of motion with a single shaft by rotating or stopping the spline nut.

It is optimal for machines using a combination of rotary and straight motions, such as scholar robot's Z-axis, assembly robot, automatic loader, and machining center's ATC equipment.

[Zero Axial Clearance]

The Ball Spline has an angular-contact structure that causes no backlash in the rotational direction, enabling highly accurate positioning.

[Lightweight and Compact]

Since the nut and the support bearing are integrated, highly accurate, compact design is achieved. In addition, small inertia because of the lightweight ball screw nut ensures high responsiveness.

[Easy Installation]

The Ball Spline nut is designed so that balls do not fall off even if the spline nut is removed from the shaft, making installation easy. The Ball Screw/Spline can easily be mounted simply by securing it to the housing with bolts. (For the housing's inner-diameter tolerance, H7 is recommended.)

[Smooth Motion with Low Noise]

As the Ball Screw is based on an end cap mechanism, smooth motion with low noise is achieved.

[Highly Rigid Support Bearing]

The support bearing on the Ball Screw has a contact angle of 60° in the axial direction while that on the Ball Spline has a contact angle of 30° in the moment direction, thus to provide a highly rigid shaft support.

In addition, a dedicated rubber seal is attached as standard to prevent entry of foreign materials.

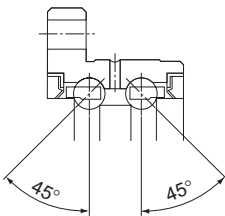


Fig.1 Structure of Support Bearing Model BNS-A

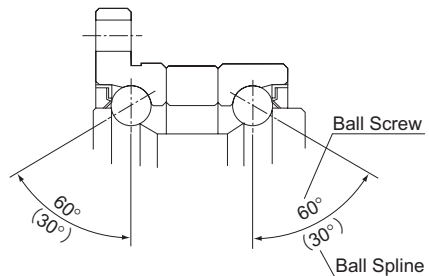
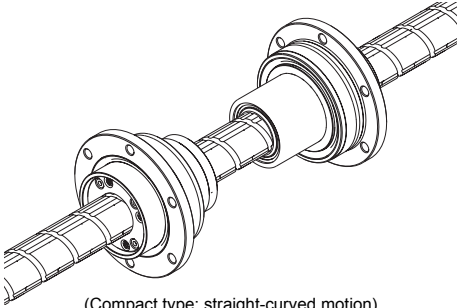


Fig.2 Structure of Support Bearing Model BNS

Type

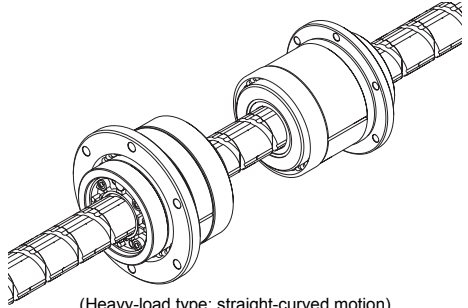
[No Preload Type]

Model BNS-A Specification Table⇒B-766



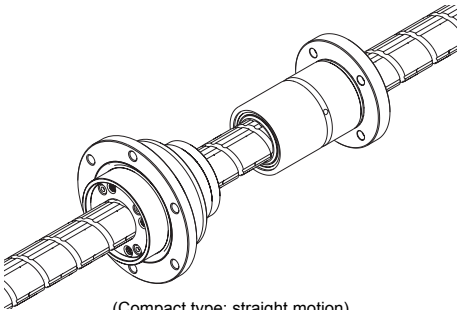
(Compact type: straight-curved motion)

Model BNS Specification Table⇒B-768



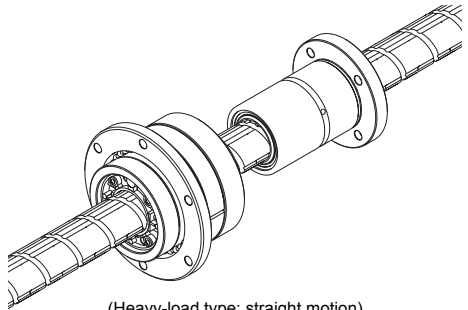
(Heavy-load type: straight-curved motion)

Model NS-A Specification Table⇒B-770



(Compact type: straight motion)

Model NS Specification Table⇒B-772



(Heavy-load type: straight motion)

Service Life

For details, see A-722.

Axial Clearance

For details, see A-703.

Accuracy Standards

The Ball Screw/Spline is manufactured with the following specifications.

[Ball Screw]

Axial clearance: 0 or less

Lead angle accuracy: C5

(For detailed specifications, see A-696.)

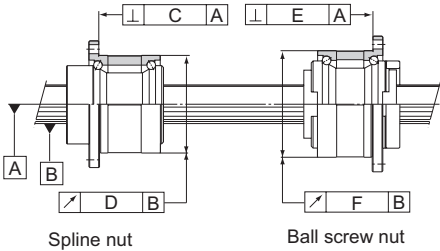
[Ball Spline]

Clearance in the rotational direction: 0 or less (CL: light preload)

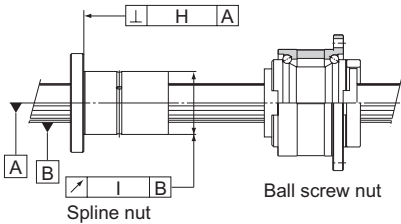
(For detailed specifications, see A-499.)

Accuracy grade: class H

(For detailed specifications, see A-500.)



Model BNS



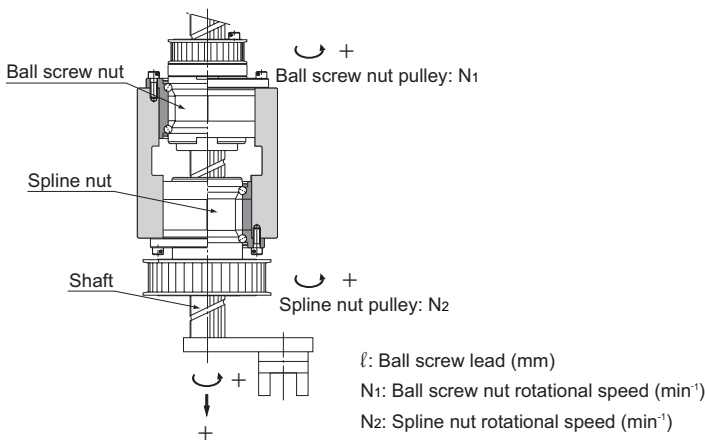
Model NS

Unit: mm

Model No.	C	D	E	F	H	I
BNS 0812 NS 0812	0.014	0.017	0.014	0.016	0.010	0.013
BNS 1015 NS 1015	0.014	0.017	0.014	0.016	0.010	0.013
BNS 1616 NS 1616	0.018	0.021	0.016	0.020	0.013	0.016
BNS 2020 NS 2020	0.018	0.021	0.016	0.020	0.013	0.016
BNS 2525 NS 2525	0.021	0.021	0.018	0.024	0.016	0.016
BNS 3232 NS 3232	0.021	0.021	0.018	0.024	0.016	0.016
BNS 4040 NS 4040	0.025	0.025	0.021	0.033	0.019	0.019
BNS 5050 NS 5050	0.025	0.025	0.021	0.033	0.019	0.019

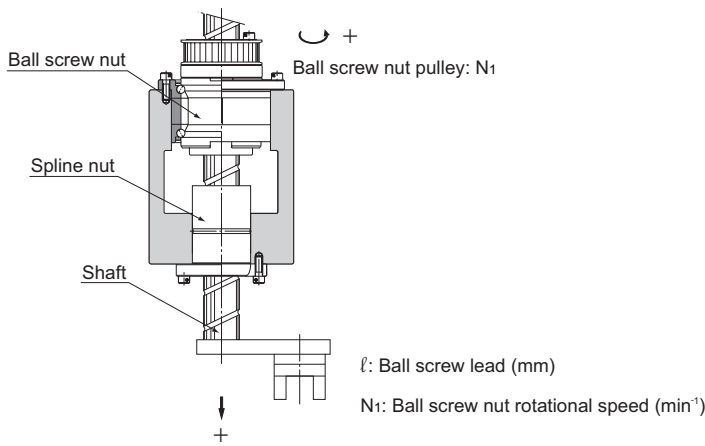
Action Patterns

[Model BNS Basic Actions]



Motion	Action direction	Input		Shaft motion	
		Ball screw pulley	Ball spline pulley	Vertical direction (speed)	Rotational direction (rotation speed)
1. Vertical 	(1)	N ₁ (Forward)	0	$V=N_1 \cdot \ell$ (N ₁ ≠ 0)	0
	(2)	-N ₁ (Reverse)	0	$V=-N_1 \cdot \ell$ (N ₁ ≠ 0)	0
2. Rotation 	(1)	N ₁	N ₂ (Forward)	0	N ₂ (Forward) (N ₁ =N ₂ ≠ 0)
	(2)	-N ₁	-N ₂ (Reverse)	0	-N ₂ (Reverse) (-N ₁ =-N ₂ ≠ 0)
3. Spiral 	(1)	0	N ₂ (N ₂ ≠ 0)	$V=N_2 \cdot \ell$	N ₂ (Forward)
	(2)	0	-N ₂ (-N ₂ ≠ 0)	$V=-N_2 \cdot \ell$	-N ₂ (Reverse)

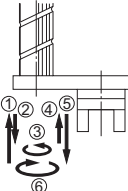
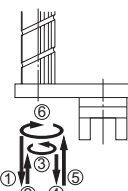
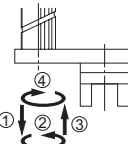
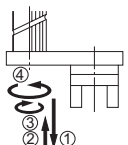
[Model NS Basic Actions]



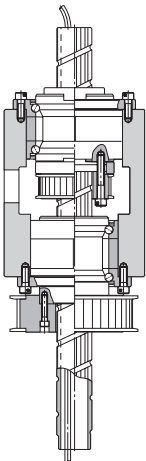
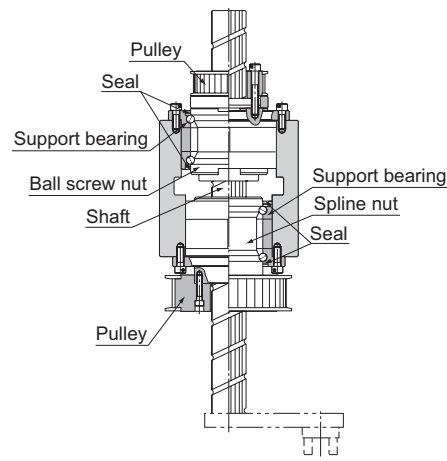
Motion		Action direction	Input	Shaft motion
			Ball screw pulley	Vertical direction (speed)
1. Vertical 	(1)	Vertical direction →down	N_1 (Forward)	$V=N_1 \cdot l$ ($N_1 \neq 0$)
	(2)	Vertical direction →up	$-N_1$ (Reverse)	$V=-N_1 \cdot l$ ($N_1 \neq 0$)

Ball Screw

[Model BNS Extended Actions]

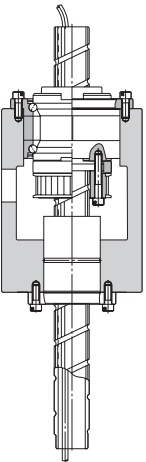
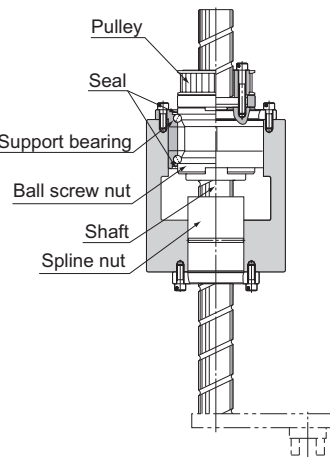
Motion		Action direction	Input		Shaft motion	
			Ball screw pulley	Ball spline pulley	Vertical direction (speed)	Rotational direction (rotational speed)
1. Up→down→forward →up→down→reverse 	(1)	Vertical direction→up	$-N_1$ (Reverse)	0	$V=-N_1 \cdot \ell$ ($N_1 \neq 0$)	0
	(2)	Vertical direction→down	N_1 (Forward)	0	$V=N_1 \cdot \ell$ ($N_1 \neq 0$)	0
	(3)	Rotational direction→forward	N_1	N_2 (Forward)	0	N_2 (Forward) ($N_1=N_2 \neq 0$)
	(4)	Vertical direction→up	$-N_1$	0	$V=-N_1 \cdot \ell$ ($N_1 \neq 0$)	0
	(5)	Vertical direction→down	N_1	0	$V=N_1 \cdot \ell$ ($N_1 \neq 0$)	0
	(6)	Rotational direction→reverse	$-N_1$	$-N_2$ (Reverse)	0	$-N_2$ (Reverse) ($-N_1=N_2 \neq 0$)
2. Down→up→forward →down→up→reverse 	(1)	Vertical direction→down	N_1	0	$V=N_1 \cdot \ell$ ($N_1 \neq 0$)	0
	(2)	Vertical direction→up	$-N_1$	0	$V=-N_1 \cdot \ell$ ($N_1 \neq 0$)	0
	(3)	Rotational direction→forward	N_1	N_2	0	N_2 ($N_1=N_2 \neq 0$)
	(4)	Vertical direction→down	N_1	0	$V=N_1 \cdot \ell$ ($N_1 \neq 0$)	0
	(5)	Vertical direction→up	$-N_1$	0	$V=-N_1 \cdot \ell$ ($N_1 \neq 0$)	0
	(6)	Rotational direction→reverse	$-N_1$	$-N_2$	0	$-N_2$ ($-N_1=N_2 \neq 0$)
3. Down→forward →up→reverse 	(1)	Vertical direction→down	N_1	0	$V=N_1 \cdot \ell$ ($N_1 \neq 0$)	0
	(2)	Rotational direction→forward	N_1	N_2	0	N_2 ($N_1=N_2 \neq 0$)
	(3)	Vertical direction→up	$-N_1$	0	$V=-N_1 \cdot \ell$ ($N_1 \neq 0$)	0
	(4)	Rotational direction→reverse	$-N_1$	$-N_2$	0	$-N_2$ ($-N_1=N_2 \neq 0$)
4. Down→up →reverse→forward 	(1)	Vertical direction→down	N_1	0	$V=N_1 \cdot \ell$ ($N_1 \neq 0$)	0
	(2)	Vertical direction→up	$-N_1$	0	$V=-N_1 \cdot \ell$ ($N_1 \neq 0$)	0
	(3)	Rotational direction→reverse	$-N_1$	$-N_2$	0	$-N_2$ ($-N_1=N_2 \neq 0$)
	(4)	Rotational direction→forward	N_1	N_2	0	N_2 ($N_1=N_2 \neq 0$)

Example of Assembly



- Example of installing the ball screw nut input pulley and the spline nut input pulley, both outside the housing. The housing length is minimized.
- Example of installing the ball screw nut pulley inside the housing.

Fig.3 Example of Assembling Model BNS



- Example of installing the ball screw nut pulley outside the housing. The housing length is minimized.
- Example of installing the ball screw nut pulley inside the housing.

Fig.4 Example of Assembling Model NS

Example of Using the Spring Pad

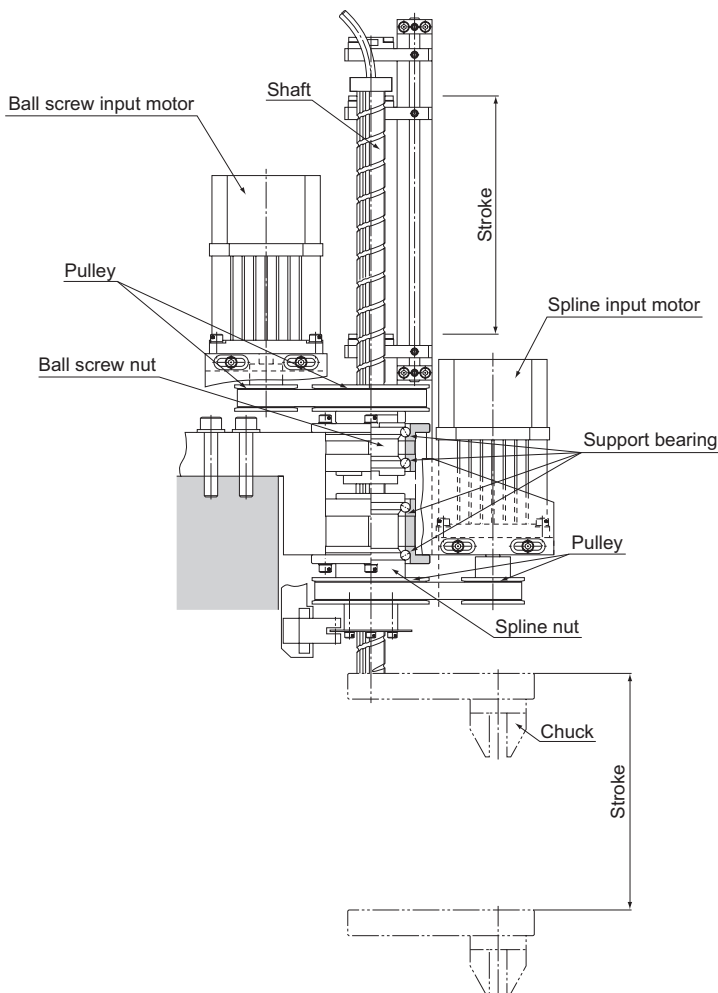


Fig.5 Example of Using Model BNS

Precautions on Use

[Lubrication]

When lubricating the Ball Screw/Spline, attach the greasing plate to the housing in advance.

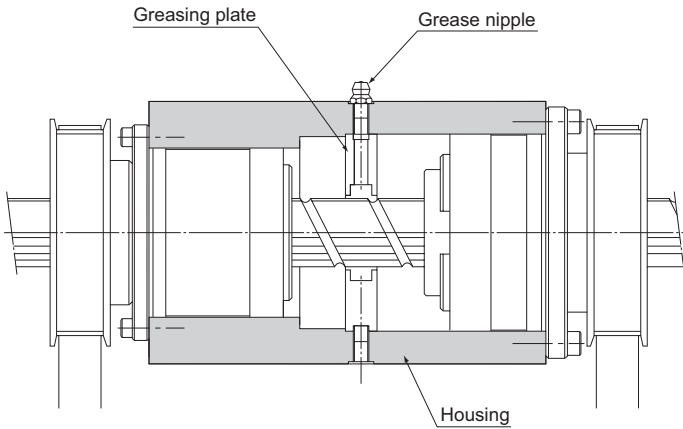


Fig.6 Lubrication Methods

Rolled Ball Screw

Models JPF, BTK, MTF, BLK/WTF, CNF and BNT



Structure and Features	▶▶▶ A-813
Types and Features	▶▶▶ A-814
Service Life	▶▶▶ A-722
Axial Clearance	▶▶▶ A-703
Accuracy Standards	▶▶▶ A-696
Dimensional Drawing, Dimensional Table (Preload Type)	▶▶▶ B-776
Dimensional Drawing, Dimensional Table (No Preload Type)	▶▶▶ B-778
Model number coding	▶▶▶ B-786

Structure and Features

THK Rolled Ball Screws are low priced feed screws that use a screw shaft rolled with high accuracy and specially surface-ground, instead of a thread-ground shaft used in the Precision Ball Screws.

The ball raceways of the ball screw nut are all thread-ground, thus to achieve a smaller axial clearance and smoother motion than the conventional rolled ball screw.

In addition, a wide array of types are offered as standard in order to allow optimal products to be selected according to the application.

[Achieves Lead Angle Accuracy of Class C7]

Screw shafts with travel distance error of classes C7 and C8 are also manufactured as the standard in addition to class C10 to meet a broad range of applications.

Travel distance C7: $\pm 0.05/300$ (mm)

 C8: $\pm 0.10/300$ (mm)

 C10: $\pm 0.21/300$ (mm)

(For maximum length of screw shaft by accuracy grade, see A-709.)

[Achieves Roughness of the Ball Raceways of the Screw Shaft at 0.20 μ m or Less]

The surface of the screw shaft's ball raceways is specially ground after the shaft is rolled to ensure surface roughness of 0.20 μ m or less, which is equal to that of the ground thread of the Precision Ball Screw.

[The Ball Raceways of the Ball Screw Nut are All Finished by Grinding]

THK finishes the ball raceways of Rolled Ball Screw nuts by grinding, just as the Precision Ball Screws, to secure the durability and the smooth motion.

[Low Price]

The screw shaft is induction-hardened or carburized after being rolled, and its surface is then specially ground. This allows the rolled Ball Screw to be priced lower than the Precision Ball Screw with a ground thread.

[High Dust-prevention Effect]

The ball screw nut is incorporated with a compact labyrinth seal or a brush seal. This achieves a low friction, a high dust-prevention effect and a longer service life of the Ball Screw.

Types and Features

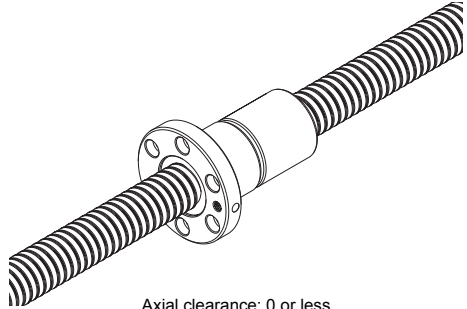
[Preload Type]

Model JPF

Specification Table⇒B-776

This model achieves a zero-backlash through a constant preloading method by shifting the phase with the central part of a simple nut as the spring structure.

The constant preload method allows the ball screw to absorb a pitch error and achieve a smooth motion.



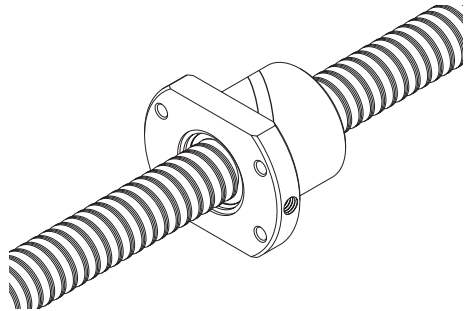
Axial clearance: 0 or less

[No Preload Type]

Model BTK

Specification Table⇒B-778

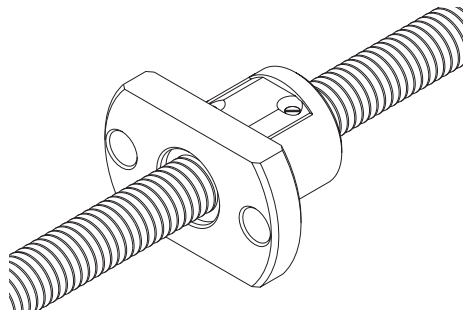
A compact type with a round nut incorporated with a return pipe. The flange circumference is cut flat at the top and bottom, allowing the shaft center to be positioned lower.



Model MTF

Specification Table⇒B-778

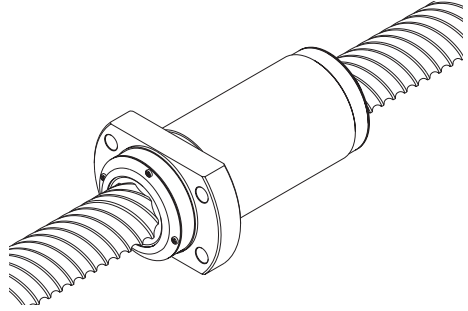
A miniature type with a screw shaft diameter of $\phi 6$ to $\phi 12$ mm and a lead of 1 to 2 mm.



Models BLK/WTF

Specification Table⇒B-778

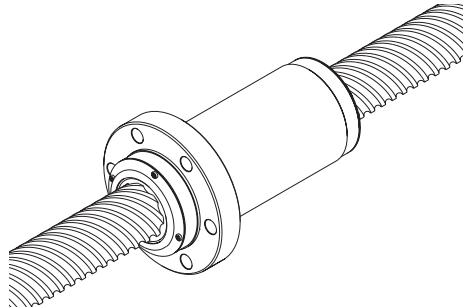
Using an end-cap method, these models achieve stable motion in a high-speed rotation.



Model CNF

Specification Table⇒B-778

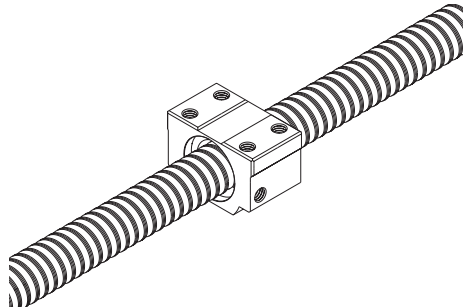
With a combination of 4 rows of large-lead loaded grooves and a long nut, a long service life is achieved.



Square Ball Screw Nut Model BNT

Specification Table⇒B-784

Since the mounting screw holes are machined on the square ball screw nut, this model can compactly be mounted on the machine without a housing.



Service Life

For details,see A-722.

Axial Clearance

For details,see A-703.

Accuracy Standards

For details,see A-696.

Rolled Rotary Ball Screw

Model BLR

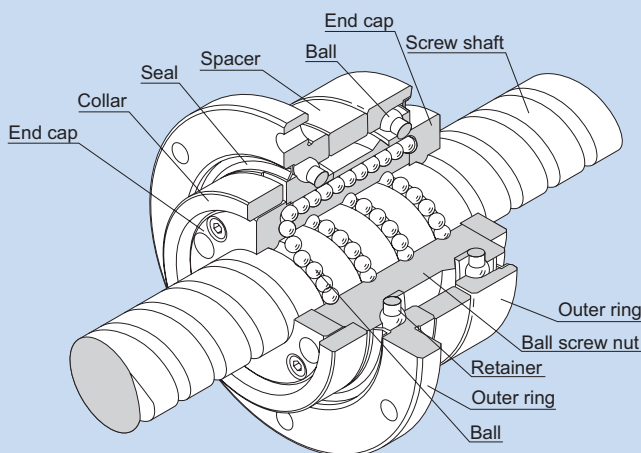


Fig.1 Structure of Large Lead Rotary Nut Ball Screw Model BLR

Structure and Features	▶▶▶ A-819
Type	▶▶▶ A-819
Service Life	▶▶▶ A-722
Axial Clearance	▶▶▶ A-703
Accuracy Standards	▶▶▶ A-820
Example of Assembly	▶▶▶ A-821
Dimensional Drawing, Dimensional Table, Example of Model Number Coding	▶▶▶ B-788

Structure and Features

The Rotary Ball Screw is a rotary-nut ball screw unit that has an integrated structure consisting of a ball screw nut and a support bearing. The support bearing is an angular bearing that has a contact angle of 60°, contains an increased number of balls and achieves a large axial rigidity. Model BLR is divided into two types: the Precision Ball Screw and the Rolled Screw Ball.

[Smooth Motion]

It achieves smoother motion than the rack-and-pinion based straight motion. Also, since the screw shaft does not rotate because of the ball screw nut drive, this model does not show skipping, produces low noise and generates little heat.

[Low Noise even in High-speed Rotation]

Model BLR produces very low noise when the balls are picked up along the end cap. In addition, the balls circulate by passing through the ball screw nut, allowing this model to be used at high speed.

[High Rigidity]

The support bearing of this model is larger than that of the screw shaft rotational type. Thus, its axial rigidity is significantly increased.

[Compact]

Since the nut and the support bearing are integrated, a highly accurate, and a compact design is achieved.

[Easy Installation]

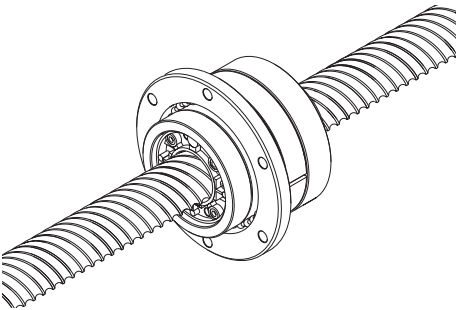
By simply mounting this model to the housing using bolts, a ball screw nut rotating mechanism can be obtained. (For the housing's inner-diameter tolerance, H7 is recommended.)

Type

[No Preload Type]

Model BLR

Specification Table⇒B-788



Service Life

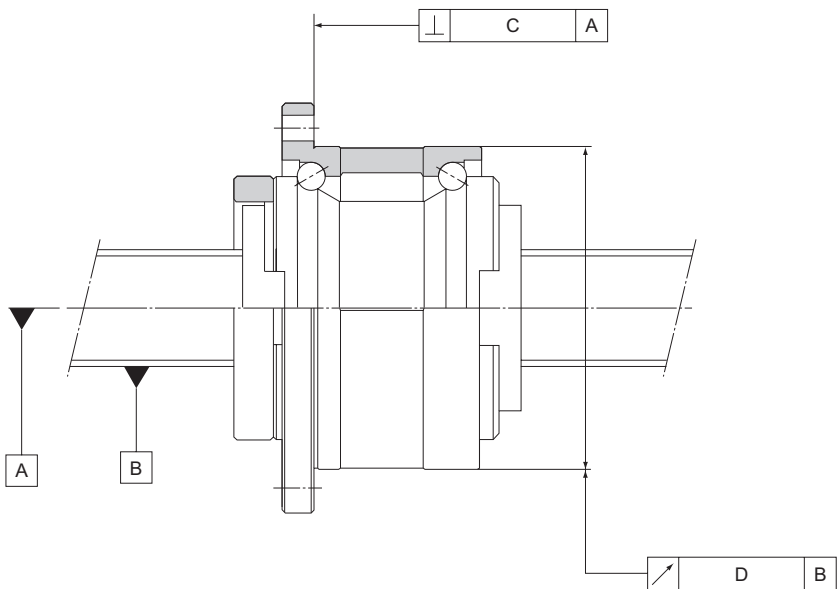
For details,see A-722.

Axial Clearance

For details,see A-703.

Accuracy Standards

The accuracy of model BLR is compliant with the JIS standard (JIS B 1192-1997) except for the radial runout of the circumference of the ball screw nut from the screw axis (D) and the perpendicularity of the flange-mounting surface against the screw axis (C).

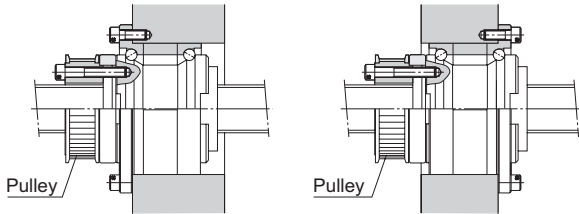


Unit: mm

Lead angle accuracy	C7, C8, C10	
Accuracy grades	C10	
Model No.	C	D
BLR 1616	0.035	0.065
BLR 2020	0.035	0.065
BLR 2525	0.035	0.065
BLR 3232	0.035	0.065
BLR 3636	0.036	0.066
BLR 4040	0.046	0.086
BLR 5050	0.046	0.086

Example of Assembly

[Example of Mounting Ball Screw Nut Model BLR]



Standard installation method

Inverted flange

Note) If the flange is to be inverted, indicate "K" in the model number. (applicable only to model BLR)

Example: BLR 2020-3.6 **K** UU

Symbol for invert

(No symbol for standard flange orientation)

[Example of Mounting Model BLR on the Table]

- (1) Screw shaft free, ball screw nut fixed
(Suitable for a long table)

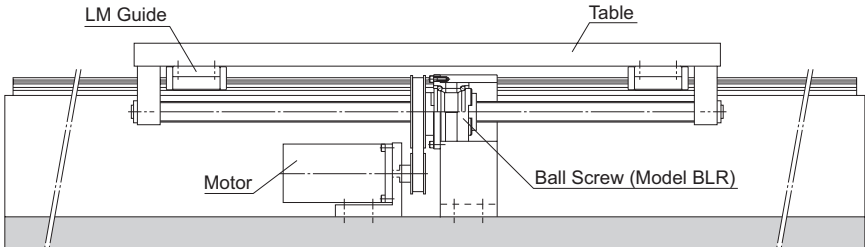


Fig.2 Example of Installation on the Table (Ball Screw Nut Fixed)

- (2) Ball screw nut free, screw shaft fixed
(Suitable for a short table and a long stroke)

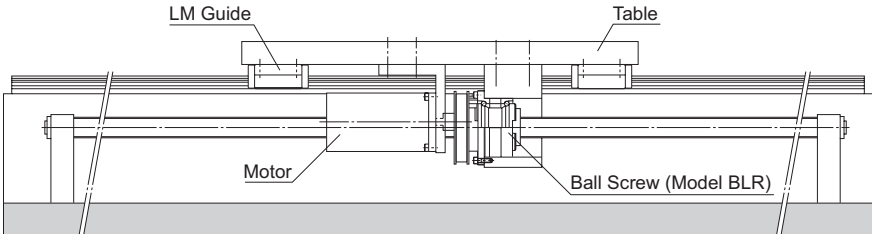


Fig.3 Example of Installation on the Table (Screw Shaft Fixed)

Ball Screw

Ball Screw Peripherals

Support Unit

Models EK, BK, FK, EF, BF and FF

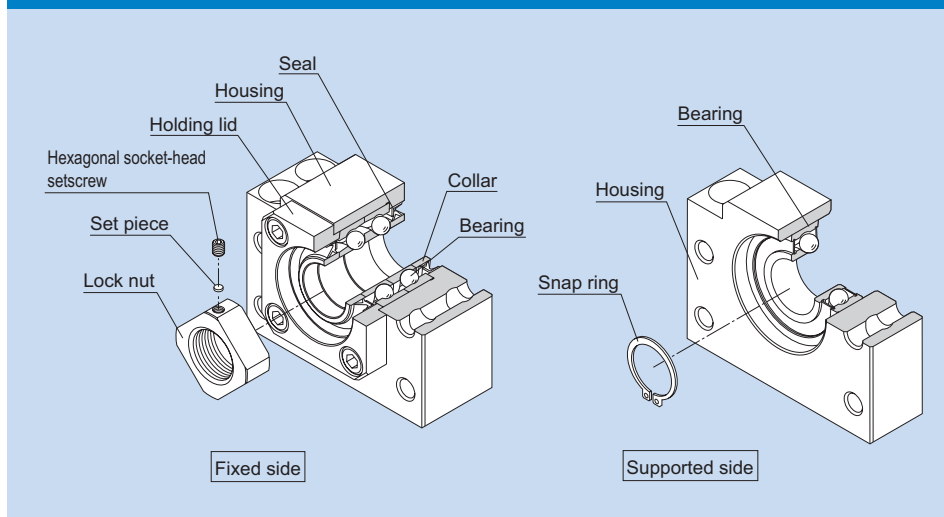


Fig.1 Structure of the Support Unit

Structure and Features

The Support Unit comes in six types: models EK, FK, EF, and FF, which are standardized for the standard Ball Screw assembly provided with the finished shaft ends, and models BK and BF, which are standardized for ball screws in general.

The Support Unit on the fixed side contains a JIS Class 5-compliant angular bearing provided with an adjusted preload. The miniature type Support Unit models EK/FK 4, 5, 6 and 8, in particular, incorporate a miniature bearing with a contact angle of 45° developed exclusively for miniature Ball Screws. This provides stable rotational performance with a high rigidity and an accuracy.

The Support Unit on the supported side uses a deep-groove ball bearing.

The internal bearings of the Support Unit models EK, FK and BK contain an appropriate amount of lithium soap-group grease that is sealed with a special seal. Thus, these models are capable of operating over a long period.

[Uses the Optimal Bearing]

To ensure the rigidity balance with the Ball Screw, the Support Unit uses an angular bearing (contact angle: 30°; DF configuration) with a high rigidity and a low torque. Miniature Support Unit models EK/FK 4, 5, 6 and 8 are incorporated with a miniature angular bearing with a contact angle of 45° developed exclusively for miniature Ball Screws. This bearing has a greater contact angle of 45° and an increased number of balls with a smaller diameter. The high rigidity and accuracy of the miniature angular bearing provides the stable rotational performance.

[Support Unit Shapes]

The square and round shapes are available for the Support Unit to allow the selection according to the intended use.

[Compact and Easy Installation]

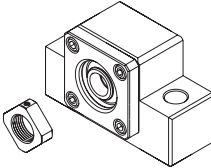
The Support Unit is compactly designed to accommodate the space in the installation site. As the bearing is provided with an appropriately adjusted preload, the Support Unit can be assembled with a Ball Screw unit with no further machining. Accordingly, the required man-hours in the assembly can be reduced and the assembly accuracy can be increased.

Type

[For the Fixed Side]

Square Type Model EK

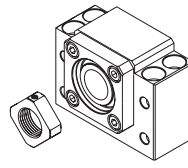
Specification Table⇒B-794



(Inner diameter: $\phi 4$ to $\phi 20$)

Square Type Model BK

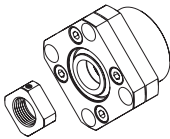
Specification Table⇒B-796



(Inner diameter: $\phi 10$ to $\phi 40$)

Round Type Model FK

Specification Table⇒B-798

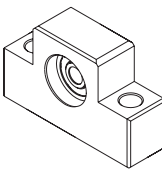


(Inner diameter: $\phi 4$ to $\phi 30$)

[For the Supported Side]

Square Type Model EF

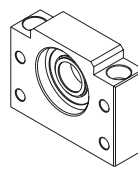
Specification Table⇒B-802



(Inner diameter: $\phi 6$ to $\phi 20$)

Square Type Model BF

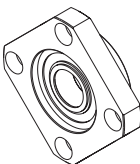
Specification Table⇒B-804



(Inner diameter: $\phi 8$ to $\phi 40$)

Round Type Model FF

Specification Table⇒B-806



(Inner diameter: $\phi 6$ to $\phi 30$)

Types of Support Units and Applicable Screw Shaft Outer Diameters

Inner diameter of the fixed side Support Unit (mm)	Applicable model No. of the fixed side Support Unit	Inner diameter of the supported side Support Unit (mm)	Applicable model No. of the supported side Support Unit	Applicable screw shaft outer diameter (mm)
4	EK 4 FK 4	—	—	φ4
5	EK 5 FK 5	—	—	φ6
6	EK 6 FK 6	6	EF 6 FF 6	φ8
8	EK 8 FK 8	6	EF 8 FF 6	φ10
10	EK 10 FK 10 BK 10	8	EF 10 FF 10 BF 10	φ12, φ14
12	EK 12 FK 12 BK 12	10	EF 12 FF 12 BF 12	φ14, φ15, φ16
15	EK 15 FK 15 BK 15	15	EF 15 FF 15 BF 15	φ20
17	BK 17	17	BF 17	φ20, φ25
20	EK 20 FK 20 BK 20	20	EF 20 FF 20 BF 20	φ25, φ28, φ32
25	FK 25 BK 25	25	FF 25 BF 25	φ36
30	FK 30 BK 30	30	FF 30 BF 30	φ40, φ45
35	BK 35	35	BF 35	φ45
40	BK 40	40	BF 40	φ50

Note) The Supports Units in this table apply only to those Ball Screw models with recommended shaft ends shapes H, J and K, indicated on A-832.

Model Numbers of Bearings and Characteristic Values

Angular ball bearing on the fixed side					Deep-groove ball bearing on the supported side			
Support Unit model No.	Bearing model No.	Axial direction			Support Unit model No.	Bearing model No.	Radial direction	
		Basic dynamic load rating Ca (kN)	Note) Permissible load (kN)	Rigidity (N/μm)			Basic dynamic load rating C (kN)	Basic static load rating Co(kN)
EK 4 FK 4	AC4-12P5	0.93	1.1	27	—	—	—	—
EK 5 FK 5	AC5-14P5	1	1.24	29	—	—	—	—
EK 6 FK 6	AC6-16P5	1.38	1.76	35	EF 6 FF 6	606ZZ	2.19	0.87
EK 8 FK 8	79M8DF GMP5	2.93	2.15	49	EF 8	606ZZ	2.19	0.87
EK 10 FK 10 BK 10	7000HTDF GMP5	6.08	3.1	65	EF 10 FF 10 BF 10	608ZZ	3.35	1.4
EK 12 FK 12 BK 12	7001HTDF GMP5	6.66	3.25	88	EF 12 FF 12 BF 12	6000ZZ	4.55	1.96
EK 15 FK 15 BK 15	7002HTDF GMP5	7.6	4	100	EF 15 FF 15 BF 15	6002ZZ	5.6	2.84
BK 17	7203HTDF GMP5	13.7	5.85	125	BF 17	6203ZZ	9.6	4.6
EK 20 FK 20	7204HTDF GMP5	17.9	9.5	170	EF 20 FF 20	6204ZZ	12.8	6.65
BK 20	7004HTDF GMP5	12.7	7.55	140	BF 20	6004ZZ	9.4	5.05
FK 25 BK 25	7205HTDF GMP5	20.2	11.5	190	FF 25 BF 25	6205ZZ	14	7.85
FK 30 BK 30	7206HTDF GMP5	28	16.3	195	FF 30 BF 30	6206ZZ	19.5	11.3
BK 35	7207HTDF GMP5	37.2	21.9	255	BF35	6207ZZ	25.7	15.3
BK 40	7208HTDF GMP5	44.1	27.1	270	BF 40	6208ZZ	29.1	17.8

Note) "Permissible load" indicates the static permissible load.

Example of Installation

[Square Type Support Unit]

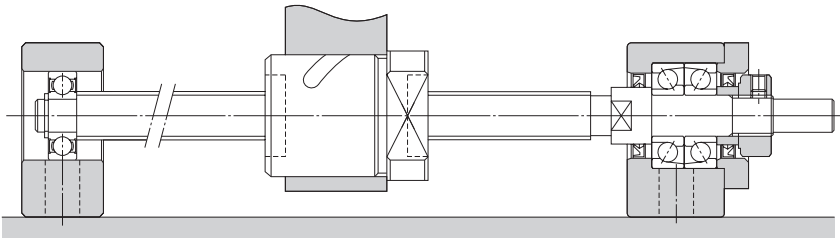


Fig.2 Example of Installing a Square Type Support Unit

[Round Type Support Unit]

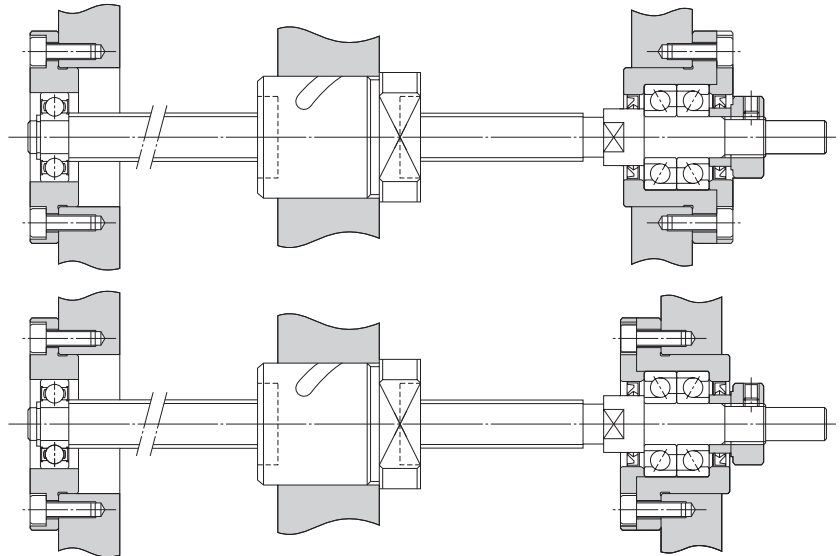


Fig.3 Example of Installing a Round Type Support Unit

Mounting Procedure

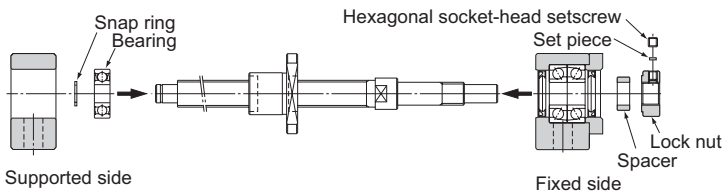
[Installing the Support Unit]

- (1) Install the fixed side Support Unit with the screw shaft.
- (2) After inserting the fixed side Support Unit, secure the lock nut using the fastening set piece and the hexagonal socket-head setscrews.
- (3) Attach the supported side bearing to the screw shaft and secure the bearing using the snap ring, and then install the assembly to the housing on the supported side.

Note1) Do not disassemble the Support Unit.

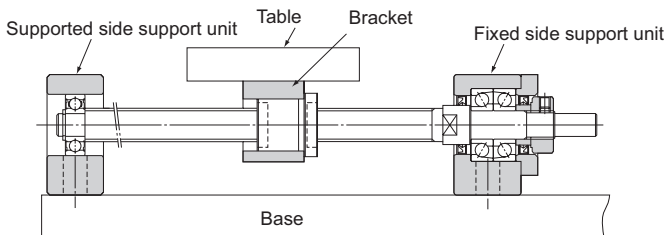
Note2) When inserting the screw shaft to the Support Unit, take care not to let the oil seal lip turn outward.

Note3) When securing the set piece with a hexagonal socket-head setscrew, apply an adhesive to the hexagonal socket-head setscrew before tightening it in order to prevent the screw from loosening. If planning to use the product in a harsh environment, it is also necessary to take a measure to prevent other components/parts from loosening. Contact THK for details.



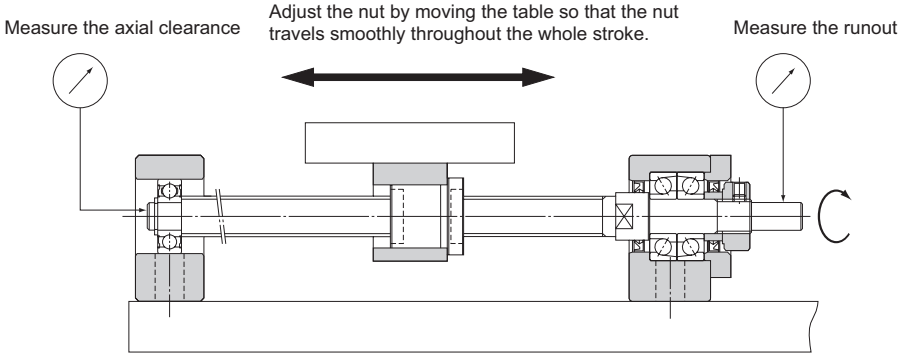
[Installation onto the Table and the Base]

- (1) If using a bracket when mounting the ball screw nut to the table, insert the nut into the bracket and temporarily fasten it.
- (2) Temporarily fasten the fixed side Support Unit to the base.
In doing so, press the table toward the fixed side Support Unit to align the axial center, and adjust the table so that it can travel freely.
 - If using the fixed side Support Unit as the reference point, secure a clearance between the ball screw nut and the table or inside the bracket when making adjustment.
 - If using the table as the reference point, make the adjustment either by using the shim (for a square type Support Unit), or securing the clearance between the outer surface of the nut and the inner surface of the mounting section (for a round type Support Unit).
- (3) Press the table toward the fixed-side Support Unit to align the axial center. Make the adjustment by reciprocating the table several times so that the nut travels smoothly throughout the whole stroke, and temporarily secure the Support Unit to the base.



[Checking the Accuracy and Fully Fastening the Support Unit]

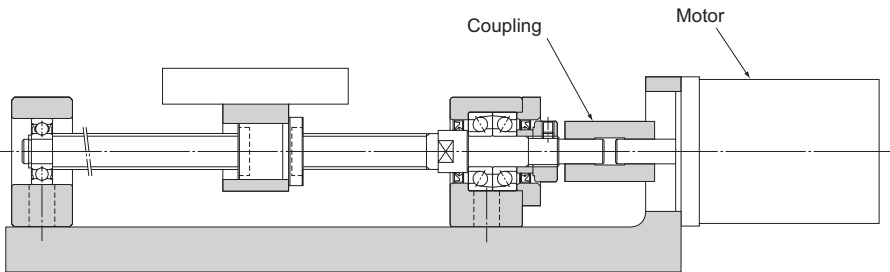
While checking the runout of the ball screw shaft end and the axial clearance using a dial gauge, fully fasten the ball screw nut, the nut bracket, the fixed side Support Unit and the supported-side Support Unit, in this order.



[Connection with the Motor]

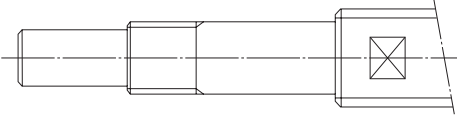
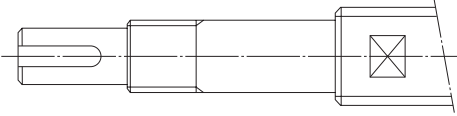
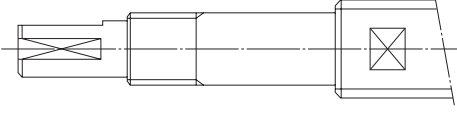
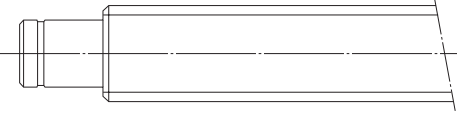
- (1) Mount the motor bracket to the base.
- (2) Connect the motor and the ball screw using a coupling.
- (3) Thoroughly perform the break-in for the system.

Note) Make sure the mounting accuracy is maintained.



Types of Recommended Shapes of the Shaft Ends

To ensure speedy estimates and manufacturing of Ball Screws, THK has standardized the shaft end shapes of the screw shafts. The recommended shapes of shaft ends consist of shapes H, K and J, which allow standard Support Units to be used.

Mounting method	Symbol for shaft end shape		Shape	Supported Support Unit
Fixed	H J	H1		FK EK
		J1		BK
		H2		FK EK
		J2		BK
		H3		FK EK
		J3		BK
Sup-ported	K			FF EF BF

Nut bracket

Model MC

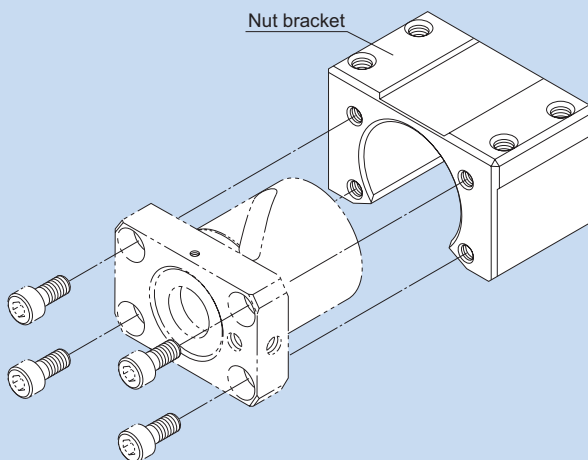


Fig.1 Structure of the Nut Bracket

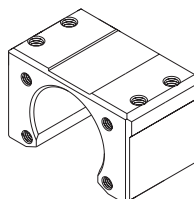
Structure and Features

The Nut Bracket is standardized for the standard Ball Screw assembly provided with finished shaft ends. It is designed to be secured directly on the table with bolts. Since the height is low, it can be mounted on the table only using bolts.

Type

Nut Bracket Model MC

Specification Table⇒B-814



Lock nut

Model RN

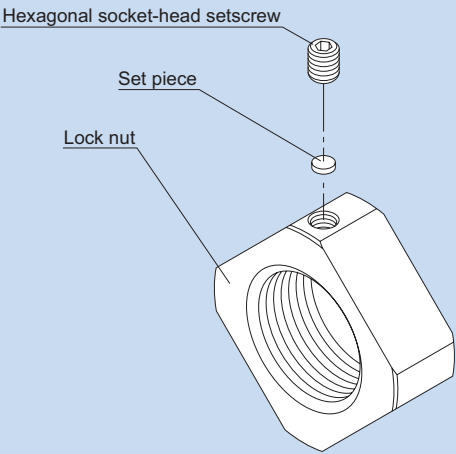


Fig.1 Structure of the Lock Nut

Structure and Features

The Lock Nut for the Ball Screws is capable of fastening the screw shaft and the bearing with a high accuracy.

The provided hexagonal socket-head setscrew and the set piece prevent the Lock Nut from loosening and ensure firm fastening. The Lock Nut comes in various types ranging from model M4 to model M40.

Type

Lock Nut Model RN

Specification Table⇒B-816



Ball Screw Options

Lubrication

To maximize the performance of the Ball Screw, it is necessary to select a lubricant and a lubrication method according to the conditions.

For types of lubricants, characteristics of lubricants and lubrication methods, see the section on "Accessories for Lubrication" on A-976.

Also, QZ Lubricator is available as an optional accessory that significantly increases the maintenance interval.

Corrosion Prevention (Surface Treatment, etc.)

Depending on the service environment, the Ball Screw requires anticorrosive treatment or a different material. For details of an anticorrosive treatment and a material change, contact THK. (see A-18)

Contamination Protection

The dust and foreign materials that enter the Ball Screw may cause accelerated wear and breakage, as with roller bearings. Therefore, on parts where contamination by dust or foreign materials (e.g., cutting chips) is predicted, screw shafts must always be completely covered by contamination protection devices (e.g., bellows, screw cover, wiper ring).

If the Ball Screw is used in an atmosphere free from the foreign materials but with suspended dust, a labyrinth seal (for precision Ball Screws) with symbol RR and a brush seal (for rolled Ball Screws) with symbol ZZ can be used as contamination protection devices.

The labyrinth seal is designed to maintain a slight clearance between the seal and the screw shaft raceway so that torque does not develop and no heat is generated, though its effect in contamination protection is limited.

With Ball Screws except the large lead and super lead types, there is no difference in nut dimensions between those with and without a seal.

With the wiper ring, special resin with high wear resistance and low dust generation removes foreign materials while closely contacting the circumference of the ball screw shaft and the screw thread. It is capable of preventing foreign materials from entering the Ball Screw even in a severe environment.

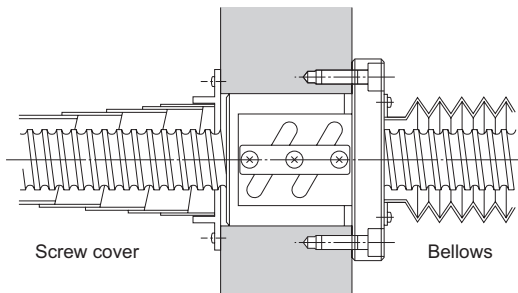


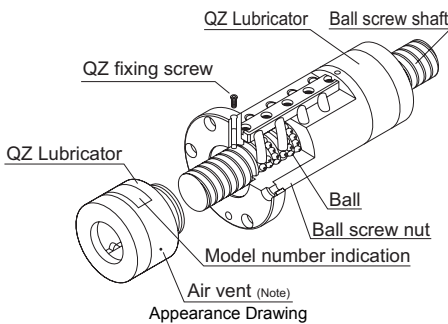
Fig.1 Contamination Protection Cover

QZ Lubricator

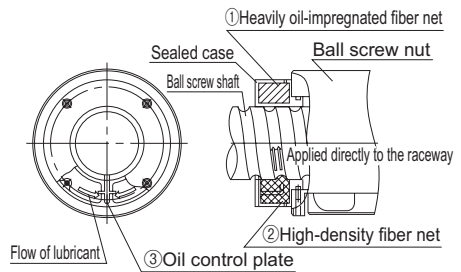
● For the supported models and the ball screw nut dimension with QZ attached, see B-818 to B-823.

QZ Lubricator feeds a right amount of lubricant to the ball raceway of the ball screw shaft. This allows an oil film to be constantly formed between the balls and the raceway, improves lubrications and significantly extends the lubrication maintenance interval.

The structure of QZ Lubricator consists of three major components: (1) a heavily oil-impregnated fiber net (stores the lubricant), (2) a high-density fiber net (applies the lubricant to the raceway) and (3) an oil-control plate (adjusts the oil flow). The lubricant contained in the QZ Lubricator is fed by the capillary phenomenon, which is used also in felt pens and many other products.



Appearance Drawing



Structural Drawing

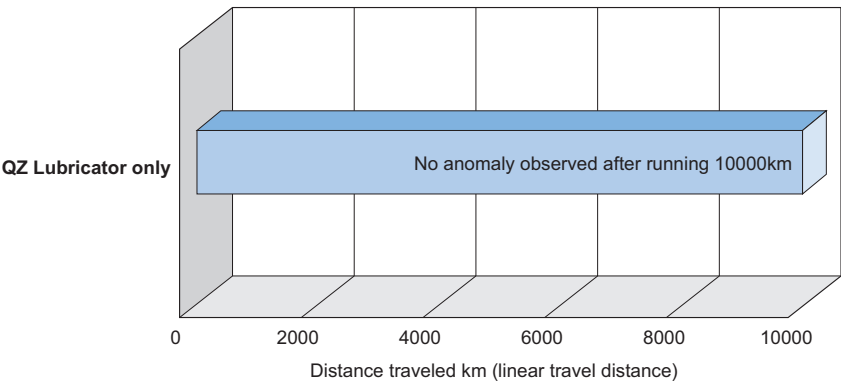
[Features]

- Since it supplements an oil loss, the lubrication maintenance interval can be significantly extended.
- Since the right amount of lubricant is applied to the ball raceway, an environmentally friendly lubrication system that does not contaminate the surroundings is achieved.

Note) QZ Lubricator has a vent hole. Do not block the hole with grease or the like.

● Significantly extended maintenance interval

Since QZ Lubricator continuously feeds a lubricant over a long period, the maintenance interval can be extended significantly.

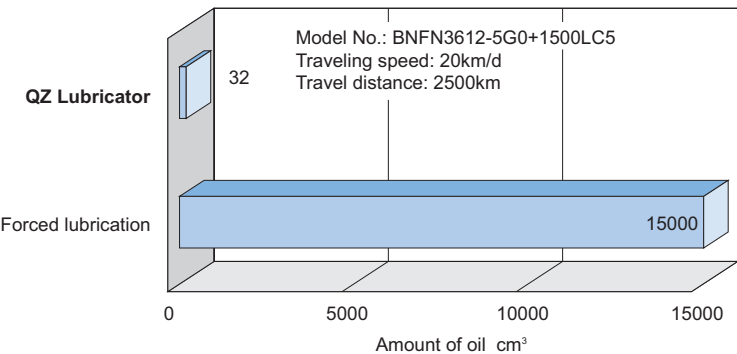


[Test conditions]

Item	Description
Ball Screw	BIF2510
Maximum rotational speed	2500min ⁻¹
Maximum speed	25m/min
Stroke	500mm
Load	Internal preload only

● Environmentally friendly lubrication system

Since the QZ Lubricator feeds the right amount of lubricant directly to the raceway, the lubricant can effectively be used without waste.



QZ Lubricator + THK AFA Grease
32cm³
(QZ Lubricator attached to both ends of the ball screw nut)



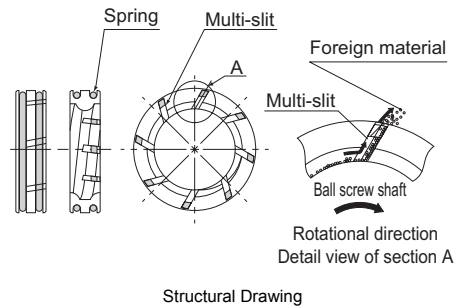
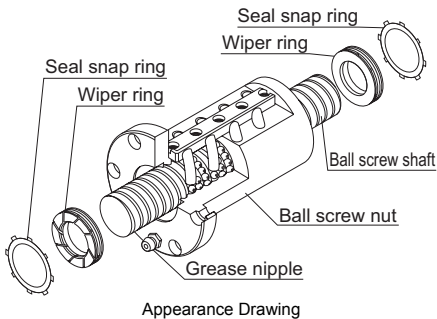
Forced lubrication
0.25cm³/3min×24h×125d
=15000cm³

Reduced to approx. $\frac{1}{470}$

Wiper Ring W

● For the supported models and the ball screw nut dimension with Wiper ring W attached, see B-818 to B-823.

With the wiper ring W, special resin with a high wear resistance and a low dust generation which removes and prevents foreign materials from entering the ball screw nut while elastically contacting the circumference of the ball screw shaft and the screw thread.



[Features]

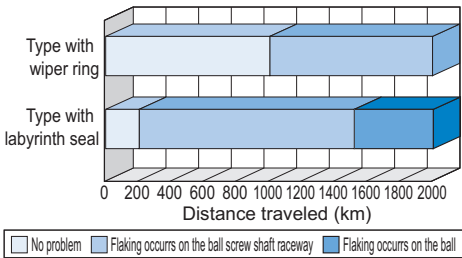
- A total of eight slits on the circumference remove foreign materials in succession, and prevent entrance of foreign material.
- Contacts the ball screw shaft to reduce the flowing out of grease.
- Contacts the ball screw shaft at a constant pressure level using a spring, thus to minimize the heat generation.
- Since the material is highly resistant to the wear and the chemicals, its performance will not easily be deteriorated even if it is used over a long period.

● **Test in an environment exposed to contaminated environment**

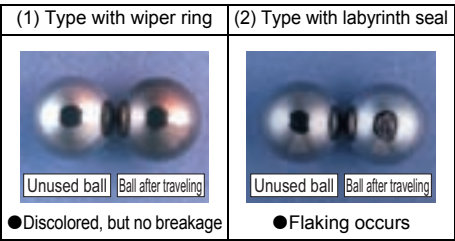
[Test conditions]

Item	Description
Model No.	BIF3210-5G0+1500LC5
Maximum rotational speed	1000min ⁻¹
Maximum speed	10m/min
Maximum circumferential speed	1.8m/s
Time constant	60ms
Dowel	1s
Stroke	900mm
Load (through internal load)	1.31kN
Grease	THK AFG Grease 8cm ³ (Initial lubrication to the ball screw nut only)
Foundry dust	FCD400 average particle diameter: 250μm
Volume of foreign material per shaft	5g/h

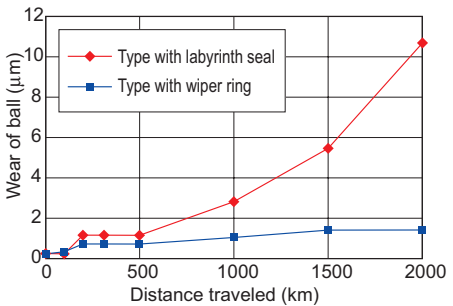
[Test result]



Change in the ball after traveling 2000 km



- Type with wiper ring
Slight flaking occurred in the ball screw shaft at travel distant of 1,000 km.
- Type with labyrinth seal
Flaking occurred throughout the circumference of the screw shaft raceway at travel distance of 200 km.
Flaking occurred on the balls after traveling 1,500 km.



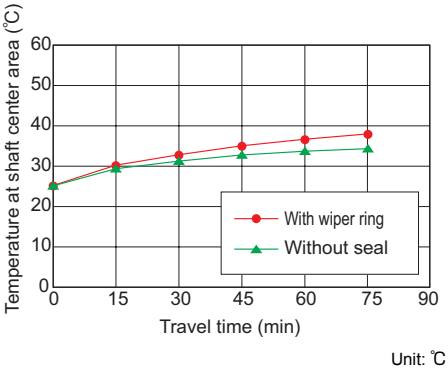
- Type with wiper ring
Wear of balls at a travel distance of 2,000 km: 1.4 μm.
- Type with labyrinth seal
Starts to be worn rapidly after 500 km, and the ball wear amount at the travel distance of 2,000 km: 11 μm

● Heat Generation Test

[Test conditions]

Item	Description
Model No.	BLK3232-3.6G0+1426LC5
Maximum rotational speed	1000min ⁻¹
Maximum speed	32m/min
Maximum circumferential speed	1.7m/s
Time constant	100ms
Stroke	1000mm
Load (through internal load)	0.98kN
Grease	THK AFG Grease 5cm ³ (contained in the ball screw nut)

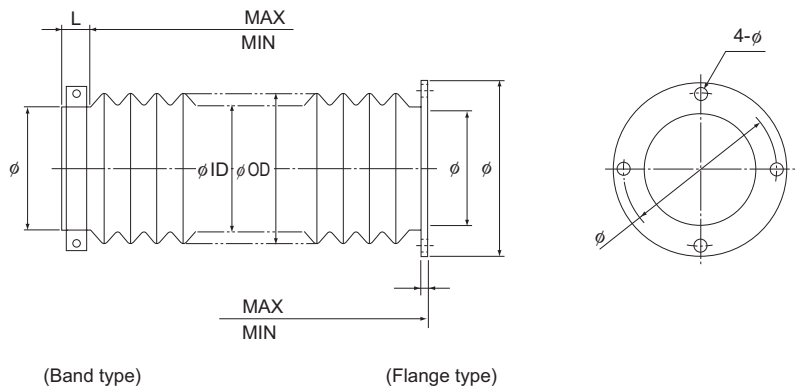
[Test result]



Item	With wiper ring	Without seal
Heat generation temperature	37.1	34.5
Temperature rise	12.2	8.9

Specifications of the Bellows

Bellows are available as a contamination protection accessory. Use this specification sheet.



Specifications of the Bellows

Supported Ball Screw models:

Dimensions of the Bellows

Stroke:() mm MAX:() mm MIN:() mm
Permissible outer diameter:(ϕ OD) Desired inner diameter:(ϕ ID)

How It Is Used

Installation direction:(horizontal, vertical, slant) Speed: ()mm/sec. mm/min.
Motion:(reciprocation, vibration)

Conditions

Resistance to oil and water: (necessary, unnecessary) Oil name ()
Chemical resistance: Name () $\times$ () %
Location: (indoor, outdoor)

Remarks:

Number of Units To Be Manufactured:



Method for Mounting the Ball Screw Shaft

Fig.1 to Fig.4 show the representative mounting methods for the screw shaft.

The permissible axial load and the permissible rotational speed vary with mounting methods for the screw shaft. Therefore, it is necessary to select an appropriate mounting method according to the conditions.

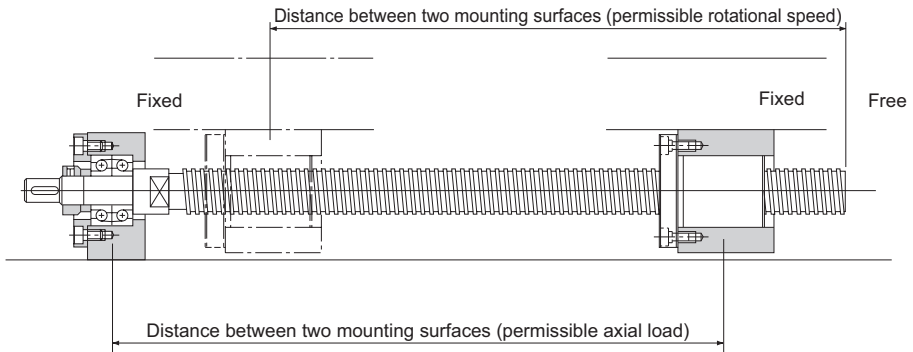


Fig.1 Screw Shaft Mounting Method: Fixed - Free

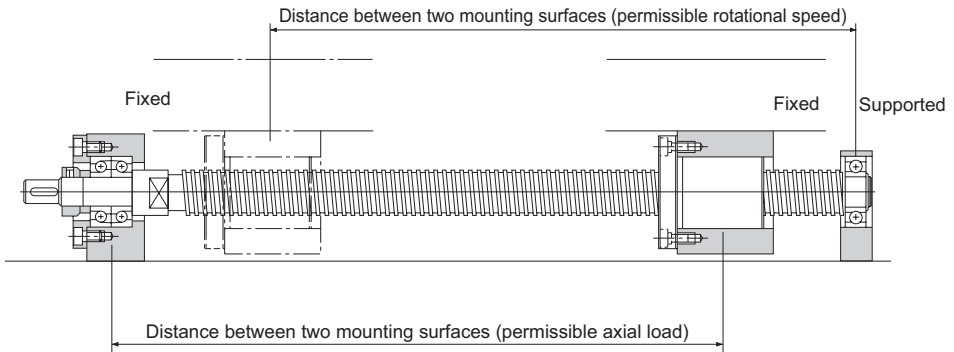


Fig.2 Screw Shaft Mounting Method: Fixed - Supported

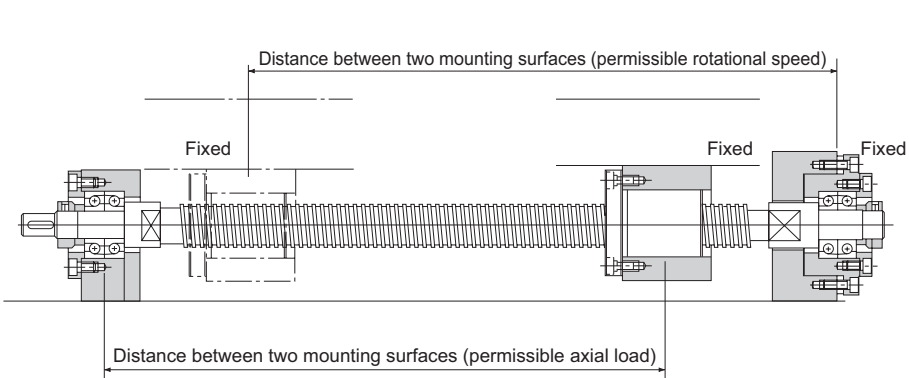


Fig.3 Screw Shaft Mounting Method: Fixed - Fixed

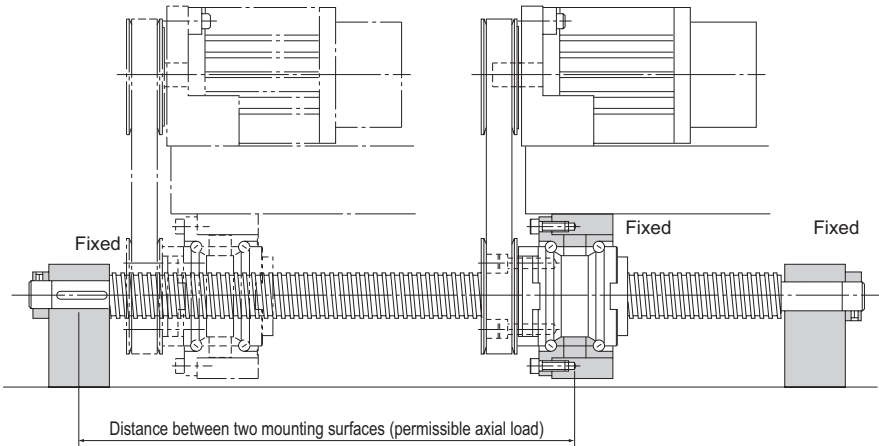


Fig.4 Screw Shaft Mounting Method for Rotary Nut Ball Screw: Fixed - Fixed

Maintenance Method

Amount of Lubricant

If the amount of the lubricant to the Ball Screw is insufficient, it may cause a lubrication breakdown, and if it is excessive, it may cause heat to be generated and the resistance to be increased. It is necessary to select an amount that meets the conditions.

[Grease]

The feed amount of grease is generally approximately one third of the spatial volume inside the nut.

[Oil]

Table 1 shows a guideline for the feed amount of oil.

Note, that the amount varies according to the stroke, the oil type and the conditions (e.g., suppressed heat generation).

Table1 Guideline for the Feed Amount of Oil
(Interval: 3 minutes)

Shaft diameter (mm)	Amount of lubricant (cc)
4 to 8	0.03
10 to 14	0.05
15 to 18	0.07
20 to 25	0.1
28 to 32	0.15
36 to 40	0.25
45 to 50	0.3
55 to 63	0.4
70 to 100	0.5

[Handling]

- (1) Disassembling the components may cause dust to enter the system or degrade the mounting accuracy of parts. Do not disassemble the product.
- (2) Tilting the screw shaft and the ball screw nut may cause them to fall by their own weight.
- (3) Dropping or hitting the Ball Screw may damage the ball circulation section, which may cause the functional loss. Giving an impact to the product could also cause a damage to its function even if the product looks intact.

[Lubrication]

- (1) Thoroughly remove anti-rust oil and feed lubricant before using the product.
- (2) Do not mix the lubricants of different physical properties.
- (3) In locations exposed to constant vibrations or in special environments such as clean rooms, a vacuum and a low/high temperature, normal lubricants may not be used. Contact THK for details.
- (4) When planning to use a special lubricant, contact THK before using it.
- (5) The lubrication interval varies according to the conditions. Contact THK for details.

[Precautions on Use]

- (1) Do not remove the ball screw nut from the ball screw shaft. Doing so may cause the balls or the nut to fall off.
- (2) Entrance of foreign materials to the ball screw nut may cause damages to the ball circulating path or functional loss. Prevent foreign materials, such as dust or cutting chips, from entering the system.
- (3) If the foreign materials such as dust or cutting chips adheres to the product, replenish the lubricant after cleaning the product with pure white kerosene. For available types of detergent, contact THK.
- (4) When planning to use the product in an environment where the coolant penetrates the spline nut, it may cause problems to product functions depending on the type of the coolant. Contact THK for details.
- (5) Contact THK if you desire to use the product at a temperature of 80°C or higher.
- (6) If using the product with vertical mount, the ball screw nut may fall by its weight. Attach a mechanism to prevent it from falling.
- (7) Exceeding the permissible rotational speed may lead the components to be damaged or cause an accident. Be sure to use the product within the specification range designated by THK.
- (8) Forcefully driving in the ball screw shaft or the ball screw nut may cause an indentation on the raceway. Use care when mounting the components.
- (9) If an offset or skewing occurs with the ball screw shaft support and the ball screw nut, it may substantially shorten the service life. Pay attention to components to be mounted and to the mounting accuracy.
- (10) When using the product in locations exposed to constant vibrations or in special environments such as clean rooms, a vacuum and a low/high temperature, contact THK in advance.
- (11) Letting the ball screw nut overshoot will cause balls to fall off or the ball-circulating components to be damaged.

[Storage]

When storing the Ball Screw, enclose it in a package designated by THK and store it in a horizontal orientation while avoiding a high temperature, a low temperature and a high humidity.