# Ball Screw

**THK General Catalog**

# Ball Screw

## THK General Catalog

**A Technical Descriptions of the Products**

* 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.
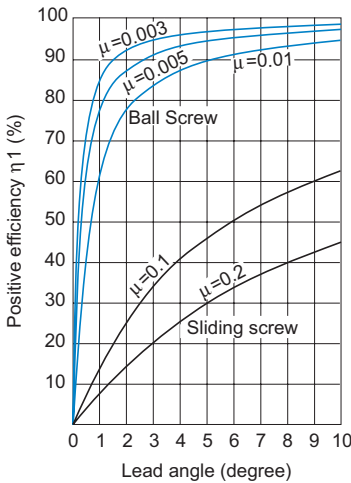
Fig.1 Positive Efficiency (Rotational to Linear)
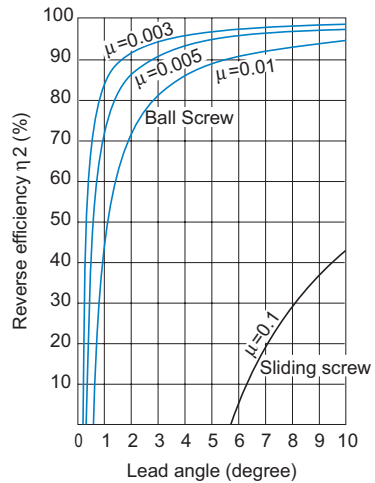
Fig.2 Reverse Efficiency (Linear to Rotational)

[**Calculating the Lead Angle**]

$$\tan\beta = \frac{Ph}{\pi \cdot d_P} \quad \cdots\cdots(1)$$

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**

$$T = \frac{Fa \cdot Ph}{2\pi \cdot \eta 1} \quad \cdots\cdots (2)$$

T   : Driving torque            (N-mm)
Fa   : Frictional resistance on
      the guide surface         (N)
Fa=μ×mg
  μ   : Frictional coefficient of
      the guide surface
  g   : Gravitational acceleration   ($9.8 \text{ m/s}^2$)
  m   : Mass of the transferred object   (kg)
Ph   : Feed screw lead         (mm)
η1   : Positive efficiency of feed screw
                (see Fig.1 on A-682)

Fa: Frictional resistance

m: Mass

T: Driving torque

Feed screw

Guide surface
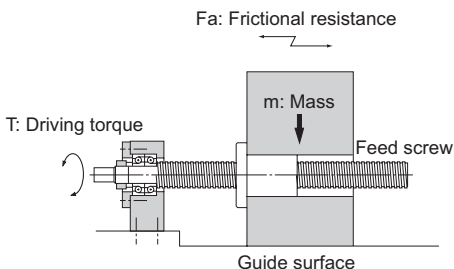
● **Thrust Generated When Torque is Applied**

$$Fa = \frac{2\pi \cdot \eta 1 \cdot T}{Ph} \quad \cdots\cdots (3)$$

Fa   : 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**

$$T = \frac{Ph \cdot \eta 2 \cdot Fa}{2\pi} \quad \cdots\cdots (4)$$

T   : Torque generated        (N-m)
Fa   : Thrust generated         (N)
Ph   : Feed screw lead         (mm)
η2   : Reverse efficiency of feed screw
                (see Fig.2 on A-682)

**Ball Screw**

# [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)**

Fa: Frictional resistance
（14.7N）

T: Driving torque
（24N·mm）

m: Mass
（500kg）

Feed screw
(Ball screw efficiency
$\eta$ = 96%)

Guide surface
(Rolling friction coefficient $\mu$ = 0.003)
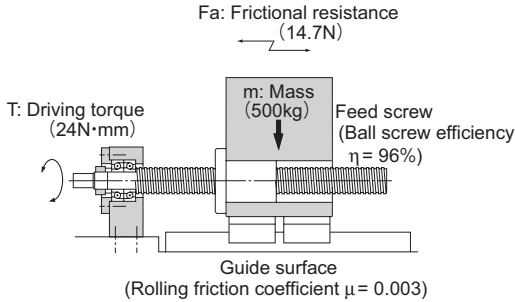
Frictional resistance on the guide surface

Fa=0.003×500×9.8=14.7N

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)**

Fa: Frictional resistance
（14.7N）

T: Driving torque
（73N·mm）

m: Mass
（500kg）

Feed screw
(Sliding screw efficiency
$\eta$ = 32%)

Guide surface
(Rolling friction coefficient $\mu$ = 0.003)
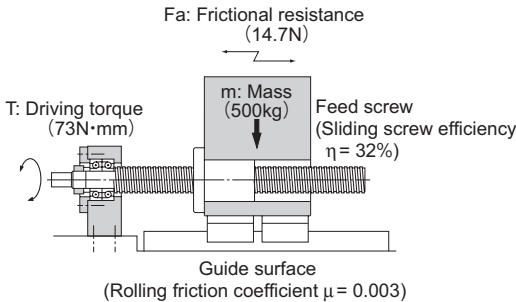
Frictional resistance on the guide surface

Fa=0.003×500×9.8=14.7N

Driving torque

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

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# Ensuring High Accuracy

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



Automatic lead-measuring machine using laser
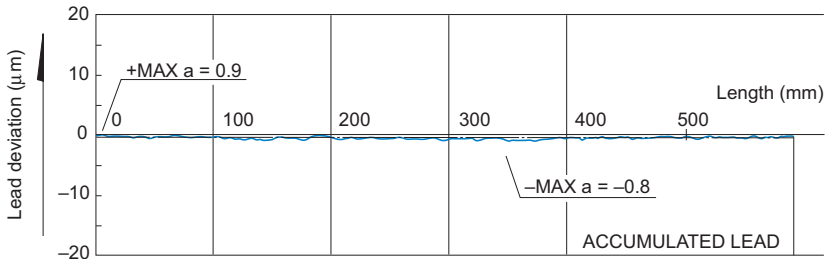


Fig.3 Lead Accuracy Measurement

[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 |

**Ball Screw**

# 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-$\mu$m feeding. (LM Guide is used for the guide surface.)

Travel distance ($\mu$m)

0.2$\mu$m

Time (s)
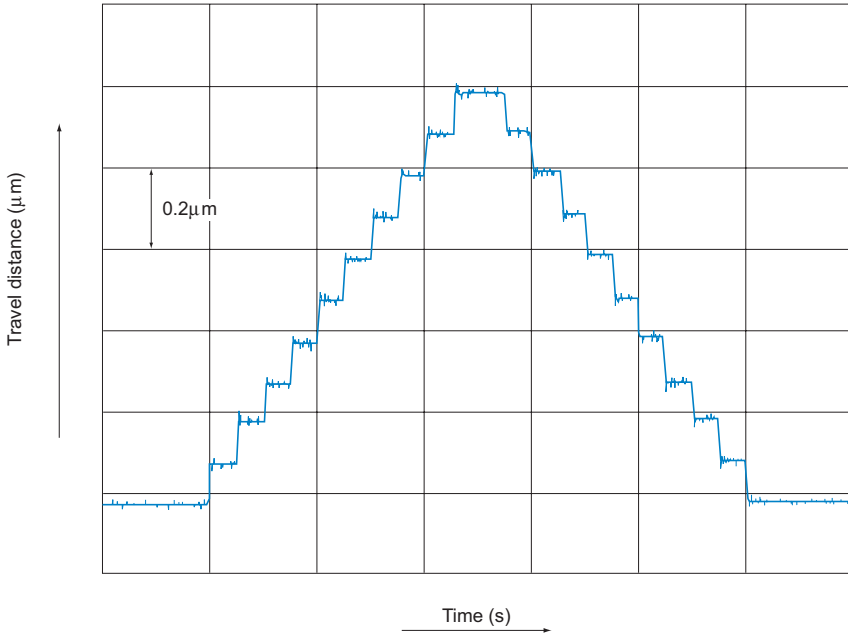
Fig.4 Data on Travel in 0.1-$\mu$m Feeding

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# 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.

Axial displacement

$(-)$    $(+)$

Axial load

$(+)$

$(-)$

Fig.5

**Ball Screw**

Axial displacement

$(+)$

$(-)$                                                    $(+)$

Axial clearance: 0.02

Axial clearance: 0

Applied preload (0.1×Ca)

Axial load

$(-)$
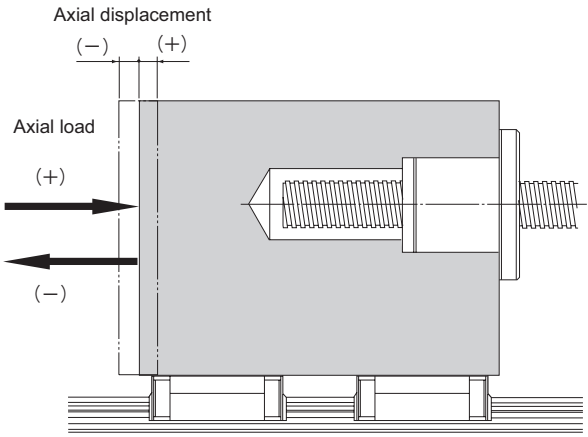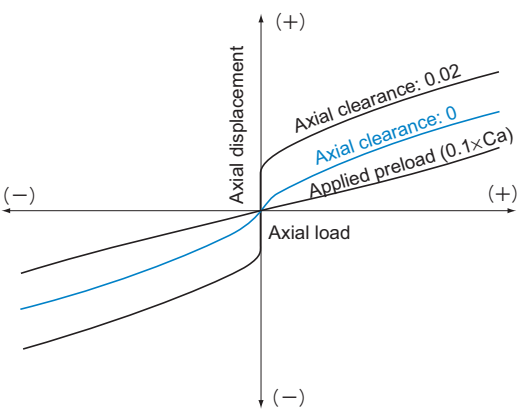
Fig.6 Axial Displacement in Relation to Axial Load

# 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 |
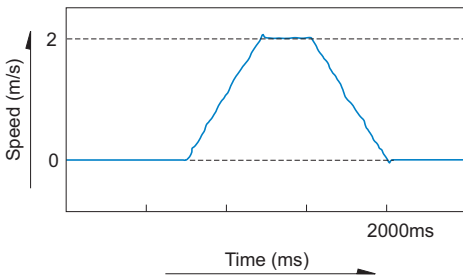


Fig.7 Velocity diagram

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[**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<br>BNFN4010-5<br>(Shaft diameter: 40 mm; lead: 10 mm; applied preload: 2,700 N) |
| Maximum speed | 0.217m/s (13m/min)<br>(Ball Screw rotational speed: 1300 $min^{-1}$) |
| Low speed | 0.0042m/s (0.25m/min)<br>(Ball Screw rotational speed: 25 $min^{-1}$) |
| Guide surface | LM Guide model HSR35CA |
| Lubricant | Lithium-based grease (No. 2) |
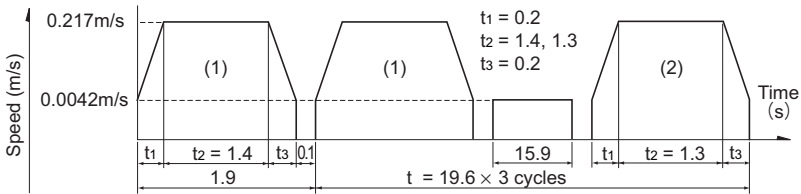


Fig.8 Operating Pattern
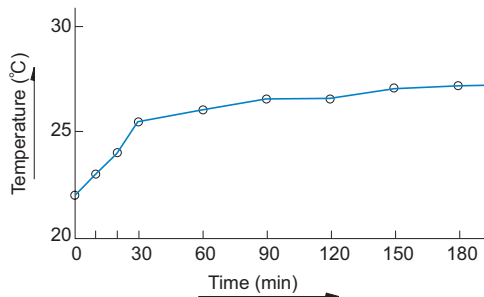


Fig.9 Ball Screw Heat Generation Data

**Ball Screw**

# Types of Ball Screws

## Ball Screw

### Precision Grade

#### Caged Ball

**Preload**

**Model SBN**
- Offset Preload
- High Speed

**Model SBK**
- Offset Preload
- High Speed Large Lead

**No Preload**

**Model HBN**
- High Load

##### Precision Rotary

**Preload**

**Model DIR**
- Rotary Nut

**No Preload**

**Model BLR**
- Large Lead Rotary Nut

#### Full-Ball

**Preload**

**Model BIF**
- With Unfinished Shaft Ends

**Model DIK**
- Slim Nut

**Model BNFN**
- With Unfinished Shaft Ends

**Model DKN**
- Slim Nut

**Model BLW**
- Large Lead

**No Preload**

**Model BNF**
- Standard Nut

**Model BNT**
- Square Nut

**Model DK**
- Slim Nut

**Model MDK**
- Miniature

**Model BLK**
- Large Lead

**Model WGF**
- Super Lead

#### Standard-Stock

**Preload**

**Model BIF**
- With Unfinished Shaft Ends

**Model BNFN**
- With Unfinished Shaft Ends

**No Preload**

**Model MDK**
- With Unfinished Shaft Ends

**Model MBF**
- With Unfinished Shaft Ends

**Model BNF**
- With Unfinished Shaft Ends

**Preload, No Preload**

**Model BNK**
- Finished Shaft Ends

#### Precision Ball Screw/Spline

**No Preload**

**Model BNS**
- Standard Nut

**Model NS**
- Standard Nut

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# Ball Screw Peripherals

## Rolled

### Full-Ball

#### Preload

**Model JPF**
- Constant Pressure Preload
- Slim Nut

#### No Preload

**Model BTK**
- Standard Nut

**Model BNT**
- Square Nut

**Model MTF**
- Miniature

**Model BLK**
- Large Lead

**Model WTF**
- Super Lead

**Model CNF**
- Super Lead

## Rolled Rotary

### No Preload

**Model BLR**
- Large Lead Rotary Nut

## Support Unit

### Fixed Side

Model EK

Model BK

Model FK

### Supported Side

Model EF

Model BF

Model FF

## Nut Bracket

**Model MC**

## Lock Nut

**Model RN**

**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.

| Selection Starts | |
|---|---|
| Selecting conditions | A-694 |
| Selecting Ball Screw accuracy | |
| ❶ Lead angle accuracy | A-695- |

**Selecting axial clearance**

| Axial clearance of Precision Ball Screw | A-703 | Axial clearance of Rolled Ball Screw | A-703 |
|---|---|---|---|

| | |
|---|---|
| Estimating the shaft length | A-708- |
| ❷ Selecting lead | A-710- |
| ❸ Selecting a shaft diameter | A-710- |
| ❹ Selecting a method for mounting the screw shaft | A-846- |

| Studying the permissible axial load | A-712- | → ❸(❹) |
|---|---|---|

| Selecting the permissible rotational speed | A-714- | → ❸❷❹) |
|---|---|---|

| ❺ Selecting a model number (type of nut) | A-717- |
|---|---|

| Calculating the permissible axial load | A-720- | → ❺(❷❸) |
|---|---|---|

**Ball Screw**

| | |
|---|---|
| **Studying the service life** | **A-722-** → ⑤②③ |

| | |
|---|---|
| Studying the rigidity | |
| Calculating the axial rigidity of the screw shaft | **A-725-** |
| Calculating the rigidity of the nut | **A-727-** |
| Calculating the rigidity of the support bearing | **A-728-** |

**Studying the rigidity** → ③④⑤

**Studying the positioning accuracy** **A-729-** → ①③④⑤

| | |
|---|---|
| Studying the rotational torque | |
| Calculating the friction torque from an external load | **A-735-** |
| Calculating the torque from the preload on the Ball Screw | **A-736-** |
| Calculating the torque required for acceleration | **A-736-** |

**Studying the rotational torque** → ②③⑤

| | |
|---|---|
| Studying the driving motor | **A-737-** |

| | |
|---|---|
| Safety design | |
| Studying the lubrication and contamination protection | **A-838-** |

**Selection Completed**

THK **A-693**

## [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    $\mu$ (-)
Guide surface resistance        $f$ (N)
External load in the axial direction     $F$ (N)
Desired service life time        $L_h$ (h)

Stroke length        $\ell_S$ (mm)
Operating speed        $V_{max}$ (m/s)
Acceleration time        $t_1$ (s)
Even speed time        $t_2$ (s)
Deceleration time        $t_3$ (s)

Acceleration

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

Acceleration distance   $\ell_1 = V_{max} \times t_1 \times 1000/2$ (mm)
Even speed distance     $\ell_2 = V_{max} \times t_2 \times 1000$ (mm)
Deceleration distance   $\ell_3 = V_{max} \times t_3 \times 1000/2$ (mm)
Number of reciprocations per minute    $n$ (min$^{-1}$)
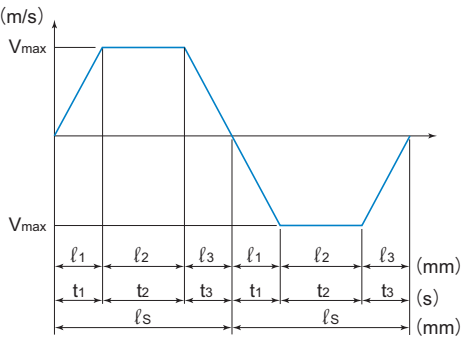
Positioning accuracy        (mm)
Positioning accuracy repeatability        (mm)
Backlash        (mm)
Minimum feed amount        $s$ (mm/pulse)

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        $A$ (-)



Velocity diagram

# 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.
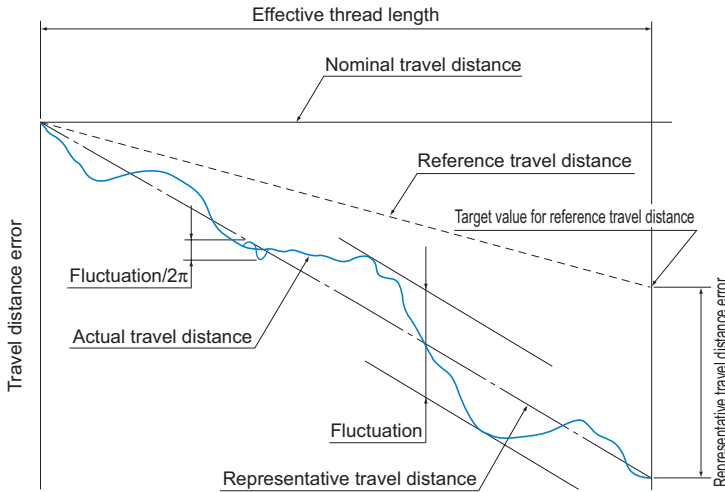


Fig.1 Terms on Lead Angle Accuracy

[**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$\pi$**]
A fluctuation in one revolution of the screw shaft.

**Ball Screw**

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Table1 Lead Angle Accuracy (Permissible Value)　　　　Unit: µm

| Accuracy grades | | Precision Ball Screw | | | | | | | | | | Rolled Ball Screw | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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 | ±50/ 300mm | ±100/ 300mm | ±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 | 18 | | | |
| 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 $-9\,\mu$m/500 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.
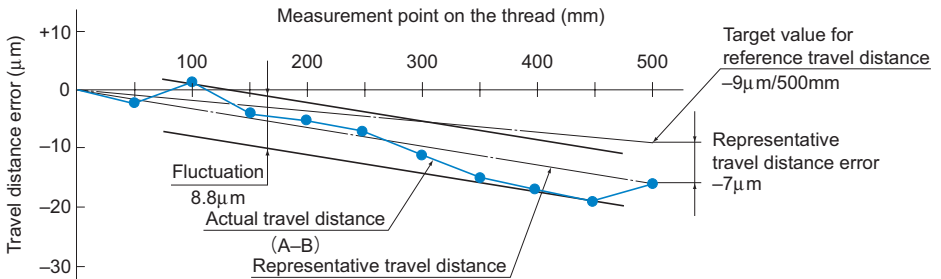


Fig.2 Measurement Data on Travel Distance Error

[Measurements]
Representative travel distance error: -7$\mu$m
Fluctuation: 8.8$\mu$m

**Ball Screw**

# 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

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[**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: $\mu$m

| 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
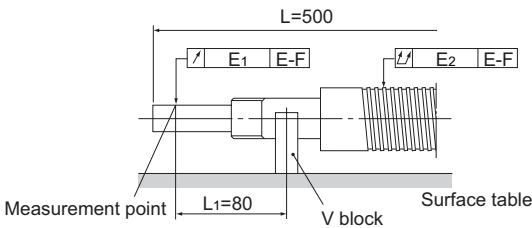


$E_1 = e + \Delta e$

$e$ : Standard value in Table5 (0.012)
$\Delta e$ : Correction value

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

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

$= 0.01$

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

$E_1 = 0.012 + 0.01$

$= 0.022$

**Ball Screw**

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.



Surface table

● **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.
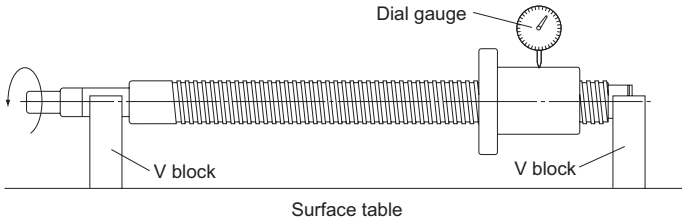
Dial gauge

V block

V block

Surface table

● **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.

Dial gauge

V block

V block

Surface table

● **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.

Dial gauge

V block

V block

Surface table

**Ball Screw**

**THK** **A-701**

● **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.
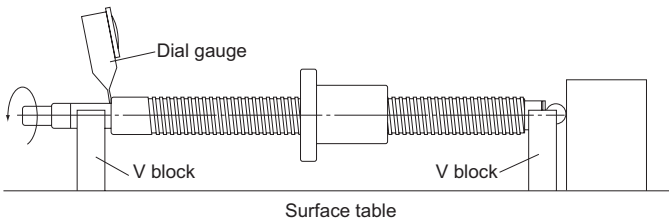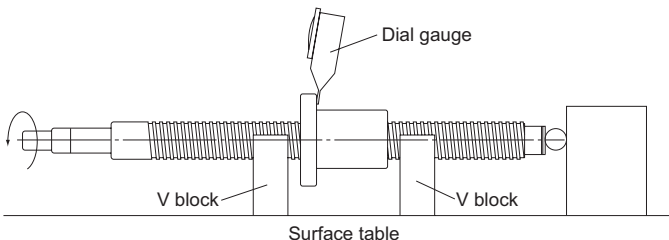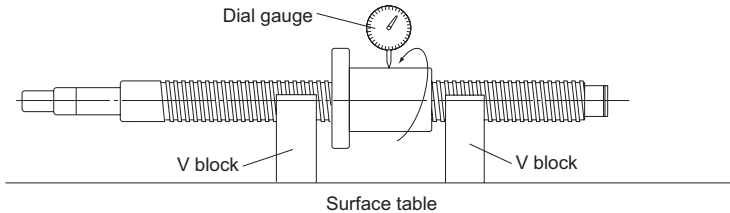


Dial gauge

V block    V block

Surface table

● **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.



Dial gauge

V block    V block

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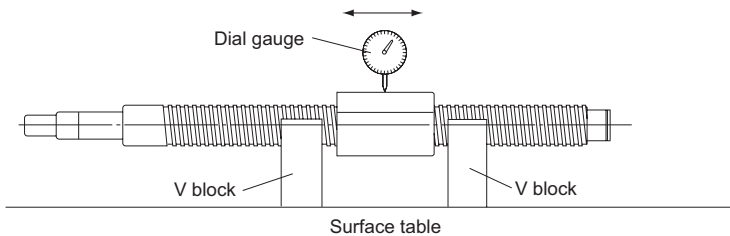
● **Overall Radial Runout of the Screw Shaft Axis**

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.
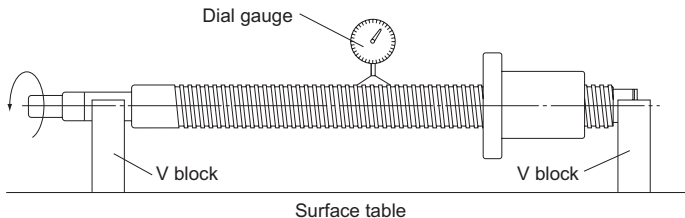


Dial gauge

V block    V block

Surface table

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

THK

# 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 |

**Ball Screw**

THK          **A-703**

# 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.
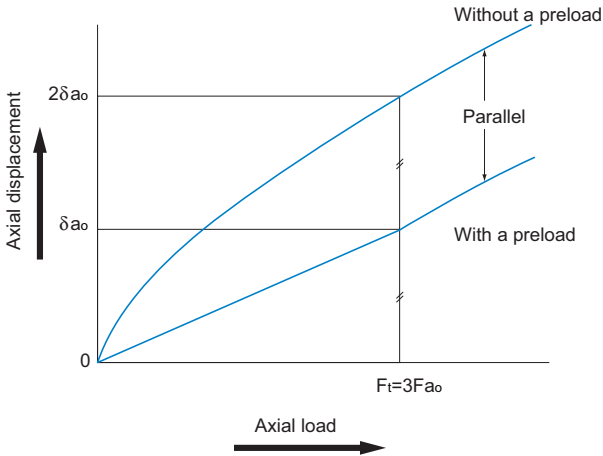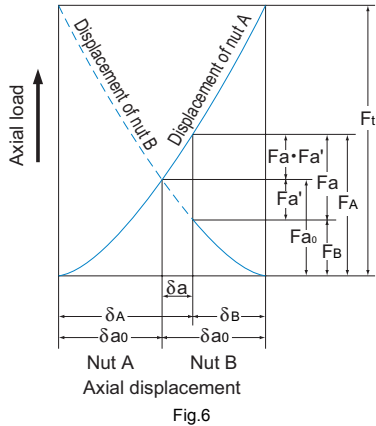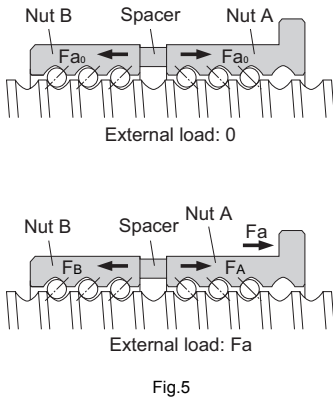


Fig.4 Elastic Displacement Curve of the Ball Screw

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



External load: 0

External load: Fa

Fig.5



Fig.6

Nuts A and B are provided with preload $Fa_0$ from the spacer. Because of the preload, nuts A and B are elastically displaced by $\delta a_0$ each. If an axial load (Fa) is applied from outside in this state, the displacement of nuts A and B is calculated as follows.

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

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

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

Therefore, under a preload, the load that nut A receives equals to Fa - Fa'. This means that since load Fa', which is applied when nut A receives no preload, is deducted from Fa, the displacement of nut A is smaller.
This effect extends to the point where the displacement ($\delta a_0$) 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 $\delta a \propto Fa^{2/3}$. From Fig.6, the following equations are established.

$$\delta a_0 = K Fa_0^{2/3} \qquad (K : \text{constant})$$
$$2\delta a_0 = K F_t^{2/3}$$

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

Thus, the Ball Screw under a preload is displaced by $\delta a_0$ when an axial load ($F_t$) approximately three times greater than the preload is provided from outside. As a result, the displacement of the Ball Screw under a preload is half the displacement ($2\delta a_0$) of the Ball Screw without a preload.
As stated above, since the preloading is effective up to approximately three times the applied preload, the optimum preload is one third of the maximum axial load.
Note, however, that an excessive preload adversely affects the service life and heat generation. As a guideline, the maximum preload should be set at 10% of the basic dynamic load rating (Ca) at a maximum.

**Ball Screw**

## [Preload Torque]

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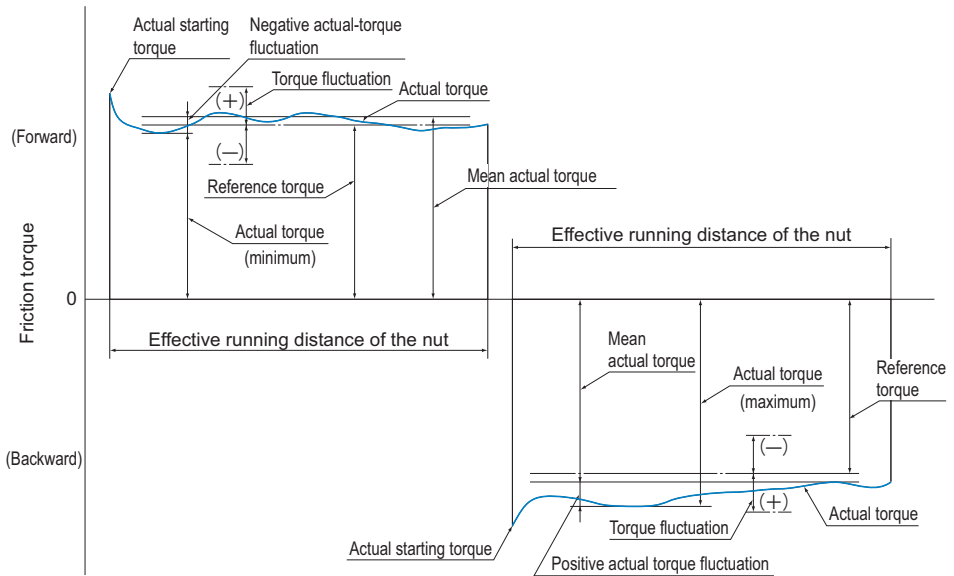


Fig.7 Terms on Preload Torque

● **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).

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

$T_P$ : Reference torque (N-mm)
$\beta$ : Lead angle
$Fa_0$ : Applied preload (N)
$Ph$ : Lead (mm)

THK

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

$\beta$ : Lead angle

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

$Fa_0$ : Applied preload=3000N

$Ph$ : Lead = 10mm

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

### ■Calculating the Torque Fluctuation

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

Thus, with the reference torque in 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 ±30%.

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

$865 \times (1 \pm 0.3)$ = 606 N・mm to 1125 N・mm

### ■Result

Reference torque　: 865 N-mn

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

Table14 Tolerance Range in Torque Fluctuation

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

**Ball Screw**

# 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 |

**Ball Screw**

THK **A-709**

# 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 | 90 | 100 |
| 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

THK　A-711

# 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.

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

$P_1$ : Buckling load                    (N)
$\ell_a$ : Distance between two mounting
      surfaces                   (mm)
$E$    : Young's modulus      ($2.06 \times 10^5$ N/mm$^2$)
$I$     : Minimum geometrical moment of
      inertia of the shaft          (mm$^4$)

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

$\eta_1$, $\eta_2$ =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).

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

$P_2$    : Permissible tensile compressive load (N)
$\sigma$    : Permissible tensile compressive
      stress                 (147 MPa)
$d_1$    : Screw-shaft thread minor diameter (mm)
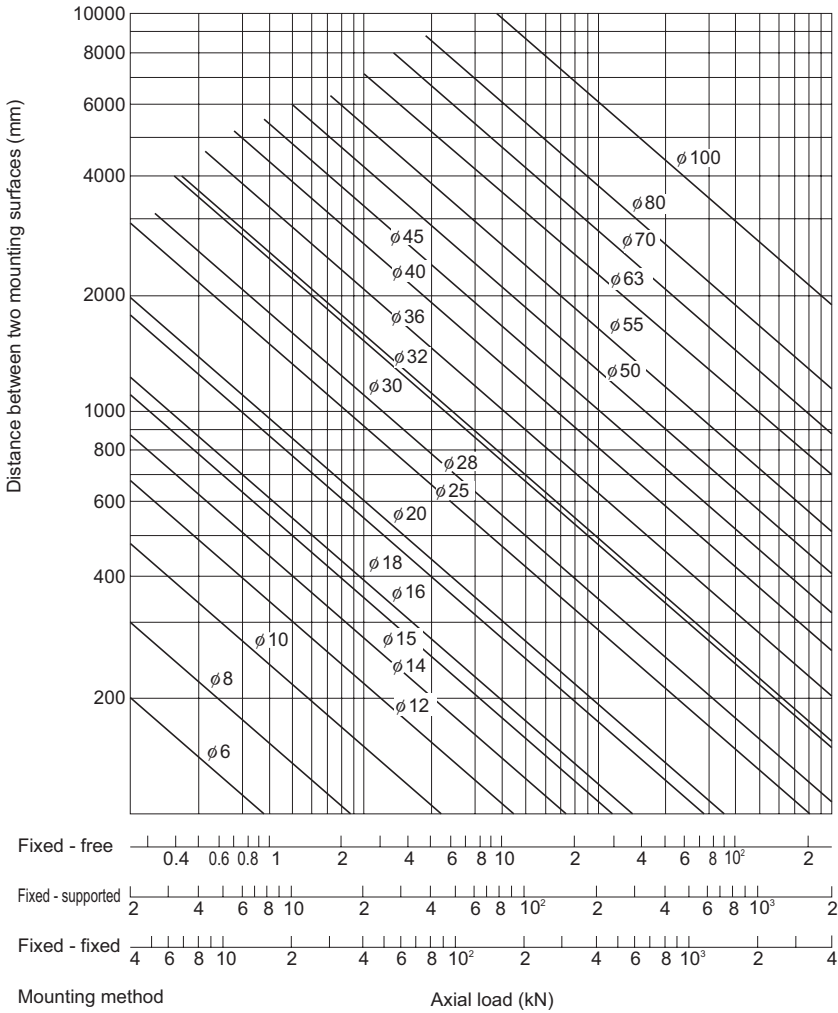
Fig.8 Permissible Tensile Compressive Load Diagram

**Ball Screw**

# 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.

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

$N_1$ : Permissible rotational speed determined by dangerous speed $\quad$ (min$^{-1}$)

$\ell_b$ : Distance between two mounting surfaces $\quad$ (mm)

E : Young's modulus $\quad$ (2.06 × 10$^5$ N/mm$^2$)

I : Minimum geometrical moment of inertia of the shaft $\quad$ (mm$^4$)

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

$\gamma$ : Density (specific gravity) $\quad$ (7.85 × 10$^{-6}$ kg/mm$^3$)

A : Screw shaft cross-sectional area $\quad$ (mm$^2$)

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

$\lambda_1$, $\lambda_2$ : Factor according to the mounting method

Fixed - free $\quad\quad$ $\lambda_1$=1.875 $\quad$ $\lambda_2$=3.4
Supported - supported $\lambda_1$=3.142 $\quad$ $\lambda_2$=9.7
Fixed - supported $\quad$ $\lambda_1$=3.927 $\quad$ $\lambda_2$=15.1
Fixed - fixed $\quad\quad$ $\lambda_1$=4.73 $\quad$ $\lambda_2$=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**

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

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

D : Ball center-to-center diameter

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

■**Model SBK**

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

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

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

● **Precision Ball Screw**

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

● **Rolled Ball Screw**
(excluding large lead type)

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

● **Large-Lead Rolled Ball Screw**

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

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.
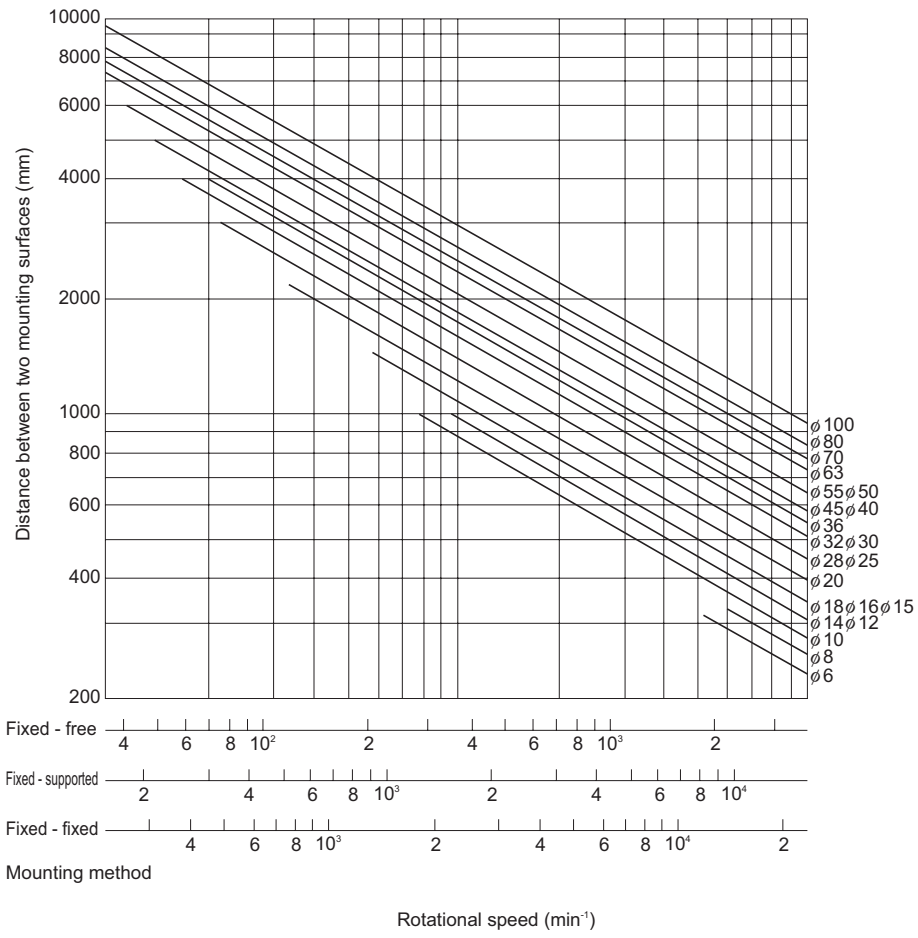
**Ball Screw**

Fig.9 Permissible Rotational Speed Diagram

The chart axes:
- Vertical axis: Distance between two mounting surfaces (mm), ranging from 200 to 10000
- Horizontal axis: Rotational speed (min⁻¹)

Diameter lines (top to bottom): ∅100, ∅80, ∅70, ∅63, ∅55 ∅50, ∅45 ∅40, ∅36, ∅32 ∅30, ∅28 ∅25, ∅20, ∅18 ∅16 ∅15, ∅14 ∅12, ∅10, ∅8, ∅6

Mounting method scales:
- Fixed - free: 4, 6, 8, 10², 2, 4, 6, 8, 10³, 2
- Fixed - supported: 2, 4, 6, 8, 10³, 2, 4, 6, 8, 10⁴
- Fixed - fixed: 4, 6, 8, 10³, 2, 4, 6, 8, 10⁴, 2

# 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.
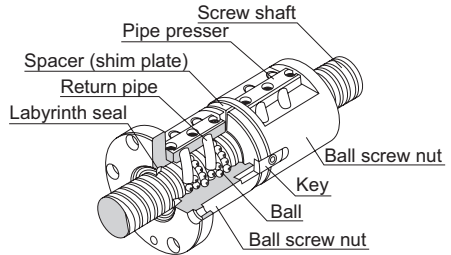
Example of Structure of Return-Pipe Nut

● **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.
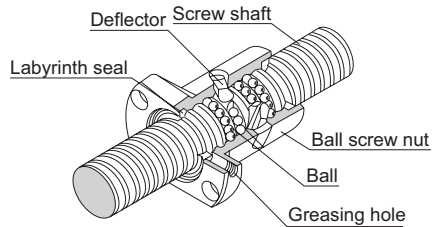
Example of Structure of Simple Nut

● **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.
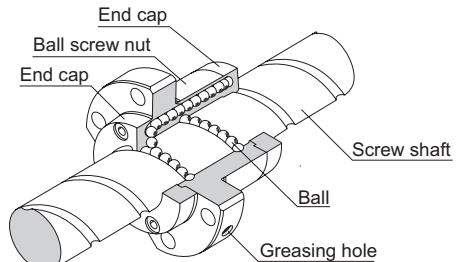
Example of Structure of Large lead Nut

**Ball Screw**

● **Fixed-point Preloading**

■**Double-nut Preload (Models BNFN, DKN and BLW)**
A spacer is inserted between two nuts to provide a preload.

(3.5 to 4.5) pitches + preload

Spacer

Applied preload ← → Applied preload
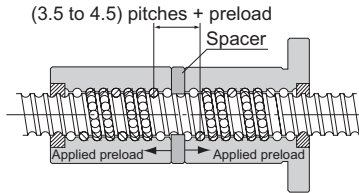
Model BNFN                 Model DKN                  Model BLW

■**Offset Preload (Models SBN, BIF, DIK, SBK and DIR)**
More compact than the double-nut method, the offset preloading provides a preload by changing the groove pitch of the nut without using a spacer.

0.5 pitch + preload

Applied preload ← → Applied preload
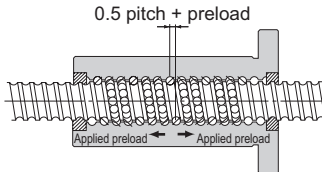
Model SBN                  Model BIF                  Model DIK

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 pre-load by changing the groove pitch in the middle of the nut.



4 pitches - preload

Applied preload ➡  ⬅ Applied preload

Spring section
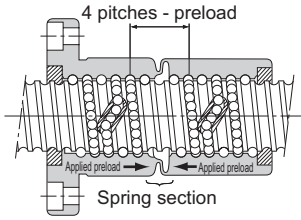


Model JPF

# Selecting a Model Number

## Calculating the Axial Load

### [In Horizontal Mount]

With ordinary conveyance systems, the axial load ($Fa_n$) applied when horizontally reciprocating the work is obtained in the equation below.

$$Fa_1 = \mu \cdot mg + f + m\alpha \quad \cdots\cdots\cdots (14)$$
$$Fa_2 = \mu \cdot mg + f \quad \cdots\cdots\cdots\cdots (15)$$
$$Fa_3 = \mu \cdot mg + f - m\alpha \quad \cdots\cdots\cdots (16)$$
$$Fa_4 = -\mu \cdot mg - f - m\alpha \quad \cdots\cdots\cdots (17)$$
$$Fa_5 = -\mu \cdot mg - f \quad \cdots\cdots\cdots\cdots (18)$$
$$Fa_6 = -\mu \cdot mg - f + m\alpha \quad \cdots\cdots\cdots (19)$$

$V_{max}$ : Maximum speed (m/s)
$t_1$ : Acceleration time (m/s)

$\alpha = \dfrac{V_{max}}{t_1}$ : Acceleration (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)
$\mu$ : Frictional coefficient of the guide surface (−)
f : Guide surface resistance (without load) (N)

Mass: m
Axial load: $Fa_n$
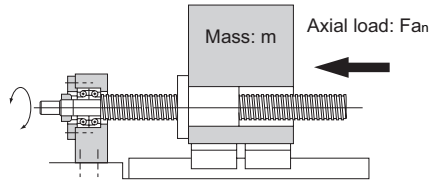
Guide surface
Friction coefficient : $\mu$
Resistance without load : f
Gravitational acceleration: g

### [In Vertical Mount]

With ordinary conveyance systems, the axial load ($Fa_n$) applied when vertically reciprocating the work is obtained in the equation below.

$$Fa_1 = mg + f + m\alpha \quad \cdots\cdots\cdots (20)$$
$$Fa_2 = mg + f \quad \cdots\cdots\cdots\cdots (21)$$
$$Fa_3 = mg + f - m\alpha \quad \cdots\cdots\cdots (22)$$
$$Fa_4 = mg - f - m\alpha \quad \cdots\cdots\cdots (23)$$
$$Fa_5 = mg - f \quad \cdots\cdots\cdots\cdots (24)$$
$$Fa_6 = mg - f + m\alpha \quad \cdots\cdots\cdots (25)$$

$V_{max}$ : Maximum speed (m/s)
$t_1$ : Acceleration time (m/s)

$\alpha = \dfrac{V_{max}}{t_1}$ : Acceleration (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)
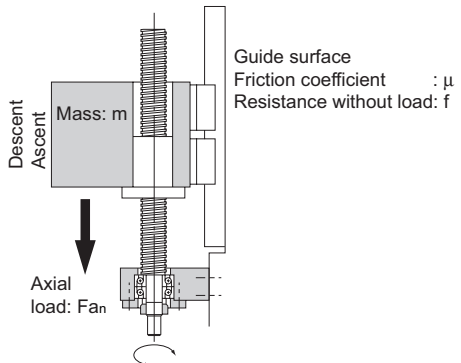
Descent
Ascent
Mass: m

Guide surface
Friction coefficient : $\mu$
Resistance without load: f

Axial load: $Fa_n$

THK

# 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.

$$Fa_{max} = \frac{C_0a}{f_s} \quad \cdots\cdots (26)$$

$Fa_{max}$ : 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.)

**Ball Screw**

# 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)

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

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

Table22 Load Factor ($f_w$)

| Vibrations/ impact | Speed(V) | $f_w$ |
|---|---|---|
| Faint | Very low $V \leqq 0.25$m/s | 1 to 1.2 |
| Weak | Slow $0.25 < V \leqq 1$m/s | 1.2 to 1.5 |
| Medium | Medium $1 < V \leqq 2$m/s | 1.5 to 2 |
| Strong | High $V > 2$m/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 $10^6$rev. 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).

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

$L_h$ : Service life time (h)
$N$ : Revolutions per minute (min$^{-1}$)
$n$ : Number of reciprocations
    per minute (min$^{-1}$)
$Ph$ : Ball Screw lead (mm)
$\ell_s$ : 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.

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

$L_s$ : 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.

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

$F_m$ : Average Axial Load (N)
$Fa_n$ : Varying load (N)
$\ell_n$ : Distance traveled under load ($F_n$)
$\ell$ : Total travel distance

**Ball Screw**

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.

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

$\ell_1 = N_1 \cdot t_1$

$\ell_2 = N_2 \cdot t_2$

$\ell_n = N_n \cdot t_n$

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.



Positive-sign load
Negative-sign load
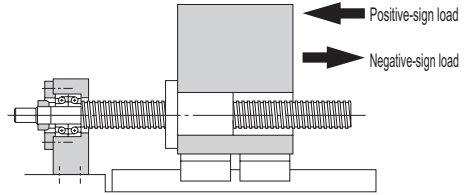
| Operation No. | Varying load $Fa_n$(N) | Travel distance $\ell_n$(mm) |
|---|---|---|
| No.1 | 10 | 10 |
| No.2 | 50 | 50 |
| No.3 | −40 | 10 |
| No.4 | −10 | 70 |

The subscripts of the fluctuating load symbol and the travel distance symbol indicate operation numbers.

● Average axial load of positive-sign load

To calculate the average axial load of the positive-sign load, assume $Fa_3$ and $Fa_4$ to be zero.

$$Fm_1 = \sqrt[3]{\frac{Fa_1^{\ 3} \times \ell_1 + Fa_2^{\ 3} \times \ell_2}{\ell_1 + \ell_2 + \ell_3 + \ell_4}} = 35.5N$$

● Average axial load of negative-sign load

To calculate the average axial load of the negative-sign load, assume $Fa_1$ and $Fa_2$ to be zero.

$$Fm_2 = \sqrt[3]{\frac{|Fa_3|^3 \times \ell_3 + |Fa_4|^3 \times \ell_4}{\ell_1 + \ell_2 + \ell_3 + \ell_4}} = 17.2N$$

Accordingly, the average axial load of the positive-sign load ($Fm_1$) is adopted as the average axial load ($Fm$) 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.

$$\delta = \frac{Fa}{K} \quad \cdots\cdots (31)$$

$\delta$ : Elastic displacement of a feed screw
system in the axial direction ($\mu$m)
$Fa$ : Applied axial load (N)

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

$$\frac{1}{K} = \frac{1}{K_S} + \frac{1}{K_N} + \frac{1}{K_B} + \frac{1}{K_H} \quad \cdots\cdots (32)$$

$K$ : Axial Rigidity of the Feed
Screw System (N/$\mu$m)
$K_S$ : Axial rigidity of the screw shaft (N/$\mu$m)
$K_N$ : Axial rigidity of the nut (N/$\mu$m)
$K_B$ : Axial rigidity of the support bearing (N/$\mu$m)
$K_H$ : Rigidity of the nut bracket and
the support bearing bracket (N/$\mu$m)

[**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**

$$K_S = \frac{A \cdot E}{1000 \cdot L} \quad \cdots\cdots (33)$$

$A$ : Screw shaft cross-sectional area (mm$^2$)

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

$d_1$ : Screw-shaft thread minor diameter (mm)
$E$ : Young's modulus (2.06×10$^5$ N/mm$^2$)
$L$ : Distance between two mounting surfaces
(mm)
Fig.10 onA-726 shows an axial rigidity diagram for the screw shaft.



Fixed                    Supported
(Free)

**Ball Screw**
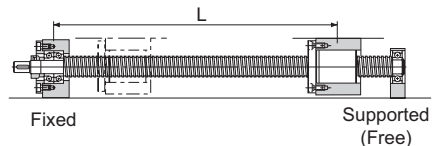
## ● For Fixed-Fixed Configuration

$$K_S = \frac{A \cdot E \cdot L}{1000 \cdot a \cdot b} \quad \cdots\cdots(34)$$

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

$$K_S = \frac{4A \cdot E}{1000L}$$
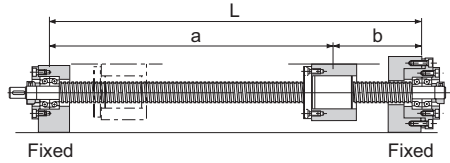
Fig.11 on A-727 shows an axial rigidity diagram of the screw shaft in this configuration.
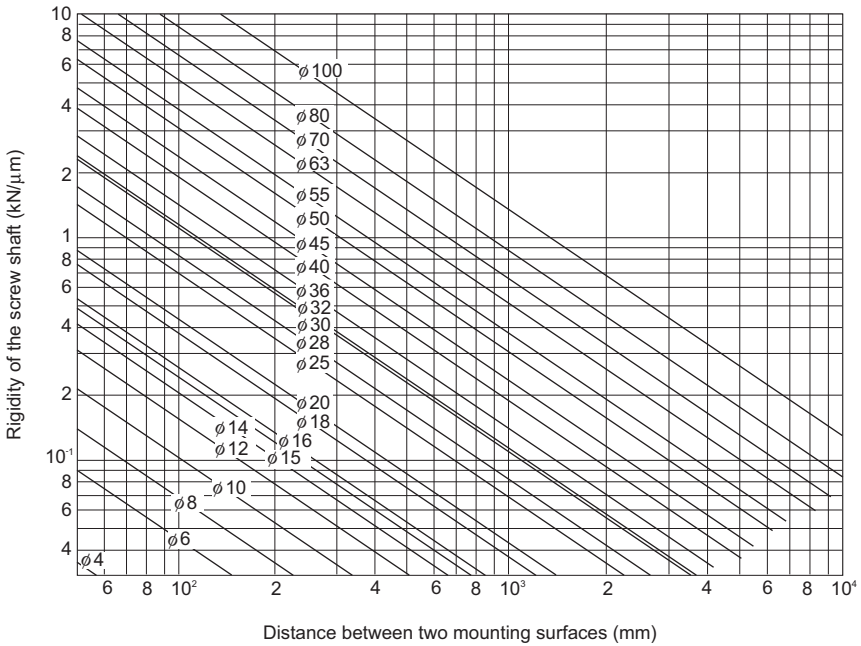




Fig.10 Axial Rigidity of the Screw Shaft (Fixed-Free, Fixed-Supported)
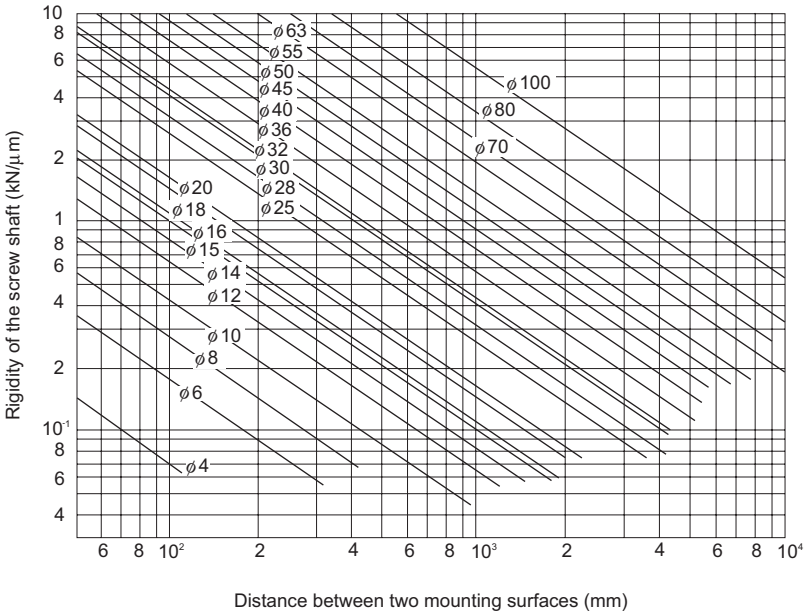
Fig.11 Axial Rigidity of the Screw Shaft (Fixed-Fixed)

[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.

$$K_N = K \left( \frac{Fa}{0.3Ca} \right)^{\frac{1}{3}} \times 0.8 \quad \cdots\cdots (35)$$

$K_N$ : Axial rigidity of the nut     $(N/\mu m)$
$K$    : Rigidity value in the specification
      tables                $(N/\mu m)$
$Fa$   : Applied axial load        $(N)$
$Ca$   : Basic dynamic load rating    $(N)$

**Ball Screw**

THK   **A-727**

## ● 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.

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

$K_N$ : Axial rigidity of the nut        (N/$\mu$m)
K    : Rigidity value in the specification
      tables                          (N/$\mu$m)
$Fa_0$ : 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.

$$K_B \fallingdotseq \frac{3Fa_0}{\delta a_0} \quad \cdots\cdots (37)$$

$K_B$    : Axial rigidity of the support
       bearing                      (N/$\mu$m)
$Fa_0$ : Applied preload of the support
       bearing                       (N)
$\delta a_0$    : Axial displacements         ($\mu$m)

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

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

Q     : Axial load                         (N)
Da    : Ball diameter of the support bearing (mm)
$\alpha$      : 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.

**Ball Screw**

Table23 Examples of Selecting Accuracy Grades by Application

| Applications | | Shaft | Accuracy grades | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | C0 | C1 | C2 | C3 | C5 | C7 | C8 | C10 |
| 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 Wire cutting machine | XY | ● | ● | ● | | | | | |
| | | Z | ● | ● | ● | ● | | | | |
| | | 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
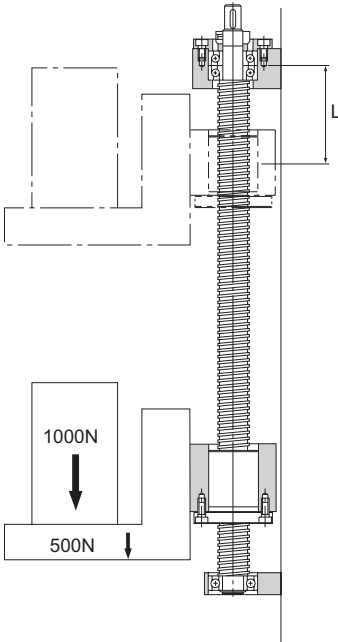


**Ball Screw**

[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 mm

$$K_{S1} = \frac{77.6 \times 10^3}{100} = 776 \text{ N/}\mu\text{m}$$

(2) When L = 700mm

$$K_{S2} = \frac{77.6 \times 10^3}{700} = 111 \text{ N/}\mu\text{m}$$

**[Axial Displacement due to Axial Rigidity of the Screw Shaft]**
(1) When L = 100 mm

$$\delta_1 = \frac{Fa}{K_{S1}} = \frac{1000 + 500}{776} = 1.9\mu\text{m}$$

(2) When L = 700mm

$$\delta_2 = \frac{Fa}{K_{S2}} = \frac{1000 + 500}{111} = 13.5\mu\text{m}$$

**[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 $\mu$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.

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

$\Delta\ell$ : Axial expansion/contraction of
the screw shaft       (mm)
$\rho$ : Thermal expansion coefficient ($12 \times 10^{-6}$/℃)
$\Delta t$ : Temperature change in
the screw shaft       (℃)
$\ell$ : Effective thread length       (mm)

Thus, if the temperature of the screw shaft increases by 1℃, the screw shaft is elongated by 12 μm 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℃ to 5℃ by heat.
(−0.02mm to −0.06 mm/m)
● Preload the shaft screw with tension. (See Fig.3 of the structure on A-847.)

**Ball Screw**

## 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.

$$A = \ell \times \sin\theta \quad \cdots\cdots(39)$$

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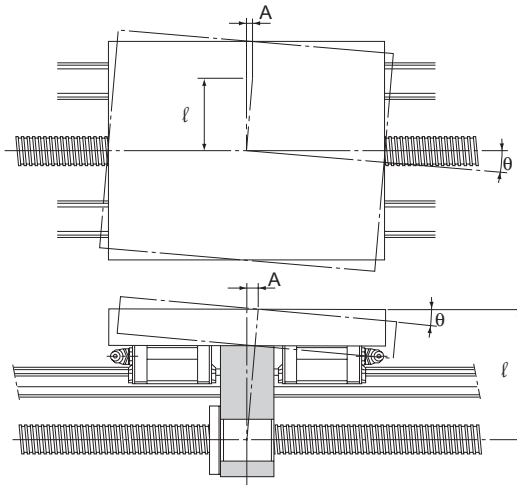


Fig.12

# 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**]

$$T_t = T_1 + T_2 + T_4 \quad \cdots\cdots(40)$$

$T_t$ : 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**]

$$T_K = T_t + T_3 \quad \cdots\cdots(41)$$

$T_K$ : Rotational torque required during acceleration (N-mm)

$T_3$ : Torque required for acceleration (N-mm)

[**During Deceleration**]

$$T_g = T_t - T_3 \quad \cdots\cdots(42)$$

$T_g$ : 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

$$T_1 = \frac{Fa \cdot Ph}{2\pi \cdot \eta} \cdot A \quad \cdots\cdots(43)$$

$T_1$ : Frictional torque due to an external load (N-mm)

$Fa$ : Applied axial load (N)

$Ph$ : Ball Screw lead (mm)

$\eta$ : Ball Screw efficiency (0.9 to 0.95)

$A$ : Reduction ratio

**Ball Screw**

## Torque Due to a Preload on the Ball Screw

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

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

$T_2$ : 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

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

$T_3$ : Torque required for acceleration  (N-mm)
$J$ : Inertial moment                      (kg·m²)
$\omega'$ : 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 d      (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.

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

$N_M$ : 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.

$N_M \leqq N_R$

$N_R$ : 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.

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

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

**Ball Screw**

[**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.

$T_{max} \leqq Tp_{max}$

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

$Tp_{max}$   : 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.

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

$T_{rms}$  : 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.

$T_{rms} \leqq T_R$

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

[**Inertial Moment**]

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

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

$J_M$    : Inertial moment required for the motor (kg·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.

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

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.

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

   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.

**Ball Screw**

# Examples of Selecting a Ball Screw

## High-speed Transfer Equipment (Horizontal Use)

[Selection Conditions]

| | | | |
|---|---|---|---|
| Table Mass | $m_1$ =60kg | Positioning Repeatability | ±0.1 mm |
| Work Mass | $m_2$ =20kg | Minimum feed amount | s = 0.02mm/pulse |
| Stroke length | $\ell_s$=1000mm | Desired service life time | 30000h |
| Maximum speed | $V_{max}$=1m/s | Driving motor | AC servo motor |
| Acceleration time | $t_1$ = 0.15s | | Rated rotational speed: |
| Deceleration time | $t_3$ = 0.15s | | 3,000 min$^{-1}$ |

Number of reciprocations per minute
n =8min$^{-1}$

Inertial moment of the motor
$J_m$ =1×10$^{-3}$ kg·m$^2$

Backlash  0.15mm

Reduction gear  None (direct coupling)
A=1

Positioning accuracy  ±0.3 mm/1000 mm
(Perform positioning from the negative direction)

Frictional coefficient of the guide surface
μ =0.003 (rolling)

Guide surface resistance  f=15 N (without load)

Work mass
+
Table mass
$m_2$
+
$m_1$

Motor   Ball screw shaft   Ball screw nut
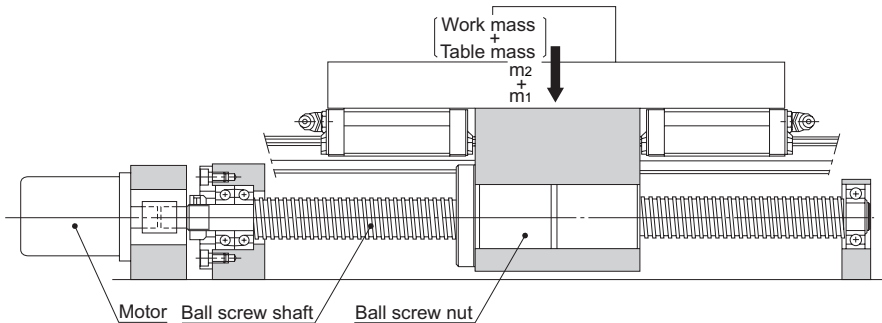
[Selection Items]
Screw shaft diameter
Lead
Nut model No.
Accuracy
Axial clearance
Screw shaft support method
Driving motor

[**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: ±0.05mm/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 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(quadrupled)
   6000 p/rev(quadrupled)

**Ball Screw**

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 N (without load) |
| Table Mass | $m_1$ =60 kg |
| Work Mass | $m_2$ =20 kg |
| Frictional coefficient of the guide surface | $\mu$ = 0.003 |
| Maximum speed | $V_{max}$=1 m/s |
| Gravitational acceleration | g = 9.807 m/s² |
| Acceleration time | $t_1$ = 0.15s |

Accordingly, the required values are obtained as follows.
Acceleration:

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

During forward acceleration:
  $Fa_1 = \mu \cdot (m_1 + m_2) g + f + (m_1 + m_2) \cdot \alpha = 550$ N
During forward uniform motion:
  $Fa_2 = \mu \cdot (m_1 + m_2) g + f = 17$ N
During forward deceleration:
  $Fa_3 = \mu \cdot (m_1 + m_2) g + f - (m_1 + m_2) \cdot \alpha = -516$ N
During backward acceleration:
  $Fa_4 = -\mu \cdot (m_1 + m_2) g - f - (m_1 + m_2) \cdot \alpha = -550$ N
During uniform backward motion:
  $Fa_5 = -\mu \cdot (m_1 + m_2) g - f = -17$ N
During backward deceleration:
  $Fa_6 = -\mu \cdot (m_1 + m_2) g - f + (m_1 + m_2) \cdot \alpha = 516$ N

Thus, the maximum axial load applied on the Ball Screw is as follows:
  $Fa_{max} = Fa_1 = 550$ 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.

**Ball Screw**

## ■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

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

THK

■**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          $d_1$=17.5mm

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

● Screw shaft diameter: 30mm; lead: 60mm
   Screw-shaft thread minor diameter          $d_1$=26.4mm

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

■**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, $C_0a$=13.6 kN)
   WTF2040-3
   (Ca=6.6 kN, $C_0a$=17.2 kN)
   WTF3060-2
   (Ca=11.8 kN, $C_0a$=30.6 kN)
   WTF3060-3
   (Ca=14.5 kN, $C_0a$=38.9 kN)

**Ball Screw**

## ● 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 | $t_1$ = 0.15s |
| Deceleration time | $t_3$ = 0.15s |

● 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 $Fa_N$(N) | Travel distance $\ell_N$(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 $Fa_3$, $Fa_4$ and $Fa_5$, 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 $Fa_{3, 4, 5} = 0N$.

$$F_{m1} = \sqrt[3]{\frac{Fa_1{}^3 \times \ell_1 + Fa_2{}^3 \times \ell_2 + Fa_6{}^3 \times \ell_6}{\ell_1 + \ell_2 + \ell_3 + \ell_4 + \ell_5 + \ell_6}} = 225 \text{ N}$$

● Average axial load in the negative direction

Since the load direction varies, calculate the average axial load while assuming $Fa_{1, 2, 6} = 0N$.

$$F_{m2} = \sqrt[3]{\frac{\left|Fa_3\right|^3 \times \ell_3 + \left|Fa_4\right|^3 \times \ell_4 + \left|Fa_5\right|^3 \times \ell_5}{\ell_1 + \ell_2 + \ell_3 + \ell_4 + \ell_5 + \ell_6}} = 225 \text{ N}$$

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

■**Nominal Life**

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

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

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

**Ball Screw**

## ■Average Revolutions per Minute

Number of reciprocations per minute $\quad$ n $=8$min$^{-1}$

Stroke $\quad$ $\ell_s$=1000 mm

● Lead: Ph = 40 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 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 $\quad$ L=$4.1 \times 10^9$ rev

Average revolutions per minute $\quad$ Nm = 400 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 $\quad$ L=$7.47 \times 10^9$ rev

Average revolutions per minute $\quad$ Nm = 400 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 $\quad$ L=$4.27 \times 10^{10}$ rev

Average revolutions per minute $\quad$ Nm = 267 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 $\quad$ L=$7.93 \times 10^{10}$ rev

Average revolutions per minute $\quad$ Nm = 267 min$^{-1}$

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

THK

■**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

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

● WTF2040-3

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

    Lead                                      Ph = 40 mm

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

● WTF3060-2

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

    Lead                                      Ph = 60 mm

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

● WTF3060-3

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

    Lead                                      Ph = 60 mm

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

**Ball Screw**

[**Studying the Rigidity**]

Since the conditions for selection do not include rigidity and this element is not particularly neces-
sary, 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: ±0.05mm/300mm)

● **Studying the Axial Clearance**

Since positioning is performed in a given direction only, axial clearance is not included in the posi-
tioning 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℃.

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

$$\Delta\ell \quad = \rho \times \Delta t \times \ell$$
$$= 12 \times 10^{-6} \times 5 \times 1000$$
$$= 0.06 \text{ mm}$$

● **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:

$$\Delta a \quad = \ell \times \sin\theta$$
$$= 150 \times \sin(\pm10'')$$
$$= \pm 0.007 \text{ mm}$$

Thus, the positioning accuracy ($\Delta p$) 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 require-
ments throughout the studying process in Section [Selecting Lead Angle Accuracy and Axial Clear-
ance] on A-741 to Section [Studying the Positioning Accuracy] on A-750, the most compact model
WTF2040-2 is selected.

THK

[**Studying the Rotational Torque**]

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

The friction toruque is obtained as follows:

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

● **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 $1.23 \times 10^{-3}$ kg•cm²/mm (see the specification table), the inertial moment of the screw shaft with an overall length of 1200 mm is obtained as follows.

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

$$J = (m_1 + m_2)\left(\frac{Ph}{2 \times \pi}\right)^2 \cdot A^2 \times 10^{-6} + J_s \cdot A^2 = (60 + 20)\left(\frac{40}{2 \times \pi}\right)^2 \times 1^2 \times 10^{-6} + 1.48 \times 10^{-4} \times 1^2$$

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

Angular acceleration:

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

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

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

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

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

During deceleration

$$T_g = T_1 - T_2 = 120 - 4.61 \times 10^3 = -4490 \text{ N} \cdot \text{mm}$$

**Ball Screw**

### [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.

$T_{max}$ = 4730 N・mm

Therefore, the instantaneous maximum torque of the AC servomotor needs to be at least 4,730 N-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 N・mm

$t_1$ = 0.15 s

During uniform motion:

$T_t$ = 120 N・mm

$t_2$ = 0.85 s

During deceleration:

$T_g$ = 4490 N・mm

$t_3$ = 0.15 s

When stationary:

$T_s$ = 0

$t_4$ = 2.6 s

The effective torque is obtained as follows, and the rated torque of the motor must be 1305 N•mm or greater.

$$T_{rms} = \sqrt{\frac{T_k^2 \cdot t_1 + T_t^2 \cdot t_2 + T_g^2 \cdot t_3 + T_s^2 \cdot t_4}{t_1 + t_2 + t_3 + t_4}} = \sqrt{\frac{4730^2 \times 0.15 + 120^2 \times 0.85 + 4490^2 \times 0.15 + 0}{0.15 + 0.85 + 0.15 + 2.6}}$$

$$= 1305 \, N \cdot mm$$

● **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 $3.39 \times 10^{-4} \text{kg-m}^2$ or greater.

The selection has been completed.

# Vertical Conveyance System

[**Selection Conditions**]

| | |
|---|---|
| Table Mass | $m_1$ =40kg |
| Work Mass | $m_2$ =10kg |
| Stroke length | $\ell_s$= 600mm |
| Maximum speed | $V_{max}$=0.3m/s |
| Acceleration time | $t_1$ = 0.2s |
| Deceleration time | $t_3$ = 0.2s |
| Number of reciprocations per minute | |
| | n =5min$^{-1}$ |
| Backlash | 0.1mm |
| Positioning accuracy | ±0.7mm/600mm |
| Positioning Repeatability | ±0.05mm |
| Minimum feed amount | s = 0.01mm/pulse |
| Service life time | 20000h |
| Driving motor | AC servo motor |
| | Rated rotational speed: |
| | 3,000 min$^{-1}$ |
| Inertial moment of the motor | |
| | $J_m$ =5×10$^{-5}$ kg·m$^2$ |
| Reduction gear | None (direct coupling) |
| Frictional coefficient of the guide surface | |
| | μ =0.003 (rolling) |
| Guide surface resistance | |
| | f=20 N (without load) |
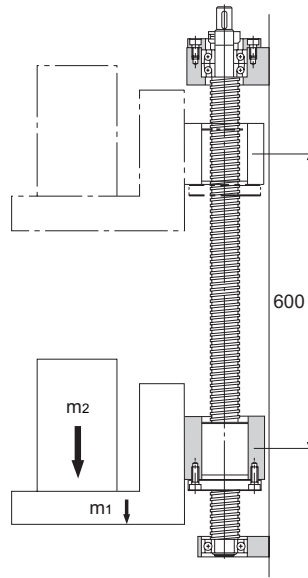
[**Selection Items**]
Screw shaft diameter
Lead
Nut model No.
Accuracy
Axial clearance
Screw shaft support method
Driving motor

[**Selecting Lead Angle Accuracy and Axial Clearance**]
● **Selecting the Lead Angle Accuracy**
To achieve positioning accuracy of ±0.7mm/600mm:

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

The lead angle accuracy must be ±0.35mm/300 mm or higher.
Therefore, the accuracy grade of the Ball Screw (see Table1 on A-696) needs to be C10 (travel distance error: ±0.21 mm/300 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 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 $min^{-1}$ 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(quadrupled)
                    6000 p/rev(quadrupled)

**Ball Screw**

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                $t_1$ = 0.2s

Accordingly, the required values are obtained as follows.
Acceleration

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

During upward acceleration:
$\quad Fa_1 = (m_1 + m_2) \cdot g + f + (m_1 + m_2) \cdot \alpha = 585$ N
During upward uniform motion:
$\quad Fa_2 = (m_1 + m_2) \cdot g + f = 510$ N
During upward deceleration:
$\quad Fa_3 = (m_1 + m_2) \cdot g + f - (m_1 + m_2) \cdot \alpha = 435$ N
During downward acceleration:
$\quad Fa_4 = (m_1 + m_2) \cdot g - f - (m_1 + m_2) \cdot \alpha = 395$ N
During downward uniform motion:
$\quad Fa_5 = (m_1 + m_2) \cdot g - f = 470$ N
During downward deceleration:
$\quad Fa_6 = (m_1 + m_2) \cdot g - f + (m_1 + m_2) \cdot \alpha = 545$ N

Thus, the maximum axial load applied on the Ball Screw is as follows:
$\quad Fa_{max} = Fa_1 = 585$ 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             $d_1$=12.5 mm

$$P_1 = \eta_2 \cdot \frac{d_1^4}{\ell_a^2} \times 10^4 = 20 \times \frac{12.5^4}{700^2} \times 10^4 = 9960 \text{ N}$$

■**Permissible Compressive and Tensile Load of the Screw Shaft**

$\quad P_2 = 116 d_1^2 = 116 \times 12.5^2 = 18100$ 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.

**Ball Screw**

● **Studying the Permissible Rotational Speed**

**■Maximum Rotational Speed**

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

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

    Lead                  Ph= 10 mm

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

**■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 mm (estimate)

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

    Screw-shaft thread minor diameter         $d_1$=12.5 mm

$$N_1 = \lambda_2 \times \frac{d_1}{\ell_b^2} 10^7 = 15.1 \times \frac{12.5}{700^2} \times 10^7 = 3852 \ min^{-1}$$

**■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 mm

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

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

($C_a$=9.8 kN, $C_0a$=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 Table21 on A-721).

$$Fa_{max} = \frac{C_0a}{f_S} = \frac{25.2}{2} = 12.6 \text{ kN} = 12600 \text{ N}$$

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 $t_1$ = 0.2s

Deceleration time $t_3$ = 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 $Fa_N$(N) | Travel distance $\ell_N$(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.

**Ball Screw**

THK **A-759**

**■Average Axial Load**

$$Fm = \sqrt[3]{\frac{1}{2 \times \ell_s}(Fa_1{}^3 \cdot \ell_1 + Fa_2{}^3 \cdot \ell_2 + Fa_3{}^3 \cdot \ell_3 + Fa_4{}^3 \cdot \ell_4 + Fa_5{}^3 \cdot \ell_5 + Fa_6{}^3 \cdot \ell_6)} = 225 \text{ N}$$

**■Nominal Life**

Dynamic load rating     $Ca = 9800$ N
Load factor     $f_w = 1.5$ (see Table22 on A-722)
Average load     $F_m = 492$ N
Nominal life     L (rev)

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

**■Average Revolutions per Minute**

Number of reciprocations per minute     $n = 5 \text{ min}^{-1}$
Stroke     $\ell_s = 600$ 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     $L = 2.34 \times 10^9$ rev
Average revolutions per minute     $N_m = 600 \text{ min}^{-1}$

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

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

Nominal life     $L = 2.34 \times 10^9$ rev
Lead     $Ph = 10$ mm
$L_s = L \times Ph \times 10^{-6} = 23400$ 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 neces-sary, 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: ±0.21mm/300mm)

● **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:

$$T_1 = \frac{Fa_2 \cdot Ph}{2 \times \pi \times \eta} = \frac{510 \times 10}{2 \times \pi \times 0.9} = 900 \ N \cdot mm$$

During downward uniform motion:

$$T_2 = \frac{Fa_5 \cdot Ph}{2 \times \pi \times \eta} = \frac{470 \times 10}{2 \times \pi \times 0.9} = 830 \ N \cdot mm$$

● **Torque Due to a Preload on the Ball Screw**
The Ball Screw is not provided with a preload.

**Ball Screw**

THK  **A-761**

● **Torque Required for Acceleration**

Inertial Moment:

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

$J_s = 3.9 \times 10^{-4} \times 800 = 0.31$ kg・cm$^2$

$= 0.31 \times 10^{-4}$ kg・m$^2$

$$J = (m_1 + m_2)\left(\frac{Ph}{2 \times \pi}\right)^2 \cdot A^2 \times 10^{-6} + J_s \cdot A^2 = (40+10)\left(\frac{10}{2 \times \pi}\right)^2 \times 1^2 \times 10^{-6} + 0.31 \times 10^{-4} \times 1^2$$

$= 1.58 \times 10^{-4}$ kg・m$^2$

Angular acceleration:

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

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

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

Therefore, the required torque is specified as follows.

During upward acceleration:

$T_{k1} = T_1 + T_3 = 900 + 200 = 1100$ N・mm

During upward uniform motion:

$T_{t1} = T_1 = 900$ N・mm

During upward deceleration:

$T_{g1} = T_1 - T_3 = 900 - 200 = 700$ N・mm

During downward acceleration:

$T_{k2} = 630$ N・mm

During downward uniform motion:

$T_{t2} = 830$ N・mm

During downward deceleration:

$T_{g2} = 1030$ N-mm

THK

[**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.

$T_{max} = T_{k1} = 1100$ N・mm

Therefore, the maximum peak torque of the AC servomotor needs to be at least 1100 N-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:

$T_{k1} = 1100$ N・mm

$t_1 = 0.2$ s

During upward uniform motion:

$T_{t1} = 900$ N・mm

$t_2 = 1.8$ s

During upward deceleration:

$T_{g1} = 700$ N・mm

$t_3 = 0.2$ s

During downward acceleration:

$T_{k2} = 630$ N・mm

$t_1 = 0.2$ s

During downward uniform motion:

$T_{t2} = 830$ N・mm

$t_2 = 1.8$ s

During downward deceleration:

$T_{g2} = 1030$ N-mm

$t_3 = 0.2$ s

When stationary($m_2$=0):

$T_s = 658$ N・mm

$t_4 = 7.6$ s

**Ball Screw**

THK **A-763**

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 $1.58 \times 10^{-5}$ kg-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
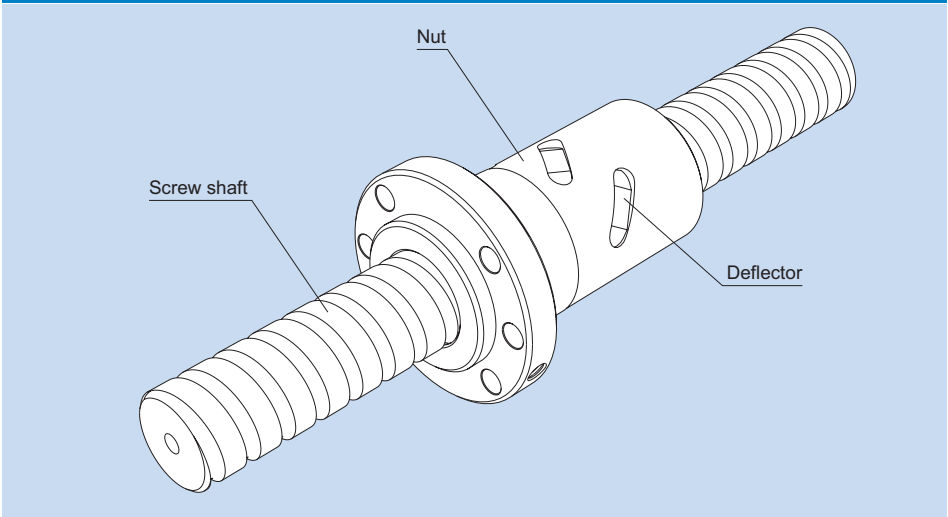


Fig.1 DIN Standard (DIN69051-1989) Compliant Precision Ball Screw

## Structure and Features

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.

**Ball Screw**

# Types and Features

## Models EPA/EBA

[Flange shape: round-flange type]
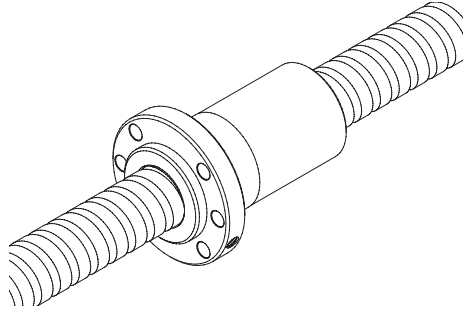
## Models EPB/EBB

[Flange shape: type with two cut faces]
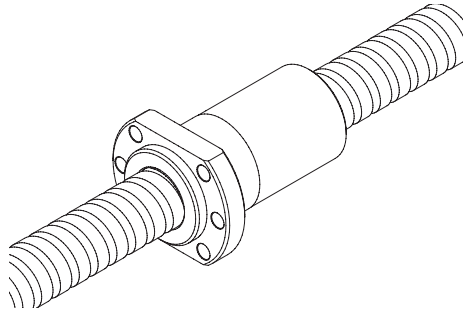
## Models EPC/EBC

[Flange shape: type with one cut face]
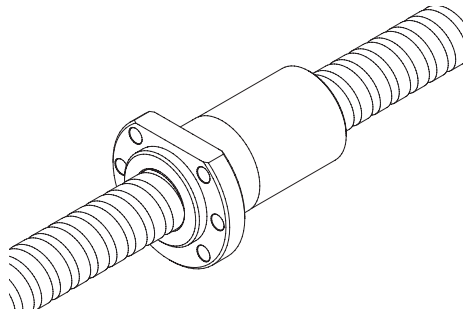
THK

## 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
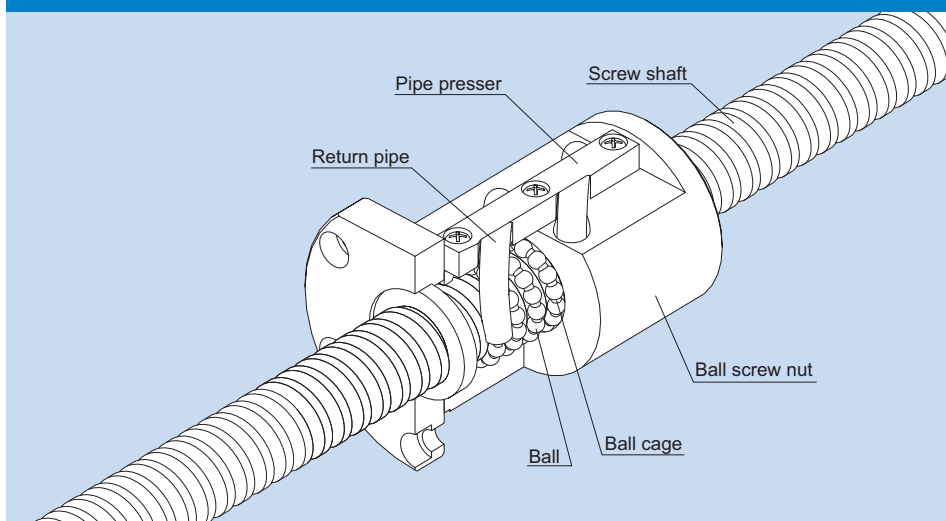


Fig.1 Structure of High-Speed Ball Screw with Ball Cage Model SBN

## Structure and Features

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.

Point (metal) contact

Conventional Structure

Grease pocket    Oil film contact

Structure of the Ball Screw with Ball Cage

**Ball Screw**

**THK** **A-771**
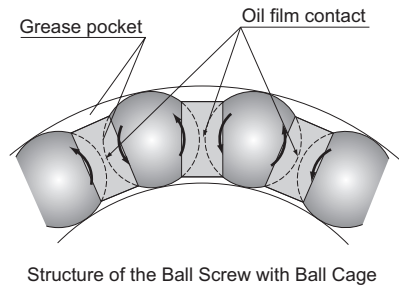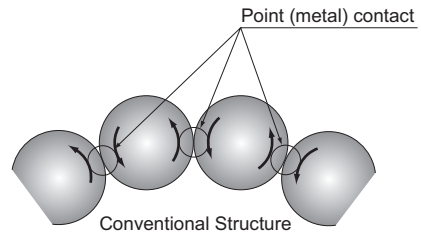
## [Low Noise]
### ● Noise Level Data
Since the balls in the Ball Screw with the Ball Cage do not collide with each other, they do not produce a metallic sound and a low noise level is achieved.

### ■ Noise Measurement
[Conditions]

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



Noise measurement instrument
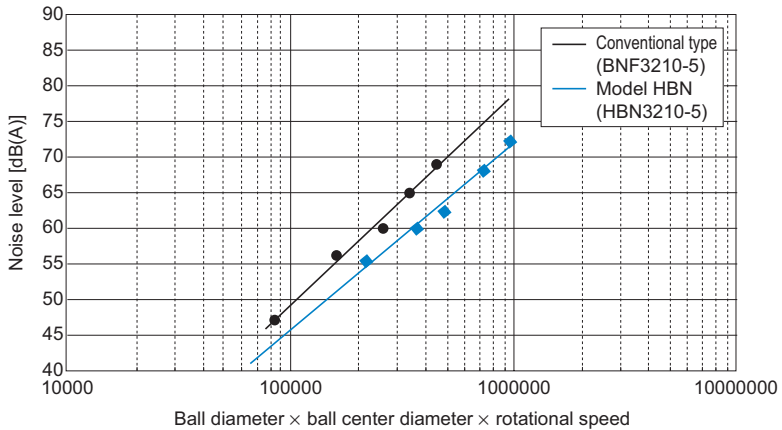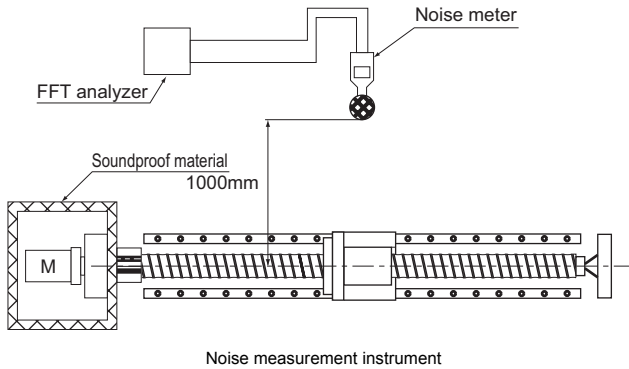


Fig.2 Ball Screw Noise Level

[**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 | 12cm³(lubricated every 1000km) |
| Applied load | 1.73kN |
| Acceleration | 1G |

| 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 | 12cm³ |
| Applied load | 17.3kN(0.5Ca) |
| Acceleration | 0.5G |

■**Load Bearing Test**
[Test conditions]

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

[Test result]
Shows no deviation after running 10,000 km.

[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 |
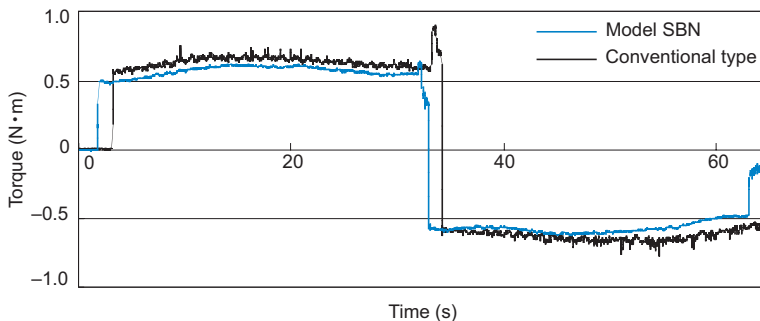


Fig.3 Torque Fluctuation Data

**Ball Screw**

# Types and Features

## Model SBN

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.
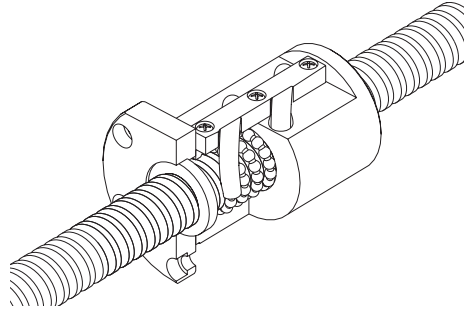
## Model SBK

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.
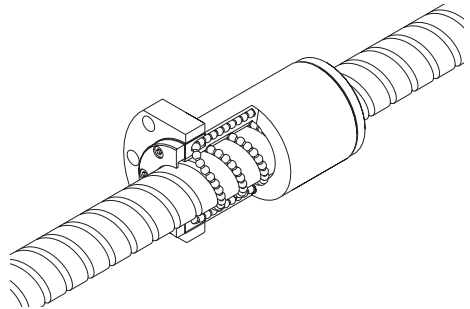
## Model HBN

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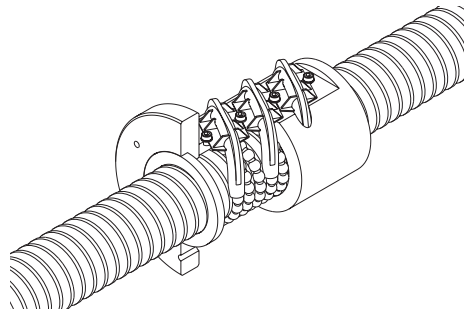
THK

## Service Life

For details,see A-722.

## Axial Clearance

For details,see A-703.

## Accuracy Standards

For details,see A-696.

**Ball Screw**

# Standard-Stock Precision Ball Screw

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

## 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.

**Ball Screw**

# Types and Features

## 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.
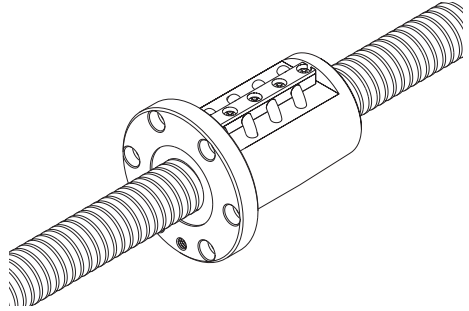
## Model BNFN

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.
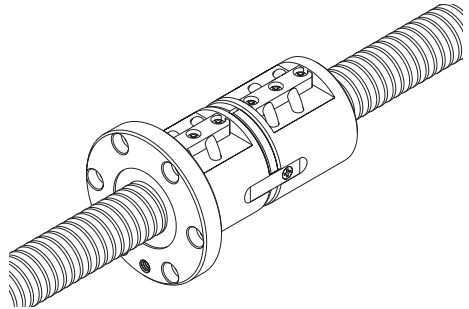
[**No Preload Type**]

# 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.
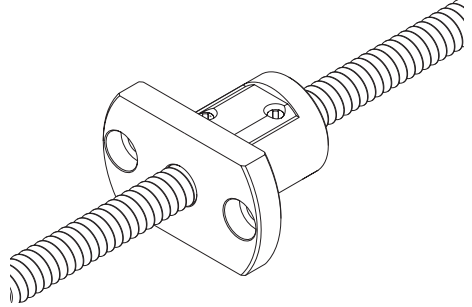
# Model BNF

**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.

**Ball Screw**

**THK** **A-779**
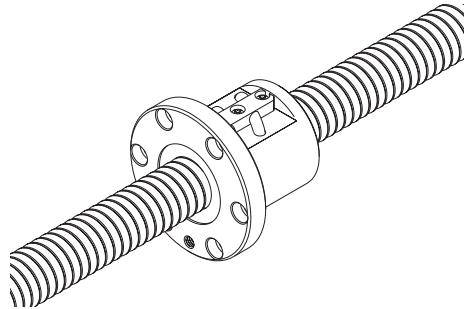
# Service Life

For details, see A-722.

# Nut Types and Axial Clearance

| Screw shaft outer diameter (mm) | $\phi$ 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) | $\phi$16 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.

THK

**Ball Screw**

# Standard-Stock Precision Ball Screw

**Finished Shaft Ends**
**Model BNK**

## 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.
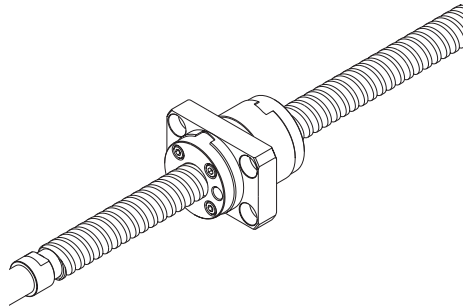
**Ball Screw**

# 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 | 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 | | | | | | ● | | | ● |
| 350 | | | | | | | | | |
| 400 | | | | | | | | | |
| 450 | | | | | | | | | |
| 500 | | | | | | | | | |
| 550 | | | | | | | | | |
| 600 | | | | | | | | | |
| 700 | | | | | | | | | |
| 800 | | | | | | | | | |
| 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**

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).

| Accuracy grades | Precision Ball Screw | | | | | | Rolled Ball Screw | |
|---|---|---|---|---|---|---|---|---|
| | 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.
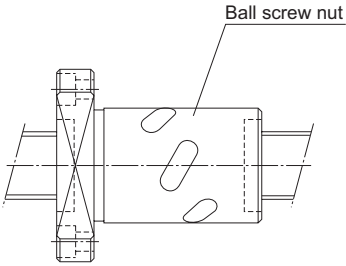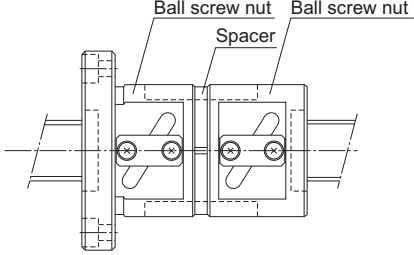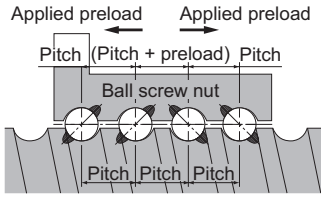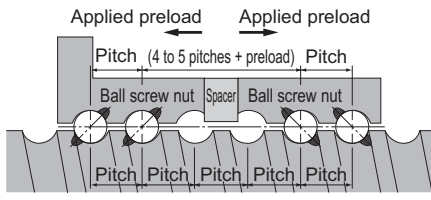
**Ball Screw**

**THK** **A-787**
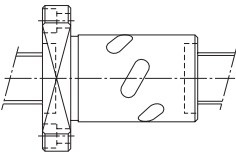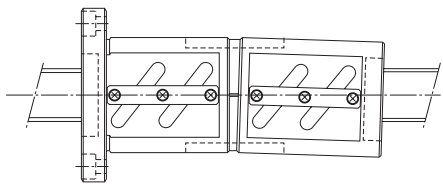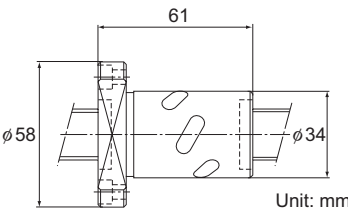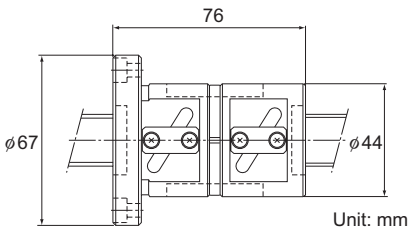
[**Structure and Features of Offset Preload Type Simple-Nut Ball Screw Model DIK**]
The Simple-Nut Ball Screw model DIK is an offset preload type in which a phase is provided in the middle of a single ball screw nut, and an axial clearance is set at a below-zero value (under a pre-load).
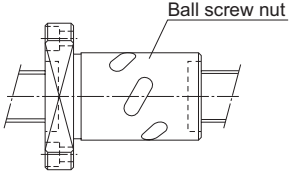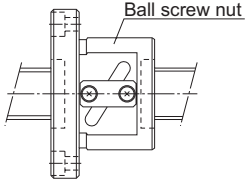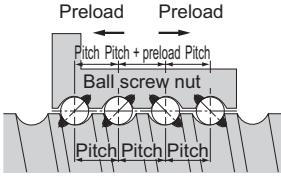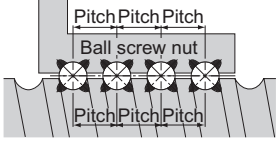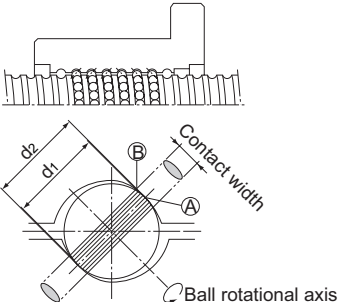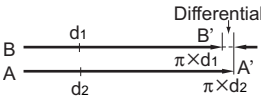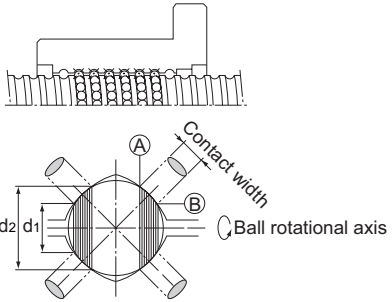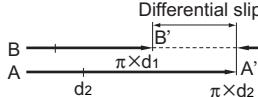
Model DIK has a more compact structure and allows smoother motion than the conventional double-nut type (spacer inserted between two nuts).

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

| Simple-Nut Ball Screw Model DIK | Conventional Double-Nut Type Ball Screw Model BNFN |
|---|---|
|  Ball screw nut |  Ball screw nut  Ball screw nut  Spacer |
| **Preloading Structure** | |
|  Applied preload  Applied preload  Pitch (Pitch + preload) Pitch  Ball screw nut  Pitch Pitch Pitch  Screw shaft |  Applied preload  Applied preload  Pitch (4 to 5 pitches + preload) Pitch  Ball screw nut Spacer Ball screw nut  Pitch Pitch Pitch Pitch Pitch  Screw shaft |

| 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. | |

61
ø58  ø34
Unit: mm
Model DIK 2005-6

76
ø67  ø44
Unit: mm
Model BNFN 2005-2.5

**Ball Screw**

**[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 |
|---|---|
| Ball screw nut | Ball screw nut |
| **Preloading Structure** | |
| Preload   Preload<br>Pitch Pitch + preload Pitch<br>Ball screw nut<br>Pitch Pitch Pitch<br>Screw shaft | Pitch Pitch Pitch<br>Ball screw nut<br>Pitch Pitch Pitch<br>Screw shaft |
| **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. | 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. |
| 2 point contact structure<br> | 4 point contact structure<br> |

A-790   THK

# Types and Features

[**Preload Type**]
## Model BIF

Specification Table⇒B-692

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.

## Model DIK

Specification Table⇒B-692

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.

## Model BNFN
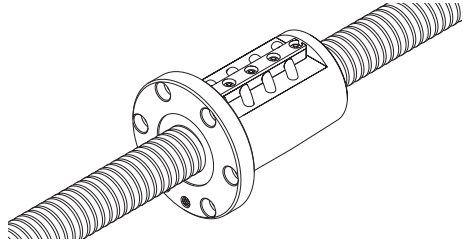
Specification Table⇒B-692

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.

## Model DKN
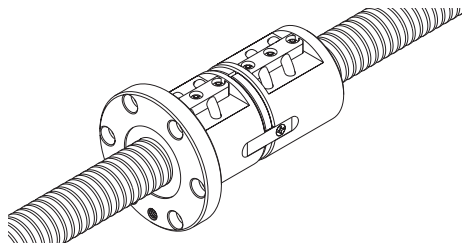
Specification Table⇒B-712

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

**Ball Screw**

THK  A-791
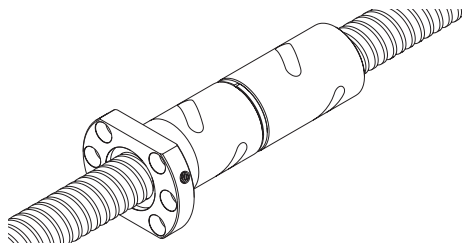
# Model BLW

Since a preload is provided through a spacer between two large lead nuts, high-speed feed without by backlash is ensured.
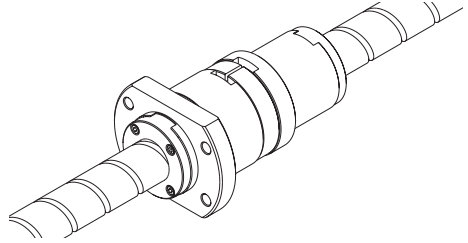
[No Preload Type]

# Model BNF

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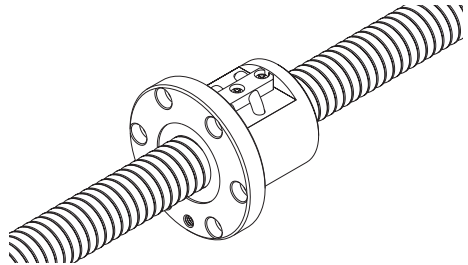
# Model DK

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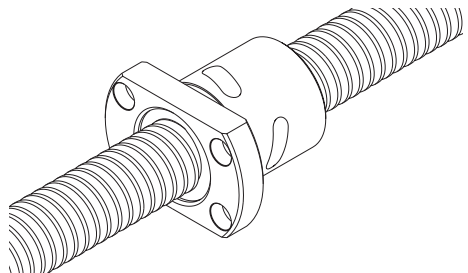
# Model MDK

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.

THK
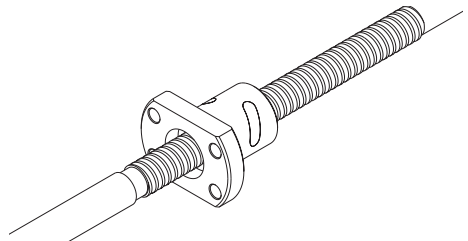
# Models BLK/WGF

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.
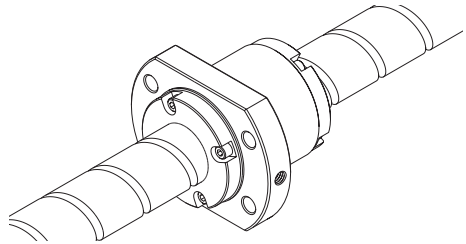
# Square Ball Screw Nut Model BNT

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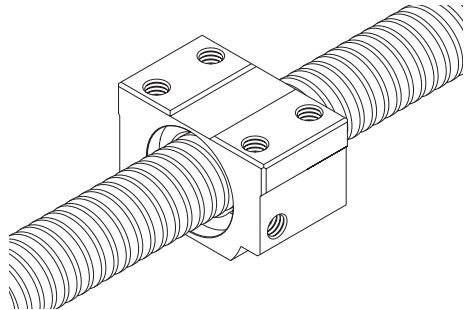
## Service Life

For details,see A-722.

## Axial Clearance

For details,see A-703.

## Accuracy Standards

For details,see A-696.
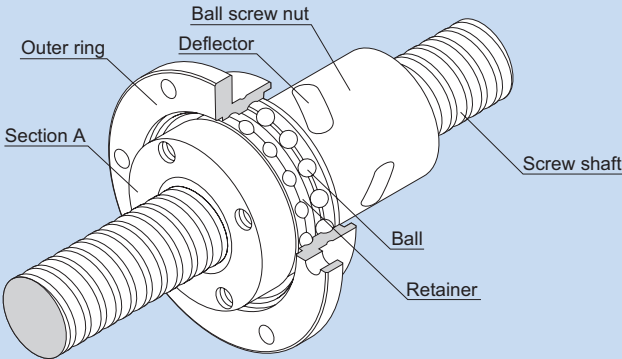
**Ball Screw**

**Structure of Standard-Lead Rotary Nut Ball Screw Model DIR**



**Structure of Large Lead Rotary Nut Ball Screw Model BLR**

# 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.)
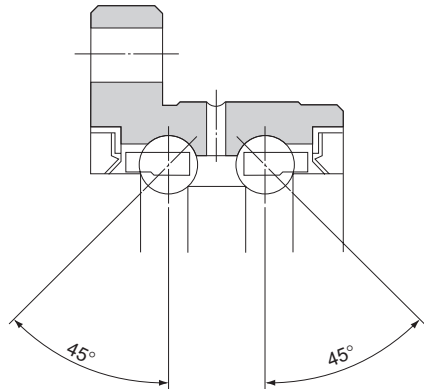


Fig.1 Structure of the Support Bearing

● **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.

**Ball Screw**

**THK** A-795

● **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
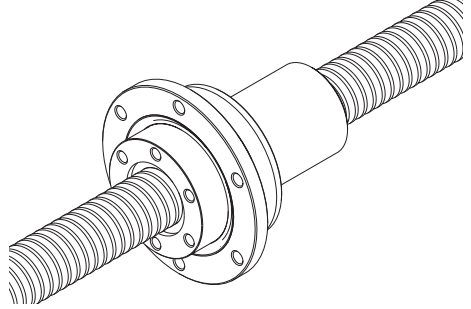
**[No Preload Type]**

## Model BLR
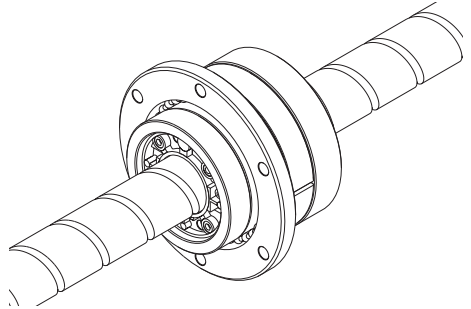
**Ball Screw**

## 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).
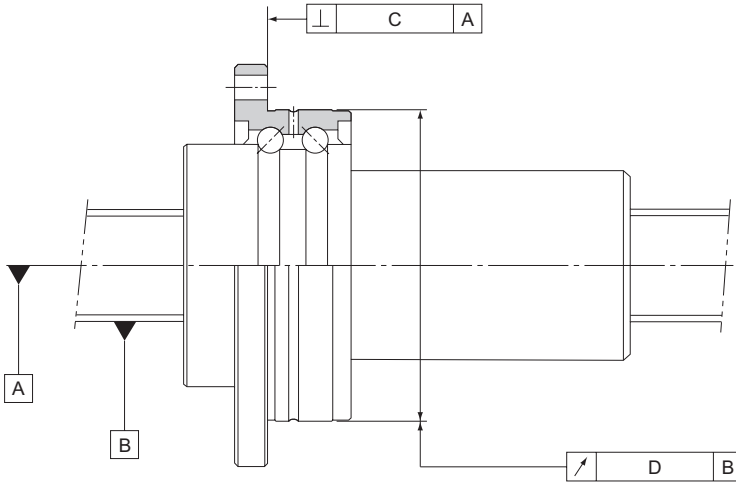
Unit: mm

| 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 |

THK

[**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).
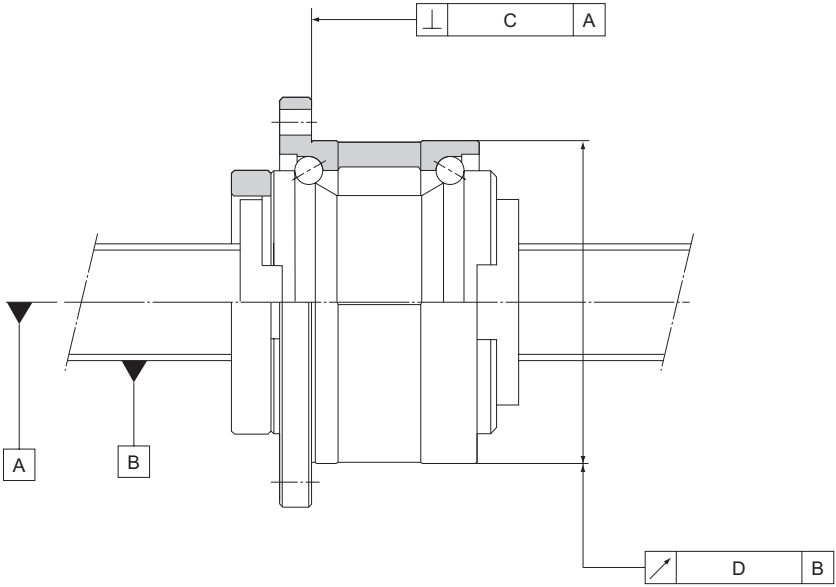
**Ball Screw**

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]
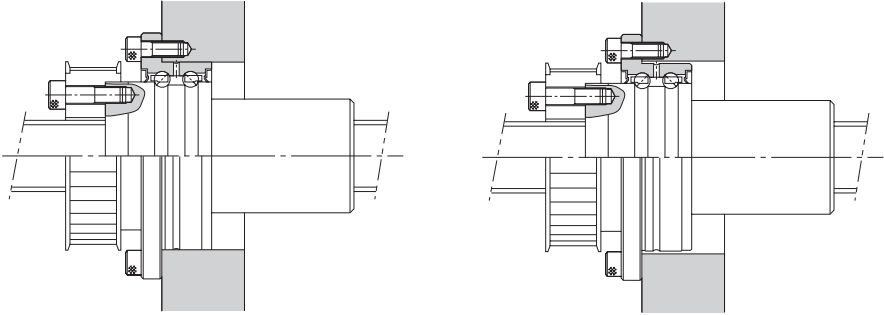


Installation to the housing can be performed
on the end face of the outer ring flange.

## [Example of Mounting Ball Screw Nut Model BLR]
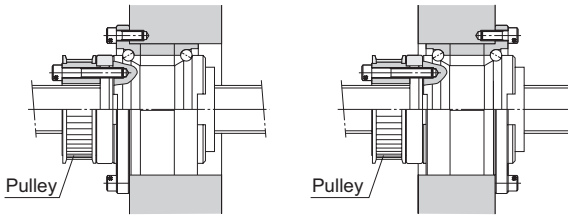


Pulley                          Pulley

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)

LM Guide

Table

Motor

Ball Screw (Model BLR)

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)

LM Guide

Table

Motor

Ball Screw (Model BLR)

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

**Ball Screw**

THK  **A-801**
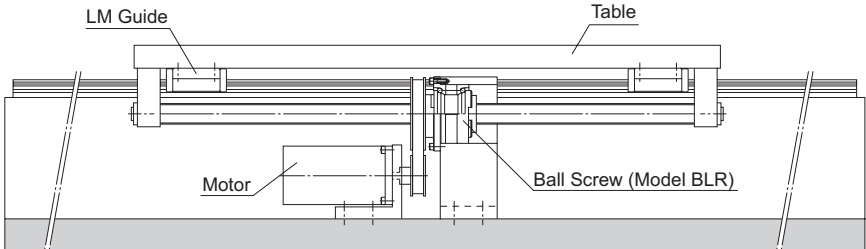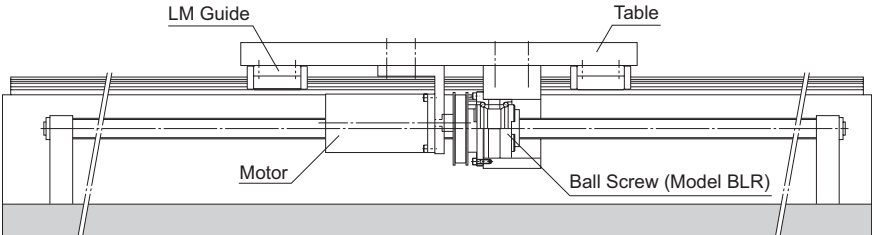
# Precision Ball Screw/Spline

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

# 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.

**Ball Screw**
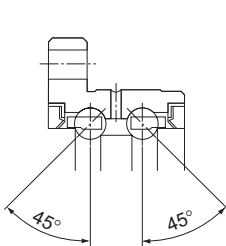
Fig.1 Structure of Support Bearing Model BNS-A
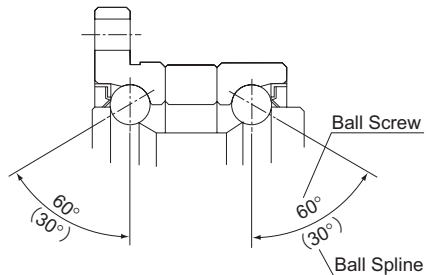
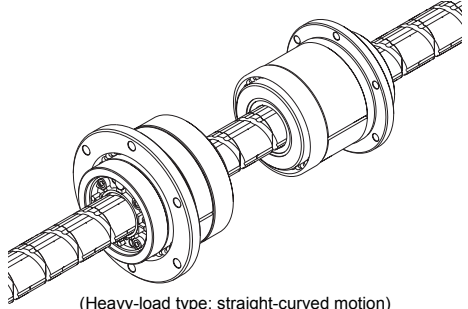Fig.2 Structure of Support Bearing Model BNS

# Type

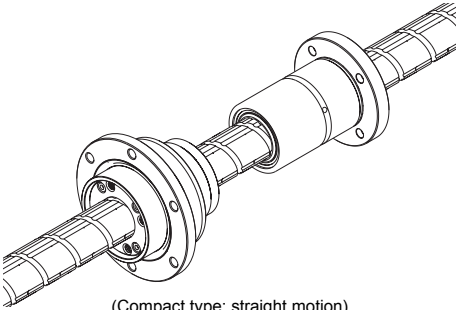**[No Preload Type]**

## Model BNS-A Specification Table⇒B-766
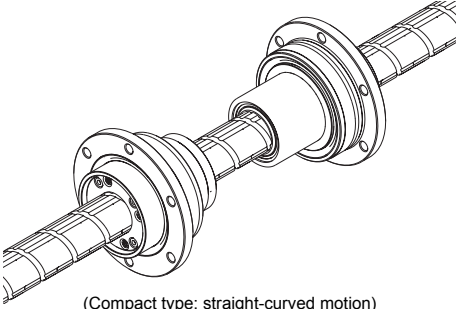


(Compact type: straight-curved motion)
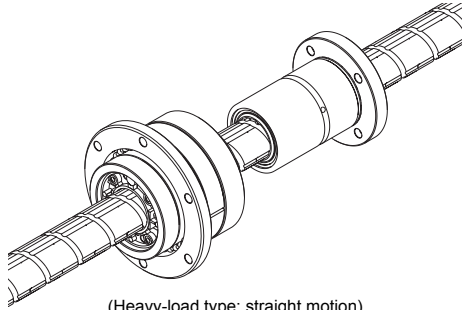
## Model BNS Specification Table⇒B-768



(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.)
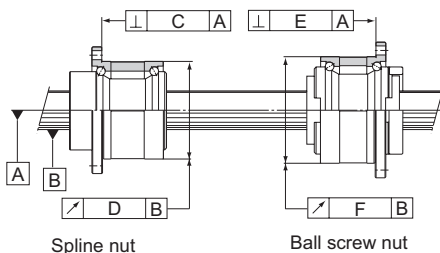


Model BNS
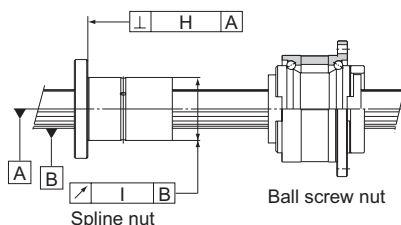
Model NS

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 |

**Ball Screw**

# Action Patterns

[**Model BNS Basic Actions**]



Ball screw nut
Ball screw nut pulley: $N_1$
Spline nut
Shaft
Spline nut pulley: $N_2$

$\ell$: Ball screw lead (mm)
$N_1$: Ball screw nut rotational speed (min$^{-1}$)
$N_2$: Spline nut rotational speed (min$^{-1}$)

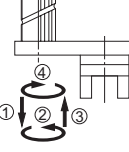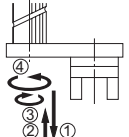| Motion | | Action direction | Input | | Shaft motion | |
|---|---|---|---|---|---|---|
| | | | Ball screw pulley | Ball spline pulley | Vertical direction (speed) | Rotational direction (rotation speed) |
| 1. Vertical | (1) | Vertical direction→down / Rotational direction→0 | $N_1$ (Forward) | 0 | $V = N_1 \cdot \ell$ ($N_1 \neq 0$) | 0 |
| | (2) | Vertical direction→up / Rotational direction→0 | $-N_1$ (Reverse) | 0 | $V = -N_1 \cdot \ell$ ($N_1 \neq 0$) | 0 |
| 2. Rotation | (1) | Vertical direction→0 / Rotational direction→forward | $N_1$ | $N_2$ (Forward) | 0 | $N_2$(Forward) ($N_1 = N_2 \neq 0$) |
| | (2) | Vertical direction→0 / Rotational direction→reverse | $-N_1$ | $-N_2$ (Reverse) | 0 | $-N_2$(Reverse) ($-N_1 = -N_2 \neq 0$) |
| 3. Spiral | (1) | Vertical direction→up / Rotational direction→forward | 0 | $N_2$ ($N_2 \neq 0$) | $V = N_2 \cdot \ell$ | $N_2$ (Forward) |
| | (2) | Vertical direction→down / Rotational direction→reverse | 0 | $-N_2$ ($-N_2 \neq 0$) | $V = -N_2 \cdot \ell$ | $-N_2$ (Reverse) |

**[Model NS Basic Actions]**



Ball screw nut

Ball screw nut pulley: $N_1$

Spline nut

Shaft

$\ell$: Ball screw lead (mm)

$N_1$: Ball screw nut rotational speed (min$^{-1}$)
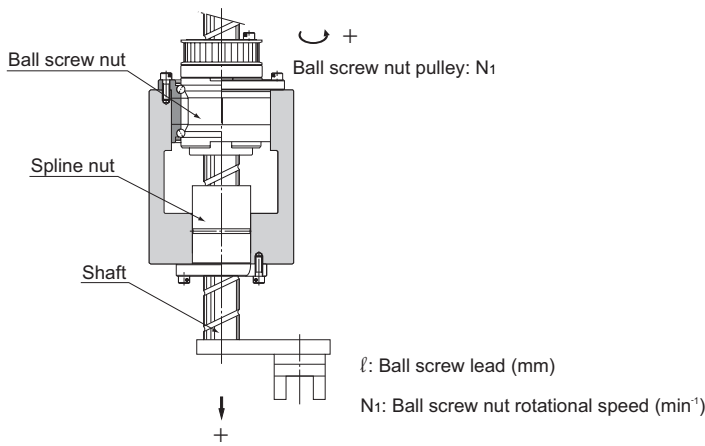
| Motion | | | Action direction | Input | Shaft motion |
|---|---|---|---|---|---|
| | | | | Ball screw pulley | Vertical direction (speed) |
| 1. Vertical | | (1) | Vertical direction →down | $N_1$ (Forward) | $V=N_1 \cdot \ell$ ($N_1 \neq 0$) |
| | | (2) | Vertical direction →up | $-N_1$ (Reverse) | $V=-N_1 \cdot \ell$ ($N_1 \neq 0$) |
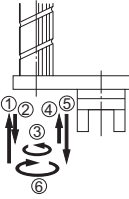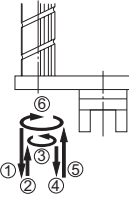
**Ball Screw**

[**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

Pulley
Seal
Support bearing
Ball screw nut
Shaft
Support bearing
Spline nut
Seal
Pulley
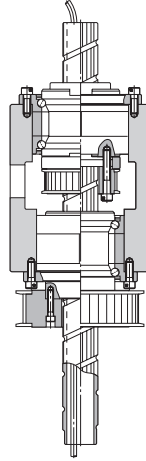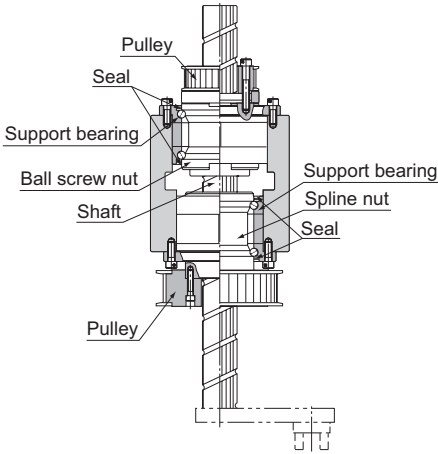
● Example of installing the ball screw nut input pulley and the spline nut input pulley, both outside the housing. The housing length is minimized.

● Example of installing the ball screw nut pulley inside the housing.
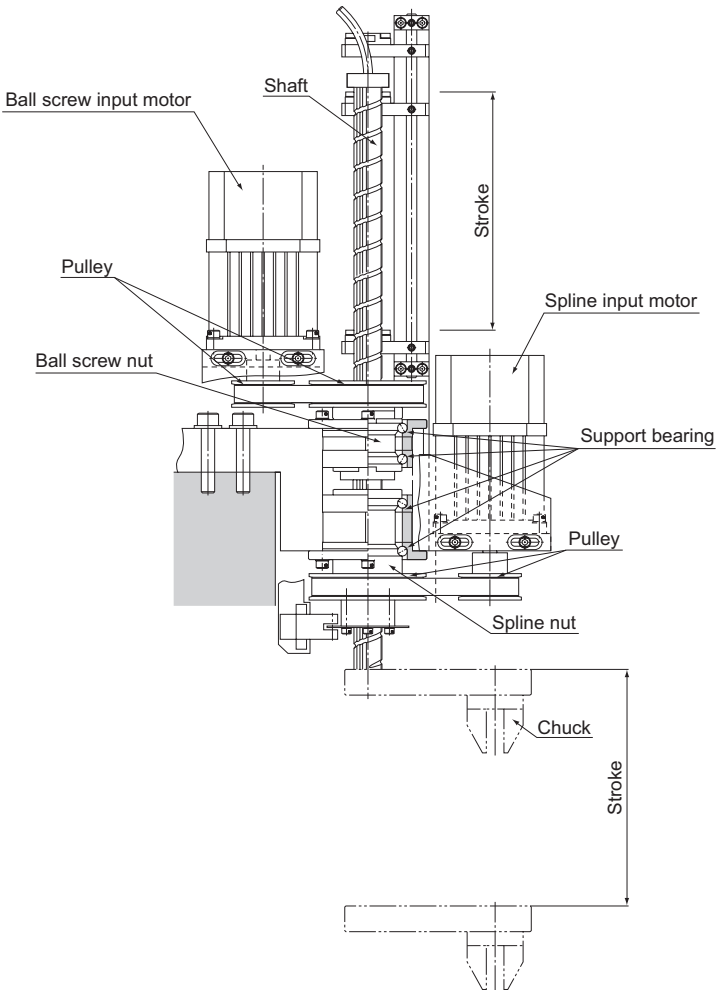
Fig.3 Example of Assembling Model BNS

Pulley
Seal
Support bearing
Ball screw nut
Shaft
Spline nut
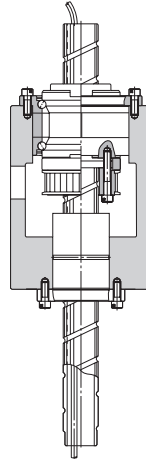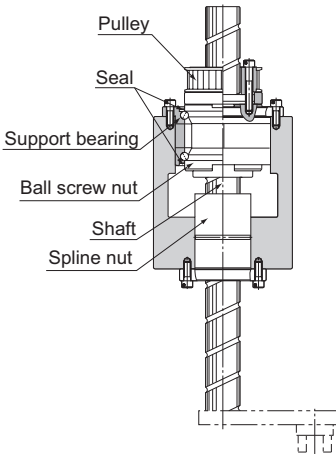
● Example of installing the ball screw nut pulley outside the housing. The housing length is minimized.

● Example of installing the ball screw nut pulley inside the housing.

Fig.4 Example of Assembling Model NS

**Ball Screw**

# Example of Using the Spring Pad

Ball screw input motor

Shaft

Pulley

Ball screw nut

Spline input motor

Support bearing

Pulley

Spline nut

Chuck

Stroke

Stroke

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.
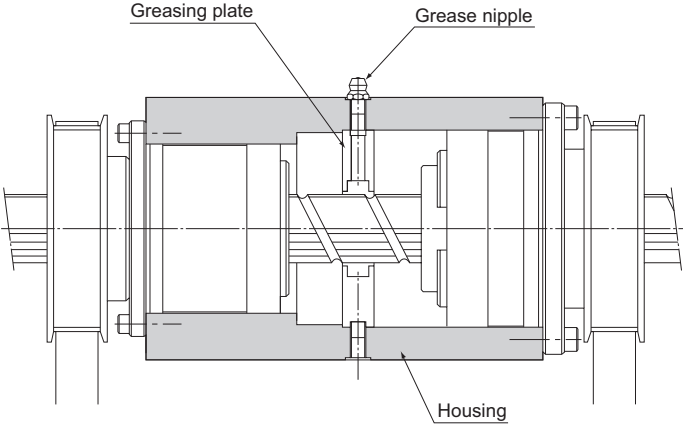


Fig.6 Lubrication Methods

# Rolled Ball Screw

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

# Structure and Features

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: ±0.05/300 (mm)

                    C8: ±0.10/300 (mm)

              C10: ±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 a 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 a 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.

**Ball Screw**

# Types and Features
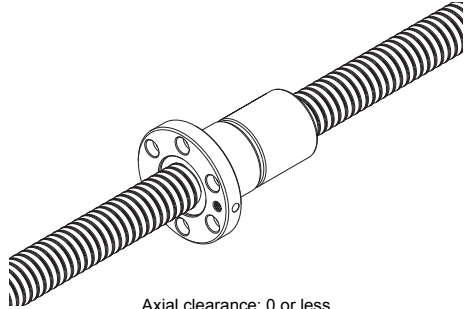
## Model JPF

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.

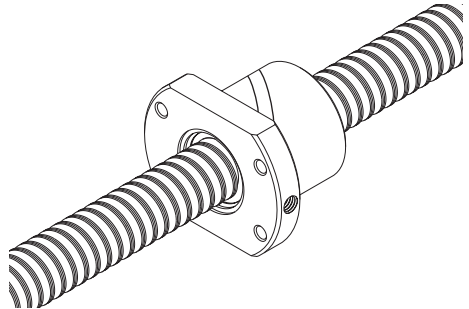The constant preload method allows the ball screw to absorb a pitch error and achieve a smooth motion.

Axial clearance: 0 or less

## Model BTK

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

A miniature type with a screw shaft diameter of $\phi$6 to $\phi$12 mm and a lead of 1 to 2 mm.
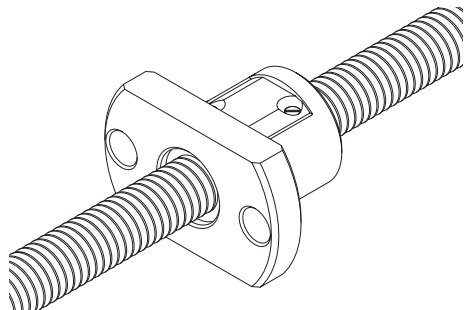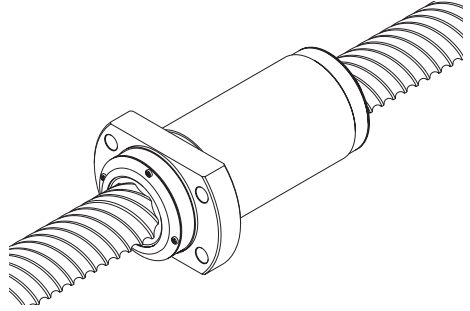
# Models BLK/WTF

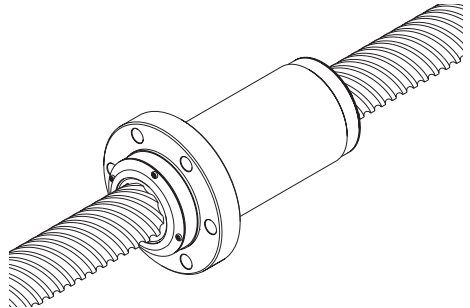Using an end-cap method, these models achieve stable motion in a high-speed rotation.

# Model CNF

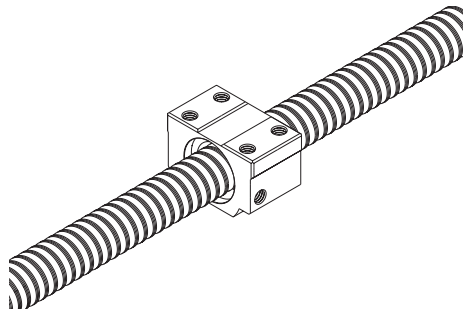With a combination of 4 rows of large-lead loaded grooves and a long nut, a long service life is achieved.

# Square Ball Screw Nut Model BNT

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.

**Ball Screw**

## Service Life

For details,see A-722.

## Axial Clearance

For details,see A-703.

## Accuracy Standards

For details,see A-696.

**Ball Screw**

# Rolled Rotary Ball Screw

## Model BLR



Fig.1 Structure of Large Lead Rotary Nut Ball Screw Model BLR

## 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.)
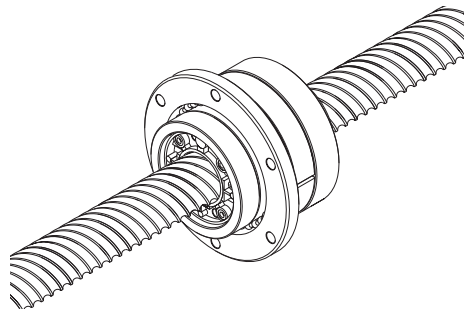
## Type

**[No Preload Type]**

# Model BLR

**Ball Screw**

THK **A-819**
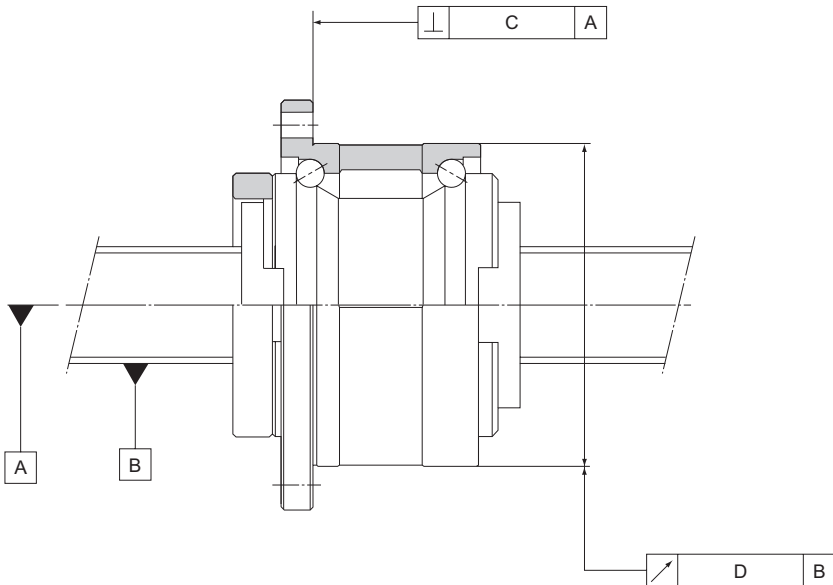
## Service Life

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 |

THK

# Example of Assembly

[**Example of Mounting Ball Screw Nut Model BLR**]

Pulley             Pulley

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)

LM Guide            Table

Motor         Ball Screw (Model BLR)

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)

LM Guide            Table

Motor         Ball Screw (Model BLR)

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

**Ball Screw**

THK

**Ball Screw**
# Ball Screw Peripherals
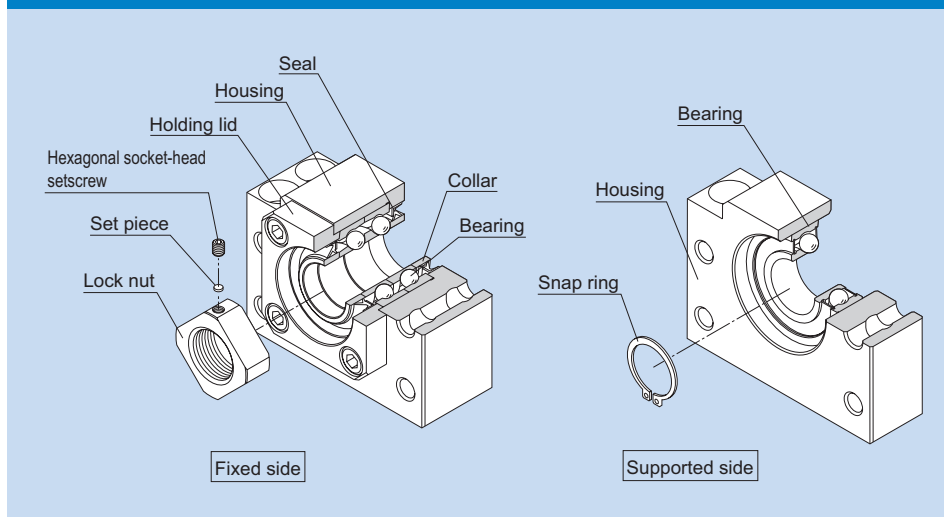
# Support Unit

## 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.

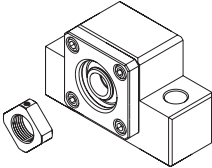**Ball Screw Peripherals**

# Type

## Square Type Model EK

**Specification Table⇒B-794**

(Inner diameter: $\phi 4$ to $\phi 20$)
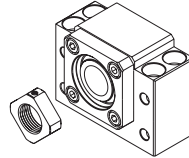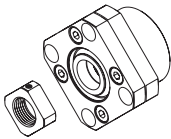
## Round Type Model FK

**Specification Table⇒B-798**

(Inner diameter: $\phi 4$ to $\phi 30$)

## Square Type Model BK

**Specification Table⇒B-796**

(Inner diameter: $\phi 10$ to $\phi 40$)

## Square Type Model EF

**Specification Table⇒B-802**
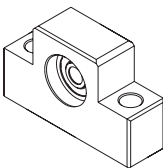
(Inner diameter: $\phi 6$ to $\phi 20$)
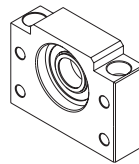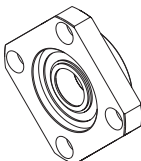
## Round Type Model FF

**Specification Table⇒B-806**

(Inner diameter: $\phi 6$ to $\phi 30$)

## Square Type Model BF

**Specification Table⇒B-804**

(Inner diameter: $\phi 8$ to $\phi 40$)

# 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<br>FK 4 | — | — | $\phi$4 |
| 5 | EK 5<br>FK 5 | — | — | $\phi$6 |
| 6 | EK 6<br>FK 6 | 6 | EF 6<br>FF 6 | $\phi$8 |
| 8 | EK 8<br>FK 8 | 6 | EF 8<br>FF 6 | $\phi$10 |
| 10 | EK 10<br>FK 10<br>BK 10 | 8 | EF 10<br>FF 10<br>BF 10 | $\phi$12, $\phi$14 |
| 12 | EK 12<br>FK 12<br>BK 12 | 10 | EF 12<br>FF 12<br>BF 12 | $\phi$14, $\phi$15, $\phi$16 |
| 15 | EK 15<br>FK 15<br>BK 15 | 15 | EF 15<br>FF 15<br>BF 15 | $\phi$20 |
| 17 | BK 17 | 17 | BF 17 | $\phi$20, $\phi$25 |
| 20 | EK 20<br>FK 20<br>BK 20 | 20 | EF 20<br>FF 20<br>BF 20 | $\phi$25, $\phi$28, $\phi$32 |
| 25 | FK 25<br>BK 25 | 25 | FF 25<br>BF 25 | $\phi$36 |
| 30 | FK 30<br>BK 30 | 30 | FF 30<br>BF 30 | $\phi$40, $\phi$45 |
| 35 | BK 35 | 35 | BF 35 | $\phi$45 |
| 40 | BK 40 | 40 | BF 40 | $\phi$50 |

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.

**Ball Screw Peripherals**

# 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 C$_0$(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.

THK

# Example of Installation

[**Square Type Support Unit**]



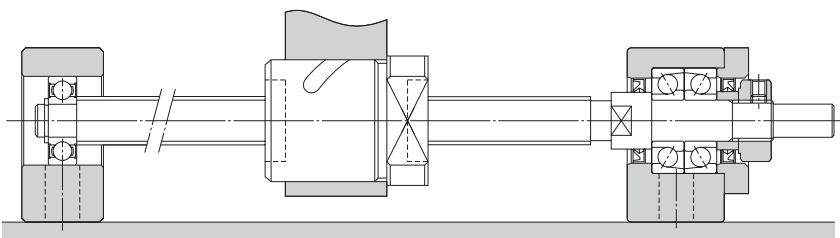Fig.2 Example of Installing a Square Type Support Unit
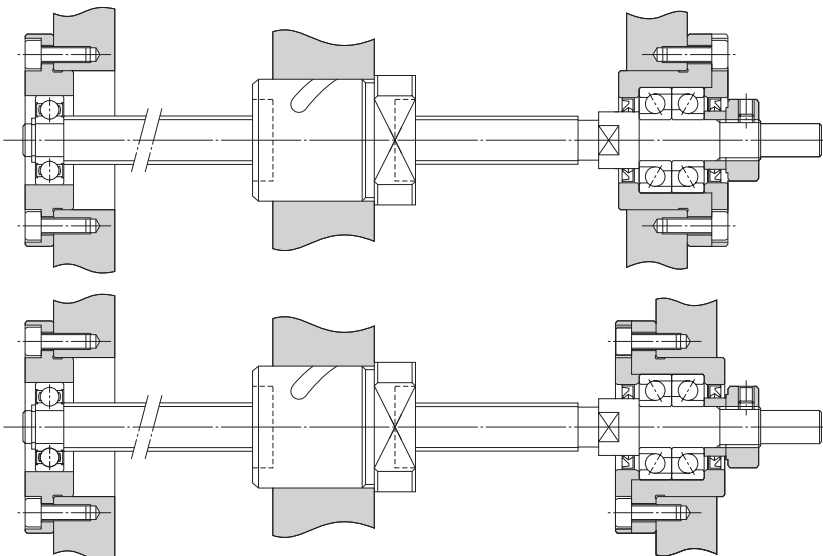
[**Round Type Support Unit**]



Fig.3 Example of Installing a Round Type Support Unit

**Ball Screw Peripherals**

THK **A-829**

# 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 no 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.
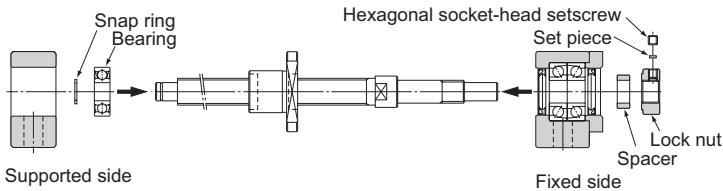


[**Installation onto the Table and the Base**]
(1) If using a bracket when mounting the ball screw nut to the table, insert the nut into the bracket and temporarily fasten it.
(2) Temporarily fasten the fixed side Support Unit to the base.
In doing so, press the table toward the fixed side Support Unit 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.
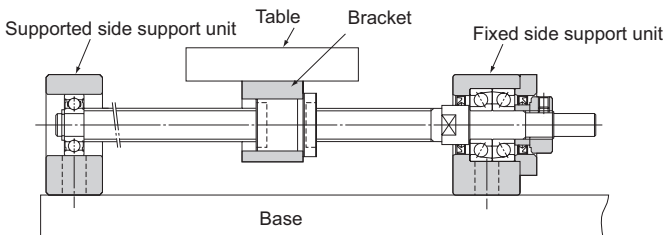
[**Checking the Accuracy and Fully Fastening the Support Unit**]

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.
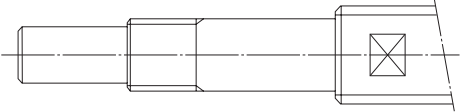
Measure the axial clearance

Adjust the nut by moving the table so that the nut travels smoothly throughout the whole stroke.
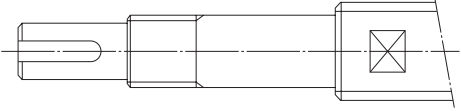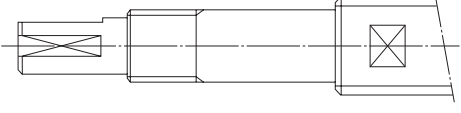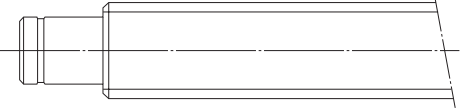
Measure the runout
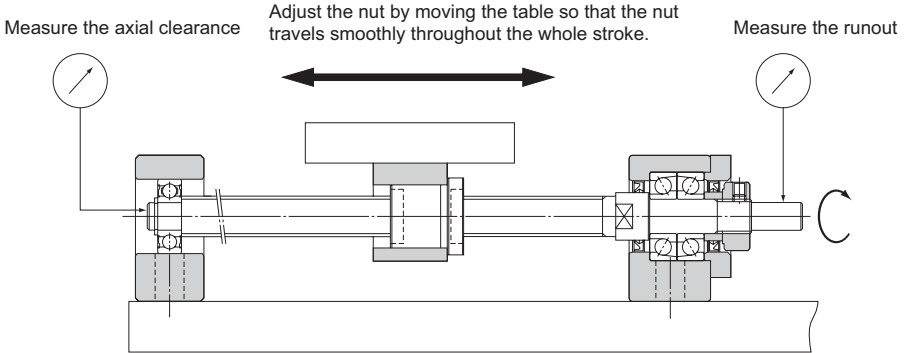
[**Connection with the Motor**]

(1)  Mount the motor bracket to the base.

(2)  Connect the motor and the ball screw using a coupling.

Note) Make sure the mounting accuracy is maintained.

(3)  Thoroughly perform the break-in for the system.

Coupling

Motor
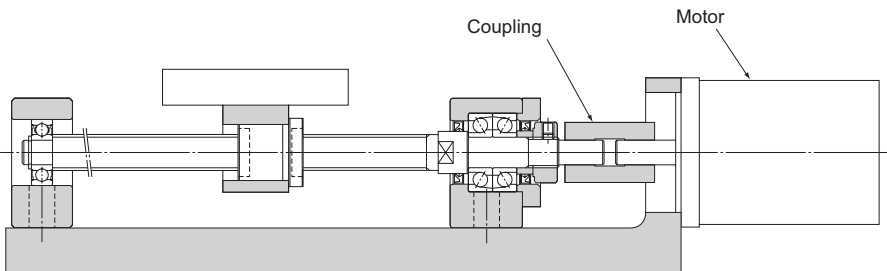
# Types of Recommended Shapes of the Shaft Ends

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 |
| Supported | K |  | FF EF BF |

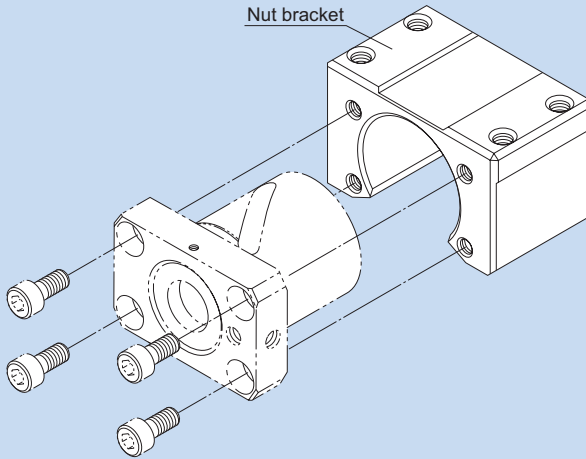# Nut bracket

## Model MC



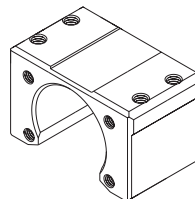Fig.1 Structure of the Nut Bracket

## 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
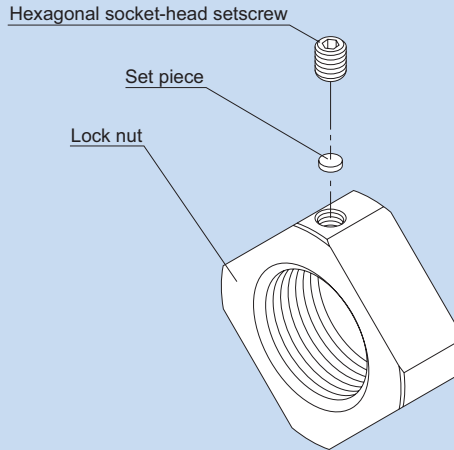


Fig.1 Structure of the Lock Nut

## Structure and Features
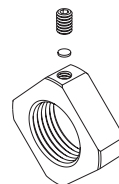
The Lock Nut for the Ball Screws is capable of fastening the screw shaft and the bearing with a high accuracy.

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

**THK**   **A-835**

**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.
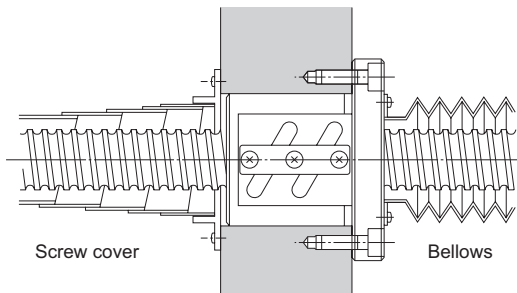
Screw cover          Bellows
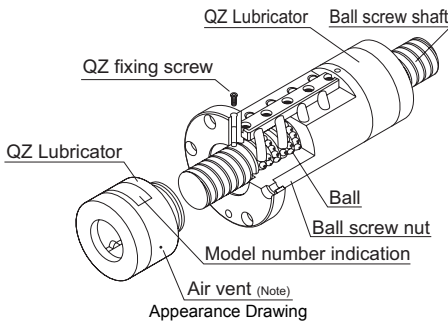
Fig.1 Contamination Protection Cover
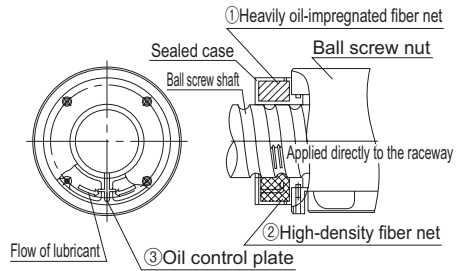
# QZ Lubricator

●**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.

QZ Lubricator　Ball screw shaft

QZ fixing screw

QZ Lubricator

Ball
Ball screw nut
Model number indication
Air vent (Note)

Appearance Drawing

①Heavily oil-impregnated fiber net
Sealed case　Ball screw nut
Ball screw shaft
Applied directly to the raceway
Flow of lubricant　③Oil control plate
②High-density fiber net

Structural Drawing

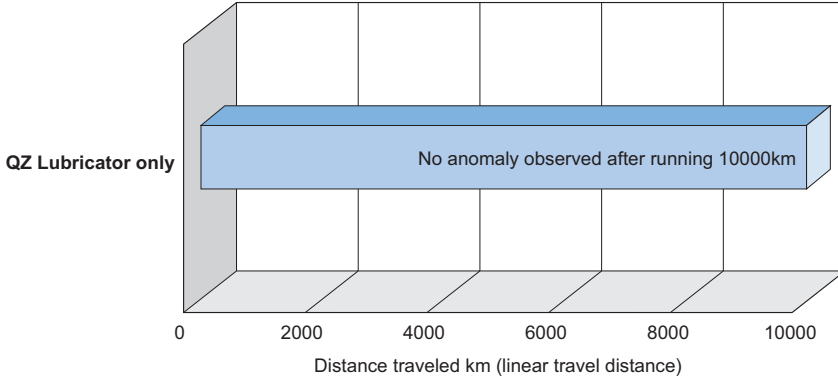[Features]
● Since it supplements an oil loss, the lubrication maintenance interval can be significantly extended.
● Since the right amount of lubricant is applied to the ball raceway, an environmentally friendly lubrication system that does not contaminate the surroundings is achieved.
Note) QZ Lubricator has a vent hole. Do not block the hole with grease or the like.

**Ball Screw (Options)**

## ● Significantly extended maintenance interval

Since QZ Lubricator continuously feeds a lubricant over a long period, the maintenance interval can be extended significantly.



**QZ Lubricator only**

No anomaly observed after running 10000km

0    2000    4000    6000    8000    10000

Distance traveled km (linear travel distance)

[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**    32    Model No.: BNFN3612-5G0+1500LC5
Traveling speed: 20km/d
Travel distance: 2500km

Forced lubrication                                                15000

0    5000    10000    15000

Amount of oil  cm$^3$
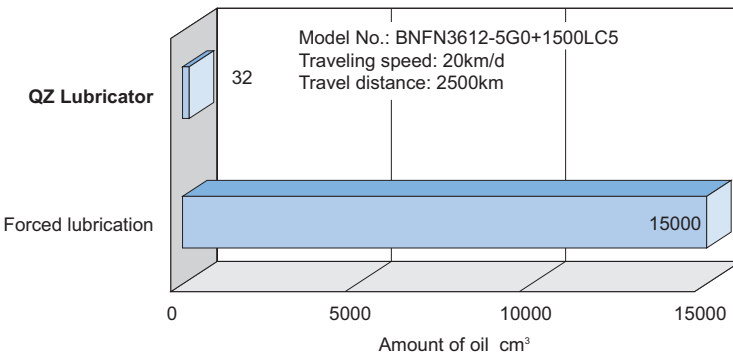
**QZ Lubricator + THK AFA Grease**
**32cm$^3$**
(QZ Lubricator attached to both ends of the ball screw nut)

**Compared**

**Forced lubrication**
**0.25cm$^3$/3min×24h×125d**
**＝15000cm$^3$**

Reduced to approx. $\dfrac{1}{470}$

# 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.

Appearance Drawing

Structural Drawing
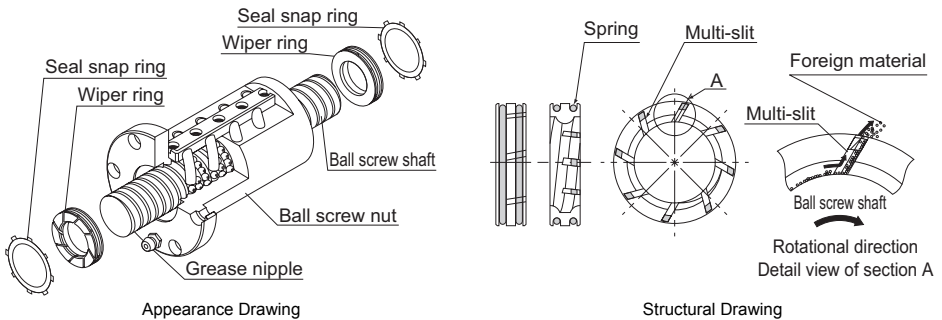
[Features]
● A total of eight slits on the circumference remove foreign materials in succession, and prevent entrance of foreign material.
● Contacts the ball screw shaft to reduce the flowing out of grease.
● Contacts the ball screw shaft at a constant pressure level using a spring, thus to minimize 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.

**Ball Screw (Options)**

● **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 8cm³ (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]



Type with wiper ring
Type with labyrinth seal

Distance traveled (km)

☐ No problem ☐ Flaking occurrs on the ball screw shaft raceway ☐ Flaking occurrs on the ball
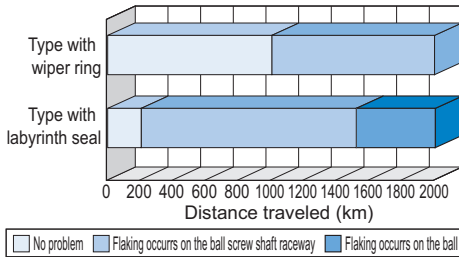
Change in the ball after traveling 2000 km

| (1) Type with wiper ring | (2) Type with labyrinth seal |
|---|---|
|  |  |
| Unused ball · Ball after traveling | Unused ball · Ball after traveling |
| ●Discolored, but no breakage | ●Flaking occurs |
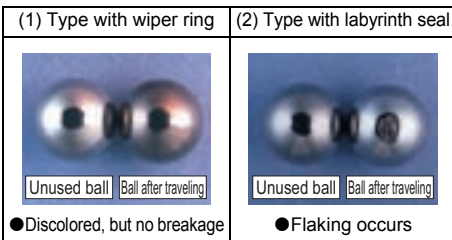
● Type with wiper ring
  Slight flaking occurred in the ball screw shaft at travel distant of 1,000 km.
● Type with labyrinth seal
  Flaking occurred throughout the circumference of the screw shaft raceway at travel distance of 200 km.
  Flaking occurred on the balls after traveling 1,500 km.



Wear of ball (μm)

Distance traveled (km)

— Type with labyrinth seal
— Type with wiper ring
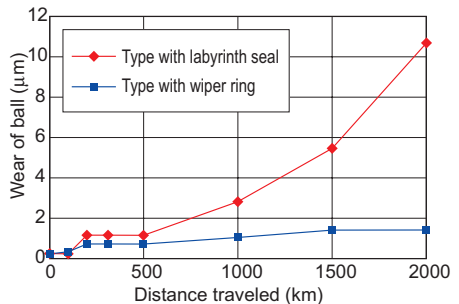
● Type with wiper ring
  Wear of balls at a travel distance of 2,000 km: 1.4 μm.
● Type with labyrinth seal
  Starts to be worn rapidly after 500 km, and the ball wear amount at the travel distance of 2,000 km: 11 μm

## ● 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 5cm³ (contained in the ball screw nut) |

[Test result]
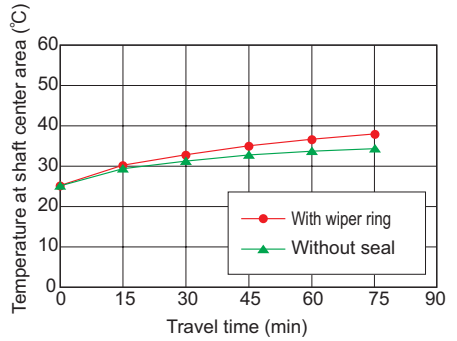


Unit: ℃

| Item | With wiper ring | Without seal |
|---|---|---|
| Heat generation temperature | 37.1 | 34.5 |
| Temperature rise | 12.2 | 8.9 |

**Ball Screw (Options)**

THK  **A-843**

# Specifications of the Bellows

Bellows are available as a contamination protection accessory. Use this specification sheet.



(Band type)                (Flange type)
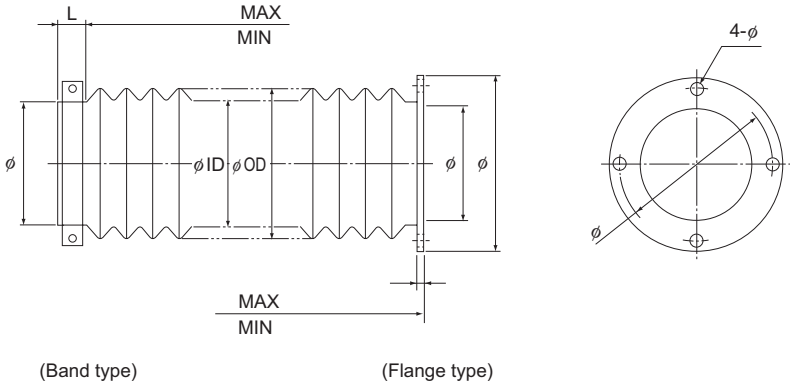
## Specifications of the Bellows

**Supported Ball Screw models:**

### Dimensions of the Bellows

**Stroke:**(            ) mm      **MAX:**(            ) mm      **MIN:**(            ) mm

**Permissible outer diameter:**( $\phi$OD          )      **Desired inner diameter:**( $\phi$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** (                            ) × (        ) %

**Location: (indoor, outdoor)**

### Remarks:

### Number of Units To Be Manufactured:

**Ball Screw (Options)**

# 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.
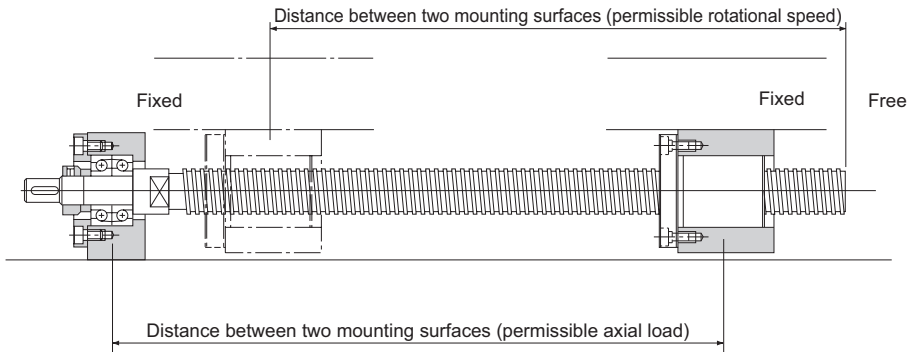
Distance between two mounting surfaces (permissible rotational speed)

Fixed                                           Fixed      Free

Distance between two mounting surfaces (permissible axial load)

Fig.1 Screw Shaft Mounting Method: Fixed - Free

Distance between two mounting surfaces (permissible rotational speed)

Fixed                                           Fixed    Supported

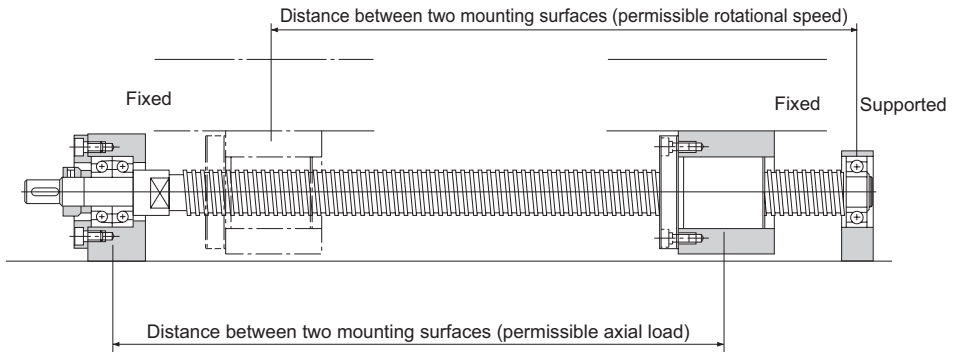Distance between two mounting surfaces (permissible axial load)

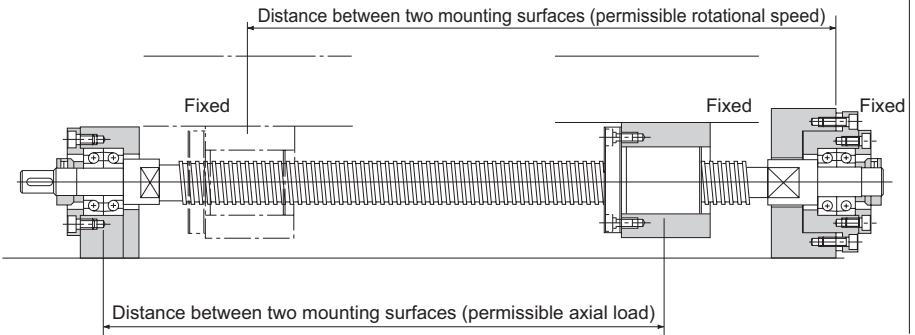Fig.2 Screw Shaft Mounting Method: Fixed - Supported

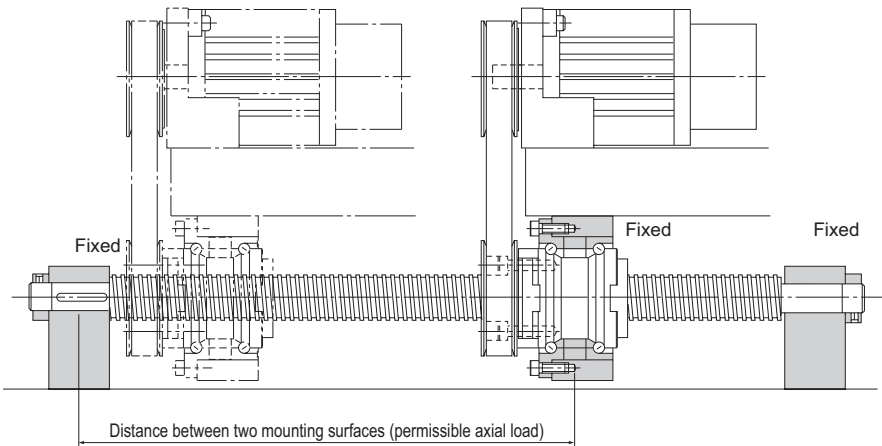Fig.3 Screw Shaft Mounting Method: Fixed - Fixed



Fig.4 Screw Shaft Mounting Method for Rotary Nut Ball Screw: Fixed - Fixed

Ball Screw

# 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 |

THK

[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℃ 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.

**Ball Screw**

**[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.

THK