Ball Screw

THK General Catalog
Ball Screw

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* Please see the separate “B Product Specifications”. 

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THK A-663
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.

[Calculating the Lead Angle]

\[
\tan \beta = \frac{Ph}{\pi \cdot d_i}
\]

\( \beta \) : Lead angle \(^{\circ}\)

\( d_i \) : Ball center-to-center diameter (mm)

\( Ph \) : Feed screw lead (mm)
Features and Types
Features of the Ball Screw

[Relationship between Thrust and Torque]
The torque or the thrust generated when thrust or torque is applied is obtained from equations (2) to (4).

● **Driving Torque Required to Gain Thrust**

\[
T = \frac{F_a \cdot \varphi}{2\pi \cdot \eta_1} \quad \cdots (2)
\]

- \(T\): Driving torque (N-mm)
- \(F_a\): Frictional resistance on the guide surface (N)
- \(\varphi\): Frictional coefficient of the guide surface
- \(\eta_1\): Positive efficiency of feed screw

(see Fig.1 on A-664)

● **Thrust Generated When Torque is Applied**

\[
F_a = \frac{2\pi \cdot \eta_1 \cdot T}{\varphi} \quad \cdots (3)
\]

- \(F_a\): Thrust generated (N)
- \(T\): Driving torque (N-mm)
- \(\varphi\): Feed screw lead (mm)
- \(\eta_1\): Positive efficiency of feed screw

(see Fig.1 on A-664)

● **Torque Generated When Thrust is Applied**

\[
T = \frac{\varphi \cdot \eta_2 \cdot F_a}{2\pi} \quad \cdots (4)
\]

- \(T\): Torque generated (N-m)
- \(F_a\): Thrust generated (N)
- \(\eta_2\): Reverse efficiency of feed screw

(see Fig.2 on A-664)
### 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 (µ = 0.003)**

<table>
<thead>
<tr>
<th>Ball Screw (from µ = 0.003, η = 0.96)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frictional resistance on the guide surface</td>
</tr>
<tr>
<td>Fa = 0.003 × 500 × 9.8 = 14.7 N</td>
</tr>
<tr>
<td>Driving torque</td>
</tr>
<tr>
<td>T = ( \frac{14.7 \times 10}{2\pi \times 0.96} ) = 24 N × mm</td>
</tr>
</tbody>
</table>

**Rolling guide (µ = 0.003)**

<table>
<thead>
<tr>
<th>Ball Screw (from µ = 0.2, η = 0.32)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frictional resistance on the guide surface</td>
</tr>
<tr>
<td>Fa = 0.003 × 500 × 9.8 = 14.7 N</td>
</tr>
<tr>
<td>Driving torque</td>
</tr>
<tr>
<td>T = ( \frac{14.7 \times 10}{2\pi \times 0.32} ) = 73 N × mm</td>
</tr>
</tbody>
</table>
Features and Types
Features of the Ball Screw

Ensuring High Accuracy

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

![Automatic lead-measuring machine using laser](image)

**Table 1: Lead Accuracy Measurement**

<table>
<thead>
<tr>
<th>Item</th>
<th>Standard Value</th>
<th>Actual Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directional target point</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>Representative travel distance error</td>
<td>±0.011</td>
<td>–0.0012</td>
</tr>
<tr>
<td>Fluctuation</td>
<td>0.008</td>
<td>0.0017</td>
</tr>
</tbody>
</table>

[Conditions]
Model No.: BIF3205-10RRG0+903LC2

![Fig. 3: Lead Accuracy Measurement](image)
Capable of Micro Feeding

The Ball Screw requires a minimal starting torque due to its rolling motion, and does not cause a slip, which is inevitable with a sliding motion. Therefore, it is capable of an accurate micro feeding.

Fig. 4 shows a travel distance of the Ball Screw in one-pulse, 0.1-µm feeding. (LM Guide is used for the guide surface.)

![Figure 4: Data on Travel in 0.1-µm Feeding](image-url)
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.
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]

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
<td>Large Lead Rolled Ball Screw WTF3060 (Shaft diameter: 30mm; lead: 60mm)</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>2m/s (Ball Screw rotational speed: 2,000 min⁻¹)</td>
</tr>
</tbody>
</table>

Fig.7 Velocity diagram
[Example of Heat Generation]

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

[Conditions]

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
<td>Double-nut precision Ball Screw BFN4010-5 (Shaft diameter: 40 mm, lead: 10 mm, applied preload: 2,700 N)</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>0.217m/s (13m/min) (Ball Screw rotational speed: 1300 min⁻¹)</td>
</tr>
<tr>
<td>Low speed</td>
<td>0.0042m/s (0.25m/min) (Ball Screw rotational speed: 25 min⁻¹)</td>
</tr>
<tr>
<td>Guide surface</td>
<td>LM Guide model HSR35CA</td>
</tr>
<tr>
<td>Lubricant</td>
<td>Lithium-based grease (No. 2)</td>
</tr>
</tbody>
</table>

![Fig. 8 Operating Pattern](image1)

![Fig. 9 Ball Screw Heat Generation Data](image2)
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

Full-Ball
- Preload
  - Model BIF
    - No Preload
    - Standard Nut
  - Model DIK
    - Slim Nut
  - Model BNFN
    - Slim Nut
  - Model BLW
    - Large Lead
- No Preload
  - Model BNF
    - Standard Nut
  - Model BNT
    - Square Nut
  - Model DK
    - Slim Nut
  - Model MDK
    - Slim Nut
  - Model BLK
    - Large Lead
  - Model WGF
    - Super Lead

Precision Rotary
- Preload
  - Model DIR
    - Rotary Nut
  - Model BLR
    - Large Lead Rotary Nut
- No Preload

Standard-Stock
- Preload
  - Model BIF
    - No Preload
    - Standard Nut
  - Model MDK
    - No Preload
    - Standard Nut
  - Model MBF
    - No Preload
    - Standard Nut
  - Model BNF
    - No Preload
    - Standard Nut
- No Preload
  - Model NS
    - Standard Nut

Precision Ball Screw/Spline
- No Preload
  - Model BNS
    - Standard Nut
  - Model NS
    - Standard Nut
Features and Types
Types of Ball Screws

Ball Screw

- Miniature
  - Model MTF

- Square Nut
  - Model BNT

- Large Lead
  - Model BLK
  - Model WTF
  - Model CNF

- Super Lead
  - Model CNF

- No Preload
  - Model BTK
  - Model JPF

- Standard Nut
  - Model BNT
  - Model MTF

- Preload
  - Model JPF

- Full-Ball
  - Model BLK
  - Model WTF
  - Model CNF

- Rolled
  - Model BLR

- Rotary Nut
  - Model BF

Ball Screw Peripherals

- Support Unit
  - Model MC

- Lock Nut
  - Model RN

- Nut Bracket
  - Model EK

- Fixed Side
  - Model EF

- Supported Side
  - Model BK
  - Model BF
  - Model FF
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.

**Flowchart for Selecting a Ball Screw**

1. **Selecting conditions**
   - Lead angle accuracy

2. **Selecting Ball Screw accuracy**
   - Axial clearance of Precision Ball Screw
   - Axial clearance of Rolled Ball Screw

3. **Selecting axial clearance**

4. **Estimating the shaft length**

5. **Selecting lead**

6. **Selecting a shaft diameter**

7. **Selecting a method for mounting the screw shaft**

8. **Studying the permissible load**

9. **Selecting the permissible rotational speed**

10. **Selecting a model number (type of nut)**

11. **Calculating the permissible axial load**
Point of Selection
Flowchart for Selecting a Ball Screw

Studying the service life
- Calculating the friction torque from an external load
- Calculating the torque from the preload on the Ball Screw
- Calculating the torque required for acceleration
Selection Completed

Studying the rigidity
- Calculating the axial rigidity of the screw shaft
- Calculating the rigidity of the nut
- Calculating the rigidity of the support bearing

Studying the positioning accuracy
- Calculating the rotational torque

Studying the driving motor
- Safety design
- Studying the lubrication and contamination protection
## 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)
- **Stroke length** \( l_s \) (mm)
- **Operating speed** \( V_{\text{max}} \) (m/s)
- **Acceleration time** \( t_1 \) (s)
- **Even speed time** \( t_2 \) (s)
- **Deceleration time** \( t_3 \) (s)
- **Acceleration** \( \alpha = \frac{V_{\text{max}}}{t_1} \) (m/s\(^2\))
- **Acceleration distance** \( l_1 = V_{\text{max}} \times t_1 \times \frac{1000}{2} \) (mm)
- **Even speed distance** \( l_2 = V_{\text{max}} \times t_2 \times 1000 \) (mm)
- **Deceleration distance** \( l_3 = V_{\text{max}} \times t_3 \times \frac{1000}{2} \) (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** \( N_{\text{RPM}} \) (min\(^{-1}\))
- **Inertial moment of the motor** \( J_0 \) (kg \( \cdot \) m\(^2\))
- **Motor resolution** (pulse/rev)
- **Reduction ratio** \( A \) (-)

---

```
<table>
<thead>
<tr>
<th>Conditions</th>
<th>Unit</th>
</tr>
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<tbody>
<tr>
<td>Transfer orientation</td>
<td></td>
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<tr>
<td>Transferred mass</td>
<td>kg</td>
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<tr>
<td>Table guide method</td>
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<tr>
<td>Frictional coefficient of the</td>
<td></td>
</tr>
<tr>
<td>Guide surface resistance</td>
<td>N</td>
</tr>
<tr>
<td>External load in the axial</td>
<td>N</td>
</tr>
<tr>
<td>Service life time</td>
<td>h</td>
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<tr>
<td>Stroke length</td>
<td>mm</td>
</tr>
<tr>
<td>Operating speed</td>
<td>m/s</td>
</tr>
<tr>
<td>Acceleration time</td>
<td>s</td>
</tr>
<tr>
<td>Even speed time</td>
<td>s</td>
</tr>
<tr>
<td>Deceleration time</td>
<td>s</td>
</tr>
<tr>
<td>Acceleration</td>
<td>m/s²</td>
</tr>
<tr>
<td>Acceleration distance</td>
<td>mm</td>
</tr>
<tr>
<td>Even speed distance</td>
<td>mm</td>
</tr>
<tr>
<td>Deceleration distance</td>
<td>mm</td>
</tr>
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<td>Number of reciprocations per</td>
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<td>minute</td>
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<td>Positioning accuracy</td>
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<td>Backlash</td>
<td>mm</td>
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<td>Minimum feed amount</td>
<td>mm/pulse</td>
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<td>Driving motor</td>
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<tr>
<td>Rated rotational speed of the</td>
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<tr>
<td>motor</td>
<td>RPM</td>
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<tr>
<td>Inertial moment of the motor</td>
<td>kg( \cdot )m²</td>
</tr>
<tr>
<td>Motor resolution</td>
<td>pulse/rev</td>
</tr>
<tr>
<td>Reduction ratio</td>
<td>-</td>
</tr>
</tbody>
</table>
```
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.

[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.

[Effective thread length]

[Nominal travel distance]

[Reference travel distance]

[Target value for 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 ±)]
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/2π]
A fluctuation in one revolution of the screw shaft.
### Table 1: Lead Angle Accuracy (Permissible Value)  
Unit: μm

<table>
<thead>
<tr>
<th>Accuracy grades</th>
<th>C0</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C5</th>
<th>C7</th>
<th>C8</th>
<th>C10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective thread length</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Above 125 less</td>
<td>—</td>
<td>3</td>
<td>3</td>
<td>3.5</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>100 200</td>
<td>3.5</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>10</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>200 315</td>
<td>4</td>
<td>3.5</td>
<td>6</td>
<td>5</td>
<td>8</td>
<td>7</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>315 400</td>
<td>5</td>
<td>3.5</td>
<td>7</td>
<td>5</td>
<td>9</td>
<td>7</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>400 500</td>
<td>6</td>
<td>4</td>
<td>8</td>
<td>5</td>
<td>10</td>
<td>7</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>500 630</td>
<td>6</td>
<td>4</td>
<td>9</td>
<td>6</td>
<td>11</td>
<td>8</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>630 800</td>
<td>7</td>
<td>5</td>
<td>10</td>
<td>7</td>
<td>13</td>
<td>9</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td>800 1000</td>
<td>8</td>
<td>6</td>
<td>11</td>
<td>8</td>
<td>15</td>
<td>10</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>1000 1250</td>
<td>9</td>
<td>6</td>
<td>13</td>
<td>9</td>
<td>18</td>
<td>11</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>1250 1600</td>
<td>11</td>
<td>7</td>
<td>15</td>
<td>10</td>
<td>21</td>
<td>13</td>
<td>29</td>
<td>18</td>
</tr>
<tr>
<td>1600 2000</td>
<td>—</td>
<td>—</td>
<td>18</td>
<td>11</td>
<td>25</td>
<td>15</td>
<td>35</td>
<td>21</td>
</tr>
<tr>
<td>2000 2500</td>
<td>—</td>
<td>—</td>
<td>22</td>
<td>13</td>
<td>30</td>
<td>18</td>
<td>41</td>
<td>24</td>
</tr>
<tr>
<td>2500 3150</td>
<td>—</td>
<td>—</td>
<td>26</td>
<td>15</td>
<td>36</td>
<td>21</td>
<td>50</td>
<td>29</td>
</tr>
<tr>
<td>3150 4000</td>
<td>—</td>
<td>—</td>
<td>30</td>
<td>18</td>
<td>44</td>
<td>25</td>
<td>60</td>
<td>35</td>
</tr>
<tr>
<td>4000 5000</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>52</td>
<td>30</td>
<td>72</td>
<td>41</td>
</tr>
<tr>
<td>5000 6300</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>65</td>
<td>36</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>6300 8000</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>110</td>
<td>60</td>
</tr>
<tr>
<td>8000 10000</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Note: Unit of effective thread length: mm

### Table 2: Fluctuation in Thread Length of 300 mm and in One Revolution (permissible value)  
Unit: μm

<table>
<thead>
<tr>
<th>Accuracy grades</th>
<th>C0</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C5</th>
<th>C7</th>
<th>C8</th>
<th>C10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluctuation/300</td>
<td>3.5</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>18</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Fluctuation/2π</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

### Table 3: Types and Grades

<table>
<thead>
<tr>
<th>Type</th>
<th>Series symbol</th>
<th>Grade</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>For positioning</td>
<td>Cp</td>
<td>1, 3, 5</td>
<td>ISO compliant</td>
</tr>
<tr>
<td>For conveyance</td>
<td>Ct</td>
<td>1, 3, 5, 7, 10</td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Command position (A)</th>
<th>0</th>
<th>50</th>
<th>100</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel distance (B)</td>
<td>0</td>
<td>49.998</td>
<td>100.001</td>
<td>149.996</td>
</tr>
<tr>
<td>Travel distance error (A-B)</td>
<td>0</td>
<td>$-0.002$</td>
<td>$0.001$</td>
<td>$-0.004$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Command position (A)</th>
<th>200</th>
<th>250</th>
<th>300</th>
<th>350</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel distance (B)</td>
<td>199.995</td>
<td>249.993</td>
<td>299.989</td>
<td>349.885</td>
</tr>
<tr>
<td>Travel distance error (A-B)</td>
<td>$-0.005$</td>
<td>$-0.007$</td>
<td>$-0.011$</td>
<td>$-0.015$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Command position (A)</th>
<th>400</th>
<th>450</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel distance (B)</td>
<td>399.983</td>
<td>449.981</td>
<td>499.984</td>
</tr>
<tr>
<td>Travel distance error (A-B)</td>
<td>$-0.017$</td>
<td>$-0.019$</td>
<td>$-0.016$</td>
</tr>
</tbody>
</table>

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.

![Measurement Data on Travel Distance Error](image)

[Measurements]
Representative travel distance error: $-7 \mu m$
Fluctuation: $8.8 \mu m$
Accuracy of the Mounting Surface

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

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

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

[Accuracy Standards for the Mounting Surface]
Table 5 to Table 9 show accuracy standards for the mounting surfaces of the precision Ball Screw.

Table 5: Radial Runout of the Circumference of the Thread Root
in Relation to the Supporting Portion Axis of the Screw Shaft

Unit: µm

<table>
<thead>
<tr>
<th>Screw shaft outer diameter (mm)</th>
<th>Runout (maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above</td>
<td>C0</td>
</tr>
<tr>
<td>—</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>32</td>
</tr>
<tr>
<td>32</td>
<td>50</td>
</tr>
<tr>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>80</td>
<td>100</td>
</tr>
</tbody>
</table>

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

\[ E_1 = e + \Delta e \]

\[ \Delta e = \frac{L_1}{L} \times E_2 \]

\[ \frac{80}{500} \times 0.06 = 0.01 \]

\[ E_1 = 0.012 + 0.01 = 0.022 \]
### Table 6: Perpendicularity of the Supporting Portion End of the Screw Shaft to the Supporting Portion Axis

<table>
<thead>
<tr>
<th>Screw shaft outer diameter (mm)</th>
<th>Perpendicularity (maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above</td>
<td>Or less</td>
</tr>
<tr>
<td></td>
<td>C0</td>
</tr>
<tr>
<td>—</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>32</td>
</tr>
<tr>
<td>32</td>
<td>50</td>
</tr>
<tr>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>80</td>
<td>100</td>
</tr>
</tbody>
</table>

### Table 7: Perpendicularity of the Flange Mounting Surface of the Screw Shaft to the Screw Shaft Axis

<table>
<thead>
<tr>
<th>Nut diameter (mm)</th>
<th>Perpendicularity (maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above</td>
<td>Or less</td>
</tr>
<tr>
<td></td>
<td>C0</td>
</tr>
<tr>
<td>—</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>32</td>
</tr>
<tr>
<td>32</td>
<td>50</td>
</tr>
<tr>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>80</td>
<td>125</td>
</tr>
<tr>
<td>125</td>
<td>160</td>
</tr>
<tr>
<td>160</td>
<td>200</td>
</tr>
</tbody>
</table>

### Table 8: Radial Runout of the Nut Circumference in Relation to the Screw Shaft Axis

<table>
<thead>
<tr>
<th>Nut diameter (mm)</th>
<th>Runout (maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above</td>
<td>Or less</td>
</tr>
<tr>
<td></td>
<td>C0</td>
</tr>
<tr>
<td>—</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>32</td>
</tr>
<tr>
<td>32</td>
<td>50</td>
</tr>
<tr>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>80</td>
<td>125</td>
</tr>
<tr>
<td>125</td>
<td>160</td>
</tr>
<tr>
<td>160</td>
<td>200</td>
</tr>
</tbody>
</table>

### Table 9: Parallelism of the Nut Circumference (Flat Mounting Surface) to the Screw Shaft Axis

<table>
<thead>
<tr>
<th>Mounting reference length (mm)</th>
<th>Parallelism (maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above</td>
<td>Or less</td>
</tr>
<tr>
<td></td>
<td>C0</td>
</tr>
<tr>
<td>—</td>
<td>50</td>
</tr>
<tr>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>100</td>
<td>200</td>
</tr>
</tbody>
</table>

### 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 Table 5 on A-681)

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.

![Dial gauge and V blocks](image)
Point of Selection
Accuracy of the Ball Screw

• Radial Runout of the Circumference of the Thread Root in Relation to the Supporting Portion Axis of the Screw Shaft (see Table 5 on A-681)
Support the supporting portion of the screw shaft with V blocks. Place a probe on the circumference of the nut, and read the largest difference on the dial gauge as a measurement when turning the screw shaft by one revolution without turning the nut.

• Perpendicularity of the Supporting Portion End of the Screw Shaft to the Supporting Portion Axis (see Table 6 on A-682)
Support the supporting portion of the screw shaft with V blocks. Place a probe on the screw shaft's supporting portion end, and read the largest difference on the dial gauge as a measurement when turning the screw shaft by one revolution.

• Perpendicularity of the Flange Mounting Surface of the Screw Shaft to the Screw Shaft Axis (see Table 7 on A-682)
Support the thread of the screw shaft with V blocks near the nut. Place a probe on the flange end, and read the largest difference on the dial gauge as a measurement when simultaneously turning the screw shaft and the nut by one revolution.
**Radial Runout of the Nut Circumference in Relation to the Screw Shaft Axis (see Table 8 on A-682)**
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.

![Diagram of Radial Runout](image)

**Parallelism of the Nut Circumference (Flat Mounting Surface) to the Screw Shaft Axis (see Table 9 on A-682)**
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.

![Diagram of Parallelism](image)

**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.

![Diagram of Overall Radial Runout](image)

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

[Axial Clearance of the Precision Ball Screw]
Table 10 shows the axial clearance of the precision Ball Screw. If the manufacturing length exceeds the value in Table 11, the resultant clearance may partially be negative (preload applied).

Table 10 Axial Clearance of the Precision Ball Screw

<table>
<thead>
<tr>
<th>Clearance symbol</th>
<th>G0</th>
<th>GT</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial clearance</td>
<td>0 or less</td>
<td>0 to 0.005</td>
<td>0 to 0.01</td>
<td>0 to 0.02</td>
<td>0 to 0.05</td>
</tr>
</tbody>
</table>

Table 11 Maximum Length of the Precision Ball Screw in Axial Clearance

<table>
<thead>
<tr>
<th>Overall thread length</th>
<th>Clearance GT</th>
<th>Clearance G1</th>
<th>Clearance G2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C0 to C3</td>
<td>C5</td>
<td>C0 to C3</td>
</tr>
<tr>
<td>4 to 6</td>
<td>80</td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>8 to 10</td>
<td>250</td>
<td>200</td>
<td>250</td>
</tr>
<tr>
<td>12 to 16</td>
<td>500</td>
<td>400</td>
<td>500</td>
</tr>
<tr>
<td>18 to 25</td>
<td>800</td>
<td>700</td>
<td>800</td>
</tr>
<tr>
<td>28 to 32</td>
<td>900</td>
<td>800</td>
<td>1100</td>
</tr>
<tr>
<td>36 to 45</td>
<td>1000</td>
<td>800</td>
<td>1300</td>
</tr>
<tr>
<td>50 to 70</td>
<td>1200</td>
<td>1000</td>
<td>1600</td>
</tr>
<tr>
<td>80 to 100</td>
<td>—</td>
<td>—</td>
<td>1800</td>
</tr>
</tbody>
</table>

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

[Axial Clearance of the Rolled Ball Screw]
Table 12 shows axial clearance of the rolled Ball Screw.

Table 12 Axial Clearance of the Rolled Ball Screw

<table>
<thead>
<tr>
<th>Screw shaft outer diameter</th>
<th>Axial clearance (maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 to 12</td>
<td>0.05</td>
</tr>
<tr>
<td>14 to 28</td>
<td>0.1</td>
</tr>
<tr>
<td>30 to 32</td>
<td>0.14</td>
</tr>
<tr>
<td>36 to 45</td>
<td>0.17</td>
</tr>
<tr>
<td>50</td>
<td>0.2</td>
</tr>
</tbody>
</table>
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. 5 shows a double-nut type of the Ball Screw.

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

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

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

$$F_A = F_a + (F_a - F_a') \quad F_B = F_a - F_a'$$

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

This effect extends to the point where the displacement ($\delta a_0$) 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 $\delta a_0 = Fa^{\frac{2}{3}}$. From Fig. 6, the following equations are established.

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

$$2\delta a_0 = K F_a^{\frac{2}{3}}$$

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

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

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

**Actual Torque**
A dynamic preload torque measured with an actual Ball Screw.

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

**Coefficient of Torque Fluctuation**
Ratio of torque fluctuation to the reference torque.

**Reference Torque**
A dynamic preload torque set as a target.

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

\[
T_p = 0.05 (\tan \beta)^{0.5} \frac{F_{a0} \cdot Ph}{2\pi}
\]  

- \(T_p\) : Reference torque (N-mm)
- \(\beta\) : Lead angle
- \(F_{a0}\) : Applied preload (N)
- \(Ph\) : Lead (mm)
Example: When a preload of 3,000 N is provided to the Ball Screw model BNFN4010-5G0 + 1500LC3 with a thread length of 1,300 mm (shaft diameter: 40 mm; ball center-to-center diameter: 41.75 mm; lead: 10 mm), the preload torque of the Ball Screw is calculated in the steps below.

**Calculating the Reference Torque**

\[ \beta : \text{Lead angle} \]

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

\[ F_a : \text{Applied preload}=3000N \]

\[ P_h : \text{Lead}=10mm \]

\[ T_p = 0.05 \left( \tan \beta \right)^{0.5} \frac{F_a \times P_h}{2 \pi} = 0.05 \left( 0.0762 \right)^{0.5} \frac{3000 \times 10}{2 \pi} = 865N \cdot mm \]

**Calculating the Torque Fluctuation**

\[ \frac{\text{thread length}}{40} \frac{\text{screw shaft outer diameter}}{1300} \]

Thus, with the reference torque in Table13 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.

\[ 865 \times \left( 1 \pm 0.3 \right) = 606 \text{ N-mm to } 1125 \text{ N-mm} \]

**Result**

Reference torque : 865 N-mm

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

**Table13 Tolerance Range in Torque Fluctuation**

<table>
<thead>
<tr>
<th>Reference torque N·mm</th>
<th>Effective thread length</th>
<th>Above 4,000 mm or and 10,000 mm or less</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>thread length</td>
<td>thread length</td>
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<tr>
<td></td>
<td>screw shaft outer diameter</td>
<td>≤40</td>
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<tr>
<td>Accuracy grades</td>
<td>Accuracy grades</td>
<td>Accuracy grades</td>
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<tr>
<td>C0</td>
<td>C1</td>
<td>C2, C3</td>
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<tr>
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<td>400</td>
<td>±35%</td>
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<td>400</td>
<td>600</td>
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<td>600</td>
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<td>±10%</td>
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<tr>
<td>6300</td>
<td>10000</td>
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</table>
Selecting a Screw Shaft

Maximum Length of the Screw Shaft

The maximum length of the precision Ball Screw and the rolled Ball Screw are shown in Table 14 and Table 15 (A-691) respectively.

If the shaft dimensions exceed the manufacturing limit in Table 14 or Table 15, contact THK.

<table>
<thead>
<tr>
<th>Screw shaft outer diameter</th>
<th>Overall screw shaft length</th>
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<tr>
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</table>
### Point of Selection

Selecting a Screw Shaft

Table 15: Maximum Length of the Rolled Ball Screw by Accuracy Grade

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<thead>
<tr>
<th>Screw shaft outer diameter</th>
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<td>6 to 8</td>
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<td>10 to 12</td>
<td>500</td>
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<td>14 to 15</td>
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## Standard Combinations of Shaft Diameter and Lead for the Precision Ball Screw

Table 16 shows the standard combinations of shaft diameter and lead for the precision Ball Screw. If a Ball Screw not covered by the table is required, contact THK.

<table>
<thead>
<tr>
<th>Screw shaft outer diameter</th>
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</tbody>
</table>

- o: off-the-shelf products [standard-stock products equipped with the standardized screw shafts (with unfinished shaft ends/finished shaft ends)]
- O: Semi-standard stock
Table 17 shows the standard combinations of shaft diameter and lead for the rolled Ball Screw.

### Table 17: Standard Combinations of Screw Shaft Diameter and Lead (Rolled Ball Screw) Unit: mm

<table>
<thead>
<tr>
<th>Screw shaft outer diameter</th>
<th>Lead</th>
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<td></td>
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<td>45</td>
<td>●</td>
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<td>50</td>
<td>●</td>
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</tbody>
</table>

●: Standard stock
○: Semi-standard stock
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-695 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.

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

- \( P_1 \): Buckling load (N)
- \( l_a \): Distance between two mounting surfaces (mm)
- \( E \): Young’s modulus \( (2.06 \times 10^5 \text{ N/mm}^2) \)
- \( I \): Minimum geometrical moment of inertia of the shaft (mm^4)
- \( \eta_1, \eta_2 \): 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).

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

- \( P_2 \): Permissible tensile compressive load (N)
- \( \sigma \): Permissible tensile compressive stress (147 MPa)
- \( d_1 \): Screw-shaft thread minor diameter (mm)
Point of Selection
Selecting a Screw Shaft

Fig. 8 Permissible Tensile Compressive Load Diagram
Permissible Rotational Speed

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

Fig.9 on A-698 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.

\[
N_1 = \frac{60 \cdot \lambda_1^2}{2\pi \cdot \frac{d_1}{l_b^2}} \times \sqrt{\frac{E \times 10^5 \cdot I}{\gamma \cdot A}} \times 0.8 = \lambda_2 \cdot \frac{d_1}{l_b^2} \cdot 10^7 \quad \cdots (8)
\]

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

\(l_b\) : Distance between two mounting surfaces \((\text{mm})\)

\(E\) : Young’s modulus \((2.06 \times 10^5 \text{ N/mm}^2)\)

\(I\) : Minimum geometrical moment of inertia of the shaft \((\text{mm}^4)\)

\(\gamma\) : Density (specific gravity) \((7.85 \times 10^{-6} \text{ kg/mm}^3)\)

\(A\) : Screw shaft cross-sectional area \((\text{mm}^2)\)

\(\lambda_1, \lambda_2\) : Factor according to the mounting method

- Fixed - free \(\lambda_1 = 1.875 \quad \lambda_2 = 3.4\)
- Supported - supported \(\lambda_1 = 3.142 \quad \lambda_2 = 9.7\)
- Fixed - supported \(\lambda_1 = 3.927 \quad \lambda_2 = 15.1\)
- Fixed - fixed \(\lambda_1 = 4.73 \quad \lambda_2 = 21.9\)

\(d_1\): screw-shaft thread minor diameter \((\text{mm})\)

\(l_b = \frac{\pi}{64} d_1^4\)

\(A = \frac{\pi}{4} d_1^2\)
Point of Selection
Selecting a Screw Shaft

[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 (13) below.

- Ball Screw with Ball Cage
  - Models SBN and HBN
    \[ N_2 = \frac{130000}{D} \] (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
  \[ N_2 = \frac{160000}{D} \] (10)

- Precision Ball Screw
  \[ N_2 = \frac{70000}{D} \] (11)

- Rolled Ball Screw
  (excluding large lead type)
  \[ N_2 = \frac{50000}{D} \] (12)

- Large-Lead Rolled Ball Screw
  \[ N_2 = \frac{70000}{D} \] (13)

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 \( N_1 \), a high-speed type Ball Screw is available. Contact THK for details.
Fig. 9 Permissible Rotational Speed Diagram
Selecting a Nut

Types of Nuts

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

In addition to the circulation methods, the Ball Screws are categorized also by the preloading method.

[Types by Ball Circulation Method]

- **Return-pipe Type**
  (Models SBN, BNF, BNT, BNFN, BIF and BTK)
  Return-piece Type (Model HBN)
  These are most common types of nuts that use a return pipe for ball circulation. The return pipe allows balls to be picked up, pass through the pipe, and return to their original positions to complete infinite motion.

- **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.

- **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.
Types by Preloading Method

• Fixed-point Preloading

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

Model BNFN  Model DKN  Model BLW

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

Model SBN  Model BIF  Model DIK

Model SBK  Model DIR
● Constant Pressure Preloading (Model JPF)
With this method, a spring structure is installed almost in the middle of the nut, and it provides a pre-load by changing the groove pitch in the middle of the nut.
Selecting a Model Number

Calculating the Axial Load

[In Horizontal Mount]

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

\[
\begin{align*}
F_{a1} &= \mu \cdot mg + f + m\alpha \quad \text{(14)} \\
F_{a2} &= \mu \cdot mg + f \quad \text{(15)} \\
F_{a3} &= \mu \cdot mg + f - m\alpha \quad \text{(16)} \\
F_{a4} &= -\mu \cdot mg - f - m\alpha \quad \text{(17)} \\
F_{a5} &= -\mu \cdot mg - f \quad \text{(18)} \\
F_{a6} &= -\mu \cdot mg - f + m\alpha \quad \text{(19)}
\end{align*}
\]

- \(V_{max}\): Maximum speed (m/s)
- \(t\): Acceleration time (m/s)
- \(\alpha\): Acceleration (m/s²)

\[
\begin{align*}
\alpha &= \frac{V_{max}}{t}
\end{align*}
\]

\(F_{ah}\) : Axial load during forward acceleration (N)
\(F_{ai}\) : Axial load during forward uniform motion (N)
\(F_{ad}\) : Axial load during forward deceleration (N)
\(F_{ab}\) : Axial load during backward acceleration (N)
\(F_{ak}\) : Axial load during uniform backward motion (N)

\(m\) : Transferred mass (kg)
\(\mu\) : Frictional coefficient of the guide surface (–)
\(f\) : Guide surface resistance (without load) (N)
\(g\) : Gravitational acceleration (m/s²)

[In Vertical Mount]

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

\[
\begin{align*}
F_{a1} &= mg + f + m\alpha \quad \text{(20)} \\
F_{a2} &= mg + f \quad \text{(21)} \\
F_{a3} &= mg + f - m\alpha \quad \text{(22)} \\
F_{a4} &= mg - f - m\alpha \quad \text{(23)} \\
F_{a5} &= mg - f \quad \text{(24)} \\
F_{a6} &= mg - f + m\alpha \quad \text{(25)}
\end{align*}
\]

- \(V_{max}\): Maximum speed (m/s)
- \(t\): Acceleration time (m/s)

\[
\begin{align*}
\alpha &= \frac{V_{max}}{t}
\end{align*}
\]

\(F_{ah}\) : Axial load during upward acceleration (N)
\(F_{ai}\) : Axial load during uniform upward motion (N)
\(F_{ad}\) : Axial load during upward deceleration (N)
\(F_{ab}\) : Axial load during downward acceleration (N)
\(F_{ak}\) : Axial load during uniform downward motion (N)

\(m\) : Transferred mass (kg)
\(\mu\) : Frictional coefficient of the guide surface (–)
\(f\) : Guide surface resistance (without load) (N)
The basic static load rating (C₀a) generally equals to the permissible axial load of a Ball Screw. Depending on the conditions, it is necessary to take into account the following static safety factor against the calculated load. When the Ball Screw is stationary or in motion, unexpected external force may be applied through an inertia caused by the impact or the start and stop.

\[ F_{a,\max} = \frac{C₀a}{f_s} \quad \text{(26)} \]

- \( F_{a,\max} \): Permissible Axial Load (kN)
- \( C₀a \): Basic static load rating* (kN)
- \( f_s \): Static safety factor (see Table18)

### Table18 Static Safety Factor (f_s)

<table>
<thead>
<tr>
<th>Machine using the LM system</th>
<th>Load conditions</th>
<th>Lower limit of ( f_s )</th>
</tr>
</thead>
<tbody>
<tr>
<td>General industrial machinery</td>
<td>Without vibration or impact</td>
<td>1 to 1.3</td>
</tr>
<tr>
<td></td>
<td>With vibration or impact</td>
<td>2 to 3</td>
</tr>
<tr>
<td>Machine tool</td>
<td>Without vibration or impact</td>
<td>1 to 1.5</td>
</tr>
<tr>
<td></td>
<td>With vibration or impact</td>
<td>2.5 to 7</td>
</tr>
</tbody>
</table>

The basic static load rating (C₀a) is a static load with a constant direction and magnitude whereby the sum of the permanent deformation of the rolling element and that of the raceway on the contact area under the maximum stress is 0.0001 times the rolling element diameter. With the Ball Screw, it is defined as the axial load. (Specific values of each Ball Screw model are indicated in the specification tables for the corresponding model number.)
Studying the Service Life

[Service Life of the Ball Screw]
The Ball Screw in motion under an external load receives the continuous stress on its raceways and balls. When the stress reaches the limit, the raceways break from the fatigue and their surfaces partially disintegrate in scale-like pieces. This phenomenon is called flaking. The service life of the Ball Screw is the total number of revolutions until the first flaking occurs on any of the raceways or the balls as a result of the rolling fatigue of the material.
The service life of the Ball Screw varies from unit to unit even if they are manufactured in the same process and used in the same operating conditions. For this reason, when determining the service life of a Ball Screw unit, the nominal life as defined below is used as a guideline.
The nominal life is the total number of revolutions that 90% of identical Ball Screw units in a group achieve without developing flaking (scale-like pieces of a metal surface) after they independently operate in the same conditions.

[Calculating the Rated Life]
The service life of the Ball Screw is calculated from the equation (27) below using the basic dynamic load rating (Ca) and the applied axial load.

\[ L = \left( \frac{C_a}{f_w \times F_a} \right)^3 \times 10^6 \]  \hspace{1cm} (27)

- \( L \): Nominal life (total number of revolutions)
- \( Ca \): Basic dynamic load rating (N)
- \( Fa \): Applied axial load (N)
- \( f_w \): Load factor (see Table19)

* 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 10^6rev. 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.)

### Table19 Load Factor (f_w)

<table>
<thead>
<tr>
<th>Vibration/impact</th>
<th>Speed(V)</th>
<th>f_w</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faint</td>
<td>Very low V&lt;0.25m/s</td>
<td>1 to 1.2</td>
</tr>
<tr>
<td>Weak</td>
<td>Slow 0.25&lt;V&lt;1m/s</td>
<td>1.2 to 1.5</td>
</tr>
<tr>
<td>Medium</td>
<td>Medium V&lt;2m/s</td>
<td>1.5 to 2</td>
</tr>
<tr>
<td>Strong</td>
<td>High V&gt;2m/s</td>
<td>2 to 3.5</td>
</tr>
</tbody>
</table>
Point of Selection
Selecting a Model Number

● 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).

\[
L_s = \frac{L}{60 \times N} = \frac{L \times Ph}{2 \times 60 \times n \times l_s} \quad \text{(28)}
\]


- \(L_s\) : Service life time (h)
- \(N\) : Revolutions per minute (min⁻¹)
- \(n\) : Number of reciprocations per minute (min⁻¹)
- \(Ph\) : Ball Screw lead (mm)
- \(l_s\) : Stroke length (mm)

● Service Life in Travel Distance
The service life in travel distance can be calculated from the equation (29) below using the nominal life (L) and the Ball Screw lead.

\[
L_s = \frac{L \times Ph}{10^5} \quad \text{(29)}
\]


- \(L_s\) : 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.

\[
F_m = \sqrt{\frac{1}{l} (Fa_1 \times l_1 + Fa_2 \times l_2 + \cdots + Fa_n \times l_n)} \quad \text{(30)}
\]


- \(F_m\) : Average Axial Load (N)
- \(Fa_i\) : Varying load (N)
- \(l_i\) : Distance traveled under load (F_i)
- \(l\) : Total travel distance
To determine the average axial load using a rotational speed and time, instead of a distance, calculate the average axial load by determining the distance in the equation below.

\[ l = l_1 + l_2 + \cdots + l_n \]

\[ l_i = N_i \cdot t_i \]

\[ N_i \text{: Rotational speed} \]

\[ t_i \text{: Time} \]

**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 into 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.

<table>
<thead>
<tr>
<th>Operation No.</th>
<th>Varying load Fa(N)</th>
<th>Travel distance ( l_i )(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.1</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>No.2</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>No.3</td>
<td>-40</td>
<td>10</td>
</tr>
<tr>
<td>No.4</td>
<td>-10</td>
<td>70</td>
</tr>
</tbody>
</table>

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 \( Fa_1 \) and \( Fa_3 \) to be zero.

\[ F_{m1} = \sqrt{\frac{Fa_1^2 \cdot l_1 + Fa_2^2 \cdot l_2}{l_1 + l_2 + l_3 + l_4}} = 35.5N \]

- **Average axial load of negative-sign load**

To calculate the average axial load of the negative-sign load, assume \( Fa_1 \) and \( Fa_3 \) to be zero.

\[ F_{m2} = \sqrt{\frac{|Fa_1| \cdot l_1 + |Fa_2| \cdot l_2}{l_1 + l_2 + l_3 + l_4}} = 17.2N \]

Accordingly, the average axial load of the positive-sign load \( (F_{m1}) \) is adopted as the average axial load \( (F_{m}) \) for calculating the service life.
Studying the Rigidity

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

Axial Rigidity of the Feed Screw System

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

\[
\delta = \frac{F_a}{K} \quad \cdots \cdots \quad (31)
\]

\( \delta \) : Elastic displacement of a feed screw system in the axial direction \((\mu\text{m})\)

\( F_a \) : Applied axial load \( (N) \)

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

\[
\frac{1}{K} = \frac{1}{K_S} + \frac{1}{K_n} + \frac{1}{K_B} + \frac{1}{K_H} \quad \cdots \cdots \quad (32)
\]

\( K \) : Axial Rigidity of the Feed Screw System \( (N/\mu\text{m}) \)

\( K_s \) : Axial rigidity of the screw shaft \( (N/\mu\text{m}) \)

\( K_n \) : Axial rigidity of the nut \( (N/\mu\text{m}) \)

\( K_B \) : Axial rigidity of the support bearing \( (N/\mu\text{m}) \)

\( K_H \) : Rigidity of the nut bracket and the support bearing bracket \( (N/\mu\text{m}) \)

[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

\[
K_s = \frac{A \cdot E}{1000 \cdot L} \quad \cdots \cdots \quad (33)
\]

\( A \) : Screw shaft cross-sectional area \( (\text{mm}^2) \)

\[
A = \frac{\pi}{4} \cdot d_1^2
\]

\( d_1 \) : Screw-shaft thread minor diameter \( (\text{mm}) \)

\( E \) : Young’s modulus \( (2.06 \times 10^5 \text{ N/mm}^2) \)

\( L \) : Distance between two mounting surfaces \( (\text{mm}) \)

Fig.10 on A-708 shows an axial rigidity diagram for the screw shaft.
For Fixed-Fixed Configuration

\[
K_s = \frac{A \cdot E \cdot L}{1000 \cdot a \cdot b}
\]  \hspace{1cm} (34)

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

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

Fig. 11 on A-709 shows an axial rigidity diagram of the screw shaft in this configuration.

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

\[
K_N = K \left( \frac{Fa}{0.3Ca} \right)^{0.5} \times 0.8 \quad \text{(35)}
\]

- $K_N$ : Axial rigidity of the nut (N/μm)  
- $K$ : Rigidity value in the specification tables (N/μm)  
- $Fa$ : Applied axial load (N)  
- $Ca$ : Basic dynamic load rating (N)
**Preload Type**

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

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

\[
K_n = K \left( \frac{F_{a_0}}{0.1Ca} \right)^{\frac{1}{3}} \times 0.8 \quad \ldots \ldots \quad (36)
\]

- \(K_n\) : Axial rigidity of the nut \((N/\mu m)\)
- \(K\) : Rigidity value in the specification tables \((N/\mu m)\)
- \(F_{a_0}\) : 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.

\[
K_B = \frac{3F_{a_0}}{\delta_{a_0}} \quad \ldots \ldots \quad (37)
\]

- \(K_B\) : Axial rigidity of the support bearing \((N/\mu m)\)
- \(F_{a_0}\) : Applied preload of the support bearing \((N)\)
- \(\delta_{a_0}\) : Axial displacements \((\mu m)\)

\[
\delta_{a_0} = \frac{0.45 \left( Q \right)^{\frac{1}{3}}}{Da} \quad \sin \alpha
\]

- \(Q\) : Axial load \((N)\)
- \(Da\) : Ball diameter of the support bearing \((mm)\)
- \(\alpha\) : Initial contact angle of the support bearing \((^\circ)\)
- \(Z\) : 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.
Point of Selection
Studying the Positioning Accuracy

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-678). Table20 on A-712 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 Table12 on A-885.
<table>
<thead>
<tr>
<th>Applications</th>
<th>Shaft</th>
<th>Accuracy grades</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C0</td>
</tr>
<tr>
<td>Lathe</td>
<td>X</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>●</td>
</tr>
<tr>
<td>Machining center</td>
<td>XY</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>●</td>
</tr>
<tr>
<td>Drilling machine</td>
<td>XY</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>●</td>
</tr>
<tr>
<td>Jig borer</td>
<td>XY</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>●</td>
</tr>
<tr>
<td>Surface grinder</td>
<td>X</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>●</td>
</tr>
<tr>
<td>Cylindrical grinder</td>
<td>X</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>●</td>
</tr>
<tr>
<td>Electric discharge machine</td>
<td>XY</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>●</td>
</tr>
<tr>
<td>Electric discharge machine</td>
<td>XY</td>
<td>●</td>
</tr>
<tr>
<td>Wire cutting machine</td>
<td>XY</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>●</td>
</tr>
<tr>
<td>Punching press</td>
<td>XY</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>●</td>
</tr>
<tr>
<td>Laser beam machine</td>
<td>XY</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>●</td>
</tr>
<tr>
<td>Woodworking machine</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>General-purpose machine; dedicated machine</td>
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<td>●</td>
</tr>
<tr>
<td>Industrial robot</td>
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<td>●</td>
</tr>
<tr>
<td>Cartesian coordinate</td>
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<tr>
<td>Vertical articulated type</td>
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<td>Cylindrical coordinate</td>
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<td>Photolithography machine</td>
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<td>Chemical treatment machine</td>
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<tr>
<td>Wire bonding machine</td>
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<tr>
<td>Prober</td>
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<td>●</td>
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<tr>
<td>Printed circuit board drilling machine</td>
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<td>●</td>
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<tr>
<td>Electronic component inserter</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>3D measuring instrument</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Image processing machine</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Injection molding machine</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Office equipment</td>
<td></td>
<td>●</td>
</tr>
</tbody>
</table>
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-707 to A-710).

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

[Conditions]
- Transferred weight: 1,000 N; table weight: 500 N
- Ball Screw used: model BNF2512-2.5 (screw-shaft thread minor diameter $d_1 = 21.9$ mm)
- Stroke length: 600 mm ($L=100$ mm to 700 mm)
- Screw shaft mounting type: fixed-supported

[Consideration]
The difference in axial rigidity between $L = 100$ mm and $L = 700$ mm applied only to the axial rigidity of the screw shaft.
Therefore, positioning error due to the axial rigidity of the feed screw system equals to the difference in the axial displacement of the screw shaft between $L = 100$ mm and $L = 700$ mm.
Axial Rigidity of the Screw Shaft (see A-707 and A-708)

\[ K_s = \frac{A \cdot E}{1000L} = \frac{376.5 \times 2.06 \times 10^5}{1000 \times L} = 77.6 \times 10^3 \frac{N}{mm^2} \]

\[ A = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times 21.9^2 = 376.5 mm^2 \]

\[ E = 2.06 \times 10^5 N/mm^2 \]

1. When \( L = 100 \) mm

\[ K_{s1} = \frac{77.6 \times 10^3}{100} = 776 \frac{N}{\mu m} \]

2. When \( L = 700 \) mm

\[ K_{s2} = \frac{77.6 \times 10^3}{700} = 111 \frac{N}{\mu m} \]

Axial Displacement due to Axial Rigidity of the Screw Shaft

1. When \( L = 100 \) mm

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

2. When \( L = 700 \) mm

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

Positioning Error due to Axial Rigidity of the Feed Screw System

Positioning accuracy \( = \delta_1 - 1.9 - 13.5 \)

\(-11.6 \mu m \)

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.

\[
\Delta l = \rho \times \Delta t \times l \quad \text{……(38)}
\]

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

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

[Measures to Cope with the Temperature Rise]

- **Minimize the Heat Generation**
- Minimize the preloads on the Ball Screw and the support bearing.
- Increase the Ball Screw lead and reduce the rotational speed.
- Select a correct lubricant. (See Accessories for Lubrication on A-954.)
- Cool the circumference of the screw shaft with a lubricant or air.

- **Avoid Effect of Temperature Rise through Heat Generation**
- Set a negative target value for the reference travel distance of the Ball Screw. Generally, set a negative target value for the reference travel distance assuming a temperature increase of 2°C to 5°C by heat. \((-0.02\text{mm} \text{ to } -0.06 \text{ mm/m})\)
- Preload the shaft screw with tension. (See Fig.3 of the structure on A-825.)
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.

\[ A = l \times \sin \theta \] .......(39)

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

\[ T_1 = \frac{F_a \cdot \Phi_h}{2\pi \cdot \eta} \cdot A \quad \cdots \cdots (43) \]

- \( T_1 \): Frictional torque due to an external load (N-mm)
- \( F_a \): Applied axial load (N)
- \( \Phi_h \): Ball Screw lead (mm)
- \( \eta \): Ball Screw efficiency (0.9 to 0.95)
- \( A \): Reduction ratio
Torque Due to a Preload on the Ball Screw

For a preload on the Ball Screw, see "Preload Torque" on A-688.

\[ T_2 = T_\Delta \cdot A \]  \hspace{1cm} (44)

- \( T_\Delta \): Preload torque of the Ball Screw (N-mm)
- \( T_\Delta \): Preload torque of the Ball Screw (N-mm)
- \( A \): Reduction ratio

Torque Required for Acceleration

\[ T_3 = J \times \omega' \times 10^7 \]  \hspace{1cm} (45)

- \( T_3 \): Torque required for acceleration (N-mm)
- \( J \): Inertial moment (kg\( \cdot \)m\(^2\))
- \( \omega' \): Angular acceleration (rad/s\(^2\))

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

- \( m \): Transferred mass (kg)
- \( Ph \): Ball Screw lead (mm)
- \( J_s \): Inertial moment of the screw shaft (kg\( \cdot \)m\(^2\)) (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\( \cdot \)m\(^2\))
- \( J_B \): Inertial moment of gears, etc. attached to the motor side (kg\( \cdot \)m\(^2\))

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

- \( Nm \): Motor revolutions per minute (min\(^{-1}\))
- \( t \): Acceleration time (s)

[Ref.] Inertial moment of a round object

\[ J = \frac{m \cdot D^2}{6} \cdot 10^6 \]

- \( J \): Inertial moment (kg\( \cdot \)m\(^2\))
- \( m \): 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.

\[
N_m = \frac{V \times 1000 \times 60}{Ph} \times \frac{1}{A} \quad \ldots (46)
\]

- \( N_m \): Required rotational speed of the motor (min\(^{-1}\))
- \( V \): Feeding speed (m/s)
- \( Ph \): Ball Screw lead (mm)
- \( A \): Reduction ratio

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

\( N_m \leq N_r \)

\( N_r \): The rated rotational speed of the motor (min\(^{-1}\))

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

\[
B = \frac{Ph \times A}{S} \quad \ldots (47)
\]

- \( B \): Resolution required for the encoder and the driver (p/rev)
- \( Ph \): Ball Screw lead (mm)
- \( A \): Reduction ratio
- \( S \): Minimum feed amount (mm)
[Motor Torque]
The torque required for the motor differs between uniform motion, acceleration and deceleration. To calculate the rotational torque, see "Studying the Rotational Torque" on A-717.

a. Maximum torque
The maximum torque required for the motor must be equal to or below the maximum peak torque of the motor.
\[ T_{\text{max}} \leq T_{\text{p,max}} \]
\( T_{\text{max}} \): Maximum torque acting on the motor
\( T_{\text{p,max}} \): Maximum peak torque of the motor

b. Effective torque value
The effective value of the torque required for the motor must be calculated. The effective value of the torque is obtained using the equation (48) below.
\[ T_{\text{rms}} = \sqrt{\frac{T_1^2 \times t_1 + T_2^2 \times t_2 + T_3^2 \times t_3}{t}} \quad \cdots \cdots (48) \]
\( T_{\text{rms}} \): Effective torque value \ (N-mm)
\( T_i \): Fluctuating torque \ (N-mm)
\( t_i \): Time during which the torque \( T_i \) 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.
\[ T_{\text{rms}} \leq T_R \]
\( T_R \): Rated torque of the motor \ (N-mm)

[Inertial Moment]
The inertial moment required for the motor is obtained using the equation (49) below.
\[ J_M = \frac{J}{C} \quad \cdots \cdots (49) \]
\( J_M \): Inertial moment required for the motor \ (kg\cdot m^2)
\( J \): Factor determined by the motor and the driver
(\( J \) 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.

\[ E = \frac{360S}{\text{Ph} \cdot A} \]  

\[ E \] : Step angle required for the motor and the driver (°)  
\[ S \] : Minimum feed amount (mm)  
\[ \text{Ph} \] : 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.

\[ f = \frac{V \times 1000}{S} \]  

\[ f \] : 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-717.

Thus, the pulse speed required for the motor and the required torque can be calculated in the manner described above. Although the torque varies depending on the motors, normally the calculated torque should be doubled to ensure safety. Check if the torque can be used in the motor's speed-torque curve.
Examples of Selecting a Ball Screw

High-speed Transfer Equipment (Horizontal Use)

[Selection Conditions]

<table>
<thead>
<tr>
<th>Selection Conditions</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table Mass ( m_1 )</td>
<td>60 kg</td>
</tr>
<tr>
<td>Work Mass ( m_2 )</td>
<td>20 kg</td>
</tr>
<tr>
<td>Stroke length ( l_s )</td>
<td>1000 mm</td>
</tr>
<tr>
<td>Maximum speed ( V_{\text{max}} )</td>
<td>1 m/s</td>
</tr>
<tr>
<td>Acceleration time ( t_1 )</td>
<td>0.15 s</td>
</tr>
<tr>
<td>Deceleration time ( t_2 )</td>
<td>0.15 s</td>
</tr>
<tr>
<td>Number of reciprocations per minute ( n )</td>
<td>8 min(^{-1})</td>
</tr>
<tr>
<td>Backlash</td>
<td>0.15 mm</td>
</tr>
<tr>
<td>Positioning accuracy</td>
<td>±0.3 mm/1000 mm</td>
</tr>
<tr>
<td>Positioning Repeatability</td>
<td>±0.1 mm</td>
</tr>
<tr>
<td>Minimum feed amount ( s )</td>
<td>0.02 mm/pulse</td>
</tr>
<tr>
<td>Desired service life time</td>
<td>30000 h</td>
</tr>
<tr>
<td>Driving motor</td>
<td>AC servo motor</td>
</tr>
<tr>
<td>Rated rotational speed</td>
<td>3000 min(^{-1})</td>
</tr>
<tr>
<td>Inertial moment of the motor ( J_m )</td>
<td>( 1 \times 10^{-3} ) kg m(^2)</td>
</tr>
<tr>
<td>Reduction gear</td>
<td>None (direct coupling)</td>
</tr>
<tr>
<td>Frictional coefficient of the guide surface ( \mu )</td>
<td>0.003 (rolling)</td>
</tr>
<tr>
<td>Guide surface resistance ( f )</td>
<td>15 N (without load)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selection Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screw shaft diameter</td>
</tr>
<tr>
<td>Lead</td>
</tr>
<tr>
<td>Nut model No.</td>
</tr>
<tr>
<td>Accuracy</td>
</tr>
<tr>
<td>Axial clearance</td>
</tr>
<tr>
<td>Screw shaft support method</td>
</tr>
<tr>
<td>Driving motor</td>
</tr>
</tbody>
</table>
Point of Selection
Examples of Selecting a Ball Screw

[Selecting Lead Angle Accuracy and Axial Clearance]

● Selecting Lead Angle Accuracy
To achieve positioning accuracy of \(\pm 0.3 \text{ mm/1,000 mm}\):

\[
\frac{\pm 0.3}{1000} = \frac{\pm 0.09}{300}
\]

The lead angle accuracy must be \(\pm 0.09 \text{ mm/300 mm}\) or higher.
Therefore, select the following as the accuracy grade of the Ball Screw (see Table 1 on A-678).

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

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 Table 12 on A-685) meets the requirements.

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

[Selecting a Screw Shaft]

● Assuming the Screw Shaft Length
Assume the overall nut length to be 100 mm and the screw shaft end length to be 100 mm.

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

\[1000 + 200 = 1200 \text{ mm}\]

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

● Selecting a Lead
With the driving motor's rated rotational speed being 3,000 min\(^{-1}\) and the maximum speed 1 m/s, the Ball Screw lead is obtained as follows:

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

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

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

- 1000 p/rev (without multiplication)
- 1500 p/rev (without multiplication)
- 2000 p/rev (doubled)
- 3000 p/rev (doubled)
- 4000 p/rev (quadrupled)
- 6000 p/rev (quadrupled)
To meet the minimum feed amount of 0.02 mm/pulse, which is the selection requirement, the following should apply.

<table>
<thead>
<tr>
<th>Lead</th>
<th>20mm —— 1000 p/rev</th>
</tr>
</thead>
<tbody>
<tr>
<td>30mm</td>
<td>1500 p/rev</td>
</tr>
<tr>
<td>40mm</td>
<td>2000 p/rev</td>
</tr>
<tr>
<td>60mm</td>
<td>3000 p/rev</td>
</tr>
<tr>
<td>80mm</td>
<td>4000 p/rev</td>
</tr>
</tbody>
</table>

**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-723: 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-723: a lead of 20, 30, 40, 60 or 80 mm (see Table 17 on A-693) are as follows.

<table>
<thead>
<tr>
<th>Shaft diameter</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>15mm</td>
<td>20mm</td>
</tr>
<tr>
<td>15mm</td>
<td>30mm</td>
</tr>
<tr>
<td>20mm</td>
<td>20mm</td>
</tr>
<tr>
<td>20mm</td>
<td>40mm</td>
</tr>
<tr>
<td>30mm</td>
<td>60mm</td>
</tr>
</tbody>
</table>

Since the screw shaft length has to be 1,200 mm as indicated in Section [Selecting a Screw Shaft] on A-723, 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.
Point of Selection
Examples of Selecting a Ball Screw

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

    Accordingly, the required values are obtained as follows.

    Acceleration:
    \[
    \alpha = \frac{V_{\text{max}}}{t_1} = 6.67 \text{ m/s}^2
    \]

    During forward acceleration:
    \[
    F_{a1} = \mu \cdot (m_1 + m_2) \cdot g + f + (m_1 + m_2) \cdot \alpha = 550 \text{ N}
    \]

    During forward uniform motion:
    \[
    F_{a2} = \mu \cdot (m_1 + m_2) \cdot g + f = 17 \text{ N}
    \]

    During forward deceleration:
    \[
    F_{a3} = \mu \cdot (m_1 + m_2) \cdot g + f - (m_1 + m_2) \cdot \alpha = -516 \text{ N}
    \]

    During backward acceleration:
    \[
    F_{a4} = -\mu \cdot (m_1 + m_2) \cdot g - f - (m_1 + m_2) \cdot \alpha = -550 \text{ N}
    \]

    During uniform backward motion:
    \[
    F_{a5} = -\mu \cdot (m_1 + m_2) \cdot g - f = -17 \text{ N}
    \]

    During backward deceleration:
    \[
    F_{a6} = -\mu \cdot (m_1 + m_2) \cdot g - f + (m_1 + m_2) \cdot \alpha = 516 \text{ N}
    \]

    Thus, the maximum axial load applied on the Ball Screw is as follows:
    \[
    F_{a_{\text{max}}} = F_{a1} = 550 \text{ N}
    \]

    Therefore, if there is no problem with a shaft diameter of 20 mm and a lead of 20 mm (smallest thread minor diameter of 17.5 mm), then the screw shaft diameter of 30 mm should meet the requirements. Thus, the following calculations for the buckling load and the permissible compressive and tensile load of the screw shaft are performed while assuming a screw shaft diameter of 20 mm and a lead of 20 mm.
Buckling Load on the Screw Shaft
Factor according to the mounting method $\eta_2 = 20$ (see A-694)
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 $l = 1100$ mm (estimate)
Screw-shaft thread minor diameter $d_1 = 17.5$ mm
$$P_i = \eta_2 \cdot \frac{d_1^4}{l^2} \times 10^4 = 20 \times \frac{17.5^4}{1100^2} \times 10^4 = 15500 \text{ N}$$

Permissible Compressive and Tensile Load of the Screw Shaft
$$P_t = 116 \times d_1^4 = 116 \times 17.5^4 = 35500 \text{ N}$$
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 $V_{\text{max}} = 1$ m/s
  Lead $P_h = 20$ mm
  $$N_{\text{rot}} = \frac{V_{\text{max}} \times 60 \times 10^3}{P_h} = 3000 \text{ min}^{-1}$$
- Screw shaft diameter: 20 mm; lead: 40 mm
  Maximum speed $V_{\text{max}} = 1$ m/s
  Lead $P_h = 40$ mm
  $$N_{\text{rot}} = \frac{V_{\text{max}} \times 60 \times 10^3}{P_h} = 1500 \text{ min}^{-1}$$
- Screw shaft diameter: 30 mm; lead: 60 mm
  Maximum speed $V_{\text{max}} = 1$ m/s
  Lead $P_h = 60$ mm
  $$N_{\text{rot}} = \frac{V_{\text{max}} \times 60 \times 10^3}{P_h} = 1000 \text{ min}^{-1}$$
Point of Selection
Examples of Selecting a Ball Screw

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

Factor according to the mounting method $\lambda = 15.1$ (see A-696)

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 $i_b = 1100$ mm (estimate)

- Screw shaft diameter: 20 mm; lead: 20 mm and 40 mm
  - Screw-shaft thread minor diameter $d_1 = 17.5$ mm
  - $N_1 = \lambda \times \frac{d_1}{i_b^2} 10^7 = 15.1 \times \frac{17.5}{1100} \times 10^7 = 2180 \text{ min}^{-1}$

- Screw shaft diameter: 30 mm; lead: 60 mm
  - Screw-shaft thread minor diameter $d_1 = 26.4$ mm
  - $N_1 = \lambda \times \frac{d_1}{i_b^2} 10^7 = 15.1 \times \frac{26.4}{1100} \times 10^7 = 3294 \text{ min}^{-1}$

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

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

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, Ca=13.6 kN)
- WTF2040-3
  - (Ca=6.8 kN, Ca=17.2 kN)
- WTF3060-2
  - (Ca=11.8 kN, Ca=30.6 kN)
- WTF3060-3
  - (Ca=14.5 kN, Ca=38.9 kN)
● Studying the Permissible Axial Load

Study the permissible axial load of model WTF2040-2 ($C_{0a} = 13.6$ kN).

Assuming that this model is used in high-speed transfer equipment and an impact load is applied during deceleration, set the static safety factor ($f_S$) at 2.5 (see Table 18 on A-703).

$$\frac{C_{0a}}{f_S} = \frac{13.6}{2.5} = 5.44 \text{ kN} = 5440 \text{ N}$$

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 $V_{\text{max}} = 1 \text{ m/s}$
- Acceleration time $t_1 = 0.15 \text{ s}$
- Deceleration time $t_3 = 0.15 \text{ s}$

- Travel distance during acceleration

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

- Travel distance during uniform motion

$$\ell_{2,1} = \ell_5 = \frac{V_{\text{max}} \cdot t_1 + V_{\text{max}} \cdot t_3}{2} \times 10^3 = 1000 - \frac{1 \times 0.15 + 1 \times 0.15}{2} \times 10^3 = 850 \text{ mm}$$

- Travel distance during deceleration

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

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

<table>
<thead>
<tr>
<th>Motion</th>
<th>Applied axial load ($F_a$)(N)</th>
<th>Travel distance ($\ell_2$)(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.1: During forward acceleration</td>
<td>550</td>
<td>75</td>
</tr>
<tr>
<td>No.2: During forward uniform motion</td>
<td>17</td>
<td>850</td>
</tr>
<tr>
<td>No.3: During forward deceleration</td>
<td>-516</td>
<td>75</td>
</tr>
<tr>
<td>No.4: During backward acceleration</td>
<td>-550</td>
<td>75</td>
</tr>
<tr>
<td>No.5: During uniform backward motion</td>
<td>-17</td>
<td>850</td>
</tr>
<tr>
<td>No.6: During backward deceleration</td>
<td>516</td>
<td>75</td>
</tr>
</tbody>
</table>

* The subscript (N) indicates a motion number.

Since the load direction (as expressed in positive or negative sign) is reversed with $F_a$, $F_a$, and $F_a$, calculate the average axial load in the two directions.
Point of Selection
Examples of Selecting a Ball Screw

**Average Axial Load**
- Average axial load in the positive direction
  Since the load direction varies, calculate the average axial load while assuming \( F_{a1,4,5} = 0 \) N.
  \[
  F_{m1} = \sqrt[3]{\frac{F_{a1}\times l_1 + F_{a2}\times l_2 + F_{a5}\times l_5}{l_1 + l_2 + l_5}} = 225 \text{ N}
  \]
- Average axial load in the negative direction
  Since the load direction varies, calculate the average axial load while assuming \( F_{a1,2,6} = 0 \) N.
  \[
  F_{m2} = \sqrt[3]{\frac{F_{a3}\times l_3 + F_{a4}\times l_4 + F_{a6}\times l_6}{l_3 + l_4 + l_6}} = 225 \text{ N}
  \]
  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 Table 19 on A-704)
- Average load \( F_m = 225 \) N
- Nominal life \( L \) (rev)

\[
L = \left( \frac{Ca}{f_w \times F_m} \right)^{\frac{3}{2}} \times 10^6
\]

<table>
<thead>
<tr>
<th>Assumed model number</th>
<th>Dynamic load rating ( Ca ) (N)</th>
<th>Nominal life ( L ) (rev)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WTF 2040-2</td>
<td>5400</td>
<td>( 4.1 \times 10^6 )</td>
</tr>
<tr>
<td>WTF 2040-3</td>
<td>6600</td>
<td>( 7.47 \times 10^6 )</td>
</tr>
<tr>
<td>WTF 3060-2</td>
<td>11800</td>
<td>( 4.27 \times 10^6 )</td>
</tr>
<tr>
<td>WTF 3060-3</td>
<td>14500</td>
<td>( 7.93 \times 10^6 )</td>
</tr>
</tbody>
</table>
**Average Revolutions per Minute**

Number of reciprocations per minute \( n = 8 \text{ min}^{-1} \)

Stroke \( l_s = 1000 \text{ mm} \)

- **Lead: Ph = 40 mm**
  \[
  N_{in} = \frac{2 \times n \times l_s}{Ph} = \frac{2 \times 8 \times 1000}{40} = 400 \text{ min}^{-1}
  \]

- **Lead: Ph = 60 mm**
  \[
  N_{in} = \frac{2 \times n \times l_s}{Ph} = \frac{2 \times 8 \times 1000}{60} = 267 \text{ min}^{-1}
  \]

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

- **WTF2040-2**
  Nominal life \( L = 4.1 \times 10^9 \text{ rev} \)
  Average revolutions per minute \( N_m = 400 \text{ min}^{-1} \)
  \[
  L_h = \frac{L}{60 \times N_{in}} = \frac{4.1 \times 10^9}{60 \times 400} = 171000 \text{ h}
  \]

- **WTF2040-3**
  Nominal life \( L = 7.47 \times 10^9 \text{ rev} \)
  Average revolutions per minute \( N_m = 400 \text{ min}^{-1} \)
  \[
  L_h = \frac{L}{60 \times N_{in}} = \frac{7.47 \times 10^9}{60 \times 400} = 311000 \text{ h}
  \]

- **WTF3060-2**
  Nominal life \( L = 4.27 \times 10^9 \text{ rev} \)
  Average revolutions per minute \( N_m = 267 \text{ min}^{-1} \)
  \[
  L_h = \frac{L}{60 \times N_{in}} = \frac{4.27 \times 10^9}{60 \times 267} = 2670000 \text{ h}
  \]

- **WTF3060-3**
  Nominal life \( L = 7.93 \times 10^9 \text{ rev} \)
  Average revolutions per minute \( N_m = 267 \text{ min}^{-1} \)
  \[
  L_h = \frac{L}{60 \times N_{in}} = \frac{7.93 \times 10^9}{60 \times 267} = 4950000 \text{ h}
  \]
Calculating the Service Life in Travel Distance on the Basis of the Nominal Life

- WTF2040-2
  - Nominal life: $L = 4.1 \times 10^9$ rev
  - Lead: $Ph = 40$ mm
  - $L_S = L \times Ph \times 10^4 = 164000$ km

- WTF2040-3
  - Nominal life: $L = 7.47 \times 10^9$ rev
  - Lead: $Ph = 40$ mm
  - $L_S = L \times Ph \times 10^4 = 298800$ km

- WTF3060-2
  - Nominal life: $L = 4.27 \times 10^{10}$ rev
  - Lead: $Ph = 60$ mm
  - $L_S = L \times Ph \times 10^4 = 2562000$ km

- WTF3060-3
  - Nominal life: $L = 7.93 \times 10^{10}$ rev
  - Lead: $Ph = 60$ mm
  - $L_S = L \times Ph \times 10^4 = 4758000$ 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
[Studying the Rigidity]
Since the conditions for selection do not include rigidity and this element is not particularly necessary, it is not described here.

[Studying the Positioning Accuracy]

- **Studying the Lead Angle Accuracy**
  Accuracy grade C7 was selected in Section [Selecting Lead Angle Accuracy and Axial Clearance] on A-723.
  
  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 positioning accuracy. As a result, there is no need to study the axial clearance.
  
  WTF2040: axial clearance: 0.1 mm
  WTF3060: axial clearance: 0.14 mm

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

- **Studying the Thermal Displacement through Heat Generation**
  Assume the temperature rise during operation to be 5°C.
  The positioning accuracy based on the temperature rise is obtained as follows:
  
  \[ \Delta l = \rho \times \Delta t \times l \]
  
  \[ = 12 \times 10^{-4} \times 5 \times 1000 \]
  
  \[ = 0.06 \text{ mm} \]

- **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:
  
  \[ \Delta a = l \times \sin \theta \]
  
  \[ = 150 \times \sin (\pm 10^\circ) \]
  
  \[ = \pm 0.007 \text{ mm} \]

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 requirements throughout the studying process in Section [Selecting Lead Angle Accuracy and Axial Clearance] on A-723 to Section [Studying the Positioning Accuracy] on A-732, the most compact model WTF2040-2 is selected.
Point of Selection
Examples of Selecting a Ball Screw

[Studying the Rotational Torque]

- Friction Torque Due to an External Load
  The friction torque is obtained as follows:
  \[ T_f = \frac{F_a \cdot Ph}{2\pi} \cdot A = \frac{17 \times 40}{2 \times \pi \times 0.9} \times 1 = 120 \text{ N} \cdot \text{mm} \]

- 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 \(1.23 \times 10^{-1}\) kg\(\cdot\)cm\(^2\)/mm (see the specification table), the inertial moment of the screw shaft with an overall length of 1200 mm is obtained as follows.
  \[ J_s = 1.23 \times 10^{-1} \times 1200 = 1.48 \text{ kg} \cdot \text{cm}^2 \]
  \[ = 1.48 \times 10^{-4} \text{ kg} \cdot \text{m}^2 \]
  \[ J = (m_1 + m_2) \left( \frac{Ph}{2 \times \pi} \right)^2 \cdot A^2 \times 10^{-4} + J_s \cdot A^2 = (60 + 20) \left( \frac{40}{2 \times \pi} \right)^2 \times 1^2 \times 10^{-4} + 1.48 \times 10^{-4} \times 1^2 \]
  \[ = 3.39 \times 10^{-3} \text{ kg} \cdot \text{m}^2 \]
  Angular acceleration:
  \[ \omega' = \frac{2\pi \cdot Nm}{60 \cdot t} = \frac{2\pi \times 1500}{60 \times 0.15} = 1050 \text{ rad/s}^2 \]

Based on the above, the torque required for acceleration is obtained as follows.
  \[ T_c = (J + J_s) \times \omega' = (3.39 \times 10^{-3} + 1 \times 10^{-4}) \times 1050 = 4.61 \text{ N} \cdot \text{m} \]
  \[ = 4.61 \times 10^3 \text{ N} \cdot \text{mm} \]

Therefore, the required torque is specified as follows.
  During acceleration
  \[ T = T_i + T_c = 120 + 4.61 \times 10^3 = 4730 \text{ N} \cdot \text{mm} \]
  During uniform motion
  \[ T = T_i = 120 \text{ N} \cdot \text{mm} \]
  During deceleration
  \[ T = T_1 = 120 - 4.61 \times 10^3 = -4490 \text{ N} \cdot \text{mm} \]
[Studying the Driving Motor]

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

Maximum working rotational speed: 1500 min⁻¹
Rated rotational speed of the motor: 3000 min⁻¹

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

Encoder resolution: 1000 p/rev.
Doubled: 2000 p/rev

● Motor Torque
The torque during acceleration calculated in Section [Studying the Rotational Torque] on A-733 is the required maximum torque.

T_{aw} = 4730 N \cdot \text{mm}

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

● Effective Torque Value
The selection requirements and the torque calculated in Section [Studying the Rotational Torque] on A-733 can be expressed as follows.

During acceleration:
\[ T_1 = 4730 \text{ N} \cdot \text{mm} \]
\[ t_1 = 0.15 \text{ s} \]

During uniform motion:
\[ T_2 = 120 \text{ N} \cdot \text{mm} \]
\[ t_2 = 0.85 \text{ s} \]

During deceleration:
\[ T_3 = 4490 \text{ N} \cdot \text{mm} \]
\[ t_3 = 0.15 \text{ s} \]

When stationary:
\[ T_4 = 0 \text{ N} \cdot \text{mm} \]
\[ t_4 = 2.6 \text{ s} \]

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

\[
T_{\text{rms}} = \sqrt{\frac{T_1^2 \cdot t_1 + T_2^2 \cdot t_2 + T_3^2 \cdot t_3 + T_4^2 \cdot t_4}{t_1 + t_2 + t_3 + t_4}} = \sqrt{\frac{4730^2 \times 0.15 + 120^2 \times 0.85 + 4490^2 \times 0.15 + 0}{0.15 + 0.85 + 0.15 + 2.6}} = 1305 \text{ N} \cdot \text{mm}
\]
Inertial Moment
The inertial moment applied to the motor equals to the inertial moment calculated in Section [Studying the Rotational Torque] on A-733.

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

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 \(3.39 \times 10^{-4}\) kg-m² or greater.

The selection has been completed.
Vertical Conveyance System

[Selection Conditions]
Table Mass \( m_1 = 40\text{kg} \)
Work Mass \( m_2 = 10\text{kg} \)
Stroke length \( l_s = 600\text{mm} \)
Maximum speed \( V_{max} = 0.3\text{m/s} \)
Acceleration time \( t_a = 0.2\text{s} \)
Deceleration time \( t_d = 0.2\text{s} \)
Number of reciprocations per minute \( n = 5\text{min}^{-1} \)
Backlash \( 0.1\text{mm} \)
Positioning accuracy \( \pm 0.7\text{mm}/600\text{mm} \)
Positioning Repeatability \( \pm 0.05\text{mm} \)
Minimum feed amount \( s = 0.01\text{mm/pulse} \)
Service life time \( 20000\text{h} \)
Driving motor AC servo motor
Rated rotational speed: \( 3000 \text{min}^{-1} \)
Inertial moment of the motor \( J_m = 5 \times 10^{-4} \text{kg} \cdot \text{m}^2 \)
Reduction gear None (direct coupling)
Frictional coefficient of the guide surface \( \mu = 0.003 \) (rolling)
Guide surface resistance \( f = 20 \text{N (without load)} \)

[Selection Items]
Screw shaft diameter
Lead
Nut model No.
Accuracy
Axial clearance
Screw shaft support method
Driving motor
Point of Selection
Examples of Selecting a Ball Screw

[Selecting Lead Angle Accuracy and Axial Clearance]

● Selecting the Lead Angle Accuracy
To achieve positioning accuracy of $\pm 0.7\,\text{mm/600}\,\text{mm}$:

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

The lead angle accuracy must be $\pm 0.35\,\text{mm/300}\,\text{mm}$ or higher. Therefore, the accuracy grade of the Ball Screw (see Table 1 on A-678) needs to be C10 (travel distance error: $\pm 0.21\,\text{mm/300}\,\text{mm}$). Accuracy grade C10 is available for low priced, Rolled Ball Screws. Assume that a Rolled Ball Screw is selected.

● Selecting the Axial Clearance
The required backlash 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 600 mm.

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

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

● Selecting the Lead
With the driving motor's rated rotational speed being 3,000 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 6 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)
To meet the minimum feed amount of 0.010mm/pulse, which is the selection requirement, the following should apply.

- 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-737 and Section [Selecting a Screw Shaft] on A-737 (see Table17 on A-693) are as follows.

<table>
<thead>
<tr>
<th>Shaft diameter</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>15mm</td>
<td>10mm</td>
</tr>
<tr>
<td>20mm</td>
<td>10mm</td>
</tr>
<tr>
<td>25mm</td>
<td>10mm</td>
</tr>
</tbody>
</table>

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.
Point of Selection
Examples of Selecting a Ball Screw

- Studying the Permissible Axial Load
  
  Calculating the Maximum Axial Load
  
  Guide surface resistance \( f = 20 \text{ N (without load)} \)
  
  Table Mass \( m_1 = 40 \text{ kg} \)
  
  Work Mass \( m_2 = 10 \text{ kg} \)
  
  Maximum speed \( V_{\text{max}} = 0.3 \text{ m/s} \)
  
  Acceleration time \( t_1 = 0.2s \)

  Accordingly, the required values are obtained as follows.

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

  During upward acceleration:
  
  \[ F_{\alpha 1} = (m_1 + m_2) \cdot g + f + (m_1 + m_2) \cdot \alpha = 585 \text{ N} \]

  During upward uniform motion:
  
  \[ F_{\alpha 2} = (m_1 + m_2) \cdot g + f = 510 \text{ N} \]

  During upward deceleration:
  
  \[ F_{\alpha 3} = (m_1 + m_2) \cdot g + f - (m_1 + m_2) \cdot \alpha = 435 \text{ N} \]

  During downward acceleration:
  
  \[ F_{\alpha 4} = (m_1 + m_2) \cdot g - f - (m_1 + m_2) \cdot \alpha = 395 \text{ N} \]

  During downward uniform motion:
  
  \[ F_{\alpha 5} = (m_1 + m_2) \cdot g - f = 470 \text{ N} \]

  During downward deceleration:
  
  \[ F_{\alpha 6} = (m_1 + m_2) \cdot g - f + (m_1 + m_2) \cdot \alpha = 545 \text{ N} \]

  Thus, the maximum axial load applied on the Ball Screw is as follows:
  
  \[ F_{\alpha \text{max}} = F_{\alpha 1} = 585 \text{ N} \]

- Buckling Load of the Screw Shaft
  
  Factor according to the mounting method \( \eta_2 = 20 \) (see A-694)

  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 \( l_a = 700 \text{ mm (estimate)} \)

  Screw-shaft thread minor diameter \( d_1 = 12.5 \text{ mm} \)

  \[ P_1 = \eta_2 \cdot \frac{d_1^4}{l_a^2} \cdot 10^4 = 20 \cdot \frac{12.5^4}{700^2} \cdot 10^4 = 9960 \text{ N} \]

- Permissible Compressive and Tensile Load of the Screw Shaft
  
  \[ P_2 = 116d_1^2 = 116 \times 12.5^2 = 18100 \text{ N} \]

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

Maximum Rotational Speed

- Screw shaft diameter: 15mm; lead: 10mm
- Maximum speed \( V_{\text{max}} = 0.3 \text{ m/s} \)
- Lead \( \Phi_h = 10 \text{ mm} \)

\[
N_{\text{max}} = \frac{V_{\text{max}} \times 60 \times 10^3}{\Phi_h} = 1800 \text{ min}^{-1}
\]

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

Factor according to the mounting method \( \lambda = 15.1 \) (see A-696)

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 \( l_b = 700 \text{ mm (estimate)} \)
- Screw shaft diameter: 15mm; lead: 10mm
  - Screw-shaft thread minor diameter \( d_1 = 12.5 \text{ mm} \)

\[
N_r = \lambda \times \frac{d_1}{l_b} \times 10^7 = 15.1 \times \frac{12.5}{700} \times 10^7 = 3852 \text{ min}^{-1}
\]

Permissible Rotational Speed Determined by the DN Value

- Screw shaft diameter: 15mm; lead: 10mm (large lead Ball Screw)
  - Ball center-to-center diameter \( D = 15.75 \text{ mm} \)

\[
N_d = \frac{70000}{D} = \frac{70000}{15.75} = 4444 \text{ min}^{-1}
\]

Thus, the dangerous speed and the DN value of the screw shaft are met.
Point of Selection
Examples of Selecting a Ball Screw

[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.
  \[
  \text{BLK1510-5.6} \quad (C_a=9.8 \text{ kN}, C_{a0}=25.2 \text{ kN})
  \]

- **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 Table18 on A-703).
  \[
  F_{a_{\max}} = \frac{C_a}{f_S} = \frac{25.2}{2} = 12.6 \text{ kN} = 12600 \text{ N}
  \]
  The obtained permissible axial load is greater than the maximum axial load of 585 N, and therefore, there will be no problem with this model.

- **Studying the Service Life**

  - **Calculating the Travel Distance**
    1. Maximum speed \( V_{\text{max}}=0.3 \text{ m/s} \)
    2. Acceleration time \( t_1 = 0.2 \text{ s} \)
    3. Deceleration time \( t_3 = 0.2 \text{ s} \)

    - Travel distance during acceleration
      \[
      l_{1,4} = \frac{V_{\text{max}} \cdot t_1}{2} \times 10^3 = \frac{1.3 \times 0.2}{2} \times 10^3 = 30 \text{ mm}
      \]

    - Travel distance during uniform motion
      \[
      l_{2,5} = \frac{1}{2} \left( \frac{V_{\text{max}} \cdot t_1 + V_{\text{max}} \cdot t_3}{2} \times 10^3 \right) = 600 - \frac{0.3 \times 0.2 + 0.3 \times 0.2}{2} \times 10^3 = 540 \text{ mm}
      \]

    - Travel distance during deceleration
      \[
      l_{3,6} = \frac{V_{\text{max}} \cdot t_3}{2} \times 10^3 = \frac{0.3 \times 0.2}{2} \times 10^3 = 30 \text{ mm}
      \]

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

<table>
<thead>
<tr>
<th>Motion</th>
<th>Applied axial load ( F_{a(N)} )</th>
<th>Travel distance ( l_{(mm)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>No1: During upward acceleration</td>
<td>585</td>
<td>30</td>
</tr>
<tr>
<td>No2: During upward uniform motion</td>
<td>510</td>
<td>540</td>
</tr>
<tr>
<td>No3: During upward deceleration</td>
<td>435</td>
<td>30</td>
</tr>
<tr>
<td>No4: During downward acceleration</td>
<td>395</td>
<td>30</td>
</tr>
<tr>
<td>No5: During downward uniform motion</td>
<td>470</td>
<td>540</td>
</tr>
<tr>
<td>No6: During downward deceleration</td>
<td>545</td>
<td>30</td>
</tr>
</tbody>
</table>

* The subscript \( (N) \) indicates a motion number.
Average Axial Load

\[ F_m = \frac{1}{2 \times \ell_s} (F_{a1} \cdot \ell_1 + F_{a2} \cdot \ell_2 + F_{a3} \cdot \ell_3 + F_{a4} \cdot \ell_4 + F_{a5} \cdot \ell_5 + F_{a6} \cdot \ell_6) = 225 \text{ N} \]

Nominal Life
- Dynamic load rating: \( C_a = 9800 \text{ N} \)
- Load factor: \( f_w = 1.5 \) (see Table 19 on A-704)
- Average load: \( F_m = 492 \text{ N} \)
- Nominal life: \( L \) (rev)

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

Average Revolutions per Minute
- Number of reciprocations per minute: \( n = 5 \text{ min}^{-1} \)
- Stroke: \( \ell_s = 600 \text{ mm} \)
- Lead: \( \text{Ph} = 10 \text{ mm} \)

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

Calculating the Service Life Time on the Basis of the Nominal Life
- Nominal life: \( L = 2.34 \times 10^9 \text{ rev} \)
- Average revolutions per minute: \( N_m = 600 \text{ min}^{-1} \)

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

Calculating the Service Life in Travel Distance on the Basis of the Nominal Life
- Nominal life: \( L = 2.34 \times 10^9 \text{ rev} \)
- Lead: \( \text{Ph} = 10 \text{ mm} \)

\[ L_s = L \times \text{Ph} \times 10^6 = 23400 \text{ km} \]

With all the conditions stated above, model BLK1510-5.6 satisfies the desired service life time of 20,000 hours.
Point of Selection
Examples of Selecting a Ball Screw

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

[Studying the Positioning Accuracy]
- **Studying the Lead Angle Accuracy**
Accuracy grade C10 was selected in Section [Selecting Lead Angle Accuracy and Axial Clearance] on A-737.
  - C10 (travel distance error: \( \pm 0.21\text{mm/300mm} \))
- **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:

\[
T_1 = \frac{F_a \cdot P_h}{2 \times \pi \times \eta} = \frac{510 \times 10}{2 \times \pi \times 0.9} = 900 \text{ N} \cdot \text{mm}
\]
During downward uniform motion:

\[
T_2 = \frac{F_a \cdot P_h}{2 \times \pi \times \eta} = \frac{470 \times 10}{2 \times \pi \times 0.9} = 830 \text{ N} \cdot \text{mm}
\]
- **Torque Due to a Preload on the Ball Screw**
The Ball Screw is not provided with a preload.
Torque Required for Acceleration

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

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

$$= 0.31 \times 10^{-4} \text{ kg \cdot m}^2$$

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

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

Angular acceleration:

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

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

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

Therefore, the required torque is specified as follows.

- During upward acceleration:
  $$T_u = T_1 + T_3 = 900 + 200 = 1100 \text{ N \cdot mm}$$

- During upward uniform motion:
  $$T_i = T_1 = 900 \text{ N \cdot mm}$$

- During upward deceleration:
  $$T_{ig} = T_i - T_3 = 900 - 200 = 700 \text{ N \cdot mm}$$

- During downward acceleration:
  $$T_{g} = 630 \text{ N \cdot mm}$$

- During downward uniform motion:
  $$T_u = 830 \text{ N \cdot mm}$$

- During downward deceleration:
  $$T_{ug} = 1030 \text{ N \cdot mm}$$
Point of Selection
Examples of Selecting a 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: 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-743 is the required maximum torque.
  \[ T_{\text{max}} = T_1 = 1100 \text{ N-mm} \]
  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-743 can be expressed as follows.
  During upward acceleration:
  \[ T_1 = 1100 \text{ N-mm} \]
  \[ t_1 = 0.2 \text{ s} \]
  During upward uniform motion:
  \[ T_2 = 900 \text{ N-mm} \]
  \[ t_2 = 1.8 \text{ s} \]
  During upward deceleration:
  \[ T_3 = 700 \text{ N-mm} \]
  \[ t_3 = 0.2 \text{ s} \]
  During downward acceleration:
  \[ T_4 = 630 \text{ N-mm} \]
  \[ t_4 = 0.2 \text{ s} \]
  During downward uniform motion:
  \[ T_5 = 830 \text{ N-mm} \]
  \[ t_5 = 1.8 \text{ s} \]
  During downward deceleration:
  \[ T_6 = 1030 \text{ N-mm} \]
  \[ t_6 = 0.2 \text{ s} \]
  When stationary (m=0):
  \[ T_7 = 658 \text{ N-mm} \]
  \[ t_7 = 7.6 \text{ s} \]
The effective torque is obtained as follows, and the rated torque of the motor must be 743 N·mm or greater.

\[
T_{\text{rms}} = \sqrt{\frac{T_{t1} \cdot t_1 + T_{t2} \cdot t_2 + T_{t3} \cdot t_3 + T_{t4} \cdot t_4 + T_{t5} \cdot t_5 + T_{t6} \cdot t_6 + T_{t7} \cdot t_7 + T_{t8} \cdot t_8 + T_{t9} \cdot t_9}{t_1 + t_2 + t_3 + t_4 + t_5 + t_6 + t_7 + t_8 + t_9}}
\]

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

\[= 743 \text{ N} \cdot \text{mm}\]

\* Inertial Moment

The inertial moment applied to the motor equals to the inertial moment calculated in Section [Studying the Rotational Torque] on A-743.

\[J = 1.58 \times 10^{-1} \text{ kg} \cdot \text{m}^2\]

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 \(1.58 \times 10^{-1} \text{kg} \cdot \text{m}^2\) or greater.

The selection has been completed.
Ball Screw
Accuracy of Each Model
Fig.1 Structure of High-Speed Ball Screw with Ball Cage Model SBN

Structure and Features  
Ball Cage Effect  
Types and Features  
Service Life  
Axial Clearance  
Accuracy Standards  
Dimensional Drawing, Dimensional Table, Example of Model Number Coding
Features of Each Model
Precision, Caged Ball Screw

Structure and Features
The use of a ball cage in the Ball Screw with the Ball Cage eliminates collision and friction between balls and increases the grease retention. This makes it possible to achieve a low noise, a low torque fluctuation and a long-term maintenance-free operation. In addition, this Ball Screw is superbly capable of responding to the high speed because of an ideal ball recirculation structure, a strengthened circulation path and an adoption of the ball cage.

Ball Cage Effect

[Low Noise, Acceptable Running Sound]
The use of the ball cage eliminates the collision noise between the balls. Additionally, as balls are picked up in the tangential direction, the collision noise from the ball circulation has also been eliminated.

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

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

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

Noise Measurement
[Conditions]

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
<td>High load ball screw with ball cage</td>
</tr>
<tr>
<td></td>
<td>HBN3210-5</td>
</tr>
<tr>
<td></td>
<td>Conventional type: model BNF310-5</td>
</tr>
<tr>
<td>Stroke</td>
<td>600mm</td>
</tr>
<tr>
<td>Lubrication</td>
<td>Grease lubrication (lithium-based grease containing extreme pressure agent)</td>
</tr>
</tbody>
</table>

![Noise measurement instrument](image)

![Fig.2 Ball Screw Noise Level](image)
Features of Each Model
Precision, Caged Ball Screw

[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.

<table>
<thead>
<tr>
<th>High Speed Durability Test</th>
<th>Load Bearing Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test conditions</strong></td>
<td><strong>Test conditions</strong></td>
</tr>
<tr>
<td>Sample</td>
<td>High Speed Ball Screw with Ball Cage SBN3210-7</td>
</tr>
<tr>
<td>Speed</td>
<td>3900(min⁻¹)(DN value: 130,000)</td>
</tr>
<tr>
<td>Stroke</td>
<td>400mm</td>
</tr>
<tr>
<td>Lubricant</td>
<td>THK AFG Grease</td>
</tr>
<tr>
<td>Quantity</td>
<td>12cm³(lubricated every 1000km)</td>
</tr>
<tr>
<td>Applied load</td>
<td>1.73kN</td>
</tr>
<tr>
<td>Acceleration</td>
<td>1G</td>
</tr>
<tr>
<td>Speed</td>
<td>1500(min⁻¹)(DN value: 50,000)</td>
</tr>
<tr>
<td>Stroke</td>
<td>300mm</td>
</tr>
<tr>
<td>Lubricant</td>
<td>THK AFG Grease</td>
</tr>
<tr>
<td>Quantity</td>
<td>12cm³</td>
</tr>
<tr>
<td>Applied load</td>
<td>17.3kN(0.5Ca)</td>
</tr>
<tr>
<td>Acceleration</td>
<td>0.5G</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaft diameter/lead</td>
<td>32/10mm</td>
</tr>
<tr>
<td>Shaft rotational speed</td>
<td>60min⁻¹</td>
</tr>
</tbody>
</table>

![Fig.3 Torque Fluctuation Data]
## Types and Features

### [Preload Type]

**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.

### [No Preload Type]

**Model HBN**

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

<table>
<thead>
<tr>
<th>Model</th>
<th>Specification Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBN</td>
<td>B-576</td>
</tr>
<tr>
<td>SBK</td>
<td>B-578</td>
</tr>
<tr>
<td>HBN</td>
<td>B-580</td>
</tr>
</tbody>
</table>
### Features of Each Model

**Precision, Caged Ball Screw**

<table>
<thead>
<tr>
<th>Service Life</th>
<th>For details, see A-704.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial Clearance</td>
<td>For details, see A-685.</td>
</tr>
<tr>
<td><strong>Accuracy Standards</strong></td>
<td>For details, see A-678.</td>
</tr>
</tbody>
</table>
Standard-Stock Precision Ball Screw
Unfinished Shaft Ends
Models BIF, BNFN, MDK, MBF and BNF

Structure and Features
Types and Features
Service Life
Nut Types and Axial Clearance
Dimensional Drawing, Dimensional Table, Example of Model Number Coding
Features of Each Model
Standard-Stock Precision Ball Screw (Unfinished Shaft Ends)

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-810 for details.
Types and Features

[Preload Type]

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

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.
Features of Each Model
Standard-Stock Precision Ball Screw (Unfinished Shaft Ends)

[No Preload Type]

**Models MDK and MBF**
A miniature type with a screw shaft diameter of φ4 to φ14 mm and a lead of 1 to 5 mm.

**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.
## Service Life

For details, see A-704.

### Nut Types and Axial Clearance

<table>
<thead>
<tr>
<th>Screw shaft outer diameter (mm)</th>
<th>φ 4 to 14</th>
<th>[ \text{φ} 16 \to 50 ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nut type</td>
<td>Model MDK</td>
<td>Model MBF</td>
</tr>
<tr>
<td>No preload type</td>
<td>No preload type</td>
<td></td>
</tr>
<tr>
<td>Accuracy grades</td>
<td>C3, C5</td>
<td>C7</td>
</tr>
<tr>
<td>Axial clearance (mm)</td>
<td>0.005 or less (GT)</td>
<td>0.02 or less (G2)</td>
</tr>
<tr>
<td>Preload</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

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

### Screw shaft out diameter (mm) | \[ \phi 16 \to 50 \] |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nut type</td>
<td>Model BIF</td>
</tr>
<tr>
<td>Preload type</td>
<td>Preload Type</td>
</tr>
<tr>
<td>Accuracy grades</td>
<td>C5</td>
</tr>
<tr>
<td>Axial clearance (mm)</td>
<td>0 or less (G0)</td>
</tr>
<tr>
<td>Preload</td>
<td>0.05Ca</td>
</tr>
</tbody>
</table>

Note 1: The symbols in the parentheses indicate axial clearance symbols.

Note 2: Symbol “Ca” for preload indicates the basic dynamic load rating.
Features of Each Model
Standard-Stock Precision Ball Screw (Unfinished Shaft Ends)
# Standard-Stock Precision Ball Screw

## Finished Shaft Ends

Model BNK

---

<table>
<thead>
<tr>
<th>Features</th>
<th>►►► A-761</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types and Features</td>
<td>►►► A-761</td>
</tr>
<tr>
<td>Table of Ball Screw Types with Finished Shaft Ends and the Corresponding Support Units and Nut Brackets</td>
<td>►►► A-762</td>
</tr>
<tr>
<td>Dimensional Drawing, Dimensional Table</td>
<td>►►► B-608</td>
</tr>
</tbody>
</table>

---

A-760 THK
Features of Each Model
Standard-Stock Precision Ball Screw (Finished Shaft Ends)

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
For this model, screw shafts with a diameter φ4 to φ25 mm and a lead 1 to 20 mm are available as the standard.
# Table of Ball Screw Types with Finished Shaft Ends and the Corresponding Support Units and Nut Brackets

<table>
<thead>
<tr>
<th>Model No.</th>
<th>BNK</th>
</tr>
</thead>
<tbody>
<tr>
<td>0401</td>
<td></td>
</tr>
<tr>
<td>0501</td>
<td></td>
</tr>
<tr>
<td>0601</td>
<td></td>
</tr>
<tr>
<td>0801</td>
<td></td>
</tr>
<tr>
<td>0802</td>
<td></td>
</tr>
<tr>
<td>0810</td>
<td></td>
</tr>
<tr>
<td>1002</td>
<td></td>
</tr>
<tr>
<td>1004</td>
<td></td>
</tr>
<tr>
<td>1010</td>
<td></td>
</tr>
</tbody>
</table>

### Accuracy grades
- C3, C5, C7
- C3, C5, C7
- C3, C5, C7
- C3, C5, C7
- C3, C5, C7
- C3, C5, C7
- C3, C5, C7
- C3, C5, C7

### Axial clearance
- G0: 0 or less
- GT: 0.005 mm or less
- G2: 0.02 mm or less

### Stroke (mm)
| 20  | 20 |
| 30  | 30 |
| 40  | 20 |
| 50  | 20 |
| 60  | 20 |
| 70  | 20 |
| 100 | 20 |
| 120 | 20 |
| 150 | 20 |
| 170 | 20 |
| 200 | 20 |
| 250 | 20 |
| 300 | 20 |
| 350 | 20 |
| 400 | 20 |
| 450 | 20 |
| 500 | 20 |
| 550 | 20 |
| 600 | 20 |
| 700 | 20 |
| 800 | 20 |
| 1000| 20 |
| 1100| 20 |
| 1200| 20 |
| 1400| 20 |
| 1600| 20 |

### Support units
- Square on fixed side: EK4, EK5, EK6, EK8, EK10, EK10
- Round on fixed side: FK4, FK5, FK6, FK8, FK10, FK10
- Square on supported side: —, —, —, EF6, EF6, EF6, EF6, EF6, EF6, EF10, EF10
- Round on supported side: —, —, —, FF6, FF6, FF6, FF6, FF6, FF6, FF10, FF10

### Nut brackets
- —, —, —, —, 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-802 onward and A-812 onward, respectively.
# Features of Each Model

Standard-Stock Precision Ball Screw (Finished Shaft Ends)

<table>
<thead>
<tr>
<th>BNK</th>
<th>1202</th>
<th>1205</th>
<th>1208</th>
<th>1402</th>
<th>1404</th>
<th>1408</th>
<th>1510</th>
<th>1520</th>
<th>1618</th>
<th>2010</th>
<th>2020</th>
<th>2520</th>
</tr>
</thead>
<tbody>
<tr>
<td>C3, C5, C7</td>
<td>C3, C5, C7</td>
<td>C7</td>
<td>C3, C5, C7</td>
<td>C3, C5, C7</td>
<td>C5, C7</td>
<td>C5, C7</td>
<td>C5, C7</td>
<td>C5, C7</td>
<td>C5, C7</td>
<td>C5, C7</td>
<td>C5, C7</td>
<td>C5, C7</td>
</tr>
<tr>
<td>G0</td>
<td>GT</td>
<td>G2</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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</table>

Ball Screw

<table>
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<tr>
<th>EK10</th>
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<th>EK10</th>
<th>EK12</th>
<th>EK12</th>
<th>EK12</th>
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<th>EK20</th>
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<tbody>
<tr>
<td>FK10</td>
<td>FK10</td>
<td>FK10</td>
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<tr>
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<td>FF10</td>
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<td>FF12</td>
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<td>FF12</td>
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<td>FF15</td>
<td>FF15</td>
<td>FF20</td>
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</tbody>
</table>
Precision Ball Screw
Models BIF, DIK, BNFN, DKN, BLW, BNF, DK, MDK, BLK/WGF and BNT

Structure and Features ▶▶▶ A-765
Types and Features ▶▶▶ A-769
Service Life ▶▶▶ A-704
Axial Clearance ▶▶▶ A-685
Accuracy Standards ▶▶▶ A-678
Dimensional Drawing, Dimensional Table (Preload Type) ▶▶▶ B-652
Dimensional Drawing, Dimensional Table (No Preload Type) ▶▶▶ B-686
Model number coding ▶▶▶ B-718
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).

<table>
<thead>
<tr>
<th>Accuracy grades</th>
<th>Precision Ball Screw</th>
<th>Rolled Ball Screw</th>
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</thead>
<tbody>
<tr>
<td>C0</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>C1</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>C2</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>C3</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>C5</td>
<td>C</td>
<td>C</td>
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<tr>
<td>C7</td>
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<td>C8</td>
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<td>C</td>
</tr>
<tr>
<td>C10</td>
<td>C</td>
<td>C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Series symbol</th>
<th>Grade</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>For positioning</td>
<td>C</td>
<td>0, 1, 3, 5</td>
<td>JIS series</td>
</tr>
<tr>
<td></td>
<td>Cp</td>
<td>1, 3, 5</td>
<td>ISO compliant</td>
</tr>
<tr>
<td>For conveyance</td>
<td>Ct</td>
<td>1, 3, 5, 7</td>
<td>ISO compliant</td>
</tr>
</tbody>
</table>

**[Options that Meet the Environment are Available]**

Options are available consisting of a lubricator (QZ), which enables the maintenance interval to be significantly extended, and a wiper ring (W), which improves the ability to remove foreign materials in adverse environments.
Structure and Features of Offset Preload Type Simple-Nut Ball Screw Model DIK

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

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

Comparison between the Simple Nut and the Double-Nuts

<table>
<thead>
<tr>
<th>Simple-Nut Ball Screw Model DIK</th>
<th>Conventional Double-Nut Type Ball Screw Model BNFN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preloading Structure</td>
</tr>
<tr>
<td>Applied preload Pitch</td>
<td>Applied preload Pitch</td>
</tr>
<tr>
<td>(Pitch + preload)</td>
<td>(Pitch + preload)</td>
</tr>
<tr>
<td>Ball screw nut</td>
<td>Spacer</td>
</tr>
<tr>
<td>Pitch</td>
<td>Ball screw nut</td>
</tr>
<tr>
<td>Screw shaft</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Preloading Structure</td>
</tr>
<tr>
<td>Applied preload Pitch</td>
<td>Applied preload Pitch</td>
</tr>
<tr>
<td>(Pitch + preload)</td>
<td>(Pitch + preload)</td>
</tr>
<tr>
<td>Ball screw nut</td>
<td>Ball screw nut</td>
</tr>
<tr>
<td>Pitch</td>
<td>Pitch</td>
</tr>
<tr>
<td>Screw shaft</td>
<td></td>
</tr>
</tbody>
</table>
### Features of Each Model
**Precision Ball Screw**

<table>
<thead>
<tr>
<th>Simple-Nut Ball Screw Model DIK</th>
<th>Conventional Double-Nut Type Ball Screw Model BNFN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rotational Performance</strong></td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td>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.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dimensions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>

#### Simple-Nut Ball Screw Model DIK

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>φ58</td>
<td>61</td>
</tr>
<tr>
<td>φ34</td>
<td></td>
</tr>
</tbody>
</table>

Unit: mm

#### Conventional Double-Nut Type Ball Screw Model BNFN

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>φ67</td>
<td>76</td>
</tr>
<tr>
<td>φ44</td>
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</tbody>
</table>

Unit: mm
### Comparison between the Offset Preload Type of Simple-Nut Ball Screw and the Oversize Preload Nut Ball Screw

<table>
<thead>
<tr>
<th>Preloading Structure</th>
<th>Accuracy Life</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Simple-Nut Ball Screw Model DIK</strong></td>
<td><strong>Conventional Oversize Preload Nut Ball Screw Model SNF</strong></td>
</tr>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

**Preloading Structure**
- **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.

**Conventional 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.

**Accuracy Life**
- 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.

![Diagram](image3.png)
# Types and Features

## [Preload Type]

### Model BIF

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

### Model DIK

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

### Model BNFN

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

### Model DKN

A preload is provided via a spacer between the two combined ball screw nuts to achieve a below-zero axial clearance (under a preload).
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 φ4 to 14 mm and a lead of 1 to 5 mm.
Features of Each Model
Precision Ball Screw

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-704.

Axial Clearance
For details, see A-685.

Accuracy Standards
For details, see A-678.
### Structure and Features

<table>
<thead>
<tr>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>A-775</td>
</tr>
<tr>
<td>Service Life</td>
<td>A-704</td>
</tr>
<tr>
<td>Axial Clearance</td>
<td>A-685</td>
</tr>
<tr>
<td>Accuracy Standards</td>
<td>A-776</td>
</tr>
<tr>
<td>Example of Assembly</td>
<td>A-778</td>
</tr>
</tbody>
</table>

### Additional Information

- Dimensional Drawing, Dimensional Table, Example of Model Number Coding: B-720
Features of Each Model
Precision Rotary Ball Screw

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).

- **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.

The support bearing comprises of two rows of DB type angular bearings with a contact angle of $45^\circ$ 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
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.)
### Features of Each Model

**Precision Rotary Ball Screw**

<table>
<thead>
<tr>
<th>Type</th>
<th>Model DIR</th>
<th>Specification Table ⇒ B-720</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Preload Type]</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Model BLR</th>
<th>Specification Table ⇒ B-720</th>
</tr>
</thead>
<tbody>
<tr>
<td>[No Preload Type]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Service Life

For details, see A-704.

### Axial Clearance

For details, see A-685.
Accuracy Standards

[Model DIR]
The accuracy of model DIR 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).

<table>
<thead>
<tr>
<th>Model No.</th>
<th>C3 (A)</th>
<th>C5 (B)</th>
<th>C7 (C)</th>
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</thead>
<tbody>
<tr>
<td>DIR 16</td>
<td>0.013</td>
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<td>0.020</td>
</tr>
<tr>
<td>DIR 20</td>
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<td>0.016</td>
</tr>
<tr>
<td>DIR 25</td>
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<tr>
<td>DIR 32</td>
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<tr>
<td>DIR 40</td>
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<td>0.026</td>
<td>0.021</td>
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</table>

Unit: mm
Features of Each Model
Precision Rotary Ball Screw

[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).

<table>
<thead>
<tr>
<th>Model No.</th>
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<th>C7</th>
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</thead>
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<td>BLR 3232</td>
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<tr>
<td>BLR 3636</td>
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<td>0.025</td>
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<td>BLR 4040</td>
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<td>0.021</td>
<td>0.026</td>
</tr>
<tr>
<td>BLR 5050</td>
<td>0.018</td>
<td>0.026</td>
<td>0.026</td>
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</tbody>
</table>

Unit: mm

Lead angle accuracy

<table>
<thead>
<tr>
<th>Accuracy grades</th>
<th>C3</th>
<th>C5</th>
<th>C7</th>
</tr>
</thead>
<tbody>
<tr>
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<td>C5</td>
<td>C7</td>
</tr>
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<td>BLR 1616</td>
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<td>0.017</td>
<td>0.023</td>
</tr>
<tr>
<td>BLR 2020</td>
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<td>0.017</td>
<td>0.023</td>
</tr>
<tr>
<td>BLR 2525</td>
<td>0.015</td>
<td>0.018</td>
<td>0.023</td>
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<tr>
<td>BLR 3232</td>
<td>0.015</td>
<td>0.018</td>
<td>0.023</td>
</tr>
<tr>
<td>BLR 3636</td>
<td>0.016</td>
<td>0.021</td>
<td>0.024</td>
</tr>
<tr>
<td>BLR 4040</td>
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<td>0.021</td>
<td>0.026</td>
</tr>
<tr>
<td>BLR 5050</td>
<td>0.018</td>
<td>0.026</td>
<td>0.026</td>
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</tbody>
</table>
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]

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)
Features of Each Model
Precision Rotary Ball Screw

[Example of Mounting Model BLR on the Table]
(1) Screw shaft free, ball screw nut fixed
(Suitable for a long table)

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

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

Fig. 3 Example of Installation on the Table (Screw Shaft Fixed)
Precision Ball Screw/Spline
Models BNS-A, BNS, NS-A and NS

Structure and Features ▲▲▲ A-781
Type ▲▲▲ A-782
Service Life ▲▲▲ A-704
Axial Clearance ▲▲▲ A-685
Accuracy Standards ▲▲▲ A-783
Action Patterns ▲▲▲ A-784
Example of Assembly ▲▲▲ A-787
Example of Using the Spring Pad ▲▲▲ A-788
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Dimensional Drawing, Dimensional Table, Example of Model Number Coding ▲▲▲ B-726
Features of Each Model
Precision Ball Screw/Spline

Structure and Features

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

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

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

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

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

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

[Smooth Motion with Low Noise]
As the Ball Screw is based on an end cap mechanism, smooth motion with low noise is achieved.

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

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

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

<table>
<thead>
<tr>
<th>Model</th>
<th>Specification Table</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model BNS-A</td>
<td>B-726</td>
<td>[No Preload Type]</td>
</tr>
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<td>Model BNS</td>
<td>B-728</td>
<td></td>
</tr>
<tr>
<td>Model NS-A</td>
<td>B-730</td>
<td>(Compact type: straight-curved motion)</td>
</tr>
<tr>
<td>Model NS</td>
<td>B-732</td>
<td>(Heavy-load type: straight-curved motion)</td>
</tr>
</tbody>
</table>

---

**Service Life**

For details, see A-704.

**Axial Clearance**

For details, see A-685.
Features of Each Model
Precision Ball Screw/Spline

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-678.)

[Ball Spline]
Clearance in the rotational direction: 0 or less (CL: light preload)
(For detailed specifications, see A-481.)
Accuracy grade: class H
(For detailed specifications, see A-482.)

<table>
<thead>
<tr>
<th>Model No.</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>H</th>
<th>I</th>
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</thead>
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<td>BNS 0812 NS 0812</td>
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<td>0.017</td>
<td>0.014</td>
<td>0.016</td>
<td>0.010</td>
<td>0.013</td>
</tr>
<tr>
<td>BNS 1015 NS 1015</td>
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<td>0.017</td>
<td>0.014</td>
<td>0.016</td>
<td>0.010</td>
<td>0.013</td>
</tr>
<tr>
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<td>0.021</td>
<td>0.016</td>
<td>0.020</td>
<td>0.013</td>
<td>0.016</td>
</tr>
<tr>
<td>BNS 2020 NS 2020</td>
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<td>0.021</td>
<td>0.016</td>
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<tr>
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</table>
## Action Patterns

[Model BNS Basic Actions]

### Motion

<table>
<thead>
<tr>
<th>Action direction</th>
<th>Input</th>
<th>Shaft motion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ball screw pulley</td>
<td>Ball spline pulley</td>
</tr>
<tr>
<td>1. Vertical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Vertical direction → down</td>
<td>N₁ (Forward)</td>
<td>0</td>
</tr>
<tr>
<td>(2) Vertical direction → up</td>
<td>-N₁ (Reverse)</td>
<td>0</td>
</tr>
<tr>
<td>2. Rotation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Vertical direction → forward</td>
<td>N₁ (Forward)</td>
<td>N₂ (Forward)</td>
</tr>
<tr>
<td>(2) Vertical direction → reverse</td>
<td>-N₁ (Reverse)</td>
<td>-N₂ (Reverse)</td>
</tr>
<tr>
<td>3. Spiral</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Vertical direction → up</td>
<td>0</td>
<td>N₂ (N₂ ≠ 0)</td>
</tr>
<tr>
<td>(2) Vertical direction → forward</td>
<td>0</td>
<td>-N₂ (-N₂ ≠ 0)</td>
</tr>
</tbody>
</table>

\[ t : \text{ Ball screw lead (mm)} \]
\[ N₁ : \text{ Ball screw nut rotational speed (min}^{-1}) \]
\[ N₂ : \text{ Spline nut rotational speed (min}^{-1}) \]
Features of Each Model
Precision Ball Screw/Spline

[Model NS Basic Actions]

Ball screw nut
Spline nut
Shaft

Ball screw nut pulley: \( N_1 \)

\( l \): Ball screw lead (mm)
\( N_1 \): Ball screw nut rotational speed (min\(^{-1}\))

<table>
<thead>
<tr>
<th>Motion</th>
<th>Action direction</th>
<th>Input</th>
<th>Shaft motion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ball screw pulley</td>
<td>Vertical direction (speed)</td>
</tr>
<tr>
<td>1. Vertical</td>
<td>Vertical direction ( \rightarrow ) down</td>
<td>( N_1 ) ((\text{Forward}))</td>
<td>( V= N_1 \cdot \frac{l}{N} ) ((N): \neq 0)</td>
</tr>
<tr>
<td>(1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Vertical</td>
<td>Vertical direction ( \rightarrow ) up</td>
<td>( -N_1 ) ((\text{Reverse}))</td>
<td>( V= -N_1 \cdot \frac{l}{N} ) ((N): \neq 0)</td>
</tr>
<tr>
<td>(2)</td>
<td></td>
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</tr>
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</table>
## Model BNS Extended Actions

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<th>Input</th>
<th>Shaft motion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ball screw pulley</td>
<td>Ball spline pulley</td>
</tr>
<tr>
<td>1. Up→down→forward</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>→up→down→reverse</td>
<td>(1) Vertical direction→up</td>
<td>-N&lt;sub&gt;1&lt;/sub&gt; (Reverse)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(2) Vertical direction→down</td>
<td>N&lt;sub&gt;1&lt;/sub&gt; (Forward)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(3) Rotational direction→forward</td>
<td>N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>N&lt;sub&gt;1&lt;/sub&gt; (Forward)</td>
</tr>
<tr>
<td></td>
<td>(4) Vertical direction→up</td>
<td>-N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(5) Vertical direction→down</td>
<td>N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(6) Rotational direction→reverse</td>
<td>-N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>-N&lt;sub&gt;1&lt;/sub&gt; (Reverse)</td>
</tr>
<tr>
<td>2. Down→up→forward</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>→down→up→reverse</td>
<td>(1) Vertical direction→down</td>
<td>N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(2) Vertical direction→up</td>
<td>-N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(3) Rotational direction→forward</td>
<td>N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>N&lt;sub&gt;1&lt;/sub&gt;</td>
</tr>
<tr>
<td></td>
<td>(4) Vertical direction→down</td>
<td>N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(5) Vertical direction→up</td>
<td>-N&lt;sub&gt;1&lt;/sub&gt;</td>
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</tr>
<tr>
<td></td>
<td>(6) Rotational direction→reverse</td>
<td>-N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>-N&lt;sub&gt;1&lt;/sub&gt;</td>
</tr>
<tr>
<td>3. Down→up→forward</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>→up→reverse</td>
<td>(1) Vertical direction→down</td>
<td>N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(2) Rotational direction→forward</td>
<td>N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>N&lt;sub&gt;1&lt;/sub&gt;</td>
</tr>
<tr>
<td></td>
<td>(3) Vertical direction→up</td>
<td>-N&lt;sub&gt;1&lt;/sub&gt;</td>
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<td></td>
<td>(4) Rotational direction→reverse</td>
<td>-N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>-N&lt;sub&gt;1&lt;/sub&gt;</td>
</tr>
<tr>
<td>4. Down→up→reverse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>→reverse→forward</td>
<td>(1) Vertical direction→down</td>
<td>N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(2) Vertical direction→up</td>
<td>-N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(3) Rotational direction→reverse</td>
<td>-N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>-N&lt;sub&gt;1&lt;/sub&gt;</td>
</tr>
<tr>
<td></td>
<td>(4) Rotational direction→forward</td>
<td>N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>N&lt;sub&gt;1&lt;/sub&gt;</td>
</tr>
</tbody>
</table>
Example of Assembly

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

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

Fig. 3 Example of Assembling Model BNS

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

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

Fig. 4 Example of Assembling Model NS
Example of Using the Spring Pad

Ball screw input motor
Shaft
Pulley
Ball screw nut
Support bearing
Pulley
Spline nut
Chuck
Stoke
Stoke

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

<table>
<thead>
<tr>
<th>Category</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure and Features</td>
<td>A-791</td>
</tr>
<tr>
<td>Types and Features</td>
<td>A-792</td>
</tr>
<tr>
<td>Service Life</td>
<td>A-704</td>
</tr>
<tr>
<td>Axial Clearance</td>
<td>A-685</td>
</tr>
<tr>
<td>Accuracy Standards</td>
<td>A-678</td>
</tr>
<tr>
<td>Dimensional Drawing, Dimensional Table (Preload Type)</td>
<td>B-736</td>
</tr>
<tr>
<td>Dimensional Drawing, Dimensional Table (No Preload Type)</td>
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<tr>
<td>Model number coding</td>
<td>B-746</td>
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</table>
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-691.)

[Achieves Roughness of the Ball Raceways of the Screw Shaft at 0.20μm or Less]
The surface of the screw shaft’s ball raceways is specially ground after the shaft is rolled to ensure surface roughness of 0.20μm or less, which is equal to that of the ground thread of the Precision Ball Screw.

[The Ball Raceways of the Ball Screw Nut are All Finished by Grinding]
THK finishes the ball raceways of Rolled Ball Screw nuts by grinding, just as the Precision Ball Screws, to secure the durability and the smooth motion.

[Low Price]
The screw shaft is induction-hardened or carburized after being rolled, and its surface is then specially ground. This allows the rolled Ball Screw to be priced lower than the Precision Ball Screw with a ground thread.

[High Dust-prevention Effect]
The ball screw nut is incorporated with a compact labyrinth seal or a brush seal. This achieves a low friction, a high dust-prevention effect and a longer service life of the Ball Screw.
# Types and Features

## Preload Type

### Model JPF

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.

### No Preload Type

### 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.
**Features of Each Model**

**Rolled Ball Screw**

**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.
<table>
<thead>
<tr>
<th><strong>Service Life</strong></th>
</tr>
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<tbody>
<tr>
<td>For details, see A-704.</td>
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<table>
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<table>
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<tr>
<th><strong>Accuracy Standards</strong></th>
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</thead>
<tbody>
<tr>
<td>For details, see A-678.</td>
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</tbody>
</table>
Features of Each Model
Rolled Ball Screw
Rolled Rotary Ball Screw
Model BLR

Structure and Features
Type
Service Life
 Axial Clearance
 Accuracy Standards
 Example of Assembly
 Dimensional Drawing, Dimensional Table, Example of Model Number Coding
Features of Each Model
Rolled Rotary Ball Screw

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

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

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

[Low Noise even in High-speed Rotation]
Model BLR produces very low noise when the balls are picked up along the end cap. In addition, the balls circulate by passing through the ball screw nut, allowing this model to be used at high speed.

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

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

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

Type

[No Preload Type]

Model BLR

Specification Table→B-748
Service Life

For details, see A-704.

Axial Clearance

For details, see A-685.

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).

<table>
<thead>
<tr>
<th>Model No.</th>
<th>C</th>
<th>D</th>
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<tr>
<td>BLR 1616</td>
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<td>BLR 2020</td>
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<td>BLR 2525</td>
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</tr>
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<td>BLR 3232</td>
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<td>BLR 3636</td>
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<td>BLR 4040</td>
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<td>0.086</td>
</tr>
<tr>
<td>BLR 5050</td>
<td>0.046</td>
<td>0.086</td>
</tr>
</tbody>
</table>

Unit: mm
Features of Each Model
Rolled Rotary Ball Screw

Example of Assembly

[Example of Mounting Ball Screw Nut Model BLR]

![Diagram of Mounting Ball Screw Nut Model BLR]

Standard installation method
Inverted flange

Note: If the flange is to be inverted, indicate "K" in the model number. (applicable only to model BLR)
Example: BLR 2020-3.6 K UU
Symbol for invert
(No symbol for standard flange orientation)

[Example of Mounting Model BLR on the Table]
(1) Screw shaft free, ball screw nut fixed
(Suitable for a long table)

![Diagram of Mounting Model BLR on the Table (Screw Shaft Fixed)]

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

![Diagram of Mounting Model BLR on the Table (Ball Screw Nut Fixed)]
Ball Screw
Ball Screw Peripherals
**Support Unit**

Models EK, BK, FK, EF, BF and FF

---

**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.

---

Fig.1 Structure of the Support Unit
[Uses the Optimal Bearing]
To ensure the rigidity balance with the Ball Screw, the Support Unit uses an angular bearing (contact angle: 30°; DF configuration) with a high rigidity and a low torque. Miniature Support Unit models EK/FK 4, 5, 6 and 8 are incorporated with a miniature angular bearing with a contact angle of 45° developed exclusively for miniature Ball Screws. This bearing has a greater contact angle of 45° and an increased number of balls with a smaller diameter. The high rigidity and accuracy of the miniature angular bearing provides the stable rotational performance.

[Support Unit Shapes]
The square and round shapes are available for the Support Unit to allow the selection according to the intended use.

[Compact and Easy Installation]
The Support Unit is compactly designed to accommodate the space in the installation site. As the bearing is provided with an appropriately adjusted preload, the Support Unit can be assembled with a Ball Screw unit with no further machining. Accordingly, the required man-hours in the assembly can be reduced and the assembly accuracy can be increased.
### Type

#### [For the Fixed Side]

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
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<td></td>
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</tbody>
</table>

   ![Image](image1.png)

(Inner diameter: φ4 to φ20)

<table>
<thead>
<tr>
<th>Round Type Model FK</th>
<th>Specification Table</th>
<th>B-758</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   ![Image](image2.png)

(Inner diameter: φ6 to φ30)

#### [For the Supported Side]

<table>
<thead>
<tr>
<th>Square Type Model EF</th>
<th>Specification Table</th>
<th>B-762</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   ![Image](image3.png)

(Inner diameter: φ6 to φ20)

<table>
<thead>
<tr>
<th>Round Type Model FF</th>
<th>Specification Table</th>
<th>B-766</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   ![Image](image4.png)

(Inner diameter: φ6 to φ30)

<table>
<thead>
<tr>
<th>Square Type Model BK</th>
<th>Specification Table</th>
<th>B-756</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   ![Image](image5.png)

(Inner diameter: φ10 to φ40)

<table>
<thead>
<tr>
<th>Round Type Model BF</th>
<th>Specification Table</th>
<th>B-764</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   ![Image](image6.png)

(Inner diameter: φ8 to φ40)
### Types of Support Units and Applicable Screw Shaft Outer Diameters

<table>
<thead>
<tr>
<th>Inner diameter of the fixed side Support Unit (mm)</th>
<th>Applicable model No. of the fixed side Support Unit</th>
<th>Inner diameter of the supported side Support Unit (mm)</th>
<th>Applicable model No. of the supported side Support Unit</th>
<th>Applicable screw shaft outer diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>EK 4</td>
<td>—</td>
<td>—</td>
<td>φ4</td>
</tr>
<tr>
<td>5</td>
<td>EK 5</td>
<td>—</td>
<td>—</td>
<td>φ6</td>
</tr>
<tr>
<td>6</td>
<td>EK 6</td>
<td>6</td>
<td>EF 6</td>
<td>φ8</td>
</tr>
<tr>
<td>8</td>
<td>EK 8</td>
<td>6</td>
<td>EF 8</td>
<td>φ10</td>
</tr>
<tr>
<td>10</td>
<td>EK 10</td>
<td>8</td>
<td>EF 10</td>
<td>φ12, φ14</td>
</tr>
<tr>
<td>12</td>
<td>EK 12</td>
<td>10</td>
<td>EF 12</td>
<td>φ14, φ15, φ16</td>
</tr>
<tr>
<td>15</td>
<td>EK 15</td>
<td>15</td>
<td>EF 15</td>
<td>φ20</td>
</tr>
<tr>
<td>17</td>
<td>BK 17</td>
<td>17</td>
<td>BF 17</td>
<td>φ20, φ25</td>
</tr>
<tr>
<td>20</td>
<td>EK 20</td>
<td>20</td>
<td>EF 20</td>
<td>φ25, φ28, φ32</td>
</tr>
<tr>
<td>25</td>
<td>FK 25</td>
<td>25</td>
<td>FF 25</td>
<td>φ36</td>
</tr>
<tr>
<td>30</td>
<td>FK 30</td>
<td>30</td>
<td>FF 30</td>
<td>φ40, φ45</td>
</tr>
<tr>
<td>35</td>
<td>BK 35</td>
<td>35</td>
<td>BF 35</td>
<td>φ45</td>
</tr>
<tr>
<td>40</td>
<td>BK 40</td>
<td>40</td>
<td>BF 40</td>
<td>φ50</td>
</tr>
</tbody>
</table>

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-810.
## Model Numbers of Bearings and Characteristic Values

<table>
<thead>
<tr>
<th>Support Unit model No.</th>
<th>Bearing model No.</th>
<th>Axial direction</th>
<th>Support Unit model No.</th>
<th>Bearing model No.</th>
<th>Radial direction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Basic dynamic load rating Ca (kN)</td>
<td>Note) Permissible load (kN)</td>
<td>Rigidity (N/µm)</td>
<td>Basic dynamic load rating C (kN)</td>
</tr>
<tr>
<td>EK 4 FK 4</td>
<td>AC4-12P5</td>
<td>0.93</td>
<td>1.1</td>
<td>27</td>
<td>—</td>
</tr>
<tr>
<td>EK 5 FK 5</td>
<td>AC5-14P5</td>
<td>1</td>
<td>1.24</td>
<td>29</td>
<td>—</td>
</tr>
<tr>
<td>EK 6 FK 6</td>
<td>AC6-16P5</td>
<td>1.38</td>
<td>1.76</td>
<td>35</td>
<td>EF 6 FF 6</td>
</tr>
<tr>
<td>EK 8 FK 8</td>
<td>79M8DF GMP5</td>
<td>2.93</td>
<td>2.15</td>
<td>49</td>
<td>EF 8</td>
</tr>
<tr>
<td>EK 10 FK 10 BK 10</td>
<td>7000HTDF GMP5</td>
<td>6.08</td>
<td>3.1</td>
<td>65</td>
<td>EF 10 FF 10 BF 10</td>
</tr>
<tr>
<td>EK 12 FK 12 BK 12</td>
<td>7001HTDF GMP5</td>
<td>6.66</td>
<td>3.25</td>
<td>88</td>
<td>EF 12 FF 12 BF 12</td>
</tr>
<tr>
<td>EK 15 FK 15 BK 15</td>
<td>7002HTDF GMP5</td>
<td>7.6</td>
<td>4</td>
<td>100</td>
<td>EF 15 FF 15 BF 15</td>
</tr>
<tr>
<td>BK 17</td>
<td>7203HTDF GMP5</td>
<td>13.7</td>
<td>5.85</td>
<td>125</td>
<td>BF 17</td>
</tr>
<tr>
<td>EK 20 FK 20</td>
<td>7204HTDF GMP5</td>
<td>17.9</td>
<td>9.5</td>
<td>170</td>
<td>EF 20 FF 20</td>
</tr>
<tr>
<td>BK 20</td>
<td>7004HTDF GMP5</td>
<td>12.7</td>
<td>7.55</td>
<td>140</td>
<td>BF 20</td>
</tr>
<tr>
<td>FK 25 BK 25</td>
<td>7205HTDF GMP5</td>
<td>20.2</td>
<td>11.5</td>
<td>190</td>
<td>FF 25 BF 25</td>
</tr>
<tr>
<td>FK 30 BK 30</td>
<td>7206HTDF GMP5</td>
<td>28</td>
<td>16.3</td>
<td>195</td>
<td>FF 30 BF 30</td>
</tr>
<tr>
<td>BK 35</td>
<td>7207HTDF GMP5</td>
<td>37.2</td>
<td>21.9</td>
<td>255</td>
<td>BF35</td>
</tr>
<tr>
<td>BK 40</td>
<td>7208HTDF GMP5</td>
<td>44.1</td>
<td>27.1</td>
<td>270</td>
<td>BF 40</td>
</tr>
</tbody>
</table>

*Note*) "Permissible load" indicates the static permissible load.
Example of Installation

[Square Type Support Unit]

Fig.2 Example of Installing a Square Type Support Unit

[Round Type Support Unit]

Fig.3 Example of Installing a Round Type Support Unit
Mounting Procedure

[Installing the Support Unit]
(1) Install the fixed side Support Unit with the screw shaft.
(2) After inserting the fixed side Support Unit, secure the lock nut using the fastening set piece and the hexagonal socket-head setscrews.
(3) Attach the supported side bearing to the screw shaft and secure the bearing using the snap ring, and then install the assembly to the housing on the supported side.

Note1) Do not disassemble the Support Unit.
Note2) When inserting the screw shaft to the Support Unit, take care not to let the oil seal lip turn outward.
Note3) When securing the set piece with a hexagonal socket-head setscrew, apply an adhesive to the hexagonal socket-head setscrew before tightening it in order to prevent the screw from loosening. If planning to use the product in a harsh environment, it is also necessary to take a measure to prevent other components/parts from loosening. Contact THK for details.

[Installation onto the Table and the Base]
(1) If using a bracket when mounting the ball screw nut to the table, insert the nut into the bracket and temporarily fasten it.
(2) Temporarily fasten the fixed side Support Unit to the base.
   In doing so, press the table toward the fixed side Support Unit to align the axial center, and adjust the table so that it can travel freely.
   • If using the fixed side Support Unit as the reference point, secure a clearance between the ball screw nut and the table or inside the bracket when making adjustment.
   • If using the table as the reference point, make the adjustment either by using the shim (for a square type Support Unit), or securing the clearance between the outer surface of the nut and the inner surface of the mounting section (for a round type Support Unit).
(3) Press the table toward the fixed-side Support Unit to align the axial center. Make the adjustment by reciprocating the table several times so that the nut travels smoothly throughout the whole stroke, and temporarily secure the Support Unit to the base.
[Checking the Accuracy and Fully Fastening the Support Unit]
While checking the runout of the ball screw shaft end and the axial clearance using a dial gauge, fully fasten the ball screw nut, the nut bracket, the fixed side Support Unit and the supported-side Support Unit, in this order.

[Connection with the Motor]
(1) Mount the motor bracket to the base.
(2) Connect the motor and the ball screw using a coupling.  
Note: Make sure the mounting accuracy is maintained.
(3) Thoroughly perform the break-in for the system.
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.

<table>
<thead>
<tr>
<th>Mounting method</th>
<th>Symbol for shaft end shape</th>
<th>Shape</th>
<th>Supported Support Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed</td>
<td>H J</td>
<td>H1</td>
<td>FK EK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>J1</td>
<td>BK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H2</td>
<td>FK EK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>J2</td>
<td>BK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H3</td>
<td>FK EK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>J3</td>
<td>BK</td>
</tr>
<tr>
<td>Supported</td>
<td>K</td>
<td></td>
<td>FF EF BF</td>
</tr>
</tbody>
</table>
Ball Screw Peripherals
Support Unit
Nut bracket
Model MC

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-774
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

<table>
<thead>
<tr>
<th>Lock Nut Model RN</th>
<th>Specification Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model RN</td>
<td>B-776</td>
</tr>
</tbody>
</table>
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-954. Also, QZ Lubricator is available as an optional accessory that significantly increases the maintenance interval.

Corrosion Prevention (Surface Treatment, etc.)
Depending on the service environment, the Ball Screw requires anticorrosive treatment or a different material. For details of an anticorrosive treatment and a material change, contact THK. (see A-18)

Contamination Protection
The dust and foreign materials that enter the Ball Screw may cause accelerated wear and breakage, as with roller bearings. Therefore, on parts where contamination by dust or foreign materials (e.g., cutting chips) is predicted, screw shafts must always be completely covered by contamination protection devices (e.g., bellows, screw cover, wiper ring). If the Ball Screw is used in an atmosphere free from the foreign materials but with suspended dust, a labyrinth seal (for precision Ball Screws) with symbol RR and a brush seal (for rolled Ball Screws) with symbol ZZ can be used as contamination protection devices. The labyrinth seal is designed to maintain a slight clearance between the seal and the screw shaft raceway so that torque does not develop and no heat is generated, though its effect in contamination protection is limited.

With Ball Screws except the large lead and super lead types, there is no difference in nut dimensions between those with and without a seal. With the wiper ring, special resin with high wear resistance and low dust generation removes foreign materials while closely contacting the circumference of the ball screw shaft and the screw thread. It is capable of preventing foreign materials from entering the Ball Screw even in a severe environment.

Fig. 1 Contamination Protection Cover
QZ Lubricator 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.

[Features]
- Since it supplements an oil loss, the lubrication maintenance interval can be significantly extended.
- Since the right amount of lubricant is applied to the ball raceway, an environmentally friendly lubrication system that does not contaminate the surroundings is achieved.

Note) QZ Lubricator has a vent hole. Do not block the hole with grease or the like.
**Significantly extended maintenance interval**

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

[Graph: QZ Lubricator only]

No anomaly observed after running 10000km

[Distance traveled km (linear travel distance)]

- 0
- 2000
- 4000
- 6000
- 8000
- 10000

**Test conditions**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball Screw</td>
<td>BIF2510</td>
</tr>
<tr>
<td>Maximum rotational speed</td>
<td>2500min⁻¹</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>25m/min</td>
</tr>
<tr>
<td>Stroke</td>
<td>500mm</td>
</tr>
<tr>
<td>Load</td>
<td>Internal preload only</td>
</tr>
</tbody>
</table>

**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.

[Graph: QZ Lubricator + THK AFA Grease]

- QZ Lubricator + THK AFA Grease
- 32cm³
- (QZ Lubricator attached to both ends of the ball screw nut)

**Compared**

- Forced lubrication
- 0.25cm³/3min×24h×125d
- =15000cm³

Reduced to approx. $\frac{1}{470}$
Wiper Ring W

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.

<table>
<thead>
<tr>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>● A total of eight slits on the circumference remove foreign materials in succession, and prevent entrance of foreign material.</td>
</tr>
<tr>
<td>● Contacts the ball screw shaft to reduce the flowing out of grease.</td>
</tr>
<tr>
<td>● Contacts the ball screw shaft at a constant pressure level using a spring, thus to minimize the heat generation.</td>
</tr>
<tr>
<td>● 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.</td>
</tr>
</tbody>
</table>
Test in an environment exposed to contaminated environment

[Test conditions]

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model No.</td>
<td>BIF3210-550+1500LC5</td>
</tr>
<tr>
<td>Maximum rotational speed</td>
<td>1000min⁻¹</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>10m/min</td>
</tr>
<tr>
<td>Maximum circumferential speed</td>
<td>1.8m/s</td>
</tr>
<tr>
<td>Time constant</td>
<td>60ms</td>
</tr>
<tr>
<td>Dowel</td>
<td>1s</td>
</tr>
<tr>
<td>Stroke</td>
<td>900mm</td>
</tr>
<tr>
<td>Load (through internal load)</td>
<td>1.31kN</td>
</tr>
<tr>
<td>Grease</td>
<td>THK AFG Grease 8cm³</td>
</tr>
<tr>
<td></td>
<td>(initial lubrication to the ball screw nut only)</td>
</tr>
<tr>
<td>Foundry dust</td>
<td>FC400 average particle diameter: 250μm</td>
</tr>
<tr>
<td>Volume of foreign material per shaft</td>
<td>5g/h</td>
</tr>
</tbody>
</table>

[Test result]

- **Type with wiper ring**
  - Slight flaking occurred in the ball screw shaft at travel distance of 1,000 km.
  - Wear of balls at a travel distance of 2,000 km: 1.4 μm.

- **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.
  - Starts to be worn rapidly after 500 km, and the ball wear amount at the travel distance of 2,000 km: 11 μm.

<table>
<thead>
<tr>
<th>Distance traveled (km)</th>
<th>No problem</th>
<th>Flaking occurs on the ball screw shaft raceway</th>
<th>Flaking occurs on the ball</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1600</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Change in the ball after traveling 2000 km

- **(1) Type with wiper ring**
  - Unused ball
  - Flaking occurs
- **(2) Type with labyrinth seal**
  - Unused ball
  - Flaking occurs

- **(3) Type with wiper ring**
  - Discolored, but no breakage
  - Flaking occurs

- **(4) Type with labyrinth seal**
  - Discolored, but no breakage
  - Flaking occurs
Heat Generation Test

[Test conditions]

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model No.</td>
<td>BLK3232-3.6G0+1426LC5</td>
</tr>
<tr>
<td>Maximum rotational speed</td>
<td>1000min⁻¹</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>32m/min</td>
</tr>
<tr>
<td>Maximum circumferential speed</td>
<td>1.7m/s</td>
</tr>
<tr>
<td>Time constant</td>
<td>100ms</td>
</tr>
<tr>
<td>Stroke</td>
<td>1000mm</td>
</tr>
<tr>
<td>Load (through internal load)</td>
<td>0.98kN</td>
</tr>
<tr>
<td>Grease</td>
<td>THK AFG Grease 5cm³ (contained in the ball screw nut)</td>
</tr>
</tbody>
</table>

[Test result]

**Item** | **With wiper ring** | **Without seal** |
--- | --- | ---
Heat generation temperature | 37.1 | 34.5 |
Temperature rise | 12.2 | 8.9 |
Specifications of the Bellows

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

<table>
<thead>
<tr>
<th>Band type</th>
<th>Flange type</th>
</tr>
</thead>
</table>

**Number of Units To Be Manufactured:**

**Remarks:**

**Location:** (indoor, outdoor)

**Speed:** (          )mm/sec.   mm/min.

**Motion:**

**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:**

---

**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:**

---

**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:**

---
Options
Specifications of the Bellows
Method for Mounting the Ball Screw Shaft

Fig. 1 to Fig. 4 show the representative mounting methods for the screw shaft. The permissible axial load and the permissible rotational speed vary with mounting methods for the screw shaft. Therefore, it is necessary to select an appropriate mounting method according to the conditions.

Fig. 1 Screw Shaft Mounting Method: Fixed - Free

Fig. 2 Screw Shaft Mounting Method: Fixed - Supported
Mounting Procedure and Maintenance
Method for Mounting the Ball Screw Shaft

Fig. 3 Screw Shaft Mounting Method: Fixed - Fixed

Distance between two mounting surfaces (permissible axial load)
Distance between two mounting surfaces (permissible rotational speed)

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

Distance between two mounting surfaces (permissible axial load)
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).

<table>
<thead>
<tr>
<th>Shaft diameter (mm)</th>
<th>Amount of lubricant (cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 8</td>
<td>0.03</td>
</tr>
<tr>
<td>10 to 14</td>
<td>0.05</td>
</tr>
<tr>
<td>15 to 18</td>
<td>0.07</td>
</tr>
<tr>
<td>20 to 25</td>
<td>0.1</td>
</tr>
<tr>
<td>28 to 32</td>
<td>0.15</td>
</tr>
<tr>
<td>36 to 40</td>
<td>0.25</td>
</tr>
<tr>
<td>45 to 50</td>
<td>0.3</td>
</tr>
<tr>
<td>55 to 63</td>
<td>0.4</td>
</tr>
<tr>
<td>70 to 100</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Precautions on Use

[Handling]
1. Disassembling the components may cause dust to enter the system or degrade the mounting accuracy of parts. Do not disassemble the product.
2. Tilting the screw shaft and the ball screw nut may cause them to fall by their own weight.
3. Dropping or hitting the Ball Screw may damage the ball circulation section, which may cause the functional loss. Giving an impact to the product could also cause a damage to its function even if the product looks intact.

[Lubrication]
1. Thoroughly remove anti-rust oil and feed lubricant before using the product.
2. Do not mix the lubricants of different physical properties.
3. In locations exposed to constant vibrations or in special environments such as clean rooms, a vacuum and a low/high temperature, normal lubricants may not be used. Contact THK for details.
4. When planning to use a special lubricant, contact THK before using it.
5. The lubrication interval varies according to the conditions. Contact THK for details.

[Precautions on Use]
1. Do not remove the ball screw nut from the ball screw shaft. Doing so may cause the balls or the nut to fall off.
2. Entrance of foreign materials to the ball screw nut may cause damages to the ball circulating path or functional loss. Prevent foreign materials, such as dust or cutting chips, from entering the system.
3. If the foreign materials such as dust or cutting chips adheres to the product, replenish the lubricant after cleaning the product with pure white kerosene. For available types of detergent, contact THK.
4. When planning to use the product in an environment where the coolant penetrates the spline nut, it may cause problems to product functions depending on the type of the coolant. Contact THK for details.
5. Contact THK if you desire to use the product at a temperature of 80°C or higher.
6. If using the product with vertical mount, the ball screw nut may fall by its weight. Attach a mechanism to prevent it from failing.
7. Exceeding the permissible rotational speed may lead the components to be damaged or cause an accident. Be sure to use the product within the specification range designated by THK.
8. Forcefully driving in the ball screw shaft or the ball screw nut may cause an indentation on the raceway. Use care when mounting the components.
9. If an offset or skewing occurs with the ball screw shaft support and the ball screw nut, it may substantially shorten the service life. Pay attention to components to be mounted and to the mounting accuracy.
10. When using the product in locations exposed to constant vibrations or in special environments such as clean rooms, a vacuum and a low/high temperature, contact THK in advance.
11. Letting the ball screw nut overshoot will cause balls to fall off or the ball-circulating components to be damaged.
[Storage]
When storing the Ball Screw, enclose it in a package designated by THK and store it in a horizontal orientation while avoiding a high temperature, a low temperature and a high humidity.
Lead Screw Nut

THK General Catalog

A Technical Descriptions of the Products

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  • Features of the Special Rolled Shafts A-831
  • High Strength Zinc Alloy A-831

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Selecting a Lead Screw Nut A-833
Efficiency and Thrust A-836
Accuracy Standards A-837

Point of Design A-838
Fit A-838

Mounting Procedure and Maintenance A-839
Installation A-839
Lubrication A-840

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* Please see the separate "B Product Specifications".
Features of the Lead Screw Nut

Structure and Features

The lead Screw Nut models DCM and DC are manufactured to meet the standards for the 30° trapezoidal threads. They use a special alloy (see A-831) for the nuts and have a precision male thread, formed through die casting, as the core. As a result, these bearings achieve less unevenness in accuracy and higher accuracy and wear resistance than the machined lead screw nuts.

For the screw shafts to be used with this product, the rolled shafts are available as the standard. In addition, the cut screw shafts and the ground screw shafts are also available according to the application. Contact THK for details.
Features of the Special Rolled Shafts

The dedicated rolled shafts with the standardized lengths are available for the Lead Screw Nut.

[Increased Wear Resistance]
The shaft teeth are formed by cold gear rolling, and the surface of the tooth surface is hardened to over 250 HV and are mirror-finished. As a result, the shafts are highly wear resistant and achieve significantly smooth motion when used in combination with lead screw nuts.

[Improved Mechanical Properties]
Inside the teeth of the rolled shaft, a fiber flow occurs along the contour of the tooth surface of the shaft, making the structure around the teeth roots dense. As a result, the fatigue strength is increased.

[Additional Machining of the Shaft End Support]
Since each shaft is rolled, additional machining of the support bearing of the shaft end can easily be performed by lathing or milling.

High Strength Zinc Alloy

The high strength zinc alloy used in the lead screw nuts is a material that is highly resistant to seizure and the wear and has a high load carrying capacity. Its composition, the mechanical properties, the physical properties and the wear resistance are given below.

[Composition]

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>3 to 4</td>
</tr>
<tr>
<td>Cu</td>
<td>3 to 4</td>
</tr>
<tr>
<td>Mg</td>
<td>0.03 to 0.06</td>
</tr>
<tr>
<td>Be</td>
<td>0.02 to 0.06</td>
</tr>
<tr>
<td>Ti</td>
<td>0.04 to 0.12</td>
</tr>
<tr>
<td>Zn</td>
<td>Remaining portion</td>
</tr>
</tbody>
</table>
### Mechanical Properties

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>275 to 314 N/mm²</td>
</tr>
<tr>
<td>Tensile yield strength (0.2%)</td>
<td>216 to 245 N/mm²</td>
</tr>
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<td>Compressive strength</td>
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<td>294 to 343 N/mm²</td>
</tr>
<tr>
<td>Fatigue strength</td>
<td>132 N/mm²×10⁷ (Schenk bending test)</td>
</tr>
<tr>
<td>Charpy impact</td>
<td>0.098 to 0.49 N·m/mm²</td>
</tr>
<tr>
<td>Elongation</td>
<td>1 to 5 %</td>
</tr>
<tr>
<td>Hardness</td>
<td>120 to 145 HV</td>
</tr>
</tbody>
</table>

### Physical Properties

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
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</tr>
<tr>
<td>Specific heat</td>
<td>460 J/(kg·K)</td>
</tr>
<tr>
<td>Melting point</td>
<td>390°C</td>
</tr>
<tr>
<td>Thermal expansion coefficient</td>
<td>$24 \times 10^{-6}$</td>
</tr>
</tbody>
</table>

### Wear Resistance

![Fig 1 Wear Resistance of the High Strength Zinc Alloy](image)

<table>
<thead>
<tr>
<th>Test conditions: Amsler wear-tester</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test piece rotational speed</td>
<td>185 min⁻¹</td>
</tr>
<tr>
<td>Load</td>
<td>392 N</td>
</tr>
<tr>
<td>Lubricant</td>
<td>Dynamo oil</td>
</tr>
</tbody>
</table>
Selecting a Lead Screw Nut

[Dynamic Permissible Torque T and Dynamic Permissible Thrust F]

The dynamic permissible torque (T) and the dynamic permissible thrust (F) are the torque and the thrust at which the contact surface pressure on the tooth surface of the bearing is 9.8 N/mm². These values are used as a measuring stick for the strength of the lead screw nut.

[pV Value]

With a sliding bearing, a pV value, which is the product of the contact surface pressure (p) and the sliding speed (V), is used as a measuring stick to judge whether the assumed model can be used. Use the corresponding pV value indicated in Fig. 1 as a guide for selecting a lead screw nut. The pV value varies also according to the lubrication conditions.

* f₁: Safety Factor

To calculate a load applied to the lead screw nut, it is necessary to accurately obtain the effect of the inertia that changes with the weight and dynamic speed of an object. In general, with the reciprocating or the rotating machines, it is not easy to accurately obtain all the factors such as the effect of the start and stop, which are always repeated. Therefore, if the actual load cannot be obtained, it is necessary to select a bearing while taking into account the empirically obtained safety factors (f₁) shown in Table 1.

<table>
<thead>
<tr>
<th>Type of load</th>
<th>Lower limit of f₁</th>
</tr>
</thead>
<tbody>
<tr>
<td>For a static load less frequently used</td>
<td>1 to 2</td>
</tr>
<tr>
<td>For an ordinary single-directional load</td>
<td>2 to 3</td>
</tr>
<tr>
<td>For a load accompanied by vibrations/impact</td>
<td>4 or greater</td>
</tr>
</tbody>
</table>

![Fig. 1 pV Value](image-url)
Temperature Factor

If the temperature of the lead screw nut exceeds the normal temperature range, the seizure resistance of the nut and the strength of the material will decrease. Therefore, it is necessary to multiply the dynamic permissible torque (T) and the dynamic permissible thrust (F) by the corresponding temperature factor indicated in Fig. 2. Accordingly, when selecting a lead screw nut, the following equations need to be met in terms of its strength.

Dynamic permissible torque (T)

\[ f_s \cdot f_T \cdot T \]

Static permissible thrust (F)

\[ f_s \cdot f_T \cdot F \]

- \( f_s \): Safety factor (see A-833 Table 1)
- \( f_T \): Temperature factor (see Fig. 2)
- \( T \): Dynamic permissible torque (N-m)
- \( P_T \): Applied torque (N-m)
- \( F \): Dynamic permissible thrust (N)
- \( P_F \): Axial load (N)

Hardness of the Surface and the Wear Resistance

The hardness of the shaft significantly affects the wear resistance of the lead screw nut. If the hardness is equal to or less than 250 HV, the abrasion loss increases as indicated in Fig. 3. The roughness of the surface should preferably be 0.80a or less.

A special rolled shaft achieves the surface hardness of 250 HV or greater, through hardening as a result of rolling, and surface roughness of 0.20a or less. Therefore, the dedicated rolled shaft is highly wear resistant.
Point of Selection
Selecting a Lead Screw Nut

[Calculating the Contact Surface Pressure \(p\)]
The value of "\(p\)" is obtained as followed.

\[
p = \frac{P_f \times 9.8}{F}
\]

- \(p\) : Contact surface pressure on the tooth from an axial load \((P_f, N)\) (N/mm\(^2\))
- \(F\) : Dynamic permissible thrust \((N)\)
- \(P_f\) : Axial load \((N)\)

[Calculating the Sliding Speed \(V\) on the Teeth]
The value of "\(V\)" is obtained as followed.

\[
V = \frac{\pi \times D_0 \times n \times \cos \alpha \times 10^{-3}}{10}
\]

- \(V\) : Sliding speed \((m/min)\)
- \(D_0\) : Effective diameter \((mm)\)
  (see specification table)
- \(n\) : Rotation speed per minute \((min^{-1})\)
- \(\alpha\) : Lead angle \((degree)\)
  (see specification table)
- \(R\) : Lead \((mm)\)

[Example of Calculation]
Assuming that Lead Screw Nut model DCM is used, select a lead screw nut that travels at feed speed \(S = 3\ m/min\) while receiving an axial load \(P_f = 1,080\ N\), which is applied in one direction. First, tentatively select model DCM32 (dynamic permissible thrust \(F = 21,100\ N\)). Obtain the contact surface pressure \((p)\).

\[
p = \frac{P_f \times 9.8}{F} = \frac{1080 \times 9.8}{21100} \approx 0.50\ N/mm^2
\]

Obtain the sliding speed \((V)\).
The rotation speed per minute \((n)\) of the screw shaft needed to move it at feed speed \(S = 3\ m/min\) is calculated as follows.

\[
n = \frac{S}{l \times 10^{-2}} = \frac{3}{6 \times 10^{-2}} = 500\ min^{-1}
\]

\[
V = \frac{\pi \times D_0 \times n \times \cos \alpha \times 10^{-3}}{10} = \frac{\pi \times 29 \times 500}{\cos 3^\circ 46' \times 10^{-3}} \approx 45.6\ m/min
\]

From the diagram of \(pV\) values (see Fig.1 on A-833), it is judged that there will be no abnormal wear if the sliding speed \((V)\) is 47 m/min or below against the "\(p\)" value of 0.50 N/mm\(^2\). Second, obtain the safety factor \((f_s)\) against the dynamic permissible thrust \((F)\). Given the conditions: temperature factor \(f_t = 1\) and applied load \(P_f = 1,080\ N\), the safety factor is calculated as follows.

\[
f_s \geq \frac{f_r \times F}{P_f} = \frac{1 \times 21100}{1080} = 19.5
\]

Since the required strength will be met if "\(f_s\)" is at least 2 because of the type of load, it is appropriate to select model DCM32.
Efficiency and Thrust

The efficiency ($\eta$) at which the screw transfers a torque into thrust is obtained from the following equation.

$$\eta = \frac{1 - \mu \tan \alpha}{1 + \mu / \tan \alpha}$$

$\eta$: Efficiency
$\alpha$: Lead angle
$\mu$: Frictional resistance

Fig.4 shows the result of the above equation.

The thrust generated when a torque is applied is obtained from the following equation.

$$F_a = \frac{2 \cdot \pi \cdot \eta \cdot T}{R \times 10^{-3}}$$

$F_a$: Thrust generated (N)
$T$: Torque (input) (N-m)
$R$: Lead (mm)

\[ \text{Fig.4 Efficiency} \]

**[Example of Calculation]**

Assuming that Lead Screw Nut model DCM20 is used and the input torque $T = 19.6$ N-m, obtain the thrust to be generated.

Calculate the efficiency ($\eta$) when $\mu = 0.2$.

The lead angle ($\alpha$) of model DCM20: 4° 3'

From the diagram in Fig.4, the efficiency ($\eta$) when the friction coefficient $\mu = 0.2$ is obtained as $\eta = 0.257$.

Obtain the thrust generated.

$$F_a = \frac{2 \cdot \pi \cdot \eta \cdot T}{R \times 10^{-3}} = \frac{2 \times \pi \times 0.25 \times 19.6}{4 \times 10^{-3}} \approx 7700 \text{ N}$$
## Accuracy Standards

### Table 2: Accuracy of the Screw Shaft of Models DCM and DC

<table>
<thead>
<tr>
<th>Shaft symbol</th>
<th>Rolled shaft</th>
<th>Cut shaft</th>
<th>Ground shaft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>T&lt;sup&gt;max&lt;/sup&gt;</td>
<td>K&lt;sup&gt;max&lt;/sup&gt;</td>
<td>G&lt;sup&gt;max&lt;/sup&gt;</td>
</tr>
<tr>
<td>Single pitch error (max)</td>
<td>±0.020</td>
<td>±0.015</td>
<td>±0.005</td>
</tr>
<tr>
<td>Accumulated pitch error (max)</td>
<td>±0.15/300</td>
<td>±0.05/300</td>
<td>±0.015/300</td>
</tr>
</tbody>
</table>

Note: Symbols T, K and G indicate machining methods for the screw shaft. The cut shafts and ground shafts are built-to-order.
Fit

For the fitting between the lead screw nut circumference and the housing, we recommend a loose fitting or a tight fitting.

Housing inner-diameter tolerance: H8 or J8
Installation

[About Chamfer of the Housing’s Mouth]
To increase the strength of the root of the flange of the lead screw nut, the corner is machined to have an R shape. Therefore, it is necessary to chamfer the inner edge of the housing’s mouth.

![Fig.1](image1)

<table>
<thead>
<tr>
<th>Table 1 Chamfer of the Housing’s Mouth</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Unit: mm</em></td>
</tr>
<tr>
<td>Model No.</td>
</tr>
<tr>
<td>DCM</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td>18</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>22</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>28</td>
</tr>
<tr>
<td>32</td>
</tr>
<tr>
<td>36</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>45</td>
</tr>
<tr>
<td>50</td>
</tr>
</tbody>
</table>

[Recommended Mounting Orientation]
When vertically conveying a heavy object using the screw shaft, it is safe to mount the screw as shown in Fig.2 where supports are provided on the mounting holes to prevent the moving object from falling even if the lead screw nut is broken due to an overload or an impact.

![Fig.2](image2)
Example of Installation

Fig.3 shows examples of mounting the lead screw nuts. When mounting a lead screw nut, secure sufficient tightening strength in the axial direction. For the housing inner-diameter tolerance, see the section concerning fitting on A-838.

Lubrication

Select a lubrication method according to the conditions of the lead screw nut.

Oil Lubrication

For a lubrication of the lead screw nut, an oil lubrication is recommended. Specifically, an oil-bath lubrication or drop lubrication is particularly effective. An oil-bath lubrication is the most appropriate method since it meets harsh conditions such as high speed, a heavy load or an external heat transmission and it cools the lead screw nut. The drop lubrication is appropriate for low to medium speed and a light to medium load. Select a lubricant according to the conditions as indicated in Table2.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Types of Lubricants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low speed, high load, high temp.</td>
<td>High-viscosity sliding surface oil or turbine oil</td>
</tr>
<tr>
<td>High speed, light load, low temp.</td>
<td>Low-viscosity sliding surface oil or turbine oil</td>
</tr>
</tbody>
</table>

Grease Lubrication

In the low-speed feed, which occurs less frequently, the user can lubricate the slide system by manually applying grease to the shaft on a regular basis or using the greasing hole on the lead screw nut. We recommend using lithium-soap group grease No. 2.
Change Nut

THK General Catalog

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• Features of the Special Rolled Shafts... A-843
• High Strength Zinc Alloy............... A-843

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Accuracy Standards...................... A-849

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Fit ........................................... A-850

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B Product Specifications (Separate)

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Models DCMA and DCMB ................. B-792

* Please see the separate "B Product Specifications".
Features of the Change Nut

Structure and Features

The Change Nut models DCMA and DCMB have a lead angle of 45°, which is difficult to achieve through machining. Each model is capable of converting a straight motion to a rotary motion, or vice versa, at 70% efficiency. Because of the large leads, they are optimal for providing a fast feed mechanism at a low-speed rotation. The multi-thread screw shafts to be combined with these change nuts are formed through cold gear rolling. The surface of the teeth is hardened to over 250 HV and mirror-finished. As a result, the shafts are highly wear resistant and achieve significantly smooth motion when used in combination with these change nuts. Models DCMA40, DCMB40 or higher are designed for use in combination with the cut screw shafts.

The Miniature Change Nuts are made of an oil-impregnated plastic, and have a wear resistance and excel in lubrication especially in an oil-less operation. In addition, since the high level of their performances can be maintained for a long period, they allow long-term maintenance-free operation.
Features of the Special Rolled Shafts

Dedicated rolled shafts with the standardized lengths are available for the Change Nut.

[Increased Wear Resistance]
The shaft teeth are formed by cold gear rolling, and the tooth surface is hardened to over 250 HV and mirror-finished. As a result, the shafts are highly wear resistant and achieve significantly smooth motion when used in combination with the nuts.

[Improved Mechanical Properties]
Inside the teeth of the rolled shaft, a fiber flow occurs along the contour of the tooth surface of the shaft, making the structure around the teeth roots dense. As a result, the fatigue strength is increased.

[Additional Machining of the Shaft End Support]
Since each shaft is rolled, additional machining of the support bearing of the shaft end can easily be performed by lathing or milling.

High Strength Zinc Alloy

The high strength zinc alloy used in the change nuts is a material that is highly resistant to seizure and the wear and has a high load carrying capacity. Its composition, the mechanical properties, the physical properties and the wear resistance are given below.

[Composition]

Table 1 Composition of the High Strength Zinc Alloy

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<tr>
<td>Thermal expansion coefficient</td>
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[Wear Resistance]

[Test conditions: Amsler wear-tester]

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<td>Lubricant</td>
<td>Dynamo oil</td>
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</table>
Selecting a Change Nut

[Dynamic Permissible Torque T and Dynamic Permissible Thrust F]

The dynamic permissible torque (T) and the dynamic permissible thrust (F) are the torque and the thrust at which the contact surface pressure on the tooth surface of the bearing is 9.8 N/mm². These values are used as a measuring stick for the strength of the change nut.

[pV Value]

With a sliding bearing, a pV value, which is the product of the contact surface pressure (p) and the sliding speed (V), is used as a measuring stick to judge whether the assumed model can be used. Use the corresponding pV value indicated in Fig.1 as a guide for selecting a change nut. The pV value varies also according to the lubrication conditions.

● \( f_s \): Safety Factor

To calculate a load applied to the change nut, it is necessary to accurately obtain the effect of the inertia that changes with the weight and the dynamic speed of an object. In general, with the reciprocating or the rotating machines, it is not easy to accurately obtain all the factors such as the effect of the start and stop, which are always repeated. Therefore, if the actual load cannot be obtained, it is necessary to select a bearing while taking into account the empirically obtained safety factors \( f_s \) shown in Table1.
If the temperature of the change nut exceeds the normal temperature range, the seizure resistance of the nut and the strength of the material will decrease. Therefore, it is necessary to multiply the dynamic permissible torque \( T \) and the dynamic permissible thrust \( F \) by the corresponding temperature factor indicated in Fig.2.

Note: In the case of a miniature Change Nut, be sure to use it at 60°C or below.

Accordingly, when selecting a change nut, the following equations need to be met in terms of its strength.

**Dynamic permissible torque**

\[
\text{Dynamic permissible torque (T)} \quad f_s = \frac{f_r \cdot T}{P_r}
\]

**Static permissible thrust**

\[
\text{Static permissible thrust (F)} \quad f_s = \frac{f_r \cdot F}{P_r}
\]

- \( f_s \): Static safety factor (see Table 1 on A-845)
- \( f_r \): Temperature factor (see Fig.2)
- \( T \): Dynamic permissible torque \( (\text{N-m}) \)
- \( P_r \): Applied torque \( (\text{N-m}) \)
- \( F \): Dynamic permissible thrust \( (\text{N}) \)
- \( P_r \): Axial load \( (\text{N}) \)

**Hardness of the Surface and Wear Resistance**

The hardness of the shaft significantly affects the wear resistance of the change nut. If the hardness is equal to or less than 250 HV, the abrasion loss increases as indicated in Fig.3. The roughness of the surface should preferably be 0.80a or less.

A special rolled shaft achieves surface hardness of 250 HV or greater, through hardening as a result of rolling, and surface roughness of 0.20a or less. Thus, the dedicated rolled shaft is highly wear resistant.
[Calculating the Contact Surface Pressure \( p \)]
The value of "\( p \)" is obtained as followed.

● If an axial load is applied:

\[
p = \frac{P_r}{F} \times 9.8
\]

\( p \) : Contact surface pressure on the tooth from an axial load (\( P_r \) N) (N/mm\(^2\))
\( F \) : Dynamic permissible thrust (N)
\( P_r \) : Axial load (N)

● If a torque is applied:

\[
p = \frac{P_T}{T} \times 9.8
\]

\( p \) : Contact surface pressure on the tooth under a load torque (\( P_T \) N-m) (N/mm\(^2\))
\( T \) : Dynamic permissible torque (N-m)
\( P_T \) : Applied torque (N-m)

[Calculating the Sliding Speed \( V \) on the Teeth]
The value of "\( V \)" is obtained as followed.

\[
V = \frac{Z \cdot \pi \cdot D_o \cdot n}{10^3}
\]

\( V \) : Sliding speed (m/min)
\( D_o \) : Effective diameter (see specification table) (mm)
\( n \) : Rotation speed per minute (min\(^{-1}\))
\( R \) : Lead (mm)
**Example of Calculation**

Assuming that Change Nut model DCMB is used, select a screw nut that travels at feed speed $S = 10$ m/min while receiving an axial load $P_F = 1,760$ N accompanied by vibrations.

First, tentatively select model DCMB25T (dynamic permissible thrust $F = 12,700$ N).

Obtain the contact surface pressure ($p$).

\[
p = \frac{P_F \times 9.8}{F} = \frac{1760 \times 9.8}{12700} \approx 1.36 \text{ N/mm}^2
\]

Obtain the sliding speed ($V$). The revolutions per minute ($n$) of the screw shaft needed to move it at feed speed $S = 10$ m/min is calculated as follows.

\[
n = \frac{S}{R \times 10^{-3}} = \frac{3}{73.3 \times 10^{-2}} \approx 136 \text{ min}^{-1}
\]

\[
V = \frac{\sqrt{2} \cdot \pi \cdot D_o \cdot n}{10^3} = \frac{\sqrt{2} \times \pi \times 23.1 \times 136}{10^3} \approx 14.0 \text{ m/min}
\]

From the diagram of $pV$ values (see Fig.1 on A-845), it is judged that there will be no abnormal wear if the sliding speed ($V$) is 16 m/min or below against the $p$ value of 1.36 N/mm².

Second, obtain the safety factor ($f_S$) against the dynamic permissible thrust ($F$). Given the conditions:

- Temperature factor $f_T = 1$, and
- Applied load $P_F = 1,760$ N, the safety factor is calculated as follows.

\[
f_S = \frac{f_T \cdot F}{P_F} = \frac{1 \times 12700}{1760} = 7.2
\]

Since the required strength will be met if $f_S$ is at least 4 because of the type of load, it is appropriate to select model DCMB25T.
Efficiency, Thrust and Torque

The efficiency ($\eta$) of the change nut in relation to the friction coefficient ($\mu$) is indicated in Table 2.

<table>
<thead>
<tr>
<th>Frictional coefficient ($\mu$)</th>
<th>0.1</th>
<th>0.15</th>
<th>0.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency ($\eta$)</td>
<td>0.82</td>
<td>0.74</td>
<td>0.67</td>
</tr>
</tbody>
</table>

The thrust generated when a torque is applied is obtained from the following equation.

$$F_a = 2 \cdot \pi \cdot \eta \cdot \frac{T}{R} \times 10^{-3}$$

- $F_a$ : Thrust generated (N)
- $T$ : Torque (input) (N-m)
- $R$ : Lead (mm)

Also, the torque generated when a thrust is applied is obtained from the following equation.

$$T = \eta \cdot F_a \cdot R \cdot 10^{-3}/2\pi$$

- $T$ : Torque generated (N-m)
- $F_a$ : Thrust (input) (N)
- $R$ : Lead (mm)

[Example of Calculation - 1]

Assuming that Change Nut model DCMB20T is used and the torque $T$ is equal to 19.6 N-m, obtain the thrust to be generated.

If $\mu$ is 0.2, the efficiency $\eta$ is 0.67 (see Table 2), and the generated thrust ($F_a$) is calculated as follows.

$$F_a = 2 \cdot \pi \cdot \eta \cdot \frac{T}{R} \times 10^{-3} = \frac{2 \times \pi \times 0.67 \times 19.6}{60 \times 10^{-3}} \approx 1370 \text{ N}$$

[Example of Calculation - 2]

Assuming that Change Nut model DCMB20T is used and the thrust $F_a$ is equal to 980 N, obtain the torque to be generated.

If $\mu$ is 0.2, the efficiency $\eta$ is 0.67 (see Table 2), and the generated torque ($T$) is calculated as follows.

$$T = \frac{\eta \cdot F_a \cdot R \cdot 10^{-3}}{2\pi} = \frac{0.67 \times 980 \times 60 \times 10^{-3}}{2\pi} = 6.27 \text{ N-m}$$

Accuracy Standards

<table>
<thead>
<tr>
<th>Shaft symbol</th>
<th>Rolled shaft</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>$T$</td>
</tr>
<tr>
<td>Single pitch error (max)</td>
<td>$\pm 0.025$</td>
</tr>
<tr>
<td>Accumulated pitch error (max)</td>
<td>$\pm 0.02$</td>
</tr>
</tbody>
</table>

Note: Symbol $T$ indicates the machining method for the screw shaft.
**Fit**

For the fitting between the change nut circumference and the housing, we recommend a loose fitting or a tight fitting.

Housing inner-diameter tolerance: H8 or J8
Installation

[About Chamfer of the Housing’s Mouth]
To increase the strength of the root of the flange of the change nut, the corner is machined to have an R shape. Therefore, it is necessary to chamfer the inner edge of the housing’s mouth.

![Fig.1]

[Recommended Mounting Orientation]
When vertically conveying a heavy object using the screw shaft, it is safe to mount the screw as shown in Fig.2 where supports are provided on the mounting holes to prevent the moving object from falling even if the change nut is broken due to an overload or an impact.

![Fig.2 Recommended Mounting Orientation]

<table>
<thead>
<tr>
<th>Table 1 Chamfer of the Housing’s Mouth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model No.</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>DCMA</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>15</td>
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<td>40</td>
</tr>
<tr>
<td>45</td>
</tr>
<tr>
<td>50</td>
</tr>
</tbody>
</table>

Unit: mm
Lubrication

Select a lubrication method according to the conditions of the change nut.

[Oil Lubrication]
For the lubrication of the change nut, an oil lubrication is recommended. Specifically, an oil-bath lubrication or a drop lubrication is particularly effective. An oil-bath lubrication is the most appropriate method since it meets the harsh conditions such as a high speed, a heavy load or an external heat transmission and it cools the change nut. The drop lubrication is appropriate for the low to medium speed and a light to medium load. Select a lubricant according to the conditions as indicated in Table 2.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Types of Lubricants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low speed, high load, high temp.</td>
<td>High-viscosity sliding surface oil or turbine oil</td>
</tr>
<tr>
<td>High speed, light load, low temp.</td>
<td>Low-viscosity sliding surface oil or turbine oil</td>
</tr>
</tbody>
</table>

[Grease Lubrication]
In a low-speed feed, which occurs less frequently, the user can lubricate the slide system by manually applying the grease to the shaft on a regular basis or using the greasing hole on the change nut. We recommend using the lithium-soap group grease No. 2.

[Initial Lubrication of the Miniature Change Nut]
Since the Miniature Change Nut is made of oil-impregnated plastics, it can be used without the lubrication during an operation. For the initial lubrication, use some oil or grease. Note that lubricants containing large amount of extreme pressure agent are not suitable.