Use the following steps to select a ball screw suited to the usage criteria.

**Step 1** Check on Operating Conditions
Refer to Operating Conditions below.

<table>
<thead>
<tr>
<th>NO</th>
<th>Item</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Positioning Accuracy</td>
<td>mm</td>
</tr>
<tr>
<td>2</td>
<td>Stroke</td>
<td>mm</td>
</tr>
<tr>
<td>3</td>
<td>Travel Speeds</td>
<td>mm/s</td>
</tr>
<tr>
<td>4</td>
<td>Drive Motor Speed</td>
<td>min⁻¹</td>
</tr>
<tr>
<td>5</td>
<td>Weight of Workpiece and Table</td>
<td>Kg</td>
</tr>
<tr>
<td>6</td>
<td>Mounting Orientation</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>Life Hours</td>
<td>Time</td>
</tr>
<tr>
<td>8</td>
<td>Motion pattern (Duty Cycle Line Diagram)</td>
<td>-</td>
</tr>
</tbody>
</table>

**Step 2** Interim Selection of Ball Screw
Consider the applicability of the following items to the conditions confirmed in step 1 and provisionally decide the ball screw.

1. Selection of Lead Accuracy of Ball Screws
   - Select the ball screw that satisfies the positioning precision. Check the following two points.
     - Lead Accuracy
     - Axial Clearance
   For details, see P.2224 on the catalog.

2. Selection of Ball Screw Shaft Length
   Generally, the shaft length should be + stroke + shaft end of 50~150 mm + allowance.
   The allowance is to prevent detachment, and one end should be (lead x 1.5~2) mm or more.

3. Provisional positioning of lead
   - Travel speeds, and speed of the drive motor should be used to select the lead.

4. Temporary selection of the shaft diameter
   - Weight of work and table, and mounting position, and provisionally decided load should be used to select the shaft diameter.

**Step 3** Allowable Axial Load Check
The max. axial load to the ball screw must be equal to or less than the allowable axial load value.
If a load exceeding the allowable axial load is applied, it is possible that the ball screw’s shaft will buckle. (Figure 2)

**Allowable Axial Load**
The allowable axial load represents an allowed maximum load, including a safety margin, to prevent shaft buckling from occurrence.
The finer the shaft diameter or the longer the shaft the easier it is for buckling to occur.
For details, see P.2225 on the catalog.

**Step 4** Allowable Rotational Speed Check
The rotational speed of the ball screw must be less than the allowable rotational speed.
If it exceeds the allowable rotational speed, the thread and the nut will be affected in the following way.

- Screw Shaft: When the allowable rotational speed is exceeded, resonance will begin at a unique oscillating frequency and this might disable operation. (Figure 3)
- Nut: If the orbital speed of the steel balls inside the nut becomes large, it is possible that the circulation components will be damaged by the impact force. (Figure 4)

**Allowable Rotational Speed**
Referring to the allowable rotational speed that is 90% or less of the critical speed that matches the rotational speed of a ball screw at which there is a unique oscillation possessed by the screw shaft.
The allowable rotational speed is decided by the necessary travel speed and ball screw lead.
To decide the allowable rotational speed, it is necessary to consider the following two elements.
1. Critical speed for the rotating shaft
2. Limit rotational speed of the balls circulating inside the nut
For details, see P.2226 on the catalog.

**Step 5** Life Check
In order to use the equipment beyond the expected life, life calculations are required.

**Operating Hours of Ball Screws**
This refers to the ball revolutions, time, or distances up until chipping begins to occur due to fatigue causes by some kind of repetitive stress on the ball rolling surface or balls. The Whisker of the ball screw is calculated from the basic dynamic load rating. See Figures 5 and 6 for expired parts that have chips.

- When a certain group of the same ball screws are operated with a certain axial load and 90% of the screws achieve 1 million rotations (10⁶) without flaking in its operating life, such axial load is defined as a basic dynamic load rating.

For details, see P.2227 on the catalog.

**Step 6** Determination
If the results of steps 1 through 5 are NG, return to the previous step. If all are OK, you can use the ball screw.

**Figure 1 (Ex.) Duty Cycle Line Diagram**

**Figure 2 Buckled Ball Screw**

**Figure 3 Resonating Ball Screw**

**Figure 4 Ball Screw Circulation Structure (Tube Style)**

**Figure 5 Thread Inside Nut**

**Figure 6 Flaking on Ball Screw Components**
### Ball Screw Lineup

<table>
<thead>
<tr>
<th>Type</th>
<th>Standard Type</th>
<th>Shaft Dia.</th>
<th>Lead</th>
<th>Axial Play</th>
<th>Shaft Length Tolerance (MIN, MAX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Product</td>
<td>BSSC</td>
<td>15</td>
<td>5</td>
<td>0.005 or Less</td>
<td>100 - 110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>10</td>
<td>0.010 or Less</td>
<td>110 - 120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
<td>10</td>
<td>0.012 or Less</td>
<td>110 - 120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>10</td>
<td>0.020 or Less</td>
<td>110 - 120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25</td>
<td>10</td>
<td>0.025 or Less</td>
<td>110 - 120</td>
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<tr>
<td></td>
<td></td>
<td>32</td>
<td>10</td>
<td>0.040 or Less</td>
<td>110 - 120</td>
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<td></td>
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<td>32</td>
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<td>0.060 or Less</td>
<td>110 - 120</td>
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<td></td>
<td></td>
<td>40</td>
<td>10</td>
<td>0.040 or Less</td>
<td>110 - 120</td>
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<td>10</td>
<td>0.050 or Less</td>
<td>110 - 120</td>
</tr>
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<td></td>
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<td>50</td>
<td>15</td>
<td>0.070 or Less</td>
<td>110 - 120</td>
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<td>0.060 or Less</td>
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<td>63</td>
<td>15</td>
<td>0.080 or Less</td>
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<td>110 - 120</td>
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<td>80</td>
<td>15</td>
<td>0.100 or Less</td>
<td>110 - 120</td>
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<td>20</td>
<td>0.120 or Less</td>
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<td>0.180 or Less</td>
<td>110 - 120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>125</td>
<td>25</td>
<td>0.250 or Less</td>
<td>110 - 120</td>
</tr>
</tbody>
</table>

### Accuracy Grade

- **Accuracy Grade**: Lead Accuracy of Ball Screws defined by JIS Standards. Smaller numbers mean higher lead precision.

### Meaning of Terms

- **Accuracy Grade**: Lead Accuracy of Ball Screws defined by JIS Standards. Smaller numbers mean higher lead precision.
- **Shaft Dia.**: Screw O.D.
- **Lead**: Refers to the distance a nut moves when the screw shaft makes a full rotation.
- **Axial Play**: Axial play between the screw shaft and nuts.
**Precautions on Handling Ball Screws**

- **Precautions on Handling**
  1. When removing the nut from the screw shaft, the ball screw may be damaged due to misalignment or tilting. Do not disassemble the ball screw. It may also affect the dust ingress, vibration, and wear of the ball screw. Damage to the ball screw may reduce its life expectancy.
  2. When using Ball Screws, do not let a ball screw nut overrun. It may cause the balls to fall out or damage the ball recirculation parts.
  3. Cautions on use
     - Do not give an external impact to a screw shaft outer diameter, thread, and recirculation parts. It may cause recirculation failure and a malfunction.
  4. Precautions on Handling
     - Use dedicated temporary shafts when removing Ball Nuts. If the nut is removed from the shaft, the balls contained in the nut will fall out and the ball screw will become unusable.

- **Cautions on use**
  1. Do not give an external impact to a screw shaft outer diameter, thread, and recirculation parts. It may cause recirculation failure and a malfunction.
  2. Do not let a ball screw nut overrun. It may cause the balls to fall out or damage the ball recirculation parts.
  3. Do not use Ball Screws at temperatures of more than 60°C, as it may damage recirculation parts or shafts.
  4. Do not misuse or install ball screws on the support side and a ball nut. Nut faces may become extremely distorted due to an offset load to a ball screw nut.

- **Rolled Ball Screws - About Removing Ball Screws**
  If the nut is removed from the shaft, the balls contained in the nut will fall out and the ball screw will become unusable. Use dedicated temporary shafts when removing Ball Nuts. Refer to the steps described above. Nut faces can be damaged by removing the nuts using the temporary shafts without the dedicated tools. The use of other tools may cause damage to the ball screw, therefore, it is important to use the dedicated tools.

- **Precautions on Designing and Assembling Peripherals**
  1. Be cautious when assembling the ball screw peripherals, particularly when the ball screw peripherals are mounted in a position where they will be subjected to a radial load or a moment load. The assembly should be done carefully to avoid causing misalignment and tilting of the ball screw peripherals.
  2. Design/machining precision of ball screw peripherals can be factors that cause misalignment and tilting. Be particularly cautious when the ball screw peripherals are mounted in a position where they will be subjected to a radial load or a moment load.

**Lubrication, Grease Measures, Cautions on Designing and Assembling Peripherals**

- **Precautions on Designing and Assembling Peripherals**
  1. Be cautious when assembling the ball screw peripherals, particularly when the ball screw peripherals are mounted in a position where they will be subjected to a radial load or a moment load. The assembly should be done carefully to avoid causing misalignment and tilting of the ball screw peripherals.
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**Available Ball Screws and Grease Types**

- **Grease Performance**
  - Type | L Type | G Type
  - Standard Load | Minimum Load

**Grease Performance**

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**Design of Ball Screws and Peripherals, Caution when Assembling**

- **Misalignment of Ball Screw and Support Unit (Figure 1)**
  - Misalignment occurs when the shaft center of the ball screw fixed to the fixed-side support unit is misaligned with the center of the shaft bearing of the support unit on the support side.
  - Measurement allowance (reference):
    - ±10 µm
  - When there is excessive misalignment, the ball screw may jam or the support unit may be damaged.

- **Parallelism of ball screw and linear guide (Figure 2)**
  - Parallelism is required when the ball screw is fitted to the guide's linear guide or precision ball screw. The parallelism should be within the specified range by the ball screw manufacturer.
  - Tolerances allowed (reference):
    - ±100 µm
  - When the parallelism is excessive, the linear guide or precision ball screw may jam or be damaged.

- **Lubrication, Grease Measures, Cautions on Designing and Assembling Peripherals**
  1. Be cautious when assembling the ball screw peripherals, particularly when the ball screw peripherals are mounted in a position where they will be subjected to a radial load or a moment load. The assembly should be done carefully to avoid causing misalignment and tilting of the ball screw peripherals.
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- **Grease Performance**
  - Type | L Type | G Type
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  1. Be cautious when assembling the ball screw peripherals, particularly when the ball screw peripherals are mounted in a position where they will be subjected to a radial load or a moment load. The assembly should be done carefully to avoid causing misalignment and tilting of the ball screw peripherals.
  2. Design/machining precision of ball screw peripherals can be factors that cause misalignment and tilting. Be particularly cautious when the ball screw peripherals are mounted in a position where they will be subjected to a radial load or a moment load.
1. Ball Screw Selection Procedure

Basic ball screw selection procedure and required evaluation items are shown below.

- Determine the application parameters
- Select a set of ball screw specifications
- Evaluate various basic safety factors

Moving mass, feed speed, motion pattern, screw shaft rotational speed, stroke, mounting orientation (horizontal or vertical), life, positioning accuracy

Temporary selection of ball screw lead accuracy grade (C3~C10), shaft diameter, load, and length.

- Axial Lead Capacity: Confirm that the applied axial load is within the ball screw’s axial load capacity rating.
- Allowable Rotational Speed: Confirm that the intended shaft rotational speed is within the ball screw’s allowable rotational speed rating.
- Life: Confirm that the ball screw satisfies the life requirement.

Ball screw lead accuracy is defined by JIS Standards property parameters (ep, vu, v300, v2π).

2. Ball Screw Lead Accuracy

Ball screw lead accuracy is defined by JIS Standards property parameters (ep, vu, v300, v2π).

Parameter definitions and allowable values are shown below.

- Actual Travel:
- Travel:
- Specified:
- Terms Symbols Meaning

3. Axial Clearances of Ball Screws

Axial clearance does not affect positioning accuracy if the feed is unidirectional, but will generate backlash and negatively affect on positioning accuracy if the direction or the axial load is reversed.

Select the axial clearance in such a way that the current requirement for positioning accuracy are met.

### Table 5. Axial Clearances of Precision Ball Screws

<table>
<thead>
<tr>
<th>Types</th>
<th>Screw</th>
<th>Lead</th>
<th>Axial Clearance (μm)</th>
<th>Screw Shell Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-VALUE Products Standard Nut Accuracy Grade C3</td>
<td>10</td>
<td>0.05 or less</td>
<td>2000</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.10 or less</td>
<td>2000</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.20 or less</td>
<td>3000</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>0.30 or less</td>
<td>3000</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>0.30 or less</td>
<td>3000</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>0.30 or less</td>
<td>3000</td>
<td>1200</td>
</tr>
<tr>
<td>Existing Products Standard Nut Accuracy Grade C3</td>
<td>10</td>
<td>0.05 or less</td>
<td>2000</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.10 or less</td>
<td>2000</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.20 or less</td>
<td>3000</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>0.30 or less</td>
<td>3000</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>0.30 or less</td>
<td>3000</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>0.30 or less</td>
<td>3000</td>
<td>1200</td>
</tr>
</tbody>
</table>

Selection Example of Axial Clearance

- Requirements:
  - Ball screw diameter Ø15, lead 5.
  - Allowable backlash ±0.01mm
- Selection Details:
  - From Table 5., it can be determined that C5 grade with 0.005mm or less axial clearance satisfies the allowable backlash amount of ±0.01mm for the Ø15 group.

### Table 4. Axial Clearances of Rolled Ball Screws

<table>
<thead>
<tr>
<th>Types</th>
<th>Screw</th>
<th>Lead</th>
<th>Axial Clearance (μm)</th>
<th>Screw Shell Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSSC</td>
<td>8</td>
<td>0.10 or less</td>
<td>1200</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.20 or less</td>
<td>1200</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.30 or less</td>
<td>1200</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.30 or less</td>
<td>1200</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>0.30 or less</td>
<td>1200</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>0.30 or less</td>
<td>1200</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>0.30 or less</td>
<td>1200</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>0.30 or less</td>
<td>1200</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>0.30 or less</td>
<td>1200</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>0.30 or less</td>
<td>1200</td>
<td>600</td>
</tr>
</tbody>
</table>

Selection Example of Lead Accuracy

- Requirements:
  - Ball screw diameter Ø15, lead 5.
  - Allowable backlash ±0.01mm
- Selection Details:
  - From Table 1., it can be determined that C5 grade with 0.005mm or less axial clearance satisfies the allowable backlash amount of ±0.01mm for the Ø15 group.

### Table 5. Axial Clearances of Precision Ball Screws

- **Selection Details**:
  - "Selection Details":
  - Select an appropriate lead accuracy grade based on the application requirements.
  - (1) Evaluating the screw thread length:
    - Stiffness Value Length = 2 × (Ø + D + L + M + E)
    - "The Margin above is an overrun buffer and normally determined as 1.5~2 times the screw lead.
    - Lead 20 × 3/4 (both ends) ≤ 60
  - (2) Evaluating the lead accuracy:
    - Verify the actual mean travel error and for 842mm ball screw thread by referencing the Table 1. on P2223.
    - C3 = ±0.020mm/1000mm
    - C5 = ±0.040mm/1000mm
  - (3) Determining the lead accuracy:
    - It can be determined that a C5 grade ±0.040/1000mm ball screw can satisfy the required positioning accuracy of ±0.05/720mm.
### Selection of Ball Screws

#### 4. Allowable Axial Load
Allowable Axial Load is a load with a safety margin built-in against a shaft bucking load. Axial load that applies to a ball screw needs to be less than Allowable Maximum Axial Load. Allowable Axial Load can be obtained by the following formula.

$$P = \frac{n\pi^2 E I}{d^4}$$

Where:
- **P**: Allowable Axial Load (N)
- **n**: Coefficient Determined by Method of Screw Support
- **m**: Coefficient Determined by Method of Screw Support
- **I**: Min. Geometrical Moment of Inertia of Across Root Thread Area (mm4)
- **E**: Young’s Modulus (2.06×10^5 N/mm2)
- **d**: Thread Root Diameter (mm)

### Allowable Axial Load Calculation Example

#### Figure 1. Allowable Axial Load Curve

#### Table 1

<table>
<thead>
<tr>
<th>Distance of Supports (mm)</th>
<th>Allowable Axial Load Calculation Example</th>
<th>Minimum Allowable Axial Load Calculation Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>1000 rpm</td>
<td>682 rpm</td>
</tr>
<tr>
<td>1500</td>
<td>1500 rpm</td>
<td>1076 rpm</td>
</tr>
</tbody>
</table>

**How to use**
- Thread shaft diameter ø15, Lead 5
- Mounting method Fixed - Support
- Distance between Points of Buckling Load ø15 = 830mm

- **Calculations**
  - \(g = \frac{P}{10^7} \) = 2.382 × 10^7 (rpm)
  - \(d = \frac{d}{12.5} \) = 1.25 mm

Therefore, the rotational speed will need to be 3024 rpm or less.

### Selection of Ball Screws

#### 5. Allowable Rotational Speed

Ball screw rotational speed is determined by required feed speed and the given screw lead, and needs to be less than the Allowable Maximum Rotational Speed. Ball screw rotational speed is evaluated based on the shaft’s critical speed and ball recirculation speed limit DmN value.

#### 5-1. Critical Speed

Allowable rotational speed is defined as a speed 80% or less of the Critical Speed where the rotational speed coincides with a natural resonant frequency of the screw shaft. The Allowable Rotational Speed can be obtained by the following formula.

$$Nc = g \frac{60}{\sqrt{\pi d}} \times 10^7$$

Where:
- **g**: Geometrical Moment of Inertia (mm4)
- **d**: Thread outer diameter (mm)
- **m**: Coefficient Determined by Method of Screw Support

#### Table 2

<table>
<thead>
<tr>
<th>Screw Shaft Dia. Calculation Example</th>
<th>Minimum Allowable Rotational Speed Calculation Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) From Table 2, find an intersection of a vertical line from Supported Span Distance 1500mm and Screw Shaft O.D. Ø20 line.</td>
<td>Allowable Rotational Speed Calculation Example</td>
</tr>
<tr>
<td>(2) The value 1076rpm on the Fixed-Supported scale (Y-Axis) that corresponds to the intersection (1) above is the Allowable Maximum Rotation Speed.</td>
<td>Find the Allowable Maximum Rotational Speed for Fig.2</td>
</tr>
<tr>
<td></td>
<td>(1) From Table 2, find an intersection of a vertical line from Supported Span Distance 1500mm and Screw Shaft O.D. Ø20 line.</td>
</tr>
<tr>
<td></td>
<td>(2) The value 1076rpm on the Fixed-Supported scale (Y-Axis) that corresponds to the intersection (1) above is the Allowable Maximum Rotation Speed.</td>
</tr>
</tbody>
</table>

#### Figure 2. Allowable Rotational Speed Graph
6. Life Span

Ball screws life is defined as: Total number of rotations, time, or distance where either the ball rolling surfaces or the balls begin to exhibit repetitive stress caused by flaking. Ball screw life can be calculated based on Basic Dynamic Load Rating with the following formula.

\[ L = \frac{10^6}{60N_m} \left( \frac{C}{P_{mfw}} \right)^{3} \text{ (hrs)} \]

Where:
- \( L \): Life Hours (hrs)
- \( N_m \): Basic Dynamic Load Rating (N)
- \( C \): Dynamic Load Rating (N)
- \( P_{mfw} \): Applied Load (N)
- \( t \): Work Factor

**Work Factors**
- Imperfect Run = \( t \) = 1.0 ~ 1.2
- Normal Run = \( t \) = 1.2 ~ 1.5
- Run with impact = \( t \) = 1.5 ~ 2.0

**Basic Dynamic Load Rating**: C

Basic Dynamic Load Rating (C) is defined as an axial load which a group of ball screws are subjected and 99% of the specimen will reach 1 million rotations (10^6) without experiencing any flaking of the rolling surfaces. See product catalog pages for the Basic Dynamic Load Ratings.

**Setting life span hours longer than what is actually necessary not only requires a larger ball screw, but also increases the price.**
In general, the following standards are used for life span hours:
- Machine Tools: 20,000hrs
- Automatic Control Equipment: 15,000hrs
- Industrial Machinery: 10,000hrs
- Measuring Instruments: 5,000hrs.

**The basic dynamic load rating that satisfies the set life span hours is expressed by the following formula.**

\[ C = \frac{60L_h}{N_m} P_{mfw} \times 10^6 \]

**6-2. Axial Load**

Axial loads that apply on the screw shafts will vary depending on applicable motion profile such as acceleration, constant velocity, and deceleration phases. Following formulas can be used.

**Axial Load Formulas**
- **Constant Velocity**
  - Axial Load (Pf)=μW
  - Acceleration - Axial Load (Pa)=μW
  - Deceleration - Axial Load (Pd)=μW

** (*): For vertical applications:**
- μ: Linear motion guide friction coefficient (0.02)
- W: Load Mass (N)
- g: Gravitational Acceleration (9.8m/s^2)
- Acceleration (**): m/s^2

**(*): Acceleration (a) = 0.9x(a) (min)^2**
- t: Rapid Feed Rate (mm)
- t: Acceleration/Deceleration Time (s)

**6-3. Formulas for Average Axial Load and Average Rotational Speed**

Average Axial Load and Average Rotational Speed are calculated based on proportions of motion profiles, Average Axial Load and Average Rotational Speed for Motion profiles in Table 1. can be calculated with the formulas 2.

**Table 1. Motion Profile**

<table>
<thead>
<tr>
<th>Motion Profile</th>
<th>Axial Load</th>
<th>Rotational Speed</th>
<th>Hours Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>20N</td>
<td>N/min</td>
<td>t/0.001</td>
</tr>
<tr>
<td>P</td>
<td>20N</td>
<td>N/min</td>
<td>t/0.001</td>
</tr>
<tr>
<td>P</td>
<td>20N</td>
<td>N/min</td>
<td>t/0.001</td>
</tr>
</tbody>
</table>

**([Formula 2. Average Axial Load Calculation])**

\[ P_{mfw} = \frac{P_{1}t_{1} + P_{2}t_{2} + P_{3}t_{3}}{t_{1} + t_{2} + t_{3}} \]

For machine tool applications, max. load (Pf) is applicable for the “Heaviest loading” regular load (P) for the general cutting conditions, and Minimum Load (Pd) is for the non-cutting rapid feeds during positioning moves.

**Average Axial Load Calculation Example**

**([Requirements])**
- Motion Profile A
- Axial Load 20N
- Rotational Speed 300rpm
- Hours Ratio 20/85%

**([Calculations])**

(1) Average Axial Load

\[ P_{mfw} = \frac{20N \times 0.20 + 20N \times 0.45 + 20N \times 0.35}{0.20 + 0.45 + 0.35} = 105.89 \text{ (N)} \]

Therefore, the Average Axial Load Pf will be 26N.

(2) Average Rotational Speed

\[ N_m = \frac{20N \times 0.20 + 20N \times 0.45 + 20N \times 0.35}{0.20 + 0.45 + 0.35} = 2110 \text{ (mm/rev)} \]

Therefore, the Average Rotational Speed Nm will be 2110rpm.

8. Temperature and Life

When ball screws are continuously used at 100°C or higher, or used momentarily at very high temperatures, Basic Dynamic/Static Load Ratings will be reduced according to the temperature rise due to changes in material compositions. However, there will be no effects up to 100°C. Basic Dynamic Load Rating C' and Basic Static Load Rating C'' at 100°C or higher with the temperature correction factor \( f_t \) and \( f_t' \) can be expressed with the following formula.

\[ C_0'' = f_t' C_0' (N) \]
\[ C'' = f_t C (N) \]

Where:
- C: Basic Dynamic Load Rating (N)
- C''=Basic Dynamic Load Rating C'' at 100°C or higher with the temperature correction factor \( f_t' \) and \( f_t' \)
- C': Basic Static Load Rating C' at 100°C or higher with the temperature correction factor \( f_t' \) and \( f_t' \)
- f_t: Temperature factor (0.52 ~ 1.00)
- f_t': Temperature factor (0.93 ~ 1.00)

**7. Screw Shaft Mounting Arrangements**

Representative ball screw mounting arrangements are shown below.

**Application Methods**
- Typical method: Medium—High Accuracy
- For Support Units: Type BMR

**9. Rigidity**

To improve positioning accuracy and control response of a machine, consideration must be given to the rigidity of feed screws elements. Rigidity (K) of feed screw system can be expressed with the following formula.

\[ K = \frac{P}{d^2} \text{ (Nm/µm)} \]

Where:
- P: Axial Load (N)
- d: Screw Shaft Root Diameter (mm)

The expansion and contraction are expressed in the following formula. The expansion and contraction will directly appear as ball screw backlash.

(1) Fixed-Free Arrangement

\[ \Delta = \frac{P \times L}{E \times d^2} \text{ (µm)} \]

Where:
- P: Axial Load (N)
- d: Screw Shaft Root Diameter (mm)
- L: Load Applicable Span Distance (mm)

(2) Fixed-Free Arrangement

\[ \Delta = \frac{4P^2L}{E \times d^2} \text{ (µm)} \]

Where:
- P: Axial Load (N)
- d: Screw Shaft Root Diameter (mm)
- L: Load Applicable Span Distance (mm)
- E: Young’s Modulus (2.06x10^5N/mm^2)

The formula produces the max. value when \( \ell = \ell' = \frac{L}{2} \)
[Technical Data]

Selection of Ball Screws 4

10. Driving Torque

This selection provides a guide for selecting ball screw frictional properties and the driving motor.

10-1. Friction and Efficiency

When the friction coefficient $\mu$ and lead angle $\beta$, ball screw's efficiency $\eta$ is indicated by the following formulas:

\[ \eta = \frac{1 - \mu \tan \beta}{1 + \mu \tan \beta} \]

When rotational force is converted into axial force (Forward Action)

\[ \eta = \frac{1 - \mu \tan \beta}{1 + \mu \tan \beta} \]

When axial force is converted into rotational force (Reverse Action)

\[ \eta = \frac{1 - \mu \tan \beta}{1 + \mu \tan \beta} \]

10-2. Load Torque

The load torque is the constant rotational torque required for the driving motor. Therefore, the load torque can be obtained by the following formulas.

\[ T = \frac{P}{\pi \cdot N \cdot \tan \beta} \]

Where:
- $P$: Load Torque (N)
- $N$: Motor Thread Rotational Speed (rpm)
- $\beta$: Lead Angle

(1) Friction Torque Caused by Preloading

This is the friction torque generated by preloading. As external loads increase, the friction torque also increases.

\[ T_f = \frac{P_L}{\pi \cdot N} \]

Where:
- $P_L$: Preload (N)
- $N$: Motor Thread Rotational Speed (rpm)

(2) Friction Torque Caused by Moment of Inertia

This is the friction torque generated by the moment of inertia. As external loads increase, the moment of inertia also increases.

\[ T_{inertia} = \frac{J \cdot \omega}{\pi} \]

Where:
- $J$: Moment of Inertia Exerted on Motor (kg·cm²)
- $\omega$: Angular Speed (rad/s)

(3) Friction Torque Caused by Preloading

This is the friction torque generated by preloading. As external loads increase, the friction torque also increases.

\[ T_{friction} = \frac{P_L}{\pi \cdot N} \]

Where:
- $P_L$: Preload (N)
- $N$: Motor Thread Rotational Speed (rpm)

11. Selecting the Driving Motors

When selecting a driving motor, it is necessary to satisfy the following conditions:

1. Ensures a marginal force sufficient to counter the load torque exerted on the motor's subject thread.
2. Ensures starting, stopping at prescribed axial speeds, sufficiently powered to counter the moment of inertia exerted on the motor's subject thread.
3. Ensures the prescribed acceleration and deceleration constants, sufficient to counter the moment of inertia exerted on the motor's subject thread.

Once you have temporarily found the type of motor you need, check:
- effective torque,
- acceleration constant and
- motor overload protection and heat tolerance during repeated starting, stopping.

It is necessary to ensure a sufficient margin for these parameters.

12. Example of Selection of Ball Screws (in case of X-axis)

(1) Constant Speed Torque Exerted on the Motor Output Thread

This is the amount of torque required to drive the output thread against the applied external load, at a constant speed.

\[ T = \frac{P}{\pi \cdot N \cdot \tan \beta} \]

Where:
- $P$: Driving Torque at Constant Speed (N·cm)
- $N$: Motor Thread Rotational Speed (rpm)
- $\beta$: Lead Angle

(2) Acceleration Torque Exerted on the Motor Output Thread

This is the amount of torque required to drive the output shaft against the external load during acceleration.

\[ T_{acceleration} = \frac{P}{\pi \cdot N \cdot \tan \beta} \]

Where:
- $P$: Driving Torque in Acceleration (N·cm)
- $N$: Motor Thread Rotational Speed (rpm)
- $\beta$: Lead Angle

(3) Total Torque Exerted on the Motor Output Thread

Total torque can be obtained by adding results from formulas (1) and (2).

\[ T_{total} = T + T_{acceleration} \]

Where:
- $T$: Total Torque Exerted on the Motor Output Thread (N·cm)
- $T_{acceleration}$: Driving Torque in Acceleration (N·cm)

Note: The total torque required exceeds the motor's subject thread.

1. Setting Load (L)

Select based on maximum motor revolutions and the required speed. Use the following formula.

\[ P = \frac{60 \cdot N \cdot T \cdot \pi}{\pi \cdot N \cdot \tan \beta} \]

Where:
- $N$: Motor Thread Rotational Speed (rpm)
- $T$: Motor Thread Angular Acceleration (rad/s²)
- $\beta$: Lead Angle

2. Nut selection

(1) Evaluating Axial Load

This is the axial load calculation formula. It is used to calculate the axial load for each segment of a network profile.

\[ A = \frac{M \cdot \tan \beta}{1 + \mu \tan \beta} \]

Where:
- $M$: Masses of Table and Work Piece (kg)
- $F$: Thrust Reaction Produced in Cutting Force (N)
- $P$: External Axial Load (N)

(2) Evaluating the Allowable Axial Load

This is the allowable axial load calculation formula. It is used to calculate the allowable load.

\[ A_{ allowable} = \frac{200 \cdot N \cdot T \cdot \pi}{\pi \cdot N \cdot \tan \beta} \]

Where:
- $N$: Motor Thread Rotational Speed (rpm)
- $T$: Motor Thread Angular Acceleration (rad/s²)
- $\beta$: Lead Angle

(3) Evaluating the Allowable Axial Load

This is the allowable axial load calculation formula. It is used to calculate the allowable load.

\[ A_{ allowable} = \frac{200 \cdot N \cdot T \cdot \pi}{\pi \cdot N \cdot \tan \beta} \]

Where:
- $N$: Motor Thread Rotational Speed (rpm)
- $T$: Motor Thread Angular Acceleration (rad/s²)
- $\beta$: Lead Angle

3. Accuracy Evaluation

(1) Evaluating Accuracy Grades and Axial Clearances

If utilizing the "Ball Screw Awards" table on Section 3, P222, it is found that the Accuracy Grade C3 with $\omega_{peak}<1000$/1000rpm of actual mean steady speed satisfies the positioning accuracy. Moreover, $\omega_{peak}<1000$/1000rpm and, therefore, that ESST320 is fully applicable.

Additionally, the Precision Screws axial clearance table on P222 shows that axial clearances of $\omega_{peak}<1000$/1000rpm is less than 0.01mm. The required positioning repeatability is ±0.01mm, and it can be confirmed that ESST320 satisfies this requirement.

4. Screw Shaft Selection

(1) Determining the Overall Length

Max. Stroke-Length (Margin)+ Shaft End Formations (both sides), therefore, Max. Stroke 730mm

Nut Length 63mm

Margin 1.5~2mm

Shaft End Formations (72)

Screw Shaft D.L = (20+63+2×1.5)mm

* The Margin is provided as a countermeasure against overrun, and the amount is typically set at 1.5~2 mm as much as the screw lead.

5. Selection Result

The above formula produces an Axial Load value of 343N which is well within the Allowable Max. Axial Load 3000N, and suitability is confirmed.

(2) Evaluating the Allowable Axial Load

Load and Nut Length Distance 75 in 430mm, and the Axial Load can be obtained by the formula on P222, "3. Allowable Axial Load" as indicated below.

\[ A_{ allowable} = \frac{200 \cdot N \cdot T \cdot \pi}{\pi \cdot N \cdot \tan \beta} \]

The above formula produces an Axial Load value of 343N which is well within the Allowable Max. Axial Load 3000N, and suitability is confirmed.

(3) Evaluating the Allowable Axial Load

This is the allowable axial load calculation formula. It is used to calculate the allowable load.

\[ A_{ allowable} = \frac{200 \cdot N \cdot T \cdot \pi}{\pi \cdot N \cdot \tan \beta} \]

Where:
- $N$: Motor Thread Rotational Speed (rpm)
- $T$: Motor Thread Angular Acceleration (rad/s²)
- $\beta$: Lead Angle

The max. speed requirement of 5000rpm is well within the Critical Speed of 724rpm, and the suitability is confirmed.

Additionally, the Critical Speed value can be calculated by using the formula in P222, "5.2. Drift Value" as:

\[ f_c = \frac{D}{2\pi} \cdot \sqrt{\frac{N}{10^6}} \]

where:
- $D$: Shaft Diameter (mm)
- $N$: Motor Thread Rotational Speed (rpm)
- $\pi$: Pi

The suitability is confirmed.