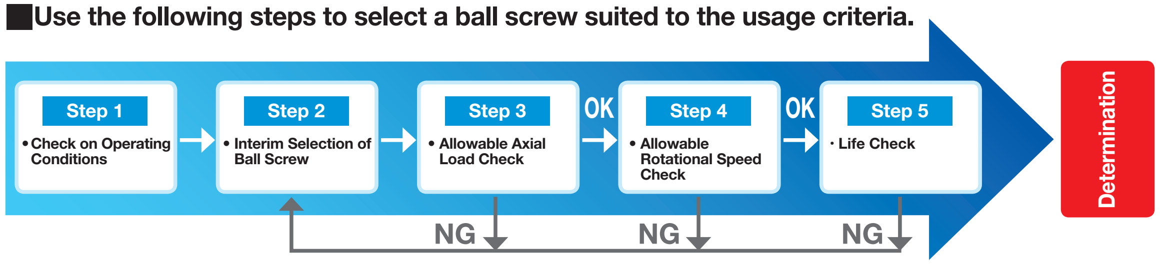
■Use the following steps to select a ball screw suited to the usage criteria.



Step 1 Check on Operating Conditions

Refer to Operating Conditions below.

NO	Item	Unit
①	Positioning Accuracy	mm
②	Stroke	mm
③	Travel Speeds	mm/s
④	Drive Motor Speed	min^{-1}
⑤	Weight of Workpiece and Table	Kg
⑥	Mounting Orientation (horizontal or vertical)	-
⑦	Life Hours	Time
⑧	Motion pattern (Duty Cycle Line Diagram) (See Figure 1)	-

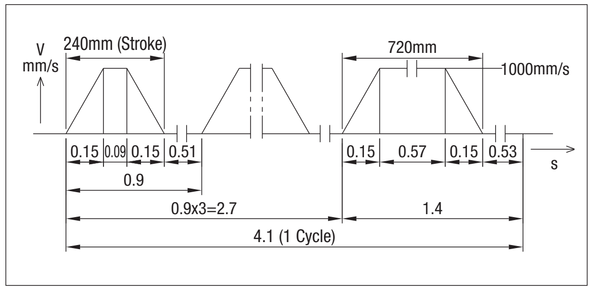


Figure 1 (Ex.) Duty Cycle Line Diagram

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

① Select the ball screw that satisfies the positioning precision. Check the following two points.

Lead Accuracy : For details, see **P.2223** on the catalog.

Axial Clearance: For details, see **P.2224** on the catalog.

2. Selection of Ball Screw Shaft Length

Generally, the shaft length should be ② 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

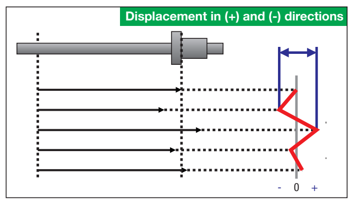
③ Travel speeds, and ④ speed of the drive motor should be used to select the lead.

4. Temporary selection of the shaft diameter

⑤ Weight of work and table, and .⑥ mounting position, and provisionally decided lead should be used to select the shaft diameter.

<Impact on Positioning Precision of Axial Clearance>

If the ball screw has axial clearance, when positioning operation is performed from the positive direction, because the work does not move even when the screw shaft rotates, a difference occurs in the clearance interval between the theoretical movement amount obtained from the revolution speed of the screw shaft and the actual movement amount.



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 loading is applied, it is possible that the ball screw's screw 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.

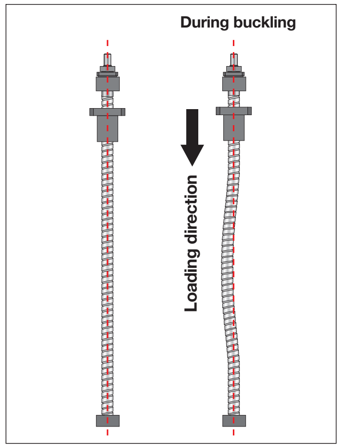


Figure 2 Buckled Ball Screw

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 allowed 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)

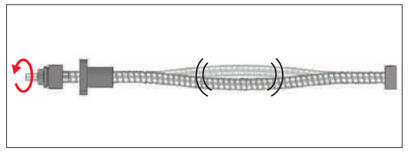


Figure 3 Resonating Ball Screw

Allowable Rotational Speed

Refers to the allowable rotational speed that is 80% 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 ball screw 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.

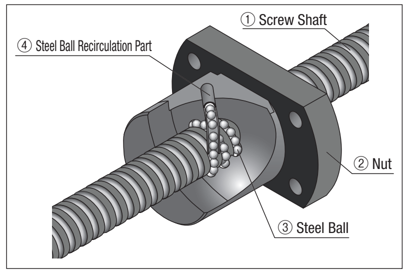


Figure 4 Ball Screw Circulation Structure (Tube Style)

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 total revolutions, time, or distance up until chipping begins to occur due to fatigue causes by some kind of repetitive stress on the ball rolling surface or balls. The lifespan 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 (10^6) 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.

Figure 5 Thread Inside Nut

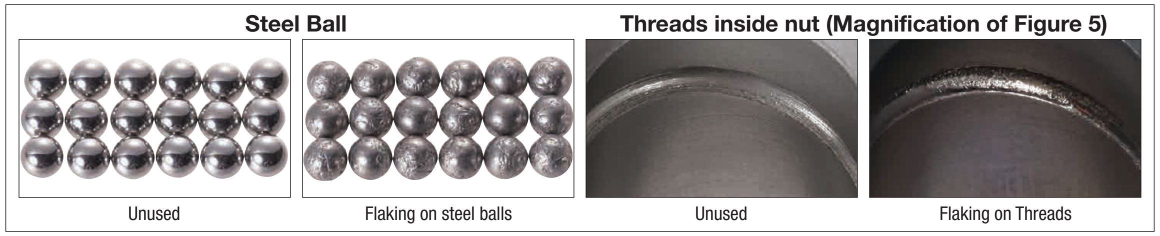
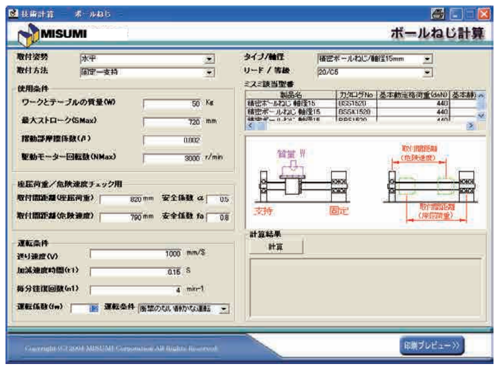


Figure 6 Flaking on Ball Screw Components

■When choosing, it is necessary to ensure the temperature impact and rigidity is suitable for the usage environment and selection criteria. For details, see P.2223~2230 of the catalog technical pages and choose a ball screw that is suitable for the purpose of use.

■Overview of MISUMI Technical Calculation Software

Ball screw's Life calculations and safety margin check can be performed just by entering some operation conditions. (http://download.misumi.jp/mol/fa_soft.html)



Ball Screw Lineup

List of Type, Accuracy Grade, Shaft Dia., Lead, Axial Play and Shaft Length of MISUMI Ball Screws
Provisionally select the ball screw suitable for the purpose of use from the list and select the product following the selection procedure on P.681.

Rolled Ball Screw Lineup

Type	Standard Type	Shaft Dia.	Lead	Axial Play (mm)	Shaft Length (mm) MIN	Shaft Length (mm) MAX
Existing Product Compact Nut Accuracy Grade C10	BSSC	8	2	0.05 or Less	100	400
		10	4		150	600
		12	4		150	800
		15	5	0.10 or Less	150	1200
			10		200	1200
		20	5		200	2000
			10	0.15 or Less	250	2000
		25	5	0.10 or Less	200	2000
Existing Product Standard Nut Accuracy Grade C10	BSSZ BSSR	8	2	0.05 or Less	100	400
			4		100	380
		10	2		150	585
			4		150	600
			10		150	585
		12	4	0.10 or Less	150	800
			10		150	800
		14	5		150	800
		15	5		150	1200
			10		200	1200
			20		200	1200
		20	5		200	2000
			10	0.15 or Less	250	2000
			20	0.10 or Less	250	2000
		25	5		200	2000
			10	0.20 or Less	300	2000
			25	0.12 or Less	300	2000
		28	6	0.10 or Less	250	2000
		32	10	0.20 or Less	300	2000
			32	0.15 or Less	300	2000
C-VALUE Products Standard Nut Accuracy Grade C10	C-BSSC	8	2	0.05 or Less	100	400
		10	2		150	585
			4		150	600
		12	5	0.10 or Less	150	800
			10		150	800
		15	5		150	1200
			10		200	1200
			20		200	1200
		20	5		200	2000
			10	0.15 or Less	250	2000
			20	0.10 or Less	250	2000
		25	5		200	2000
			10	0.20 or Less	300	2000
			25	0.12 or Less	300	2000
Existing Product Block Nut Accuracy Grade C10	BSBR	15	5	0.10 or Less	150	1200
		20			200	1200
		25			200	1500
		15	10		150	1200
		20		0.15 or Less	200	1200
		25		0.20 or Less	250	1500
Existing Product Standard Nut Accuracy Grade C7	BSST	8	2	0.03 or Less	100	380
		10	4		150	585
		12	4		150	795
		15	5		150	1200
			10		200	1200
			20		200	1200
		20	5		200	1200
			10	0.05 or Less	250	2000
			20	0.03 or Less	250	2000
		25	5		200	2000
			10	0.07 or Less	300	2000

Precision Ball Screw Lineup

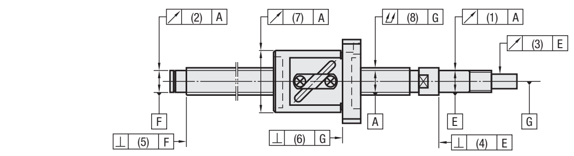
Type	Standard Type	Shaft Dia.	Lead	Axial Play (mm)	Shaft Length (mm) MIN	Shaft Length (mm) MAX
Existing Product Standard Nut Accuracy Grade C5	BSS	8	2	0.005 or Less	100	210
		10	2		100	315
			4		150	380
			10		150	450
		12	2		150	445
			4		150	400
			5		150	450
			10		200	600
		15	5		150	1095
			10		200	1095
			20		230	1095
		20	5		200	1000
			10		250	1500
			20		250	1500
		25	5		300	995
			10		300	1500
			20		300	1500
C-VALUE Standard Nut Accuracy Grade C5	C-BSS	8	2	0.008 or Less	100	210
		10	2		100	315
			4		150	380
		12	2		150	445
			5		150	450
			10		200	600
		15	5	0.015 or Less	150	1095
			10		200	1095
			20		230	1095
		20	5		200	1000
			10		250	1500
			20		250	1500
		25	5		300	995
			10		300	1500
			25		300	1500
Existing Product Standard Nut Accuracy Grade C3	BSX	6	1	0 (Preloaded)	80	205
		8	1		80	255
			2		100	240
		10	2		100	310
		12	2		150	390
			5		150	440
		15	5		150	590
Existing Product Standard Nut Accuracy Grade C7	BSSE	8	2	0.030 or Less	100	210
		10	2		100	315
			4		150	380
		12	2		150	445
			5		150	450
			10		200	600
		15	5		150	1095
			10		200	1095
			20		230	1095
		20	5		200	1000
			10		250	1500
			20		250	1500
		25	10		300	1500
			20		300	1500

Meaning of Terms

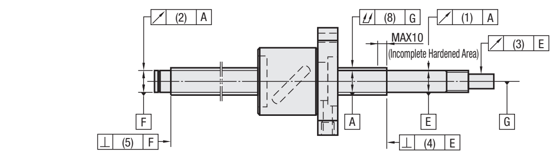
- **Accuracy Grade** Lead Accuracy of Ball Screws defined by JIS Standards. Smaller numbers mean higher lead precision.
- **Shaft Dia.** Screw O.D.
- **Lead** Refers to the distance a nut moves when the screw shaft makes a full rotation.
- **Axial Play** Axial play between the screw shaft and nuts.

Mounting Interface Accuracies

Precision Ball Screws



Rolled Ball Screws



Unit: mm

Part Number Type	Screw Shaft O.D.	(1) (2) Run-out Tolerance (Max.)	(3) Run-out Tolerance (Max.)	(4) (5) Perpendicularity Tolerance (Max.)	(6) Perpendicularity Tolerance (Max.)	(7) Run-out Tolerance (Max.)
BSX	6	0.008	0.008	0.004	0.008	0.008
	8					
	10					0.010
	12					
	15	0.009	0.009			0.012
BSS C-BSS	8	0.011	0.011	0.005	0.010	0.012
	10					
	12					
	15	0.012	0.012		0.011	0.015
	20					
	25	0.013	0.013		0.013	0.019
BSSE BSST	8	0.014	0.014	0.007	0.014	0.020
	10					
	12				0.018	0.030
	15					
	20					
	25	0.020	0.020			
BSSR□ BSSZ□ BSSC□ C-BSSC□	8	0.040	0.040	0.010	-	-
	10					
	12					
	14					
	15					
	20					
	25	0.060	0.060			
	28	0.060	0.060	0.010	-	-
	32					
BSBR□	15	0.040	0.040	0.010	-	-
	20					
	25	0.060	0.060			

(1), (2) Radial Run-out of the thread surface against the shaft support axis. These parameters are affected by "(8) Shaft's total radial run-outs" and may be subject to compensation.

(3) Radial run-out of drive component interface surface in relation to screw shaft support axis.

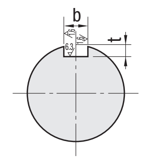
(4), (5) Perpendicularity of shaft's bearing shoulders in relation to screw shaft support axis.

(6) Perpendicularity of ball nut mounting flange surface (datum) in relation to screw shaft axis.

(7) Radial run-out of ball nut body outer circumference in relation to screw shaft axis.

(8) Shaft's total radial run-outs.

Keyway Dimension Details Located at P on Fixed Side Shaft End



Shaft Dia.	b Reference Dim.	b Tolerance (N9)	t Reference Dim.	t Tolerance
6~7	2	-0.004 -0.029	1.2	+0.1 0
8~10	3		1.8	
11~12	4	0 -0.03	2.5	
13~17	5		3.0	
18~20	6		3.5	

Unit: mm

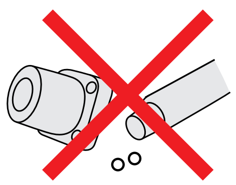
Part Number Type	Screw Shaft O.D.	(8) Run-out Tolerance (Max.) Screw Shaft Length ~125	126~200	201~315	316~400	401~500	501~630	631~800	801~1000	1001~1250	1251~1600	1601~2000
BSX	6	0.025	0.035	0.050	-	-	-	-	-	-	-	-
	8											
	10			0.040	0.050	0.065	-	-	-	-	-	-
	12											
	15	-	0.025	0.030	0.040	0.050	0.055	-	-	-	-	-
BSS C-BSS	8	0.035	0.050	0.065	-	-	-	-	-	-	-	-
	10		0.040	0.055	0.065	0.080	0.090	-	-	-	-	-
	12											
	15	-		0.045	0.055	0.060	0.075	0.090	0.120	0.150	0.190	-
	20											
	25	-	-	0.040	0.045	0.050	0.060	0.070	0.085	0.100	0.130	-
BSSE BSST	8	0.060	0.075	0.100	-	-	-	-	-	-	-	-
	10	0.055	0.065	0.080	0.100	0.120	0.150	-	-	-	-	-
	12											
	15	-	0.060	0.070	0.080	0.095	0.110	0.140	0.170	0.210	0.270	-
	20											
	25	-	-	0.060	0.070	0.080	0.090	0.100	0.130	0.150	0.190	-
BSSR□ BSSZ□ BSSC□ FBS□□ BSBR□ C-BSSC□	8	0.100	0.140	0.210	(0.270)	-	-	-	-	-	-	-
	10	-	0.120	0.160	0.210	0.270	0.350	-	-	-	-	-
	12											
	14	-	0.110	0.130	0.160	0.200	0.250	-	-	-	-	-
	15	-	0.110	0.130	0.160	0.200	0.250	0.320	0.420	0.550	0.730	0.730
	20											
	25	-	-	0.110	0.130	0.160	0.190	0.230	0.300	0.380	0.500	0.690
	28	-	-	0.110	0.130	0.160	0.190	0.230	0.300	0.380	0.500	0.690
	32											

Precautions on handling Ball Screws

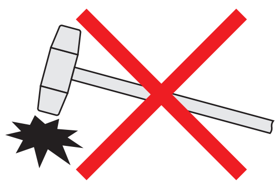
• Precautions on Handling

(1) Removing the ball nut from the screw shaft causes the ball to fall out rendering the ball screw unusable. Do not disassemble Ball Screws. It may attract dusts and degrade assembly accuracy. Use dedicated temporary shafts when removing Ball Nuts.
(2) Do not give an external impact to a screw shaft outer diameter, thread and recirculation parts. It may cause recirculation failure and a malfunction.
(3) Do not tilt the ball screw assembly since a ball screw nut may spin off from a screw shaft due to its own weight. Especially when using a ball screw vertically, place a fall-off prevention mechanism since a ball screw nut may spin off due to its own weight.
(4) When inspecting the sliding, fix the nut and cause the shaft to rotate, or fix the shaft and cause the nut to rotate.

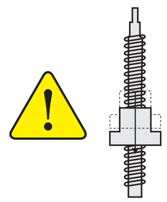
(1) Do not remove the Nuts



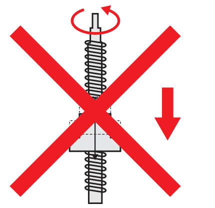
(2) Application of impacts to Nuts is prohibited



(3) Caution for free fall



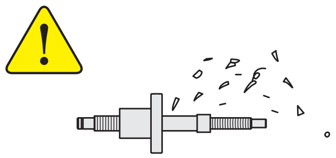
(4) Inspection by reverse operation



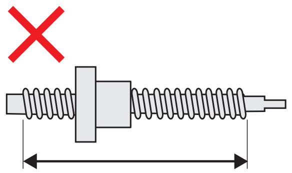
• Cautions on use

(1) Use Ball Screws in clean environments. Use covers, etc. to prevent intrusion of dusts and chips that may cause damages and performance degradations to ball recirculation components.
(2) Do not let a ball screw nut overrun. It may cause the balls to fall out or damage the ball recirculation parts.
(3) Avoid using Ball Screws at a temperature of more than 0~80°C. It may damage recirculation parts or seal parts.
(4) Do not misalign or tilt ball screws shaft support side and a ball screw nut. Life hours may become extremely short due to an offset load to a ball screw nut. When using Support Units, refer to **P.760**.

(1) Caution on Contaminations

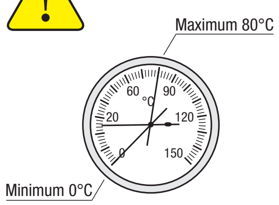


(2) Do not let a nut overrun



If the nut edges exceed this range, the balls will fall out causing malfunctions.

(3) Caution of temperature of usage environment



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.
MISUMI provides various temporary shafts as option.
To order a dedicated temporary shaft together with Ball Screws, add alterations code "-TAS" to the end of a part number.
⊗Nuts cannot be removed using the temporary shafts with Precision Ball Screw BSX, BSS, BSSE, C-BSS and Rolled Ball Screw C-BSSC.

Alterations	Part Number	-	L	-	F	-	P	-	(TAS)
	BSSZ1510	-	300					-	TAS
	BSSR2005	-	700	-	F30	-	P12	-	TAS

• Caution on use of Temporary Shaft

When Taking Out Ball Screws Nut from Screw Shaft
• Stand a screw shaft vertically and place a temporary shaft to the screw shaft support side edge in consistent with screw shaft center. (Refer to Fig. 2)(*)
• Lightly rotate the nut and install it onto the temporary shaft. (Refer to Fig. 4)
• After confirming that both nut edges are on the temporary shaft, take out the temporary shaft from the screw shaft.
• Store the assembly while ensuring that the nut does not fall off of the temporary shaft.

When Installing Ball Screws Nut to Screw Shaft
• Stand a ball screw shaft vertically and place a temporary shaft to the screw shaft support side edge in consistent with screw shaft center.
• Rotate the nut with pressing the screw shaft lightly and install it into the shaft.
• In case there is any interference, do not insert the ball screw forcibly. Try reassembling.
(*) In BSSZ, BSSR0802, BSSR0804, BSSR1002, BSSR2510, BSST0802 and BSST2510, the screw shaft support side and the temporary shaft are placed as shown in the following Figure 3. Since TAS is unstable, grip TAS firmly from the above until the installation is finished.

Fig. 1

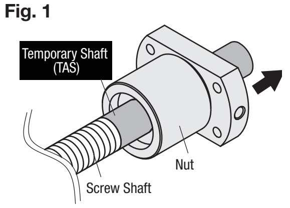


Fig. 2

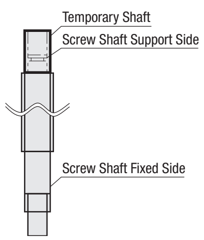


Fig. 3

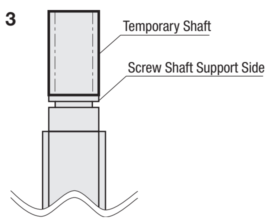
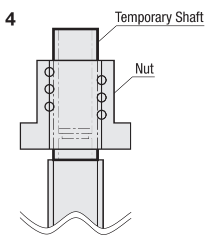


Fig. 4



Lubrication (grease inspection and replenishment)

The grease forms an oil film on the ball screw's screw shaft, rolling surface inside the nut, and surface of the balls and acts to reduce friction and prevent heat damage.
MISUMI ball screws are filled with grease before shipping, however after commencing use, it is necessary to perform regular and appropriate inspection and grease replenishment.
When adding grease, use the same grease that was used at shipment and do not mix with other greases.

• Guides for inspection and grease replenishment

After 2~ 3 months of operation, if the grease is very dirty, we recommend to remove the old grease and fill with new grease.
Subsequent inspection intervals are recommended to be every 6 months, however, we recommend this timing be adjusted to an interval appropriate for the usage environment.

Available Grease

Ball screw products are shipped with grease filled. If not otherwise indicated, lithium soap based grease (Alvania Grease S2 made by Showa Shell Sekiyu K.K) is the standard type that is used. (BSX0601, BSX0801, and BSX0802 are filled with Multemp Grease PS2 made by Kyodo Yushi Co., Ltd.)
Grease type can be changed from the standard to the following types.

Part Number	Product Name	Main Features
● L Type	ET-100K (Made by Kyodo Yushi)	Excels in heat resistance, oxidation stability, adhesion and adhesive power. In addition, splash or leakage is little.
● G Type	LG2 (Made by NSK Ltd.)	Special grease for linear guides, ball screws and etc. for clean-room use.

Item		Condition	Unit	Measurement Method	Standard	L Type	G Type
Grease Performance	Thickener	-	-	-	Lithium Type	Aromatic Diurea	Lithium Type
	Base Oil	-	-	-	Mineral Oil	Ether Synthetic Oil	Mineral Oil + Synthetic Hydrocarbon Oil
	Base Oil Viscosity	40°C	mm²/s	JIS K2220 5.19	131	103	30
		100°C			12.2	12.8	-
	Worked Penetration	-	-	JIS K2220 5.3	283	280	207
	Dropping Point	-	°C	JIS K2220 5.4	181	<260	200
	Evaporation Amount	99°Cx22h	wt%	-	-	0.15%	1.40%
	Oil Separation Rate	100°Cx24h	wt%	JIS K2220 514	2.8%	1.2%	0.8%
	Operating Temp.	In Air	°C	-	-25~+135	-40~200	-10~80

Usage temperature is for grease performance and not the usable temperature of the ball screw.
⊗Avoid using Ball Screws at a temperature of more than 0~80°C.

Available Ball Screws and Grease Types

Type	Accuracy Grade	Type	Unit Price (Add to the price of Standard Type) L≤1000	Unit Price (Add to the price of Standard Type) L>1000
Precision Ball Screws	C 5	BSS	● L Type ● G Type	● L Type ● G Type
	C 7	BSSE		
Rolled Ball Screws	C 7	BSST		
	C10	BSSR BSSZ		
		BSSRK BSSZK		

⊗Not applicable to Precision Ball Screw BSX, C-BSS, Rolled Ball Screw BSSC and C-BSSC.

Ordering Example	Part Number	-	L
	● BSS2010L	-	700 (L Type Greased)
	● BSS2010G	-	700 (G Type Greased)

Please add L or G after the part number of standard type when placing an order.

Design of Ball Screws and Peripherals, Caution when Assembling

Ball screws are parts that receive only axial load, when a radial load or moment load is received, it could cause sliding failure, vibration/abnormal noise and reduction in lifespan.
To prevent parallelism error and misalignment of peripherals that causes radial load and moment load on ball screws, it is important to appropriately design and assemble peripherals.

• 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.
- Misalignment allowance value (reference)
• 20μ or Less
• When there is high precision usage criteria or when using preloaded ball screws, keep the value as low as possible.

• Parallelism of ball screw and linear guide (Figure 2)

- Parallelism error is where the ball screw is tilting toward up/down or left/right with respect to the linear guide or other references.
- Tilting allowable value (reference) (Figure 3)
• 1/2000 or Less
• When there is high precision usage criteria or when using preloaded ball screws, keep the value as low as possible.

• Caution During Design

Design/machining precision of ball screw peripherals can be factors that cause misalignment and tilting.
Particularly be cautious of the following two points.
• Flatness of base plate　　• Dimensional precision from edge of support unit to shaft center

• Precautions on Installation

• Mounting/assembly of ball screw peripherals can cause misalignments and tilting.
Particularly be cautious of the following four points.
- Error in left/right direction of support unit (Figure 1)　- Parallelism error of linear guide and ball screw (Figure 2)
- Fixing of table and nut bracket　- Fixing of ball screw nut and nut bracket
• If abnormal noise/sliding is being caused by the ball screw movement after assembly, loosen each of the fastened parts again and reassemble while ensuring smooth sliding.

Figure 1 Misalignment of Ball Screw and Support Unit

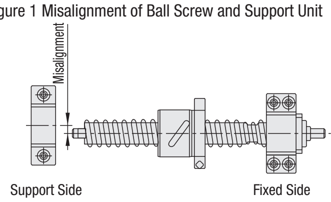


Figure 2 Parallelism Error of Linear Guide and Ball Screw

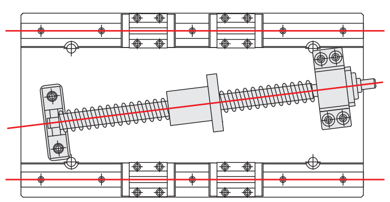
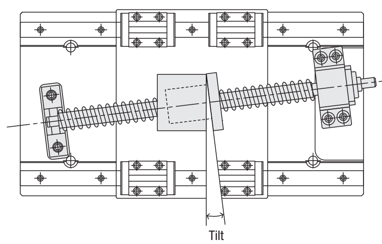


Figure 3 Tilt of Ball Screw and Nut Bracket



[Technical Data]
Selection of Ball Screws 1

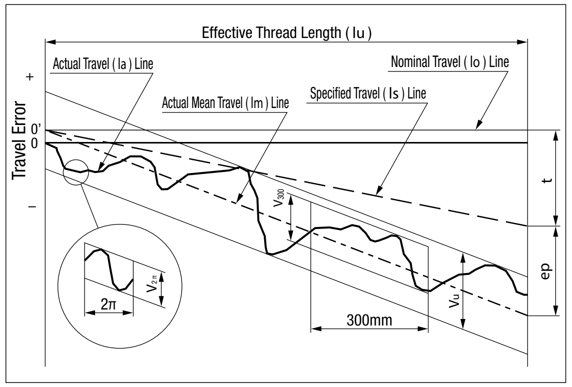
1. Ball Screw Selection Procedure

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

- **Determine the application parameters** ⋯ Moving mass, feed speed, motion pattern, screw shaft rotational speed, stroke, mounting orientation (horizontal or vertical), life, positioning accuracy
- ↓ **Interim selection of ball screw specifications** ⋯ Temporary selection of ball screw lead accuracy grade (C3~C10), shaft diameter, lead, and length. P.2223 , 2224
- ↓ **Evaluation of various basic safety factors** (NG → back to start) ⋯
  - •Axial Load Capacity: Confirm that the applied axial load is within the ball screw's axial load capacity rating. P.2225
  - •Allowable Rotational Speed: Confirm that the intended shaft rotational speed is within the ball screw's allowable rotational speed rating. P.2226
  - • Life: Confirm that the ball screw satisfies the life requirement. P.2227
- ↓ **Evaluations based on required performances** (NG → back to start) ⋯ If higher positioning accuracy and/or improved responsiveness is needed, below parameters need to be evaluated.
  - •Screw shaft rigidity P.2228
  - •Effects of temperature variation on life P.2228

2. Ball Screw Lead Accuracy

Ball screw lead accuracy is defined by JIS Standards property parameters (e_p, V_u, V_{300}, $V_{2\pi}$).
Parameter definitions and allowable values are shown below.
In general, a ball screw lead accuracy grade is selected by evaluating if the Actual Mean Travel Error of a candidate is within the allowable positioning error.



Terms	Symbols	Meaning
Actual Mean Travel Error	ep	A value that is Specified Travel subtracted from Actual Mean Travel.
Variation		The maximum difference of the actual travel contained between two lines drawn parallel to the actual mean travel, and is defined by three parameters below.
	V_u	Variation for the effective thread length of screw shaft.
	V_{300}	Variation for an arbitrarily taken length of 300mm within the effective thread length of screw shaft.
	$V_{2\pi}$	Variation for an arbitrary one revolution (2πrad) taken within the effective thread length of screw shaft.
Specified Travel	ls	Axial travel compensated for temperature rise and loading conditions, in relation to the Nominal Travel (Lead).
Specified Travel Target Value	t	A value that is Nominal Travel subtracted from Specified Travel, over the effective thread length. This value is set to compensate for possible screw shaft expansion and contraction due to temperature changes and applied loads. The value is to be determined based on experiments or experiences.
Actual Travel	la	Actually measured travel distance
Actual Mean Travel	lm	A straight line representing the actual travel trend. A straight line obtained by the least-squares method or other approximation methods from the curve representing the actual travel.

■Table 1. Positioning Screw (C Class) Actual Mean Travel Error ($\pm e_p$) and Variation (V_u) allowances

Unit : μm

Thread Effective Length (mm)		Accuracy Grade			
		C3		C5	
over	or less	Actual Mean Travel Error	Variation	Actual Mean Travel Error	Variation
	315	12	8	23	18
315	400	13	10	25	20
400	500	15	10	27	20
500	630	16	12	30	23
630	800	18	13	35	25
800	1000	21	15	40	27
1000	1250	24	16	46	30
1250	1600	29	18	54	35

■Table 2. Positioning Screws (C Class) variation per 300mm (300) Variation per rotation (2π) standard values

Unit : μm

Accuracy Grade	C3		C5	
Parameters	V_{300}	$V_{2\pi}$	V_{300}	$V_{2\pi}$
Standard Values	8	6	18	8

■Table 3. Transfer Screw (Ct Class) variation per 300mm (V_{300}) Standards

Unit : μm

Accuracy Grade	Ct7	Ct10
V_{300}	52	210

Actual Mean Travel Error (ep) for Transfer Screws (Ct Class) is calculated as $e_p=2 \cdot L_u/300 \cdot V_{300}$

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 4. Axial Clearances of Rolled Ball Screws

Types	Prod. Example	Screw Shaft Dia.	Lead	Axial Clearance (mm)	Screw Shaft Length (mm) MIN	Screw Shaft Length (mm) MAX
Existing Products Compact Nut Accuracy Grade C10	BSSC	8	2	0.05 or less	100	400
		10	4		150	600
		12	4		150	800
		15	5	0.10 or less	150	1200
			10		200	1200
		20	5		200	2000
			10	0.15 or less	250	2000
		25	5	0.10 or less	200	2000
Existing Products Standard Nut Accuracy Grade C10	BSSZ BSSR	8	2	0.05 or less	100	400
			4		100	380
		10	2		150	585
			4		150	600
			10		150	585
		12	4		150	800
			10	0.10 or less	150	800
		14	5		150	800
		15	5		150	1200
			10		200	1200
			20		200	1200
		20	5		200	2000
			10	0.15 or less	250	2000
			20	0.10 or less	250	2000
		25	5		200	2000
			10	0.20 or less	300	2000
			25	0.12 or less	300	2000
		28	6	0.10 or less	250	2000
		32	10	0.20 or less	300	2000
			32	0.15 or less	300	2000
C-VALUE Products Standard Nut Accuracy Grade C10	C-BSSC	8	2	0.05 or less	100	400
		10	2		150	585
			4		150	600
		12	5		150	800
			10	0.10 or less	150	800
		15	5		150	1200
			10		200	1200
			20		200	1200
		20	5		200	2000
			10	0.15 or less	250	2000
			20	0.10 or less	250	2000
		25	5		200	2000
			10	0.20 or less	300	2000
			25	0.12 or less	300	2000
Existing Products Block Nut Accuracy Grade C10	BSBR	15	5	0.10 or less	150	1200
		20			200	1200
		25			200	1500
		15	10		150	1200
		20		0.15 or less	200	1200
		25		0.20 or less	200	1500
Existing Products Standard Nut Accuracy Grade C7	BSST	8	2	0.03 or less	100	380
		10	4		150	585
		12	4		150	795
		15	5		150	1200
			10		200	1200
			20		200	1200
		20	5		200	1200
			10	0.05 or less	250	2000
			20	0.03 or less	250	2000
		25	5		200	2000
			10	0.07 or less	300	2000

■Table 5. Axial Clearances of Precision Ball Screws

Types	Prod. Example	Screw Shaft Dia.	Lead	Axial Clearance (mm)	Screw Shaft Length (mm) MIN	Screw Shaft Length (mm) MAX
Existing Products Standard Nut Accuracy Grade C5	BSS	8	2	0.005 or less	100	210
		10	2		100	315
			4		150	380
			10		150	450
		12	2		150	445
			4		150	400
			5		150	450
			10		200	600
		15	5		150	1095
			10		200	1095
			20		230	1095
		20	5		200	1000
			10		250	1500
			20		250	1500
		25	5		300	995
			10		300	1500
			20		300	1500
C–Value Standard Nut Accuracy Grade C5	C-BSS	8	2	0.008 or less	100	210
		10	2		100	315
			4		150	380
		12	2		150	445
			5		150	450
			10		200	600
		15	5	0.015 or less	150	1095
			10		200	1095
			20		230	1095
		20	5		200	1000
			10		250	1500
			20		250	1500
		25	5		300	995
			10		300	1500
			25		300	1500
Existing Products Standard Nut Accuracy Grade C3	BSX	6	1	0 (Preloaded)	80	205
		8	1		80	255
			2		100	240
		10	2		100	310
		12	2		150	390
			5		150	440
		15	5		150	590
Existing Products Standard Nut Accuracy Grade C7	BSSE	8	2	0.030 or less	100	210
		10	2		100	315
			4		150	380
		12	2		150	445
			5		150	450
			10		200	600
		15	5		150	1095
			10		200	1095
			20		230	1095
		20	5		200	1000
			10		250	1500
			20		250	1500
		25	10		300	1500
			20		300	1500

Selection Example of Lead Accuracy

<Requirements>
- · Ball screw diameter Ø15, lead 20.
- · Stroke 720mm
- · Positioning accuracy ±0.05mm/720mm

<Selection Details>
Select an appropriate lead accuracy grade based on the application requirements.

(1) Evaluating the screw thread length
Stroke+Nut Length+Margin=720+62+60=842
*The Margin shown above is an overrun buffer, and normally determined as 1.5~2 times the screw lead.
Lead 20x1.5x2 (both ends)=60

(2) Evaluating the lead accuracy
Verify the actual mean travel error ±ep for 842mm ball screw thread by referencing the Table 1. on **P.2223**.
C3 · · · ±0.021mm/800~1000mm
C5 · · · ±0.040mm/800~1000mm

(3) Determining the lead accuracy
It can be determined that a C5 grade (±0.040/800~1000mm) ball screw can satisfy the required positioning accuracy of ±0.05/720mm.

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.

[Technical Data]
Selection of Ball Screws 2

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.
Additionally, approximate Allowable Axial Load can be obtained from Table 1. Allowable Axial Load Graph.

•Allowable Axial Load (P)

$$P = \frac{n\pi^2 EI}{\ell^2}\alpha = m\frac{d^4}{\ell^2}\times 10^4 (N)$$

Where:
P: Allowable Axial Load (N)
ℓ: Distance between Points of Buckling Load (mm)
E: Young's Modulus ($2.06\times10^5 N/mm^2$)
I: Min. Geometrical Moment of Inertia of Across Root Thread Area (mm^4)

$$I = \frac{\pi}{64}d^4$$

d : Thread Root Diameter (mm)
n, m : Coefficient Determined by Method of Screw Support

Method of Screw Support	n	m
Support - Support	1	5
Fixed - Support	2	10
Fixed - Fixed	4	19.9
Fixed- Free	0.25	1.2

α : Safety Factor = 0.5
For higher safety, a higher safety factor should be required.

Allowable Axial Load Calculation Example

Find the Allowable Axial Load for Fig.1

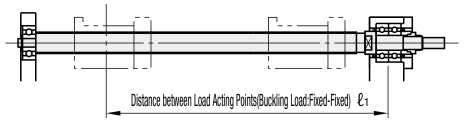
<How to use>
· Thread shaft diameter Ø15, Lead 5
· Mounting method Fixed - Support
· Distance between Points of Buckling Load ℓ_1 820mm
· Screw Shaft Root Diameter d 12.5

<Calculations>
g=15.1 since the mounting method is Fixed-Supported,
the Allowable Rotational Speed (Nc) is,

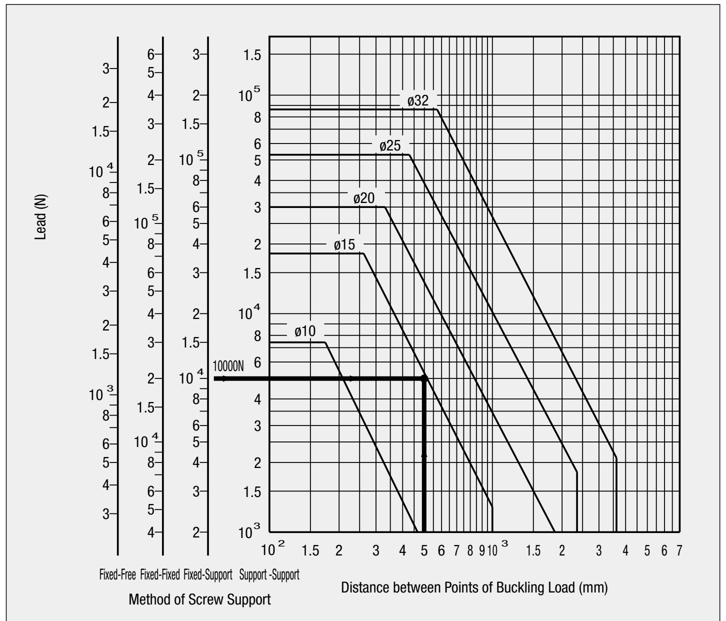
$$P = m\frac{d^4}{\ell^2}\times10^4 = 10\times\frac{12.5^4}{820^2}\times10^4 = 3630(N)$$

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

Table.1



•Figure1. Allowable Axial Load Curve



Screw Shaft Dia. Calculation Example

<Requirements>
· Distance between Points of Buckling Load 500mm
· Mounting method Fixed - Support
· the max. axial load 10000N

<Calculations>
(1) Find the intersection between a distance of 500mm between load acting points and the axial load of 10000N(from the fixed-support graduation).[Figure 1]

(2) Read the shaft diameter of the diagonal line nearest to the intersection on the outside. The shaft diameter can be a min. 15mm.

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 limitation 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.
Additionally, approximate Allowable Rotational Speeds can be obtained from Table 2. Allowable Maximum Rotational Speed Graph.

•Allowable Rotational Speed (rpm)

$$N_c = f_a\frac{60\lambda^2}{2\pi\ell^2}\sqrt{\frac{EI\times10^3}{\gamma A}} = g\frac{d}{\ell^2}10^7 (min^{-1})$$

Where:
ℓ: Distance of Supports (mm)
fa: Safety Factor (0.8)
E: Young's Modulus ($2.06\times10^5 N/mm^2$)
I: Min. Geometrical Moment of Inertia of Across Root Thread Area (mm^4)

$$I = \frac{\pi}{64}d^4$$

d: Thread Root Diameter (mm)
γ: Specific Gravity ($7.8\times10^{-6} kg/mm^3$)
A: Root Thread Section Area (mm^2)

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

g, λ: Coefficient Determined by Method of Screw Support

Method of Screw Support	g	λ
Support - Support	9.7	π
Fixed - Support	15.1	3.927
Fixed - Fixed	21.9	4.73
Fixed- Free	3.4	1.875

Allowable Rotational Speed Calculation Example

Find the Allowable Maximum Rotational Speed for Fig.2

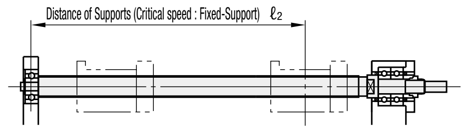
<How to use>
· Thread shaft diameter ø15, Lead 5
· Mounting method Fixed - Support
· Distance between Points of Buckling Load ℓ_1 790mm

<Calculations>
g=15.1 since the mounting method is Fixed-Supported,
the Allowable Rotational Speed (Nc) is,

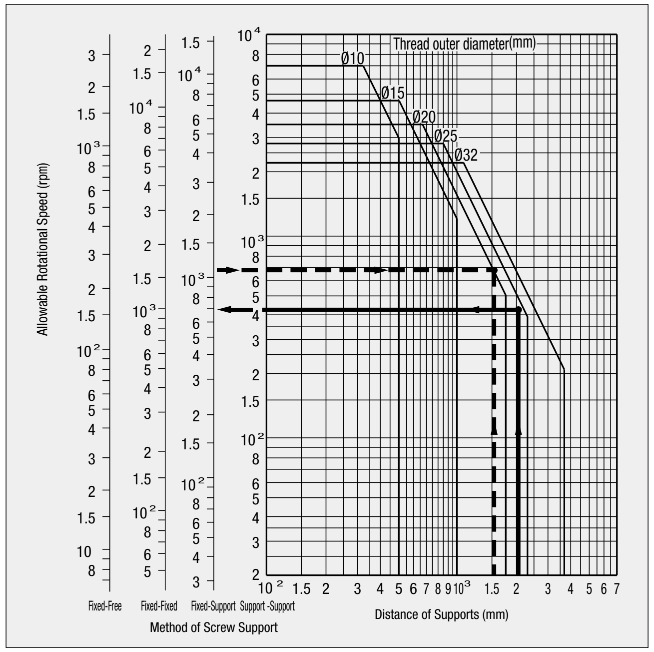
$$Nc = g\frac{d}{l^2}10^7(rpm) = 15.1\times\frac{12.5}{790^2}\times10^7(rpm) = 3024(rpm)$$

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

Table.2



•Figure2. Allowable Rotational Speed Graph



Allowable Rotational Speed Calculation Example

<Requirements>
· Thread outer diameter 20
· Distance of Supports 1500mm
· Mounting method Fixed - Support

<Calculations>
(1) From Table 2., find an intersection of a vertical line from Supported Span Distance 1500mm and Screw Shaft O.D. Ø20 line.

(2) The value 1076rpm on the Fixed-Supported scale (Y-Axis) that corresponds to the intersection of (1) above is the Allowable Maximum Speed.

Screw Shaft Dia. Calculation Example

<Requirements>
· Distance of Supports 2000mm
· Maximum Rotational Speed 1000rpm
· the max. axial load Fixed - Fixed

<Calculations>
(1) From Table 2., find a intersection of a vertical line from Supported Span Distance 2000mm and a horizontal line from Fixed-Fixed max. speed scale (Y-Axis) at 1000rpm.

(2) A line that reaches down to the intersection in (1) is the Ø25 ball screw that satisfies the required speed of 1000rpm.

5-2. DmN Value

The DmN value represents a ball recirculation (orbit) speed limit within a ball nut.
If this vale is exceeded, the recirculation components will be damaged.
The DmN value can be calculated with the following formula.

•Allowable Rotational Speed (min^{-1})

DmN≤70000 (Precision Ball Screws)
DmN≤50000 (Rolled Ball Screws)

Where:
Dm: Thread outer diameter (mm)+A Value
N: Maximum Rotational Speed (min^{-1})

Ball Dia.	A Value
1.5875	0.3
2.3812	0.6
3.175	0.8
4.7625	1.0
6.35	1.8

Selection of Ball Screws 3

6. Life Span

Ball screw's 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 flaking. Ball screw's life can be calculated based on Basic Dynamic Load Rating with the following formula.

6-1. Life Hours (Lh)

$$L_h = \frac{10^6}{60N_m}\left(\frac{C}{P_m f_w}\right)^3 \text{(hrs)}$$

Where:
L_h: Life Span Hours (hrs)
C: Basic Dynamic Load Rating (N)
P_m: Mean Axial Load (N)
N_m: Mean Rotational Speed (min^{-1})
f_w: Work Factor

Impactless Run	f_w = 1.0~1.2
Normal Run	f_w = 1.2~1.5
Run with Impact	f_w = 1.5~2.0

•Basic Dynamic Load Rating : C
Basic Dynamic Load Rating (C) is defined as: An axial load which a group of same ball screws are subjected and 90% 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:15,000hrs

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

$$C = \left(\frac{60L_h N_m}{10^6}\right)^{\frac{1}{3}} P_m f_w \text{(N)}$$

Life Calculation Example

<Requirements>

· Ball Screw Model	BSS1520 (Ø15 Lead 5)
· Mean Axial Load Pm	250N
· Mean Rotational Speed Nm	2118 (min^{-1})
· Work Factor fw	1.2

<Calculations>
Since Basic Dynamic Load Rating C for BSS1520 is 4400N,

$$L_h = \frac{10^6}{60\times2118}\left(\frac{4400}{250\times1.2}\right)^3 = 24824 \text{ (hr)}$$

Therefore, Life will be 24824 hours.

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 formula can be used.

-Axial Load Formula-
Constant Velocity · · · Axial Load (Pb)=μWg
Acceleration · · · Axial Load (Pa)=Wα+μWg
Deceleration · · · Axial Load (Pc)=Wα-μWg

* Omit the "μ" for vertical applications.

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

(*) Acceleration (α)=(Vmax/t)x10^{-3}
Vmax: Rapid Feed Rate mm/s
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 formula 2.

[Table 1. Motion Profile] ($t_1+t_2+t_3$=100%)

Motion Profile	Axial Load	Rotational Speed	Hours Ratio
A	P_1 (N)	N_1 (min^{-1})	t_1 (%)
B	P_2 (N)	N_2 (min^{-1})	t_2 (%)
C	P_3 (N)	N_3 (min^{-1})	t_3 (%)

[Formula 2. Average Axial Load Calculation]

$$P_m = \left(\frac{P_1^3N_1t_1+P_2^3N_2t_2+P_3^3N_3t_3}{N_1t_1+N_2t_2+N_3t_3}\right)^{\frac{1}{3}} \text{(N)}$$

$$N_m = \frac{N_1t_1+N_2t_2+N_3t_3}{t_1+t_2+t_3} \text{(min}^{-1}\text{)}$$

For machine tool applications, max. load (P1) is applicable for the "Heaviest cutting". Regular Load (P2) is for the general cutting conditions, and Minimum Load (P3) is for the non-cutting rapid feeds during positioning moves.

Average Axial Load and Average Rotational Seed Calculation Example

<Requirements>

Motion Profile	Axial Load	Rotational Speed	Hours Ratio
A	343N	1500rpm	29.4%
B	10N	3000rpm	41.2%
C	324N	1500rpm	29.4%

<Calculations>

(1) Average Axial Load

$$P_m = \left(\frac{343^3\times1500\times0.294+10^3\times3000\times0.412+324^3\times1500\times0.294}{1500\times0.294+3000\times0.412+1500\times0.294}\right)^{\frac{1}{3}} = 250 \text{ (N)}$$

Therefore, the Average Axial Load Pm will be 250N.

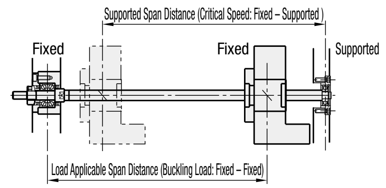
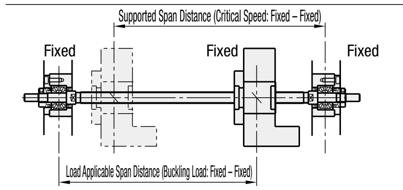
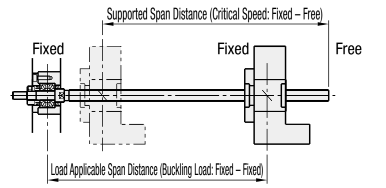
(2) Average Rotational Speed

$$N_m = \left(\frac{1500\times0.294+3000\times0.412+1500\times0.294}{0.294+0.412+0.294}\right) = 2118 \text{ (min}^{-1}\text{)}$$

Therefore, the Average Rotational Speed Nm will be 2118rpm.

7. Screw Shaft Mounting Arrangements

Representative ball screw mounting arrangements are shown below.

Mounting Methods	Application Example
	· Typical method · Medium~ High Speeds · Medium~High Accuracy For Support Units, Standard Type BRW / BUR is selected.
	· Medium Speeds · High Accuracy · For Support Units, Standard Type BRW is selected.
	· Low Speeds · For Short Screw Shafts · Medium Accuracy · For Support Units, Economy Type BRWE is selected

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 Co" at 100°C or higher with the temperature factors ft and ft' can be expressed with the following formula.

C"=ftC (N)
Co"=ft'Co (N)

Temperature °C	100 or less	125	150	175	200	225	250	350
ft	1.0	0.95	0.90	0.85	0.75	0.65	0.60	0.50
ft'	1.0	0.93	0.85	0.78	0.65	0.52	0.46	0.35

For high temperature applications, the current grease should be replaced with the heat-resistant type and the current components should be checked for the heat resistant temperature.

9. Rigidity

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

$$K = \frac{P}{\delta} \text{ (N/μm)}$$

Where:
P: Axial Loads Applied on Feed Screw System (daN)
δ: Elastic Deformation of Feed Screw System (μm)
Additionally, the following relationship exists between the feed screw system rigidity and other various construction element rigidity.

$$\frac{1}{K} = \frac{1}{K_\ell} + \frac{1}{K_n} + \frac{1}{K_b} + \frac{1}{K_h}$$

Where:
K_ℓ: Screw Shaft Compressive, Tensile Rigidity
K_n: Nut Rigidity
K_b: Support Bearing Rigidity
K_h: Nut and Bearing Mount Rigidity

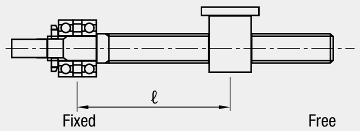
•Screw Shaft Compressive/Tensile Rigidity : Kℓ

$$K_\ell = \frac{P}{\delta_\ell} \text{ (N/μm)}$$

Where:
P: Axial Load (N)
δ_ℓ: Screw Shaft Expansion/Contraction (μm)

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

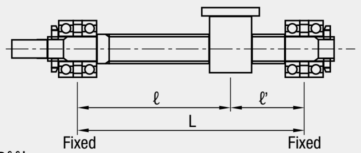
(1) Fixed-Free Arrangement



$$\delta_\ell = \frac{4P\ell}{E\pi d^2} \times 10^3 \text{ (μm)}$$

Where:
P: Axial Load (N)
E: Young's Modulus (2.06x10^{5}N/mm^2)
d: Screw Shaft Root Diameter (mm)
ℓ: Load Applicable Span Distance (mm)

(2) Fixed-Fixed Arrangement



$$\delta_\ell = \frac{4P\ell\ell'}{E\pi d^2 L} \times 10^3 \text{ (μm)}$$

Where:
P: Axial Load(N)
E: Young's Modulus (2.06x10^{5}N/mm^2)
d: Screw Shaft Root Diameter (mm)
ℓ, ℓ': Load Applicable Span Distance (mm)
L: Mounting Span Distance (mm)

The formula produces the max. value when $\ell = \ell' = \frac{L}{2}$

$$\left(\delta_\ell = \frac{PL}{E\pi d^2} \times 10^3\right)$$

Therefore, the max. shaft expansion and contraction will be 1/4 of Fixed-Free arrangement.

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 is μ, and lead angle is β, ball screw's efficiency η is indicated by the following formulas.

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 (constant velocity torque) required for the drive power source (motor, etc.) selection is as follows.

(1) Forward Action

Torque required when converting rotational force into axial force

$$T=\frac{PL}{2\pi\eta}\ (N\cdot cm)$$

Where:

T: Load Torque (N·cm)

P: External Axial Load (N)

L: Ball Screw Lead (cm)

η: Ball Screw Efficiency (0.9)

(2) Reverse Action

External axial load when converting axial force into rotational

$$P=\frac{2\pi\ T}{\eta' L}\ (N)$$

Where:

P: External Axial Load (N)

T: Load Torque (N·cm)

L: Ball Screw Lead (cm)

η': Ball Screw Efficiency (0.9)

(3) Friction Torque Caused by Preloading

This is a torque generated by preloading. As external loads increase, the preload of the nut is released and therefore the friction torque by preloading also decreases.

Under No load

$$T_P=K\frac{P_L L}{2\pi}\ (N\cdot cm)$$

$$K=0.05(\tan\beta)^{-\frac{1}{2}}$$

Where:

P_L: Preload (N)

L: Ball Screw Lead (cm)

K: Coefficient of Internal Friction

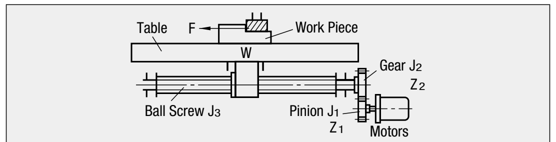
β: Lead Angle $\quad \beta\approx\tan^{-1}\left(\frac{L}{\pi D}\right)$

D: Thread Outer Diameter

11. Selecting the Driving Motors

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

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



(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.

$$T_1=\left(\frac{PL}{2\pi\eta}+T_P\frac{(3P_L-P)}{3P_L}\right)\frac{Z_1}{Z_2}\ (N\cdot cm)$$

Where: $P\leqq 3P_L$

T_1: Driving Torque at Constant Speed (N·cm)

P: External Axial Load (N)

$P=F+\mu Mg$

F: Thrust Reaction Produced in Cutting Force (N)

M: Masses of Table and Work Piece (kg)

μ: Coefficient of Friction on Sliding Surfaces

g: Gravitational Acceleration (9.8m/s²)

L: Ball Screw Lead (cm)

η: Mechanical Efficiency of Ball Screw or Gear

T_P: Friction Torque Caused by Preloading (N·cm) Referto Formula 10-2-(3)

P_L: Preload (N)

Z_1: Number of Pinion's Teeth

Z_2: No. of Gear's Teeth

(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.

$$T_2=J_M\omega=J_M\frac{2\pi N}{60t}\times10^{-3}\ (N\cdot cm)$$

$$J_M=J_1+J_4+\left(\frac{Z_1}{Z_2}\right)^2\left\{J_2+J_3+J_5+J_6\right\}\ (kg\cdot cm^2)$$

Where:

T_2: Driving Torque in Acceleration (N·cm)

ω: Motor Thread Angular Acceleration (rad/s²)

N: Motor Thread Rotational Speed (rpm)

t: Acceleration Time (s)

J_M: Moment of Inertia Exerted on the Motor (kg·cm²)

J_1: Moment of Inertia Exerted on Pinion (kg·cm²)

J_2: Moment of Inertia Exerted on Gear (kg·cm²)

J_3: Moment of Inertia Exerted on Ball Screw (kg·cm²)

J_4: Moment of Inertia Exerted on Motor's Rotor (kg·cm²)

J_5: Moment of Inertia of Moving Body (kg·cm²)

J_6: Moment of Inertia of Coupling (kg·cm²)

M: Masses of Table and Work Piece (kg)

L: Ball Screw Lead (cm)

Moment of inertia exerted on cylinders as screws and cylinders such as Gears (Calculation of J_1~J_4, J_6)

$$J=\frac{\pi\gamma}{32}D^4\ell\ (kg\cdot cm^2)$$

Where:

D: Cylinder Outer Diameter (cm)

ℓ: Cylinder Length (cm)

γ: Material Specific Gravity

$\gamma=7.8\times10^{-3}$ (kg/cm³)

$$J_5=M\left(\frac{L}{2\pi}\right)^2\ (kg\cdot cm^2)$$

(3) Total Torque Exerted on the Motor Output Thread

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

$$T_M=T_1+T_2=\left(\frac{PL}{2\pi\eta}+T_P\frac{(3P_L-P)}{3P_L}\right)\frac{Z_1}{Z_2}+J_M\frac{2\pi\ N}{60t}\times10^{-3}(N\cdot cm)$$

Where:

T_M: Total Torque Exerted on the Motor Output Thread (N·cm)

T_1: Driving Torque at Constant Speed (N·cm)

T_2: Driving Torque at In Acceleration (N·cm)

Once you have temporarily found the type of motor you need, check

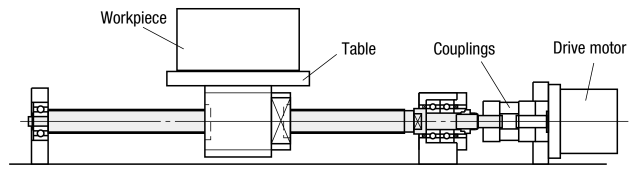
1. effective torque,
2. acceleration constant and
3. motor overload properties and heat tolerance during repeated starting, stopping.

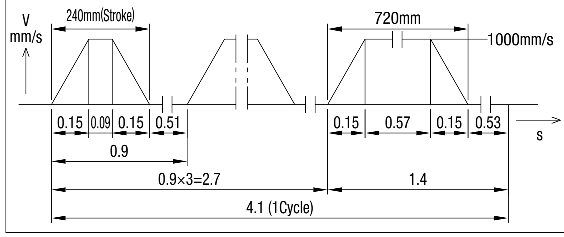
It is necessary to ensure a sufficient margin for these parameters.

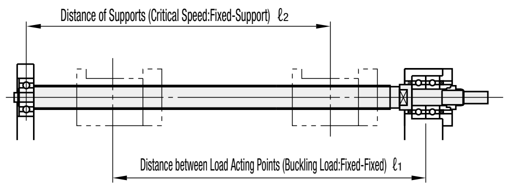
12. Example of Selection of Ball Screws (in case of X-axis)

Condition of Use

- Work & Table Mass: W=40(kg)
- Maximum Strokes: Smax.=720 (mm)
- Threading Speed: Vmax.=1000 (mm/s)
- Acceleration Constant: t=0.15(s)
- Positioning Precision: ±0.1/720(mm)
- Repeat Accuracy: ±0.01(mm)
- Life Span: Lh=30000Hours
- Linear Motion Guide Friction Coefficient: μ=0.02
- Driving Motor: Nmax.=3000 (min⁻¹)
- Duty Cycle Model Diagram







1. Setting Lead (L)

Set lead based on maximum motor revolutions and threading speed. Use the following formula.

$$L\geqq\frac{V_{max}\times60}{N_{max}}=\frac{1000\times60}{3000}=20(mm)$$

Required lead is 20mm or higher.

2. Nut selection

(1) Calculating Axial Load

The axial load calculation formula on Clause 6-2, **P.2227** is used to calculate the axial loads for each segment of a motion profile.

· At Constant Speed

Axial Load (Pb) =μWg=0.02×40×9.8≈8 (N)

· In Acceleration

Acceleration(α) = (Vmax/t)×10⁻³ = (1000/0.15)×10⁻³=6.67 (m/s²)

Axial Load (Pa) =Wα+μWg=40×6.67+0.02×40×9.3≈274 (N)

· In Deceleration

Axial Load (Pc) Wα-μWg=40×6.67-0.02×40×9.8≈260 (N)

(2) Actual moving time during each segment in a motion profile

Below derived from Duty Cycle Model Diagram.

Operating Pattern	In Acceleration	At Constant Speed	In Deceleration	Total Operating Time
Operating Time	0.60	0.84	0.60	2.04

(3) Summary of Axial Loads, Rotational Speeds, and Operation Time for Each Motion Profile

Operating Pattern	In Acceleration	At Constant Speed	In Deceleration
Axial Load	274N	8N	260N
Rotational Speed	1500min⁻¹	3000min⁻¹	1500min⁻¹
Operating Time Ratio	29.4%	41.2%	29.4%

(4) Calculating the Average Axial Load with a formula in **P.2227**, 6-3.

$$\text{Mean Axial Load}(P_m)=\left(\frac{P_1^3N_1t_1+P_2^3N_2t_2+P_3^3N_3t_3}{N_1t_1+N_2t_2+N_3t_3}\right)^{\frac{1}{3}}=200(N)$$

(5) Calculating the mean turns

$$\text{Mean Turns }(N_m)=\frac{N_1t_1+N_2t_2+N_3t_3}{t_1+t_2+t_3}=2118(min^{-1})$$

(6) Calculation of the required basic dynamic load rating

(1) Calculating Continuous Operational Life (Lho)

A Continuous Operational Life which is derived by subtracting Resting time from Desired Life while a motion profile of 4.01s with a moving time of 2.04s can be calculated as follows.

$$L_{ho}=\text{Desired Life }(L_h)\times\left(\frac{2.04}{4.1}\right)=14927\ (Hours)$$

(2) Calculating Required Basic Dynamic Load Rating

The formula on Clause 6-1., **P.2227** is used to calculate the basic dynamic load rating required to retain the net operational life of ball screw.

$$C=\left(\frac{60L_{ho}N_m}{10^6}\right)^{\frac{1}{3}}\times P_m\times f_w=\left(\frac{60\times14927\times2118}{10^6}\right)^{\frac{1}{3}}\times200\times1.2=2970\ (N)$$

(7) Tentative Ball Screw Selection

A ball screw to satisfy the requirements of Lead 20 and Basic Dynamic Load Rating of 2970N, BSS1520 is tentatively selected.

3. Accuracy Evaluation

(1) Evaluating Accuracy Grades and Axial Clearances

By referencing the "Ball Screw Lead Accuracy" table on Section 2., **P.2223**, it is found that the Accuracy Grade C5 with ±ep0.040 / 800~1000m of actual mean travel error satisfies the positioning accuracy: ±0.1/720mm and therefore, that BSS1520 is fully applicable.

Additionally, the Precision Screws axial clearance table on **P.2224** shows that axial clearance of BSS1520 is 0.005 or less.

The required positioning repeatability is ±0.01mm, and it can be confirmed that BSS1520 satisfies the requirement.

4. Screw Shaft Selection

(1) Determining the Overall Length

Screw Shaft O.A.L. (L)=

Max. Stroke+Nut Length+Margin+Shaft End Terminations (both sides). Therefore,

Max Stroke: 720mm

Nut Length: 62mm

Margin: Lead×1.5=60mm

Shaft End Termination Dims.: 72

Screw Shaft O.A.L. (L)=720+62+60+72=914 (mm)

* The Margin is provided as a countermeasure against overruns, and the amount is typically set as 1.5~2 times as much as the screw lead.
  Lead 20×1.5×2(Both Ends)=60(mm)

(2) Evaluating the Allowable Axial Load

Load Applicable Span Distance l1 is 820mm, and the Axial Load can be obtained by the formula on **P.2225**, "4. Allowable Axial Load" as indicated below.

$$P=m\frac{d^4}{\ell^2}10^4=10\times\frac{12.5^4}{820^2}\times10^4=3660\ (N)$$

The above formula produces an Axial Load value of 343N which is well within the Allowable Max. Axial Load 3660N, and suitability is confirmed.

(3) Evaluating the Allowable Max. Rotational Speed

Shaft supported span is 790mm, and the Critical Speed Nc value is calculated as follows by using the formula on "5-1. Critical Speed" in **P.2226**:

$$N_c=g\frac{d}{\ell^2}10^7=15.1\times\frac{12.5}{790^2}\times10^7=3024\ (min^{-1})$$

The max. speed requirement of 3000rpm is within the Critical Speed of 3024min⁻¹, and the suitability is confirmed.

Additionally, the DmN value can be calculated by using the formula in **P.2226**, "5-2. DmN Value" as:

DmN=(Shaft O.D.+A value)×Max Rotational Speed=15.8×3000=47400≤70000

and the suitability is confirmed.

5. Selection Result

From the above, it is determined that a suitable ball screw model is BSS1520-914.