Supporting industries across the world through precision technology

Achieving "the precision infinitely close to zero error" to fulfill customers' requirements for high accuracy and high productivity in every field of industry is the basic and primary focus of product manufacturing at KURODA.

● Precision machining technology

KURODA, based on its strong commitment to precision and its craftsman's DNA that dictates it "make the things it needs using its own faculties", has developed a large number of underlying technologies originating from its legacy as a gauge manufacturer ranging from measurement techniques to machine tools such as proprietary surface grinding machines and in-house-developed thread grinding machines. KURODA's products manufactured from these underlying technologies have become essential in a wide range of fields, such as machines, cars, medical care, and semiconductors.

● More than 90 years of history

Since its foundation in 1925, KURODA has continuously supported many industries with reliable technologies related to "precision". The relationships, trust, mutual technologies, and know-how KURODA has accumulated over these 90 years of history make it a highly credible company.

● Global network

In recent years, KURODA has accelerated its global expansion to support industrial advancement all over the world through precision technology.
As part of this effort, KURODA has entered into partnerships including the acquisition of the JENATEC group and will continue to expand its overseas sales organization to make the KURODA brand and KURODA-JENATEC brand better known in the world.

"Always challenging what is new, and creating new value"

● Ball screw related manufacturing locations

Kazusa Akademia Plant (Chiba)
· Precision Ball Screws
· Support Units

Asahi Plant (Chiba)
· Rolled Ball Screws
· Ballscrew Actuators

Futtsu Plant (Chiba)
· Ball Screw-Related Components

JENAER GEWINDETECHNIK GmbH (Germany)
· Precision Ball Screws

● Overseas locations

United States	KURODA JENA TEC INC.
South Korea	KURODA PRECISION INDUSTRIES KOREA LTD.
China	KURODA PRECISION INDUSTRIES PINGHU CO., LTD.
	KURODA JENA TEC PRECISION INDUSTRIES PINGHU CO., LTD.
Malaysia	KURODA PRECISION INDUSTRIES(M) SDN.BHD.
Germany	JENAER GEWINDETECHNIK GmbH

KURODA aspires to the principle of "CHALLENGE & CREATE", making linear motion systems based on expertise in gauge manufacturing.

KURODA's Ball Screws

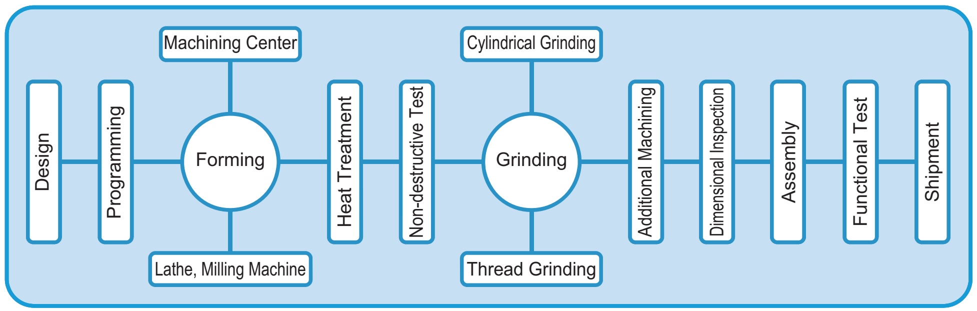
KURODA's Ball Screws are an outgrowth of a legacy in gauge manufacturing.
In order to obtain characteristically advantageous features such as high efficiency in motion control, KURODA's ball screws are utilized as an essential element in the control mechanism of a wide variety of automatic machines including machining tools, precision positioning tables, industrial robots, and semiconductor fabrication devices.

High Quality Standards

In recent years, the technical development of various machines for higher accuracy and higher speed has been increasingly accelerated and the users' needs are much more diversified than ever. On the strength of our traditional precision machining technology and our unceasing research into ideal ball screws, we are supplying high quality ball screws that are manufactured from carefully selected materials especially in terms of quality with our advanced grinding technologies and under our extremely tight quality control using the most modern test and measuring equipment.

Research and Development

Responding to rapid diversification of needs, KURODA has been pursuing more research and development on ball screws by looking ahead to the advancement of precision engineering technology for the next generation. We are conducting intensive studies into the basics of ideal ball screws jointly with academic laboratories to accumulate and analyze comprehensive test data on the accuracy, hardness, service life, and other vital factors of ball screws, and have established various evaluation systems.



KURODA supports high precision applications using materials and equipment that can achieve JIS lead accuracy grade C0.

Materials and Heat Treatment

KURODA makes it a rule to purchase dedicated ball screw materials based on detailed specifications intended for our company and internally control the heat treatment processes such as carburizing, quenching and induction hardening, of which records are carefully kept to assure traceability.

Grinding

KURODA uses high precision thread grinders dedicated for ball screws developed and manufactured uniquely by KURODA based on its screw gauge manufacturing know-how. These are carefully maintained at KURODA to enable ball screw manufacturing with JIS C0 grade high accuracy. These machines realize the world's highest level of machining precision due to the combination of a vast machining database built up over a half-century with KURODA's highly proficient technicians.

Assembly

The ball screw shafts, nuts, and recirculation parts that were machined to a high accuracy are meticulously assembled and finished through excellent work by experienced workers. The axial clearance and preloading are strictly administered to realize a smooth operability and high positioning accuracy that satisfies the requirements of a variety of machines and equipment.

Inspection

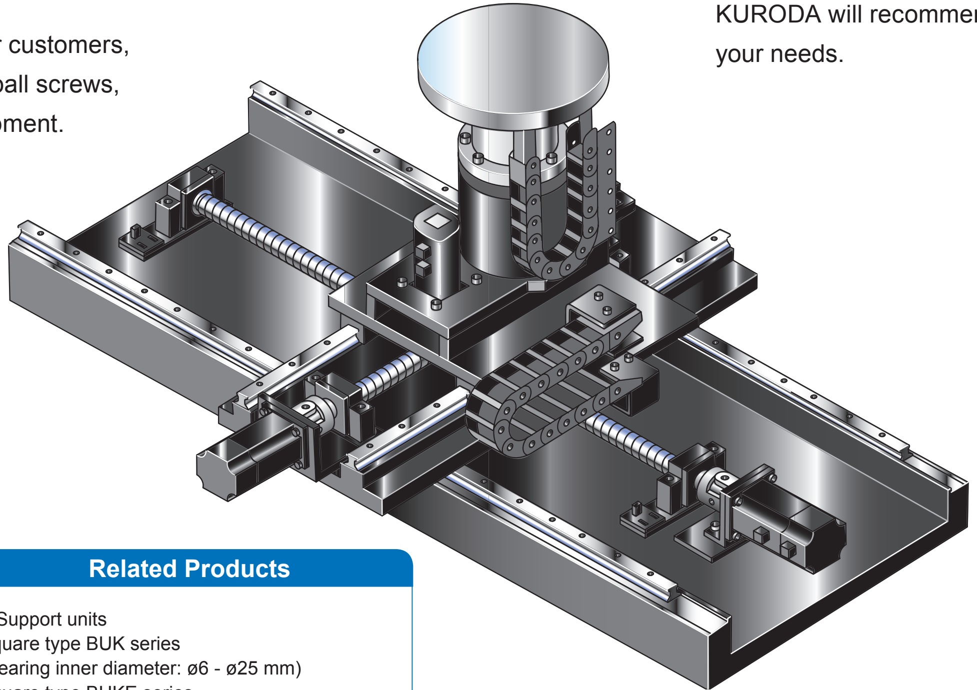
In order to assure stable measurement at JIS C0 grade lead accuracy, we have established a structure including our proprietary lead measuring machine installed in a strictly controlled thermostatic chamber as well as measuring machines classified by applications so as to satisfy any needs for various applications and measurement accuracies covering all processes from development to mass production.

BALL SCREWS AND LINEAR MOTION PRODUCTS

KURODA products can support your linear motion systems.

To fulfill a variety of needs and requirements of our customers, we provide a wide selection of products including ball screws, linear motion products, and related tools and equipment.

KURODA will recommend the optimal linear motion system which satisfies your needs.



Standard Precision Ball Screws

■ Ball screws with C3 accuracy grade
GP series (ø8 - ø20 mm)
DP series (ø6 - ø14 mm)

■ Ball screws with C5 accuracy grade
GG series (ø8 - ø32 mm)
FG series (ø10 - ø25 mm)
HG series (ø8 - ø20 mm)

■ Ball screws with C7 accuracy grade
GE series (ø8 - ø32 mm)
FE series (ø10 - ø25 mm)
GW series (ø8 - ø25 mm, with rolled screw shaft)
RW series (ø8 mm, resin nut)

■ Ball screws with C10 accuracy grade
GY series (ø8 - ø40 mm, with rolled screw shaft)

Custom Precision Ball Screws

■ Ball screws with C0-C10 accuracy grades
GR series (ø5 - ø125 mm)
DR series (ø6 - ø50 mm)

■ Ball screws with C3-C7 accuracy grades
FR series (ø10 - ø40 mm)

Related Products

■ Support units
Square type BUK series
(Bearing inner diameter: ø6 - ø25 mm)
Square type BUKE series
(Bearing inner diameter: ø6 - ø12 mm)
Round type BUM series
(Bearing inner diameter: ø6 - ø25 mm)
Round type BUT series
(Bearing inner diameter: ø20 - ø40 mm)

■ Low particle generating grease
KURODA C-Grease (Clean grease)
KURODA S-Grease (Clean and oscillation-proof grease)

■ Lubricating unit for ball screws
LUBSEAL (Applicable shaft diameter: ø10 - ø25 mm)

■ Slide screws with resin nuts
PW series (Accuracy grade C7, ø10, ø12 mm)
PY series (Accuracy grade C10, ø10, ø12 mm)

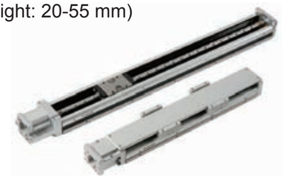
Couplings and Other Related Products

■ Couplings
Miki Pulley Co., Ltd.
http://www.mikipulley.co.jp/JP/
Sakai Manufacturing Co., Ltd.
http://www.sakai-mfg.com/
ISEL Co., Ltd.
http://isel.jp/

Ballscrew Actuators

A ballscrew actuator is a product in which ball screws and linear motion guides are integrated in one unit.
Please refer to KURODA's ballscrew actuator catalog.

■ Actuators with repeated positioning accuracy of ±1 μm (P grade) and ±3 μm (H grade)
SG series (Mounting height: 20-55 mm)

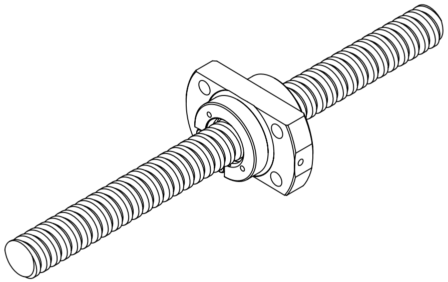


■ Actuators with repeated positioning accuracy of ±3 μm (H grade), ± 5μm (U grade) and ±10 μm (W grade)
SE series (Mounting height: 15-45 mm)

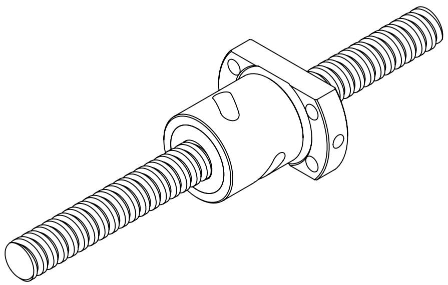
■ Full-cover type actuators
SC series (Mounting height: 23-45 mm)
(Repeated positioning accuracy: ±3 μm (H grade), ±5 μm (U grade) and ±10 μm (W grade))

Ball Screws Product Range

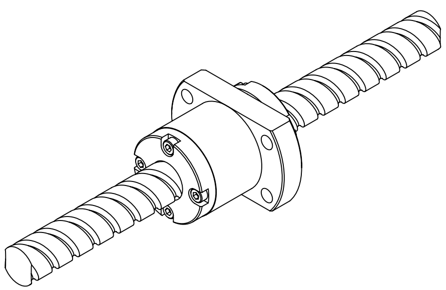
Features and keywords	Series		Nut combination	Accuracy grade	Shaft diameter	Screw shaft type	Product line
· High rotational speed · Low noise · Compact · Long service life	F series	FG series	Single nut	C5	ø10 to ø25	Unfinished shaft ends	Standard product
		FE series		C7			
		FR series	Single nut	C3 to C7	ø10 to ø40	Free design	Custom product
			Double nut	C3 to C5	ø32 to ø40		



Features and keywords	Series		Nut combination	Accuracy grade	Shaft diameter	Screw shaft type	Product line
· Compact · Fine-pitch positioning	D series	DP series	Single nut	C3	ø6 to ø14	One end finished	Standard product
		DR series	Single nut	C0 to C7	ø6 to ø50	Free design	Custom product
			Integral nut	C0 to C5	ø16 to ø50		

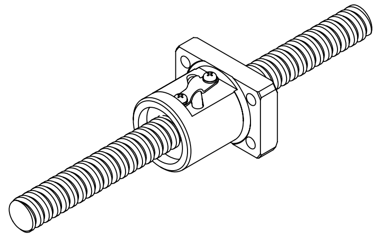


Features and keywords	Series		Nut combination	Accuracy grade	Shaft diameter	Screw shaft type	Product line
· High speed conveyance · Large lead	H series	HG series	Single nut	C5	ø8 to ø20	Unfinished shaft ends	Standard product

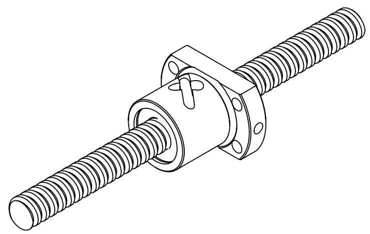


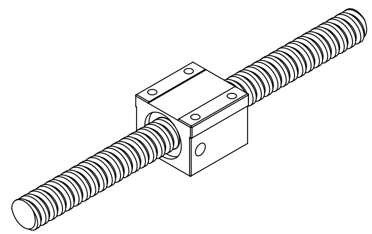
Ball Screws Product Range

Features and keywords	Series		Nut combination	Accuracy grade	Shaft diameter	Screw shaft type	Product line
· Wide variety of shaft diameters · Wide variety of lead sizes · For positioning · For transfer	G series	GP series	Single nut	C3	ø8 to ø20	One end finished	Standard product
		GG series		C5	ø8 to ø32	Unfinished shaft ends	
		GE series		C7			
		GR series	Single nut	C0 to C7	ø5 to ø125	Free design	Custom product
			Integral nut	C0 to C5	ø20 to ø63		
			Double nut	C0 to C5	ø8 to ø125		

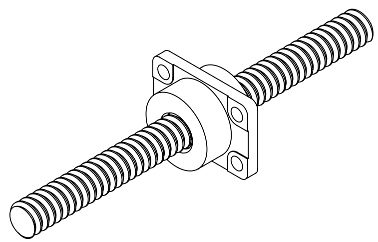


Features and keywords	Series		Nut combination	Accuracy grade	Shaft diameter	Screw shaft type	Product line
· For transfer · Wide variety of nut types (round and square types)	Rolled G series	GW series	Single nut	C7	ø8 to ø25	Unfinished shaft ends	Standard rolled product
		GY series		C10	ø8 to ø40		





Features and keywords	Series		Nut combination	Accuracy grade	Shaft diameter	Screw shaft type	Product line
· For transfer · For lighter load applications	R series	RW series	Single nut	C7	ø8	Unfinished shaft ends	Standard rolled product



Products Related to Ball Screws

Support units

Features and keywords	Series		Bearing type	Bearing combination	Accuracy grade of bearing	Bearing inner diameter
· Compact body · Fit for any mounting configurations · Built-in locking function	Square type	BUK series	Combined angular ball bearing	DF (face-to-face)	P5 grade (P0 grade for deep groove ball bearing)	ø6 to ø25
	Round type	BUM series				
	Round type	BUT series	High-thrust angular ball bearing	DF (face-to-face)	P4 grade	ø20 to ø40
	Square type	BUKE series	Radial ball bearing	---	P0 grade	ø6 to ø12

BUK (Square type)
BUKE (Square type)
BUM (Round type)

BUT (Round type)

Low particle generating grease

Features and keywords	Series	Operating temperature range	Thickener	Model number
· For clean environment · Excellent lubricating performance · Excellent torque performance · High rust prevention performance	KURODA C-Grease	-30 to +150°C	Urea	C1-080G-J (Supplied in a 80 g bellows-shaped container)
				C1-400G-J (Supplied in a 400 g bellows-shaped container)
	KURODA S-Grease	-20 to +150°C	Urea	S1-080G-J (Supplied in a 80 g bellows-shaped container)
				S1-400G-J (Supplied in a 400 g bellows-shaped container)

Slide screws with resin nuts

Features and keywords	Series		Nut combination	Accuracy grade	Shaft diameter	Screw shaft type	Product line
· Precise resin nut · Excellent mechanical property · Chemical-proof performance · Compact · Low price	Slide screw	PW series	Single nut	C7	ø10, ø12	Unfinished shaft ends	Standard product
		PY series		C10			

Data including product information, technical information, catalogs, and CAD data of linear motion products such as ball screws and ballscrew actuators can also be viewed from the KURODA website.

www. kuroda-precision.co.jp

2D CAD data

2D CAD data (DXF format) can be downloaded free of charge from the KURODA website.

3D CAD data

3D CAD data can be downloaded free of charge from the PARTcommunity CAD data downloading service.

Catalogs

The catalogs of ball screws, ball screw linear motion products, ballscrew actuators and other products can be downloaded from the KURODA website.
For pamphlets, please contact your nearest sales location.

KURODA Ball Screws Catalog

Proper usage for safety

Be sure to read the following instructions before use.
For general instructions, refer to the text of this catalog.

The following safety precautions recommend the correct usage of our products to prevent an injury and damage.
These precautions are classified into 3 categories: “**DANGER**”, “**WARNING**” and “**CAUTION**” according to the degree of possible injury or damage and the degree of impendence of such injury or damage.
Be sure to follow all these precautions, as they contain important matters regarding safety.

⚠ DANGER	⚠ WARNING	⚠ CAUTION
Indicates an impending hazardous situation that may arise due to improper handling or operation and could result in a serious injury or death.	Indicates a potentially hazardous situation that may arise due to improper handling or operation and could result in a serious injury or death.	Indicates a potentially hazardous situation that may arise due to improper handling or operation and could result in an injury or property damage only.

Be sure to obey “Industrial Safety and Health Act” and other safety rules and regulations in addition to these precautions.
There are some situations that may lead to a serious result according to circumstances, even if it is mentioned in the category of “**CAUTION**”. Be sure to follow these precautions, as they contain important matters.

⚠ WARNING

- **Select a ball screw properly.**
  As operating conditions for products mentioned in this catalog are diverse, the applicability of ball screw to the intended system should be determined by the total system designer or the person who determined specifications for such system after conducting analysis and testing as necessary.
  The person who determined the applicability of the system shall be responsible for assuring the intended system’s performance and safety. When configuring a system, the system designer should thoroughly examine all specifications for such a system by referring to the latest product catalog and data, and also take into consideration the possibility of equipment-related issues.
- **The ball screw should be handled by persons who have sufficient knowledge and experience.**
  · Thoroughly read this catalog and operation manual before use.
  · Never disassemble the ball screw. Dust may enter inside, degrading the accuracy of the ball screw and may lead to an accident. When the ball screw has been disassembled from necessity, return it to KURODA for repair and reassembling. (Fees will be incured.)
  · When mounting a ball screw to a machine and dismounting it from the machine, check that a means of fall prevention has been put in place and that the moving part of the machine has been fixed beforehand.
- **The products listed here are primarily for industrial use. When using the ball screw in the following conditions or environments, take the proper safety measures and consult KURODA beforehand.**
  · Conditions and environments other than specified and outdoor use.
  · Applications to nuclear power equipment, railroads aircraft, vehicles, medical equipment, equipment contacting food and drink, and the like.
  · Applications which require extreme safety and will also greatly affect persons and property.
- **During operation, make sure to keep your hands away from screws and ends of ball screw shafts, which are rotating parts, to prevent your hands from being caught.**
- **Pay adequate attention not to allow the products to be used for military purpose including for arms and weapons.**

Ball screw/General instructions (1)

Be sure to read the following instructions before use.
Also refer to "Proper usage for safety".

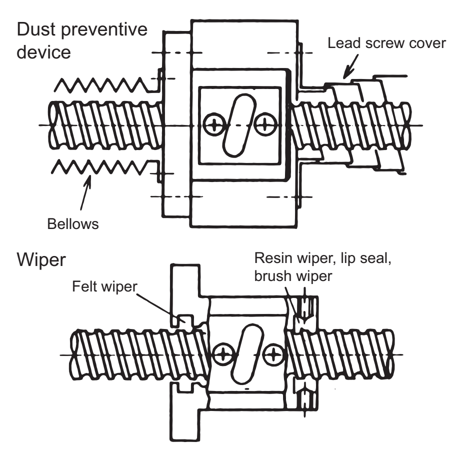
Caution for design

WARNING

● **Rotational speed**
Referring to the section describing permissible rotational speed in this catalog, use a ball screw at or lower than the listed permissible rotational speed. Using the product at or above the permissible rotational speed could cause damage of its recirculation components and result in inoperable conditions. When using a vertical shaft, the damage may lead to dangerous accidents such as falling balls or parts.

CAUTION

● **Dust preventive cover**
If it is likely that dust or other contaminant may enter inside the ball screw, be sure to attach a dust preventive cover, such as bellows or lead screw cover (steel bellows). Attaching a wiper at both ends of a nut will be more effective for dust prevention.
The dust or contaminant caught in the ball screw could cause various defects including malfunction, abnormal noise, excessive vibration, accelerated wear-out, and early chipping.



● **Imbalanced load**
In your system design, ensure that a radial or moment load is not directly loaded to the ball screw. Otherwise, it may result in shorter product service life due to concentrated load to a certain portion of balls in the screw.

● **Mounting of the ball screw**
When mounting of the ball screw to a machine, the system design should allow its screw shaft to be mounted without taking off the nut. Removing and attaching the nut may cause some balls to drop outside of their recirculation path, which may result in damage of recirculation components. If such removal of a nut is inevitable, consult KURODA beforehand.

Caution for mounting and use

WARNING

● **Do not overrun the product.**
If a nut of the ball screw is overrun and receives an impact at a stroke end, a resulting impression created on a screw groove could cause malfunction. If an end of the screw groove has a portion with no flute, such overturn could damage ball recirculation components, which may result in inoperable conditions.
If a ball screw nut has been allowed to overrun, please contact KURODA to have it repaired at charge.

● **Pay adequate attention to the accuracy grade.**
A moment load caused by misalignment of a ball screw, bearing, guide, nut, and housing and improper angularity may result in malfunction, abnormal noise, excessive vibration, shorter product service life as well as breakage of screw shafts due to rotating bending fatigue. Be careful with such defects because they may lead to a serious accident.

● **Be careful with falling off of components due to their own weight.**
Since a ball screw has a low friction factor, its shaft or nut could potentially fall off due to its own weight. Be careful not to have your hand or fingers be caught under the fallen component.

● **Take care not to injure yourself.**
The shafts and nut corners may have sharp edges for structural reasons, and there may be a risk of injuries such as cuts.
In order to prevent injuries, take adequate care when handling products and wear protective equipment such as gloves during work.

CAUTION

● **Do not remove the nut.**
When balls have dropped out of the nut or the nut has been removed from a shaft, do not attempt to reassemble them yourself. Return them to KURODA for repair. (Fees will be incured.)
KURODA's standard precision ball screws have unfinished shaft ends. The unfinished products are provided with a sleeve for separating the nut.

Ball screw/General instructions (2)

Be sure to read the following instructions before use.
Also refer to "Proper usage for safety".

● **Be careful of any dust or contaminants.**
While a machine is assembled, put a cover to prevent the screw shaft from catching any dust or contaminants. Such contamination could cause malfunction of the machine.

● **When a component such as bearing, gear, or pulley is attached to a screw shaft, handle them with care so that there is no damage from impact.**
Such impact could cause the screw shaft to bend.
If an impact is accidentally applied to the shaft, check it first to see if it is not bent by checking the coupling of the screw shaft with a dial gauge, before assembling the additional components.

● **Use the product within the operating temperature limit.**
Ball screws are designed to have a normal operating temperature limit of 60°C or below. Using them in an environment exceeding the temperature limit may result in a damaged lubrication or sealing components.
If you need to use the screw in a special environment, consult with KURODA beforehand.

Lubricants

CAUTION

● **Type of lubricant**
Unless specified, Alvania Grease S2 or Maltemp PS No.2 is contained in the nut as lubricant. Since rust preventive oil applied to the screw shaft also serves as lubricant, the ball screw can be used without additional application.
Do not replace the initially applied lubricant with any product not listed below. Do not remove the rust preventive oil, either.

Grease

Application	Product name	Manufacturer
General purpose	Alvania Grease S2	SHOWA SHELL SEKIYU K.K.
	Multemp PS No. 2 Grease	KYODO YUSHI CO., LTD.
For dust prevention	KURODA C-Grease	KURODA PRECISION INDUSTSRIES LTD.
	KURODA S-Grease (Support for oscillation resistance)	KURODA PRECISION INDUSTSRIES LTD.

Lubricating oil

Application	Product name	Manufacturer
General purpose	Daphne Mechanic Oil	IDEMITSU KOSAN CO., LTD.
	Mobil Vactra Oil	EXXON MOBIL CORPORATION

Note) All product names of greases and oils are registered trademarks of their respective companies.

Storage

CAUTION

● **Storage method**
Store the ball screws in an indoor place where temperature difference is as small as possible, avoiding high and low temperatures and high humidity.
It should be stored in a horizontal state in the packaging originally sent by KURODA. In order to prevent unnecessary contamination by dust or rusting of the ball screws, do not open the outer packaging or any of the internal packaging unless necessary.

Checkup and caution

CAUTION

● **Checking the lubricant status and application of grease**
For the sake of usability and dust prevention, lubricant for ball screws is, in general, contained only in the nut. When specified or required for overseas export, lubricant may be applied to the screw shaft.
Depending on the screw size and screw shaft length, the amount of grease in the nut may not be sufficient. After running the nut back and forth the length of the shaft, check to see if the rolling side of the screw groove has enough grease on it. If the amount is not enough, apply additional grease to the screw shaft.

● **Checkup and reapplication of lubricant**
Check the lubricant 2 to 3 months after the ball screw is used for the first time. If it is extremely dirty, it is recommend that you wipe off old grease and apply new grease. Then, check and supply the lubricant once every year as a general rule. However, as the service life of lubricants varies according to operating conditions and environment, adjust the intervals properly.

When reapplying additional lubricant, use the same brand of lubricant as was initially included.
For a ball screw model provided with a nut which does not have a grease filler hole, supply a sufficient amount of grease directly to the screw shaft and screw groove, carefully applying it over the components until the grease goes into the nut. For a model provided with a nut having a filler hole, supply a necessary amount of grease from the filler hole or a feeder (grease nipple, etc).
After applying additional grease, run the work for a full stroke to ensure the proper coverage of the grease on all components. Wipe off excess grease attached on the end of the screw shaft.
For more details on the size of the filler hole, refer to dimensions of each ball screws size.

KURODA ball screws

Excellent reliability and high accuracy

KURODA ball screws provide high accuracy as well as excellent reliability, as a result of our grinding, assembly, and inspection operations implemented in our plants under a strict temperature control, which is built on our gauge production expertise accumulated over many years.

High transmission efficiency

Ball screws have outstanding transmission efficiency of over 90%, incomparably higher than slide screws. Their required torque is just less than a third of what slide screws require. Therefore, it is easier to transfer linear motion into rotary motion.

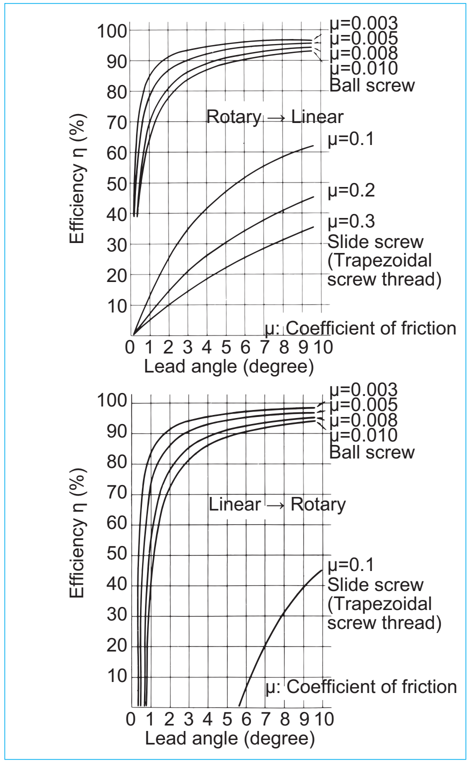


Figure 1: Mechanical efficiency of ball screws

Excellent durability

KURODA ball screws maintain excellent durability achieved by carefully selected materials, proper heat treatment, and machining with advanced product technologies.

Small axial clearance

Since KURODA ball screws adopt a gothic-arch groove profile, its axial clearance can be finely adjusted and rotated with minimal force. In addition, by applying preload to the screw, the axial clearance could be adjusted to 0 to achieve advanced rigidity.

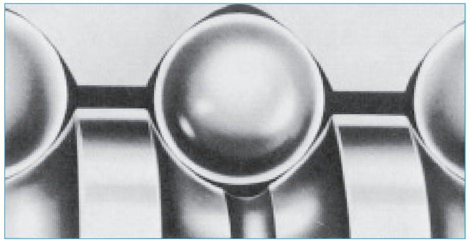


Figure 2: Ball screw groove profile

Fine feeding

Due to rolling contacts made by balls, the ball screws can accurately provide fine feeding, even with extremely small starting friction at low speed, without exhibiting the stick slip tendency of slide screws.

High-speed operation

With high transmission efficiency and a low rate of self heat generation, KURODA ball screws can provide a high speed rotation.

Easy maintenance

Due to rolling contacts made by balls, no special maintenance other than regular supply of grease is required under normal operating conditions.

Wide variation

In order to fulfill a diverse range of customer requirements there are a wide variety of series and models of KURODA ball screws made available. Products include miniature ball screws, super large lead ball screws, high rotational speed ball screws, standard precision ball screws and more.

Construction

Ball screws are configured to have steel balls enclosed between a screw shaft and a nut, wherein steel balls rotate while they recirculate in the device.

KURODA ball screws are designed to adopt one of the following four standard recirculation systems.

■ Tube Method

This is a standard recirculation system for ball screws, using a curved tube as a recirculation part. In this system, steel balls are guided into the tube, make 1.5, 2.5, or 3.5 turns along the screw groove to return to the starting point, forming a circuit.

To enhance the load capacity of the screw, the number of circuits can be increased.

■ End Cap Method

This recirculation system has end caps attached to both ends of the nut, which are capable of scooping up the steel balls and forwarding them back to the starting point. A through hole is provided in the body of the nut to allow the steel balls to pass through. This system is adopted by ball screws with large leads (e.g. screw lead with twice or three times as large as the screw shaft diameter).

■ Deflector Method

This system is compact and has the most optimal rotational balance among the recirculation systems listed in this catalog. Steel balls rolling between a screw shaft and a nut are guided by a deflector inserted in the nut to make one recirculation per lead, forming a circuit.

■ End Deflector Method

This system has end deflectors incorporated into both ends of the nut, which are capable of scooping up steel balls and forwarding them back to the starting point. A through hole is provided in the body of the nut to allow the steel balls to pass through. The system is designed for a smooth flow of the steel balls. This structure realized higher rotational speed and low-noise operation in a compact nut body.

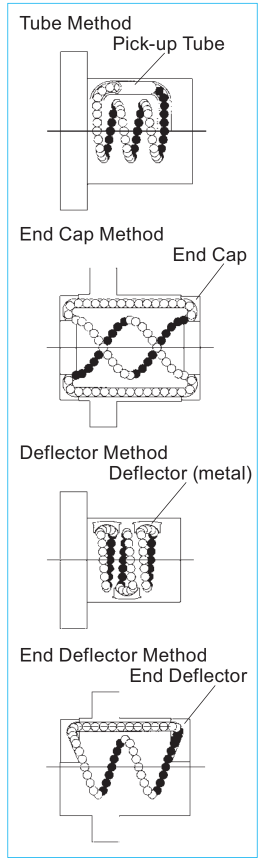


Figure 3: Recirculation system

Materials and heat treatment

The hardness of the screw groove surface is a critical factor for the service life of a ball screw. The rigidity of the shaft must satisfy the requirements of a shaft for transmission of loads. In order to fulfill such needs, KURODA ball screws are generally manufactured to maintain the minimum standard hardness of 58 HRC with the materials listed in Table 1. The screws also go through a surface hardening process to enhance their hardness to attain 58 to 62 HRC. Additionally, for some products which required heat resistance and/or corrosion resistance, stainless steel may be used to achieve hardness of 56 to 59 HRC through a surface hardening process.

Table 1: Materials and heat treatment

● Ground ball screws

	Material	Heat treatment	Hardness
Nut	Chromium-molybdenum steel SCM420	Carburizing and quenching	58 to 62 HRC
Screw shaft	Chromium-molybdenum steel SCM415 SCM420	Carburizing and quenching	58 to 62 HRC
	Chromium-molybdenum steel AISI4150HV	Induction quenching	58 to 62 HRC

● Rolled ball screws

	Material	Heat treatment	Hardness
Screw shaft	S45C S55C	Induction quenching	56 to 62HRC
Nut	SCM420	Steel balls	58 to 62HRC
Steel ball	SUJ2	Quenching	60 HRC or above

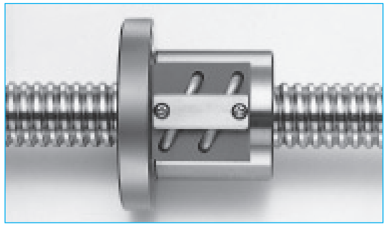
Overview of ball screws

Types

■ Nut combination types

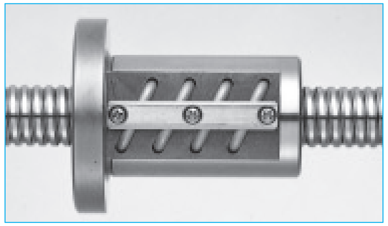
Single Nut

This is the simplest configuration. It is usually used with a small axial clearance. In order to improve the positioning accuracy, axial clearance can be eliminated and a preload can be applied by loading oversized balls. The single nut type with a preload is suitable for machines requiring small to medium loads and light to normal preloading, including semiconductor fabrication devices, assembling robots, precision instruments, and small NC machine tools, which require very high positioning accuracy.



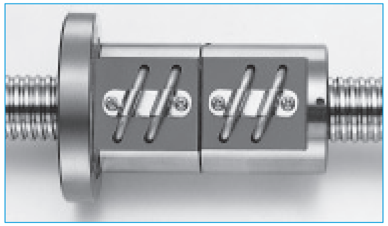
Integral Nut

This type of nut has a screw portion separated into a load side and preload side via a pitch shift. The nut is offset according to the desired amount of preload. It provides the features of having a load side and preload side of a double nut integrated in one component. The integration into one body enables the nut to be shorter while maintaining stable rigidity and excellent operational performance.
The integral nut is suitable for all types of machines and equipment requiring medium to higher loads and normal to higher preloading.



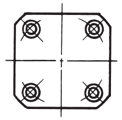
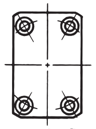
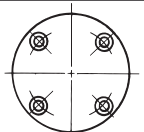
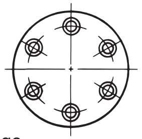
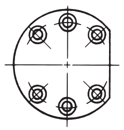
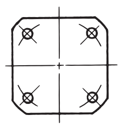
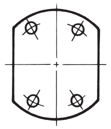
Double Nut

Two separate nuts, one designated as the load side and the other as the preload side are joined. They are rotated in opposite directions and fixed in tension by a pin inserted between them. A double nut is available in wider variety of sizes than integral nuts, and is suitable for applications with medium to higher preloading and with medium to higher loads, such as machines or equipment requiring highly precise positioning as well as high rigidity.



■ Flange types

The type of a flange is represented by a symbol provided for each nominal size as shown below.

Type symbol	A	B	C	
Flange type	 Square flange	 Rectangle flange	 Round flange	
Type symbol	D	E	H	
Flange type	 Single side cut, round flange	 Square (without spot facing)	 Double side cut, round flange	

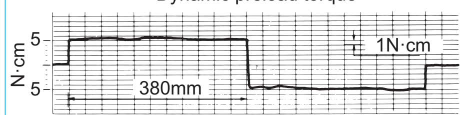
Custom products

In order to fulfill the diversified needs of our customer in various industries such as mounting/placement machines, semiconductor fabrication equipment, liquid crystal (LC) manufacturing machines, clean robots, SEM equipment, small machine tools, medical instruments, automotive production facilities, etc., KURODA provides, upon your request, various customized ball screws with special specifications. Our custom products include super precision ball screws (C0 grade or above), high rotational speed ball screws, stainless ball screws for special environments, low maintenance ball screws, and ball screws compliant with various environmental requirements.

■ Super precision ball screws (capable of fine pitch forwarding by a scale of 0.1 μm/pulse)

When a machine requires fine feeding with high accuracy, torque variation contributes to accuracy degradation. With a laser scanner, SEM instrument, and test/analysis equipment, torque variation causes fluctuations in the transfer speed of the machine. Under such conditions, a highly accurate continuous operation may not be achieved. However, building upon precision processing expertise acquired through years of gauge production business, KURODA has successfully developed in-house screw grinders to control the profile of the screw groove, circularity, and cylindricality in a highly accurate manner. With the reduced torque variation achieved by this precise control, we have realized ball screws capable of fine feeding by to a degree of 0.1 μm/pulse.

Dynamic preload torque



Shaft diameter: 15
Lead: 5
Rotational speed for measurement: 50 min^{-1}
Lubricant: Turbine oil #2
(ISO VG68)

■ Super precision ball screw (entire deflection of a screw shaft is 1/4 to 1/3 of C0 grade screw)

As long as the deflection of the screw shaft is within the permissible range and the shaft is kept straight though a typical mounting arrangement where rigid linear bearings are set at both ends of the ball screw, there is usually limited influence on operational accuracy. However, in such cases that a simplified guiding system has been put in place for weight or size considerations, bending of the ball screw may adversely impact operational accuracy, resulting in pitching or yawing errors. To prevent such issues, KURODA provides customized ball screws manufactured through our unique processing method, with which the deflection of the screw shaft center is mitigated to 1/4 to 1/3 of permissible deflection for C0 grade screws. For more information, please contact KURODA.

■ High rotational speed ball screw

KURODA provides special ball screws capable of fulfilling our customers' needs for rotational speed with a DmN of over 70,000. These ball screws are suitable for use in machine tools, robots, and other applications requiring high rotational speed. The F series is the standard product line designed for high rotational speed and low noise. Custom products in the G series can also be designed to meet the DmN requirements of high speed applications.
For more information, please contact KURODA.

■ Ball screw compliant with special environmental requirements

● All-stainless steel ball screw

Stainless steel ball screws which can be used in vacuum atmospheric conditions, clean room conditions, or an environment with special requirements such as chemical resistance, are also available. The stainless steel screws demonstrate minimal outgassing and excellent corrosion resistance.
For more information, please contact KURODA.

Materials of all-stainless steel screws

· Screw shaft, nut, and balls	Martensitic stainless steel
· Recirculation components	Austenitic stainless steel, precipitation hardening stainless steel, etc.
· Small screws and parts	Austenitic stainless steel

● Customized surface treatment

If you intend to use a ball screw in an environment where corrosion resistance is necessary, we can accommodate your needs by applying an additional anticorrosive black coating for rust-proofing. The black coating has a thickness of 1-2 µm. Some of the coating may be partially removed from areas subjected to consistent ball contact during the initial period after commencement of operation, but rust prevention will be maintained thereafter. If you need more advanced corrosion resistance, further additional fluorine coating on top of the anticorrosive black coating can be applied. Other types of surface treatment will also be provided upon request.
For more information, please contact KURODA.

■ Ball screws with lubricating unit

LUBSEAL is a lubricating unit attached to the ball screw nut which supplies a proper amount of grease to the screw groove. Recommended for use in semiconductor fabrication equipment, liquid crystal manufacturing machines, testing instruments, food processing machines, medical instruments, machine tools, and automobile manufacturing equipment. By adding LUBSEAL to compatible ball screws, the maintainance interval between grease applications can be greatly increased.

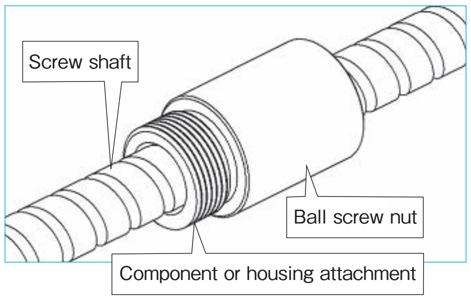
■ Various types of grease

KURODA also provides a wide range of grease which fulfills your requirements, including clean room compliance, anti-fretting corrosion, extreme pressure, low temperature, and wide temperature range. For more information, please contact KURODA.

■ Examples of other custom ball screws with special dimensions and rating requirements

KURODA also provides custom ball screws with dimensions or specifications which are not listed as standard products in the catalog.
Various ball screws which require special profiles and dimensions to accommodate right-handed and left-handed screws, leads in imperial/US units (i.e. inches), hollow screw shafts, square nuts and others are available. Ball screws which are configured with a screw shaft having a gear, spline, serration or the like, or are capable of withstanding heavy loads can also be made upon request. For more information, please contact KURODA.

● Example of custom nut dimensions



Ordering instructions (How to interpret ball screw model numbers)

Model number	Series	Shaft Diameter	Lead	Number of Circuits	Nut Type		Flange Type	Ball Re-circulation System	Wiper Material	Thread Direction		Overall Screw Shaft Length	Shaft End Type	Thread Length		Accuracy Grade	Axial Clearance
	FE	15	10	P	S	–	H	P	N	R	–	1500	X	1440	–	C5	F
	(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)		(10)	(11)	(12)		(13)	(14)

(1) Ball Screw Series

Series	Standard series	Order-made series	Remarks
F Series	FE/C7 grade, FG/C5 grade	FR, FM, FZ/C3-C7 grades	* Order-made Ball Screws are indicated with □R, □M, and □Z which designate the following: □R: Order-made Ball Screws with established KURODA specifications and design. Details are listed in this catalog. □M: Customized Order-made Ball Screws with established KURODA specifications and design, but with a customized flange. □Z: Customized Order-made Ball Screws with specifications and design other than the above. GT indicates customized rolled ball screws.
D Series	DP/C3 grade	DR, DM, DZ/C0-C7 grades	
G Series	GE/C7 grade, GG/C5 grade, GP/C3 grade	GR, GM, GZ/C0-C10 grades	
	GY/C10 grade (rolled screw), GW/C7 grade (rolled screw)	GT/C7 or C10 grade (rolled screw)	
H Series	HG/C5 grade	–	
R Series	RW/C7 grade	–	

(2) Screw Shaft Diameter (unit: mm)
Indicated by a two-digit number or a number-alphabet combination.
· To show a screw shaft diameter with a 1-digit number, 0 needs to be added in front of the diameter to make it a two-digit code.
(Example) Screw shaft diameter 5 mm → 05
· Screw shaft diameters with 3-digits are indicated as follows: 100 mm → A0, 125 mm → C5

(3) Ball Screw Lead
Indicated by a two-digit number or a number-alphabet combination.
· To show a lead with a 1-digit number, 0 needs to be added in front to make it a two-digit code.
(Example) Lead of 1 mm → 01
· Leads whose actual value is not a whole number (i.e. including an increment of 0.5 mm) are represented with the letter F as indicated below. 1.5 mm → 1F, 2.5 mm → 2F

(4) Number of Circuits of the Ball Screw Nut

Symbol	Number of circuits	Applicable recirculation system
A	1.5 turns, 1 circuit	Tube method
B	1.5 turns, 2 circuits	
C	1.5 turns, 3 circuits	
D	2.5 turns, 1 circuit	
E	2.5 turns, 2 circuits	
F	2.5 turns, 3 circuits	
G	3.5 turns, 1 circuit	
R	3.5 turns, 2 circuits	

Symbol	Number of circuits	Applicable recirculation system
H	1 turn, 2 circuits	Deflector method
J	1 turn, 3 circuits	
K	1 turn, 4 circuits	
L	1 turn, 5 circuits	
M	1 turn, 6 circuits	
P	See specifications.	End deflector method
Q	See specifications.	End cap method
Z	Other	Not listed above (including ball screw shafts sold separately)

(5) Nut Type

Symbol	Nut type
S	Single nut
T	Integral nut
D	Double nut (pin type)
E	Double nut (spacer type)
F	Flange double nut (spacer type)
Z	Other (including ball screw shafts sold separately)

(6) Flange Type

Symbol	Flange type
A, B, C, D, E, H	Refer to page A-7.
N	No flange (e.g. square nut)
Z	Other: shapes and dimensions not listed in the catalog (including ball screw shafts sold separately)

(7) Ball Recirculation System (nut body shape)

Symbol	Ball recirculation system
A	Round type (tube method)
T	Protruded tube type (tube method)
U	Inlaid tube type (tube method)
K	Square type (tube method)
D	Deflector method
G	Guide plate method
E	End cap method
P	End deflector method

(8) Wiper Material

Symbol	Wiper material
P	Plastic wiper
L	Lip seal
F	Felt wiper
B	Brush wiper
N	No wiper
S	LUBSEAL™
Z	Other (including ball screw shafts sold separately)

(9) Thread Direction

Symbol	Description
R	Right-hand thread
L	Left-hand thread
Z	Other (including ball screw shafts sold separately)

(10) Overall Screw Shaft Length (indicated by a 4-digit number)
· The shaft length is indicated in the metric system (unit: mm), rounded down to the nearest whole number.

(11) Shaft End Configuration

Symbol	Description	Product line
A	Both ends unfinished	Standard product line
B	One end finished	Standard product line
X	Both ends finished	Standard product line, order-made product line
D	Both ends unfinished	For ordering GY series screw shafts without ball screw nuts
Y	Both ends finished	

(12) Thread Length (indicated by a 4-digit number)
· The length is indicated in the metric system (unit: mm), rounded down to the nearest whole number.

(13) Accuracy Grade
· The accuracy grade is indicated by C0, C1, C2, C3, C4, C5, and C7. Because accuracy grade C10 is 3-digits long, “CA” is used instead.

(14) Axial Clearance

Symbol	Axial clearance
S	0 mm (preloaded)
F	0.005 mm or less
H	0.010 mm or less
M	0.030 mm or less
L	0.200 mm or less
Y	Axial clearance for rolled ball screws (Refer to the specifications of the GY/GW series.)
Z	Other

■ Ordering instructions for standard precision ball screws

Unfinished shaft ends

■ GE, GG, FE, or FG series ball screws

● For screws without additional end machining

<Example>

GE/FE ☐☐☐☐ - ☐☐☐☐ - Overall screw shaft length A
GG/FG ☐☐☐☐ - ☐☐☐☐ - Overall screw shaft length A
Model Number

● With additional machining

Enter the overall screw shaft length followed by X (the symbol for finished shaft ends), thread length, accuracy grade, and axial clearance.

GE/FE ☐☐☐☐ - ☐☐☐☐ - Overall screw shaft length X Thread length - C7M
GG/FG ☐☐☐☐ - ☐☐☐☐ - Overall screw shaft length X Thread length - C5F

■ HG series ball screws

● For screws without additional end machining

<Example>

HG ☐☐☐☐ - ☐☐☐☐ - Overall screw shaft length A
Model Number

● With additional machining

Enter the overall screw shaft length followed by X (the symbol for finished shaft ends), thread length, accuracy grade, and axial clearance.

<Example>

HG ☐☐☐☐ - ☐☐☐☐ - Overall screw shaft length X Thread length - $C5^{F}_{H}$

One shaft end finished

■ GP/DP series ball screws

● For screws without additional end machining

<Example>

GP ☐☐☐☐ - ☐☐☐☐ - Overall screw shaft length B - $C3^{S}_{F}$
DP ☐☐☐☐ - ☐☐☐☐ - Overall screw shaft length B - $C3^{S}_{F}$
Model Number

● With additional machining

Enter the overall screw shaft length followed by X (the symbol for finished shaft ends), thread length, accuracy grade, and axial clearance.

GP ☐☐☐☐ - ☐☐☐☐ - Overall screw shaft length X Thread length - $C3^{S}_{F}$
DP ☐☐☐☐ - ☐☐☐☐ - Overall screw shaft length X Thread length - $C3^{S}_{F}$

■ Ordering instructions for rolled ball screws

Unfinished shaft ends

■ GY series ball screws

[For ball screws with both a shaft and nut]

● For screws without additional end machining

<Example>

GY ☐☐☐☐ - ☐☐☐☐ - Overall screw shaft length A
Model Number

● With additional machining

Enter the overall screw shaft length followed by X (the symbol for finished shaft ends), thread length, accuracy grade, and axial clearance.

GY ☐☐☐☐ - ☐☐☐☐ - Overall screw shaft length X Thread length - CAY

[Nut only]

Fill in the information up to “Thread Direction”. There is no need to fill in the overall screw shaft length etc. because there is no shaft.

<Example>

GY ☐☐☐☐ - ☐☐☐☐

[Shaft only]

● For screws without additional end machining

Enter D as a symbol for the shaft end type.

<Example>

GY ☐☐ZZ - ZZZZ - Overall screw shaft length D

● With additional machining

Enter the overall screw shaft length followed by Y (the symbol for GY Series shafts sold separately with finished shaft ends), thread length, accuracy grade, and axial clearance.

<Example>

GY ☐☐ZZ - ZZZZ - Overall screw shaft length Y Thread length - CAY

Note) GY Series screw shafts with the same diameter and lead size are compatible regardless of nut type.

Unfinished shaft ends

■ GW series ball screws

[For ball screws with both a shaft and nut]

● For screws without additional end machining

<Example>

GW ☐☐☐☐ - ☐☐☐☐ - Overall screw shaft length A
Model Number

● With additional machining

Enter the overall screw shaft length followed by X (the symbol for finished shaft ends), thread length, accuracy grade, and axial clearance.

GW ☐☐☐☐ - ☐☐☐☐ - Overall screw shaft length X Thread length - C7Y

■ Ordering instructions for order-made ball screws

■ For order-made ball screws with nut specifications and design listed in this catalog

Simply enter the overall screw shaft length, X (the symbol for finished shaft ends), thread length, accuracy grade, and axial clearance after the listed Model Number information.

<Example>

GR/DR/FR □□□□ - □□□□ - Overall screw shaft length X Thread length - Accuracy grade Axial clearance

Model Number

■ For order-made ball screws with a custom flange, but otherwise listed nut specifications and design

Enter GM/DM/FM followed by shaft diameter, lead, number of circuits, and nut type. Select the applicable the flange type (either N for no flange or Z for flange types other than those listed). Enter the ball recirculation system, wiper material, thread direction, and finally overall screw shaft length, X (the symbol for finished shaft ends), thread length, accuracy grade, and axial clearance.

<Example>

GM/DM/FM □□□□ - Z □□□ - Overall screw shaft length X Thread length - Accuracy grade Axial clearance

Model Number

■ For customized order-made ball screws with specifications and design other than the above

Enter GZ/DZ/FZ followed by shaft diameter, lead, number of circuits, and nut type. Enter Z for flange type. Enter the ball recirculation system, wiper material, thread direction, and finally overall screw shaft length, X (the symbol for finished shaft ends), thread length, accuracy grade, and axial clearance.

<Example>

GZ/DZ/FZ □□□□ - Z □□□ - Overall screw shaft length X Thread length - Accuracy grade Axial clearance

Model Number

■ Ordering instructions for customized rolled ball screws

■ For rolled ball screws with specifications and design other than the those listed in this catalog

Enter GT followed by shaft diameter, lead, number of circuits, and nut type. Enter Z for flange type. Enter the ball recirculation system, wiper material, thread direction, and finally overall screw shaft length, X (the symbol for finished shaft ends), thread length, accuracy grade, and axial clearance.

<Example>

GT □□□□ - Z □□□ - Overall screw shaft length X Thread length - Accuracy grade Axial clearance

Model Number

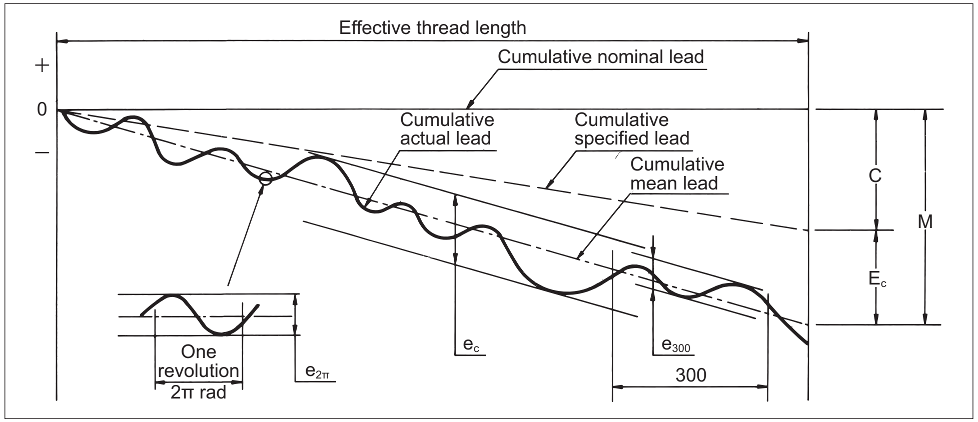
Technical data of ball screws

Page

Technical data of ball screws

Lead accuracy

The lead accuracy of ball screws is defined by the following characteristics in accordance with the JIS Standard. The permissible values are shown in Tables 2 and 3.



■ Terms and definitions

Specified lead
In most cases, the lead is the same as the nominal lead, but there are instances in which the nominal designation is adjusted when the application so requires.
(Example: Nominal lead 10 mm → Specified lead 9.9995 mm)

Cumulative specified lead target value "C"
In cases in which expansion and contraction of the screw due to temperature change or influence from the external load can be anticipated, a target value of cumulative lead determined by testing or technical experience should be established in advance. For presetting procedures, see the cumulative specified lead setting procedures on page F-20.

Cumulative actual lead
Cumulative lead obtained by either continuous measurement of an actual ball screw or by measurement of a section including the axial center of the screw shaft.

Cumulative mean lead "M"
A straight line representing the trend of cumulative actual lead. It is obtained by the least-squares method or an approximation similar to this method using the curve representing the cumulative actual lead corresponding to the effective travel of a nut or the effective thread length of the screw shaft.

Cumulative mean lead error "Ec"
A value obtained by subtracting the cumulative specified lead target value (C) from the cumulative mean lead (M).

Variation
The maximum difference of the cumulative actual lead contained between two lines drawn parallel to the cumulative mean lead. It is prescribed by e_c, e_{300}, $e_{2\pi}$.

e_c : Variation for the effective travel of the nut or the effective thread length of the screw shaft.

e_{300} : Variation for a length of 300 mm arbitrarily taken within the effective thread length of the screw shaft.

$e_{2\pi}$: Variation for one revolution (2 π rad) made within the effective thread length of the screw shaft.

KURODA JENATEC

■ Cumulative mean lead error and permissible variation values

● Accuracy grades C0-C5

Table 2 Cumulative mean lead error ($\pm E_c$) and permissible variation values (e_c) (Unit: μm)

Effective thread length (mm)	Accuracy grade	C0		C1		C2		C3		C4		C5	
Over	Or less	$\pm E_c$	e_c	$\pm E_c$	e_c	$\pm E_c$	e_c	$\pm E_c$	e_c	$\pm E_c$	e_c	$\pm E_c$	e_c
−	315	4	3.5	6	5	9	6	12	8	15	11	23	18
315	400	5	3.5	7	5	10	7	13	10	17	13	25	20
400	500	6	4	8	5	11	7	15	10	19	13	27	20
500	630	6	4	9	6	12	9	16	12	20	16	30	23
630	800	7	5	10	7	14	10	18	13	24	17	35	25
800	1000	8	6	11	8	16	11	21	15	28	19	40	27
1000	1250	9	6	13	9	18	12	24	16	32	21	46	30
1250	1600	11	7	15	10	21	13	29	18	38	24	54	35
1600	2000			18	11	26	15	35	21	46	28	65	40
2000	2500			22	13	31	18	41	24	54	32	77	46
2500	3150			26	15	37	21	50	29	66	38	93	54
3150	4000			32	18	43	24	62	35	80	46	115	65
4000	5000							76	41	97	54	140	77
5000	6000											170	93

Table 3 Permissible variation values (Unit: mm)

Accuracy grade	C0		C1		C2		C3		C4		C5	
Item	e_{300}	$e_{2\pi}$	e_{300}	$e_{2\pi}$	e_{300}	$e_{2\pi}$	e_{300}	$e_{2\pi}$	e_{300}	$e_{2\pi}$	e_{300}	$e_{2\pi}$
Permissible value	3.5	3	5	4	6	5	8	6	11	7	18	8

● Accuracy grades C7 and C10

The cumulative lead error of C7 and C10 grade ball screws is prescribed by the permissible value for the lead error of a specified lead which had a length of 300 mm arbitrarily taken within the effective thread length of the screw shaft, in accordance with JIS Standard.

Table 4 Permissible values for cumulative lead error (Unit: μm)

Accuracy grade	C7	C10
Cumulative lead error	0.05/300	0.21/300

■ Accuracy grade and axial clearance

Possible combinations of accuracy grade and axial clearance are shown in Table 5.

Table 5 Accuracy grade and axial clearance

Symbol	Axial clearance (mm)	Nut combination	Accuracy grade							
			C0	C1	C2	C3	C4	C5	C7	C10
S	0	Double nut	○	○	○	○	○	○	−	−
S	0	Single nut	○	○	○	○	○	○	−	−
F	0.005 or less		−	○	○	○	○	○	−	−
H	0.010 or less		−	−	−	−	○	○	○	−
M	0.030 or less		−	−	−	−	○	○	○	−
L	0.200 or less		−	−	−	−	−	−	○	○

* Integral Nuts have the same possible combinations of axial clearance and lead accuracy grade as Double Nuts.
* The above table is for ground ball screws only. For rolled ball screws in GY/GW series, refer to the pages describing rolled ball screws.
* For any combinations not listed above, consult KURODA.

■ Accuracy grade and manufacturable screw shaft length

When the slenderness ratio (shaft length against shaft diameter) is large, it is sometimes difficult to manufacture a ball screw with the desired accuracy. The following table shows the maximum length of screw shafts of each accuracy grade that can be reliably manufactured. When ball screws exceeding the manufacturable range are required, consult KURODA.

Table 6 Accuracy grade and manufacturable screw shaft length (Unit: mm)

Accuracy grade	Screw shaft diameter																
	5	6	8	10	12	15 · 16	20	25	28	32	36	40	45	50	55	63	70·80·100·125
C0	90	160	240	340	420	500	800	1100	1200	1600	1800	2000	2000	2000	2000	2000	−
C1	120	180	280	400	500	600	900	1300	1500	1800	2000	2200	2300	2800	3000	3000	3000
C2	120	180	280	400	500	600	1100	1600	1800	2200	2500	2800	3000	3600	4000	4500	4500
C3	140	210	340	480	600	700	1400	1800	2000	2500	2800	3200	3600	4000	5000	5000	5000
C4	140	210	340	480	600	800	1400	1800	2000	2500	2800	3200	3600	4000	5000	5000	5000
C5	140	210	340	655	900	1500	2000	2000	2200	2800	3100	3600	4100	4500	5000	5000	5000
C7	−	−	340	655	900	1500	2000	2300	2600	3200	3600	4600	5000	5000	5000	5000	5000
C10	−	−	−	−	−	1500	2000	2300	2600	3600	4000	4600	5000	5000	5000	5000	5000

(Note) When the lead is larger than the nominal screw shaft diameter, C0 and C1 accuracy grades are not manufacturable.

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Mounting accuracy and tolerance

■ Accuracy of each part of the screw shaft

Tables 7 and 8 show the tolerance of the radial runout of the thread groove and mounting portions when measured against the axial line of the supported shaft end (7) and the perpendicularity of the outer face of the supported shaft end (8).

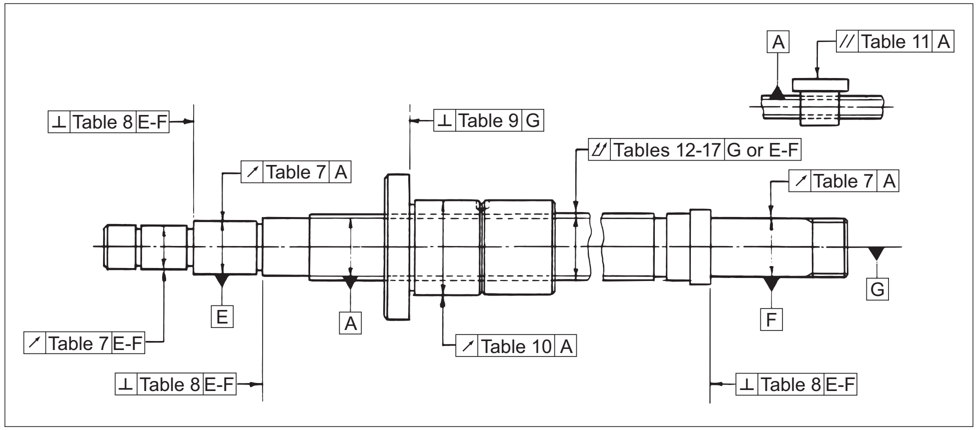


Figure 5 Mounting accuracy of the ball screw (Illustration)

Table 7 Radial runout of the thread groove and mounting portions when measured against the axial line of the supported shaft end (Unit: μm)

Nominal screw shaft diameter (mm)		Runout tolerance (maximum)					
Over	Or less	C0	C1	C2	C3	C4	C5
–	8	3	5	7	8	9	10
8	12	4	5	7	8	9	11
12	20	4	6	8	9	10	12
20	32	5	7	9	10	11	13
32	50	6	8	10	12	13	15
50	80	7	9	11	13	15	17
80	125	–	10	12	15	17	20

(Note) As the measurement of nominal screw shaft diameter takes into account the influence of the screw shaft axial runout, it is necessary to correct the measurements. Calculate the correction value by using the total runouts (tolerance) of the screw shaft axial runout shown in Tables 12 to 17 corresponding to the ratio of the overall screw shaft length to the distance between the supporting point and the measuring point (L1 and L2) and add it to the tolerance shown in the above table.

Table 8 Perpendicularity of the outer face of the supported shaft end when measured against the axial line of the supported shaft end (Unit: μm)

Nominal screw shaft diameter (mm)		Perpendicularity tolerance (axial runout) (maximum)					
Over	Or less	C0	C1	C2	C3	C4	C5
–	8	2	3	3	4	4	5
8	12	2	3	3	4	4	5
12	20	2	3	3	4	4	5
20	32	2	3	3	4	4	5
32	50	2	3	3	4	5	5
50	80	3	4	4	5	6	7
80	125	–	4	5	6	7	8

■ Accuracy of the nut mounting portion

Tables 9, 10 and 11 show the perpendicularity of the flange mounting surface and the outer diameter of the nut body (9), the radial runout of the outer diameter of the nut body (10), and the parallelism tolerance of the outer diameter of the nut body (11) when measured against the axial center of the screw shaft.

Table 9 Perpendicularity of the flange mounting surface and the outer diameter of the nut body when measured against the axial center of the screw shaft (Unit: μm)

Outer diameter of the nut (mm)		Perpendicularity tolerance (maximum)					
Over	Or less	C0	C1	C2	C3	C4	C5
–	20	5	6	7	8	9	10
20	32	5	6	7	8	9	10
32	50	6	7	8	8	10	11
50	80	7	8	9	10	11	13
80	125	7	9	10	12	13	15
125	160	8	10	11	13	15	17
160	200	–	11	12	14	16	18
200	250	–	12	13	15	17	20

Table 10 Radial runout of the outer diameter of the nut body (when cylindrical) when measured against the axial center of the screw shaft (Unit: μm)

Outer diameter of the nut (mm)		Runout tolerance (maximum)					
Over	Or less	C0	C1	C2	C3	C4	C5
–	20	5	6	7	9	10	12
20	32	6	7	8	10	11	12
32	50	7	8	10	12	13	15
50	80	8	10	12	15	17	19
80	125	9	12	16	20	23	27
125	160	10	13	17	22	26	30
160	200	–	16	20	25	29	34
200	250	–	18	23	28	33	38

Table 11 Parallelism tolerance of the outer diameter of the nut body (when planar) when measured against the axial center of the screw shaft (Unit: μm)

Basic mounting length (mm)		Parallelism tolerance (maximum)					
Over	Or less	C0	C1	C2	C3	C4	C5
–	50	5	6	7	8	9	10
50	100	7	8	9	10	11	13
100	200	–	10	11	13	15	17

■ Total runout of the axial center of the screw shaft

Tables 12 to 17 show the permissible values for total runout of the axial center of the screw shaft.

Table 12 Total runout of the axial center of the screw shaft [C0]

(Unit: mm)

Overall screw shaft length		Nominal screw shaft diameter							
		Over	−	8	12	20	32	50	80
		Or less	8	12	20	32	50	80	125
Over	Or less								
−	125		0.015	0.015	0.015				
125	200		0.025	0.020	0.020	0.015			
200	315		0.035	0.025	0.020	0.020			
315	400			0.035	0.025	0.020	0.015		
400	500			0.045	0.035	0.025	0.020		
500	630			0.050	0.040	0.030	0.020	0.015	
630	800				0.050	0.035	0.025	0.020	
800	1000				0.065	0.045	0.030	0.025	
1000	1250				0.085	0.055	0.040	0.030	
1250	1600				0.110	0.070	0.050	0.040	
1600	2000					0.095	0.065	0.045	

Table 13 Total runout of the axial center of the screw shaft [C1]

(Unit: mm)

Overall screw shaft length		Nominal screw shaft diameter							
		Over	−	8	12	20	32	50	80
		Or less	8	12	20	32	50	80	125
Over	Or less								
−	125		0.020	0.020	0.015				
125	200		0.030	0.025	0.020	0.020			
200	315		0.040	0.030	0.025	0.020			
315	400		0.045	0.040	0.030	0.025	0.020		
400	500			0.050	0.040	0.030	0.025		
500	630			0.060	0.045	0.035	0.025	0.020	
630	800				0.060	0.040	0.030	0.025	
800	1000				0.075	0.055	0.040	0.030	
1000	1250				0.095	0.065	0.045	0.035	0.030
1250	1600				0.130	0.085	0.060	0.045	0.035
1600	2000					0.120	0.080	0.055	0.040
2000	2500						0.100	0.070	0.050
2500	3150						0.130	0.090	0.060
3150	4000							0.120	0.080

Table 14 Total runout of the axial center of the screw shaft [C2]

(Unit: mm)

Overall screw shaft length		Nominal screw shaft diameter							
		Over	−	8	12	20	32	50	80
		Or less	8	12	20	32	50	80	125
Over	Or less								
−	125		0.025	0.020	0.020				
125	200		0.035	0.030	0.020	0.025			
200	315		0.045	0.035	0.025	0.025			
315	400		0.050	0.045	0.035	0.030	0.025		
400	500			0.055	0.045	0.035	0.025		
500	630			0.065	0.050	0.040	0.030	0.025	
630	800				0.065	0.045	0.035	0.030	
800	1000				0.080	0.060	0.045	0.035	
1000	1250				0.105	0.070	0.050	0.040	0.030
1250	1600				0.140	0.095	0.065	0.050	0.035
1600	2000					0.130	0.090	0.065	0.045
2000	2500						0.110	0.080	0.055
2500	3150						0.140	0.100	0.065
3150	4000							0.130	0.090
4000	5000								0.110

Table 15 Total runout of the axial center of the screw shaft [C3]

(Unit: mm)

Overall screw shaft length		Nominal screw shaft diameter							
		Over	−	8	12	20	32	50	80
		Or less	8	12	20	32	50	80	125
Over	Or less								
−	125		0.025	0.025	0.020				
125	200		0.035	0.035	0.025	0.020			
200	315		0.050	0.040	0.030	0.030			
315	400		0.060	0.050	0.040	0.035	0.025		
400	500			0.065	0.050	0.040	0.030		
500	630			0.080	0.055	0.045	0.035	0.030	
630	800				0.070	0.055	0.040	0.035	
800	1000				0.095	0.065	0.050	0.040	0.030
1000	1250				0.120	0.085	0.060	0.045	0.035
1250	1600				0.160	0.110	0.075	0.055	0.040
1600	2000					0.140	0.095	0.070	0.050
2000	2500						0.120	0.085	0.060
2500	3150						0.160	0.110	0.075
3150	4000						0.220	0.150	0.100
4000	5000							0.200	0.130

Table 16 Total runout of the axial center of the screw shaft [C4]

(Unit: mm)

Overall screw shaft length		Nominal screw shaft diameter							
		Over	−	8	12	20	32	50	80
		Or less	8	12	20	32	50	80	125
Over	Or less								
−	125		0.030	0.030	0.030				
125	200		0.040	0.040	0.035	0.030			
200	315		0.055	0.050	0.040	0.035			
315	400		0.070	0.060	0.050	0.040	0.035		
400	500			0.075	0.055	0.050	0.040		
500	630			0.090	0.070	0.055	0.050	0.035	
630	800				0.080	0.065	0.055	0.040	
800	1000				0.100	0.070	0.060	0.050	0.035
1000	1250				0.130	0.090	0.070	0.055	0.040
1250	1600				0.170	0.120	0.080	0.060	0.045
1600	2000					0.150	0.110	0.080	0.060
2000	2500						0.130	0.100	0.070
2500	3150						0.180	0.130	0.090
3150	4000						0.240	0.170	0.120
4000	5000							0.220	0.150

Table 17 Total runout of the axial center of the screw shaft [C5]

(Unit: mm)

Overall screw shaft length		Nominal screw shaft diameter							
		Over	−	8	12	20	32	50	80
		Or less	8	12	20	32	50	80	125
Over	Or less								
−	125		0.035	0.035	0.035				
125	200		0.050	0.040	0.040	0.035			
200	315		0.065	0.055	0.045	0.040			
315	400		0.075	0.065	0.055	0.045	0.035		
400	500			0.080	0.060	0.050	0.045		
500	630			0.090	0.075	0.060	0.050	0.040	
630	800				0.090	0.070	0.055	0.045	
800	1000				0.120	0.085	0.065	0.050	0.045
1000	1250				0.150	0.100	0.075	0.060	0.050
1250	1600				0.190	0.130	0.095	0.070	0.055
1600	2000					0.170	0.120	0.085	0.065
2000	2500						0.150	0.110	0.080
2500	3150						0.200	0.140	0.095
3150	4000						0.260	0.180	0.120
4000	5000							0.240	0.160
5000	6300							0.320	0.210

Preload torque

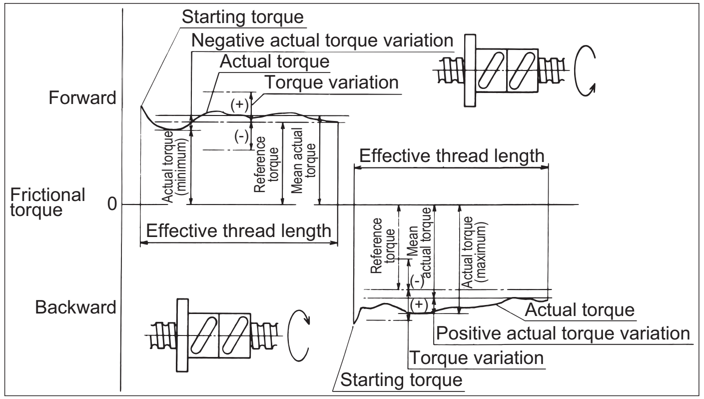


Figure 6 Characteristics of preload torque

■ Terms and definitions

Preload
A way to reduce the backlash or to increase the rigidity of ball screws. This is achieved by loading oversized steel balls or by inducing tension between a pair of nuts which are forced in opposite axial directions.

Preload torque
The torque required to continuously rotate the screw shaft or nut of a preloaded ball screw when no external load is applied.

Standard torque
The target preload torque value.

Torque variation value
The deviation in preload torque from the target preload torque. The value is described as a plus (+) or minus (-) value to the standard torque.

Torque variation ratio
A ratio of torque variation to the standard torque.

Actual torque
Preload torque measurement of an actual ball screw.

Mean actual torque
An arithmetic mean of the maximum and minimum values of the actual torque measured by running the nut back and forth over the effective thread length.

Actual torque variation
A maximum variation of actual torque measured by running the nut back and forth over the effective thread length. The value is described as a plus (+) or minus (-) value to the mean actual torque.

Actual torque variation ratio
A ratio of actual torque variation to mean actual torque.

■ Measuring conditions

Rotational speed for measurement: 100 min^{-1}
Viscosity of lubricant: ISO VG100

■ Permissible ratio of torque variation

Table 18 Permissible ratio of torque variation

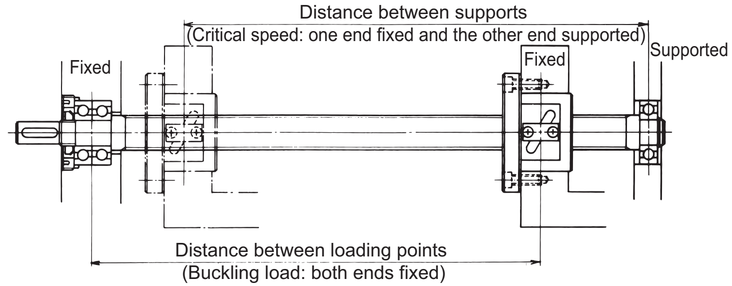
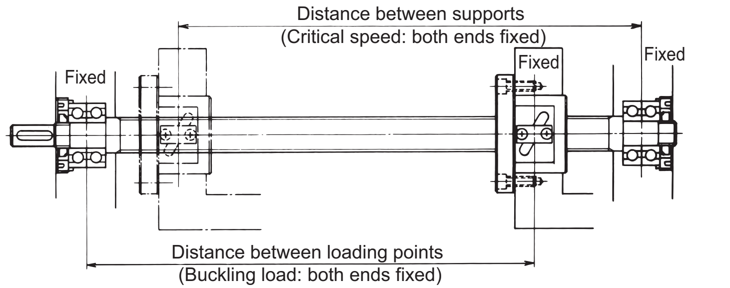
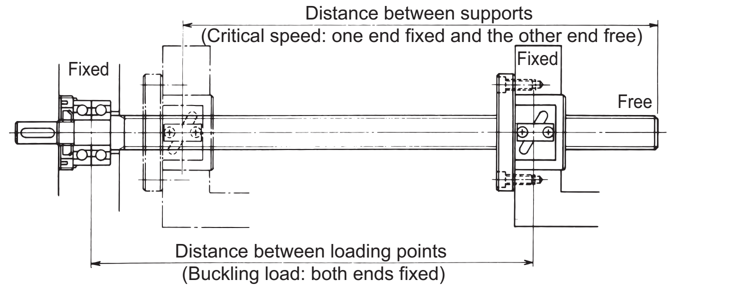
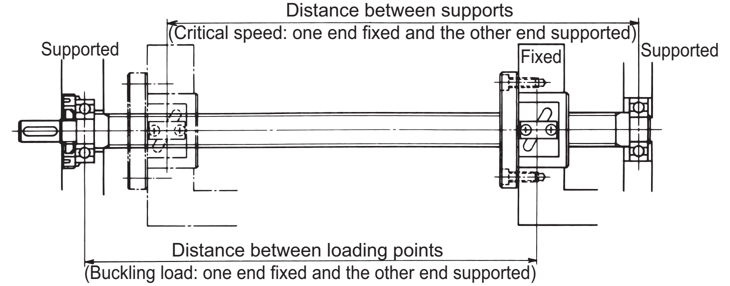
Reference torque (N·cm)		Effective thread length (mm) 4000 or less											
		Slenderness ratio: 40 or less						Slenderness ratio: 60 or less					
		Accuracy grade						Accuracy grade					
Over	Or less	C0	C1	C2	C3	C4	C5	C0	C1	C2	C3	C4	C5
20	40	±35%	±40%	±45%	±45%	±50%	±55%	±40%	±45%	±50%	±55%	±60%	±65%
40	60	±25	±30	±35	±35	±40	±45	±33	±38	±45	±45	±50	±50
60	100	±20	±25	±30	±30	±35	±35	±25	±30	±35	±35	±40	±40
100	250	±15	±20	±25	±25	±30	±30	±20	±25	±30	±30	±35	±35
250	630	±10	±15	±20	±20	±25	±25	±15	±20	±25	±25	±30	±30
630	1000	–	–	±15	±15	±20	±20	–	–	±20	±20	±25	±25

(Note) Slenderness ratio is the value obtained by dividing the thread length (mm) of the screw shaft by the nominal screw shaft diameter (mm).

Screw shaft design

■ Mounting and supporting methods for the screw shaft

There are four basic methods of mounting a screw shaft as shown below. Since the method of screw shaft support has a direct relationship to permissible axial load and permissible rotational speed at critical speed, sufficient consideration should be given, especially when the conditions of use require high accuracy or demanding performance.

Mounting method	Application example
	• Typical mounting method • Medium to high speed range • Medium accuracy to high accuracy
	• Medium speed • High accuracy
	• Low speed • Short shaft length • Medium accuracy
	• Low to medium speed range • Low accuracy to medium accuracy

Technical data of ball screws

■ Permissible axial load

A diagram of permissible axial load for selecting the minimum shaft diameter for the axial load is shown below.

(1) The diagonal line indicates the permissible axial load determined by the buckling of the screw shaft. Please refer to the scale that corresponds to the correct method of screw shaft support.

(2) The lines parallel to the line representing the distance between supports indicate the permissible tensile/compression load. Please refer to the Supported-Supported scale.

(3) The lines perpendicular to the line representing the distance between supports indicate the screw shaft lengths that can be manufactured by standard processes as KURODA. (See Table 6 on page F-3.)

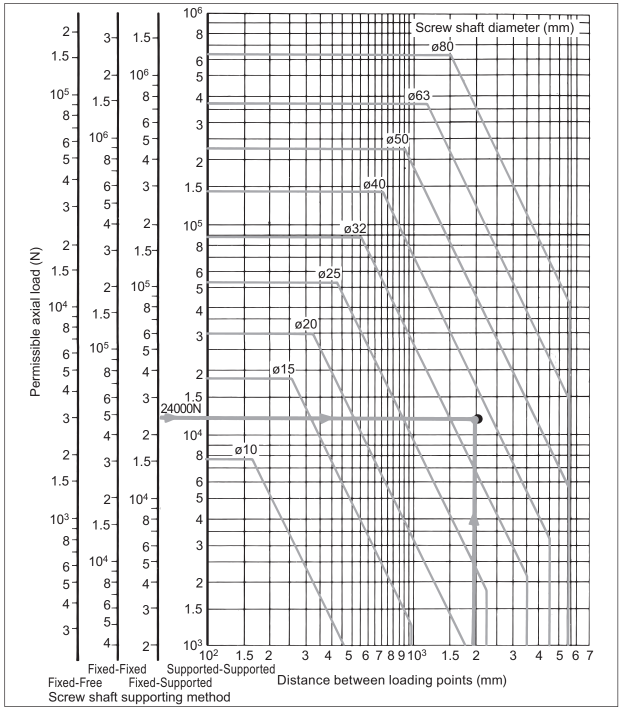


Figure 7 Diagram of permissible axial load

● Permissible axial load against buckling load: P

$P = \alpha P_k$ (N)................................... (1)

Where,

P_k: Buckling load (N)

α : Safety factor (α = 0.5)

It may be necessary to set the safety factor at a larger value according to the degree of safety required.

Generally, the buckling load of a long column can be calculated by Euler's Formula. However, when the slenderness ratio/k (k: Second cross section) is 90 or less, use the Rankine Forumla or the Tetmajer Formula.

Example: Selection of the shaft diameter

How to determine an appropriate shaft diameter when the screw shaft is supported with the "Fixed-Supported" method and a compression load of 24000N (maximum axial load) is applied to a distance of 2000 mm between loading points:

1. Find out the intersecting point where the permissible axial compression load on the scale of "Fixed-Supported" is 24000N and the distance between loading points is 2000 mm as shown by a thick line in Figure 7.
2. Then, select a shaft diameter of 40 mm or more, represented by one of the diagonal lines located above the intersecting point.

● Buckling load calculated by Euler's Formula: P_k

$$P_k = \frac{n\pi^2 EI}{\ell^2} \text{ (N)} \quad \text{.............................} \quad (2)$$

Where,

P_k: Load at which buckling starts (N)

ℓ : Distance between loading points (mm)

E : Young's modulus (2.06 X 10^5 N/mm²)

I : Minimum secondary moment of the screw shaft root cross section (mm⁴)

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

d : Screw shaft root diameter (mm)
Refer to dimension tables.

n : Coefficient to be determined by the supporting method of the ball screw
Supported-Supported n = 1
Fixed-Supported n = 2
Fixed-Fixed n = 4
Fixed-Free n = 0.25

■ Permissible rotational speed

The permissible rotational speed of ball screws is expressed by a DmN value which indicates the upper limit of the operating speed of recirculating balls in the nut and the critical speed of the rotary shaft.

The optimum shaft diameters for various rotational speeds are shown in Figure 8.

(1) The diagonal line indicates the rotational speed determined by the critical speed. Please refer to the scale that corresponds to the correct method of screw shaft support.

(2) The lines parallel to to the line representing the distance between supports indicate the limit of the permissible rotational speed obtained from the DmN value. Please refer to the scale that corresponds to the "Supported-Supported" method of screw shaft support.

(3) The lines perpendicular to the line representing the distance between supports indicate the screw shaft lengths that can be manufactured by standard processes as KURODA. (See Table 6 on page F-3.)

● DmN value

◦ GR, DR, GE/GG, GP, DP, and HG series
DmN ≤ 70000 .... (3)

◦ GY and GW series
DmN ≤ 50000 .... (3)

◦ FR and FE/FG series
DmN ≤ 135000

Where,

Dm: Screw shaft diameter (mm) + A (mm)

N : Maximum rotational speed (min^{-1})
N (max) ≤ 5000

Ball diameter	A	Ball diameter	A
0.8000	0.24	3.1750	0.80
1.0000	0.30	3.9688	0.80
1.2000	0.30	4.7625	1.00
1.5875	0.30	6.3500	1.80
2.0000	0.40	7.1438	2.00
2.3812	0.60	7.9375	2.00
2.7780	0.60	9.5250	2.40

Note) Consult KURODA if the number of revolutions on your application exceeds the DmN value above or N (max) 5000.

● **Critical speed: N_c**

$$N_c = f_a \frac{60\lambda^2}{2\pi \ell^2} \sqrt{\frac{EI \times 10^3}{\gamma A}} \quad (\text{min}^{-1}) \quad \cdots\cdots\cdots (4)$$

Where,
ℓ : Distance between supports (mm)
fa : Safety factor (0.8)
E : Young's modulus (2.06 X 10^5 N/mm^2)
I : Minimum secondary moment of the screw shaft root cross section (mm^4)

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

d : Screw shaft root diameter (mm)
Refer to dimension tables.
γ : Specific gravity (7.8 X 10^{-6} kg/mm^3)
A : Sectional area of the screw shaft root diameter (mm^2)

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

λ : Coefficient to be determined by the method of ball screw support
Supported-Supported λ = π
Fixed-Supported λ = 3.927
Fixed-Fixed λ = 4.730
Fixed-Free λ = 1.875

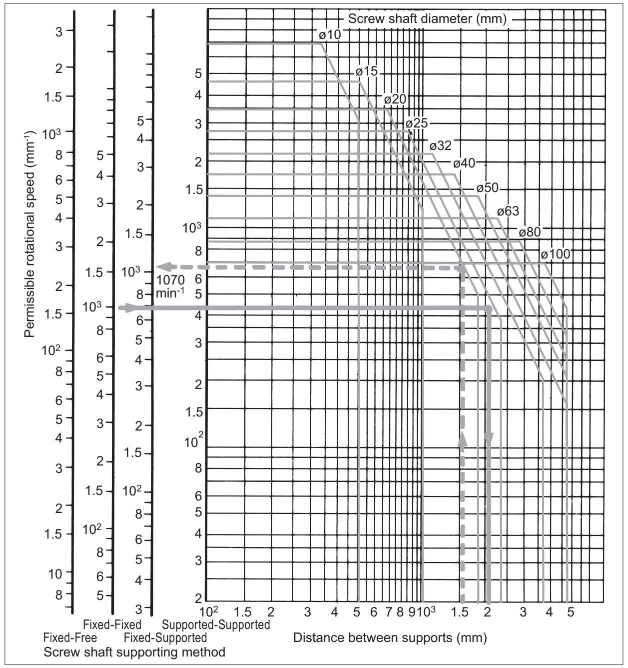


Figure 8 Diagram of the permissible rotational speed

Resonance phenomenon arising from the rotational speed of a ball screw and the characteristic frequency of the screw shaft is caused by the unbalance of deflection by the empty weight of the shaft at the distance "ℓ" between supports of the rotation system and the critical speed corresponding to the characteristic frequency increases the amplitude of the vibration.
When the ball screw is used, the nut serves as a mobile bearing, and therefore, the distance "ℓ" between supports always changes and the shaft deflection changes as well. Since the critical speed shown in Formula (4) is inconstant, consider the permissible rotational speed to assure safety.

Example 1: Determining the permissible rotational speed
How to determine permissible rotational speed when the screw shaft is supported with the "Fixed-Supported" method, the screw shaft diameter is 20 mm and the distance between supports is 1500 mm:
1. The vertical dotted line in Figure 8 shows that the distance between supports is 1500 mm. Find the point of intersection with the diagonal line representing the critical speed of a screw shaft with a diameter of 20 mm.
2. The scale for the "Supported-Supported" method of screw shaft support indicates that, in this case, the permissible rotational speed is 1076 min^{-1}.

Example 2: How to determine an appropriate shaft diameter
How to determine an appropriate shaft diameter that can meet a maximum rotational speed "1000 min^{-1}" when the screw shaft is supported with the "Fixed-Fixed" method and the distance between supports is 2000 mm:
1. The thick vertical line in Figure 8 shows that the distance between supports is 2000 mm. Find the point of intersection with the horizontal line representing the permissible rotational speed "1000 min^{-1}" on scale for the "Fixed-Fixed" method of screw shaft support.
2. Shaft diameters represented by the lines above the intersecting point have a permissible rotational speed of "1000 min^{-1}" or more. In this case, a shaft diameter of 25 mm is found to be sufficient.

Service life calculation

■ Service life of ball screws

The service life of a ball screw is defined as a total number of revolutions with which the screw can perform proper operation without causing operation-affecting wear (flaking) to the thread groove and/or balls. The flaking is caused by metal fatigue due to constant stress. The service life of a ball screw is determined by the basic dynamic load rating.

■ Service life

The service life of a ball screw is calculated by the following formula:

$$L_h = \frac{10^6}{60N_m}\left(\frac{C}{P_m f_w}\right)^3 (\text{hours}) \quad \cdots\cdots\cdots\cdots\cdots (5)$$

Where,
L_h : Service life (hours)
C : Basic dynamic load rating (N)
Refer to dimension tables.
P_m : Average axial load (N)
N_m : Average rotational speed (mm^{-1})
f_w : Load factor (coefficient by operating condition)
Smooth operation without concussive impact f_w = 1.0 to 1.2
Normal operation f_w = 1.2 to 1.5
Operation associated with concussive impact or vibration f_w = 1.5 to 2.0

The basic dynamic load rating that satisfies the intended service life is obtained from the following formula:

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

If a ball screw is selected using overly conservative service life values, the size and cost of the resulting ball screw may increase unnecessarily. Some case examples of standard life requirements are given below for reference.

Machine tools	20000 hours
Industrial machinery	10000 hours
Automated control equipment	15000 hours
Measuring instruments	15000 hours

● **Basic static load rating: C_0**

The basic static load rating (C0) represents an axial load at at certain amount of static load in which the sum of the permanent deformities of the steel balls and the thread groove surface equal to 0.01 percent of the steel ball diameter.
In most cases, the permanent deformities will not cause operational issues. However, when high accuracy or very smooth operation are required, it is recommended that a ball screw having a C0 value notably larger than the static load be selected. For basic static load ratings, refer to the dimension tables listed in this calatog.

● **Basic dynamic load rating: C**

The basic dynamic load rating (C) is an axial load in which when a certain number of ball screws are run for 1 million revolutions (106 revolutions) and 90% of that group of ball screws does not experience operation-affecting wear (flaking). For basic dynamic load ratings, refer to the dimension tables listed in this calatog.

● **Average axial load "P_m" and average rotational speed "N_m"**

To select a suitable ball screw, determine the following values. It may be difficult to accurately predict these operating conditions, but it is advisable to gather accurate values because the service life is inversely proportional to the load value multiplied by a power of three. Accurate values will result in a greater selection of suitable ball screws.

($t_1 + t_2 + t_3$ = 100%)

Axial load	Rotational speed	Operating time ratio
P_1N (maximum)	N_1 min^{-1}	t_1 %
P_2N (normal)	N_2 min^{-1}	t_2 %
P_3N (minimum)	N_3 min^{-1}	t_3 %

In the case of machine tools, the maximum load (P_1) is a "load applied at the time of heaviest cutting". The normal load (P_2) is a "load applied during general cutting". The minimum load (P_3) is a "load applied at the time of rapid feeding of the cutting tool before starting cutting and at the time of quick return after completion of cutting". Once the above-mentioned values are determined, the average axial load (P_m) and the average rotational speed (N_m) can be obtained from the following formulas:

$$P_m = \left(\frac{P_1^3N_1t_1 + P_2^3N_2t_2 + P_3^3N_3t_3}{N_1t_1 + N_2t_2 + N_3t_3}\right)^{\frac{1}{3}} \text{ (N)} \ldots (6)$$

$$N_m = \frac{N_1t_1 + N_2t_2 + N_3t_3}{t_1 + t_2 + t_3} \text{ (min}^{-1}\text{)} \ldots\ldots\ldots\ldots\ldots (7)$$

When the difference between the maximum axial load (P_1) and the minimum axial load (P_3) is small, or when the load exhibits linear change, an approximate value can be calculated from the following formula:

$$P_m \approx \frac{2P_1 + P_3}{3} \text{ (N)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

■ Hardness and service life

When special materials for corrosion resistance, etc. are used, the thread groove cannot be hardened to HRC58-62. In such cases, the basic dynamic load rating and the basic static load rating decrease in proportion to the decreased hardness. When the hardness value is low, the basic dynamic load rating (C') and the basic static load rating (C_0') are calculated with the following formulas, assuming that the respective hardness factors are (f_H) and (f_H').

$$C' = f_H C \quad \text{(N)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$
$$C_0' = f_H' C_0 \quad \text{(N)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Table 19 Hardness factors

Hardness HRC	58 or above	56	54	52	50	40	30	20	10
f_H	1.0	0.88	0.72	0.58	0.47	0.27	0.16	0.10	0.07
f_H'	1.0	0.83	0.61	0.45	0.32	0.14	0.07	0.03	0.02

■ Temperature and service life

When an operating a ball screw made of standard material (See Table 1 on page A-6) at a constant temperature of 100°C or above or when operating it at a extremely high temperature for a short period of time, the composition of the material changes; thus, the basic dynamic load rating and the basic static load rating decrease as the temperature increases. However, temperatures of up to 100°C will not adversely affect operation. When the ball screw operates at a temperature at 100°C or above, the basic dynamic load rating (C'') and the basic static load rating (C_0'') are calculated by the following formulas, assuming that the respective temperature factors are (f_t) and (f_t').

$$C'' = f_t C \quad \text{(N)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$
$$C_0'' = f_t' C_0 \quad \text{(N)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

Table 20 Temperature factors

Temperature (°C)	100 or below	125	150	175	200
f_t	1.0	0.95	0.90	0.85	0.75
f_t'	1.0	0.93	0.85	0.78	0.65

Ball screw design suitability

In order to work out an optimum design for machines, it is necessary to examine the rigidity of the feed screw system, the positioning accuracy and the driving torque in due consideration of the required function, performance and cost.

■ Rigidity of the feed screw system

To improve the positioning accuracy and responsiveness of precision machines and equipment when they are controlled, it is necessary to take into consideration the rigidity of each component of the feed screw system. The rigidity (K) of the feed screw system is calculated by the following formula:

$$K = \frac{P}{\delta} \text{ (N/μm)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Where,
P : Axial load applied to the feed screw system (N)
δ : Axial elastic deformation of the feed screw system (μm)

The relationship between the rigidity of the feed screw system and that of each component is as follows:

$$\frac{1}{K} = \frac{1}{K_\ell} + \frac{1}{K_n} + \frac{1}{K_b} + \frac{1}{K_h} \ldots\ldots\ldots\ldots (15)$$

Where,
K_ℓ: Rigidity of the screw shaft to tension and compression
K_n: Rigidity of the nut
K_b: Rigidity of the support bearing
K_h: Rigidity of the nut mounting portion and the bearing mounting portion

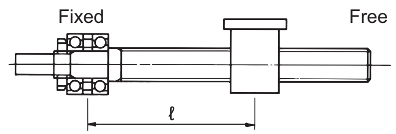
● Tension and compression strength of the screw shaft: K_ℓ

$$K_\ell = \frac{P}{\delta_\ell} \text{ (N/μm)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

Where,
P : Axial load (N)
δ_ℓ : Amount of expansion or contraction of the screw shaft (μm)

When an external axial load is applied to the screw shaft, the axial expansion and contraction is calculated by the following formulas. The axial expansion and contraction come out directly as the backlash of the ball screw.

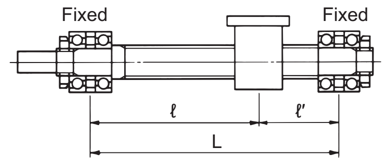
1. When the supporting method is "Fixed-Free"



$$\delta_\ell = \frac{4P\ell}{E\pi d^2} \times 10^3 \text{ (μm)} \ldots\ldots\ldots\ldots\ldots\ldots (17)$$

Where,
P : Axial load (N)
E : Young's modulus (2.06 X 10^5 N/mm²)
d : Screw shaft root diameter (mm)
ℓ : Distance between loading points (mm)

2. When the supporting method is "Fixed-Fixed"



$$\delta_\ell = \frac{4P\ell\ell'}{E\pi d^2 L} \times 10^3 \text{ (μm)} \ldots\ldots\ldots\ldots\ldots (18)$$

Where,
P : Axial load (N)
E : Young's modulus (2.06 X 10^5 N/mm²)
d : Screw shaft root diameter (mm)
ℓ, ℓ': Distance between loading points (mm)
L : Distance between supports (mm)

The maximum value is obtained from Formula (18) when $\ell = \ell' = \frac{L}{2}$.

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

Therefore, the maximum expansion and contraction of the screw shaft supported with the both ends fixed becomes 1/4 of those using the "Fixed-Free" method of screw shaft support.

● **Rigidity of the nut: K_n**

Rigidity of the single nut (non-preloaded): K_{ns}

When a ball screw receives an axial load, the steel balls and the thread groove will be deformed. The relationship between the axial load (P) and the axial elastic deformation (δ_{ns}) is calculated by the following formula:

$$\delta_{ns} = \frac{2.6}{\sin\alpha}\left(\frac{Q^2}{D_b}\times 10^{-2}\right)^{\frac{1}{3}} K \ (\mu m) \quad \cdots\cdots \quad (19)$$

Where,
α : Contact angle of steel balls with the thread groove (45°)
D_b: Steel ball diameter (mm)
K : Accuracy and structure coefficient (1.4-1.6)
Q : Load per steel ball (N)

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

P : Axial load (N)
Z : Number of steel balls

Theoretical rigidity (K_{NS}) obtained from the amount of elastic deformation when an axial load equivalent to 30% of the basic dynamic load rating (C) is shown in the dimension table for each of the product series.

Rigidity (K_{ns}) corresponding to an arbitrary axial load (P) is calculated by the following formula:

$$K_{ns} = K_{NS}\left(\frac{P}{0.3C}\right)^{\frac{1}{3}} \ (N/\mu m) \cdots\cdots\cdots\cdots\cdots \quad (20)$$

Where,
C : Basic dynamic load rating (N)
P : Axial load (N)

(δ_{ns}) in Formula (19) is calculated by the following formula using the rigidity (K_{NS}) of the single nut and the basic dynamic load rating (C).

$$\delta_{ns} = \frac{(0.3C)^{\frac{1}{3}} P^{\frac{2}{3}}}{K_{NS}} \ (\mu m) \cdots\cdots\cdots\cdots\cdots\cdots \quad (21)$$

Where,
K_{NS}: Theoretical rigidity of the single nut (N/µm) Refer to the content for each series.
C : Basic dynamic load rating (N)
P : Axial load (N)

Rigidity of the preloaded nut: K_{nw}

The dimension table for each product series gives theoretical rigidity (K_{NW}) obtained from the amount of elastic deformation that will occur when a preload of 1/15 of the basic dynamic load rating (C) is applied to the nut and an axial load of about 3 times or less of the preload is applied. These values are of practical use, because they were calculated on the basis of the results of the rigidity test including the nut rigidity test. Rigidity (K_{nw}) corresponding to an arbitrary preload can be obtained from the following formula:

$$K_{nw} = K_{NW}\left(\frac{P_L}{\frac{1}{15}C}\right)^{\frac{1}{3}} \ (N/\mu m) \cdots\cdots\cdots\cdots\cdots \quad (22)$$

Where,
P_L: Preload (N)
C : Basic dynamic load rating (N)

Backlash and preload

The backlash of a ball screw is the sum of the axial clearance and the elastic deformation caused by the axial load at the contact point of the steel balls with the thread groove. The axial elastic deformation can be reduced to a great extent by setting a proper preload and thus, the rigidity can be increased.

Double nut preload effect

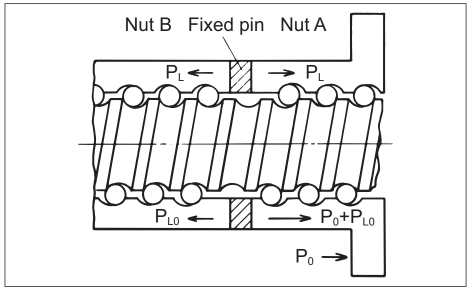


Figure 9 Double nut preload effect

In Figures 9 and 10, Nuts A and B undergo an elastic deformation of (δ_{nw0}) by preload (P_L) respectively. When external load (P_0) is applied to Nut A, the elastic deformation of Nuts A and B is:

$\delta_{nwA} = \delta_{nw0} + \delta_{nw1}$
$\delta_{nwB} = \delta_{nw0} - \delta_{nw1}$

The load applied to Nuts A and B is:

$P_A = P_L + P_0 - P_0' = P_0 + P_{L0}$
$P_B = P_L - P_0' = P_{L0}$

Therefore, an amount of (P_0') of the external load (P_0) is offset because the deformation of Nut B decreases. As a result, the elastic deformation of Nut A is reduced. This effect will continue until (δ_{nwB}) is zeroed, namely until the elastic deformation caused by the external load becomes (δ_{nw0}) and the preload applied to Nut B is completely released.

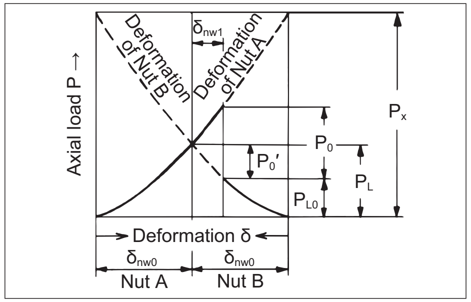


Figure 10 Preload diagram

Proper ball screw preload

The axial elastic deformation (δ_{nw0}) is proportional to a value obtained by raising the axial load (P) to two-thirds power according to the Hertz's law of point contact. Therefore, deformation caused by preloading is:

$\delta_{nw0} = C \cdot P_L^{\frac{2}{3}}$

Deformation caused by an external load when the preload applied to one nut is completely released is:

$2\delta_{nw0} = C \cdot P_x^{\frac{2}{3}}$

From the above two equations,

$$\left(\frac{P_x}{P_L}\right)^{\frac{2}{3}} = \frac{2\delta_{nw0}}{\delta_{nw0}} = 2$$

Therefore, the released preload is:

$$P_x = 2.8P_L \approx 3P_L \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (23)$$

Where,
P_x: Released preload (N)
(External axial load when preload applied to one nut returns to zero)
P_L: Preload (N)

As shown in equation (23), the preload effect is about 3 times as much as the preload amount. Generally, therefore, the preload amount is set at 1/3 of the maximum axial load. On the other hand, taking into consideration the life and efficiency, the preload amount is usually set at 1/20 to 1/10 of the basic dynamic load rating.

Classification of preload

	Light preload	Normal preload	Medium preload	Heavy preload
Preload	$\frac{1}{20}$ C or less	$\frac{1}{20}$ to $\frac{1}{15}$ C	$\frac{1}{15}$ to $\frac{1}{10}$ C	$\frac{1}{10}$ C or more

C: Basic dynamic load rating (N)

Elastic displacement curve of the preloaded nut

Figure 11 shows elastic displacement curves of a single nut (non-preloaded) and a preloaded nut. Where an axial load (P_x), which is three times as large as the preload (P_L), is applied, the elastic displacement of the preloaded nut is just one half of the elastic displacement of the single nut (non-preloaded).

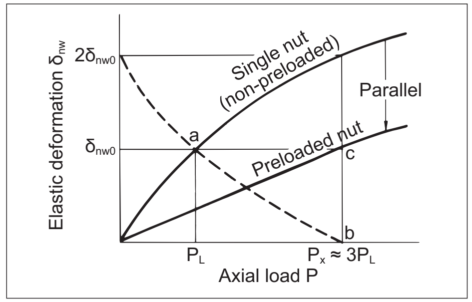


Figure 11 Elastic deformation curve of the nut

Double nut preloading methods

Preloading is to be applied, in general, to two nuts in tension (tension preloading) or in compression (compression preloading) using bolts.

KURODA's ball screws use tension preloading unless otherwise specified.

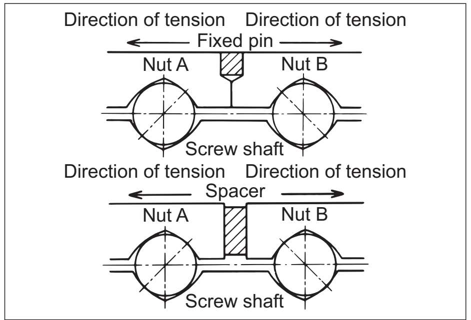


Figure 12 Tension preloading

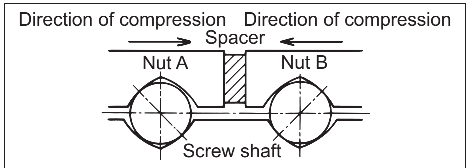


Figure 13 Compression preloading

- Preloaded with pin (standard method of KURODA)

This is the simplest and most effective tension preloading method. The required preload is attained and kept by inserting a pin between the two nuts.

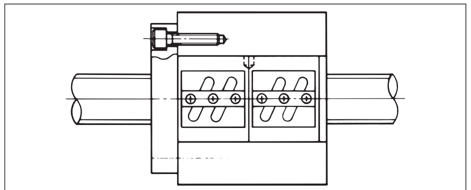


Figure 14 Preloaded with pin (I)

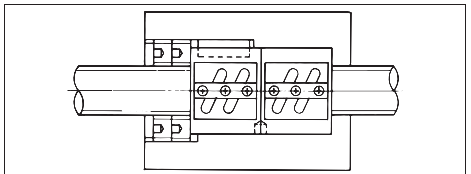


Figure 15 Preloaded with pin (II)

- Preloaded with spacer

In this method, preload is adjusted by the thickness of a spacer inserted between the two nuts. Both tension preloading and compression preloading are available.

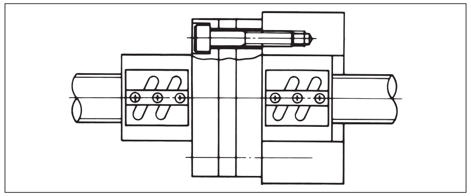


Figure 16 Preloaded with spacer (I)

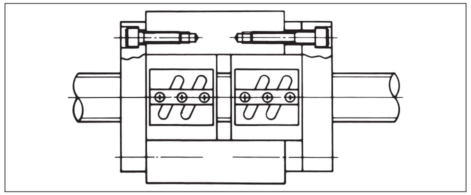


Figure 17 Preloaded with spacer (II)

Integral nut preloading method

In this method, a slightly offset lead at the center of a nut generates preload in the nut.

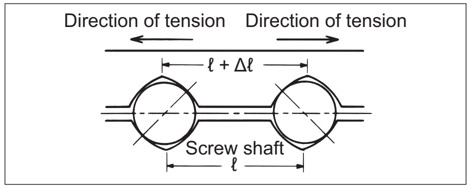


Figure 18 Integral nut preloading method

Single nut preloading method

In this method, a nut is preloaded by putting oversized steel balls between the thread groove of the screw shaft and that of the nut.

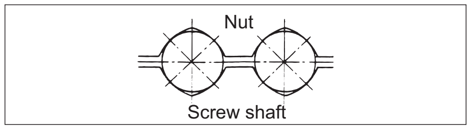


Figure 19 Single nut preloading method

• Rigidity of the support bearing: K_b

The rigidity of a bearing to which preload (P_L) is applied is calculated with the following formulas:

- Rigidity of the ball bearing

$$K_b = \frac{2.83P_L}{\delta_b} \ (\text{N/μm}) \quad \cdots\cdots \quad (24)$$

Where,
P_L: Preload (N)
δ_b: Axial elastic deformation to preload (μm)
Axial elastic deformation of the angular ball bearing is:

$$\delta_b = \frac{2}{\sin\alpha}\left(\frac{Q^2}{D_b}\right)^{\frac{1}{3}} \ (\text{μm}) \quad \cdots\cdots \quad (25)$$

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

Axial elastic deformation of the thrust ball bearing is:

$$\delta_b = 2.4\left(\frac{Q^2}{D_b}\right)^{\frac{1}{3}} \ (\text{μm}) \quad \cdots\cdots \quad (26)$$

$$Q = \frac{P}{Z}$$

Where,
δ_b: Axial elastic deformation (μm)
α : Contact angle
D_b: Steel ball diameter (mm)
Q : Load per steel ball (N)
Z : Number of steel balls
P : Axial load (N)

- Rigidity of the roller bearing

$$K_b = \frac{2.16P_L}{\delta_b} \ (\text{N/μm}) \quad \cdots\cdots \quad (27)$$

Where,
P_L: Preload (N)
δ_b: Axial elastic deformation to preload (μm)
Axial elastic deformation of the tapered roller bearing is:

$$\delta_b = \frac{0.6}{\sin\alpha} \cdot \frac{Q^{0.9}}{\ell^{0.8}} \ (\text{μm}) \quad \cdots\cdots \quad (28)$$

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

Where,
δ_b: Axial elastic deformation (μm)
α : Contact angle
Q : Load per roller (N)
Z : Number of rollers
P : Axial load (N)
ℓ : Effective contact length of the roller (mm)

• Rigidity of the nut mounting portion and the bearing mounting portion: K_h

In designing these portions, pay due regard to the thickness and the distance from the mounting surface to the ball screw shaft center, so that the rigidity of the nut bracket and the bearing box may be improved. When the distortion due to tension of the set bolt is not negligible, use the mounting method shown in Figure 17 on page F-18.

• Torsional rigidity of the screw shaft

The screw shaft is twisted around the axial line by the torsional moment (driving torque), resulting in rotational strain. The torsional deformation can be calculated as the axial deformation of the ball screw by the following formulas:

$$\delta_T = \ell\theta\frac{L}{2\pi} \quad \cdots\cdots \quad (29)$$

$$\theta = \frac{32T}{\pi d^4 G} \quad \cdots\cdots \quad (30)$$

Where,
δ_T: Axial deformation caused by torsion (cm)
ℓ : Distance between working points (cm)
θ : Angle of torsion (rad/cm)
L : Lead of the ball screw (cm)
T : Torsional moment (N·cm)
d : Root diameter of the screw shaft (cm)
G : Modulus of rigidity (83×10^5 N/cm^2)

If the angle of torsion for the driving shaft is excessively large, defections on the parts of the driving mechanism may be caused and result in torsional vibration of the shaft system. For ordinary driving shafts, the angle of torsion due to the maximum operating torsional moment should be set within 4.36×10^{-5} (rad/cm).

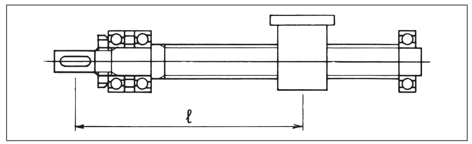


Figure 20

■ Notes for positioning accuracy

This paragraph deals with how to select the accuracy grade, how to determine the cumulative specified lead, and how to take effective measures against thermal strain, which will exert a great influence upon the positioning accuracy.

● Selection guide for the accuracy grade classified according to the type of the machine

Select the accuracy grade of the ball screw suited for the required positioning accuracy from Tables 2 and 3 on page F-3. KURODA recommends that you select the accuracy grade in accordance with the following table.

Table 21 Examples of the accuracy grade of the ball screw recommendable according to the type of the machine

Type of the machine			Accuracy grade
NC machine tools	Machining centers Milling machines	X, Y	C1 to C3
		Z	C2 to C5
	Lathes	X	C1 to C3
		Z	C3 to C5
	Grinding machines	X	C0 to C2
		Z	C1 to C3
	Electric discharge machines	X, Y	C1 to C3
		Z	C2 to C5
	Punching machines		C3 to C5
	Wood working machines (NC routers)		C5 to C7
Industrial robots	Cartesian coordinates type (assembly)		C1 to C5
	Vertical revolute type (assembly)		C2 to C5
	SCARA type (assembly)		C3 to C5
Semiconductor manufacturing equipment	Exposure system Drawing system		C0 to C1
	Etching equipment Ion implanting equipment		C3 to C7
	Wire bonders Die bonders		C1 to C2
	Wafer probers		C0 to C2
	Electrical parts charging apparatus, Insert machines		C2 to C7
Printing equipment	Electronic color separating apparatus		C0 to C2
	Electronic composing machines		C1 to C3
Business equipment	Color graphic printers		C1 to C3
	XY plotters Auto drawing machines		C1 to C3

● Determining the cumulative specified lead

In most cases, the lead is the same as the nominal lead, but there are instances in which the nominal designation is adjusted to account for expansion due to temperature increase during operation or the expansion or contraction of the screw shaft due to the external load. In such cases, inform KURODA of the target value of the cumulative lead. The typical target values of the cumulative lead classified according to the type of the machine are shown in Table 22 below. To correct the expansion, a tensile load may sometimes be applied to the screw shaft when mounting.

Table 22 Target values of the cumulative lead classified according to the machine type (Unit: mm)

Machine type	Axis	Target value of the cumulative lead (per meter)
NC lathes	X Z	-0.02 to -0.05 -0.02 to -0.03
Machining centers	X, Y	-0.03 to -0.04

● Measures to be taken for thermal displacement

As the ball screw is constructed so that its rolling motion involves a slight sliding motion, it inevitably suffers a thermal strain due to rising temperature. The temperature increase is closely related to operating conditions. The expansion of the thermal displacement can be calculated by the following formula:

$$\Delta\ell = \rho t \ell \text{ (mm)} \quad \cdots\cdots \quad (31)$$

Where,
$\Delta\ell$: Axial thermal displacement (mm)
ρ : Coefficient of thermal expansion (11.7×10^{-6}°C^{-1})
t : Temperature increase of the screw shaft (°C)
ℓ : Effective thread length (mm)

Driving torque

Frictional characteristics of the ball screw and selection of the drive motor

■ Friction and efficiency

The efficiency "η" of a ball screw obtained by the analysis of a mechanical model of the screw can be calculated as follows, assuming that the coefficient of friction = μ and the screw lead angle = β.

● When converting the rotational force into the axial force (normal operation):

$$\eta = \frac{1 - \mu / \tan\beta}{1 + \mu / \tan\beta} \quad \cdots\cdots \quad (32)$$

● When converting the axial force into the rotational force (reverse operation):

$$\eta' = \frac{1 - \mu \tan\beta}{1 + \mu \tan\beta} \quad \cdots\cdots \quad (33)$$

■ Load torque

The load torque (constant-speed driving torque) required for designing a driving unit (motor, etc.) can be calculated as follows.

● Normal operation

When converting the rotational force into the axial force

$$T = \frac{PL}{2\pi\eta} \text{ (N·cm)} \quad \cdots\cdots \quad (34)$$

Where,
T : Load torque (N·cm)
P : Axial external load (N)
L : Lead of the ball screw (cm)
η : Efficiency of the ball screw (0.9)

● Reverse operation

When converting the axial force into the rotational force

$$P = \frac{2\pi T}{\eta' L} \text{ (N)} \quad \cdots\cdots \quad (35)$$

Where,
P : Axial external load (N)
T : Load torque (N·cm)
L : Lead of the ball screw (cm)
η' : Efficiency of the ball screw (0.9)

● Friction torque caused by preload

A torque produced by preloading. As the external load increases, the preload applied to the preloaded nut is gradually released and consequently, the friction torque caused by preload is also reduced.

Without load:

$$T_P = K\frac{P_L L}{2\pi} \text{ (N·cm)} \quad \cdots\cdots \quad (36)$$

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

Where,
P_L : Preload (N)
L : Lead of the ball screw (cm)
K : Coefficient of internal friction
β : Lead angle

$$\beta \approx \tan^{-1}\left(\frac{L}{\pi D}\right)$$

D : Screw shaft diameter (cm)

■ Selection of the drive motor

Select a drive motor which meets the following conditions.

1. The motor should be able to sufficiently bear the load torque applied to its output shaft.
2. The motor should be able to start and stop at the required pulse speed when the moment of inertia is applied to its output shaft.
3. The required acceleration constant and deceleration constant can be obtained when the moment of inertia is applied to the output shaft of the motor.

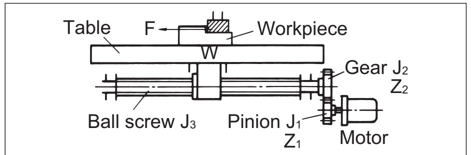


Figure 21

Technical data of ball screws

● Constant torque applied to the output shaft of a motor

A torque required for driving at a constant speed against an external load

$$T_1 = \left(\frac{PL}{2\pi\eta} + T_P\frac{(3P_L-P)}{3P_L}\right)\frac{Z_1}{Z_2} \quad (\text{N·cm}) \quad \cdots \quad (37)$$

Where, $P \leq 3P_L$

T_1: Driving torque at a constant speed (N·cm)

P : Axial external load (N)

$P = F + \mu Mg$

F : Anti-thrust repulsive force by cutting force (N)

M: Weight of the table and work (kg)

μ : Coefficient of friction of the sliding surface

g : Acceleration of gravity (9.8 m/s²)

L : Lead of the ball screw (cm)

η : Mechanical efficiency of the motor including the ball screw and the gear

T_P: Friction torque caused by preload (N·cm) Refer to Formula (36).

P : Preload (N)

Z_1: Number of teeth of the pinion

Z_2: Number of teeth of the gear

● Acceleration torque applied to the output shaft of a motor

A torque required for accelerative driving against an external load

$$T_2 = J_M\dot{\omega} = J_M \times \frac{2\pi N}{60t} \times 10^{-2} \quad (\text{N·cm}) \quad \cdots \quad (38)$$

$$J_M = J_1 + J_4 + \left(\frac{Z_1}{Z_2}\right)^2 (J_2 + J_3 + J_5 + J_6) \quad (\text{kg·cm}^2) \quad \cdots \quad (39)$$

Where,

T_2: Driving torque at the time of acceleration (N·m)

$\dot{\omega}$: Angular acceleration of the motor shaft (rad/s²)

N : Rotational speed of the motor shaft (min⁻¹)

t : Acceleration time (s)

J_M: Moment of inertia applied to the motor (kg·cm²)

J_1 : Moment of inertia of the pinion (kg·cm²)

J_2 : Moment of inertia of the gear (kg·cm²)

J_3 : Moment of inertia of the ball screw (kg·cm²)

J_4 : Moment of inertia of the motor rotor (kg·cm²)

J_5 : Moment of inertia of the moving object (kg·cm²)

J_6 : Moment of inertia of the coupling (kg·cm²)

M : Mass of the table and work (kg)

L : Lead of the ball screw (cm)

Moment of inertia of the cylinders such as the ball screw and the gear

(Calculation of J_1-J_4 and J_6)

$$J = \frac{\pi\gamma}{32} D^4 \ell \ (\text{kg·cm}^2) \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (40)$$

Where,

D : Outside diameter of the cylinder (cm)

ℓ : Length of the cylinder (cm)

γ : Specific gravity of the material

$\gamma = 7.8 \times 10^{-3}$ (kg/cm³)

$$J_5 = M\left(\frac{L}{2\pi}\right)^2 \ (\text{kg·cm}^2) \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (41)$$

● Total torque applied to the output shaft of a motor

The total torque can be calculated by adding the value of Formula (38) to that of Formula (37).

$$T_M = T_1 + T_2 \ (\text{N·cm}) \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (42)$$

Where,

T_M: Total torque applied to the output shaft of the motor (N·cm)

T_1: Driving torque at a constant speed (N·cm)

T_2: Driving torque at the time of acceleration (N·cm)

After provisionally selecting a motor, check the motor for the following three items. The motor you select should satisfactorily meet the respective values.

(1) Effective torque value

(2) Acceleration constant

(3) Over-load characteristics and tolerance to overheat of the motor at the time of repetitive starting and stopping

Guide for ball screw selection

When a ball screw is selected, a number of factors are examined from various points of view on the basis of the above-mentioned basic subjects by a process of trial and error. Therefore, the procedure cannot be categorically determined. An example of general procedures and main subjects for examination regarding each item and reference pages are mentioned below:

Selection procedures	Subjects to be examined
Operating conditions	● Work and table mass ● Maximum feed rate ● Velocity diagram ● External load ● Maximum stroke ● Mounting condition (horizontal and vertical) ● Duty (operation) cycle ● Operation coefficient ● Mounting and supporting method ● Expected life ● Positioning accuracy ● Environmental conditions ● Lubrication
Lead	(Selection of the lead) ● Maximum feed rate ● Maximum rotational speed of the motor ● Positioning resolution ● List of nominal screw shaft diameters and leads (B-3, C-3, D-3) ● Torque (F-21)
Number of circuits	(Designing and life calculation of the nut) ● Average axial load and average rotational speed (F-13) ● Service life estimation (F-13) ● Permissible rotational speed (DmN value) (F-11) ● Dimensions
Screw shaft	(Designing of the screw shaft) ● Screw shaft supporting method (F-9) ● Permissible buckling load (F-10) ● Permissible rotational speed (critical speed) (F-12) ● Accuracy grade and manufacturable shaft length (F-3)
Accuracy grade and rigidity	(Design for accuracy) ● Lead accuracy and axial clearance (F-3) ● Countermeasures against thermal change (F-20) ● Rigidity of feed screw system (F-15)
Lubrication and dust prevention	(Others) ● Lubrication and operating cautions (A-3, A-4)
Selection of ball screws	→ For the model number of ball screws, see A-10.

■ Example of ball screw selection

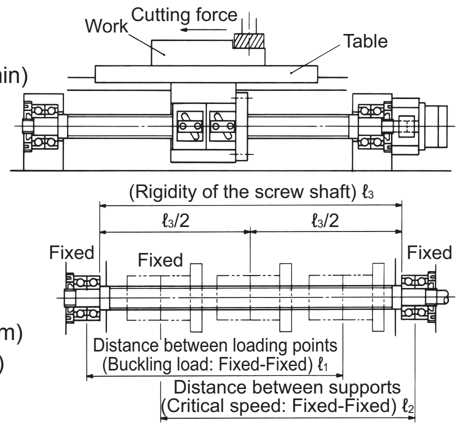
● Machine tool

<Specifications>

- Mass of the work and the table
  $M = 1300$ (kg)
- Maximum stroke $S_{max} = 800$ (mm)
- Rapid traverse speed $V_{max} = 12000$ (mm/min)
- Friction factor of the linear guide
  $\mu = 0.02$
- Load condition

Classification	Axial load (N)	Feed speed (mm/min)	Operating time rate (%)
Rapid traverse speed	300	12000	25
Light/medium cutting	5000	600	55
Heavy cutting	9000	120	20

- Positioning accuracy ±0.04/800 (mm)
- Expected service life 25000 (hours)
- Drive motor $N_{max} = 2000$ (min^{-1})
- Shaft-end supporting method Fixed-Fixed



1. Lead (L)

According to the maximum rotational speed of the motor and the rapid traverse speed of the motor, the lead can be selected as follows:

$$L \geq \frac{V_{max}}{N_{max}} = 6 \text{ (mm)}$$

2. Nut design

Examination of the necessary basic dynamic load rating and the permissible rotational speed (DmN value)

<In the case of lead 6>

Load conditions

Classification	Axial load (N)	Rotational speed (min^{-1})	Operating time rate (%)
Rapid traverse speed	300	2000	25
Light/medium cutting	5000	100	55
Heavy cutting	9000	20	20

Calculating the axial average load (P_m) and the average rotational speed (N_m) from the load conditions (Formulas (6) and (7) on page F-14) results in the following formulas:

$P_m = 2600$ (N)

$N_m = 559$ (min^{-1})

To calculate the necessary basic dynamic load rating (C), transformation formula (5) shown on page F-13 is used assuming that the life (L_h) is 25000 hours and operation coefficient (f_w) is 1.2, as shown below.

$$C = \left(\frac{60L_hN_m}{10^6}\right)^{\frac{1}{3}} P_m f_w = 29420 \text{ (N)}$$

A nut in suitable size with the smallest diameter can be selected from page C-43 as follows:

Outside diameter 36, lead 6, and 2.5 turns with 3 circuits

Then, when the DmN value (Formula (3) on page F-11) is sought to find the permissible rotational speed, DmN = 36.8 X 2000 = 73600 is found as against the permissible DmN ≤ 70000, showing that it exceeds the permissible value. Consequently, this size is not suitable. Therefore, increase the lead to 8, make the maximum rotational speed lower, and take another examination.

<In the case of lead 8>

Load conditions

Classification	Axial load (N)	Rotational speed (min^{-1})	Operating time rate (%)
Rapid traverse speed	300	1500	25
Light/medium cutting	5000	75	55
Heavy cutting	9000	15	20

The necessary basic dynamic load rating (C) calculated in the same manner as in the case of lead 6 is:

$P_m = 2600$ (N)

$N_m = 419$ (min^{-1})

$C = 26720$ (N)

Accordingly, a nut in suitable size with the smallest diameter can be selected from page C-41 as follows:

Outside diameter 32, lead 8, and 2.5 turns with 2 circuits

Then, DmN value is found to be DmN = 33 X 1500 = 49500, showing that it satisfies the permissible value. Proceed with the following examination based on this size.

3. Screw shaft design

Examining the overall screw shaft length (ℓ), permissible axial load (P_0), and critical speed (N_c)

Assuming that: ℓ = Maximum stroke + nut length + allowance + size of both shaft ends
= 800 + 145 + 80 + 175 = 1200

To obtain the permissible axial load, examine the buckling load assuming that the distance between loading points $\ell_1 = 930$.

The following formula can be obtained by Formulas (1) and (2) on pages F-10 and F-11:

$P_0 = 141400$ (N)

This can fully satisfy the operating conditions.

The critical speed is calculated from Formula (4) on page F-12 as follows: $N_c = 6490$ (min^{-1})

Where, the distance between load working points $\ell_2 = 940$.

This can fully satisfy the operating conditions.

4. Ball screw rigidity

Rigidity of the screw shaft (K_ℓ)

Calculate at the position $\ell_3/2$ where the axial deflection is maximized, assuming that the distance between bearing end faces $\ell_3 = 1005$.

The following formula is obtained by Formulas (16) and (18) on page F-15.

$$K_\ell = \frac{E\pi d^2}{\ell_3} \times 10^{-3} = 50 \text{ (N/μm)}$$

E : Young's modulus (2.06×10^5 N/mm²)

d : Screw shaft root diameter (mm)

Rigidity of the nut (K_{nw})

Rigidity to an arbitrary preload amount assuming that 1/3 of the maximum axial load is preload (P_L) can be obtained using Formula (22) on page F-16.

$$K_{nw} = K_{NW}\left(\frac{P_L}{\frac{1}{15}C}\right)^{\frac{1}{3}}$$

$$= 590\left(\frac{3000}{\frac{1}{15} \times 32300}\right)^{\frac{1}{3}} = 660 \text{ (N/μm)}$$

As a result of the above-mentioned examination, the nut model number GR3208ED-DALR is selected from page C-41.

5. Accuracy

Select C5 (e_c = ±0.025) from the positioning accuracy ±0.04/800 and the permissible values for variation (e_c) on page F-3, assuming that the directivity of cumulative mean lead can be corrected on the control side.

6. Result of ball screw selection

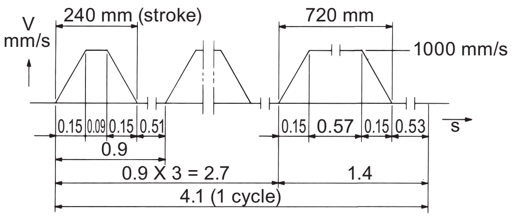
The model number of the selected ball screw is GR3208ED-DALR-1200X0985-C5S on page C-41.

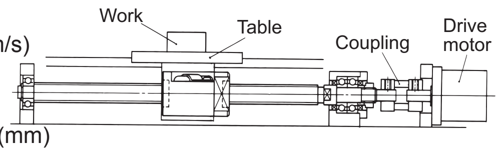
■ Example of ball screw selection

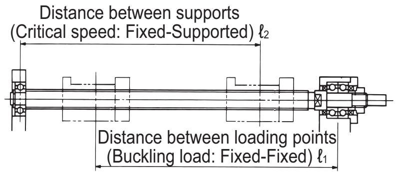
● X-axis of Cartesian robot (horizontal position)

<Specifications>

- Mass of the work and the table
  $M = 50$ (kg)
- Maximum stroke $S_{max} = 720$ (mm)
- Rapid traverse speed $V_{max} = 1000$ (mm/s)
- Acceleration/deceleration constant
  $t = 0.15$ (S)
- Positioning accuracy ±0.1/720 (mm)
- Repeat accuracy ±0.01 (mm)
- Expected life $L_h = 30000$ (hours)
- Friction factor of the linear guide
  $\mu = 0.02$
- Drive motor $N_{max} = 3000$ (min^{-1})
- Duty cycle model diagram







1. Lead (L)

According to the maximum rotational speed and the rapid traverse speed of the motor, the lead can be selected as follows:

$$L \geq \frac{V_{max} \times 60}{N_{max}} = 20 \text{ (mm)}$$

2. Nut design

Examination of the necessary basic dynamic load rating and the permissible rotational speed (DmN value)

Calculation of the axial load in each pattern of operations:

(a) At the time of acceleration

$$\text{Acceleration } (\alpha) = \frac{V_{max}}{t} \times 10^{-3} = 6.67 \text{ (m/s}^2\text{)}$$

Axial load (P_a) = ($M\alpha + \mu Mg$) = 343 (N)

(g: Gravitational acceleration 9.8 m/s^2)

(b) At the time of a constant speed

Axial load (P_b) = μMg = 10 (N)

(c) At the time of deceleration

Axial load (P_c) = ($M\alpha - \mu Mg$) = 324 (N)

Operating time (s) during one cycle of each pattern

Operation pattern	(a)	(b)	(c)	Total operating time
Operating time	0.6	0.84	0.6	2.04

Load conditions at the time of lead 20

Operation pattern	(a)	(b)	(c)
Axial load	343N	10N	324N
Rotational speed	1500 min^{-1}	3000 min^{-1}	1500 min^{-1}
Operating time ratio	29.4%	41.2%	29.4%

Calculating the axial average load (P_m) and the average rotational speed (N_m) from the load conditions (Formulas (6) and (7) on page F-14) results in the following formulas:

$P_m = 249$ (N)

$N_m = 2118$ (min^{-1})

Calculation of the necessary basic dynamic load rating (C)

The net operation life (L_{h0}) excluding downtime based on the expected life is calculated as follows:

$$L_{h0} = 30000 \left(\frac{2.04}{4.1}\right) = 14927 \text{ (hours)}$$

Transformation formula (5) shown on page F-13 is used assuming that the operation coefficient $f_w = 1.2$, as shown below.

$$C = \left(\frac{60 L_{h0} N_m}{10^6}\right)^{\frac{1}{3}} \times P_m \times f_w = 3700 \text{ (N)}$$

A ball screw in suitable size can be selected from standard ball screw GE and GG series (page B-78, B-79) as follows:

$\boxed{\text{Outside diameter 15, lead 20, and 1.5 turns with 1 circuit}}$

When looking for a DmN value (Formula (3) on page F-11) as the permissible rotational speed, DmN = 15.8 X 3000 = 47400 is found as against the permissible DmN ≤ 70000, showing that it satisfies the permissible value. Proceed with the following examination based on this size.

3. Screw shaft design

Examining the overall screw shaft length (ℓ), critical speed (N_c), and buckling load (P_k)

ℓ = Maximum stroke + nut length + allowance + size of both shaft ends = 720 + 62 + 60 + 78 = 920 (mm)

To obtain the permissible axial load, examine the buckling load assuming that the distance between loading points ℓ_1 = 820. The following formula can be obtained by Formulas (1) and (2) on pages F-10 and F-11:

$P_k = 7220$ (N)

This fully satisfies the operating condition.

Assuming that the distance between supports ℓ_2 = 790, the critical speed can be obtained by Formula (4) (Fixed-Supported) on page F-12 as follows:

$N_c = 3024$ (min^{-1})

This satisfies the operating condition.

4. Accuracy

Examination of the accuracy grade and the axial clearance

The accuracy grade that can satisfy the positioning accuracy of ±0.1/750 mm is determined, from the permissible value of the lead accuracy (page F-3), to be C5 (cumulative mean lead error $\pm E_c$ = 0.035 and variation e_c = 0.025).

Axial clearance is set to 0.005 or less based on the repeated positioning accuracy ±0.01.

5. Result of ball screw and support unit selection

Provided that additional machining of standard ball screw GG series with unfinished shaft ends is performed, the following model number is selected from page B-78 and B-79:

$\boxed{\text{GG1520AS-BALR-1100A}}$

The model number of the suitable support unit selected from page E-16 and E-17 is $\boxed{\text{BUK-12}}$.

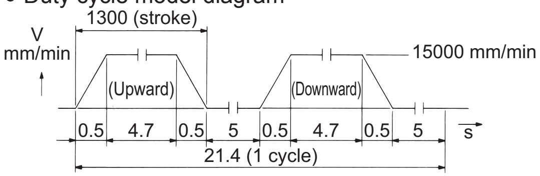
Technical data of ball screws

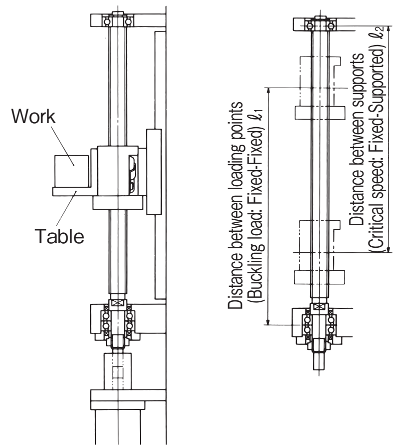
■ Example of ball screw selection

● Elevator (vertical position)

<Specifications>

- Mass of the work and the table
  $M = 100$ (kg)
- Maximum stroke $S_{max} = 1300$ (mm)
- Rapid traverse speed $V_{max} = 15000$ (mm/min)
- Acceleration/deceleration constant
  $t = 0.5$ (S)
- Repeat accuracy 0.5 (mm)
- Expected life $L_h = 20000$ (hours)
- Friction factor of the linear guide
  $\mu = 0.02$
- Drive motor $N_{max} = 1500$ (min^{-1})
- Duty cycle model diagram





1. Lead (L)

According to the maximum rotational speed and the rapid traverse speed of the motor, the lead can be selected as follows:

$$L \geq \frac{V_{max}}{N_{max}} = 10$$

2. Nut design

Examination of the necessary basic dynamic load rating and the permissible rotational speed (DmN value)

Calculation of the axial load in each pattern of operations:

(a) At the time of upward acceleration and downward deceleration

$$\text{Acceleration } (\alpha) = \frac{V_{max}}{t \cdot 60} \times 10^{-3} = 0.5 \ (m/s^2)$$

Axial load (P_a) = ($M\alpha + Mg$) = 1030 (N)

(g: Gravitational acceleration 9.8 m/s^2)

(b) At the time of a constant speed

Axial load (P_b) = Mg = 980 (N)

(c) At the time of upward deceleration and downward acceleration

Axial load (P_c) = ($Mg - M\alpha$) = 930 (N)

Operating time (s) during one cycle of each pattern (s)

Operation pattern	(a)	(b)	(c)	Total operating time
Operating time	1	9.4	1	11.4

Load conditions at the time of lead 10

Operation pattern	(a)	(b)	(c)
Axial load	1030N	980N	930N
Rotational speed	750 min^{-1}	1500 min^{-1}	750 min^{-1}
Operating time ratio	8.8 %	82.4 %	8.8 %

Calculating the axial average load (P_m) and the average rotational speed (N_m) from the load conditions (Formulas (6) and (7) on page F-14) results in the following formulas:

$P_m = 980$ (N)

$N_m = 1368$ (min^{-1})

Calculation of the necessary basic dynamic load rating (C)

The net operation life (L_{h0}) excluding downtime based on the expected life is calculated as follows:

$$L_{h0} = L_h \left(\frac{11.4}{21.4} \right) = 10654 \text{ (hours)}$$

As the operation accompanied by vibration is anticipated, transformation formula (5) shown on page F-13 is used assuming that the operation coefficient $f_w = 1.5$, as shown below.

$$C = \left(\frac{60 L_{h0} N_m}{10^6} \right)^{\frac{1}{3}} \times P_m \cdot f_w = 14057 \text{ (N)}$$

A suitable nut size can be selected from rolled ball screw GY series (page D-72 and D-73) based on the repeat accuracy 0.5 as follows:

Outside diameter 25, lead 10, and 2.5 turns with 2 circuits

When looking for a DmN value (Formula (3) on page F-11) as the permissible rotational speed, DmN = 26.8 X 1500 = 40200 is found as against the permissible $D_{mN} \leq 50000$, showing that it satisfies the permissible value. Proceed with the following examination based on this size.

3. Screw shaft design

Examination of the overall screw shaft length (ℓ) and permissible axial load (P_k)

ℓ = Maximum stroke + nut length + safety stroke + size of both shaft ends

To obtain permissible axial load, examine the buckling load, assuming that distance between load working points $\ell_1 = 1440$. The following formula can be obtained by Formulas (1) and (2) (Fixed-Fixed) on pages F-10 and F-11:

$P_k = 16290$ (N)

This satisfies the operating condition.

Assuming that distance between supports $\delta_2 = 1420$, the following formula can be obtained by Formula (4) (Fixed-Supported) on page F-12:

$N_c = 1520$ (min^{-1})

This satisfies the operating condition.

4. Result of Ball Screw Selection

Provided that additional machining of rolled ball screw GY series is performed, the following model number is selected from page D-72 and D-73:

GY2510ES-HULR-2000A

Technical data of ball screws

Ballscrew specification data sheet

Date		Contact personnel	
Company name			
Department		TEL / FAX	

Conditions of use

Mass (weight) of table		Maximum table speed	mm/sec
Moving conditions	☐Shaft rotation ☐Nut rotation	Lubrication	☐Grease ☐Oil
Mount method	☐Horizontal ☐Vertical ☐Others (Description:)		
Mount/Support method	☐Fixed-support ☐Fixed-fixed ☐Fixed-free ☐Support-support		
Oscillation	☐No ☐Yes (stroke mm)		
Environmental conditions	Temp. (°C) ☐ Clean room ☐Vacuum ☐Others ( )		
Expected life	Ex.: 8 hours/day, 240 days/year, 5 years		

Ballscrew specifications

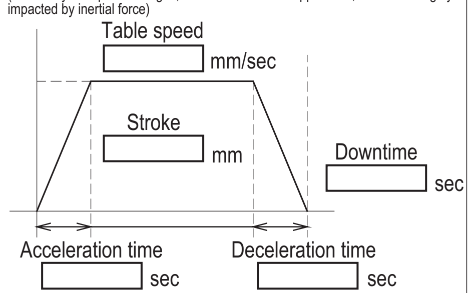
Screw shaft diameter		Thread direction		Axial clearance		Thread length	
Lead		Nuber of circuits		Accuracy grade		Overall length	
Nut type	☐Single nut ☐Double nut ☐Integral nut						

Operating conditions

☐Case A
(when axial load and table speed can be classified into several patterns, such as when using a pressing device)

No. of patterns	Axial load	Table speed	Usage time
1			
2			
3			
4			
5			
6			

☐Case B
(when only the speed changes, such as for transfer application, and when largely impacted by inertial force)



Others

Type of slide guide	☐Rolling (model number:) ☐Sliding
Name of motor	
Quantity of screw shafts used	Ex.: One per head, Four per table
Change control	☐No ☐Yes

Memo (Please draw a configuration diagram, etc.)

Request for KURODA	☐Request for selection of ball screws ☐Request for calculation of ball screw life
	Contact personnel:

Ballscrew specification data sheet (Sample)

Date		Contact personnel	
Company name	XYZ Industries, Co., Ltd.		
Department		TEL / FAX	

Conditions of use

Mass (weight) of table	50kg	Maximum table speed	250 mm/sec
Moving conditions	☑Shaft rotation ☐Nut rotation	Lubrication	☑Grease ☐Oil
Mount method	☑Horizontal ☐Vertical ☐Others (Description:)		
Mount/Support method	☑Fixed-support ☐Fixed-fixed ☐Fixed-free ☐Support-support		
Oscillation	☑No ☐Yes (stroke mm)		
Environmental conditions	Temp. (25 °C) ☐ Clean room ☐Vacuum ☐Others ( )		
Expected life	20000 hours (including downtime) Ex.: 8 hours/day, 240 days/year, 5 years		

Ballscrew specifications

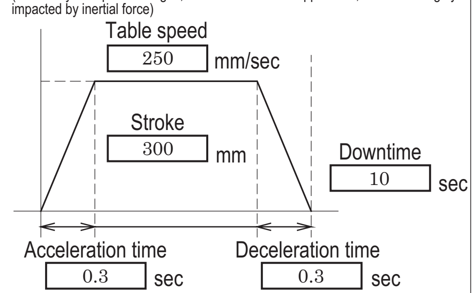
Screw shaft diameter		Thread direction		Axial clearance		Thread length	
Lead		Nuber of circuits		Accuracy grade		Overall length	
Nut type	☐Single nut ☐Double nut ☐Integral nut						

Operating conditions

☐Case A
(when axial load and table speed can be classified into several patterns, such as when using a pressing device)

No. of patterns	Axial load	Table speed	Usage time
1			
2			
3			
4			
5			
6			

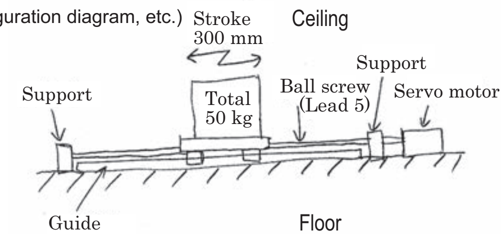
☐Case B
(when only the speed changes, such as for transfer application, and when largely impacted by inertial force)



Others

Type of slide guide	☐Rolling (model number:) ☐Sliding
Name of motor	
Quantity of screw shafts used	One per X-axis Ex.: One per head, Four per table
Change control	☐No ☐Yes

Memo (Please draw a configuration diagram, etc.)



Request for KURODA	☐Request for selection of ball screws ☐Request for calculation of ball screw life
	Contact personnel:

Reference data

Table 1: Standard tolerance grades and limit deviations for holes JIS B 0401-2:1998 (ISO 286-2:1988)

Unit: μm = 0.001 mm

Range of standard dimensions (mm)		Tolerance grades for holes																									
Over	Or less	D8	D9	D10	E7	E8	E9	F6	F7	F8	G6	G7	H6	H7	H8	H9	H10	JS6	JS7	K6	K7	M6	M7	N6	N7	P6	P7
-	3	+ 34 + 20	+ 45 + 20	+ 60 + 20	+ 24 + 14	+ 28 + 14	+ 39 + 14	+ 12 + 6	+ 16 + 6	+ 20 + 6	+ 8 + 2	+ 12 + 2	+ 6 0	+ 10 0	+ 14 0	+ 25 0	+ 40 0	± 3	± 5	0 - 6	0 - 10	- 2 - 8	- 2 - 12	- 4 - 10	- 4 - 14	- 6 - 12	- 6 - 16
3	6	+ 48 + 30	+ 60 + 30	+ 78 + 30	+ 32 + 20	+ 38 + 20	+ 50 + 20	+ 18 + 10	+ 22 + 10	+ 28 + 10	+ 12 + 4	+ 16 + 4	+ 8 0	+ 12 0	+ 18 0	+ 30 0	+ 48 0	± 4	± 6	+ 2 - 6	+ 3 - 9	- 1 - 9	0 - 12	- 5 - 13	- 4 - 16	- 9 - 17	- 8 - 20
6	10	+ 62 + 40	+ 76 + 40	+ 98 + 40	+ 40 + 25	+ 47 + 25	+ 61 + 25	+ 22 + 13	+ 28 + 13	+ 35 + 13	+ 14 + 5	+ 20 + 5	+ 9 0	+ 15 0	+ 22 0	+ 36 0	+ 58 0	± 4.5	± 7.5	+ 2 - 7	+ 5 - 10	- 3 - 12	0 - 15	- 7 - 16	- 4 - 19	- 12 - 21	- 9 - 24
10 14	14 18	+ 77 + 50	+ 93 + 50	+ 120 + 50	+ 50 + 32	+ 59 + 32	+ 75 + 32	+ 27 + 16	+ 34 + 16	+ 43 + 16	+ 17 + 6	+ 24 + 6	+ 11 0	+ 18 0	+ 27 0	+ 43 0	+ 70 0	± 5.5	± 9	+ 2 - 9	+ 6 - 12	- 4 - 15	0 - 18	- 9 - 20	- 5 - 23	- 15 - 26	- 11 - 29
18 24	24 30	+ 98 + 65	+ 117 + 65	+ 149 + 65	+ 61 + 40	+ 73 + 40	+ 92 + 40	+ 33 + 20	+ 41 + 20	+ 53 + 20	+ 20 + 7	+ 28 + 7	+ 13 0	+ 21 0	+ 33 0	+ 52 0	+ 84 0	± 6.5	± 10.5	+ 2 - 11	+ 6 - 15	- 4 - 17	0 - 21	- 11 - 24	- 7 - 28	- 18 - 31	- 14 - 35
30 40	40 50	+ 119 + 80	+ 142 + 80	+ 180 + 80	+ 75 + 50	+ 89 + 50	+ 112 + 50	+ 41 + 25	+ 50 + 25	+ 64 + 25	+ 25 + 9	+ 34 + 9	+ 16 0	+ 25 0	+ 39 0	+ 62 0	+ 100 0	± 8	± 12.5	+ 3 - 13	+ 7 - 18	- 4 - 20	0 - 25	- 12 - 28	- 8 - 33	- 21 - 37	- 17 - 42
50 65	65 80	+ 146 + 100	+ 174 + 100	+ 220 + 100	+ 90 + 60	+ 106 + 60	+ 134 + 60	+ 49 + 30	+ 60 + 30	+ 76 + 30	+ 29 + 10	+ 40 + 10	+ 19 0	+ 30 0	+ 46 0	+ 74 0	+ 120 0	± 9.5	± 15	+ 4 - 15	+ 9 - 21	- 5 - 24	0 - 30	- 14 - 33	- 9 - 39	- 26 - 45	- 21 - 51
80 100	100 120	+ 174 + 120	+ 207 + 120	+ 260 + 120	+ 107 + 72	+ 126 + 72	+ 159 + 72	+ 58 + 36	+ 71 + 36	+ 90 + 36	+ 34 + 12	+ 47 + 12	+ 22 0	+ 35 0	+ 54 0	+ 87 0	+ 140 0	± 11	± 17.5	+ 4 - 18	+ 10 - 25	- 6 - 28	0 - 35	- 16 - 38	- 10 - 45	- 30 - 52	- 24 - 59
120 140 160	140 160 180	+ 208 + 145	+ 245 + 145	+ 305 + 145	+ 125 + 85	+ 148 + 85	+ 185 + 85	+ 68 + 43	+ 83 + 43	+ 106 + 46	+ 39 + 14	+ 54 + 14	+ 25 0	+ 40 0	+ 63 0	+ 100 0	+ 160 0	± 12.5	± 20	+ 4 - 21	+ 12 - 28	- 8 - 33	0 - 40	- 20 - 45	- 12 - 52	- 36 - 61	- 28 - 68
180 200 225	200 225 250	+ 242 + 170	+ 285 + 170	+ 355 + 170	+ 146 + 100	+ 172 + 100	+ 215 + 100	+ 79 + 50	+ 96 + 50	+ 122 + 50	+ 44 + 15	+ 61 + 15	+ 29 0	+ 46 0	+ 72 0	+ 115 0	+ 185 0	± 14.5	± 23	+ 5 - 24	+ 13 - 33	- 8 - 37	0 - 46	- 22 - 51	- 14 - 60	- 41 - 70	- 33 - 79

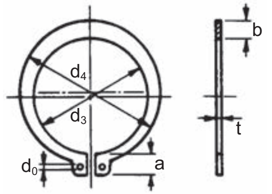
Table 2: Standard tolerance grades and limit deviations for shafts JIS B 0401-2:1998 (ISO 286-2:1988)

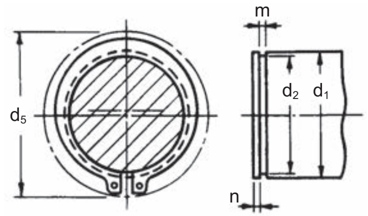
Unit: μm = 0.001 mm

Range of standard dimensions (mm)		Tolerance grades for shafts																							
Over	Or less	d8	d9	e7	e8	e9	f6	f7	f8	g5	g6	h5	h6	h7	h8	h9	js5	js6	js7	k5	k6	m5	m6	n6	p6
-	3	- 20 - 34	- 20 - 45	- 14 - 24	- 14 - 28	- 14 - 39	- 6 - 12	- 6 - 16	- 6 - 20	- 2 - 6	- 2 - 8	0 - 4	0 - 6	0 - 10	0 - 14	0 - 25	± 2	± 3	± 5	+ 4 0	+ 6 0	+ 6 + 2	+ 8 + 2	+ 10 + 4	+ 12 + 6
3	6	- 30 - 48	- 30 - 60	- 20 - 32	- 20 - 38	- 20 - 50	- 10 - 18	- 10 - 22	- 10 - 28	- 4 - 9	- 4 - 12	0 - 5	0 - 8	0 - 12	0 - 18	0 - 30	± 2.5	± 4	± 6	+ 6 + 1	+ 9 + 1	+ 9 + 4	+ 12 + 4	+ 16 + 8	+ 20 + 12
6	10	- 40 - 62	- 40 - 76	- 25 - 40	- 25 - 47	- 25 - 61	- 13 - 22	- 13 - 28	- 13 - 35	- 5 - 11	- 5 - 14	0 - 6	0 - 9	0 - 15	0 - 22	0 - 36	± 3	± 4.5	± 7.5	+ 7 + 1	+ 10 + 1	+ 12 + 6	+ 15 + 6	+ 19 + 10	+ 24 + 15
10 14	14 18	- 50 - 77	- 50 - 93	- 32 - 50	- 32 - 59	- 32 - 75	- 16 - 27	- 16 - 34	- 16 - 43	- 6 - 14	- 6 - 17	0 - 8	0 - 11	0 - 18	0 - 27	0 - 43	± 4	± 5.5	± 9	+ 9 + 1	+ 12 + 1	+ 15 + 7	+ 18 + 7	+ 23 + 12	+ 29 + 18
18 24	24 30	- 65 - 98	- 65 - 117	- 40 - 61	- 40 - 73	- 40 - 92	- 20 - 33	- 20 - 41	- 20 - 53	- 7 - 16	- 7 - 20	0 - 9	0 - 13	0 - 21	0 - 33	0 - 52	± 4.5	± 6.5	± 10.5	+ 11 + 2	+ 15 + 2	+ 17 + 8	+ 21 + 8	+ 28 + 15	+ 35 + 22
30 40	40 50	- 80 - 119	- 80 - 142	- 50 - 75	- 50 - 89	- 50 - 112	- 25 - 41	- 25 - 50	- 25 - 64	- 9 - 20	- 9 - 25	0 - 11	0 - 16	0 - 25	0 - 39	0 - 62	± 5.5	± 8	± 12.5	+ 13 + 2	+ 18 + 2	+ 20 + 9	+ 25 + 9	+ 33 + 17	+ 42 + 26
50 65	65 80	- 100 - 146	- 100 - 174	- 60 - 90	- 60 - 106	- 60 - 134	- 30 - 49	- 30 - 60	- 30 - 76	- 10 - 23	- 10 - 29	0 - 13	0 - 19	0 - 30	0 - 46	0 - 74	± 6.5	± 9.5	± 15	+ 15 + 2	+ 21 + 2	+ 24 + 11	+ 30 + 11	+ 39 + 20	+ 51 + 32
80 100	100 120	- 120 - 174	- 120 - 207	- 72 - 107	- 72 - 126	- 72 - 159	- 36 - 58	- 36 - 71	- 36 - 90	- 12 - 27	- 12 - 34	0 - 15	0 - 22	0 - 35	0 - 54	0 - 87	± 7.5	± 11	± 17.5	+ 18 + 3	+ 25 + 3	+ 28 + 13	+ 35 + 13	+ 45 + 23	+ 59 + 37
120 140 160	140 160 180	- 145 - 208	- 145 - 245	- 85 - 125	- 85 - 148	- 85 - 185	- 43 - 68	- 43 - 83	- 43 - 106	- 14 - 32	- 14 - 39	0 - 18	0 - 25	0 - 40	0 - 63	0 - 100	± 9	± 12.5	± 20	+ 21 + 3	+ 28 + 3	+ 33 + 15	+ 40 + 15	+ 52 + 27	+ 68 + 43
180 200 225	200 225 250	- 170 - 242	- 170 - 285	- 100 - 146	- 100 - 172	- 100 - 215	- 50 - 79	- 50 - 96	- 50 - 122	- 15 - 35	- 15 - 44	0 - 20	0 - 29	0 - 46	0 - 72	0 - 115	± 10	± 14.5	± 23	+ 24 + 4	+ 33 + 4	+ 37 + 17	+ 46 + 17	+ 60 + 31	+ 79 + 50

Reference data

Table 3: C-Shaped Snap Rings JIS B 2804:2001





Position the holes at the neb of the snap ring (diameter d_0) so that they protrude out of the snap ring groove and are visible above the external diameter of the shaft end.

"d_5" represents the maximum circumferential diameter when the ring is snapped onto the shaft.

Unit: mm

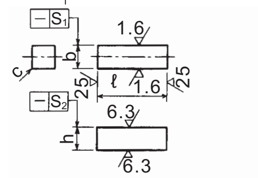
Nominal size [1]		Snap ring							Corresponding shaft (for reference purpose only)						
		d_1		f		b	a	d_0	d_3	d_1	d_2		m		n
1	2	Standard dimensions	Tolerance	Standard dimensions	Tolerance	Approximate	Approximate	Minimum			Standard dimensions	Tolerance	Standard dimensions	Tolerance	Minimum
10		9.3	± 0.15	1	± 0.05	1.6	3.0	1.2	17	10	9.6	0 - 0.09	1.15	+ 0.14 0	1.5
	11	10.2				1.8	3.1		18	11	10.5	0 - 0.11			
12		11.1	± 0.18			1.8	3.2	1.5	19	12	11.5				
14		12.9				2.0	3.4	1.7	22	14	13.4				
15		13.8				2.1	3.5		23	15	14.3				
16		14.7				2.2	3.6		24	16	15.2				
17		15.7				2.2	3.7		25	17	16.2				
18		16.5		1.2	± 0.06	2.6	3.8		26	18	17.0		1.35		
	19	17.5				2.7	3.8	2	27	19	18.0				
20		18.5	± 0.20			2.7	3.9		28	20	19.0	0 - 0.21			
22		20.5				2.7	4.1		31	22	21.0				
	24	22.2				3.1	4.2		33	24	22.9				
25		23.2				3.1	4.3		34	25	23.9				
	26	24.2				3.1	4.4		35	26	24.9				
28		25.9		1.6 [2]		3.1	4.6		38	28	26.6		1.75 [2]		
30		27.9				3.5	4.8		40	30	28.6				
32		29.6				3.5	5.0	2.5	43	32	30.3	0 - 0.25			
35		32.2	± 0.25			4.0	5.4		46	35	33.0				
	36	33.2		1.8	± 0.07	4.0	5.4		47	36	34.0		1.95		2
	38	35.2				4.5	5.6		50	38	36.0				
40		37.0	± 0.40			4.5	5.8		53	40	38.0				
	42	38.5				4.5	6.2		55	42	39.5				
45		41.5				4.8	6.3		58	45	42.5				
	48	44.5				4.8	6.5		62	48	45.5				
50		45.8		2		5.0	6.7		64	50	47.0				
55		50.8	± 0.45			5.0	7.0		70	55	52.0	0 - 0.30	2.2		
	56	51.8				5.0	7.0		71	56	53.0				
60		55.8				5.5	7.2		75	60	57.0				
65		60.8		2.5	± 0.08	6.4	7.4		81	65	62.0		2.7		2.5
70		65.5				6.4	7.8		86	70	67.0				
75		70.5				7.0	7.9		92	75	72.0				
80		74.5				7.4	8.2		97	80	76.5				
85		79.5		3	± 0.09	8.0	8.4	3	103	85	81.5	0 - 0.35	3.2	+ 0.18 0	3
90		84.5	± 0.55			8.0	8.7		108	90	86.5				
95		89.5				8.6	9.1		114	95	91.5				
100		94.5				9.0	9.5		119	100	96.5				
	105	98.0		4		9.5	9.8		125	105	101.0	0 - 0.54	4.2		4
110		103.0				9.5	10.0		131	110	106.0				
120		113.0				10.3	10.9		143	120	116.0				

(Note 1) The nominal sizes in column "1" are preferable to the sizes in column "2". The latter may be used when needed.
(Note 2) The thickness (t) = 1.6 mm. Thickness of 1.5 mm is permissible until determined otherwise. In this case the value "m" is 1.65 mm.
(Remarks) 1. The minimum width of the annular part of the snap ring must not be smaller than the board thickness (t).
2. The corresponding shaft dimensions above are shown as recommended dimensions for reference purposes only.

Table 4: Dimensions of parallel keys and key grooves JIS B 1301:1996

Key

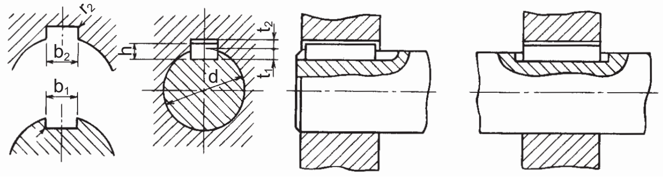
S_1 = tolerance of b × 1/2



S_2 = tolerance of h × 1/2

Key groove

Cross section of key groove



Unit: mm

Nominal key size b × h	Dimensions of key							Dimensions of key groove							Ref.
	b		h			C	ℓ [1]	Standard dimensions of b_1 and b_2	Standard groove		r_1 and r_2	Standard dimensions of t_1	Standard dimensions of t_2	Tolerance of t_1 and t_2	Corresponding shaft diameter d
	Standard dimensions	Tolerance (h9)	Standard dimensions	Tolerance					b_1 Tolerance (N9)	b_2 Tolerance (Js9)					
2 × 2	2	0 - 0.025	2	0 - 0.025	h9	0.16 to 0.25	6 to 20	2	- 0.004 - 0.029	± 0.0125	0.08 to 0.16	1.2	1.0	+ 0.1 0	6 to 8
3 × 3	3		3				6 to 36	3				1.8	1.4		8 to 10
4 × 4	4	0 - 0.030	4	0 - 0.030			8 to 45	4	0 - 0.030	± 0.0150		2.5	1.8		10 to 12
5 × 5	5		5			0.25 to 0.40	10 to 56	5			0.16 to 0.25	3.0	2.3		12 to 17
6 × 6	6		6				14 to 70	6				3.5	2.8		17 to 22
(7 × 7)	7	0 - 0.036	7	0 - 0.030			16 to 80	7	0 - 0.036	± 0.0180		4.0	3.0	+ 0.2 0	20 to 25
8 × 7	8		7	0 - 0.090	h11		18 to 90	8				4.0	3.3		22 to 30
10 × 8	10		8			0.40 to 0.60	22 to 110	10			0.25 to 0.40	5.0	3.3		30 to 38
12 × 8	12	0 - 0.043	8				28 to 140	12	0 - 0.043	± 0.0215		5.0	3.3		38 to 44
14 × 9	14		9				36 to 160	14				5.5	3.8		44 to 50
(15 × 10)	15		10				40 to 180	15				5.0	5.0		50 to 55
16 × 10	16		10				45 to 180	16				6.0	4.3		50 to 58
18 × 11	18		11	0 - 0.110			50 to 200	18				7.0	4.4		58 to 65
20 × 12	20	0 - 0.052	12			0.60 to 0.80	56 to 220	20	0 - 0.052	± 0.0260	0.40 to 0.60	7.5	4.9		65 to 75
22 × 14	22		14				63 to 250	22				9.0	5.4		75 to 85
(24 × 16)	24		16				70 to 280	24				8.0	8.0		80 to 90
25 × 14	25		14				70 to 280	25				9.0	5.4		85 to 95
28 × 16	28		16				80 to 320	28				10.0	6.4		95 to 110
32 × 18	32	0 - 0.062	18				90 to 360	32	0 - 0.062	± 0.0310		11.0	7.4		110 to 130
(35 × 22)	35		22	0 - 0.130		1.00 to 1.20	100 to 400	35			0.70 to 1.00	11.0	11.0	+ 0.3 0	125 to 140
36 × 20	36		20				-	36				12.0	8.4		130 to 150
(38 × 24)	38		24				-	38				12.0	12.0		140 to 160
40 × 22	40		22				-	40				13.0	9.4		150 to 170
(42 × 26)	42		26				-	42				13.0	13.0		160 to 180
45 × 25	45		25				-	45				15.0	10.4		170 to 200
50 × 28	50		28				-	50				17.0	11.4		200 to 230
56 × 32	56	0 - 0.074	32	0 - 0.160		1.60 to 2.00	-	56	0 - 0.074	± 0.0370	1.20 to 1.60	20.0	12.4		230 to 260
63 × 32	63		32				-	63				20.0	12.4		260 to 290
70 × 36	70		36				-	70				22.0	14.4		290 to 330
80 × 40	80		40			2.50 to 3.00	-	80			2.00 to 2.50	25.0	15.4		330 to 380
90 × 45	90	0 - 0.087	45				-	90	0 - 0.087	± 0.0435		28.0	17.4		380 to 440
100 × 50	100		50				-	100				31.0	19.5		440 to 500

(Note 1) "ℓ" must be selected from the following values: 6, 8, 10, 12, 14, 16, 18, 20, 22, 25, 28, 32, 36, 40, 45, 50, 56, 63, 70, 80, 90, 100, 110, 125, 140, 160, 180, 200, 220, 250, 280, 320, 360, or 400.
The dimensional tolerance values for "ℓ" are generally h12 in accordance with JIS B 0401 (Dimensional tolerances and fit).
(Note 2) The corresponding shaft diameters should be determined in consideration of proper torque for key strength. The the above list indicates standard diameters for general use and is intended for reference purposes only.
(Remark) It is recommended that you avoid using the nominal sizes with parentheses whenever possible.
(Reference) When you need a key with a tolerance smaller than the key tolerance specified above, the tolerance for the key width (b) should be h7. In this case, a tolerance for height (h) should be h7 for nominal sizes of 7X7 or smaller and h11 for the sizes of 8X7 or larger.

Table 5: Hardness Conversion Chart

Rockwell C-scale hardness (150 kgf)	Vickers hardness	Brinell hardness		Rockwell hardness		Shore hardness
		Standard balls	Tungsten carbide balls	A-scale 60 kgf load Brale penetrator	B-scale 100 kgf load Ball diameter: 1/16 inch	
68	940	-	-	85.6	-	97
67	900	-	-	85.0	-	95
66	865	-	-	84.5	-	92
65	832	-	739	83.9	-	91
64	800	-	722	83.4	-	88
63	772	-	705	82.8	-	87
62	746	-	688	82.3	-	85
61	720	-	670	81.8	-	83
60	697	-	654	81.2	-	81
59	674	-	634	80.7	-	80
58	653	-	615	80.1	-	78
57	633	-	595	79.6	-	76
56	613	-	577	79.0	-	75
55	595	-	560	78.5	-	74
54	577	-	543	78.0	-	72
53	560	-	525	77.4	-	71
52	544	500	512	76.8	-	69
51	528	487	496	76.3	-	68
50	513	475	481	75.9	-	67
49	498	464	469	75.2	-	66
48	484	451	455	74.7	-	64
47	471	442	443	74.1	-	63
46	458	432	432	73.6	-	62
45	446	421	421	73.1	-	60
44	434	409	409	72.5	-	58
43	423	400	400	72.0	-	57
42	412	390	390	71.5	-	56
41	402	381	381	70.9	-	55
40	392	371	371	70.4	-	54
39	382	362	362	69.9	-	52
38	372	353	353	69.4	-	51
37	363	344	344	68.9	-	50
36	354	336	336	68.4	(109.0)	49
35	345	327	327	67.9	(108.5)	48
34	336	319	319	67.4	(108.0)	47
33	327	311	311	66.8	(107.5)	46
32	318	301	301	66.3	(107.0)	44
31	310	294	294	65.8	(106.0)	43
30	302	286	286	65.3	(105.5)	42
29	294	279	279	64.7	(104.5)	41
28	286	271	271	64.3	(104.0)	41
27	279	264	264	63.8	(103.0)	40
26	272	258	258	63.3	(102.5)	38
25	266	253	253	62.8	(101.5)	38
24	260	247	247	62.4	(101.0)	37
23	254	243	243	62.0	100.0	36
22	248	237	237	61.5	99.0	35
21	243	231	231	61.0	98.5	35
20	238	226	226	60.5	97.8	34
(18)	230	219	219	-	96.7	33
(16)	222	212	212	-	95.5	32
(14)	213	203	203	-	93.9	31
(12)	204	194	194	-	92.3	29
(10)	196	187	187	-	90.7	28
(8)	188	179	179	-	89.5	27
(6)	180	171	171	-	87.1	26
(4)	173	165	165	-	85.5	25
(2)	166	158	158	-	83.5	24
(0)	160	152	152	-	81.7	24

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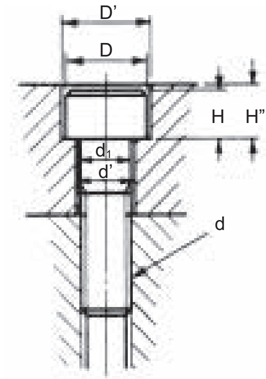
Table 6: Dimensions of the counterbore and internal thread for the hexagon-headed bolt



Unit: mm

Nominal size (d)	M3	M4	M5	M6	M8	M10	M12	(M14)	M16	(M18)	M20	(M22)	M24	(M27)	M30
Thread pitch (P)	0.5	0.7	0.8	1	1.25	1.5	1.75	2	2	2.5	2.5	2.5	3	3	3.5
d_1	3	4	5	6	8	10	12	14	16	18	20	22	24	27	30
d'	3.4	4.5	5.5	6.6	9	11	14	16	18	20	22	24	26	30	33
D	5.5	7	8.5	10	13	16	18	21	24	27	30	33	36	40	45
D'	6.5	8	9.5	11	14	17.5	20	23	26	29	32	35	39	43	48
H	3	4	5	6	8	10	12	14	16	18	20	22	24	27	30
H"	3.3	4.4	5.4	6.5	8.6	10.8	13	15.2	17.5	19.5	21.5	23.5	25.5	29	32

(Remark) The bolt hole diameters (d') listed above are in accordance with bolt hole grade 2 in JIS B 1001 (Diameter of clearance holes and counterbores for bolts and screws).

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