BEARINGS FOR USE IN EXTREME SPECIAL ENVIRONMENTS

CERAMIC BEARINGS AND EXSEV BEARINGS

KOYO SEIKO CO., LTD.

CAT. NO. 208E

EXTREME SPECIAL ENVIRONMENTS
CATALOGUE OF CERAMIC BEARINGS AND EXSEV BEARINGS

Koyo®

EXTREME SPECIAL ENVIRONMENTS
CERAMIC BEARINGS AND EXSEV BEARINGS

CAT. NO. 208E

● VALUE & TECHNOLOGY

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On the New Version of "Extreme Special Environments, Catalogue of Ceramic Bearings and EXSEV Bearings"

Thank you for your interest in KOYO's products.

With recent progress in technology, roller bearings have been used in severer environments and in extreme conditions.
Specifically, highly advanced technology requires bearings that can be used in an ultra-high vacuum environment, a corrosive environment, clean environment, high-temperature environment, etc. Conventional bearings, made of high-carbon chrome bearing steel and lubricated with grease or oil, cannot meet these requirements.

After forecasting the progress of advanced technology at its early stage, KOYO developed and marketed various types of bearings for use in special environments, such as "Ceramic Bearings," "Bearings for Use in a Vacuum Environment," and "Non-lubrication Bearings for Use in a Clean Environment."
In November 1995, KOYO took the initiative in the trade to publish a catalogue entitled "KOYO EXSEV Bearings, A Series of Bearings for Use in Extreme Special Environments." In this catalogue, KOYO defined the term "Extreme Special Environments" as "high temperature, vacuum, clean, and other severe environments that surround the bearings" and "higher speed, lighter weight, insulation, non-magnetic, and other functions required of the bearings." Nearly four years have passed since this catalogue was published. The technology associated with bearings has progressed at a surprisingly rate.

KOYO has reviewed the old catalogue from various points of view, and has published a new version entitled "Ceramic Bearings and EXSEV Bearings." This version contains much of the new technology in the field of bearings and examples of their applications.
The additional products and technologies contained in the new catalogue include corrosion resistant ceramic bearings, "Clean Pro" bearings, life formula for the EXSEV bearings, Super thin section ball bearings K-series for use in extreme special environments, and linear motion bearings and bearing units also for use in extreme special environments. Many examples of their applications are also included.
This new catalogue is designed to assist you in selecting the bearings and bearing units to be used in extreme special environments.

More and more delicate and sophisticated requirements will be given to those bearings and bearing units to be used in extreme special environments.
KOYO undertakes to continue research and development activities to meet these requirements.
We, KOYO, hope that you select KOYO products in the future.

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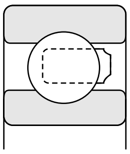
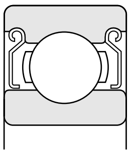
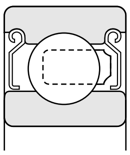
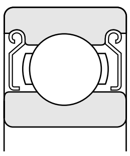
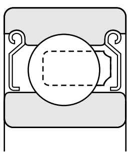
EXTREME SPECIAL ENVIRONMENTS CATALOGUE OF CERAMIC BEARINGS AND EXSEV BEARINGS

1. Selection and Composition of Ceramic Bearings and EXSEV Bearings

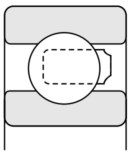
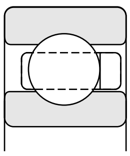
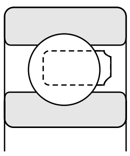
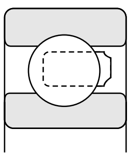
Table 1(1) Selection and Composition of Ceramic Bearings and EXSEV Bearings

Use and Environment	Vacuum					Temperature Range, ˚C							Clean Class			Outer ring, inner ring
	Atmospheric pressure	Low	Medium	High	Ultra high	− 200	− 100	0	+ 100	+ 200	+ 300	+ 400	1000	100	10	
(1) For high speed rotation 																SUJ2
																Outer ring : SUJ2 Inner ring : Silicon nitride (Si_3N_4)
(2) For a clean environment							–100			200				○		SUS440C + Special polymeric fluoride coating
	Repetition to 10^{-5} Pa						–100			200			○			SUS440C
															○	
										200	300		○			SUS440C
										200		400		○		SUS440C
							–100			200					○	SUS630
(3) For a vacuum environment 	Repetition to 10^{-5} Pa						–40			200						SUS440C
							–100				300					SUS440C
			10^{-3} to 10^{-10} Pa			–200					300					SUS440C

Remark: Bearings for (4) corrosion resistance, (5) high-temperature resistance, (6) non-magnetism, and (7) insulation is described in Table 1(2) on the following pages.

Material and Lubrication			Bearing No.	Remark
	Rolling element	Retainer		
	Silicon nitride (Si_3N_4)	Reinforced polyamide resin (FG)	**3NC...FG**	
			6NC...FG	
	SUS440C + Special polymeric fluoride	SUS304 + Special polymeric fluoride	**SE...STPR YS**	Atmosphere, vacuum
	SUS440C	Fluorocarbon resin (FA · PT)	**SE...ST FA (PT)**	
	High-hardness carbon materials		**SL...ST4 FA (PT)**	Atmosphere, vacuum, light load
	SUS440C	SUS304 + High-temperature resistant PTFE coating	**SE...STMPD7 YS**	Atmosphere, vacuum
	High-hardness carbon materials	SUS304	**SL...ST4 YS**	Atmosphere, vacuum, light load
	Silicon nitride	Fluorocarbon resin (FA · PT)	**3NC...MD4 FA (PT)**	Atmosphere, vacuum, corrosion resistance
	High-hardness carbon materials		**SL...MD4 FA (PT)**	Atmosphere, vacuum, light load, corrosion resistance
	SUS440C	SUS304 with vacuum grease	**SV...ST YS**	Atmosphere, vacuum
	SUS440C	SUS304 + MoS_2 coating	**SE...STMSA7 YS**	
		PEEK resin (PG)	**SE...ST PG**	
	SUS440C + Lead coating	SUS304	**SE...STMB3 YS**	High to extremely high vacuum, High-speed Rotation ($dn8 \times 10^4$) Lower torque than silver coating
	SUS440C + Silver coating		**SE...STMG3 YS**	High to extremely high vacuum, High-speed Rotation ($dn8 \times 10^4$)

Table 1(2) Selection and Composition of Ceramic Bearings and EXSEV Bearings

Use and Environment	Vacuum (Atmospheric pressure / Low / Medium / High / Ultra high)	Temperature Range, ˚C (−200 / −100 / 0 / +100 / +200 / +300 / +400)	Clean Class (1000 / 100 / 10)	Outer ring, inner ring
(4) For corrosion resistance 	Repetition to 10^{-5} Pa	−100 to 200		Silicon nitride (Si_3N_4)
				Corrosion resistant silicon nitride
				Silicon carbide (SiC)
(5) For high temperature resistance 		500		SKH4
		500 to 800		Silicon nitride
(6) Non-magnetism 	Repetition to 10^{-5} Pa	−100 to 200		Non-magnetic steel
				Silicon nitride
(7) Insulation 	Repetition to 10^{-5} Pa	−100 to 200		SUS440C
				Silicon nitride

Remark: Bearings for (1) high-speed rotation, (2) clean environment, and (3) vacuum environment are described in Table 1(1) on the preceding pages.

• Typical examples of ceramic bearings and EXSEV bearings

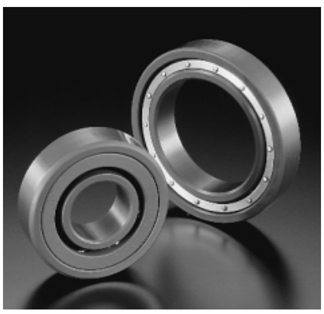
(1) For high-speed rotation

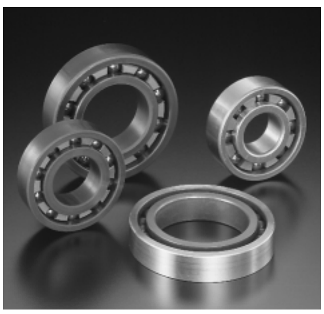
(2) For a clean environment

(3) For a vacuum environment

(4) For corrosion resistance

Material and Lubrication			Bearing No.	Remark
	Rolling element	Retainer		
	Silicon nitride (Si_3N_4)	Fluorocarbon resin (FA・PT)	NC...FA (PT)	Clean, non-magnetism, insulation
	Corrosion resistant silicon nitride		NCT...FA (PT)	
	Silicon carbide (SiC)		NCZ...FA (PT)	Lower strength than silicon nitride
	Silicon nitride	Graphite (GF)	3NC...HT4 GF	Not use in vacuum
	Silicon nitride (full complement ball type)	–	NC...V	
	Silicon nitride	Fluorocarbon resin (FA・PT)	3NC...YH4 FA (PT)	
			NC...FA (PT)	
	Silicon nitride	Fluorocarbon resin (FA・PT)	3NC...ST4 FA (PT)	
			NC...FA (PT)	


(5) For high temperature resistance


(6) Non-magnetism


(7) Insulation

2. Ceramic Bearings

2.1 Characteristics of Ceramic Bearings

The characteristics of the ceramics (silicon nitride Si_3N_4) used in ceramic bearings are compared to those of high carbon chrome bearing steel (SUJ2) used for universal types of bearings. The result is given in Table 2.1, together with the advantages of ceramic bearings. Because of the preferable characteristics of ceramic material (silicon nitride), ceramic bearings are considered useful in a variety of applications.

For example, the higher heat resistance of ceramic bearings allows them to be used in high-temperature environments. Further, their lower density greatly reduces the mass of the bearings and contributes to the reduction in centrifugal force generated by the rolling elements (balls or rollers) when the bearings run at high speeds. In addition, covalent bonding of ceramic material gives higher resistance to seizure caused by discontinued oil film during high-speed rotation.

Table 2.1 Comparison of Characteristics between Ceramic Material (Silicon Nitride) and High Carbon Chrome Bearing Steel (SUJ2) and Advantages of Ceramic Bearings

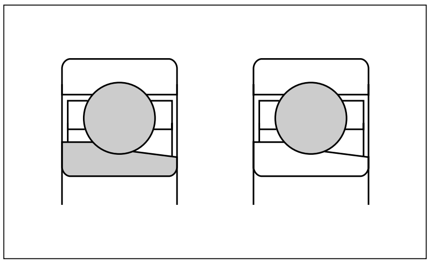
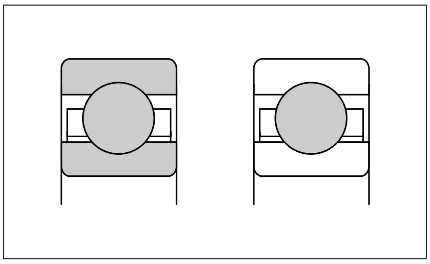
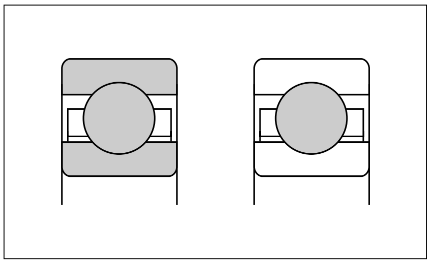
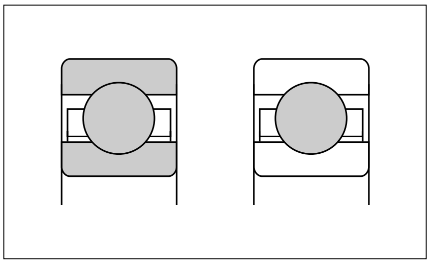
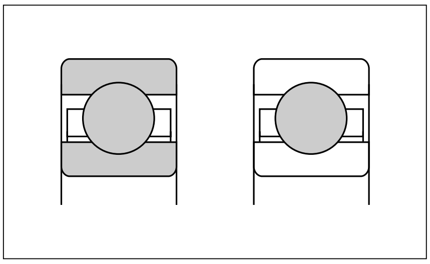
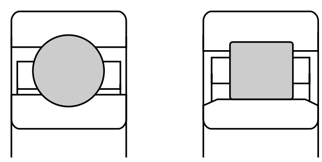
Item (Unit)	Ceramic Material (Si_3N_4)	Bearing Steel (SUJ2)	Advantage of Ceramic Bearings
Heat resistance ˚C	800	180	Higher load durability maintained in high-temperature ranges
Density g/cm^3	3.2	7.8	Reduction of centrifugal force induced by rolling elements (balls or rollers) →Increased service life and restricted increase in temperature
Linear expansion coefficient 1/˚C	3.2×10^{-6}	12.5×10^{-6}	Smaller change of internal clearance caused by temperature rise →Reduced vibration, small change of preload
Vickers hardness HV	1 500	750	Smaller change of deformation at rolling contact point →High rigidity
Module of longitudinal elasticity GPa	320	208	
Poisson's ratio	0.29	0.3	
Corrosion resistance	Good	Not good	Can be used in acid solutions, alkali solutions, and other special environments
Magnetism	Non-magnetic material	Ferromagnetic material	Smaller speed fluctuation caused by magnetism in intense magnetic field
Conductivity	Insulating material	Conductive material	Eliminates electric pitting (applicable to electric motors, etc.)
Bonding of raw material	Covalent bonding	Metallic bonding	Minimized seizure (or cohesion) at contact points, usually resulting from discontinued oil film

2.2 Composition of Ceramic Bearings

The composition of ceramic bearings, as well as some examples of their applications, are presented in Table 2.2.
Ceramic bearings can be divided into full-ceramic type and hybrid ceramic type. For the full ceramic type bearings, all the outer rings, inner rings, and rolling elements are made of ceramics. For the hybrid type bearings, only the rolling elements are made of ceramics, and the outer and inner rings are made of high carbon chrome bearing steel or other special steel.

Some applications require that the hybrid type bearings run at high speeds. In such applications, problems may occur because of inner ring expansion due to the centrifugal force produced by high speed running and hence the interference between the inner ring and shaft will loosen. In such cases, rolling elements and inner rings made of ceramics are used.
The retainers are made of metallic material or plastic material, depending upon the intended use of the bearings.

Table 2.2 Composition of Ceramic Bearings and Some Examples of Their Use ▭ : Ceramics

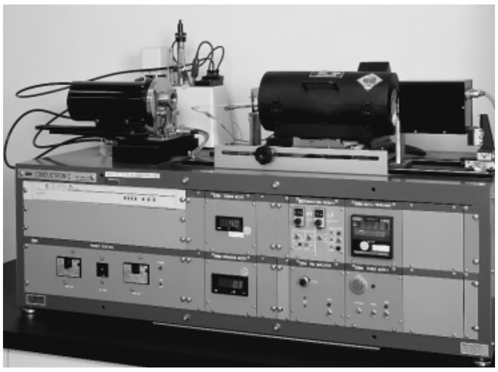
(1) High-speed Rotation	(2) For Use in a Vacuum Environment	(3) For Corrosion Resistance
Specific gravity 40% of bearing steel Suitable for high-speed rotation because lower centrifugal force is produced by the rolling elements.	Can be used in a vacuum of 1 to 10^{-10} Pa Lubricating method should be selected according to use.	Can be used in acid, alkali, salt water, and molten metal.
		
■Example of use Main spindle of machine tools, turbo chargers for automobiles, and industrial equipment (spin testers, etc.)	**■Example of use** Semi-conductor production facilities and vacuum equipment (turbo molecular pump, etc.)	**■Example of use** Chemical equipment, steel production facility, and textile machinery
(4) For High-temperatures	**(5) Non-magnetism**	**(6) Insulation**
Ceramic is heat resistant up to 800˚C. Lubricating method should be selected according to the temperature.	Can be used in magnetic fields.	Ceramics are insulating materials, and can be used in applications where electric leakage may occur.
		
■Example of use Steel production facilities, industrial equipment, and automotive diesel engines	**■Example of use** Semi-conductor production facilities, superconductivity-related equipment, and nuclear power generators	**■Example of use** Railway rolling stock and electric motors

Remarks: There are two types of ceramic bearings, full ceramic type and hybrid ceramic type.
Full ceramic type: All outer rings, inner rings, and rolling elements are made of ceramics.
Hybrid ceramic type: Only the rolling elements, or both rolling elements and inner rings are made of ceramics.

2.3 Characteristics Comparison of Various Ceramic Materials

To determine the ceramic material most suitable for roller bearings, the withstand load, rolling life, and fracture condition at the end of the rolling life of each material should be examined and checked.

The characteristics comparison between various types of ceramic materials is presented in Table 2.3, and the result of withstand load test on the materials is given in Fig. 2.1.
The result of evaluation concerning the most suitable material for rolling bearings is shown in Table 2.4.



• Test equipment for linear expansion coefficient and coefficient of thermal conductivity

(1) Characteristics comparison of various ceramic materials

Mechanical properties of various types of ceramic materials are compared in Table 2.3(1), and their corrosion resistance and heat characteristics are compared in Table 2.3(2).

Table 2.3(1) Characteristics Comparison of Various Ceramic Materials (Mechanical Properties)

Item / Unit (Ceramic Material)	Silicon Nitride Si_3N_4	Zirconia ZrO_2	Silicon Carbide SiC	Alumina Al_2O_3
Density g/cm^3	3.2	6.0	3.1	3.8
Linear expansion coefficient 1/°C	3.2×10^{-6}	10.5×10^{-6}	3.9×10^{-6}	7.1×10^{-6}
Vickers hardness HV	1 500	1 200	2 200	1 600
Modulus of longitudinal elasticity GPa	320	220	380	350
Poisson's ratio	0.29	0.31	0.16	0.25
Three-point bending strength MPa	1 100	1 400	500	300
Fracture toughness MPa · m$^{1/2}$	6	5	4	3.5

Table 2.3(2) Characteristics Comparison of Various Ceramic Materials (Corrosion Resistance and Heat Characteristics)

◎: Not corroded ○: Slightly corroded
△: May be slightly corroded ×: May be corroded

		Silicon Nitride Si_3N_4 (of standard specification)	Silicon Nitride Si_3N_4 (of corrosion-resistance specification)	Zirconia ZrO_2	Silicon Carbide SiC
Corrosion resistance 1)	Hydrochloric acid	△	○	○	◎
	Nitric acid	△	○	○	◎
	Sulfuric acid	△	○	○	◎
	Phosphoric acid	○	○	○	◎
	Hydrofluoric acid	△	△	×	◎
	Sodium hydroxide	△	△	○	△
	Potassium hydroxide	△	△	△	△
	Sodium carbonate	△	△	△	△
	Sodium nitrate	△	△	△	△
	Water and salt water	◎	◎	◎	◎
Heat resistance (in atmosphere) ˚C		800	800 or over	200	1 000 or over
Thermal shock resistance ˚C		750 or over	750 or over	350	350
Coefficient of thermal conductivity J/cm · sec˚C		0.251	0.251	0.038	0.712
Specific heat J/g · ˚C		0.670	0.670	0.502	0.670
Advantage		Corrosion resistance Higher strength Higher toughness Longer rolling life	Higher corrosion resistance Higher strength Higher toughness Longer rolling life	Higher corrosion resistance Higher strength Higher toughness	Higher corrosion resistance Heat resistance Higher strength

Note 1) Corrosion behavior of chemicals depends on their temperature, concentration, and other factors.
Extremely high corrosion may occur when some chemicals are mixed.
Accordingly, this table only a reference.

(2.3 Characteristics Comparison of Various Ceramic Materials)

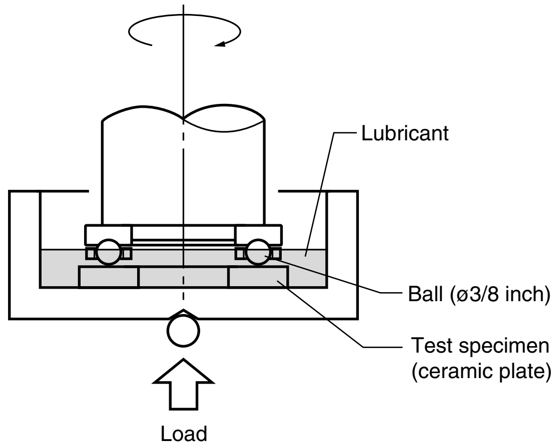
(2) Withstand load test results for various types of ceramic materials

To evaluate the withstand loads of various types of ceramic materials, rolling life tests were conducted under oil lubrication and water lubrication. Test results are shown in Fig. 2.1.

① Test condition

	Oil Lubrication	Water Lubrication
Lubricant	Spindle oil	City water
Material to be mated	3/8 inch high carbon chrome bearing steel (SUJ2) balls	3/8 inch silicon nitride (Si_3N_4) balls
Load	Increase of load in stages at every 1.08×10^7 cycles	
Rotation speed	1 200 rpm	

② Rolling life test equipment



• Thrust type life test equipment

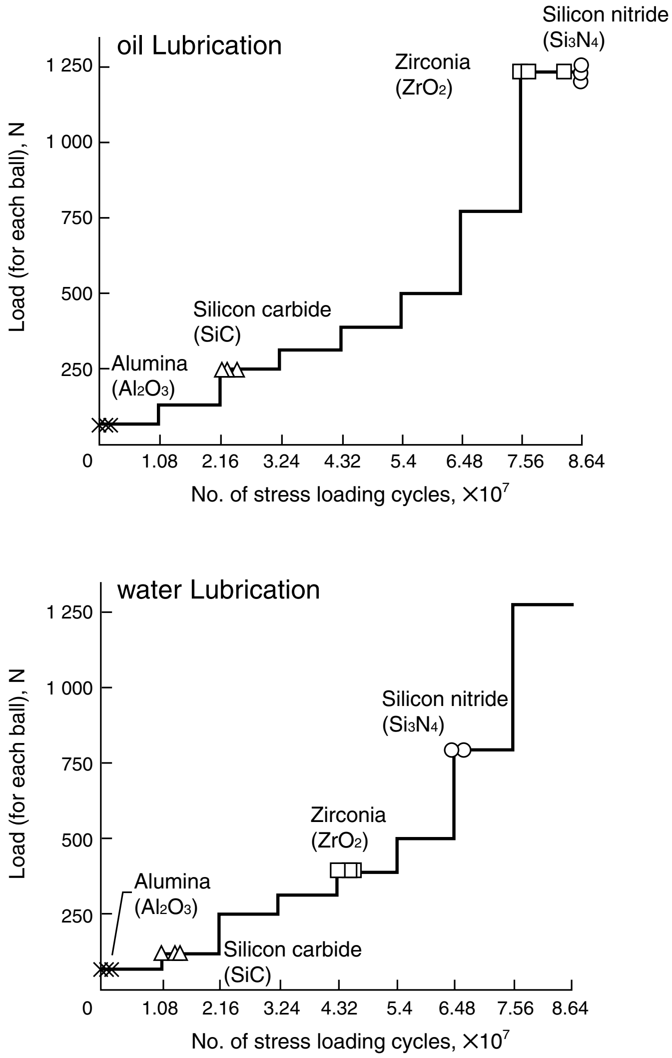


Fig. 2.1 Rolling Life Test Results of Various Ceramic Materials

(3) Ceramic material suitable for rolling bearings

Based on the characteristics comparison between various types of ceramic materials and the test results for their withstand loads, these materials were evaluated from the viewpoint of their suitability for bearings. The results are as shown in Table 2.4.
Table 2.4 indicates that silicon nitride (Si_3N_4) is the most suitable ceramic material for rolling bearings.

Silicon nitride made through HIP (Hot Isostatic Pressing) process is usually used for making rolling bearings. Zirconia (ZrO_2), silicon carbide (SiC), and alumina (Al_2O_3) are also used depending upon intended application.

Table 2.4 Evaluation of Ceramic Materials for Rolling Bearings

◎: Suitable ○: Suitable for some applications ×: Unsuitable

	Application to Rolling Bearings		
	Evaluation	Performance and use	Characteristics
Silicon nitride **Si_3N_4**	◎	• High withstand load and long life equal to or better than bearing steel • Applicable to use requiring high performance	• High-speed rotation • High vacuum • Corrosion resistance • Heat resistance • Non-magnetism • High rigidity
Zirconia **ZrO_2**	○	• Limited applicable load • Can be used in highly corrosive chemicals.	• High corrosion resistance
Silicon carbide **SiC**	○	• Limited applicable load • Can be used in highly corrosive chemicals.	• High corrosion resistance • Ultra-high temperatures
Alumina **Al_2O_3**	×	• Unsuitable for roller bearings	–

2.4 Load Rating and Life of Ceramic Bearings

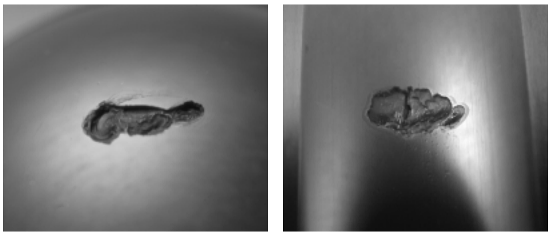
Ceramics (silicon nitride) has a modulus of elasticity higher than that of high carbon chrome bearing steel. In the ceramic bearing, therefore, higher stress is generated at the contact point between the rolling element and raceway, when compared to a steel bearing.

KOYO evaluated the life test result for ceramic bearings, the load limits allowable for ceramic materials under static loads, and the elastic deformation of high carbon chrome bearing steel. Based on the evaluation, KOYO determined the dynamic load ratings and static load ratings of the KOYO ceramic bearings as shown in Table 2.5.

2.4.1 Rolling Fatigue Life of Ceramic Bearings

An example of the life test results for full ceramic bearings and steel bearings is given in Fig. 2.2.
It was confirmed that ceramic bearings have a longer service life than that expected by calculation, which is equal to or longer than that of steel bearings.
Flaking was detected when a ceramic bearing was examined after its service life expired. The same phenomenon can be observed when a steel bearing suffers fatigue by rolling.

From the above, it can be understood that the dynamic load rating of a steel bearing can be applied to a ceramic bearing of the same size.



• Flaking on ceramic ball (left) and ceramic inner ring (right)

Table 2.5 Dynamic and Static Load Ratings for Ceramic Bearings

	Dynamic Load Rating	Static Load Rating	
		Static load rating	Definition of static load rating
Full ceramic bearing	Same as that of steel bearing (SUJ2)	Same as that of steel bearing (SUJ2)	Crack-generating load
Hybrid ceramic bearing Outer ring and inner ring: SUJ2 Rolling element: Ceramics	Same as that of steel bearing (SUJ2)	0.85 times that of steel bearing (SUJ2)	Permanent deformation

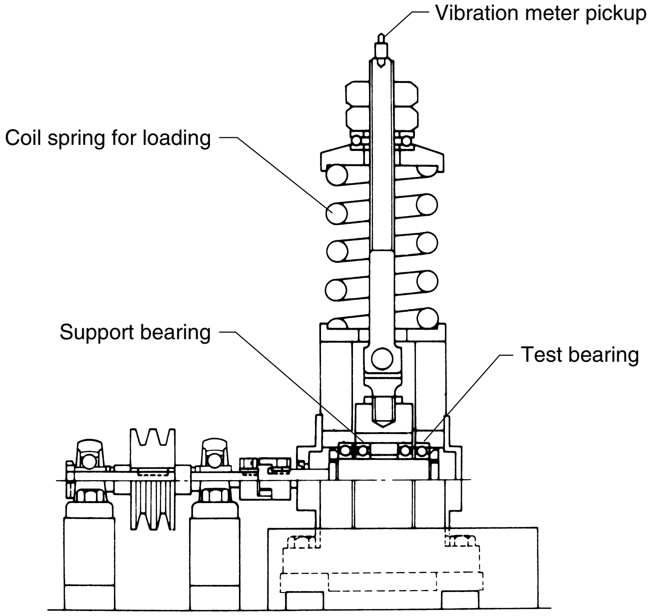
① Test bearing

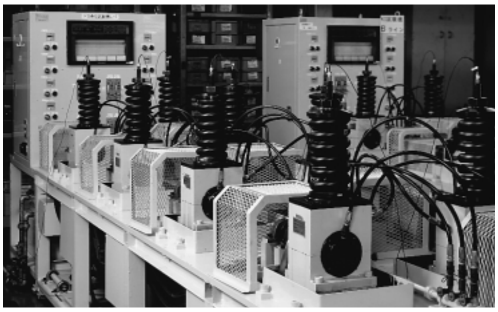
Bearing Number	Material (outer ring, inner ring, ball)	Dimensions in mm
NC6206	Si_3N_4 (ceramics)	30×62×16 (Inner diameter×Outer diameter×Width)
6206	SUJ2 (bearing steel)	

② Test conditions

Item	Condition
Load	5 800 N
Rotation speed	8 000 rpm
Lubricant oil	Aeroshell turbine oil 500
Temperature	70 ± 2˚C

③ Test equipment





• Radial type life test equipment

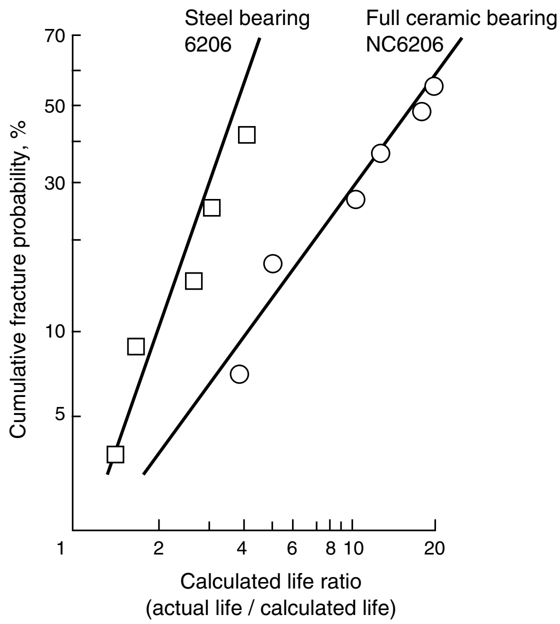


Fig. 2.2 Rolling Life Test Result for Full Ceramic Bearing and Steel Bearing

(2.4 Load Rating and Life of Ceramic Bearings)

2.4.2 Static Load Rating of Ceramic Bearings

For steel bearings, the load that can be applied statically is called basic static load rating and is specified in ISO 76-1987.
According to ISO, basic static load rating is defined as "the static load corresponding to the following calculated contact stress at the center of contact between the rolling element and raceway loaded with the maximum load;

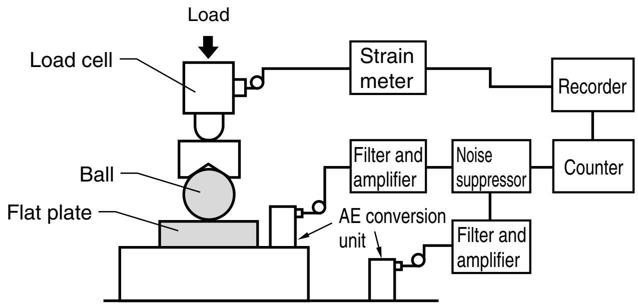
Self-aligning ball bearings	: 4 600 MPa
Other ball bearings	: 4 200 MPa
Roller bearings	: 4 000 MPa"

For ceramic bearings, the basic static load rating specified in ISO cannot be applied directly, since ceramics (silicon nitride) is brittle and thus permanent deformation is unlikely.

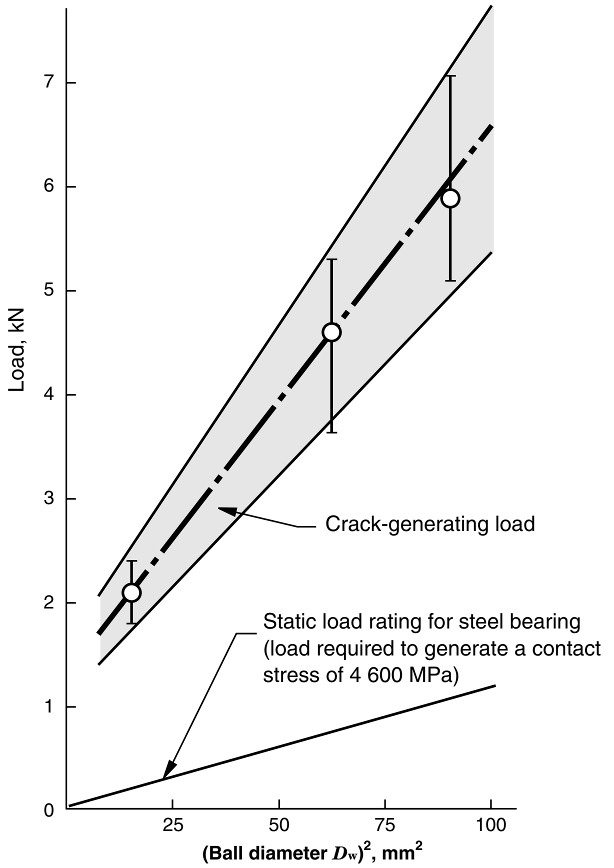
(1) Static load ratings of full ceramic bearings

When a ceramic bearing is overloaded, it will generate cracks and will eventually break.
For a full ceramic bearing consisting of a ceramic outer ring, ceramic inner ring, and ceramic balls, cracking on the ceramic surface was taken into account when determining its static load rating.

The crack-generating load measurements are compared to the static load ratings of steel bearings (as calculated on the assumption that the maximum contact stress is 4 600 MPa). The result is shown in Fig. 2.3.
This figure shows that the crack-generating loads of full ceramic bearings are significantly larger than the static load ratings of steel bearings, and hence the static load ratings for steel bearings can be also applied to full ceramic bearings.



• Crack-generating load measurement system



Comparison between Crack-generating Load for Ceramic Bearing and Static Load Rating for Steel Bearing

Fig. 2.3 Result of Crack-generating Load Measurement for Full Ceramic Bearing

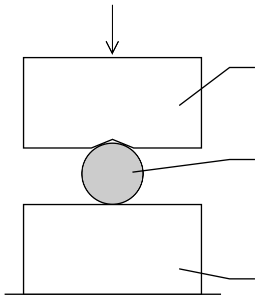
(2) Static load rating for hybrid bearing

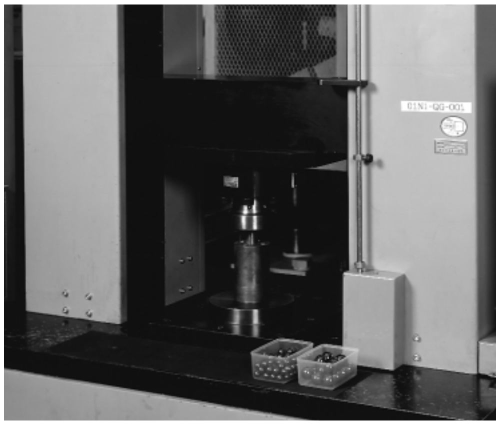
The concept of static load rating for steel bearings can be applied to hybrid ceramic bearings (consisting of outer and inner rings made of high carbon chrome bearing steel and rolling elements made of ceramics), because the outer and inner rings are made of steel and hence they deform permanently.

A high carbon chrome bearing steel ball and ceramic ball were pressed against a flat plate of high-carbon chrome bearing steel, and the resulting permanent deformations (brinelling depths) were measured. The result is shown in Table 2.6.

From the above result, it was determined that no permanent deformation is produced on the ceramic ball. The result also shows that the permanent deformation produced on the flat steel plate by the ceramic ball was approximately 1.2 times the sum of the deformations produced on both the steel ball and plate.
Accordingly, the static load ratings for hybrid ceramic bearings are limited by the deformation of the steel bearing rings.
Based on the above, KOYO determined the static load ratings for hybrid ceramic bearings to be 0.85 times the corresponding static load ratings for steel bearings.

Measurement method





• Amsler universal testing machine

Table 2.6 Measurement Result for Permanent Deformation (brinelling depth) Produced on a Flat Plate by Ceramic Ball

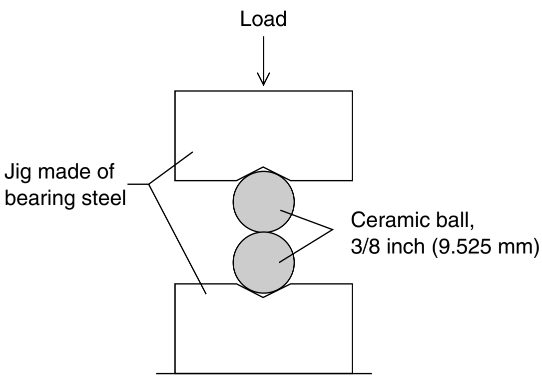
Load kN		Permanent Deformation (average), mm		Permanent Deformation (arithmetic mean), mm
		Flat plate (bearing steel)	Ball	
Ceramic ball	**0.65**	0.5	–	0.5
	1.3	1.9	–	1.9
	2.6	5.2	–	5.2
	3.9	9.3	–	9.3
Steel ball	**0.65**	0.4	–	0.4
	1.3	1.3	0.11	1.41
	2.6	4.0	0.41	4.41
	3.9	6.8	1.18	7.98

2.5 Strength of Ceramic Bearings

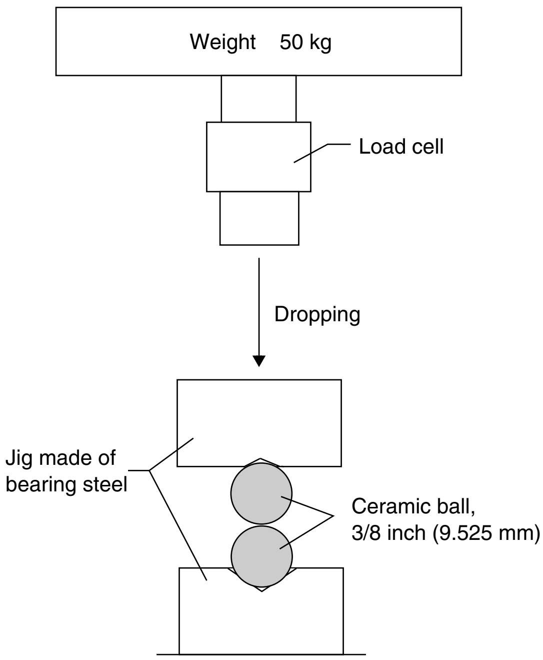
Crushing tests by static load and impact load were conducted on ceramic balls to determine the impact strength of ceramic bearings. In the former test, a load was applied statically to the ceramic ball. For the latter, two ceramic balls were fastened on a jig and a weight was dropped on them. The test results are shown in Fig. 2.4.

From the above result, it was confirmed that the ceramic bearings have sufficient impact strength and that this strength is nearly equal to their strength to static load.

① Static crushing test method



② Impact crushing test method



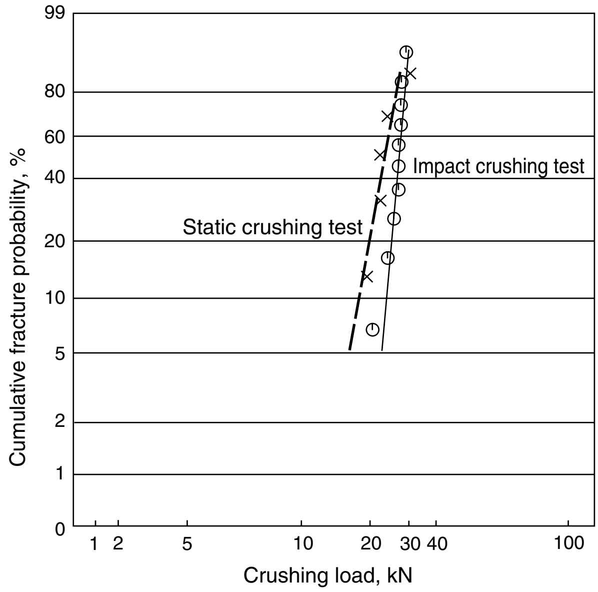


Fig. 2.4 Comparison of Static Load and Impact Load Required to Crush a Ceramic Ball

2.6 High Speed Performance of Ceramic Bearings

Hybrid ceramic bearings (3NC type), consisting of ceramic (silicon nitride) rolling elements with lower density than bearing steel elements, are best suited for high speed applications.
The reason for this is that the smaller mass of the rolling elements generates less centrifugal force and minimizes the sliding motion caused by the gyroscopic moment during bearing runs.

(1) Power loss at High speed rotation

Comparison of power loss between hybrid ceramic bearings and steel bearings is given in Fig. 2.5.

Hybrid ceramic bearings significantly reduce power loss when rotating at high speeds. The higher the speed, the larger the reduction in power loss.
Hybrid ceramic bearings also have superior anti-seizure property. Therefore, less lubricating oil is required. As a result, the rotational resistance (power loss) of the bearings can be further reduced.

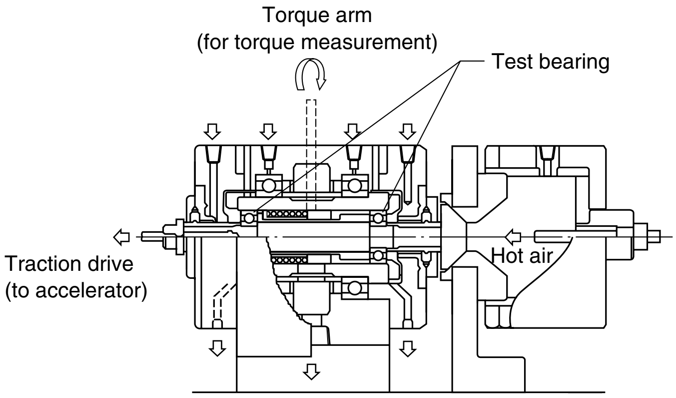
① Test bearing

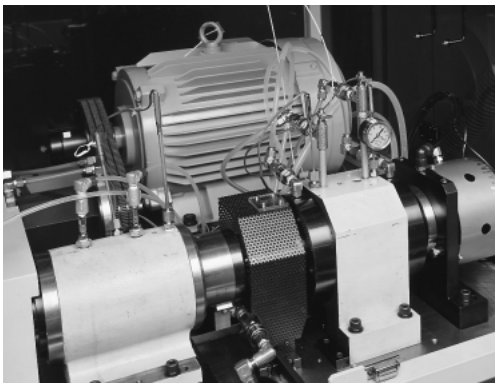
	Hybrid ceramic bearing	Steel Bearing
Outer ring, inner ring	Tool steel (AISI-M50)	
Ball – Material	Ceramics (Si_3N_4)	Tool steel (AISI-M50)
Ball – Diameter	1/4 inch (6.35 mm)	
Ball – Quantity	9	
Retainer	Polyimide resin	

② Test condition

Item	Condition
Axial load	200 N
Rotation speed (max.)	100 000 rpm
Lubricating oil	Turbine oil 500
Ambient temperature	Room temperature

③ Test equipment





• High-speed performance test equipment for bearing

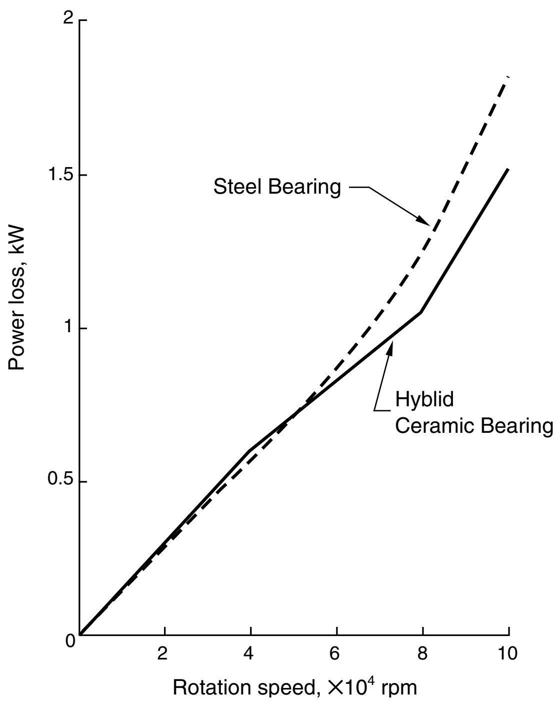


Fig. 2.5 Comparison of Power Loss between Hybrid Ceramic Bearing and Steel Bearing

(2.6 High-speed Performance of Ceramic Bearings)

(2) Maximum speed rotation to prevent seizure

Maximum speed of anti-seizure rotations was measured in both hybrid bearings and steel bearings by gradually reducing the amount of lubricating oil. The measured values for each type of bearing are compared in Fig. 2.6.

Compared to steel bearings as regards seizure, hybrid ceramic bearings require a smaller amount of lubricating oil when they run at the same speed, or when higher speed rotating with the same amount of lubricating oil.
Since steel bearings have high density rolling elements, the centrifugal force induced by each element increases as the rotation speed increases. This generates heat inside the bearings. If less lubricating oil is supplied, the rolling elements will seize in the early stage of operation.

(3) Relation between the amount of lubricating oil and power loss during high speed rotating

Power loss of hybrid ceramic bearings is compared to that of steel bearings in relation to the amount of lubricating oil, as shown in Table 2.7.
Since hybrid ceramic bearings require significantly less lubricating oil compared to steel bearings, power loss can be reduced by approximately 30% at 80 000 rpm and by approximately 55% at 100 000 rpm.

Because of their superior high-speed performance hybrid ceramic bearings have been used widely for the spindles of machine tools, etc.

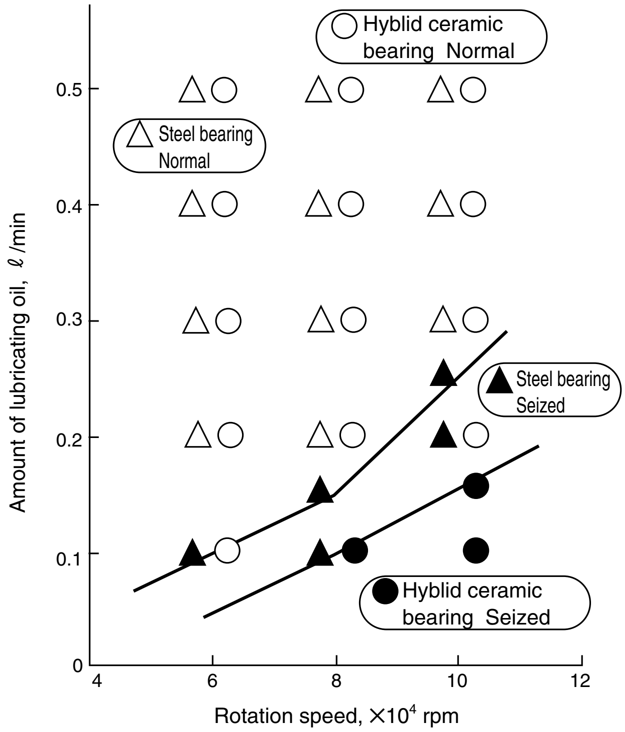


Fig. 2.6 Maximum Speed of Anti-seizure Rotations for Hybrid Ceramic Bearing and Steel Bearing

Table 2.7 Comparison of Power Loss for Ceramic Bearing and Steel Bearing (in Relation to the Amount of Lubricating Oil)

	Smallest Amount of Oil for Preventing Seizure ℓ/min		Power Loss Ratio (taking the loss in steel bearing as 1)			
			Same amount of lubricating oil (amount of oil: 1.0 ℓ/min)		When the amount of oil is considered (amount of oil: twice the smallest allowable amount of oil to prevent seizure)	
	Rotation speed, rpm		Rotation speed, rpm		Rotation speed, rpm	
	8×10^4	10×10^4	8×10^4	10×10^4	8×10^4	10×10^4
Hybrid ceramic bearing	0.1	0.15	0.9	0.7	0.7	0.45
Steel bearing	0.15	0.25	1	1	1	1

2.7 Corrosion Resistance of Ceramic Bearings

For use in acid, alkali, and other corrosive chemicals, highly corrosion-resistant bearings are required.
Generally speaking, ceramics (silicon nitride) has high corrosion resistance. However, corrosion may occur when used under severe corrosive conditions created by a particular chemical at a specific temperature. This corrosion is caused by the corrosion of sintering auxiliary (Al_2O_3-Y_2O_3), which is used during the sintering process.
To meet requirements for highly corrosion resistant bearings, KOYO developed special corrosion resistant ceramics for which a spinel-contained sintering auxiliary is employed.
The mechanical properties of standard silicon nitride ceramics and corrosion resistant type silicon nitride ceramics are given in Table 2.8.

There are some chemicals that corrode the base material of ceramics. Silicon carbide (SiC) or zirconia (ZrO_2) is used as the material for ceramic bearings to be used in such severe environments. These two materials have a higher corrosion resistance than that of silicon nitride.
When compared to bearings made of silicon nitride, however, bearings made of the ceramic materials described above have lower withstand load. Hence, sufficient study and consideration are required prior to use.
For the characteristics of various types of ceramic materials, refer to "2.3 Characteristics Comparison for Various Types of Ceramic Materials."

When using ceramic bearings in chemicals, the chemical itself acts as the lubricant. Such chemicals have relatively poor lubricity. To use ceramic bearings efficiently, the loads to these bearings should be limited to 10% or less than their load ratings. Their service life is expected to be approximately 3% of the calculated value.
Test specimens of standard silicon nitride and corrosion resistant type silicon nitride bearings were immersed in acid solution and alkali solution. After a predetermined period, their weight reduction rate and bending strength reduction rate were measured. The results are presented in Fig. 2.7. The rolling lives of each test specimen before and after immersion were also compared (Fig. 2.8). The rolling life in water of standard silicon nitride was also tested. The test results are given in Fig. 2.9.

Though ceramic materials exhibit high corrosion resistance, they may become corroded at an unexpectedly early stage of use, depending upon the type of chemical, operating temperature, and conditions of use.
If you intend to use rolling bearings in chemicals, please contact KOYO.

Table 2.8 Physical and Mechanical Properties of Standard Silicon Nitride and Corrosion Resistant Silicon Nitride

Item 1) \ Material	Silicon Nitride (standard)	Silicon Nitride (corrosion resistant)
Sintering Auxiliary	Al_2O_3 - Y_2O_3	Spinel ($MgAl_2O_4$)
Density g/cm³	3.2	3.2
Color	Black	Black
Vickers hardness HV	1 500	1 500
Bending strength MPa	1 100	1 050
Fracture toughness MPa · m$^{1/2}$	6	6

Note: 1) Density, vickers hardness, bending strength, and fracture toughness were measured in compliance with JIS.

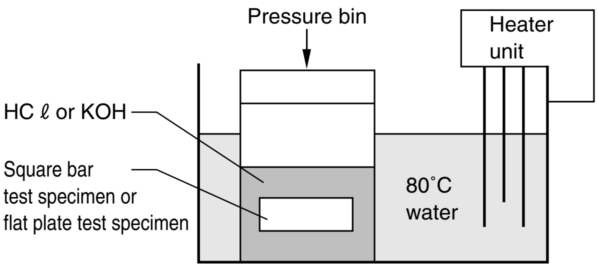
(2.7 Corrosion Resistance of Ceramic Bearings)

(1) Weight reduction rate and bending strength reduction rate of ceramic material after corrosion resistance test

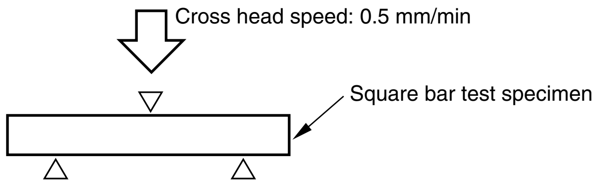
① Immersing condition

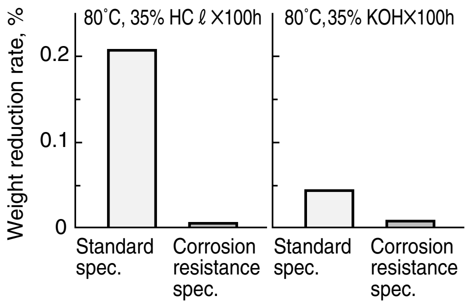
Item	Condition
Solution for immersion	a : 35 % HC ℓ b : 35 % KOH
Solution temperature	80˚C
Immersing time	100 h

② Sketch of immersing device

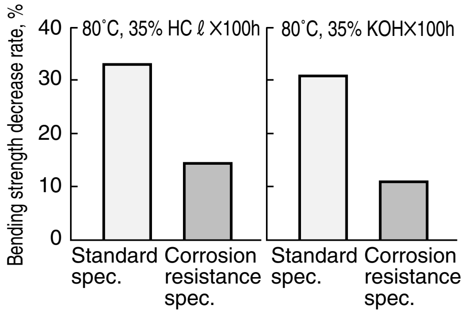


③ Bending strength test method





• Weight reduction rate after immersion



• Bending strength reduction rate after immersion

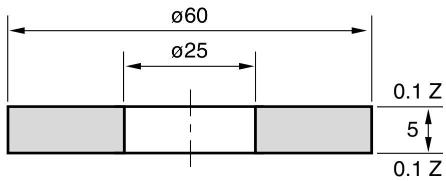
Fig. 2.7 Weight Reduction Rate and Bending Strength Reduction Rate of Ceramic Material after Immersion in Acid and Alkali Solutions for a Predetermined Period

(2) Rolling life of ceramic material after corrosion resistance test

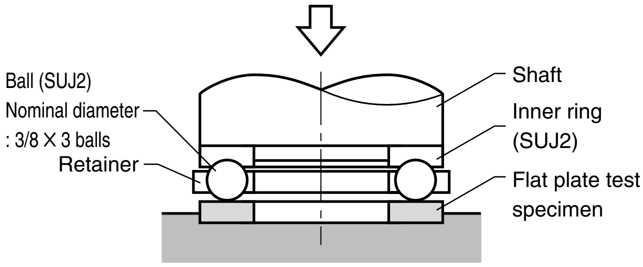
① Test condition

Item	Condition
Material to be mated	Ball (SUJ2) Nominal diameter: 3/8 X 3 balls
Retainer	Brass
Lubricating oil	Spindle oil No.60
Load **(** P max.**)**	0.98, 2.45, 3.92 kN (3.7, 5.0, 5.9 GPa)
Rotation speed	1 200 rpm
Test time	max. 400 h

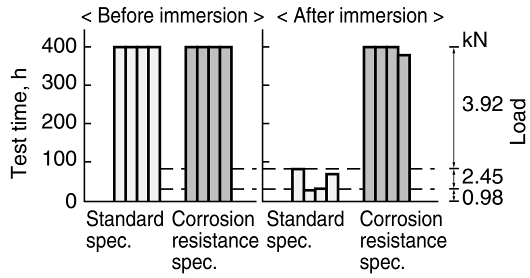
② Dimensions of flat plate test specimen



③ Sketch of test equipment



• In hydrochloric acid (HC ℓ)



• In potassium hydroxide (KOH)

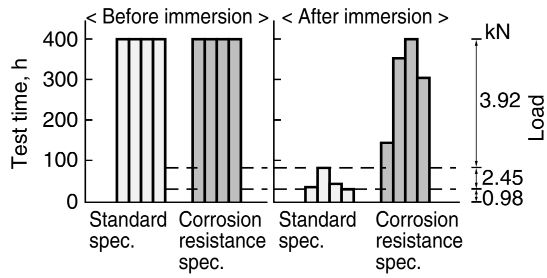
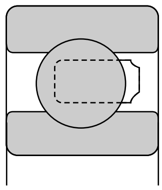


Fig. 2.8 Rolling Life Test Result for Ceramic Material after Immersion in Acid Solution and Alkali Solution for a Predetermined Period

(3) Rolling life in water of full-ceramic bearing

• Test condition

Item	Condition
Bearing	Basic number: 6206 (silicon nitride of standard specification) Boundary dimensions: 30 × 62 × 16 mm
Load	Radial load 1 470 N {150 kgf}
Rotation speed	1 500 rpm
Lubricant	Water



Item	L_{10}, h	L_{50}, h	Weibull coefficient
Result	390	500	7.6

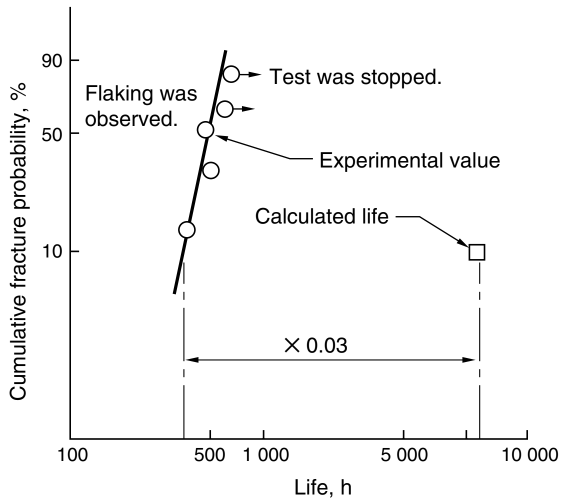


Fig. 2.9 Result of Rolling Life Test in Water of Silicon Nitride (of Standard Specification)

2.8 Weight Reduction Characteristics and Heat Resistance of Ceramic Bearings

2.8.1 Weight Reduction Characteristics of Ceramic Bearings

With a density of approximately 40% of steel, ceramics (silicon nitride) is the most suitable for reducing weight. Applications of ceramic bearings will increase in the future not only in the aerospace and aircraft industry, but also in automobiles and other transportation vehicle industries.

2.8.2 Heat Resistance of Ceramic Bearings

Hardness of ceramics and steel materials in the high-temperature range is shown in Fig. 2.10.
In some applications under high temperatures the life of the bearings is not problematic even if shortened by deterioration of the hardness of the material. For applications with an ambient temperature of up to approximately 300˚C, martensite stainless steel (SUS440C) is used for the bearings, because it has relatively high heat resistance. For applications at temperatures in excess of 300˚C, tool steel (M50 or SKH4) is usually used for the bearings.

However, these high speed steels cannot be used when the ambient temperature exceeds nearly 500˚C. For applications at temperatures in excess of nearly 500˚C, ceramics are used. Ceramics does not change their hardness and strength until the temperature reaches nearly 800˚C.

In high temperature environments, where liquid type lubricants as oil and grease cannot be used, molybdenum disulfide, tungsten disulfide, graphite, or other solid lubricant should be used.
When a solid lubricant is used, the bearings have a tendency to break due to wear.

When temperatures exceed 500˚C, only a few types of solid lubricants can be used reliably. Full complement ball or roller bearings (with no retainer) are used in such cases.

Experience is required to select the bearings best suited for a specific use. Please contact KOYO before using bearings under high temperature conditions.

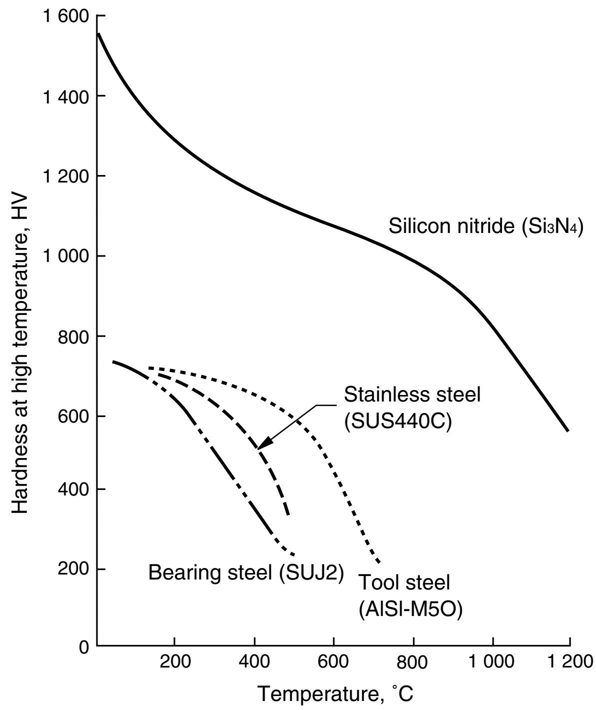


Fig. 2.10 Hardness of Ceramics and Steel Materials at High Temperatures

2.9 Non-magnetic Characteristics of Ceramic Bearings

In some applications bearings are exposed to magnetic fields. Examples of such applications include equipment associated with super-conductivity, semi-conductor production facilities, and various types of inspection machines. If steel bearings are used in such applications, they may disturb the magnetic field or may be loaded with fluctuating torque. Non-magnetic type bearings are required for such applications.

Full ceramic bearings or hybrid ceramic bearings are useful in applications requiring non-magnetic characteristics. Each of the hybrid ceramic bearings consists of a raceway ring made of non-magnetic stainless steel or non-magnetic cemented carbide. Rolling elements are also made of a ceramic material (silicon nitride).

A steel bearing, hybrid ceramic bearing, and full ceramic bearing were used in a magnetic field to measure torque fluctuation. The results are shown in Fig. 2.11.

The steel bearing is loaded with largely fluctuating torque, while the hybrid ceramic bearing and full ceramic bearing are not affected by the magnetic field.

As described above, ceramic bearings are useful as non-magnetic bearings.

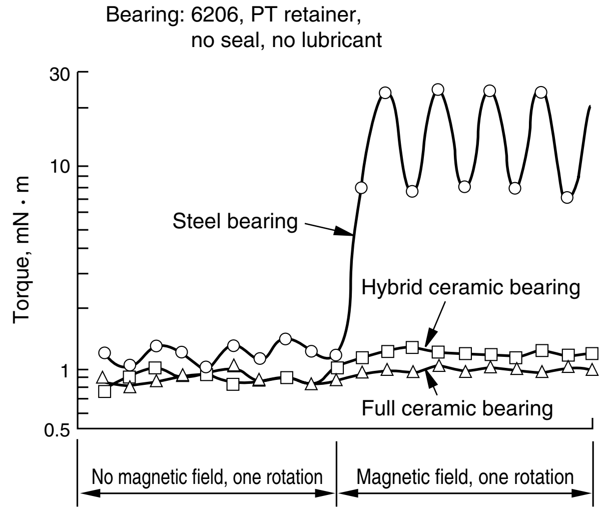


Fig. 2.11 Measurement of Torque in Magnetic Field for Ceramic Bearing and Steel Bearing

(For reference) Magnetic permeability

SUS304	: 1.01 or less
Non-magnetic stainless steel	: 1.01 or less
Non-magnetic cemented carbide	: 1.001 or less
Ceramics	: Approx. 1.000

2.10 Insulation Characteristics of Ceramic Bearings

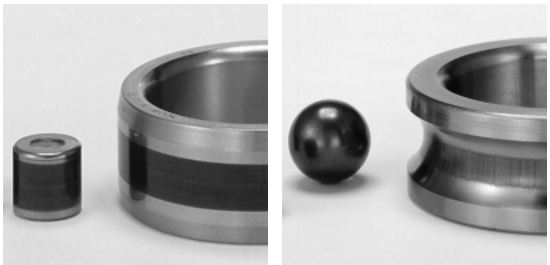
Electric pitting occurs in bearings when they are used in traction motors and other electrical devices for railway rolling stock.

Electric pitting is a phenomenon where the surface of the rolling contact becomes molten by the spark produced through the very thin lubricating oil film when an electric current passes through the bearing while in motion.
Pits or ridges are first observed on the rolling contact surface.
There are two ways to eliminate electric pitting. One is to provide an electric bypass to prevent the electric current from passing through the bearing, and the other is to use an insulation bearing.

Since ceramics has superior insulating properties, an insulation bearing is produced by building in ceramic rolling elements or by flame-coating the ceramic (alumina or other ceramic material) outer ring. (See Table 2.9.)
In addition to the elimination of electric pitting, bearings consisting of ceramic rolling elements minimize temperature increases during operation and extend the life of the grease. Therefore, these bearings are ideal for long term operation at high speeds, and are also maintenance free.

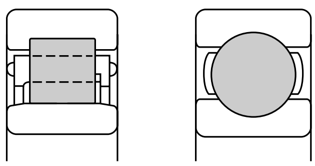
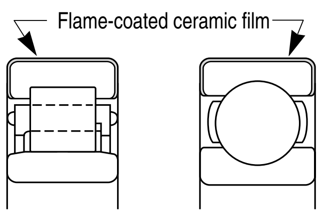
• Hybrid ceramic bearing

• Flame-coated ceramic bearing



• Electric pitting generated on steel bearing
(pits on the left figure, ridges on the right figure)

Table 2.9 Construction and Advantages of Insulation Bearing

Type	Hybrid Ceramic Bearing	Flame-coated Ceramic Bearing
Construction	Ceramic rolling element 	
Insulation method	Rolling element made of ceramics (Si_3N_4)	Peripheral of outer ring with flame-coated ceramic film (Al_2O_3) Film thickness: 0.5 mm
Advantages	Elimination of electric pitting, suppressed temperature increase, and elongated life of grease make the bearings best suited for long term, high-speed rotation.	Desired accuracy can be maintained (no dimensional change occurs even after fitting) because the ceramic surface of the outer ring is flame-coated for insulation purposes.

3. EXSEV Bearings (A series of bearings for use in extreme special environments)

Lubrication is essential for rolling bearings.
Oil and/or grease are especially important to enable bearings to maintain their performance and reliability for extensive periods. We recommend that ceramic bearings should also be lubricated with oil or grease.

However, oil and grease cannot be used in extremely special environments as in a vacuum, in high temperatures, and where cleanliness is essential. In such environments, solid lubricants should be used.
In some applications, high-speed, lightweight, insulated, non-magnetic, and other bearing requirements are essential. Bearings made of high carbon chrome bearing steel or other types of bearing steel are usually unsuitable for such applications, and various types of the EXSEV bearings are used instead.

Developed through many years of experience, KOYO offers "KOYO EXSEV Bearings, a series of bearings for use in extreme special environments."
KOYO EXSEV Bearings are made of bearing materials and use solid lubricants best suited for each specific environment. Accordingly, customers can select the most suitable type of bearings and be confident that required performances will be achieved.

The typical bearing materials used for KOYO EXSEV Bearings are shown in Table 3.1. The classification of the solid lubricants and their advantages are given in Table 3.2.
Typical combinations of the materials for "KOYO EXSEV Bearings, a series of bearings for use in extreme special environments" are shown in Table 3.3.

• KOYO EXSEV Bearings, a series of bearings for use in extreme special environments

Table 3.1 Typical Bearing Materials used for KOYO EXSEV Bearings

◎: Superior ○: Good △: Acceptable

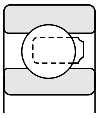
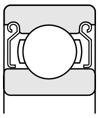
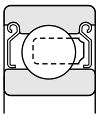
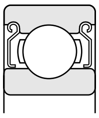
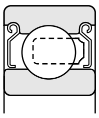
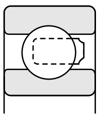
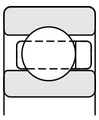
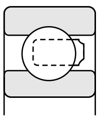
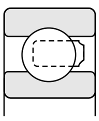
		Hardness	Young's modulus GPa	Coefficient of Linear Expansion 10^{-6}/ ˚C	Withstand Load	Abrasion resistance	Gas emission	Remarks
Steel	High carbon chrome bearing steel (SUJ2)	61 HRC	208	12.5	◎	○	◎	Standard material for general purpose bearings
	Martensite stainless steel (SUS440C)	60 HRC	208	10.5	◎	○	◎	Standard material for EXSEV bearings
	Precipitation hardened stainless steel (SUS630)	40 HRC	196	11.0	○	○	◎	
	High speed tool steel (M50)	61 HRC	207	10.6	◎	○	◎	
	High speed tool steel (SKH4)	64 HRC	207	12.0	◎	○	◎	
Ceramics	Silicon nitride (Si_3N_4)	1 500 HV	320	3.2	◎	◎	◎	Standard material for ceramic bearings
	Zirconia (ZrO_2)	1 200 HV	220	10.5	○	◎	◎	
	Silicon carbide (SiC)	2 200 HV	380	3.9	○	◎	◎	
	Alumina (Al_2O_3)	1 600 HV	350	7.1	△	◎	◎	

Table 3.2 Classification and Advantages of Solid Lubricants for Use in KOYO EXSEV Bearings

◎: Superior ○: Good △: Acceptable

Solid Lubricant	Crystaline Structure	Heat stability, ˚C		Coefficient of Friction		Withstand Load MPa	Dust Genera-tion	Gas Emission	Remarks
		Atmosphere	Vacuum	Atmosphere	Vacuum				
Silver (Ag)	Face-centered cubic	–	600 and over	–	0.2 to 0.3	Up to 2 500	△	◎	Don't use in atmosphere
Lead (Pb)		–	300 and over	0.05 to 0.5	0.1 to 0.15	Up to 2 500	△	◎	
Molybdenum disulfide (MoS_2)	Hexagonal system	350	400	0.01 to 0.25	0.001 to 0.25	Up to 2 000	△	○	
Tungsten disulfide (WS_2)		425	400	0.05 to 0.28	0.01 to 0.2	Up to 2 500	△	○	
Graphite (C)		500	–	0.05 to 0.3	0.4 to 1.0	Up to 2 000	△	○	Don't use in vacuum
Polytetrafluoroethylene (PTFE)	Long chain form	260	200	0.04 to 0.2	0.04 to 0.2	Up to 1 000	◎	△	
Polyimide		300	200 and over	0.05 to 0.6	0.05 to 0.6	Up to 1 000	○	△	

Table 3.3 Typical Combination of Bearing Materials for KOYO EXSEV Bearings

Use and Environment	Material and Lubricant			Bearing Series
	Outer ring, inner ring	Rolling element	Retainer (or cage)	
(1) For high-speed rotation 	SUJ2	Silicon nitride (Si_3N_4)	Reinforced polyamide resin (FG)	3NC…FG
	Outer ring: SUJ2 Inner ring: Silicon nitride (Si_3N_4)			6NC…FG
(2) For a clean environment	SUS440C + Special polymeric fluoride coating	SUS440C + Special polymeric fluoride coating	SUS304 + Special polymeric fluoride coating	SE…STPR YS
	SUS440C	SUS440C	Fluorocarbon resin (FA · PT)	SE…ST FA (PT)
		High-hardeness carbon material		SL…ST4 FA (PT)
	SUS440C	SUS440C	SUS304 + High-temperature resistant PTFE coating	SE…STMPD7 YS
	SUS440C	High-hardeness carbon material	SUS304	SL…ST4 YS
	SUS630	Silicon nitride	Fluorocarbon resin (FA · PT)	3NC…MD4 FA (PT)
		High-hardeness carbon material		SL…MD4 FA (PT)
(3) For use in a vacuum environment	SUS440C	SUS440C	SUS304 with vacuum grease	SV…ST YS
	SUS440C	SUS440C	SUS304 + MoS_2 coating	SE…STMSA7 YS
			PEEK resin (PG)	SE…ST PG
	SUS440C	SUS440C + Lead coating	SUS304	SE…STMB3 YS
		SUS440C + Silver acoating		SE…STMG3 YS
(4) For corrosion resistance 	Silicon nitride (Si_3N_4)	Silicon nitride (Si_3N_4)	Fluorocarbon resin (FA · PT)	NC…FA (PT)
	Corrosion resistant silicon nitride	Corrosion resistant silicon nitride		NCT…FA (PT)
	Silicon carbide (SiC)	Silicon carbide (SiC)		NCZ…FA (PT)
(5) For high temperatures 	SKH4	Silicon nitride	Graphite (GF)	3NC…HT4 GF
	Silicon nitride	Silicon nitride (full complement ball type)	–	NC…V
(6) For non-magnetism 	Non-magnetic steel	Silicon nitride	Fluorocarbon resin (FA · PT)	3NC…YH4 FA (PT)
	Silicon nitride			NC…FA (PT)
(7) For insulation 	SUS440C	Silicon nitride	Fluorocarbon resin (FA · PT)	3NC…ST4 FA (PT)
	Silicon nitride			NC…FA (PT)

3.1 EXSEV Bearings for Use in a Clean Environment

For use in environments requiring cleanliness such as those for semi-conductors and liquid crystals, electronic parts, pharmaceuticals, and foodstuffs and for use in vacuum-related equipment, dust generated by the bearings should be eliminated as much as possible.

In applications where the use of oil and grease is prohibited, KOYO recommend low dust generating bearings. These bearings are lubricated with fluorocarbon resin, PTFE, a special polymeric fluoride, and other solid lubricants. (See Table 3.4.)
These bearings do not contaminate the environment. In addition, they are resistant to corrosion and heat. The bearings are reliable even under the fluctuations in atmospheric pressure including vacuum as high as 10^{-5} Pa.

3.1.1 Low Dust Generating Bearing

The composition of the test bearings subjected to the dust generation test is shown in Table 3.5, and the test results are shown in Fig. 3.1.
The dust generation life of the special type of clean bearings, Clean PRO, is shown in Fig. 3.2. Clean PRO bearings are coated with a special type of polymeric fluoride.

Regarding initial dust generation characteristics, bearings lubricated with the special polymeric fluoride, fluorocarbon resin, or PTFE are superior to those lubricated with silver (Ag), molybdenum disulfide (MoS_2), or other solid lubricants.
Especially, Clean PRO bearings (symbol: M), the whole surface of which are coated evenly with a special polymeric fluoride, emit little dust and can thus maintain cleanliness for extensive periods. Therefore, this type of bearing is best suited for use in a clean environment.

Table 3.4 Composition and Advantage of KOYO Low Dust Generating Bearings

◎: Superior ○: Good

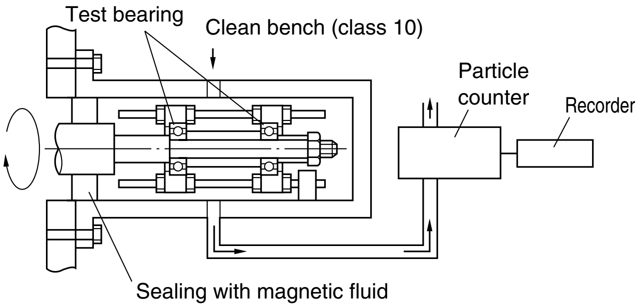
<table>
<tr><th rowspan="2">Application</th><th colspan="3">Composition</th><th rowspan="2">Pressure Pa</th><th rowspan="2">Temperature ˚C</th><th rowspan="2">Low Dust Generation</th><th rowspan="2">Corrosion Resistance</th></tr>
<tr><th>Outer ring, inner ring</th><th>Rolling element</th><th>Retainer</th></tr>
<tr><td rowspan="3">Low dust generating bearing for general use</td><td colspan="2" rowspan="2">SUS440C</td><td>Fluorocarbon resin</td><td rowspan="3">to 10^{-5}</td><td rowspan="3">to 200</td><td rowspan="3">◎</td><td rowspan="3">–</td></tr>
<tr><td>SUS304 + PTFE coating</td></tr>
<tr><td colspan="2">SUS440C +
Special polymeric fluoride coating</td><td>SUS304 +
Special polymeric fluoride coating</td></tr>
<tr><td rowspan="2">Low dust generating bearing for use in high-temp. conditions</td><td colspan="2">SUS440C</td><td rowspan="2">SUS304 +
High-temperature resistant PTFE coating</td><td rowspan="2">to 10^{-5}</td><td rowspan="2">to 300</td><td>○</td><td>–</td></tr>
<tr><td colspan="2">Silicon nitride</td><td>◎</td><td>◎</td></tr>
<tr><td rowspan="4">Low dust generating bearings for use in corrosive environments</td><td>SUS630</td><td>Silicon nitride</td><td>Fluorocarbon resin</td><td rowspan="4">to 10^{-5}</td><td rowspan="4">to 200</td><td rowspan="4">◎</td><td rowspan="3">◎</td></tr>
<tr><td colspan="2" rowspan="2">Silicon nitride</td><td>Fluorocarbon resin</td></tr>
<tr><td>SUS304 + PTFE coating</td></tr>
<tr><td colspan="2">SUS440C</td><td>SUS304 + PTFE coating</td><td>○</td></tr>
</table>

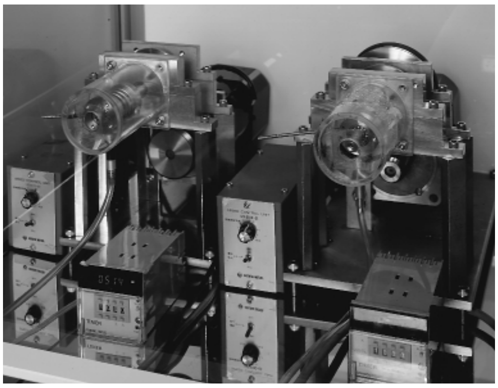
(1) Dust generation characteristics test for low dust generating bearings

① Dust generation characteristics under test conditions

Item	Condition
Bearing	Basic number ML6012
	Boundary dimensions: 6×12×3 mm
Load	Radial 2.9 N/ {0.3 kgf} two bearings
Rotation speed	200 rpm
Ambient atmosphere	In a class 10 clean bench controlled at room temperature
Test time	20 h
Particle size to be measured	0.3 μm and over

② Dust generation characteristics of test equipment





• Test equipment for dust generation into the atmosphere

Table 3.5 Composition of Bearings Subjected to Dust Generation Characteristics Test

Bearing Symbol	Material for Bearing Component and Surface-treated Area			Surface Treatment Method and Other Notes
	Outer ring, inner ring	Rolling element	Retainer	
A	SUS440C	SUS440C	SUS304	No lubricant
B		Silicon nitride		No lubricant
C		SUS440C		Fluorine-contained grease
D	SUS440C	SUS440C + Ag	SUS304	Ion plating
E		SUS440C	SUS304 + MoS_2	MoS_2-baking
F	SUS440C + PTFE	SUS440C	SUS304 + PTFE	PTFE-baking
G	SUS440C	SUS440C	SUS304 + PTFE	PTFE-baking
H			Fluorocarbon resin (FA)	–
I			SUS304 + High-temperature resistant PTFE	Baking with high-temperature resistant PTFE
J	Silicon nitride	Silicon nitride	SUS304 + High-temperature resistant PTFE	Baking with high-temperature resistant PTFE
K			SUS304 + PTFE	PTFE-baking
L			Fluorocarbon resin (FA)	–
M	SUS440C + Special polymeric fluoride	SUS440C + Special polymeric fluoride	SUS304 + Special polymeric fluoride	Baking with special polymeric fluoride

(3.1 EXSEV Bearings for Use in Clean Environment)

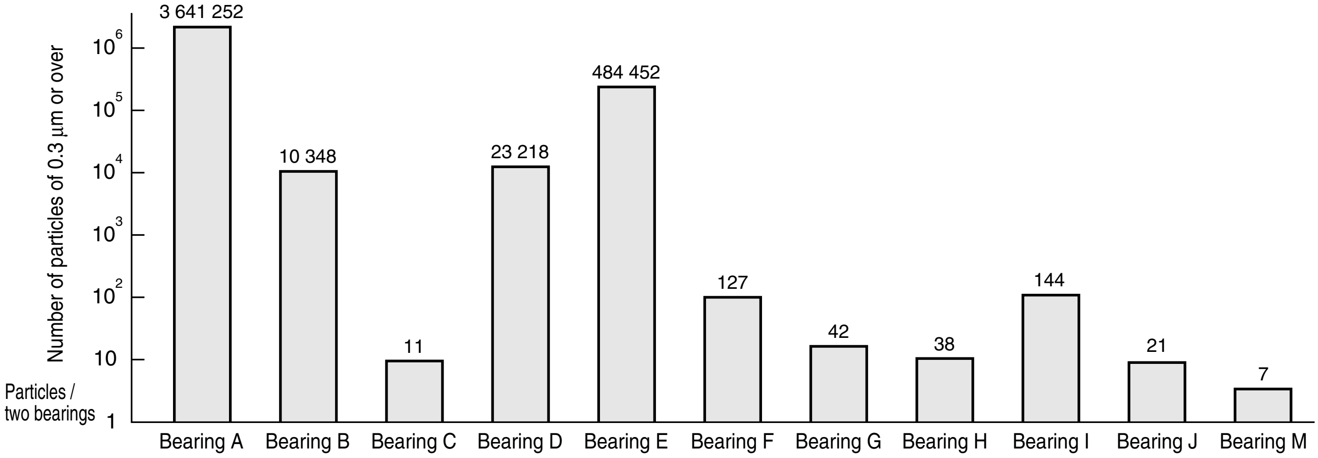
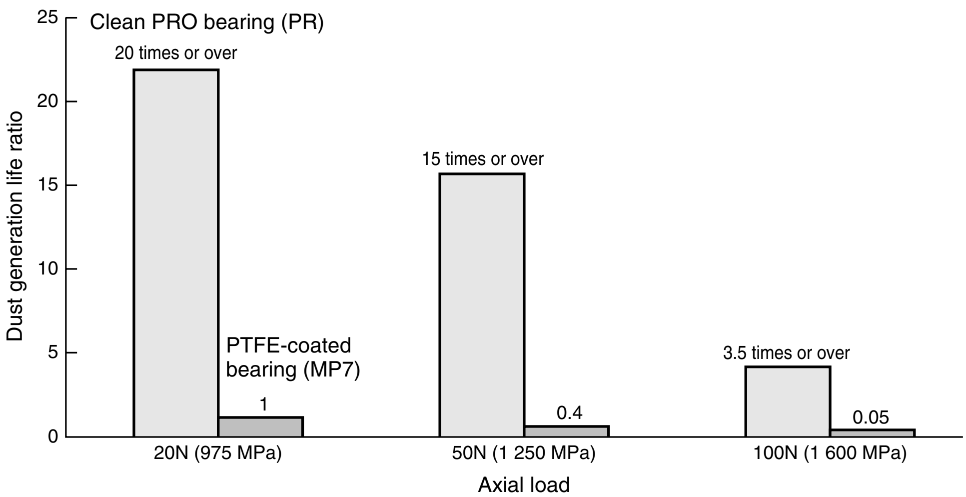


Fig. 3.1 Dust Generation Characteristics Test Result for Low Dust Generating Bearings (Total number of particles generated during 20 h testing)

(2) Dust generation life of Clean PRO bearings

- Dust generation life test condition

  Ambient conditions: Atmosphere at room temperature, rotation speed: 200 rpm, Basic number of bearing: 608 (8 × 22 × 7 mm)



(Changes in dust generation life under varied axial loads, assuming the life of PTFE-coated bearing at axial load of 20 N to be 1)

Fig. 3.2 Dust Generation Life of Clean PRO Bearings Coated with Special Polymeric Fluoride

3.1.2 Low Dust Generation Grease and Oil

To enable bearings coated with a solid lubricant to perform efficiently, the load (5 to 10% of load rating) and the rotation speed should be limited.
Accordingly, grease is used in some applications. Even in such cases, low dust generation grease should be used.

(1) Low dust generation grease

The principal specifications of the KOYO low dust generation greases are presented in Table 3.6, and the results of dust generation characteristics tests for various greases is shown in Fig. 3.3.
For use in bearings in a vacuum environment, KOYO low dust generation greases are recommended.

Table 3.6 Specifications of KOYO Low Dust Generation Greases

	Name	Base Oil	Thickener
For use in the atmosphere	KOYO low dust generation grease Type B	Mineral oil	Lithium base
For use in normal atmosphere to a vacuum	KOYO low dust generation grease Type A	Fluorine-contained oil	Fluorocarbon resin

• Specifications of various types of low dust generation greases used in the tests

	Grease A Available on the Market	KOYO A	Grease B Available on the Market	KOYO B
Base oil	Fluorine-contained oil	Fluorine-contained oil	Mineral oil	Mineral oil
Thickener	Fluorocarbon resin	Fluorocarbon resin	Lithium base	Lithium base

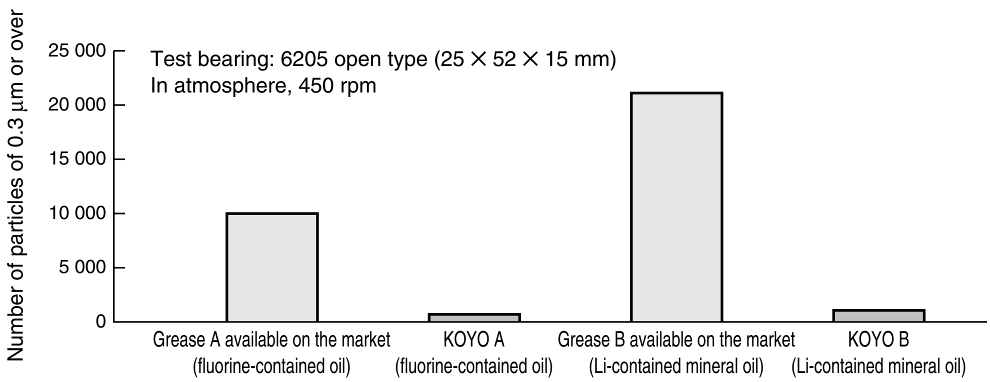


Fig. 3.3 Results of Dust Generation Characteristics Test for Various Low Dust Generation Greases

(3.1 EXSEV Bearings for Use in Clean Environment)

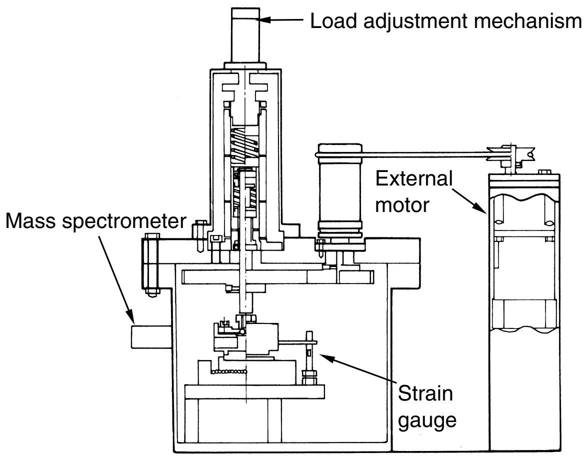
(2) Low dust generation oil

A test was conducted to measure the gases emitted from fluorine-contained lubricating oils in a vacuum environment. The results are given in Fig. 3.4.
Depending upon conditions, fluorine-contained oils evaporate under a high vacuum environment and emit gases, even under low vapor pressures. For further details, please contact KOYO.

① Physical characteristics of fluorine-contained oils used in dust generation tests

Oil	Molecular Structure	Viscosity at 20 °C, mm^2/s	Mean molecular weight	Vapor pressure at 20 °C, Pa
A	$CF_3-(OCF_2CF_2)p-(OCF_2)q-OCF_3$	255	9 500	4×10^{-10}
B	$F-(CF_2CF_2CF_2O)n-CF_2CF_3$	500	8 400	7×10^{-9}
C	$F-\left(\begin{matrix}CFCF_2O\\ \vert\\ CF_3\end{matrix}\right)_m-CF_2CF_3$	2 700	11 000	4×10^{-12}

② Gas emission measuring apparatus



Exhaust system: Turbo-molecular pump + Rotary pump (exhaust to 10^{-7} Pa)

• 4-Ball type ultra-high vacuum test equipment

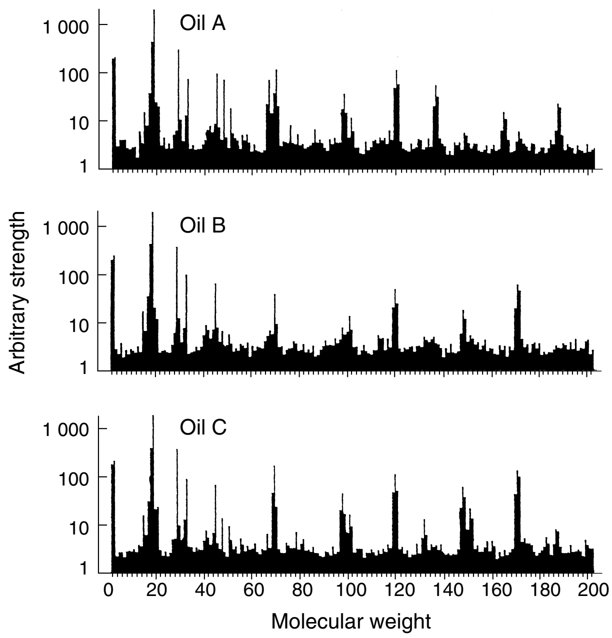


Fig. 3.4 Measurement Result for Gas Emission from Fluorine-contained Oil (PFPE) under 3.25 GPa Environment

3.2 EXSEV Bearings for Use in a Vacuum Environment

3.2.1 Construction of Ball Bearings for Use in a Vacuum Environment

Martensite stainless steel, SUS440C, is usually used for bearings to be used in a vacuum environment.
For some applications, however, ceramics (Si_3N_4, for high temperature resistance and corrosion resistance), precipitation hardened stainless steel (SUS630, for corrosion resistance), high speed tool steel (SKH4, for high temperature resistance) are also used.

No lubricants can be used in all environments ranging from atmospheric pressure to extremely high vacuum pressure.
① For use in vacuum of up to 10^{-4} Pa in the normal temperature range, vacuum-resistant grease and oil with low vapor pressure are used. Where oily substances are prohibited, solid lubricants should be used.

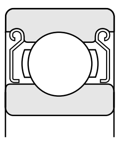
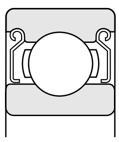
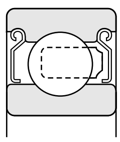
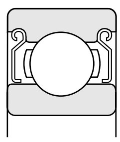
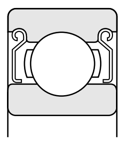
② Fluorocarbon resin (including coated PTFE) and special polymeric fluoride, both with self-lubrication characteristics, can be used in a vacuum environment of up to 10^{-5} Pa. The lowest allowable pressure limit increases as the ambient temperature rises, similarly in the case of grease and oil.

③ Depending upon intended use, KOYO uses silver (Ag), lead (Pb), molybdenum disulfide (MoS_2), fluorocarbon resin (PTFE), special polymeric fluoride, or other type of solid lubricant.
Ag and Pb are applied by ion plating process (patented to KOYO), and the treated bearings are used mainly in extremely high vacuum applications.
MoS_2 and PTFE are usually coated and baked on. Including the Clean PRO bearings, which are made by applying fluorocarbon resin or special polymeric fluoride over the entire surface of the bearing bodies. These bearings are used in environments where pressure fluctuates from atmospheric pressure to vacuum.

The composition and advantages of the ball bearings for use in a vacuum environment are presented in Table 3.7.

Table 3.7 Composition and Advantages of Ball Bearings for Use in a Vacuum Environment

◎: Superior ○: Good

Name (description)		Sealed with Vacuum Grease	Coated with MoS_2	PEEK Resin	Special Polymeric Fluoride	Ion-plating of Lead	Ion-plating of Silver
Construction of bearing							
Advantage	In extremely high vacuums	–				◎	
	In atmospheric conditions	◎				–	
	Cleanliness	–			◎	–	
Performance	Applicable temp. range	–40 to 200 ˚C	–100 to 300 ˚C		–100 to 200 ˚C	–200 to 300 ˚C	max. 550 ˚C
	High-speed rotation	◎	○	–		◎ (dn value[1] :Up to 8×10^4)	
	Load	◎	○	–		○	
	Conductivity	–	○(for semiconductors)	–		◎	
Use		<Vacuum pump> • T.M.P. • Cryopump • Other devices	<Semiconductor production facilities> • Bearings for transferring wafers (spattering device) • Bearings for transferring large trays (P-CVD) • Bearings for door opening/ closing mechanisms (in etching machines) • Bearings for supporting ball screws (in vertical type diffusing furnaces) • Bearings for supporting robot arms • Other equipment			<Semiconductor production facilities> • Bearings for supporting turning mechanisms in various types of transfer machines (Spattering devices, CVD, MBE devices) <Medical facility> • Bearings for X-ray tubes <Various types of measuring instruments and analyzers> Other equipment and devices	

Note: 1) dn is defined by "inside diameter of bearing (d) × rotation speed (n)."

(3.2 EXSEV Bearings for Use in a Vacuum Environment)

3.2.2 Gas Emission from Bearings

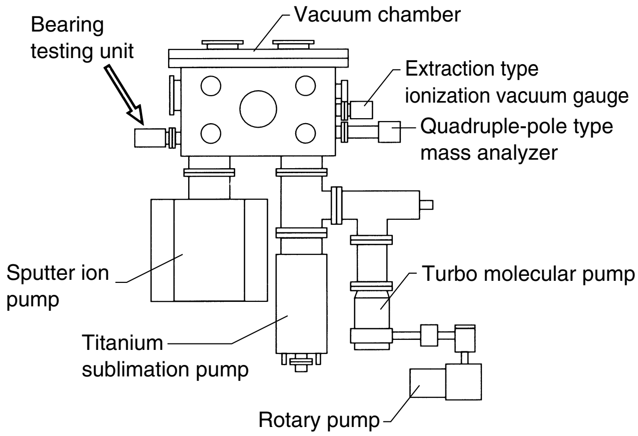
In some applications in a vacuum environment, gas emitted from the bearings produce problems.

Bearings were driven at high speeds in a vacuum atmosphere, and the gases emitted from the bearings were analyzed. The results are as shown in Fig. 3.5.
In bearings with no lubricant, both the pressure and gas composition remained almost unchanged even after one hour of testing. In bearings consisting of retainers coated with PTFE, the pressure and gas composition changed from that observed before the test.
As the result, it was found that bearings made of martensite stainless steel or ceramics do not cause problems even if used in an extremely high vacuum environment, but PTFE-coated bearings cannot be used in a vacuum range exceeding 10^{-6} Pa or so.

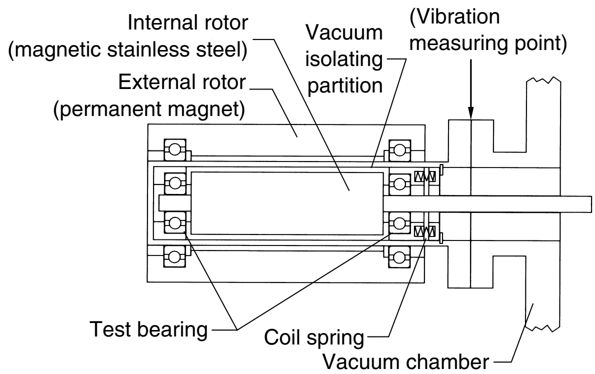
Two types of austenitic stainless steel retainers coated respectively with PTFE and high-temperature resistant PTFE were heated in order to analyze the type of gas generated. The test result is given in Fig. 3.6.
Another test was conducted on bearings coated with special polymeric fluoride, to determine ambient temperature changes. The result is shown in Fig. 3.7.

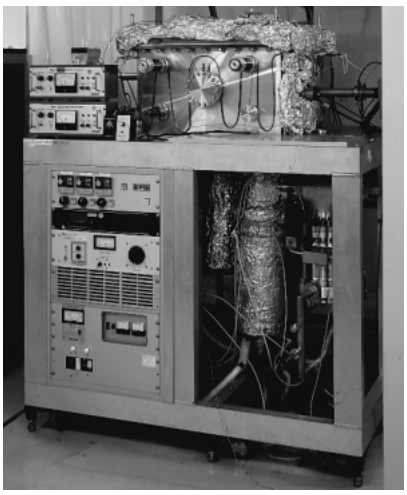
From the results of these tests, it was confirmed that bearings coated with PTFE or special polymeric fluoride can work normally in temperatures of up to 200˚C and those coated with high-temperature resistant PTFE can resist temperatures of up to 300˚C.

• Emitted gas measurement system for bearings



• Detail of bearing testing unit





• Extreme high vacuum evaluation chamber

(1) Gas emitted from bearings during their rotation in a vacuum

① Composition of test bearings

	Bearing 1	Bearing 2
Outer ring, inner ring	Martensite stainless steel	
Ball	Ceramics (silicon nitride)	Martensite stainless steel
Retainer	Austenitic stainless steel	Austenitic stainless steel + PTFE coating
Lubricant	None	PTFE

② Test conditions

Item	Test Conditions
Bearing	608 (boundary dimensions: 8×22×7 mm)
Load	Axial load 98 N
Rotation speed	140 rpm
Pressure	1.6×10^{-8} Pa
Temperature	Room temperature

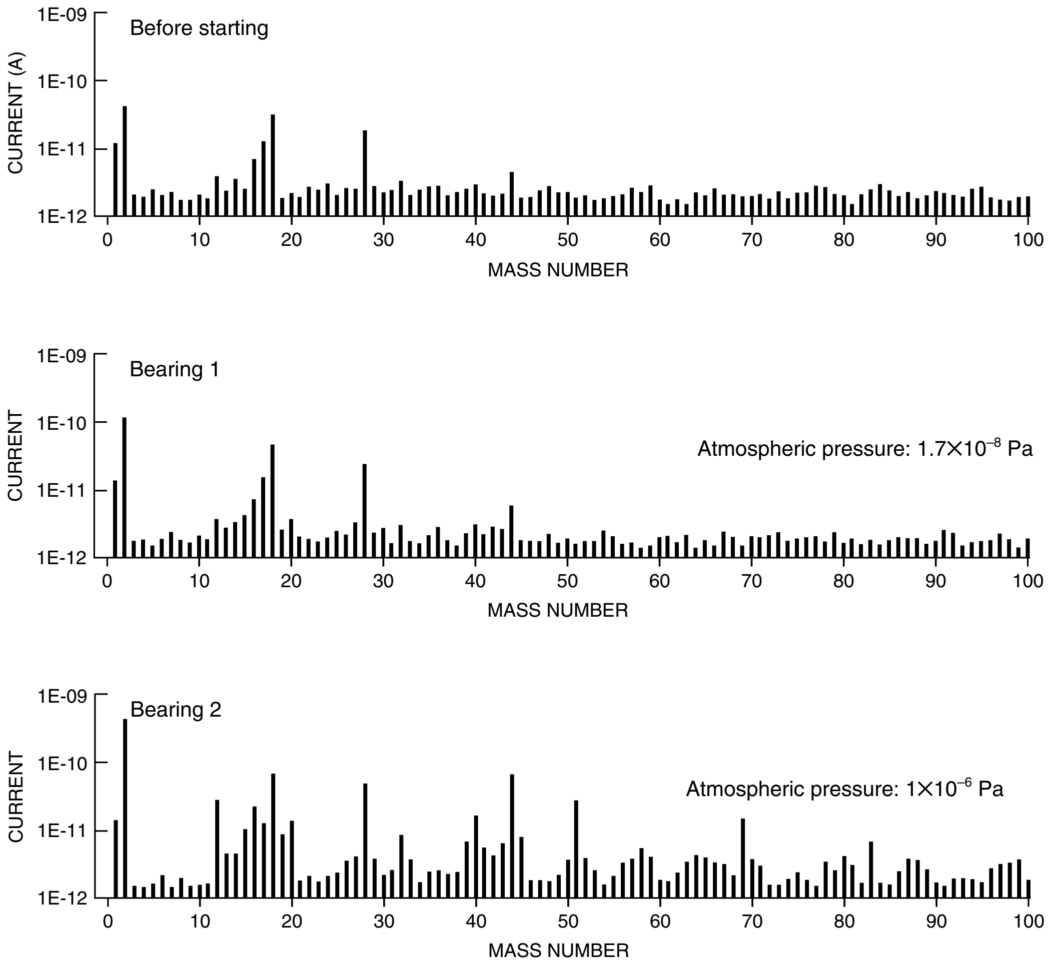


Fig. 3.5 Analysis Result for Gas Emitted from Bearings Rotated in Vacuum

(3.2 EXSEV Bearings for Use in a Vacuum Environment)

(2) Gas emitted from heated retainer

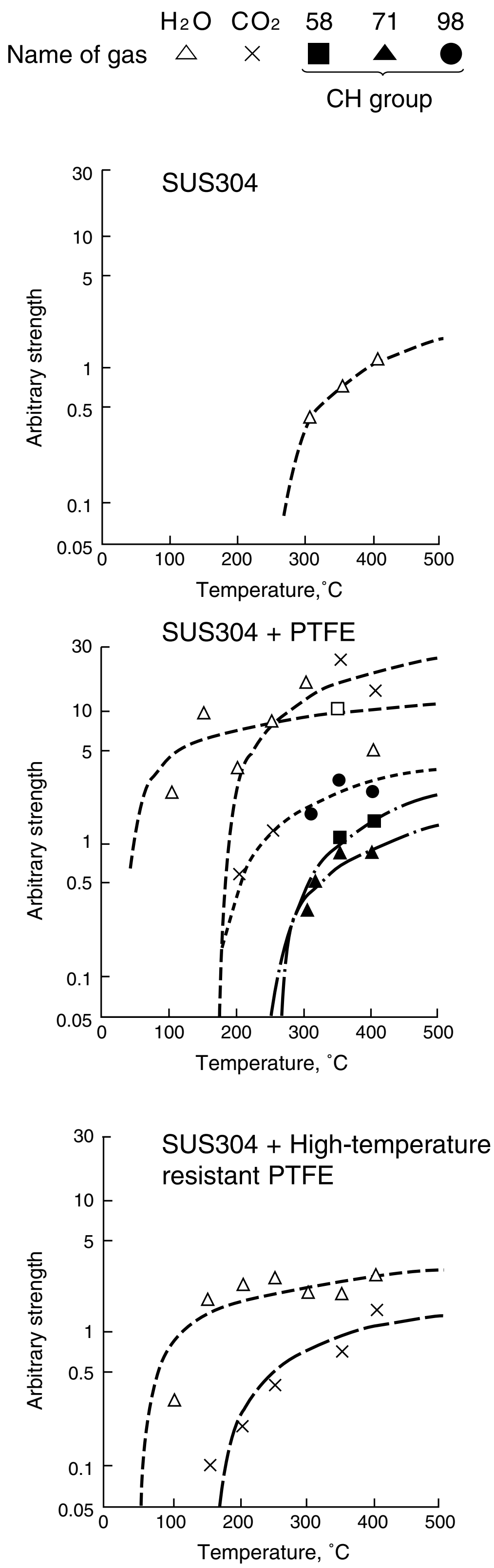


Fig. 3.6 Type of Gas Emitted from Heated Retainer

(3) Pressure changes when bearing coated with special polymeric fluoride is heated

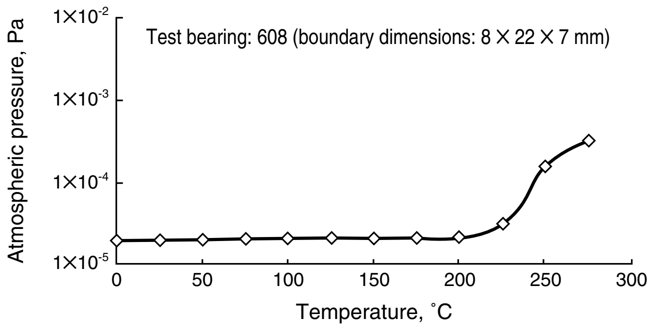


Fig. 3.7 Pressure Changes when Bearing Coated with Special Polymeric Fluoride Is Heated

3.3 Life of EXSEV Bearings

EXSEV bearings, lubricated with a solid lubricant, are usually used under relatively light load conditions, such as 10% of their static load ratings or less.
These bearings can maintain stable performance as long as the solid lubricant is maintained. Once the lubricant wears out, metallic contact occurs, which increases rotational friction torque and shortens service life.

Service life depends on use conditions. At present, it is not possible to predict their service life under varied use conditions.
However, based on a variety of experiments and tests, KOYO has established an experimental formulae to predict the lives of bearings. The formulae is described in the following subsections for reference only.

(1) Life of high-vacuum resistant bearings consisting of silver-coated balls

The life of high-vacuum resistant bearings (KOYO's serial number, SE...STMG3) can be predicted according to the following formula;

$$L_{vh} = b_1 \cdot b_2 \cdot b_3 (C_v/P)^q \times 16\,667/n$$

where,
- L_{vh} : 90% reliable life, h
- C_v : Basic dynamic load rating of vacuum-resistant ball bearings (1/13 of basic dynamic load rating of steel bearings of equal size), N
- P : Dynamic equivalent load, N
- q : Index, $q = 1$
- n : Rotation speed, rpm, limited to $10 \leqq n \leqq 10\,000$
- b_1 : Rotation-speed-dependant coefficient
  $b_1 = 1.5 \times 10^{-3} n + 1$
- b_2 : Material coefficient
  $b_2 = 1$ (for bearings ion-plated with silver by the special ion-plating process)
- b_3 : Coefficient for atmospheric pressure and temperature
  $b_3 = 1$ (for 10^{-3} Pa and room temperature)

(2) For bearings coated with PTFE or special polymeric fluoride

For those bearings coated with PTFE (MP7) or those coated with the special polymeric fluoride (PR), the following formula gives their mean life for reference only. (See Fig. 3.8.)

$$L_{av} = b_2 \cdot (C_e/P)^d \times 0.016667/n$$

where,
- L_{av} : Average life, h
- B_2 : Lubrication coefficient
  6 for bearings coated with PTFE
  42 for bearings coated with special polymeric fluoride
- C_e : 0.85 times the basic dynamic load rating of steel bearings of equal size, N
- P : Dynamic equivalent load, N
- d : Coefficient, $d = 3$
- n : Rotation speed, rpm

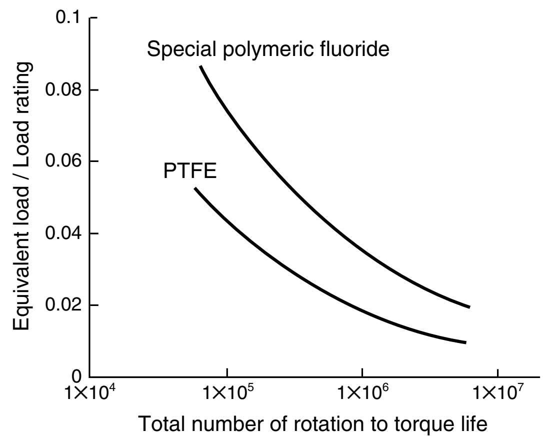


Fig. 3.8 Mean Life of Coated Bearings

4. Ceramic Bearings for Application to Machine Tools

The characteristics of ceramics such as being lightweight and having a high elastic modulus reduce the centrifugal force induced by the rolling elements when the bearing is driven at high speeds. These characteristics also reduce the sliding motion of the rolling elements caused by the gyro moment. Accordingly, ceramics suppresses the rise in temperature of the bearing.
Ceramic bearings are best suited for machine tools because they improve rigidity, extend seizure life and grease life, etc.
In some conditions, ceramic bearings can be driven at speeds 30 to 50% higher than steel bearings.

For dimensions of ceramic bearings for machine tools, refer to KOYO's catalogue NO. 297E "General Catalogue for Precision Rolling Bearings for Machine Tools/Precision Products."

• Ceramic bearings for application to machine tools

4.1 Rigidity of Ceramic Bearings

Since the modulus of longitudinal elasticity of ceramics is larger than that of bearing steel, ceramic bearings are more rigid than steel bearings.

• Bearing/ Basic number: ACH014C
Boundary dimensions: 70 × 110 × 20 mm

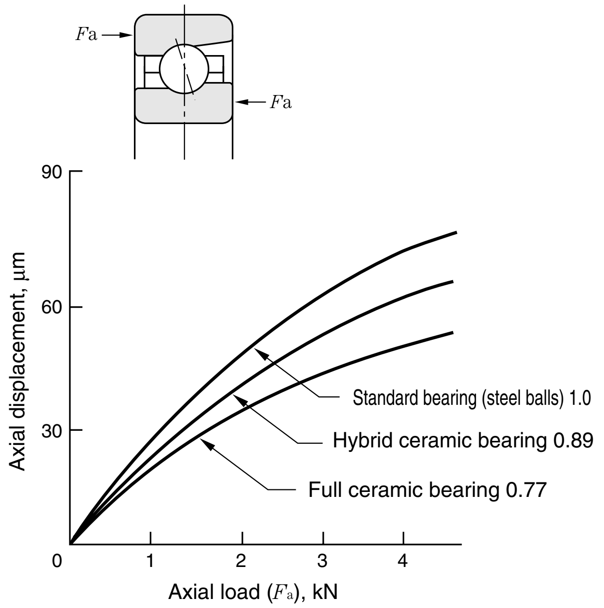


Fig. 4.1 Comparison of Rigidity between Ceramic Bearings and Steel Bearings

From Fig. 4.1, it can be understood that the rigidities of hybrid ceramic bearings (3NC type) and full ceramic bearings (NC type) are1/0.89 = 1.12 times and 1/0.77 = 1.30 times higher than that of steel bearings, respectively.

4.2 Temperature Rise in Ceramic Bearings and Displacement at Shaft Ends

Compared to steel bearings, hybrid ceramic bearings (3NC type) give lower temperature rise in all cases when lubricated with grease or oil/air. They also generate smaller shaft end displacement.

• Bearing/ Basic number: ACH018C
Boundary dimensions: 90 × 140 × 24 mm
• Test conditions/ Grease : 10% of space is filled with ISOFLEX NBU 15.
Pre-load : 588 N {60 kgf}
Oil : 0.004 m ℓ /min of oil equivalent to ISO VG10
Air : 50 N ℓ /min

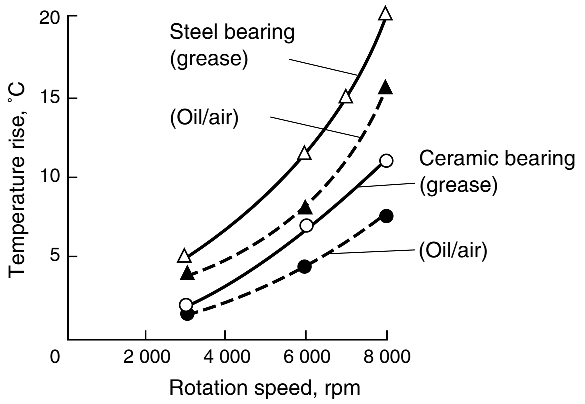


Fig. 4.2 Relation between Rotation Speed and Temperature Rise

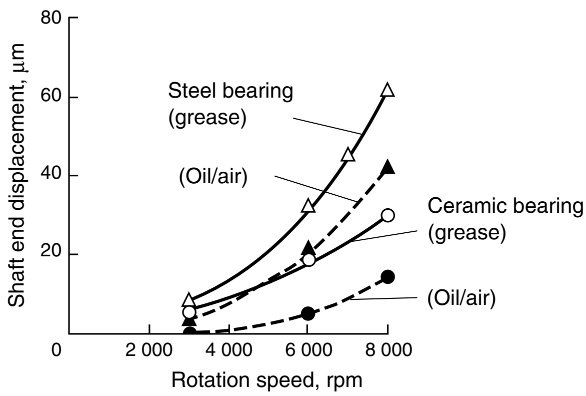


Fig. 4.3 Relation between Rotation Speed and Shaft End Displacement

4.3 High-speed Performance of Ceramic Bearings

To improve the high-speed performance of ceramic bearings, KOYO has developed a new pre-loading method, new lubricant, new bearing construction, new spindle construction, etc.
If you intend to use bearings at extremely high speeds, please contact KOYO.

1) High-speed performances of hybrid ceramic ball bearings (3NC type)

① Grease lubrication

Test conditions/ Pre-load : 0
Grease: 10% of space is filled with ISOFLEX NBU 15.

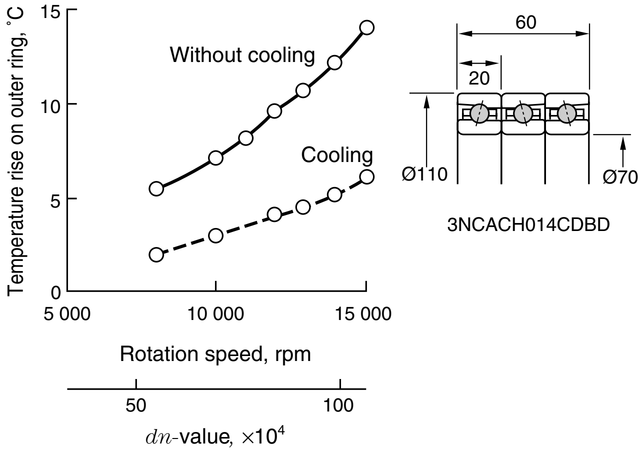


Fig. 4.4 ① High-speed Performance Test Result for Hybrid Ceramic Ball Bearings (Grease Lubrication)

② Oil/ air lubrication

Test conditions/ Oil: 0.007 m ℓ /min of oil equivalent to ISO VG10
Air: 70 N ℓ /min

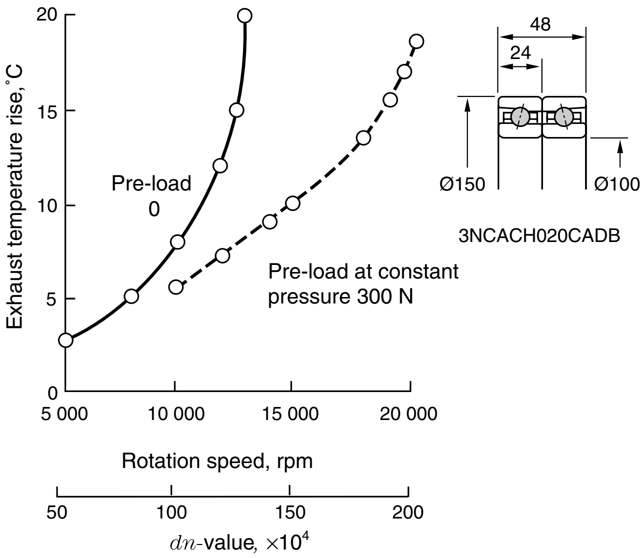
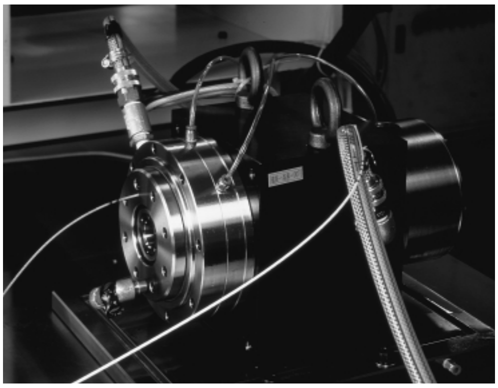


Fig. 4.4 ② High-speed Performance Test Result for Hybrid Ceramic Ball Bearings (Oil/ Air Lubrication)



• High-speed performance test equipment for bearings for machine tools

③ Jet lubrication

Test conditions/ Pre-load: 882 N {90 kgf} constant
Oil : 2.3 ℓ /min of oil equivalent to ISO VG2

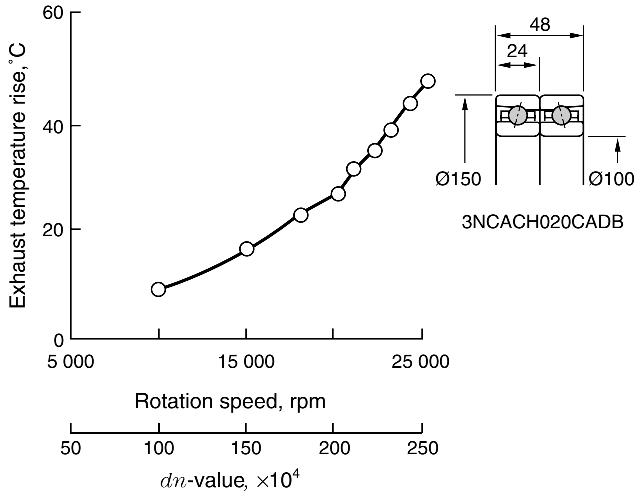


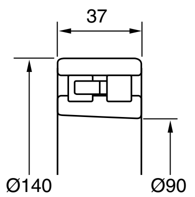
Fig. 4.4 ③ High-speed Performance Test Result for Hybrid Ceramic Ball Bearings (Jet Lubrication)

(4.3 High-speed Performance of Ceramic Bearings)

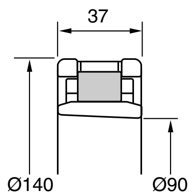
2) High-speed Performance of Hybrid Ceramic Cylindrical Roller Bearings (3NC Type)

Hybrid ceramic cylindrical roller bearings (3NC type) are superior to steel cylindrical roller bearings in both temperature and power-loss characteristics.

- Bearing/ Basic number : NN3018K
  3NCPNU3018K
  Boundary dimensions: 90 × 140 × 37 mm
- Oil/ air lubrication/
  Oil: 0.01 m ℓ /8min of oil equivalent to ISO VG10



Steel, double row cylindrical roller bearing, NN3018K



Ceramic, single row cylindrical roller bearing, 3NCPNU3018K

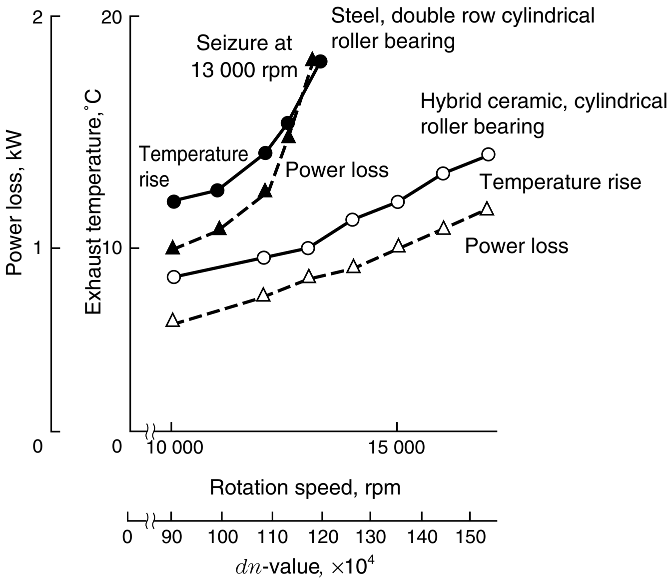


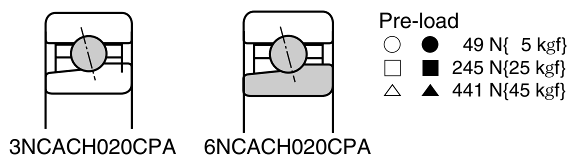
Fig. 4.5 High-speed Performance Test Result for Hybrid Ceramic Cylindrical Roller Bearings

Ceramic materials differ from steel in the coefficient of linear expansion, modulus of longitudinal elasticity, and Poisson's ratio. Hence, attention must be paid to the fitting tolerance between 6NC type assembled ceramic ball bearings and the shaft. For further details, please contact KOYO.

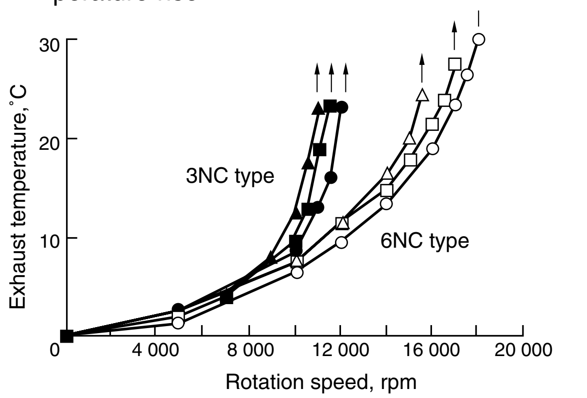
3) High-speed Performance of Hybrid Ceramic Ball Bearings (6NC and 3NC Types)

6NC type bearings comprising ceramic balls and a ceramic inner ring can be driven at a speed approximately 1.5 times above that for 3NC type bearings consisting of ceramic balls.

- Bearing/ Basic number: 6NCACH020CPA
  3NCACH020CPA
  Boundary dimensions: 100 × 150 × 24 mm
- Oil/ air lubrication/
  Oil: 0.05 m ℓ /2 min of oil equivalent to ISO VG10
  Air: 60 N ℓ /min
- Rotation speed/ Up to 17 500 rpm
  (dn-value: 175 × 10^4)
- Continuous rotation speed/ 17 000 rpm
  (dn-value: 170 × 10^4) × 60 h
- Cooling/ Jacket oil cooling
  (10 ℓ /min, room temperature control)



① Relation between rotation speed and exhaust temperature rise



② Relation between rotation speed and power loss

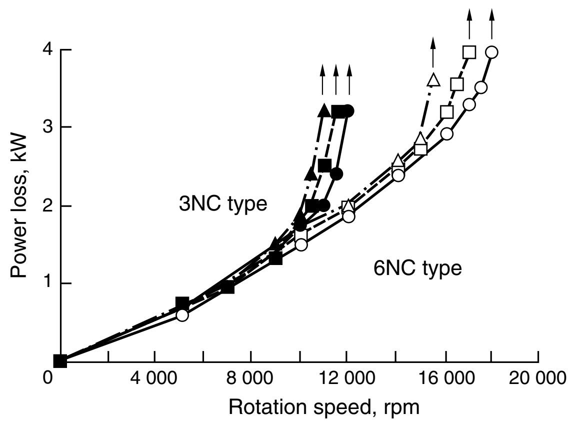


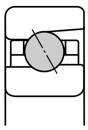
Fig. 4.6 High-speed Performance Test Results for Hybrid Ceramic Ball Bearings (6NC Type and 3NC Type)

4.4 Rolling Life and Seizure Life of Ceramic Bearings

When a low-viscosity lubricant is used, hybrid ceramic bearings (3NC type) have a significantly longer life than steel bearings. (See Fig. 4.7.)
Regarding seizure life, hybrid ceramic bearings (3NC type) have a longer service life than steel bearings when grease lubrication or oil/air lubrication are used. (See Figs. 4.8 to 4.11.)

1) Life Test Results for Hybrid Ceramic Ball Bearings (3NC Type)

- Bearing/ Basic number: ACT016
  Boundary dimensions: 80 × 125 × 20.25 mm
- Test conditions/ Rotation speed : 3 000 rpm
  (dn-value: 24 × 10^4)
  Axial load : 14.7 kN {1 500 kgf}
  Lubrication : Oil bath



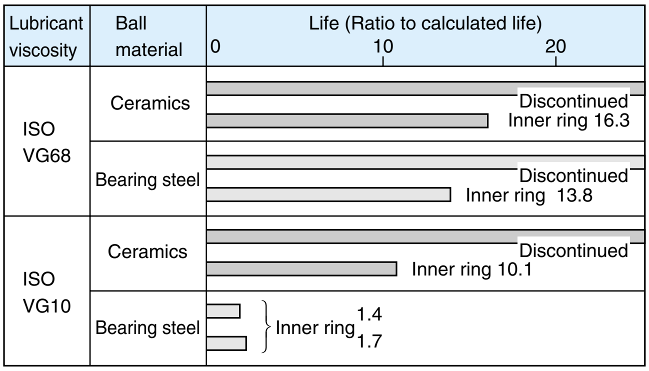


Fig. 4.7 Life Test Results for Hybrid Ceramic Ball Bearings

2) Seizure Life Test Results for Hybrid Ceramic Ball Bearings (3NC type)

- Bearing/ Basic number: ACT016
  Boundary dimensions: 80 × 125 × 20.25 mm
- Test conditions/ Rotation speed: 7 000 rpm
  (dn-value: 56 × 10^4)
  Axial load: 14.7 kN {1 500 kgf}
  Grease: 10% of space is filled with ISOFLEX NBU 15.

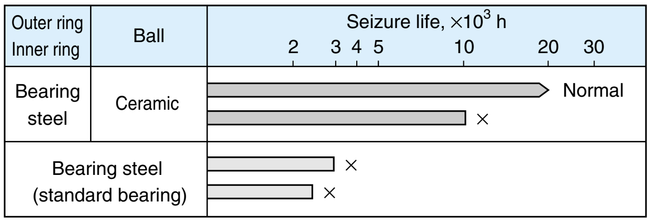
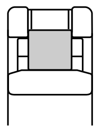


Fig. 4.8 Seizure Life Test Results for Assembled Ceramic Ball Bearings

3) Seizure Life Test Results for Hybrid Ceramic Cylindrical Roller Bearings (3NC type)

- Bearing/ Basic number: NU204
  Boundary dimensions: 20 × 47 × 14 mm
- Test conditions/ Rotation speed: 35 000 rpm
  (dn-value: 56 × 10^4)
  Temperature : 300°C
  Lubricant : Grease



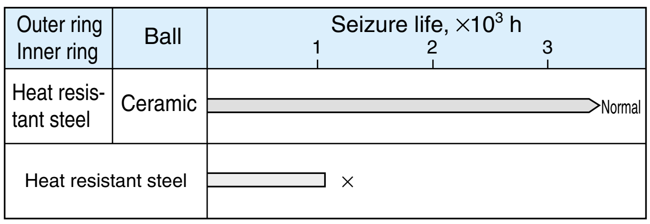


Fig. 4.9 Seizure Life Test Results for Hybrid Ceramic Cylindrical Roller Bearings

(4.4 Rolling Life and Seizure Life of Ceramic Bearings)

4) Temperature-rise Test Results for Hybrid Ceramic Ball Bearings (3NC Type)

Compared to steel bearings, hybrid ceramic bearings (3NC type) do not generate excessive heat and can run efficiently even under conditions where seizure would occur to steel bearings.

- Bearing/ Basic number: ACH018CDBD
  Boundary dimensions: 90 × 140 × 24 mm
- Test condition/ Pre-load: 0
  Grease: 10% of space is filled with INFLEX NBU 15.
  Cooling: Jacket cooling

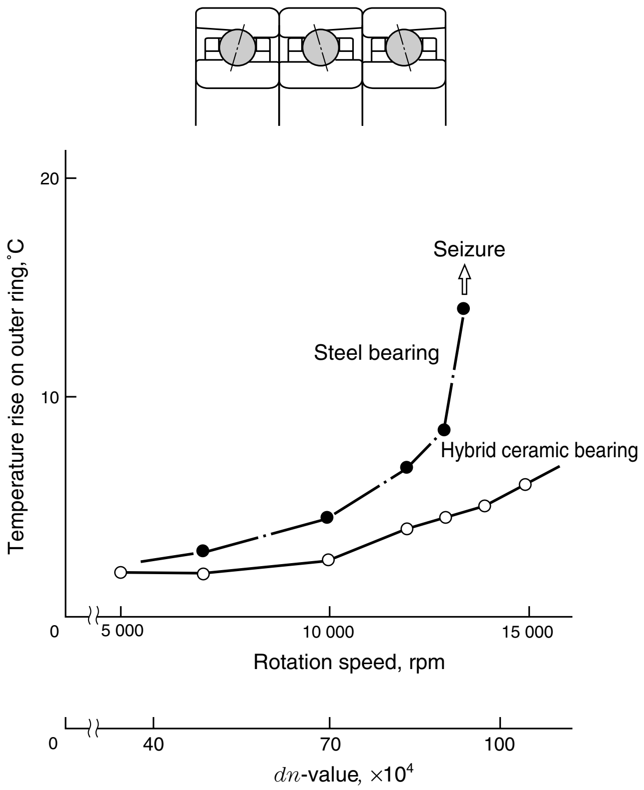


Fig. 4.10 Temperature Rise Test Results for Hybrid Ceramic Ball Bearings

5) Seizure Life Test Results for Hybrid Ceramic Ball Bearings (3NC type)

- Bearing/ Basic number: ACH018CDB
  Boundary dimensions: 90 × 140 × 24 mm
- Test conditions/ Rotation speed: 10 000 rpm
  (dn-value: 90 × 10^4)
  Pre-load: 294 N {30 kgf}
  Lubrication: Running without lubricant after 4 hours of oil/air lubrication
  Oil: 0.006 mℓ/min of oil equivalent to ISO VG 10
  Air: 50 Nℓ/min

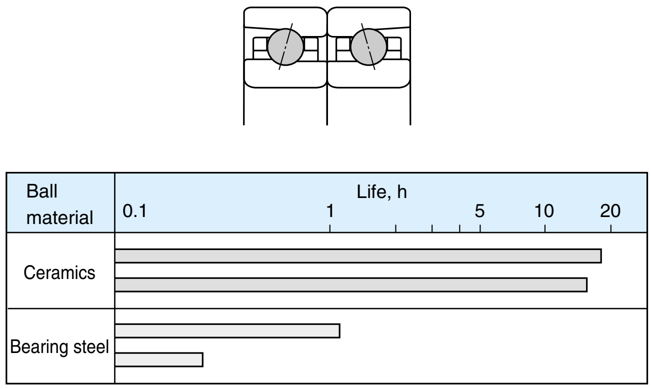
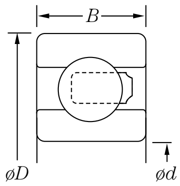
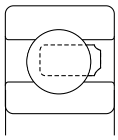
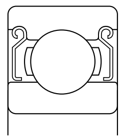
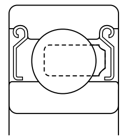


Fig. 4.11 Seizure Life Test Results for Hybrid Ceramic Ball Bearings

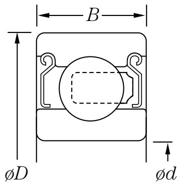
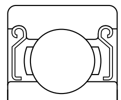
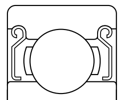
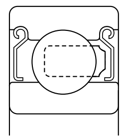
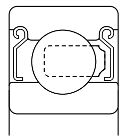
5. Dimensions Table for Ceramic Bearings and EXSEV Bearings

5.1 For High Rotation Speed — 5.2 (1) For a Clean Environment

Boundary Dimensions mm			Basic Bearing Number	For High Speed Rotation		For a Clean Environment (1)	
				3NC...FG  •Balls: Ceramics •Retainer: Reinforced polyamide resin	6NC...FG  •Balls and inner ring: Ceramics •Retainer: Reinforced polyamide resin	SE...ST PR YS  •Outer ring, inner ring, balls, and retainer are coated with special polymeric fluoride.	SE...ST FA (PT)  •Retainer: Fluorocarbon resin
d	*D*	*B*					
4	10	4	WML4010	—	—	SEWML4010ZZST PR	—
	12	4	604	3NC604	6NC604	SE604ZZST PR	SE604ZZST FA
	13	5	624	3NC624 FG	6NC624 FG	△ SE624ZZST PR	○ SE624ZZST FA
5	14	5	605	3NC605 FG	6NC605 FG	SE605ZZST PR	SE605ZZST FA
	16	5	625	3NC625 FG	6NC625 FG	SE625ZZST PR	SE625ZZST FA
6	10	3	WML6010	—	—	SEWML6010ZZST PR	—
	12	4	WML6012	—	—	SEWML6012ZZST PR	SEWML6012ZZST FA
	13	5	W686	3NCW686 FG	6NCW686 FG	SEW686ZZST PR	SEW686ZZST FA
	17	6	606	3NC606 FG	6NC606 FG	SE606ZZST PR	SE606ZZST FA
	19	6	626	3NC626 FG	6NC626 FG	△ SE626ZZST PR	○ SE626ZZST FA
7	19	6	607	3NC607 FG	6NC607 FG	SE607ZZST PR	SE607ZZST FA
	22	7	627	3NC627 FG	6NC627 FG	SE627ZZST PR	SE627ZZST FA
8	22	7	608	3NC608 FG	6NC608 FG	△ SE608ZZST PR	○ SE608ZZST FA
	24	8	628	3NC628 FG	6NC628 FG	SE628ZZST PR	SE628ZZST FA
9	24	7	609	3NC609 FG	6NC609 FG	SE609ZZST PR	SE609ZZST FA
	26	8	629	3NC629 FG	6NC629 FG	SE629ZZST PR	SE629ZZST FA
9.525	22.225	7	EE3S	3NCEE3S FG	6NCEE3S FG	SEEE3SZZST PR	—
10	26	8	6000	3NC6000 FG	6NC6000 FG	△ SE6000ZZST PR	○ SE6000ZZST FA
	30	9	6200	3NC6200 FG	6NC6200 FG	△ SE6200ZZST PR	○ SE6200ZZST FA
12	28	8	6001	3NC6001 FG	6NC6001 FG	△ SE6001ZZST PR	○ SE6001ZZST FA
	32	10	6201	3NC6201 FG	6NC6201 FG	△ SE6201ZZST PR	○ SE6201ZZST FA
15	32	9	6002	3NC6002 FG	6NC6002 FG	△ SE6002ZZST PR	○ SE6002ZZST FA
	35	11	6202	3NC6202 FG	6NC6202 FG	△ SE6202ZZST PR	○ SE6202ZZST FA
17	35	10	6003	3NC6003 FG	6NC6003 FG	△ SE6003ZZST PR	○ SE6003ZZST FA
	40	12	6203	3NC6203 FG	6NC6203 FG	△ SE6203ZZST PR	○ SE6203ZZST FA
20	42	12	6004	3NC6004 FG	6NC6004 FG	△ SE6004ZZST PR	○ SE6004ZZST FA
	47	14	6204	3NC6204 FG	6NC6204 FG	△ SE6204ZZST PR	○ SE6204ZZST FA
25	47	12	6005	3NC6005 FG	6NC6005 FG	△ SE6005ZZST PR	○ SE6005ZZST FA
	52	15	6205	3NC6205 FG	6NC6205 FG	△ SE6205ZZST PR	○ SE6205ZZST FA
30	55	13	6006	3NC6006 FG	6NC6006 FG	△ SE6006ZZST PR	○ SE6006ZZST FA
	62	16	6206	3NC6206 FG	6NC6206 FG	△ SE6206ZZST PR	○ SE6206ZZST FA
35	62	14	6007	3NC6007 FG	6NC6007 FG	SE6007ZZST PR	SE6007ZZST FA
	72	17	6207	3NC6207 FG	6NC6207 FG	SE6207ZZST PR	SE6207ZZST FA
40	68	15	6008	3NC6008 FG	6NC6008 FG	SE6008ZZST PR	SE6008ZZST FA
	80	18	6208	3NC6208 FG	6NC6208 FG	SE6208ZZST PR	SE6208ZZST FA
Use and applicable range				• 3NC: Rolling element Ceramics	• 6NC: Rolling element and inner ring Ceramics	• Clean (class 100) • Fluctuation from atmospheric pressure to 10^{-5} Pa • –100 to 200˚C	• Clean (class 1000) • Fluctuation from atmospheric pressure to 10^{-5} Pa • –100 to 200˚C

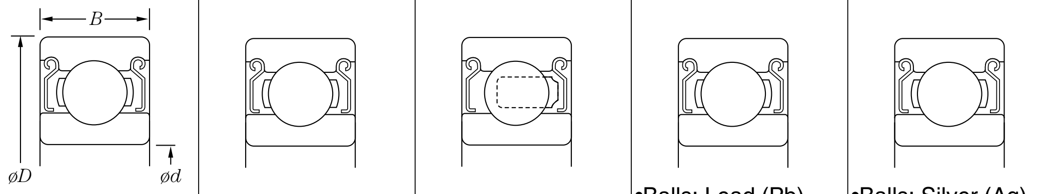
Remarks: 1. For the allowable load and limiting speed of bearings consisting of high-hardened carbon ball or retainers of fluorocarbon resin (FA), see page 52 - 5.8.
2. For ceramic bearings for application to machine tools, see CAT. NO.297E "General Catalogue for Precision Rolling Bearings for Machine Tools/Precision Products."
3. For super thin section ball bearings for use in extreme special environments, K-series, see page 56.
4. Current stocks and delivery time are as follows. KOYO will continue increasing product stocks and shortening delivery time.
○ : Bearings able to be shipped immediately　　△ : Bearings able to be shipped in one month

5.2 (2) For a Clean Environment

Boundary Dimensions mm			Basic Bearing Number	For a Clean Environment (2)				
				SL...ST4 FA (PT)	SE...STMPD7 YS	SL...ST4 YS	3NC...MD4 FA (PT)	SL...MD4 FA (PT)
d	*D*	*B*		 •Balls: High-hardened carbon •Retainer: Fluorocarbon resin	 •Retainer: High-temperature resistant PTFE coating	 •Balls: High-hardened carbon	 •Outer ring and inner ring: SUS 630 •Balls: Ceramics •Retainer: Fluorocarbon resin	 •Outer ring and inner ring: SUS 630 •Balls: High-hardened carbon •Retainer: Fluorocarbon resin
4	10	4	WML4010	———	SEWML4010ZZSTMPD7	———	———	———
	12	4	604	SL604ZZST4 FA	SE604ZZSTMPD7	SL604ZZST4	3NC604ZZMD4 FA	SL604ZZMD4 FA
	13	5	624	○ SL624ZZST4 FA	△SE624ZZSTMPD7	○ SL624ZZST4	3NC624ZZMD4 FA	○SL624ZZMD4 FA
5	14	5	605	SL605ZZST4 FA	SE605ZZSTMPD7	SL605ZZST4	3NC605ZZMD4 FA	SL605ZZMD4 FA
	16	5	625	SL625ZZST4 FA	SE625ZZSTMPD7	SL625ZZST4	3NC625ZZMD4 FA	SL625ZZMD4 FA
6	10	3	WML6010	———	SEWML6010ZZSTMPD7	———	———	———
	12	4	WML6012	———	SEWML6012ZZSTMPD7	———	3NCWML6012ZZMD4 FA	SLWML6012ZZMD4 FA
	13	5	W686	———	SEW686ZZSTMPD7	———	3NCW686ZZMD4 FA	SLW686ZZMD4 FA
	17	6	606	SL606ZZST4 FA	SE606ZZSTMPD7	SL606ZZST4	3NC606ZZMD4 FA	SL606ZZMD4 FA
	19	6	626	○ SL626ZZST4 FA	△ SE626ZZSTMPD7	○ SL626ZZST4	3NC626ZZMD4 FA	○SL626ZZMD4 FA
7	19	6	607	SL607ZZST4 FA	SE607ZZSTMPD7	SL607ZZST4	3NC607ZZMD4 FA	SL607ZZMD4 FA
	22	7	627	SL627ZZST4 FA	SE627ZZSTMPD7	SL627ZZST4	3NC627ZZMD4 FA	SL627ZZMD4 FA
8	22	7	608	○ SL608ZZST4 FA	△ SE608ZZSTMPD7	○ SL608ZZST4	○3NC608ZZMD4 FA	○SL608ZZMD4 FA
	24	8	628	SL628ZZST4 FA	SE628ZZSTMPD7	SL628ZZST4	3NC628ZZMD4 FA	SL628ZZMD4 FA
9	24	7	609	SL609ZZST4 FA	SE609ZZSTMPD7	SL609ZZST4	3NC609ZZMD4 FA	SL609ZZMD4 FA
	26	8	629	SL629ZZST4 FA	SE629ZZSTMPD7	SL629ZZST4	3NC629ZZMD4 FA	SL629ZZMD4 FA
9.525	22.225	7	EE3S	———	SEEE3SZZSTMPD7	———	3NCEE3SZZMD4 FA	SLEE3SZZMD4 FA
10	26	8	6000	○SL6000ZZST4 FA	△SE6000ZZSTMPD7	○ SL6000ZZST4	○3NC6000ZZMD4 FA	○SL6000ZZMD4 FA
	30	9	6200	○SL6200ZZST4 FA	△SE6200ZZSTMPD7	○ SL6200ZZST4	3NC6200ZZMD4 FA	○SL6200ZZMD4 FA
12	28	8	6001	○SL6001ZZST4 FA	△SE6001ZZSTMPD7	○ SL6001ZZST4	○3NC6001ZZMD4 FA	○SL6001ZZMD4 FA
	32	10	6201	○SL6201ZZST4 FA	△SE6201ZZSTMPD7	○ SL6201ZZST4	3NC6201ZZMD4 FA	○SL6201ZZMD4 FA
15	32	9	6002	○SL6002ZZST4 FA	△SE6002ZZSTMPD7	○ SL6002ZZST4	○3NC6002ZZMD4 FA	○SL6002ZZMD4 FA
	35	11	6202	○SL6202ZZST4 FA	△SE6202ZZSTMPD7	○ SL6202ZZST4	3NC6202ZZMD4 FA	○SL6202ZZMD4 FA
17	35	10	6003	○SL6003ZZST4 FA	△SE6003ZZSTMPD7	○ SL6003ZZST4	○3NC6003ZZMD4 FA	○SL6003ZZMD4 FA
	40	12	6203	○SL6203ZZST4 FA	△SE6203ZZSTMPD7	○ SL6203ZZST4	3NC6203ZZMD4 FA	○SL6203ZZMD4 FA
20	42	12	6004	○SL6004ZZST4 FA	△SE6004ZZSTMPD7	○ SL6004ZZST4	○3NC6004ZZMD4 FA	○SL6004ZZMD4 FA
	47	14	6204	○SL6204ZZST4 FA	△SE6204ZZSTMPD7	○ SL6204ZZST4	○3NC6204ZZMD4 FA	○SL6204ZZMD4 FA
25	47	12	6005	○SL6005ZZST4 FA	△SE6005ZZSTMPD7	○ SL6005ZZST4	○3NC6005ZZMD4 FA	○SL6005ZZMD4 FA
	52	15	6205	○SL6205ZZST4 FA	△SE6205ZZSTMPD7	○ SL6205ZZST4	○3NC6205ZZMD4 FA	○SL6205ZZMD4 FA
30	55	13	6006	○SL6006ZZST4 FA	△SE6006ZZSTMPD7	○ SL6006ZZST4	○3NC6006ZZMD4 FA	○SL6006ZZMD4 FA
	62	16	6206	○SL6206ZZST4 FA	△SE6206ZZSTMPD7	○ SL6206ZZST4	○3NC6206ZZMD4 FA	○SL6206ZZMD4 FA
35	62	14	6007	SL6007ZZST4 FA	SE6007ZZSTMPD7	SL6007ZZST4	3NC6007ZZMD4 F4	SL6007ZZMD4 FA
	72	17	6207	SL6207ZZST4 FA	SE6207ZZSTMPD7	SL6207ZZST4	3NC6207ZZMD4 FA	SL6207ZZMD4 FA
40	68	15	6008	SL6008ZZST4 FA	SE6008ZZSTMPD7	SL6008ZZST4	3NC6008ZZMD4 FA	SL6008ZZMD4 FA
	80	18	6208	SL6208ZZST4 FA	SE6208ZZSTMPD7	SL6208ZZST4	3NC6208ZZMD4 FA	SL6208ZZMD4 FA
Use and applicable range				• Super clean (class 10) • Fluctuation from atmospheric pressure to 10^{-5} Pa • –100 to 200˚C • Light load	• Clean (class 1 000) • Fluctuation from atmospheric pressure to 10^{-5} Pa • 200 to 300˚C	• Clean (class 100) • Fluctuation from atmospheric pressure to 10^{-5} Pa • 200 to 400˚C • Light load	• Super clean (class 10) • Fluctuation from atmospheric pressure to 10^{-5} Pa • –100 to 200˚C • High corrosion resistance	• Light load

Remarks: 1. For the allowable load and limiting speed of bearings consisting of high-hardened carbon ball or retainers of fluorocarbon resin (FA), see page 52 - 5.8.
2. For ceramic bearings for application to machine tools, see CAT. NO.297E "General Catalogue for Precision Rolling Bearings for Machine Tools/Precision Products."
3. For super thin section ball bearings for use in extreme special environments, K-series, see page 56.
4. Current stocks and delivery time are as follows. KOYO will continue increasing product stocks and shortening delivery time.
○ : Bearings able to be shipped immediately   △ : Bearings able to be shipped in one month

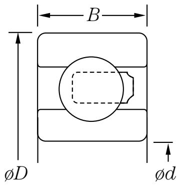
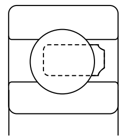
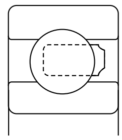
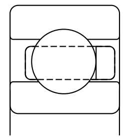
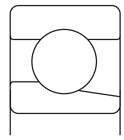
5.3 For a Vacuum Environment



Boundary Dimensions mm			Basic Bearing Number	(1) For Atmosphere and Vacuum Environment			(2) For a High-vacuum and Extra-high Vacuum Environment	
				SV...ST YS	SE...STMSA7 YS	SE...ST PG	SE...STMB3 YS	SE...STMG3 YS
				•Filled with vacuum grease	•Retainer: MoS_2 coating	•Retainer: PEEK resin	•Balls: Lead (Pb) Ion-plating	•Balls: Silver (Ag) Ion-plating
d	*D*	*B*						
4	10	4	WML4010	SVWML4010ZZST	SEWML4010ZZSTMSA7		―	―
	12	4	604	SV604ZZST	SE604ZZSTMSA7		SE604ZZSTMB3	○SE604ZZSTMG3
	13	5	624	△ SV624ZZST	△SE624ZZSTMSA7		SE624ZZSTMB3	○SE624ZZSTMG3
5	14	5	605	SV605ZZST	SE605ZZSTMSA7		SE605ZZSTMB3	SE605ZZSTMG3
	16	5	625	SV625ZZST	SE625ZZSTMSA7		SE625ZZSTMB3	○SE625ZZSTMG3
6	10	3	WML6010	SVWML6010ZZST	SEWML6010ZZSTMSA7		―	―
	12	4	WML6012	SVWML6012ZZST	SEWML6012ZZSTMSA7		―	―
	13	5	W686	SVW686ZZST	SEW686ZZSTMSA7		SEW686ZZSTMB3	SEW686ZZSTMG3
	17	6	606	SV606ZZST	SE606ZZSTMSA7	―	SE606ZZSTMB3	SE606ZZSTMG3
	19	6	626	△ SV626ZZST	△SE626ZZSTMSA7	SE626ZZST PG	SE626ZZSTMB3	○SE626ZZSTMG3
7	19	6	607	SV607ZZST	SE607ZZSTMSA7	SE607ZZST PG	SE607ZZSTMB3	SE607ZZSTMG3
	22	7	627	SV627ZZST	SE627ZZSTMSA7	SE627ZZST PG	SE627ZZSTMB3	SE627ZZSTMG3
8	22	7	608	△ SV608ZZST	△SE608ZZSTMSA7	△SE608ZZST PG	△SE608ZZSTMB3	○SE608ZZSTMG3
	24	8	628	SV628ZZST	SE628ZZSTMSA7	SE628ZZST PG	SE628ZZSTMB3	SE628ZZSTMG3
9	24	7	609	SV609ZZST	SE609ZZSTMSA7	SE609ZZST PG	SE609ZZSTMB3	SE609ZZSTMG3
	26	8	629	SV629ZZST	SE629ZZSTMSA7	SE629ZZST PG	SE629ZZSTMB3	SE629ZZSTMG3
9.525	22.225	7	EE3S	SVEE3SZZST	SEEE3SZZSTMSA7	―	SEEE3SZZSTMB3	○SEEE3SZZSTMG3
10	26	8	6000	△ SV6000ZZST	△SE6000ZZSTMSA7	△SE6000ZZST PG	△SE6000ZZSTMB3	○SE6000ZZSTMG3
	30	9	6200	△ SV6200ZZST	△SE6200ZZSTMSA7	SE6200ZZST PG	△SE6200ZZSTMB3	SE6200ZZSTMG3
12	28	8	6001	△ SV6001ZZST	△SE6001ZZSTMSA7	△SE6001ZZST PG	△SE6001ZZSTMB3	○SE6001ZZSTMG3
	32	10	6201	△ SV6201ZZST	△SE6201ZZSTMSA7	△SE6201ZZST PG	△SE6201ZZSTMB3	SE6201ZZSTMG3
15	32	9	6002	△ SV6002ZZST	△SE6002ZZSTMSA7	△SE6002ZZST PG	△SE6002ZZSTMB3	○SE6002ZZSTMG3
	35	11	6202	△ SV6202ZZST	△SE6202ZZSTMSA7	SE6202ZZST PG	△SE6202ZZSTMB3	SE6202ZZSTMG3
17	35	10	6003	△ SV6003ZZST	△SE6003ZZSTMSA7	△SE6003ZZST PG	△SE6003ZZSTMB3	○SE6003ZZSTMG3
	40	12	6203	△ SV6203ZZST	△SE6203ZZSTMSA7	SE6203ZZST PG	△SE6203ZZSTMB3	SE6203ZZSTMG3
20	42	12	6004	△ SV6004ZZST	△SE6004ZZSTMSA7	△SE6004ZZST PG	△SE6004ZZSTMB3	○SE6004ZZSTMG3
	47	14	6204	△ SV6204ZZST	△SE6204ZZSTMSA7	△SE6204ZZST PG	△SE6204ZZSTMB3	SE6204ZZSTMG3
25	47	12	6005	△ SV6005ZZST	△SE6005ZZSTMSA7	△SE6005ZZST PG	△SE6005ZZSTMB3	○SE6005ZZSTMG3
	52	15	6205	△ SV6205ZZST	△SE6205ZZSTMSA7	SE6205ZZST PG	△SE6205ZZSTMB3	SE6205ZZSTMG3
30	55	13	6006	△ SV6006ZZST	△SE6006ZZSTMSA7	△SE6006ZZST PG	△SE6006ZZSTMB3	○SE6006ZZSTMG3
	62	16	6206	△ SV6206ZZST	△SE6206ZZSTMSA7	SE6206ZZST PG	△SE6206ZZSTMB3	SE6206ZZSTMG3
35	62	14	6007	SV6007ZZST	SE6007ZZSTMSA7	△SE6007ZZST PG	SE6007ZZSTMB3	SE6007ZZSTMG3
	72	17	6207	SV6207ZZST	SE6207ZZSTMSA7	SE6207ZZST PG	SE6207ZZSTMB3	SE6207ZZSTMG3
40	68	15	6008	SV6008ZZST	SE6008ZZSTMSA7	SE6008ZZST PG	SE6008ZZSTMB3	SE6008ZZSTMG3
	80	18	6208	SV6208ZZST	SE6208ZZSTMSA7	SE6208ZZST PG	SE6208ZZSTMB3	SE6208ZZSTMG3
Use and applicable range				• Fluctuation from atmospheric pressure to 10^{-5} Pa • –40 to 200˚C	• Fluctuation from atmospheric pressure to 10^{-5} Pa • –100 to 300˚C • Lower torque than Ag coating	• Fluctuation from atmospheric pressure to 10^{-5} Pa • –100 to 300˚C	• Fluctuation from low vacuum to 10^{-10} Pa If possible do not use in low vacuum and atmospheric pressure to vacuum. • –200 to 300˚C • High rotation speed (dn = 8 × 10^4) • Lower torque than Ag coating	• Fluctuation from low vacuum to 10^{-10} Pa If possible do not use in low vacuum and atmospheric pressure to vacuum. • –200 to 300˚C(Up to 550˚C for bearings made of SKH) • High speed (dn = 8 × 10^4)

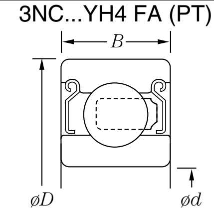
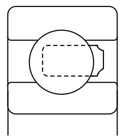
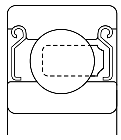
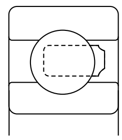
Remarks: 1. For the allowable load and limiting speed of bearings consisting of high-hardened carbon ball or retainers of fluorocarbon resin (FA), see page 52 - 5.8.
2. For ceramic bearings for application to machine tools, see CAT. NO.297E "General Catalogue for Precision Rolling Bearings for Machine Tools/Precision Products."
3. For super thin section ball bearings for use in extreme special environments, K-series, see page 56.
4. Current stocks and delivery time are as follows. KOYO will continue increasing product stocks and shortening delivery time.
○ : Bearings able to be shipped immediately △ : Bearings able to be shipped in one month

5.4 For Corrosion Resistance　　5.5 For High Temperatures

Boundary Dimensions mm			Basic Bearing Number	For Corrosion Resistance			For High Temperatures	
				NC...FA (PT)  •Outer ring, inner ring, and balls: Ceramic •Retainer: Fluorocarbon resin	NCT...FA (PT)  •Outer ring, inner ring, and balls: Corrosion resistant ceramic •Retainer: Fluorocarbon resin	NCZ...FA (PT)  •Outer ring, inner ring, and balls: Silicon carbide •Retainer: Fluorocarbon resin	3NC...HT4 GF  •Outer ring and inner ring: SKH4 •Balls: Ceramics •Retainer: Graphite	NC...V  •Outer ring, inner ring, and balls: Ceramic •Retainer: No (Full complement ball type)
d	*D*	*B*						
4	10	4	WML4010	NCWML4010	NCTWML4010	NCZWML4010		
	12	4	604	○ NC604 FA	NCT604 FA	NCZ604 FA		
	13	5	624	○ NC624 FA	NCT624 FA	NCZ624 FA		
5	14	5	605	NC605 FA	NCT605 FA	NCZ605 FA		
	16	5	625	○ NC625 FA	NCT625 FA	NCZ625 FA		
6	10	3	WML6010	NCWML6010	NCTWML6010	NCZWML6010		
	12	4	WML6012	NCWML6012 FA	NCTWML6012 FA	NCZWML6012 FA		
	13	5	W686	NCW686 FA	NCTW686 FA	NCZW686 FA	—	—
	17	6	606	○ NC606 FA	NCT606 FA	NCZ606 FA	3NC606HT4 GF	NC606 V
	19	6	626	NC626 FA	NCT626 FA	NCZ626 FA	3NC626HT4 GF	NC626 V
7	19	6	607	NC607 FA	NCT607 FA	NCZ607 FA	3NC607HT4 GF	NC607 V
	22	7	627	NC627 FA	NCT627 FA	NCZ627 FA	3NC627HT4 GF	NC627 V
8	22	7	608	○ NC608 FA	○ NCT608 FA	NCZ608 FA	3NC608HT4 GF	NC608 V
	24	8	628	NC628 FA	NCT628 FA	NCZ628 FA	3NC628HT4 GF	NC628 V
9	24	7	609	NC609 FA	NCT609 FA	NCZ609 FA	3NC609HT4 GF	NC609 V
	26	8	629	NC629 FA	NCT629 FA	NCZ629 FA	3NC629HT4 GF	NC629 V
9.525	22.225	7	EE3S	NCEE3S FA	NCTEE3S FA	NCZEE3S FA	3NCEE3SHT4 GF	NCEE3S V
10	26	8	6000	○ NC6000 FA	○ NCT6000 FA	NCZ6000 FA	3NC6000HT4 GF	NC6000 V
	30	9	6200	○ NC6200 FA	○ NCT6200 FA	NCZ6200 FA	3NC6200HT4 GF	NC6200 V
12	28	8	6001	○ NC6001 FA	○ NCT6001 FA	NCZ6001 FA	3NC6001HT4 GF	NC6001 V
	32	10	6201	○ NC6201 FA	○ NCT6201 FA	NCZ6201 FA	3NC6201HT4 GF	NC6201 V
15	32	9	6002	○ NC6002 FA	○ NCT6002 FA	NCZ6002 FA	3NC6002HT4 GF	NC6002 V
	35	11	6202	○ NC6202 FA	○ NCT6202 FA	NCZ6202 FA	3NC6202HT4 GF	NC6202 V
17	35	10	6003	○ NC6003 FA	○ NCT6003 FA	NCZ6003 FA	3NC6003HT4 GF	NC6003 V
	40	12	6203	○ NC6203 FA	○ NCT6203 FA	NCZ6203 FA	3NC6203HT4 GF	NC6203 V
20	42	12	6004	○ NC6004 FA	○ NCT6004 FA	NCZ6004 FA	3NC6004HT4 GF	NC6004 V
	47	14	6204	○ NC6204 FA	○ NCT6204 FA	NCZ6204 FA	3NC6204HT4 GF	NC6204 V
25	47	12	6005	○ NC6005 FA	○ NCT6005 FA	NCZ6005 FA	3NC6005HT4 GF	NC6005 V
	52	15	6205	○ NC6205 FA	○ NCT6205 FA	NCZ6205 FA	3NC6205HT4 GF	NC6205 V
30	55	13	6006	○ NC6006 FA	○ NCT6006 FA	NCZ6006 FA	3NC6006HT4 GF	NC6006 V
	62	16	6206	○ NC6206 FA	○ NCT6206 FA	NCZ6206 FA	3NC6206HT4 GF	NC6206 V
35	62	14	6007	NC6007 FA	NCT6007 FA	NCZ6007 FA	3NC6007HT4 GF	NC6007 V
	72	17	6207	NC6207 FA	NCT6207 FA	NCZ6207 FA	3NC6207HT4 GF	NC6207 V
40	68	15	6008	NC6008 FA	NCT6008 FA	NCZ6008 FA	3NC6008HT4 GF	NC6008 V
	80	18	6208	NC6208 FA	NCT6208 FA	NCZ6208 FA	3NC6208HT4 GF	NC6208 V
Use and applicable range				• Corrosion resistance • Fluctuation from atmospheric pressure to 10^{-5} Pa • –100 to 200˚C • Non magnetism • Insulation		• Same as left • Lower strength when compared to ceramics (silicon nitride)	• For temperatures of up to 500˚C	• For the temperature range of 500 to 800˚C

Remarks: 1. For the allowable load and limiting speed of bearings consisting of high-hardened carbon ball or retainers of fluorocarbon resin (FA), see page 52 - 5.8.
2. For ceramic bearings for application to machine tools, see CAT. NO.297E "General Catalogue for Precision Rolling Bearings for Machine Tools/Precision Products."
3. For super thin section ball bearings for use in extreme special environments, K-series, see page 56.
4. Current stocks and delivery time are as follows. KOYO will continue increasing product stocks and shortening delivery time.
○ : Bearings able to be shipped immediately　　△ : Bearings able to be shipped in one month

5.6 For Non Magnetism 5.7 Insulation

Boundary Dimensions mm			Basic Bearing Number	For Non Magnetism		Insulation	
				3NC...YH4 FA (PT)  •Outer ring and inner ring: Non magnetic steel •Balls: Ceramic •Retainer: Fluorocarbon resin	NC...FA (PT)  •Outer ring, inner ring, and balls: Ceramics •Retainer: Fluorocarbon resin	3NC...ST4 FA (PT)  •Balls: Ceramics •Retainer: Fluorocarbon resin	NC...FA (PT)  •Outer ring, inner ring, and balls: Ceramics •Retainer: Fluorocarbon resin
d	*D*	*B*					
4	10	4	WML4010	———	NCWML4010	———	NCWML4010
	12	4	604	3NC604ZZYH4 FA	○ NC604 FA	3NC604ZZST4 FA	○ NC604 FA
	13	5	624	3NC624ZZYH4 FA	○ NC624 FA	3NC624ZZST4 FA	○ NC624 FA
5	14	5	605	3NC605ZZYH4 FA	NC605 FA	3NC605ZZST4 FA	NC605 FA
	16	5	625	3NC625ZZYH4 FA	○ NC625 FA	3NC625ZZST4 FA	○ NC625 FA
6	10	3	WML6010	———	———	———	———
	12	4	WML6012	3NCWML6012ZZYH4 FA	NCWML6012 FA	3NCWML6012ZZST4 FA	NCWML6012 FA
	13	5	W686	3NCW686ZZYH4 FA	NCW686 FA	3NCW686ZZST4 FA	NCW686 FA
	17	6	606	3NC606ZZYH4 FA	○ NC606 FA	3NC606ZZST4 FA	○ NC606 FA
	19	6	626	3NC626ZZYH4 FA	NC626 FA	3NC626ZZST4 FA	NC626 FA
7	19	6	607	3NC607ZZYH4 FA	NC607 FA	3NC607ZZST4 FA	NC607 FA
	22	7	627	3NC627ZZYH4 FA	NC627 FA	3NC627ZZST4 FA	NC627 FA
8	22	7	608	3NC608ZZYH4 FA	○ NC608 FA	○ 3NC608ZZST4 FA	○ NC608 FA
	24	8	628	3NC628ZZYH4 FA	NC628 FA	3NC628ZZST4 FA	NC628 FA
9	24	7	609	3NC609ZZYH4 FA	NC609 FA	3NC609ZZST4 FA	NC609 FA
	26	8	629	3NC629ZZYH4 FA	NC629 FA	3NC629ZZST4 FA	NC629 FA
9.525	22.225	7	EE3S	3NCEE3SZZYH4 FA	NCEE3S FA	3NCEE3SZZST4 FA	NCEE3S FA
10	26	8	6000	3NC6000ZZYH4 FA	○ NC6000 FA	○ 3NC6000ZZST4 FA	○ NC6000 FA
	30	9	6200	3NC6200ZZYH4 FA	○ NC6200 FA	○ 3NC6200ZZST4 FA	○ NC6200 FA
12	28	8	6001	3NC6001ZZYH4 FA	○ NC6001 FA	○ 3NC6001ZZST4 FA	○ NC6001 FA
	32	10	6201	3NC6201ZZYH4 FA	○ NC6201 FA	○ 3NC6201ZZST4 FA	○ NC6201 FA
15	32	9	6002	3NC6002ZZYH4 FA	○ NC6002 FA	○ 3NC6002ZZST4 FA	○ NC6002 FA
	35	11	6202	3NC6202ZZYH4 FA	○ NC6202 FA	○ 3NC6202ZZST4 FA	○ NC6202 FA
17	35	10	6003	3NC6003ZZYH4 FA	○ NC6003 FA	○ 3NC6003ZZST4 FA	○ NC6003 FA
	40	12	6203	3NC6203ZZYH4 FA	○ NC6203 FA	○ 3NC6203ZZST4 FA	○ NC6203 FA
20	42	12	6004	3NC6004ZZYH4 FA	○ NC6004 FA	○ 3NC6004ZZST4 FA	○ NC6004 FA
	47	14	6204	3NC6204ZZYH4 FA	○ NC6204 FA	○ 3NC6204ZZST4 FA	○ NC6204 FA
25	47	12	6005	3NC6005ZZYH4 FA	○ NC6005 FA	○ 3NC6005ZZST4 FA	○ NC6005 FA
	52	15	6205	3NC6205ZZYH4 FA	○ NC6205 FA	○ 3NC6205ZZST4 FA	○ NC6205 FA
30	55	13	6006	3NC6006ZZYH4 FA	○ NC6006 FA	○ 3NC6006ZZST4 FA	○ NC6006 FA
	62	16	6206	3NC6206ZZYH4 FA	○ NC6206 FA	○ 3NC6206ZZST4 FA	○ NC6206 FA
35	62	14	6007	3NC6007ZZYH4 FA	NC6007 FA	3NC6007ZZST4 FA	NC6007 FA
	72	17	6207	3NC6207ZZYH4 FA	NC6207 FA	3NC6207ZZST4 FA	NC6207 FA
40	68	15	6008	3NC6008ZZYH4 FA	NC6008 FA	3NC6008ZZST4 FA	NC6008 FA
	80	18	6208	3NC6208ZZYH4 FA	NC6208 FA	3NC6208ZZST4 FA	NC6208 FA
Use and applicable range				• Non magnetism • Insulation • Fluctuation from atmospheric pressure to 10^{-5} Pa • –100 to 200˚C		• Insulation • Fluctuation from atmospheric pressure to 10^{-5} Pa • –100 to 200˚C	

Remarks: 1. For the allowable load and limiting speed of bearings consisting of high-hardened carbon ball or retainers of fluorocarbon resin (FA), see page 52 - 5.8.
2. For ceramic bearings for application to machine tools, see CAT. NO.297E "General Catalogue for Precision Rolling Bearings for Machine Tools/Precision Products."
3. For super thin section ball bearings for use in extreme special environments, K-series, see page 56.
4. Current stocks and delivery time are as follows. KOYO will continue increasing product stocks and shortening delivery time.
○ : Bearings able to be shipped immediately △ : Bearings able to be shipped in one month

5.8 Allowable Load and Limiting Speed (For Bearings with Solid Lubricant)

Boundary Dimensions mm			Basic Bearing Number	Allowable Load 1), N				Limiting Speed 2), rpm		
				Classification of bearings				Classification of bearings		
				Bearings consisting of fluorocarbon resin (FA) retainers		Bearings consisting of high-hardened carbon balls		Bearings consisting of fluorocarbon resin (FA) retainers	Bearings consisting of high-hardened carbon balls	Bearings consisting of fluorocarbon resin (FA) retainers and high-hardened carbon balls
d	*D*	*B*		Radial	Axial	Radial	Axial			
4	12	4	604	7.7	13	2.9	6.8	1 300	1 000	2 300
	13	5	624	11	18	4.0	9.3	1 600	1 000	2 300
5	14	5	605	11	18	4.0	9.3	1 300	1 000	2 300
	16	5	625	15	25	5.7	13	1 600	900	2 300
6	17	6	606	16	27	5.9	14	1 300	900	2 300
	19	6	626	20	33	7.8	18	1 600	800	2 300
7	19	6	607	20	33	7.8	18	1 300	800	2 300
	22	7	627	26	43	9.8	23	1 300	700	2 200
8	22	7	608	25	42	9.8	23	1 300	700	2 200
	24	8	628	27	45	10	23	1 200	600	2 100
9	24	7	609	27	45	10	23	1 200	600	2 100
	26	8	629	36	60	14	32	1 100	600	2 000
10	26	8	6000	33	55	13	31	1 100	600	2 100
	30	9	6200	51	85	20	34	1 000	500	2 000
12	28	8	6001	38	64	15	36	1 000	500	2 000
	32	10	6201	68	113	25	45	900	500	1 800
15	32	9	6002	43	72	17	39	900	400	2 000
	35	11	6202	75	126	29	53	800	400	1 600
17	35	10	6003	49	81	18	42	800	400	1 900
	40	12	6203	93	156	36	67	700	400	1 400
20	42	12	6004	69	114	26	65	700	300	1 600
	47	14	6204	128	214	50	89	600	300	900
25	47	12	6005	75	126	29	70	600	300	1 100
	52	15	6205	142	236	55	97	500	300	800
30	55	13	6006	96	160	37	92	500	200	900
	62	16	6206	194	323	75	134	400	200	600
35	62	14	6007	111	185	48	119	400	200	800
	72	17	6207	210	349	100	177	300	200	500
40	68	15	6008	134	223	50	123	300	200	700
	80	18	6208	231	386	114	202	300	200	400
Description				1) "Allowable load" refers to the maximum load when radial or axial loads are applied independently.				2) "Limiting speed" refers to the value for one half of the allowable radial load.		

Remarks: 1. This Table is applicable to the dimension Table for ceramic bearings and EXSEV bearings 5.1 through 5.7.
2. The allowable loads for bearings consisting of fluorocarbon (FA) retainers were determined after taking dust generation (cleanliness) into account.

6. Accuracy and Internal Clearance of Ceramic Bearings and EXSEV Bearings

The accuracy and internal clearance of ceramic bearings and EXSEV bearings have a large influence on the performances of the machines and equipment in which these bearings are used. These bearings should be selected on the basis of past experience.
For further advice, please contact KOYO.

6.1 Accuracy of Ceramic Bearings and EXSEV Bearings

The accuracy of bearings is divided into boundary dimensional accuracy and rotational accuracy. Accuracy is specified in ISO 492-1994 "Accuracy of Rolling Bearings."
The accuracy of the KOYO Ceramic Bearings and EXSEV Bearings is based on Classes 0, 6, and 5 of ISO. Higher accuracy bearings can be made on request. For such bearings, please contact KOYO.
The dimensional accuracy and rotational accuracy of the KOYO Ceramic Bearings and EXSEV Bearings are presented in Table 6.1.

6.2 Internal Clearance of Ceramic Bearings and EXSEV Bearings

The internal clearance of a bearing is defined as the displacement between the inner ring or outer ring when one of the two is fixed and the other is moved against it.
The internal clearance created when a bearing is running (called "running clearance") has a significant effect on rolling fatigue life, as well as heat generation, noise, vibration, and other faults.
The internal clearances of the KOYO Ceramic Bearings and EXSEV Bearings are based on M3 to M6 for miniature bearings and small ball bearings, and on CN to C4 for normal size bearings.
KOYO can supply bearings with special internal clearances. For further details, please contact KOYO.
The standard internal clearances of the KOYO Ceramic Bearings and EXSEV Bearings are presented in Tables 6.2 to 6.4.

(6.2 Internal Clearance of Ceramic Bearings and EXSEV Bearings)

Table 6.1 (1) Accuracy of Radial Bearings (Excl. tapered roller bearings)

(1) Inner ring (bore diameter)

Unit: μm

Bore Dia. d mm		Single Plane Mean Bore Diameter Deviation Δd_{mp}						Bore Diameter Variation in a Single Radial Plane Vd_p									Mean Bore Diameter Variation Vd_{mp}		
								Diameter series 7, 8, 9			Diameter series 0, 1			Diameter series 2, 3, 4					
		Class 0		Class 6		Class 5		Class 0	Class 6	Class 5	Class 0	Class 6	Class 5	Class 0	Class 6	Class 5	Class 0	Class 6	Class 5
Over	Up to	Upper	Lower	Upper	Lower	Upper	Lower	Maximum			Maximum			Maximum			Maximum		
0.6[1)]	2.5	0	− 8	0	− 7	0	− 5	10	9	5	8	7	4	6	5	4	6	5	3
2.5	10	0	− 8	0	− 7	0	− 5	10	9	5	8	7	4	6	5	4	6	5	3
10	18	0	− 8	0	− 7	0	− 5	10	9	5	8	7	4	6	5	4	6	5	3
18	30	0	− 10	0	− 8	0	− 6	13	10	6	10	8	5	8	6	5	8	6	3
30	50	0	− 12	0	− 10	0	− 8	15	13	8	12	10	6	9	8	6	9	8	4

(2) Inner ring (rotational accuracy and width)

Unit: μm

Bore Dia. d mm		Radial Runout K_{ia}			Face Runout with Bore S_d	Axial Runout S_{ia} [2)]	Deviation of Single Width ΔB_s						Deviation of Single Width for Matched Bearing ΔB_s [3)]						Width Variation VB_s		
		Class 0	Class 6	Class 5	Class 5	Class 5	Class 0		Class 6		Class 5		Class 0		Class 6		Class 5		Class 0	Class 6	Class 5
Over	Up to	Maximum			Maximum	Maximum	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Maximum		
0.6[1)]	2.5	10	5	4	7	7	0	− 40	0	− 40	0	− 40	–	–	–		0	− 250	12	12	5
2.5	10	10	6	4	7	7	0	− 120	0	− 120	0	− 40	0	− 250	0	− 250	0	− 250	15	15	5
10	18	10	7	4	7	7	0	− 120	0	− 120	0	− 80	0	− 250	0	− 250	0	− 250	20	20	5
18	30	13	8	4	8	8	0	− 120	0	− 120	0	− 120	0	− 250	0	− 250	0	− 250	20	20	5
30	50	15	10	5	8	8	0	− 120	0	− 120	0	− 120	0	− 250	0	− 250	0	− 250	20	20	5

Notes: 1) 0.6 mm is included in this category.
2) Applicable to deep groove ball bearings and angular ball bearings
3) Applicable to all bearing rings made for matched bearings

Table 6.1 (2) Accuracy of Radial Bearings (Excl. tapered roller bearings)

(3) Outer ring (outside diameter)

Unit: μm

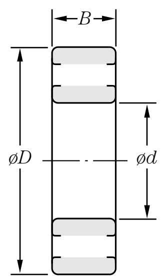
Outside Dia. D mm		Single Plane Mean Outside Diameter Deviation ΔD_{mp}						Outside Diameter Variation in a Single Radial Plane VD_p									Seal type		Mean Outside Dia. Variation VD_{mp}		
								Diameter series 7, 8, 9			Diameter series 0, 1			Diameter series 2, 3, 4			Diameter series				
																	2,3,4	0,1,2,3,4			
		Class 0		Class 6		Class 5		Class 0 [2)]	Class 6 [2)]	Class 5	Class 0 [2)]	Class 6 [2)]	Class 5	Class 0 [2)]	Class 6 [2)]	Class 5	Class 0 [2)]	Class 6 [2)]	Class 0 [2)]	Class 6 [2)]	Class 5
Over	Up to	Upper	Lower	Upper	Lower	Upper	Lower	Maximum			Maximum			Maximum			Maximum		Maximum		
2.5[1)]	6	0	− 8	0	− 7	0	− 5	10	9	5	8	7	4	6	5	4	10	9	6	5	3
6	18	0	− 8	0	− 7	0	− 5	10	9	5	8	7	4	6	5	4	10	9	6	5	3
18	30	0	− 9	0	− 8	0	− 6	12	10	6	9	8	5	7	6	5	12	10	7	6	3
30	50	0	− 11	0	− 9	0	− 7	14	11	7	11	9	5	8	7	5	16	13	8	7	4
50	80	0	− 13	0	− 11	0	− 9	16	14	9	13	11	7	10	8	7	20	16	10	8	5

(4) Outer ring (rotational accuracy and width)

Unit: μm

Outside Dia. D mm		Radial Runout K_{ea}			S_D	Axial Runout S_{ea} [3)]	Deviation of a Single Width ΔC_s		Width Variation VC_s	
		Class 0	Class 6	Class 5	Class 5	Class 5	Class 0, 6, 5		Class 0, 6	Class 5
Over	Up to	Maximum			Maximum	Maximum	Upper	Lower	Maximum	
2.5[1)]	6	15	8	5	8	8	Same as the tolerance of ΔB_s for d of the same bearing		Same as the allowable value of VB_s for d of the same bearing	5
6	18	15	8	5	8	8				5
18	30	15	9	6	8	8				5
30	50	20	10	7	8	8				5
50	80	25	13	8	8	10				6

Notes: 1) 2.5 mm is included in this category.
2) Applicable when no snap ring is fitted
3) Applicable to deep groove ball bearings and angular ball bearings



d: Nominal bearing bore diameter
D: Nominal bearing outside diameter
B: Nominal bearing width

[Tolerance Symbol]
SD: Variation of outside surface generatrix inclination with face

Table 6.2 Radial Internal Clearance of Deep Groove Ball Bearings (cylindrical bore)

Bore Dia. d, mm		Radial Internal Clearance, μm							
		CN		C3		C4		C5	
Over	Up to	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
2.5	6	2	13	8	23	14	29	20	37
6	10	2	13	8	23	14	29	20	37
10	18	3	18	11	25	18	33	25	45
18	24	5	20	13	28	20	36	28	48
24	30	5	20	13	28	23	41	30	53
30	40	6	20	15	33	28	46	40	64
40	50	6	23	18	36	30	51	45	73

Remark: When using the above values for measured clearances, correct them by adding the increased radial internal clearances caused by the measuring loads. The clearances to be added are shown below.

Bore Dia. d, mm		Measuring Load		Clearance to Be Added, μm			
Over	Up to	N	{kgf}	CN	C3	C4	C5
2.5	18	24.5	{2.5}	4	4	4	4
18	50	49	{5}	5	6	6	6

Table 6.3 Radial Internal Clearance of Miniature and Small Size Bearings

Symbol	M3		M4		M5		M6	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Radial Internal Clearance, μm	5	10	8	13	13	20	20	28

Remark: When using the above values for the measured clearances, correct them by adding the increased radial internal clearances caused by the measuring loads. The clearances to be added are shown below.

Miniature Ball Bearings, Small Size Ball Bearings	Clearance to Be Added, μm			
Measuring load, N {kgf}	M3	M4	M5	M6
2.3 {0.23}	1	1	1	1

Remark: Miniature ball bearings ... Bearings with an outside diameter of less than 9 mm
Small size ball bearings ... Bearings with an outside diameter of 9 mm or over and a bore diameter of less than 10 mm

Table 6.4 Radial Internal Clearance of Cylindrical Roller Bearings (with cylindrical bore)

Bore Dia. d, mm		Radial Internal Clearance, μm							
		CN		C3		C4		C5	
Over	Up to	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
–	10	20	45	35	60	50	75	–	–
10	24	20	45	35	60	50	75	65	90
24	30	20	45	35	60	50	75	70	95
30	40	25	50	45	70	60	85	80	105
40	50	30	60	50	80	70	100	95	125

7. Super Thin Section Ball Bearings, K-series, for Use in Extreme Special Environments

Lighter and more compact machines and equipment are demanded in every field of industry for the saving resources and energy.
In many cases, however, the size of the shafts (or bore diameter of the bearings) cannot be reduced limitlessly because of the demands for strength, rigidity, vibration, levels and other characteristics.
The principal measure for reducing bearing weight is to reduce its outside diameter, with its bore diameter remaining unchanged.
Under such circumstances, KOYO super thin section ball bearings, K-series, for use in extreme special environments have been applied widely to robots used in semiconductor production facilities and liquid crystal production facilities.
KOYO has standardized their super thin section ball bearings having a bore diameter of 3.5 inches (88.9 mm) and named them the K-series for use in extreme special environments." For any bearing of different dimensions, please contact KOYO.

7.1 Advantages of Super Thin Section Ball Bearings, K-series, for Use in Extreme Special Environments

1) Thin and lightweight
2) Same cross sectional dimensions independently of bore diameter
3) The EXSEV Specifications (ceramic balls, surface treatment, use of vacuum grease, etc.) are complied with.

The cross sectional dimensions of the super thin section ball bearings, K-series, for use in extreme special environments are compared to those of the standard type bearings and are shown in Fig. 7.1.

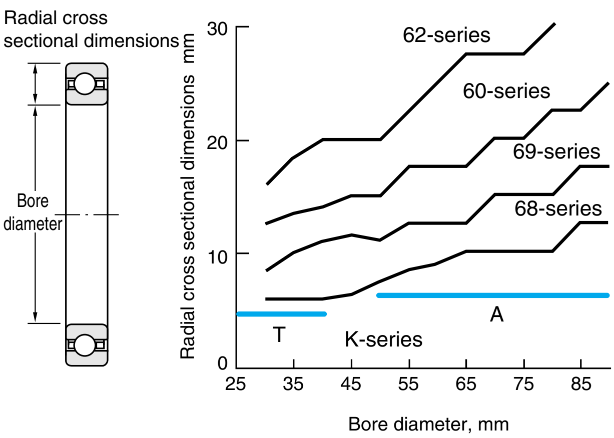


Fig. 7.1 Comparison of Cross Sectional Dimensions between the Super Thin Section Ball Bearings, K-series, for Use in Extreme Special Environments and Standard Type Bearings

• Super thin section ball bearings, K-series, for use in extreme special environments

7.2 Classification of Super Thin Section Ball Bearings, K-series, for Use in Extreme Special Environments

The classification and dimensioning system of the super thin section ball bearings, K-series, for use in extreme special environments are shown in table 7.1.
There are three types of extremely thin wall ball bearings, K-series, for use in extreme special environments; deep groove, angular, and four-point contact types.
The cross sectional dimensions are classified into three groups; 4.762, 6.35, and 7.938 mm, and the bore diameters are classified into 6 groups from 1 to 3.5 inches (25.4 to 88.9 mm).

Table 7.1 Classification and Dimensioning System of the Super Thin Section Ball Bearings, K-series, for Use in Extreme Special Environments

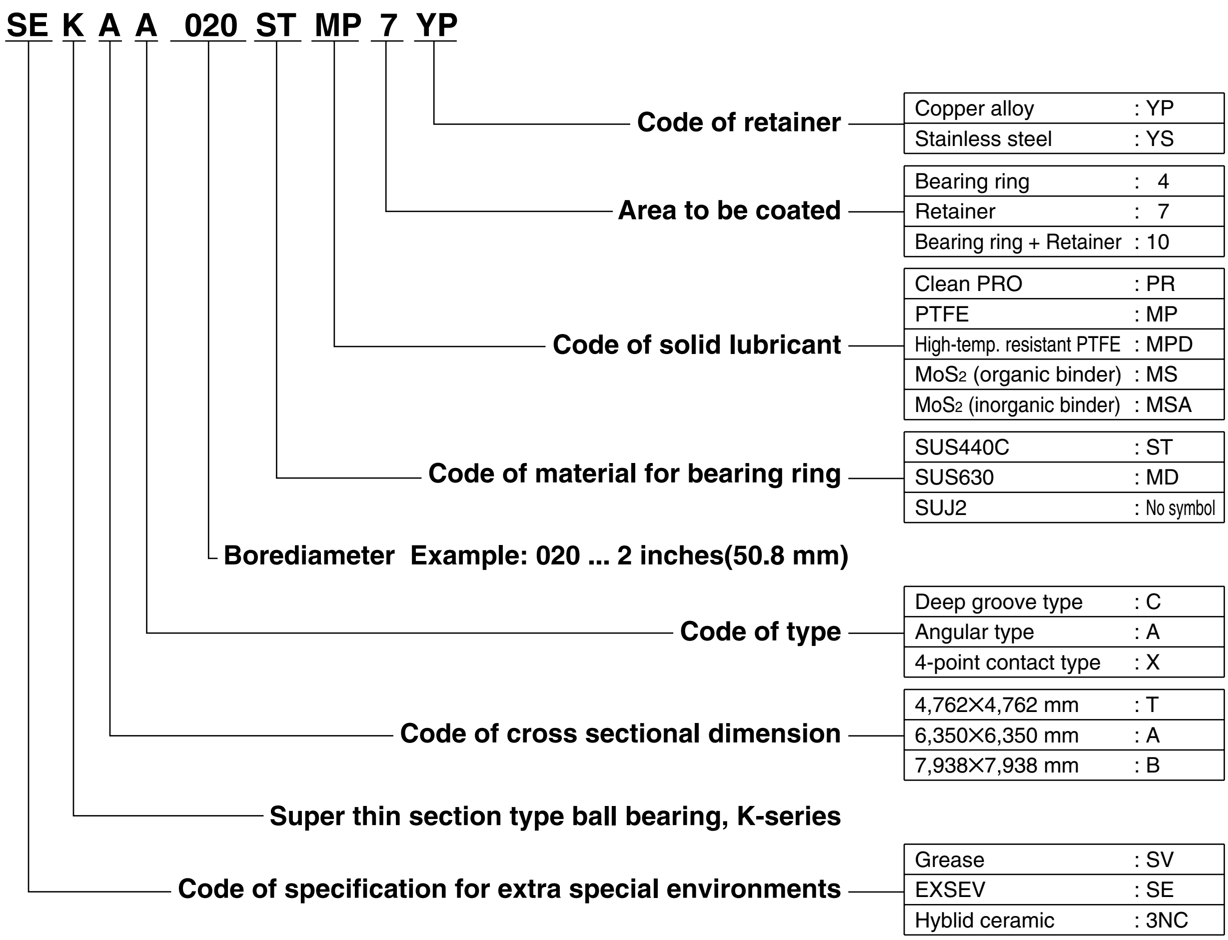
		Symbol for Bearing Type			
Symbol for dim. group	Cross sectional dimension $B = E$ mm	C (Deep groove type)	A (Angular type)	X (4-point contact type)	Bore diameter mm
T	4.762	KTC	KTA	KTX	25.4, 38.1
A	6.35	KAC	KAA	KAX	50.8 to 88.9
B	7.938	KBC	KBA	KBX	

7.3 Composition and Nominal Number of the Super Thin Section Ball Bearings, K-series, for Use in Extreme Special Environments

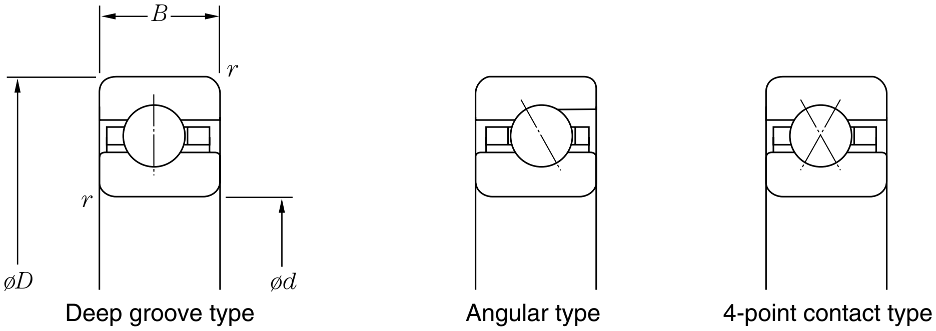
7.3.1 Example of Composition for the Super Thin Section Ball Bearings, K-series, for Use in Extreme Special Environments

Component	Material	Solid Lubricant	
Outer ring and inner ring	SUS440C, SUS630, or SUJ2	Special polymeric fluoride coating (Clean PRO)	PTFE or MoS_2 coating
Ball	SUS440C, ceramic, or SUJ2		Ag Ion-plating (for SUS440C only)
Retainer	Copper alloy or martensite stainless steel		PTFE or MoS_2 coating

7.3.2 Nominal Number of the Super Thin Section Ball Bearings, K-series, for Use in Extreme Special Environments



7.4 Dimensions Table for Super Thin Section Ball Bearings, K-series, for Use in Extreme Special Environments



Boundary Dimensions mm				Basic Number		
d	*D*	*B*	*r* (min.)	Deep groove type	Angular type	4-point contact type
25.4	34.925	4.762	0.4	**KTC010**	**KTA010**	**KTX010**
38.1	47.625	4.762	0.4	**KTC015**	**KTA015**	**KTX015**
50.8	63.5	6.35	0.6	**KAC020**	**KAA020**	**KAX020**
	66.675	7.938	1	**KBC020**	**KBA020**	**KBX020**
63.5	76.2	6.35	0.6	**KAC025**	**KAA025**	**KAX025**
	79.375	7.938	1	**KBC025**	**KBA025**	**KBX025**
76.2	88.9	6.35	0.6	**KAC030**	**KAA030**	**KAX030**
	92.075	7.938	1	**KBC030**	**KBA030**	**KBX030**
88.9	101.6	6.35	0.6	**KAC035**	**KAA035**	**KAX035**
	104.775	7.938	1	**KBC035**	**KBA035**	**KBX035**

Remark: The super thin section ball bearings, K-series, for use in extreme special environments are classified into three types; grease type (code: SV), EXSEV type (code: SE), and hyblid ceramic type (code: 3NC). Their codes are placed in front of the basic numbers.

8. Ceramic Balls

Ceramic balls (made of silicon nitride) are kept in our stock in series. They are advantageous in having a longer service life, lower friction resistance, higher seizure resistance, higher corrosion resistance, higher temperature resistance (up to 800˚C), higher rigidity, lightweight (40% of bearing steel), non magnetic, and insulated. They can be used even in an extra high-vacuum environment.
For use in jigs, tools, gauges, solenoid valves, check valves, other types of valves, high-grade bicycle parts, automotive parts, machine components, etc.

• Ceramic balls

Table 8.1 Dimension and Mass of Ceramic Balls (off-the-shelf)

Nominal number 0.8 to 3/8

Nominal number mm	Nominal number inch	Nominal Outside Diameter mm	Mass (per one ball)
0.8		0.800 00	0.866 mg
1.0		1.000 00	1.691 mg
1.2		1.200 00	2.922 mg
	1/16	1.587 50	6.766 mg
2.0		2.000 00	13.530 mg
	3/32	2.381 25	22.836 mg
	7/64	2.778 12	36.262 mg
	1/8	3.175 00	54.129 mg
3.5		3.500 00	72.511 mg
	5/32	3.968 75	0.105 7 g
	3/16	4.762 50	0.182 7 g
	7/32	5.556 25	0.290 1 g
	15/64	5.953 12	0.356 8 g
	1/4	6.350 00	0.433 0 g
	17/64	6.746 88	0.519 4 g
	9/32	7.143 75	0.616 6 g
	5/16	7.937 50	0.845 8 g
	11/32	8.731 25	1.125 7 g
	3/8	9.525 00	1.461 5 g

Nominal number 13/32 to 1 1/2

Nominal number mm	Nominal number inch	Nominal Outside Diameter mm	Mass (per one ball)
	13/32	10.318 75	1.858 2 g
	7/16	11.112 75	2.320 8 g
	15/32	11.906 25	2.854 5 g
	1/2	12.700 00	3.46 g
	17/32	13.493 75	4.2 g
	9/16	14.287 50	4.9 g
	19/32	15.081 25	5.8 g
	5/8	15.875 00	6.8 g
	3/4	19.050 00	11.7 g
	13/16	20.637 50	14.9 g
	7/8	22.225 00	18.6 g
	15/16	23.812 50	22.8 g
	1	25.400 00	27.7 g
	1 1/8	28.575 00	39.5 g
	1 3/16	30.162 50	46.4 g
	1 1/4	31.750 00	54.1 g
	1 5/16	33.337 50	62.7 g
	1 1/2	38.100 00	93.5 g

Remark: The masses are calculated on the basis of 3.23 g/cm^3 in density.

9. A Series of Linear Motion Bearings for Use in Extreme Special Environments

Similarly to the normal bearings for use in extra special environments, there are also linear motion bearings for use under the same conditions.
Their bodies are made of stainless steel, but the balls are made of ceramics or the steel balls are lubricated with a solid lubricant so that they can work efficiently in a vacuum, a clean environment, high temperatures, or a corrosive environment.

• Linear motion bearings for use in extreme special environments

9.1 Linear Motion Ball Bearings for Use in Extreme Special Environments

Linear motion bearings are made with precision to enable them to move linearly in axial directions, while the balls are kept in rolling contact with the shafts.
With a retainer, balls, side wall, and other components assembled into the external cylinder, this type of bearing is very compact and moves linearly with no stroke limitation.
Since the retainer is constructed so as to circulate the balls smoothly, high-precision positioning can be achieved with less frictional resistance.

• Linear motion ball bearings for use in extreme special environments

9.1.1 An Example of the Composition of a Linear Motion Ball Bearing for Use in Extreme Special Environments

Component	Material	Solid Lubricant	
External cylinder	SUS440C	Special polymeric fluoride coating (Clean PRO)	
Ball	SUS440C		Ag[1] Ion-plating
	Si_3N_4 (ceramic)		
Retainer	SUS304		PTFE or MoS_2 coating
Side plate	SUS631		

Note: 1) Applicable to shaft diameters of 10, 12, and 13 mm
Remark: Stainless steel shafts are also available from KOYO.

9.1.2 Composition of Nominal Number of Linear Motion Ball Bearings for Use in Extreme Special Environments

SE SDM 10 W OP ST 5 MP 7

- **7** — Code of area to be coated

Ball	: 3
Retainer	: 7

- **MP** — Code of solid lubricant

Clean PRO	: PR
General purpose PTFE	: MP
High-temp. resistant PTFE	: MPD
MoS_2 (organic binder)	: MS
MoS_2 (inorganic binder)	: MSA
Ag	: MG

- **5** — Code of stainless steel component

Component made of SUS440C	Cylinder : 1(3NC)
	Cylinder and ball : 5

- **ST** — Code of material (SUS440C)
- **OP** — Code of type (2)

Clearance adjustment type	: AJ
Open type	: OP

- **W** — Code of type (1)

Standard type	: No symbol
Tandem type	: W

- **10** — Bore diameter
- **SDM** — Code of linear ball bearing series

mm series	: SDM
inch series	: SDB
mm series (for Europe) [1)]	: SDE

With circular flange: SDMF, SDBF, SDEF	
With square flange: SDMK, SDBK, SDEK	

- **SE** — Code of specification for extreme special environments

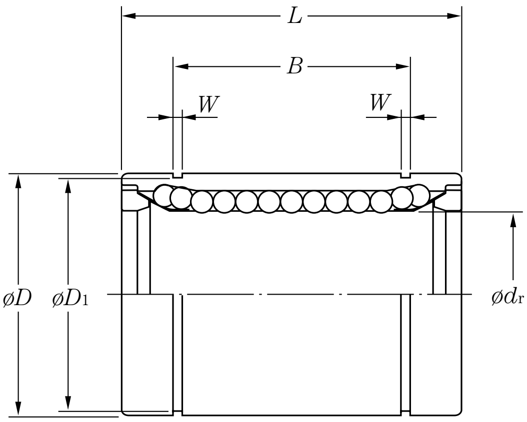
Grease	: SV
EXSEV	: SE
Hyblid ceramic	: 3NC

Note: 1) No dimension table for linear motion ball bearings of mm-series (for Europe) is presented here. Please contact KOYO when necessary.

9.1.3 Dimensions Table for Linear Motion Ball Bearings for Use in Extreme Special Environments

1. SDM Series

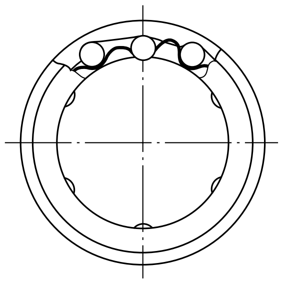
mm series



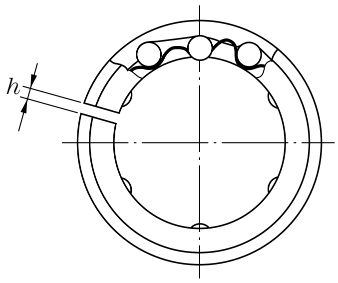
Shaft diameter mm	Standard type			Clearance adjustment type (AJ)			Open type (OP)		
	Basic number	Number of ball rows	Mass g	Basic number	Number of ball rows	Mass g	Basic number	Number of ball rows	Mass g
3	SDM 3	4	1.4						
4	SDM 4	4	2						
5	SDM 5	4	4						
6	SDM 6	4	8.5						
8	SDM 8S	4	11						
8	SDM 8	4	17						
10	SDM10	4	36						
12	SDM12	4	42	SDM12 AJ	4	41	SDM12 OP	3	32
13	SDM13	4	49	SDM13 AJ	4	48	SDM13 OP	3	37
16	SDM16	4	76	SDM16 AJ	4	75	SDM16 OP	3	58
20	SDM20	5	100	SDM20 AJ	5	98	SDM20 OP	4	79
25	SDM25	6	240	SDM25 AJ	6	237	SDM25 OP	5	203
30	SDM30	6	270	SDM30 AJ	6	262	SDM30 OP	5	228
35	SDM35	6	425	SDM35 AJ	6	420	SDM35 OP	5	355
40	SDM40	6	654	SDM40 AJ	6	640	SDM40 OP	5	546
50	SDM50	6	1 700	SDM50 AJ	6	1 680	SDM50 OP	5	1 420
60	SDM60	6	2 000	SDM60 AJ	6	1 980	SDM60 OP	5	1 650

Remark: The linear motion ball bearings for use in extra special environments are classified into three types; grease type (code: SV), EXSEV type (code: SE), and hyblid ceramic type (code: 3NC). Their codes are placed in front of the basic numbers.

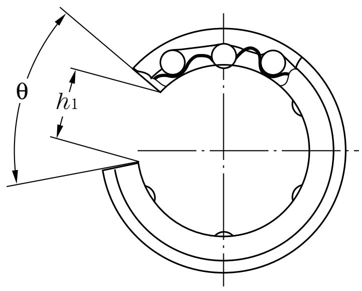
Standard type
SDM



Clearance adjustment type
SDM..AJ



Open type
SDM..OP

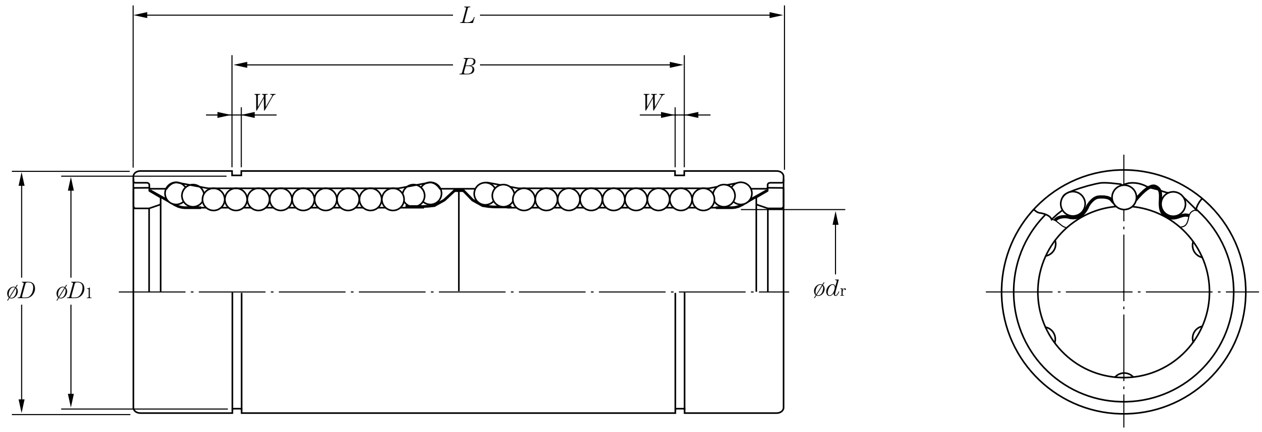


d_r mm	Basic number	Boundary dimensions mm								Basic dynamic load rating C N	Basic static load rating C_0 N
		D	L	B	W	D_1	h	h_1	θ (degree)		
3	SDM 3	7	10							69	105
4	SDM 4	8	12							88	127
5	SDM 5	10	15	10.2	1.1	9.6				167	206
6	SDM 6	12	19	13.5	1.1	11.5				206	265
8	SDM 8S	15	17	11.5	1.1	14.3				176	216
8	SDM 8	15	24	17.5	1.1	14.3				274	392
10	SDM10	19	29	22	1.3	18				372	549
12	SDM12	21	30	23	1.3	20	1.5	8	80	510	784
13	SDM13	23	32	23	1.3	22	1.5	9	80	510	784
16	SDM16	28	37	26.5	1.6	27	1.5	11	80	774	1 180
20	SDM20	32	42	30.5	1.6	30.5	1.5	11	60	882	1 370
25	SDM25	40	59	41	1.85	38	2	12	50	980	1 570
30	SDM30	45	64	44.5	1.85	43	2.5	15	50	1 570	2 740
35	SDM35	52	70	49.5	2.1	49	2.5	17	50	1 670	3 140
40	SDM40	60	80	60.5	2.1	57	3	20	50	2 160	4 020
50	SDM50	80	100	74	2.6	76.5	3	25	50	3 820	7 940
60	SDM60	90	110	85	3.15	86.5	3	30	50	4 700	10 000

(9.1.3 Dimensions Table for Linear Motion Ball Bearings for Use in Extreme Special Environments)

2. SDM .. W Series

mm series · Tandem type



Shaft diameter mm	Basic number	Mass g	Boundary dimensions mm					
			d_r	Tolerance µm	D	Tolerance µm	L	Tolerance µm
5	**SDM 5W**	11	5	0 − 10	10	0 − 11	28	0 − 300
6	**SDM 6W**	16	6		12	0 − 13	35	
8	**SDM 8W**	31	8		15		45	
10	**SDM10W**	62	10		19	0 − 16	55	
12	**SDM12W**	80	12		21		57	
13	**SDM13W**	90	13		23		61	
16	**SDM16W**	145	16		28		70	
20	**SDM20W**	180	20	0 − 12	32	0 − 19	80	
25	**SDM25W**	440	25		40		112	0 − 400
30	**SDM30W**	480	30		45		123	
35	**SDM35W**	795	35	0 − 15	52	0 − 22	135	
40	**SDM40W**	1 170	40		60		151	
50	**SDM50W**	3 100	50		80		192	
60	**SDM60W**	3 500	60	0 − 20	90	0 − 25	209	

Remark: The linear motion ball bearings for use in extra special environments are classified into three types; grease type (code: SV), EXSEV type (code: SE), and hyblid ceramic type (code: 3NC). Their codes are placed in front of the basic numbers.

d_r mm	Basic number	Boundary dimensions mm				Basic dynamic load rating C N	Basic static load rating C_0 N
		B	Tolerance μm	W	D_1		
5	SDM 5W	20.4	0 − 300	1.1	9.6	265	412
6	SDM 6W	27		1.1	11.5	323	530
8	SDM 8W	35		1.1	14.3	431	784
10	SDM10W	44		1.3	18	588	1 100
12	SDM12W	46		1.3	20	813	1 570
13	SDM13W	46		1.3	22	813	1 570
16	SDM16W	53		1.6	27	1 230	2 350
20	SDM20W	61		1.6	30.5	1 400	2 740
25	SDM25W	82	0 − 400	1.85	38	1 560	3 140
30	SDM30W	89		1.85	43	2 490	5 490
35	SDM35W	99		2.1	49	2 650	6 270
40	SDM40W	121		2.1	57	3 430	8 040
50	SDM50W	148		2.6	76.5	6 080	15 900
60	SDM60W	170		3.15	86.5	7 550	20 000

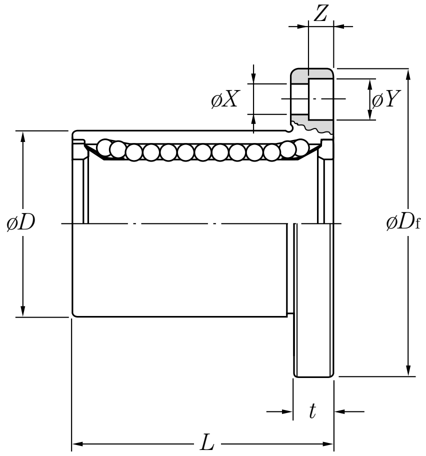
(9.1.3 Dimensions Table for Linear Motion Ball Bearings for Use in Extreme Special Environments)

3. SDMF / SDMK Series

mm series · with flange

- With circular flange SDMF series
- With square flange SDMK series

d_r 6 to 16 mm



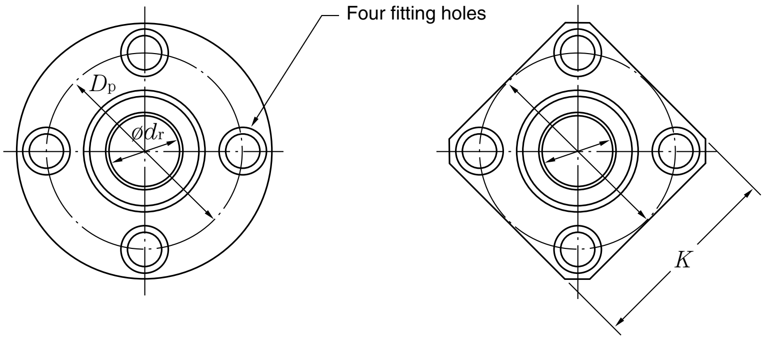
Shaft diameter (d_r) mm	Basic number	Mass g	Boundary dimensions mm									Eccentricity (max.) μm	Squareness (max.) μm	Basic dynamic load rating C N	Basic static load rating C_0 N
			D	L	D_f	K	t	D_p	X	Y	Z				
6	**SDMF 6** **SDMK 6**	24 18	12	19	28	22	5	20	3.5	6	3.1	12	12	206	265
8	**SDMF 8S** **SDMK 8S**	32 24	15	17	32	25	5	24	3.5	6	3.1			176	216
8	**SDMF 8** **SDMK 8**	37 29	15	24	32	25	5	24	3.5	6	3.1			274	392
10	**SDMF 10** **SDMK 10**	72 52	19	29	40	30	6	29	4.5	7.5	4.1			372	549
12	**SDMF 12** **SDMK 12**	76 57	21	30	42	32	6	32	4.5	7.5	4.1			510	784
13	**SDMF 13** **SDMK 13**	88 72	23	32	43	34	6	33	4.5	7.5	4.1			510	784
16	**SDMF 16** **SDMK 16**	120 104	28	37	48	37	6	38	4.5	7.5	4.1			774	1 180

Remark: The linear motion ball bearings for use in extra special environments are classified into three types; grease type (code: SV), EXSEV type (code: SE), and hyblid ceramic type (code: 3NC). Their codes are placed in front of the basic numbers.

d_r 20 to 60 mm

With circular flange
SDMF series

With square flange
SDMK series



Shaft diameter (d_r) mm	Basic number	Mass g	Boundary dimensions mm									Eccent-ricity (max.) μm	Square-ness (max.) μm	Basic dynamic load rating C N	Basic static load rating C_0 N
			D	L	D_f	K	t	D_p	X	Y	Z				
20	**SDMF 20** **SDMK 20**	180 145	32	42	54	42	8	43	5.5	9	5.1			882	1 370
25	**SDMF 25** **SDMK 25**	340 300	40	59	62	50	8	51	5.5	9	5.1	15	15	980	1 570
30	**SDMF 30** **SDMK 30**	470 375	45	64	74	58	10	60	6.6	11	6.1			1 570	2 740
35	**SDMF 35** **SDMK 35**	650 560	52	70	82	64	10	67	6.6	11	6.1			1 670	3 140
40	**SDMF 40** **SDMK 40**	1 060 880	60	80	96	75	13	78	9	14	8.1	20	20	2 160	4 020
50	**SDMF 50** **SDMK 50**	2 200 2 000	80	100	116	92	13	98	9	14	8.1			3 820	7 940
60	**SDMF 60** **SDMK 60**	3 000 2 560	90	110	134	106	18	112	11	17	11.1	25	25	4 700	10 000

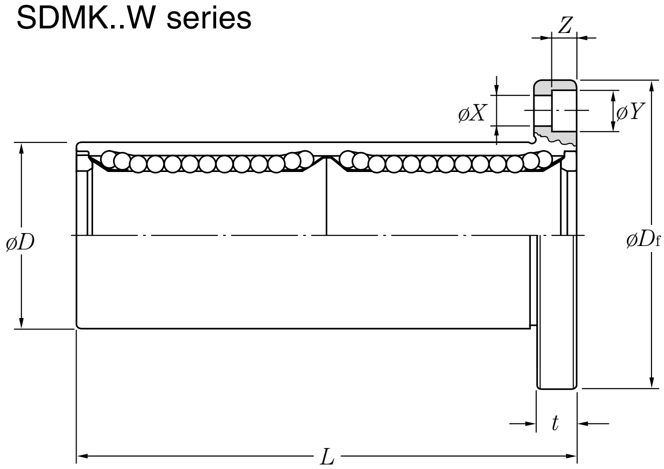
(9.1.3 Dimension Table for Linear Motion Ball Bearings for Use in Extreme Special Environments)

4. SDMF..W / SDMK..W Series

mm series · tandem type · with flange

- Dual type with circular flange SDMF..W series
- Dual type with square flange SDMK..W series

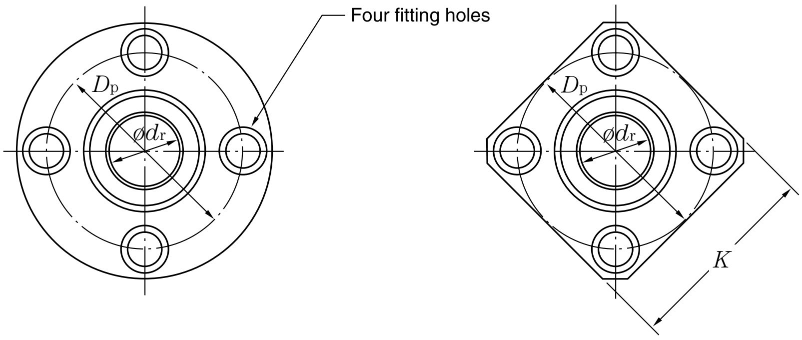
d_r 6 to 16 mm



Shaft diameter (d_r) mm	Basic number	Mass g	Boundary dimensions mm									Eccentricity (max.) µm	Squareness (max.) µm	Basic dynamic load rating C N	Basic static load rating C_0 N
			D	L	D_f	K	t	D_p	X	Y	Z				
6	SDMF 6W SDMK 6W	31 25	12	35	28	22	5	20	3.5	6	3.1	15	15	323	530
8	SDMF 8W SDMK 8W	51 43	15	45	32	25	5	24	3.5	6	3.1			431	784
10	SDMF 10W SDMK 10W	98 78	19	55	40	30	6	29	4.5	7.5	4.1			588	1 100
12	SDMF 12W SDMK 12W	110 90	21	57	42	32	6	32	4.5	7.5	4.1			813	1 570
13	SDMF 13W SDMK 13W	130 108	23	61	43	34	6	33	4.5	7.5	4.1			813	1 570
16	SDMF 16W SDMK 16W	190 165	28	70	48	37	6	38	4.5	7.5	4.1			1 230	2 350

Remark: The linear motion ball bearings for use in extra special environments are classified into three types; grease type (code: SV), EXSEV type (code: SE), and hyblid ceramic type (code: 3NC). Their codes are placed in front of the basic numbers.

d_r 20 to 60 mm

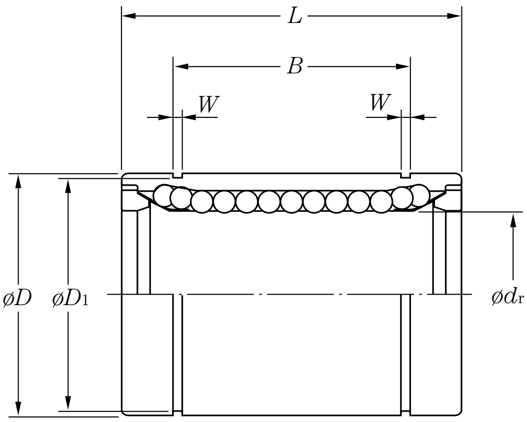


Shaft diameter (d_r) mm	Basic number	Mass g	Boundary dimensions mm									Eccent-ricity (max.) μm	Square-ness (max.) μm	Basic dynamic load rating C N	Basic static load rating C_0 N
			D	L	D_f	K	t	D_p	X	Y	Z				
20	SDMF 20W SDMK 20W	260 225	32	80	54	42	8	43	5.5	9	5.1	20	20	1 400	2 740
25	SDMF 25W SDMK 25W	540 500	40	112	62	50	8	51	5.5	9	5.1			1 560	3 140
30	SDMF 30W SDMK 30W	680 590	45	123	74	58	10	60	6.6	11	6.1			2 490	5 490
35	SDMF 35W SDMK 35W	1 020 930	52	135	82	64	10	67	6.6	11	6.1	25	25	2 650	6 270
40	SDMF 40W SDMK 40W	1 570 1 380	60	151	96	75	13	78	9	14	8.1			3 430	8 040
50	SDMF 50W SDMK 50W	3 600 3 400	80	192	116	92	13	98	9	14	8.1			6 080	15 900
60	SDMF 60W SDMK 60W	4 500 4 060	90	209	134	106	18	112	11	17	11.1	30	30	7 550	20 000

(9.1.3 Dimensions Table for Linear Motion Ball Bearings for Use in Extreme Special Environments)

5. SDB Series

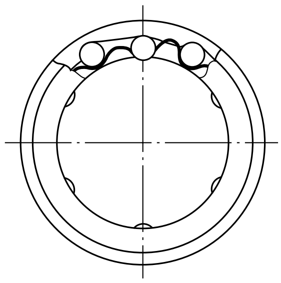
inch series



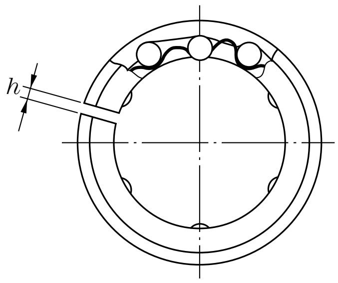
Shaft diameter mm	Standard type			Clearance adjustment type (AJ)			Open type (OP)		
	Basic number	Number of ball rows	Mass g	Basic number	Number of ball rows	Mass g	Basic number	Number of ball rows	Mass g
6.350	SDB 4	3	9.5						
9.525	SDB 6	4	15						
12.700	SDB 8		42	SDB 8 AJ	4	41	SDB 8 OP	3	32
15.857	SDB10		85	SDB10 AJ		83	SDB10 OP		64
19.050	SDB12	5	104	SDB12 AJ	5	102	SDB12 OP	4	86
25.400	SDB16	6	220	SDB16 AJ	6	218	SDB16 OP	5	190
31.750	SDB20		465	SDB20 AJ		455	SDB20 OP		390
38.100	SDB24		720	SDB24 AJ		710	SDB24 OP		610
50.800	SDB32		1 310	SDB32 AJ		1 290	SDB32 OP		1 120

Remark: The linear motion ball bearings for use in extra special environments are classified into three types; grease type (code: SV), EXSEV type (code: SE), and hyblid ceramic type (code: 3NC). Their codes are placed in front of the basic numbers.

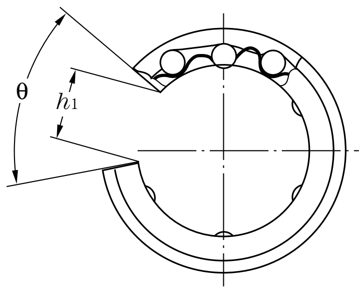
Standard type
SDB



Clearance adjustment type
SDB..AJ



Open type
SDB..OP

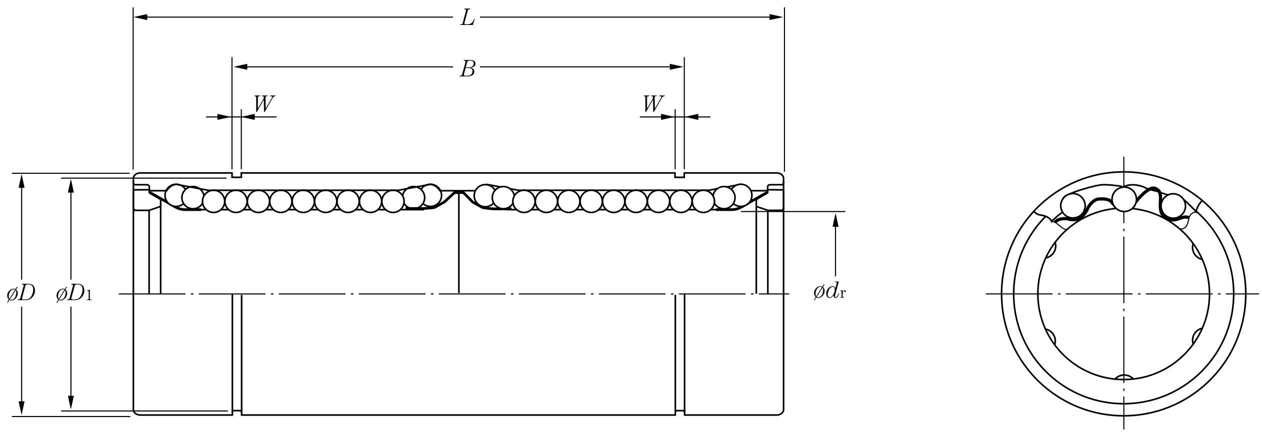


d_r mm	Basic number	Boundary dimensions mm								Basic dynamic load rating C N	Basic static load rating C_0 N
		D	L	B	W	D_1	h	h_1	θ (degree)		
6.350	SDB 4	12.700	19.050	12.98	0.992	11.906				206	265
9.525	SDB 6	15.875	22.225	16.15	0.992	14.935				225	314
12.700	SDB 8	22.225	31.750	24.46	1.168	20.853	1.5	7.938	80	510	784
15.857	SDB10	28.575	38.100	28.04	1.422	26.899	1.5	9.525	80	774	1 180
19.050	SDB12	31.750	41.275	29.61	1.422	29.870	1.5	11.112	60	862	1 370
25.400	SDB16	39.688	57.150	44.57	1.727	37.306	1.5	14.288	50	980	1 570
31.750	SDB20	50.800	66.675	50.92	1.727	47.904	2.5	15.875	50	1 570	2 740
38.100	SDB24	60.325	76.200	61.26	2.184	56.870	3	19.050	50	2 180	4 020
50.800	SDB32	76.200	101.600	81.07	2.616	72.085	3	25.400	50	3 820	7 940

(9.1.3 Dimensions Table for Linear Motion Ball Bearings for Use in Extreme Special Environments)

6. SDB.. W Series

inch series · tandem type



Shaft diameter mm	Basic number	Mass g	Boundary dimensions mm					
			d_r	Tolerance µm	D	Tolerance µm	L	Tolerance µm
6.350	SDB 4W	17.5	6.350	0 − 10	12.700	0 − 13	34.925	0 − 300
9.525	SDB 6W	28	9.525		15.875	0 − 16	40.481	
12.700	SDB 8W	80	12.700		22.225		60.325	
15.875	SDB10W	160	15.875		28.575		71.438	
19.050	SDB12W	195	19.050	0 − 12	31.750	0 − 19	78.581	
25.400	SDB16W	410	25.400		39.688		108.744	0 − 400
31.750	SDB20W	820	31.750	0 − 15	50.800	0 − 22	127.000	
38.100	SDB24W	1 250	38.100		60.325		144.463	
50.800	SDB32W	2 350	50.800		76.200	0 − 25	196.850	

Remark: The linear motion ball bearings for use in extra special environments are classified into three types; grease type (code: SV), EXSEV type (code: SE), and hyblid ceramic type (code: 3NC). Their codes are placed in front of the basic numbers.

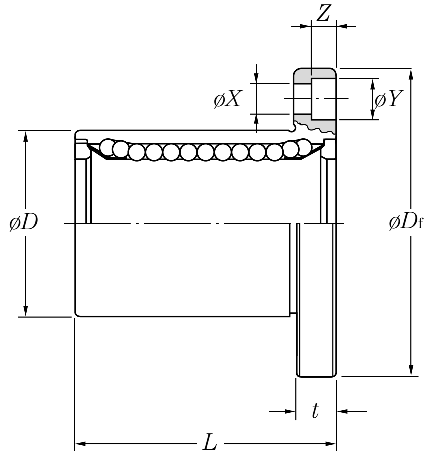
d_r mm	Basic number	Boundary dimensions mm				Basic dynamic load rating C N	Basic static load rating C_0 N
		B	Tolerance µm	W	D_1		
6.350	SDB 4W	25.959	0 − 300	0.992	11.906	323	530
9.525	SDB 6W	32.298		0.992	14.935	353	630
12.700	SDB 8W	48.895		1.168	20.853	813	1 570
15.875	SDB10W	56.080		1.422	26.899	1 230	2 350
19.050	SDB12W	59.218		1.422	29.870	1 370	2 740
25.400	SDB16W	89.139	0 − 400	1.727	37.306	1 570	3 140
31.750	SDB20W	101.839		1.727	47.904	2 500	5 490
38.100	SDB24W	122.519		2.184	56.870	3 430	8 040
50.800	SDB32W	162.138		2.616	72.085	6 080	15 900

(9.1.3 Dimensions Table for Linear Motion Ball Bearings for Use in Extreme Special Environments)

7. SDBF / SDBK Series

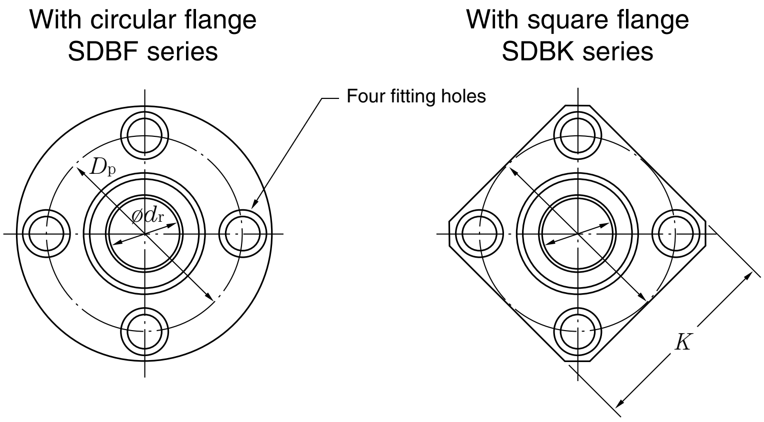
inch series · with flange

- With circular flange SDBF series
- With square flange SDBK series



Shaft diameter mm	Basic number	Mass g	Boundary dimensions mm						
			D	L	D_f	K	t	D_p	
6.350	SDBF 4 SDBK 4	32 25	12.700	19.050	31.750	25.400	5.556	22.225	
9.525	SDBF 6 SDBK 6	47 32	15.875	22.225	38.100	31.750	6.350	26.988	
12.700	SDBF 8 SDBK 8	88 68	22.225	31.750	44.450	34.925	6.350	33.338	
15.875	SDBF10 SDBK10	140 124	28.575	38.100	50.800	38.100	6.350	39.688	
19.050	SDBF12 SDBK12	190 150	31.750	41.275	55.563	42.863	7.938	43.660	
25.400	SDBF16 SDBK16	325 280	39.688	57.150	63.500	50.800	7.938	51.594	
31.750	SDBF20 SDBK20	665 580	50.800	66.675	79.375	63.500	9.525	65.088	
38.100	SDBF24 SDBK24	1 100 930	60.325	76.200	95.250	76.200	12.700	77.788	
50.800	SDBF32 SDBK32	1 760 1 580	76.200	101.600	111.125	88.900	12.700	93.662	

Remark: The linear motion ball bearings for use in extra special environments are classified into three types; grease type (code: SV), EXSEV type (code: SE), and hyblid ceramic type (code: 3NC). Their codes are placed in front of the basic numbers.



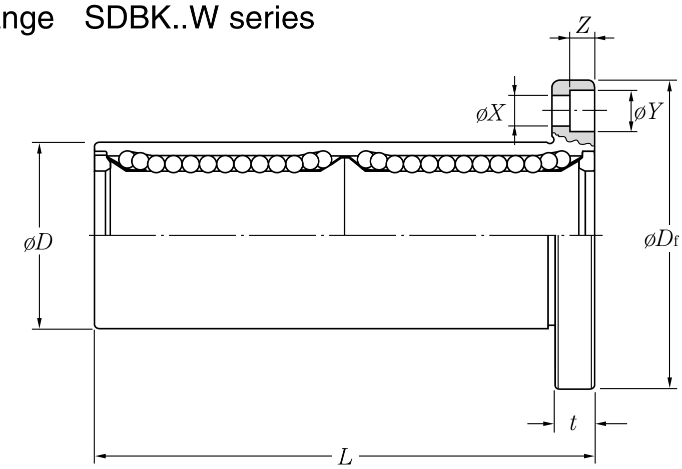
	d_r mm	Basic number	Boundary dimensions mm			Eccentricity (maximum) µm	Squareness (maximum) µm	Basic dynamic load rating *C* N	Basic static load rating C_0 N
			X	*Y*	*Z*				
	6.350	**SDBF 4** **SDBK 4**	3.969	6.350	3.572	12	12	206	265
	9.525	**SDBF 6** **SDBK 6**	4.763	7.541	4.366			225	314
	12.700	**SDBF 8** **SDBK 8**	4.763	7.541	4.366			510	784
	15.875	**SDBF10** **SDBK10**	4.763	7.541	4.366			774	1 180
	19.050	**SDBF12** **SDBK12**	5.556	8.731	5.159	15	15	862	1 370
	25.400	**SDBF16** **SDBK16**	5.556	8.731	5.159			980	1 570
	31.750	**SDBF20** **SDBK20**	7.144	10.319	6.747	20	20	1 570	2 740
	38.100	**SDBF24** **SDBK24**	8.731	12.700	8.334			2 180	4 020
	50.800	**SDBF32** **SDBK32**	8.731	12.700	8.334	25	25	3 820	7 940

(9.1.3 Dimensions Table for Linear Motion Ball Bearings for Use in Extreme Special Environments)

8. SDBF..W / SDBK..W Series

inch series · tandem type · with flange

- Tandem type with circular flange SDBF..W series
- Tandem type with square flange SDBK..W series

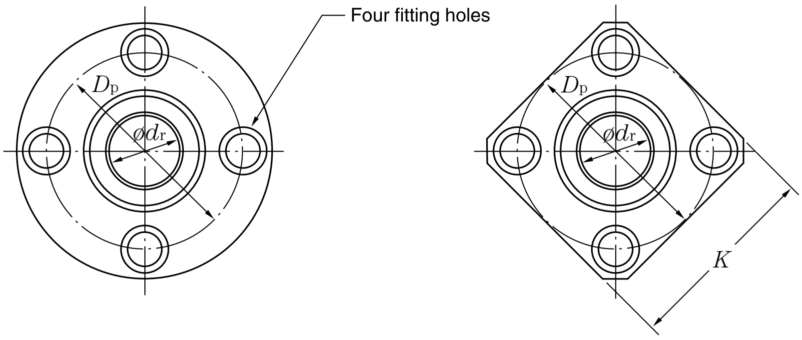


Shaft diameter mm	Basic number	Mass g	Boundary dimensions mm					
			D	L	D_f	K	t	D_p
6.350	**SDBF 4W** **SDBK 4W**	40 33	12.700	34.925	31.750	25.400	5.556	22.225
9.525	**SDBF 6W** **SDBK 6W**	60 45	15.875	40.481	38.100	31.750	6.350	26.988
12.700	**SDBF 8W** **SDBK 8W**	126 106	22.225	60.325	44.450	34.925	6.350	33.338
15.875	**SDBF 10W** **SDBK10W**	215 200	28.575	71.438	50.800	38.100	6.350	39.688
19.050	**SDBF 12W** **SDBK12W**	280 240	31.750	78.581	55.563	42.863	7.938	43.656
25.400	**SDBF 16W** **SDBK16W**	515 470	39.688	108.744	63.500	50.800	7.938	51.594
31.750	**SDBF 20W** **SDBK20W**	1 020 935	50.800	127.000	79.375	63.500	9.525	65.088
38.100	**SDBF 24W** **SDBK24W**	1 630 1 460	60.325	144.463	95.250	76.200	12.700	77.788
50.800	**SDBF 32W** **SDBK32W**	2 800 2 620	76.200	196.850	111.125	88.900	12.700	93.662

Remark: The linear motion ball bearings for use in extra special environments are classified into three types; grease type (code: SV), EXSEV type (code: SE), and hyblid ceramic type (code: 3NC). Their codes are placed in front of the basic numbers.

With circular flange
SDBF..W series

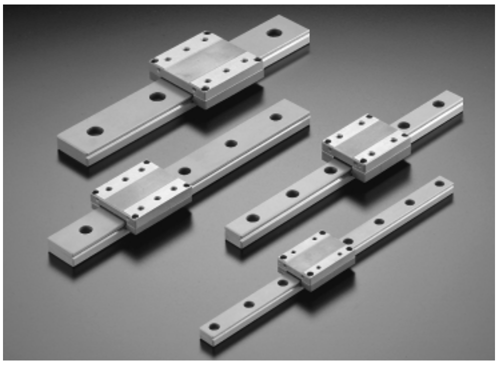
With square flange
SDBK..W series



d_r mm	Basic number	Boundary dimensions mm			Eccentricity (maximum) µm	Squareness (maximum) µm	Basic dynamic load rating C N	Basic static load rating C_0 N
		X	Y	Z				
6.350	SDBF 4W SDBK 4W	3.969	6.350	3.572	15	15	323	530
9.525	SDBF 6W SDBK 6W	4.763	7.541	4.366			353	630
12.700	SDBF 8W SDBK 8W	4.763	7.541	4.366			813	1 570
15.875	SDBF 10W SDBK10W	4.763	7.541	4.366			1 230	2 350
19.050	SDBF 12W SDBK12W	5.556	8.731	5.159	20	20	1 370	2 740
25.400	SDBF 16W SDBK16W	5.556	8.731	5.159			1 570	3 140
31.750	SDBF 20W SDBK20W	7.144	10.319	6.747	25	25	2 500	5 490
38.100	SDBF 24W SDBK24W	8.731	12.700	8.334			3 430	8 040
50.800	SDBF 32W SDBK32W	8.731	12.700	8.334	30	30	6 080	15 900

9.2 Linear Way Bearing Units for Use in Extreme Special Environments

The Linear Way bearing unit is constructed to enable the balls to circulate inside the slide unit. The slide unit moves linearly on the track rail with no stroke limitation. High-precision linear motion can be obtained by simply fastening a device to the slide unit, and the track rail to a base using bolts.



• Linear way bearing units for use in extreme special environments

9.2.1 Example of Composition of the Linear Way Bearing Unit for Use in Extreme Special Environments

Component	Material	Solid lubricant	
Casing	SUS440C	Special polymeric fluoride coating (Clean PRO)	PTFE or MoS_2 coating
Track rail	SUS440C		
Ball	SUS440C		Ag Ion-plating
	Si_3N_4 (ceramic)		
Side plate	SUS304		PTFE or MoS_2 coating

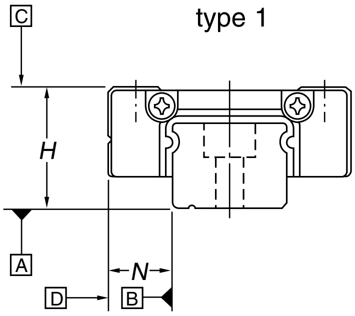
9.2.2 Composition of Nominal Number of the Linear Way Bearing Unit for Use in Extreme Special Environments

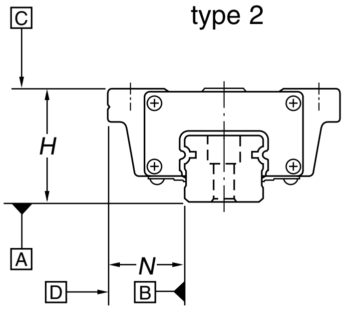
SE LWHS 20 C2 R500 MP 4

- **4** — Code of area to be coated
  - Casing : 1
  - Track rail : 2
  - Ball : 3
  - Casing + Track rail : 4
  - Whole area : No symbol
- **MP** — Code of solid lubricant
  - Clean PRO : PR
  - PTFE : MP
  - MoS_2 (inorganic binder) : MSA
  - Ag : MG
- **R500** — Track rail length
- **C2** — Code of quantity of casing
- **20** — Size
- **LWHS** — Code of Linear Way series
  - High-rigidity type : LWHS
  - Compact type : LWES
  - Miniature (L) type : LWL
  - Miniature (LF) type : LWLF
- **SE** — Code of specification for extra special environments
  - Grease : SV
  - EXSEV : SE
  - Hyblid ceramic : 3NC

(9.2 Linear Way for Use in Extreme Special Environments)

9.2.3 Accuracy of the Linear Way Bearing Unit for Use in Extreme Special Environments (Values before surface treatment)





Unit: mm

Item	LWL LWLF LWLC LWLFC LWLG LWLFG (type 1)	LWES LWHS LWESC LWESG (type 2)
Tolerance of *H* Variation of *H* [1)]	± 0.020 0.015 max.	± 0.040 0.015 max.
Tolerance of *N* [2)] Variation of *N* [2) 3)]	± 0.025 0.020 max.	± 0.050 0.020 max.
Degree of parallelism of C-plane to A-plane during operation Degree of parallelism of D-plane to B-plane during operation	Fig. 9.1	Fig. 9.2

Notes 1) The variation of the dimension *H* is defined as the dimensional variation between the slide units hyblid into the same track rail or in more than one track rail.

2) The variation of the dimension *N* is defined as the dimensional variation between the slide units assembled into the same track rail.

Remark: The pre-load is zero or very small.

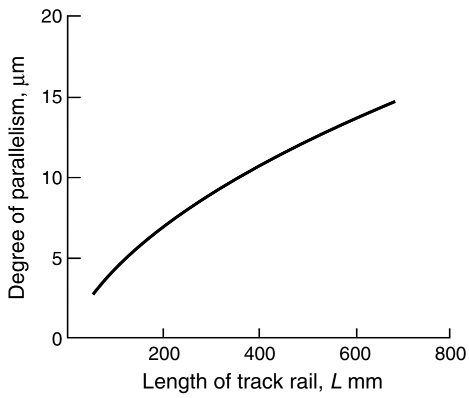


Fig. 9.1 Degree of Parallelism of the Linear Way Bearing Unit (Type 1) during Operation

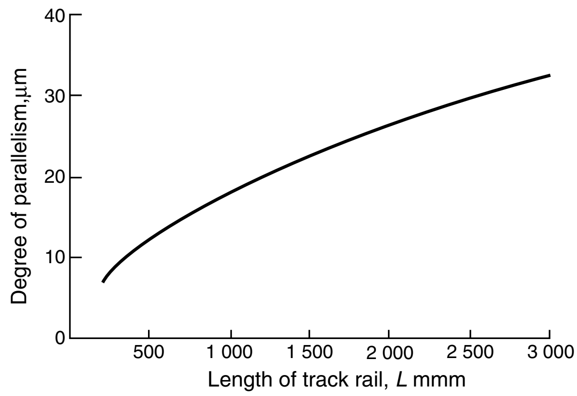
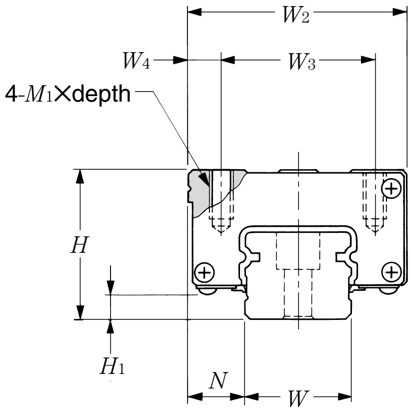


Fig. 9.2 Degree of Parallelism of the Linear Way Bearing Unit (Type 2) during Operation

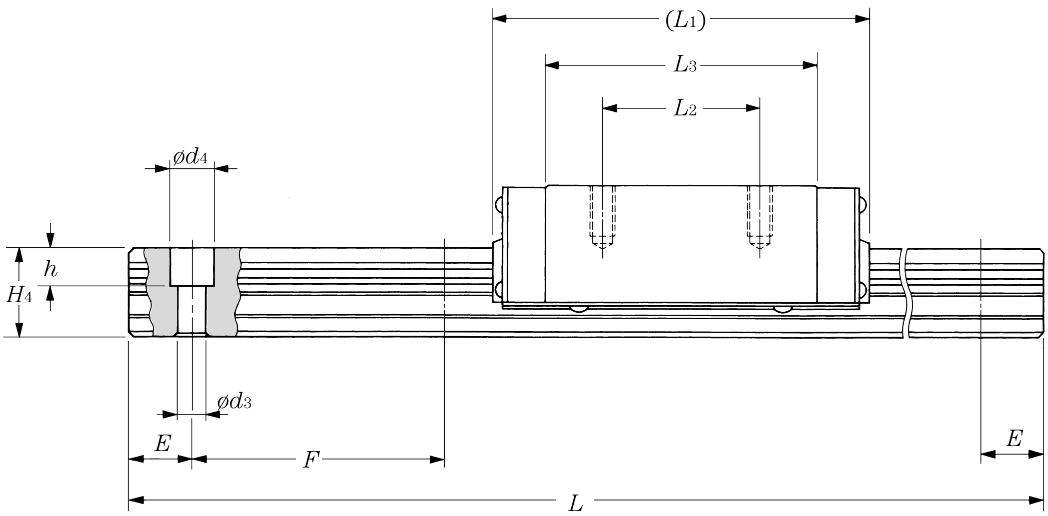
9.2.4 Dimensions Table for the Linear Way Bearing Units for Use in Extreme Special Environments

1. LWHS Series



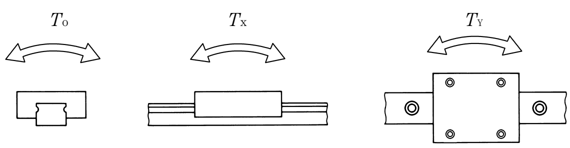
Basic Number	Mass (for reference) Slide unit kg	Mass (for reference) Track rail kg / m	Dimensions of Assembly mm H	H_1	N	Rail Width mm W	Dimensions of Slide Unit mm W_2	W_3	W_4	L_1	L_2	L_3	M_1 × depth
LWHS 15	0.18	1.47	24	4.5	9.5	15	34	26	4	66	26	44.6	M4× 8
LWHS 20	0.36	2.56	30	5	12	20	44	32	6	83	36	57.2	M5×10
LWHS 25	0.55	3.50	36	6.5	12.5	23	48	35	6.5	95	35	64.7	M6×12
LWHS 30	1.00	4.82	42	7	16	28	60	40	10	113	40	80.6	M8×16

Remark: The Linear Way bearing units for use in extra special environments are classified into three types; grease type (code: SV), EXSEV type (code: SE), and hyblid ceramic type (code: 3NC). Their codes are placed in front of the basic numbers.



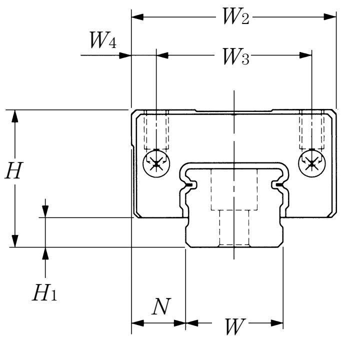
Basic Number	Dimensions of Track Rail mm						Track Rail Fitting Bolt mm (nominal) × ℓ	Max. Length of Track Rail L mm	Basic Dynamic Load Rating C N	Basic Static Load Rating C_0 N	Static Moment Rating [1)]		
	H_4	d_3	d_4	h	E	F					T_O N·m	T_X N·m	T_Y N·m
LWHS 15	15	4.5	8	6	30	60	M4×16	600	9 350	13 900	116	99.2 577	99.2 577
LWHS 20	18	6	9.5	8.5	30	60	M5×18	600	14 500	21 900	241	202 1 130	202 1 130
LWHS 25	22	7	11	9	30	60	M6×22	600	20 100	29 800	376	320 1 750	320 1 750
LWHS 30	25	9	14	12	40	80	M8×28	600	28 100	42 200	646	556 2 930	556 2 930

Note: 1) The static moment ratings T_O, T_X, and T_Y are respectively the static moment in the direction specified below. Each of the upper values in the T_X and T_Y columns shows the moment for a single slide unit, and the lower value shows the moment for two slide units in close contact.

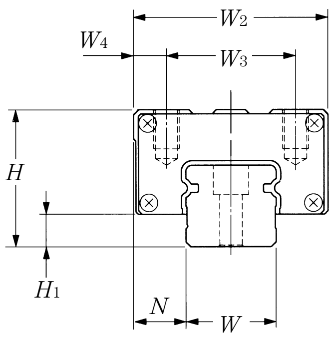


(9.2.4 Dimensions Table for the Linear Way Bearing Units for Use in Extreme Special Environments)

2. LWES Series



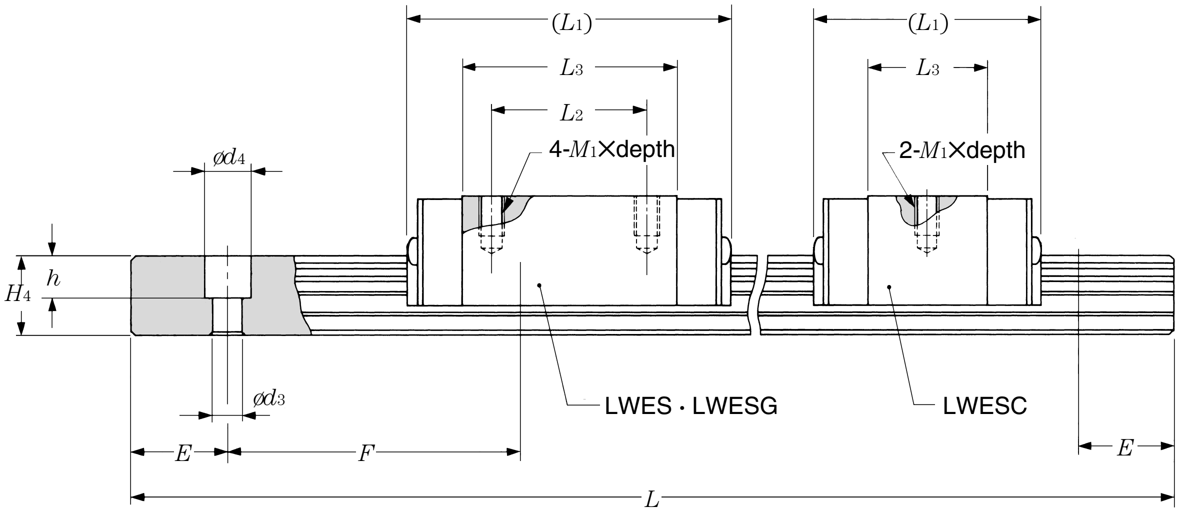
LWESC15 to 25
LWES 15 to 25
LWESG15 to 25



LWESC30
LWES 30
LWESG30

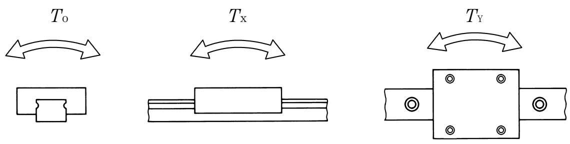
Basic Number	Mass (for reference) Slide unit kg	Track rail kg / m	Dimensions of Assembly mm H	H_1	N	Rail Width mm W	Dimensions of Slide Unit mm W_2	W_3	W_4	L_1	L_2	L_3	M_1 × depth
LWESC15	0.09									41	–	22.4	
LWES 15	0.14	1.57	24	5.8	9.5	15	34	26	4	57	26	38.4	M4× 7
LWESG15	0.18									70	36	51.1	
LWESC20	0.15									47	–	24.5	
LWES 20	0.25	2.28	28	6	11	20	42	32	5	66.5	32	44	M5× 8
LWESG20	0.33									82	45	59.9	
LWESC25	0.26									59	–	32	
LWES 25	0.42	3.09	33	7	12.5	23	48	35	6.5	83	35	56	M6× 9
LWESG25	0.55									102	50	75	
LWESC30	0.46									68	–	36	
LWES 30	0.78	5.09	42	10	16	28	60	40	10	97	40	64.8	M8×12
LWESG30	1.13									128.5	60	96.5	

Remark: The Linear Way bearing units for use in extra special environments are classified into three types; grease type (code: SV), EXSEV type (code: SE), and hyblid ceramic type (code: 3NC). Their codes are placed in front of the basic numbers.



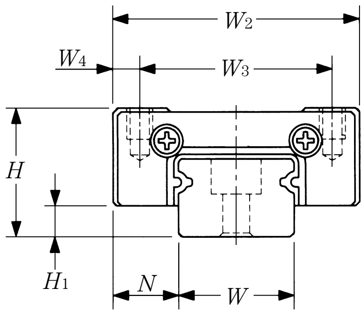
Basic Number	Dimensions of Track Rail mm						Track Rail Fitting Bolt mm (nominal)×ℓ	Max. Length of Track Rail L mm	Basic Dynamic Load Rating C N	Basic Static Load Rating C_o N	Static Moment Rating [1]		
	H_4	d_3	d_4	h	E	F					T_o N·m	T_X N·m	T_Y N·m
LWESC15								600	4 330	5 680	45.4	22.1 155	22.1 155
LWES 15	14.5	3.6	6.5	4.5	20	60	M3×16	600	6 200	9 740	77.9	59.8 346	59.8 346
LWESG15								600	7 520	13 000	104	103 553	103 553
LWESC20								600	6 250	7 610	81.8	32.6 244	32.6 244
LWES 20	16	6	9.5	8.5	20	60	M5×16	600	9 360	13 900	150	99.2 582	99.2 582
LWESG20								600	11 500	19 000	204	178 952	178 952
LWESC25								600	10 100	12 800	159	74.5 498	74.5 498
LWES 25	19	7	11	9	20	60	M6×20	600	14 500	21 900	272	202 1 130	202 1 130
LWESG25								600	17 600	29 200	362	348 1 810	348 1 810
LWESC30								600	16 800	19 500	298	134 887	134 887
LWES 30	25	7	11	9	20	80	M6×25	600	23 600	32 500	497	340 1 990	340 1 990
LWESG30								600	30 900	48 700	745	730 3 810	730 3 810

Note: 1) The static moment ratings T_O, T_X, and T_Y are respectively the static moment in the direction specified below. Each of the upper values in the T_X and T_Y columns shows the moment for a single slide unit, and the lower value shows the moment for two slide units in close contact.



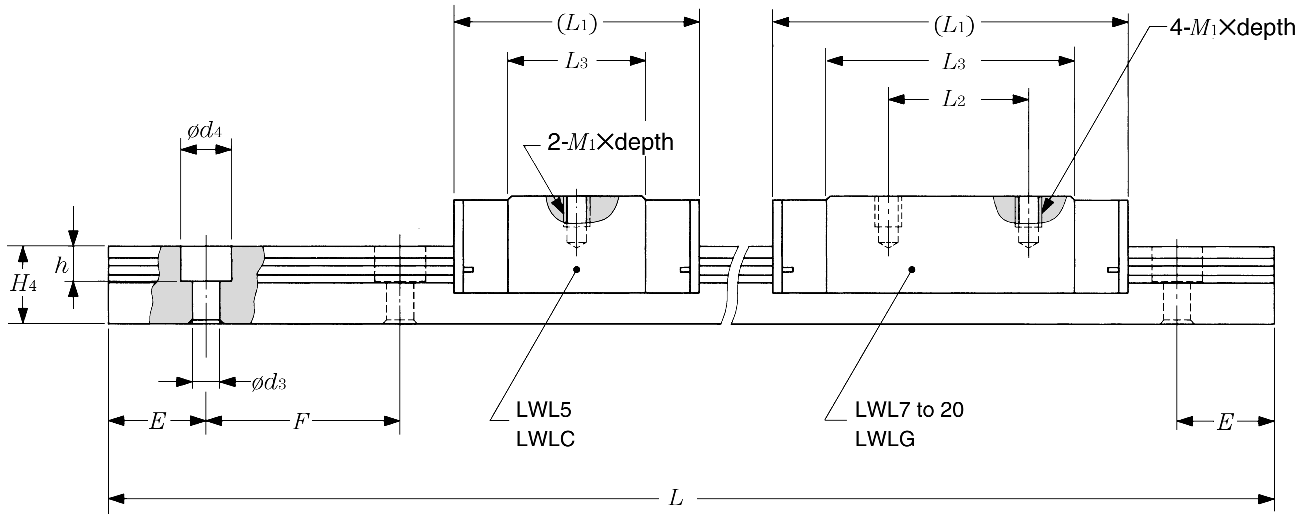
(9.2.4 Dimensions Table for the Linear Way Bearing Units for Use in Extreme Special Environments)

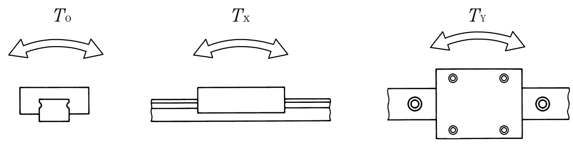
3. LWL Series



Basic Number	Mass (for reference) Slide unit g	Mass (for reference) Track rail g/100mm	Dimensions of Assembly mm H	H_1	N	Rail Width mm W	Dimensions of Slide Unit mm W_2	W_3	W_4	L_1	L_2	L_3	M_1 × depth
LWLC 5	3.4	12	6	1	3.5	5	12	8	2	16	–	9.6	M2×1.5
LWL 5	4.4									19	–	12.6	
LWLC 7	7.1	22	8	1.5	5	7	17	12	2.5	19	–	9.6	M2×2.5
LWL 7	10									23.5	8	14.3	
LWLG 7	14									31	12	21.6	
LWLC 9	11	35	10	2	5.5	9	20	15	2.5	21.5	–	11.9	M3×3
LWL 9	19									30	10	20.8	
LWLG 9	28									40.5	15	30.9	
LWLC12	22	65	13	3	7.5	12	27	20	3.5	25	–	13	M3×3.5
LWL 12	35									34	15	21.6	
LWLG12	51									44	20	32	
LWLC15	42	107	16	4	8.5	15	32	25	3.5	32	–	17.7	M3×4
LWL 15	64									42	20	27.8	
LWLG15	95									57	25	42.7	
LWLC20	89	156	20	5	10	20	40	30	5	38	–	22.3	M4×6
LWL 20	133									50	25	34.6	
LWLG20	196									68	30	52.3	

Remark: The Linear Way bearing units for use in extra special environments are classified into three types; grease type (code: SV), EXSEV type (code: SE), and hyblid ceramic type (code: 3NC). Their codes are placed in front of the basic numbers.



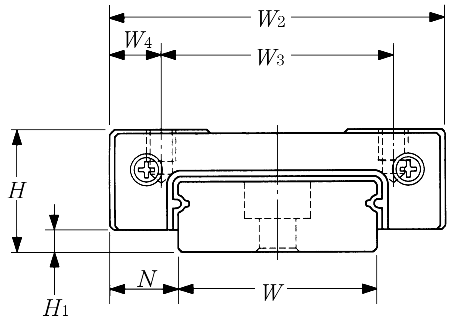


Basic Number	Dimensions of Track Rail mm H_4	d_3	d_4	h	E	F	Track Rail Fitting Bolt mm (nominal) × ℓ	Max. Length of Track Rail L mm	Basic Dynamic Load Rating C N	Basic Static Load Rating C_0 N	Static Moment Rating [1] T_0 N·m	T_X N·m	T_Y N·m
LWLC 5	3.7	2.4	3.6	0.8	7.5	15	Cross-recessed round head screw M2×6	210	514	872	2.3	1.4 8.9	1.2 7.4
LWL 5									612	1 130	3.0	2.4 13.3	2.0 11.2
LWLC 7	5	2.4	4.2	2.3	7.5	15	Hexagon socket head cap screw M2×6	300	856	1 180	4.3	1.9 15.4	1.6 12.9
LWL 7									1 200	1 960	7.2	4.9 29.2	4.1 24.5
LWLG 7									1 510	2 750	10.0	9.1 52.6	7.7 44.1
LWLC 9	6	3.5	6	3.5	10	20	Hexagon socket head cap screw M3×8	600	1 070	1 540	7.2	3.0 22.2	2.5 18.6
LWL 9									1 610	2 860	13.3	9.4 53.0	7.9 44.5
LWLG 9									2 080	4 180	19.4	19.4 102	16.3 85.6
LWLC12	8	3.5	6.5	4.5	12.5	25	Hexagon socket head cap screw M3×8	600	2 000	2 470	15.3	5.5 43.3	4.7 36.3
LWL 12									2 960	4 450	27.6	16.0 96.6	13.4 81.1
LWLG12									3 780	6 430	39.9	31.8 174	26.7 146
LWLC15	10	3.5	6.5	4.5	20	40	Hexagon socket head cap screw M3×10	600	3 120	4 040	31.1	12.1 87.6	10.2 73.5
LWL 15									4 390	6 730	51.8	30.8 178	25.9 149
LWLG15									5 750	10 100	77.7	66.2 351	55.6 294
LWLC20	11	6	9.5	5.5	30	60	Hexagon socket head cap screw M5×14	600	4 070	5 490	56.0	20.2 138	16.9 116
LWL 20									5 830	9 420	96.1	54.6 291	45.8 244
LWLG20									7 350	13 300	136	106 549	88.9 461

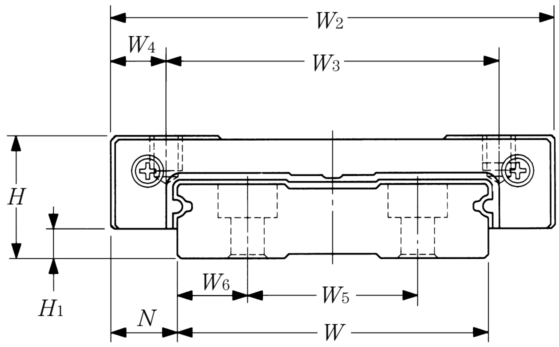
Note: 1) The static moment ratings T_0, T_X, and T_Y are respectively the static moment in the direction specified below. Each of the upper values in the T_X and T_Y columns shows the moment for a single slide unit, and the lower value shows the moment for two slide units in close contact.

(9.2.4 Dimensions Table for the Linear Way Bearing Units for Use in Extreme Special Environments)

4. LWLF Series



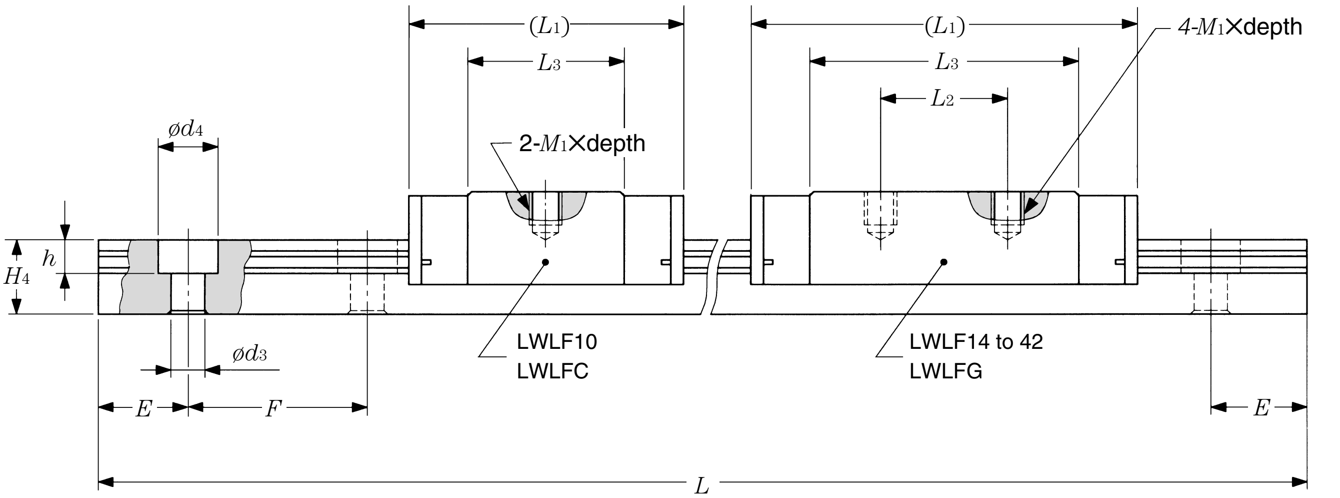
LWLFC10 to 30
LWLF 10 to 30
LWLFG14 to 30

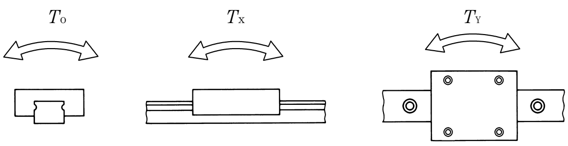


LWLFC42
LWLF 42
LWLFG42

Basic Number	Mass (for reference)		Dimensions of Assembly mm			Rail Width mm	Dimensions of Slide Unit mm						
	Slide unit g	Track rail g/100mm	H	H_1	N	W	W_2	W_3	W_4	L_1	L_2	L_3	M_1 × depth
LWLFC10	5.9	28	6.5	1.5	3.5	10	17	13	2	20.5	–	13.6	M2.5×1.5
LWLF 10	7.5									24.5	–	17.6	
LWLFC14	13									22.5	–	13	
LWLF 14	21	54	9	2	5.5	14	25	19	3	31.5	10	22	M3×3
LWLFG14	31									42	19	32.5	
LWLFC18	26							21	4.5	26.5	–	16.6	
LWLF 18	44	90	12	3	6	18	30			39	12	28.6	M3×3
LWLFG18	61							23	3.5	50.5	24	40.4	
LWLFC24	45									30.5	–	17.7	
LWLF 24	76	139	14	3	8	24	40	28	6	44	15	31	M3×3.5
LWLFG24	111									59	28	46.3	
LWLFC30	70									35.5	–	20.5	
LWLF 30	112	198	15	3	10	30	50	35	7.5	50	18	34.8	M4×4.5
LWLFG30	170									68.5	35	53.8	
LWLFC42	95									41.5	–	25.3	
LWLF 42	140	294	16	4	9	42	60	45	7.5	55	20	39	M4×4.5
LWLFG42	204									74.5	35	58.3	

Remark: The Linear Way bearing units for use in extra special environments are classified into three types; grease type (code: SV), EXSEV type (code: SE), and hyblid ceramic type (code: 3NC). Their codes are placed in front of the basic numbers.





Basic Number	Dimensions of Track Rail mm								Track Rail Fitting Bolt mm (nominal) × ℓ	Max. Length of Track Rail L mm	Basic Dynamic Load Rating C N	Basic Static Load Rating C_0 N	Static Moment Rating [1]		
	H_4	W_5	W_6	d_3	d_4	h	E	F					T_O N·m	T_X N·m	T_Y N·m
LWLFC10	4	–	–	2.9	4.8	1.6	10	20	Cross-recessed round head screw M2.5×7	300	643	1 220	6.3	2.7 15.4	2.3 13.0
LWLF 10											760	1 570	8.1	4.4 23.3	3.7 19.5
LWLFC14	5.5	–	–	3.5	6	3.2	15	30	Hexagon socket head cap screw M3×8	300	1 120	1 770	12.6	4.0 25.6	3.3 21.4
LWLF 14											1 580	2 940	21.0	10.4 56.7	8.7 47.6
LWLFG14											2 040	4 320	30.9	21.8 108	18.3 90.8
LWLFC18	7	–	–	3.5	6.5	4.5	15	30	Hexagon socket head cap screw M3×8	600	1 360	2 200	20.1	5.8 37.2	4.8 31.3
LWLF 18											2 010	3 960	36.2	17.5 93.4	14.7 78.4
LWLFG18											2 500	5 500	50.3	33.0 165	27.7 139
LWLFC24	8	–	–	4.5	8	4.5	20	40	Hexagon socket head cap screw M4×10	600	2 500	3 460	42.2	10.1 70.2	8.5 58.9
LWLF 24											3 780	6 430	78.4	31.8 174	26.7 146
LWLFG24											4 870	9 400	115	65.6 333	55.0 280
LWLFC30	9	–	–	4.5	8	4.5	20	40	Hexagon socket head cap screw M4×12	600	3 460	4 710	71.6	16.0 111	13.4 93.2
LWLF 30											5 230	8 750	133	50.5 269	42.4 226
LWLFG30											6 730	12 800	194	104 526	87.4 442
LWLFC42	10	23	9.5	4.5	8	4.5	20	40	Hexagon socket head cap screw M4×12	600	4 450	6 280	133	25.7 170	21.6 143
LWLF 42											6 150	10 200	216	63.6 346	53.3 290
LWLFG42											7 910	14 900	316	131 668	110 561

Note: 1) The static moment ratings T_O, T_X, and T_Y are respectively the static moment in the direction specified below. Each of the upper values in the T_X and T_Y columns shows the moment for a single slide unit, and the lower value shows the moment for two slide units in close contact.

9.3 Cross Roller Way Bearing Units for Use in Extreme Special Environments

The Cross Roller Way bearing unit is a linear motion unit in which cylindrical rollers are mounted on a raceway base. These rollers are housed in a retainer. The raceway base consists of two v-shaped surfaces.
In this type of bearing unit, cylindrical rollers are arranged alternately at right angles. This unit has a smooth and extremely accurate linear motion even if loaded from any direction.

• Cross roller way bearing units for use in extreme special environments

9.3.1 Composition of Cross Roller Way Bearing Unit for Use in Extreme Special Environments

Part	Material	Solid Lubricant	
Raceway base	SUS440C	Special polymeric fluoride coating (Clean PRO)	PTFE or MoS_2 coating
Cylindrical roller	SUS440C		
Retainer	SUS304		PTFE or MoS_2 coating

9.3.2 Composition of Nominal Number of Cross Roller Way Bearing Unit for Use in Extreme Special Environments

SE CRW 3 – 75 C20 MP 4

- **4** — Code of area to be coated

Raceway base	: 4
Whole area	: No symbol

- **MP** — Code of solid lubricant

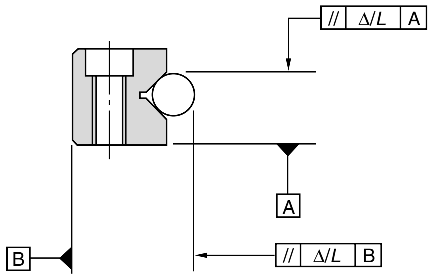
Clean PRO	: PR
PTFE	: MP
MoS_2 (inorganic binder)	: MSA

- **C20** — Quantity of cylindrical rollers built into a single unit
- **75** — Length of raceway base
- **3** — Diameter of cylindrical roller
- **CRW** — Cross roller way
- **SE** — Code of specification for extra special environments

Grease	: SV
EXSEV	: SE

9.3.3 Accuracy of Cross Roller Way Bearing Units for Use in Extreme Special Environments

The degree of parallelism of the raceway surface with respect to the datum clamp face of the cross roller way bearing unit is as shown in Fig. 9.3.



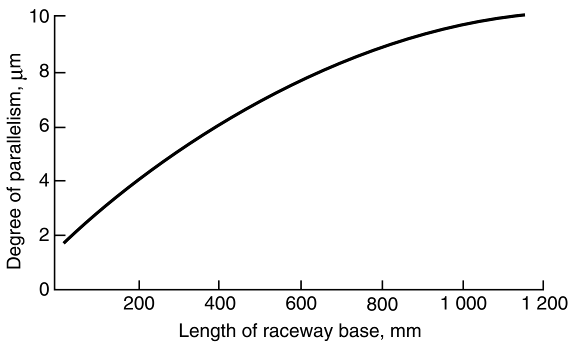
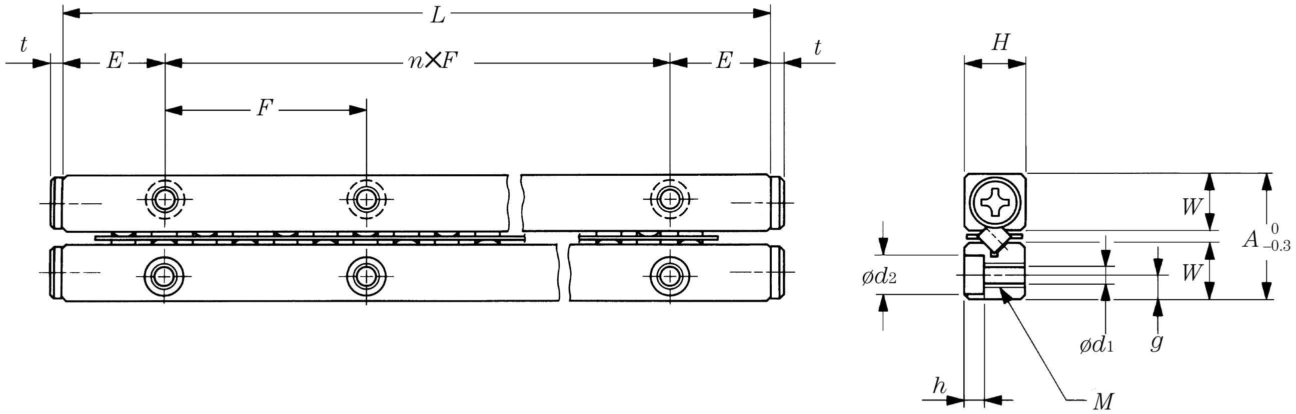


Fig. 9.3 Degree of Parallelism of Raceway Surface of Cross Roller Way Bearing Unit

9.3.4 Dimensions Table for Cross Roller Way Bearing Units for Use in Extreme Special Environments

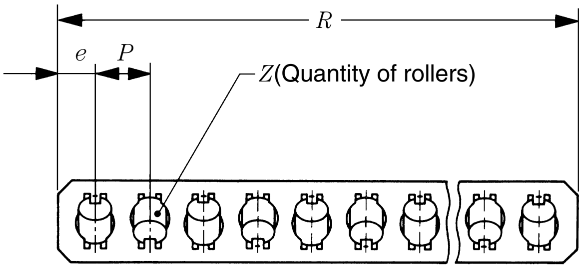
CRW Series

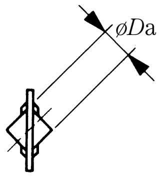
Roller diameter 1.5 to 3 mm



Basic Number	Mass (for reference) Raceway base [1] kg / m	Mass (for reference) Cylindrical roller with retainer [2] g	Boundary Dimensions mm A	H	L (n×F)	E	Dimensions of Cylindrical Roller with Retainer mm Da	R	Z	p	e
CRW1 – 20					20 (1×10)			16.5	5		
– 30					30 (2×10)			25.5	8		
– 40					40 (3×10)			31.5	10		
– 50	0.12	0.38	8.5	4	50 (4×10)	5	1.5	37.5	12	3	2.25
– 60					60 (5×10)			43.5	14		
– 70					70 (6×10)			52.5	17		
– 80					80 (7×10)			61.5	20		
CRW2 – 30					30 (1×15)			29.6	7		
– 45					45 (2×15)			41.6	10		
– 60					60 (3×15)			53.6	13		
– 75					75 (4×15)			65.6	16		
– 90					90 (5×15)			77.6	19		
– 105	0.24	0.98	12	6	105 (6×15)	7.5	2	89.6	22	4	2.8
– 120					120 (7×15)			101.6	25		
– 135					135 (8×15)			113.6	28		
– 150					150 (9×15)			125.6	31		
– 165					165 (10×15)			137.6	34		
– 180					180 (11×15)			149.6	37		
CRW3 – 50					50 (1×25)			42	8		
– 75					75 (2×25)			62	12		
– 100					100 (3×25)			82	16		
– 125					125 (4×25)			102	20		
– 150					150 (5×25)			122	24		
– 175	0.50	2.96	18	8	175 (6×25)	12.5	3	142	28	5	3.5
– 200					200 (7×25)			162	32		
– 225					225 (8×25)			182	36		
– 250					250 (9×25)			202	40		
– 275					275 (10×25)			222	44		
– 300					300 (11×25)			242	48		

Note: 1) Mass per 1 m of raceway base
2) Mass of one cylindrical roller / retainer assembly consisting of 10 rollers
3) Load per one cylindrical roller





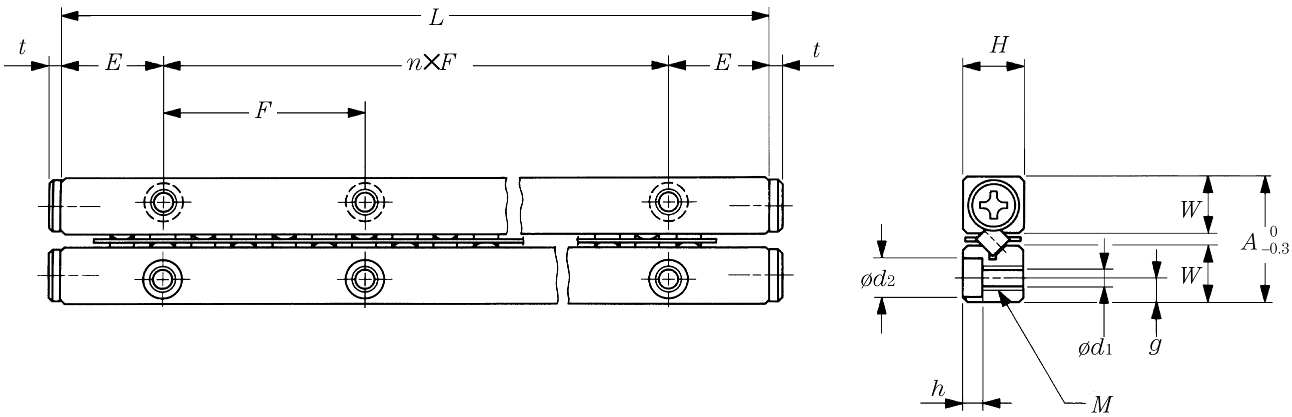
Basic Number	Fitting Dimensions mm							Basic dynamic load rating C_u 3)	Basic static load rating C_{0u} 3)	Allowable load F_u 3)
	W	*g*	*M*	d_1	d_2	*h*	*t*	N	N	N
CRW1 – 20 – 30 – 40 – 50 – 60 – 70 – 80	3.9	1.8	M2	1.65	3	1.4	1.7	131	119	39.4
CRW2 – 30 – 45 – 60 – 75 – 90 – 105 – 120 – 135 – 150 – 165 – 180	5.5	2.5	M3	2.55	4.4	2	1.5	305	292	97.3
CRW3 – 50 – 75 – 100 – 125 – 150 – 175 – 200 – 225 – 250 – 275 – 300	8.3	3.5	M4	3.3	6	3.1	2	664	606	202

Remark: The Cross Roller Way bearing units for use in extra special environments are classified into grease type (code: SV) and EXSEV type (code: SE). Their codes are placed in front of the basic numbers.

(9.3.4 Dimensions Table for Cross Roller Way Bearing Units for Use in Extreme Special Environments)

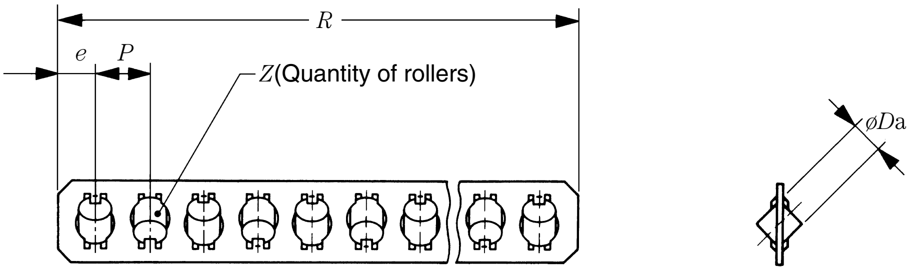
CRW Series

Roller diameter 4 and 6 mm



Basic Number	Mass (for reference) Raceway base [1] kg / m	Mass (for reference) Cylindrical roller with retainer [2] g	Boundary Dimensions mm A	H	L (n×F)	E	Dimensions of Cylindrical Roller with Retainer mm Da	R	Z	p	e
CRW4 – 80					80 (1×40)			73	10		
– 120					120 (2×40)			101	14		
– 160					160 (3×40)			136	19		
– 200					200 (4×40)			164	23		
– 240					240 (5×40)			199	28		
– 280	0.82	6.91	22	11	280 (6×40)	20	4	227	32	7	5
– 320					320 (7×40)			262	37		
– 360					360 (8×40)			297	42		
– 400					400 (9×40)			325	46		
– 440					440 (10×40)			360	51		
– 480					480 (11×40)			388	55		
CRW6 – 100					100 (1×50)			84	9		
– 150					150 (2×50)			129	14		
– 200					200 (3×50)			165	18		
– 250					250 (4×50)			210	23		
– 300					300 (5×50)			246	27		
– 350	1.57	20.3	31	15	350 (6×50)	25	6	282	31	9	6
– 400					400 (7×50)			327	36		
– 450					450 (8×50)			363	40		
– 500					500 (9×50)			408	45		
– 550					550 (10×50)			444	49		
– 600					600 (11×50)			489	54		

Note: 1) Mass per 1 m of raceway base
2) Mass of one cylindrical roller / retainer assembly consisting of 10 rollers
3) Load per one cylindrical roller



Basic Number	Fitting Dimensions mm							Basic dynamic load rating C_u [3]	Basic static load rating C_{0u} [3]	Allowable load F_u [3]
	W	g	M	d_1	d_2	h	t	N	N	N
CRW4 – 80	10	4.5	M5	4.3	7.5	4.1	2	1 290	1 170	389
–120										
–160										
–200										
–240										
–280										
–320										
–360										
–400										
–440										
–480										
CRW6 –100	14	6	M6	5.3	9.5	5.2	3	2 680	2 290	764
–150										
–200										
–250										
–300										
–350										
–400										
–450										
–500										
–550										
–600										

Remark: The Cross Roller Way bearing units for use in extra special environments are classified into grease type (code: SV) and EXSEV type (code: SE). Their codes are placed in front of the basic numbers.

10. Ball Screws for Use in Extreme Special Environments

The equipment and devices to be used in vacuum equipment, semiconductor, optical, electronic, nuclear power, and other industries are used in vacuum, corrosive, high-temperature, clean, or other environments. Various types of ball screws have been developed for various applications.

10.1 Composition and Advantages of Ball Screws for Use in Extreme Special Environments

A series of ball screws have been standardized to meet the exceptional requirements for extreme special environments. (See Table 10.1.)

• Ball screws for use in extreme special environments

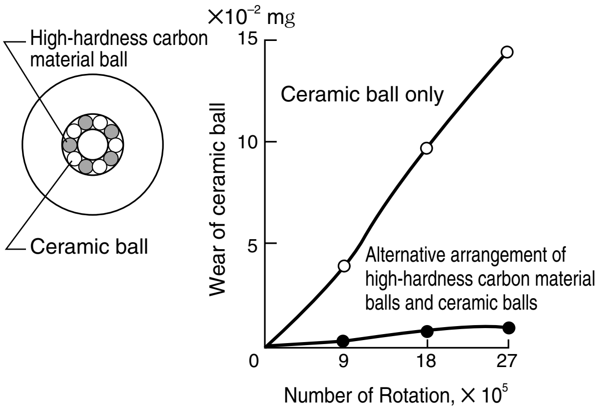
Table 10.1 Composition and Advantages of Ball Screws for Use in Extreme Special Environment

Specification		For a Vacuum Environment			Corrosion Resistance and Non-magnetic Properties	For High Temperatures
Lubrication		Filled with vacuum grease	Ag ion plating	PTFE coating	PTFE coating	High-hardness carbon material
Material	Shaft and nut	Martensite stainless steel	Martensite stainless steel	Martensite stainless steel PTFE coating	Precipitation hardened stainless steel	Martensite stainless steel
	Ball		Martensite stainless steel Ag ion plating	Martensite stainless steel	Ceramics	High-hardness carbon material or ceramics
	Circulator	Austenitic stainless steel	Austenitic stainless steel	Austenitic stainless steel PTFE coating	Austenitic stainless steel PTFE coating	Austenitic stainless steel
Applicable conditions	Ambient temperature	–40 to 200˚C	–100 to 300˚C	–100 to 200˚C	–100 to 200˚C	max. 400˚C
	Degree of vacuum	Low and medium vacuum	Medium and high vacuum	Fluctuation from atmospheric pressure to high vacuum	Atmospheric pressure to high vacuum	–
	Corrosion resistance	–	–	Superior	Superior	–
	Others	–	–	–	Insulation properties	–
Principal applications		Semiconductor production facility and vacuum table feeder			Material handling equipment	Heat treatment oven inspecting equipment

■ Relation between lubrication characteristics of solid lubricant and torque life

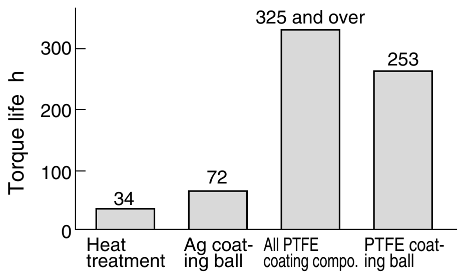
(1) Lubrication characteristics of high-hardness carbon material

Stress : 7.47 kN/mm^2
Rotation speed : 600 rpm
Temperature : 180˚C



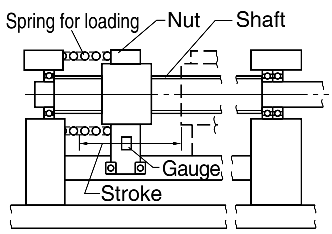
(2) Torque life comparison

Nominal number : 1404.7TS3.5
Axial load : 49 N
Rotation speed : 315 rpm
Stroke : 100 mm
Pressure : 1 Pa

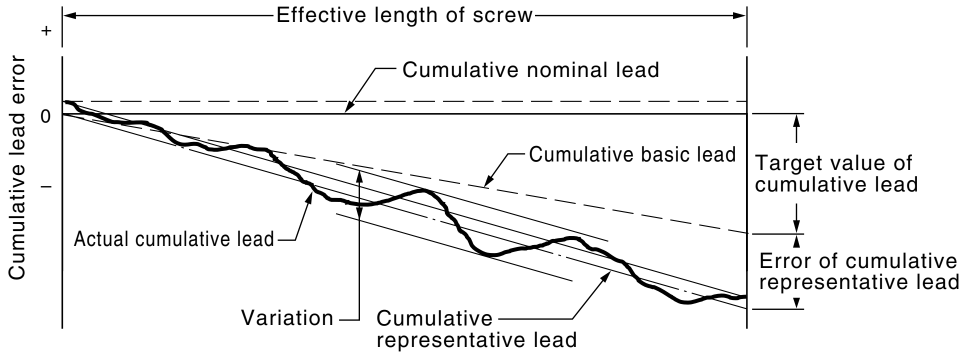


Torque life comparison

• Construction of test machine



10.2 Accuracy of Lead for Ball Screws for Use in Extreme Special Environments



Technical terms on lead accuracy

① Basic lead: Lead to be referenced
This term has the same meaning as nominal lead in general. For some purposes, the nominal lead is corrected intentionally.

② Cumulative basic lead (Target value of cumulative lead)
A value obtained by subtracting the cumulative lead of the effective length of the screw from the basic lead (or cumulative nominal lead)
To correct the influence of elastic deformation of the screw shaft caused by external loads or deformation of the same due to temperature fluctuations, the basic lead is occasionally deviated toward the positive side or negative side prior to the actual production of the screw.

③ Actual cumulative lead
A cumulative lead obtained after measurement on an optional cross section containing the axis of the screw shaft.

④ Cumulative representative lead
A line representing the tendency of the cumulative lead. To obtain this lead, the curve representing the actual cumulative lead is processed, using the method of least square or similar.

⑤ Cumulative representative lead error
A value obtained by subtracting the cumulative basic lead from the cumulative representative lead.

⑥ Variation
The maximum value among the actual cumulative leads existing between the two lines drawn in parallel with the cumulative representative lead.

For reference

The cumulative lead error of ball screws for general use, C7 and C10, is specified on the basis of the allowable value only for a distance of 300 mm taken optionally within the effective length of the screw.

Grade	Cumulative Lead Error, mm
C 7	0.05
C10	0.21

Remark: Ball screws for general use, C7 and C10, are available from KOYO. Please contact KOYO if you require these screws.

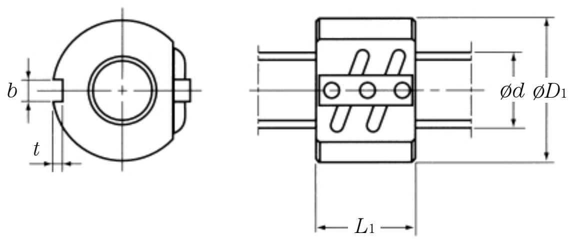
Table 10.2 Cumulative Representative Lead Error and Allowance for Variation

Unit: µm

Effective Screw Length mm		Accuracy Grade									
		C0		C1		C2		C3		C5	
Over	Up to	Cumulative representative lead error	Variation (max.)	Cumulative representative lead error	Variation (max.)	Cumulative representative lead error	Variation (max.)	Cumulative representative lead error	Variation (max.)	Cumulative representative lead error	Variation (max.)
–	100	± 3	3	± 3.5	5	± 5	7	± 8	8	± 18	18
100	200	± 3.5	3	± 4.5	5	± 7	7	± 10	8	± 20	18
200	315	± 4	3.5	± 6	5	± 8	7	± 12	8	± 23	18
315	400	± 5	3.5	± 7	5	± 9	7	± 13	10	± 25	20
400	500	± 6	4	± 8	5	± 10	7	± 15	10	± 27	20
500	630	± 6	4	± 9	6	± 11	8	± 16	12	± 30	23
630	800	± 7	5	± 10	7	± 13	9	± 18	13	± 35	25
800	1 000	± 8	6	± 11	8	± 15	10	± 21	15	± 40	27
1 000	1 250	± 9	6	± 13	9	± 18	11	± 24	16	± 46	30
1 250	1 600	± 11	7	± 15	10	± 21	13	± 29	18	± 54	35
1 600	2 000	–	–	± 18	11	± 25	15	± 35	21	± 65	40

10.3 Dimensions Table for Ball Screws for Use in Extreme Special Environments

Type TS



Type TF

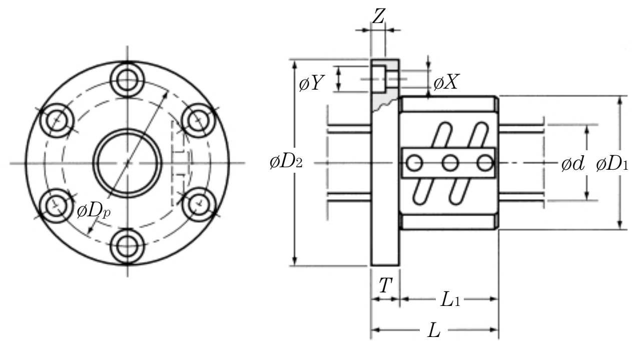


Table 10.3 Dimensions Table for Ball Screws for Use in Extreme Special Environments

Unit: mm

Basic Number of Nut	Outside Dia. of Shaft	Lead	Ball Diameter	Number of Circuits	Nut Dimensions											Basic Dynamic Load Rating[1)	Basic Static Load Rating[1)	Screw Length
	d	ℓ	D_w	Turns X rows	D_1	D_2	D_p	T	L	L_1	X	Y	Z	b	t	C_a N	C_{0a} N	(max.)
1003 TS/TF	10	3	2	2.5X1	25	45	35	5	26	21	4.5	–	–	5	3	196	441	200
1203 TS/TF	12	3	2	2.5X1	28	48	38	5	26	21	4.5	–	–	5	3	225	539	300
1204 TS/TF		4							29	24								
1403 TS/TF	14	3	2	2.5X1	30	50	40	6	27	21	5.5	–	–	5	3	245	637	400
1404 TS/TF		4							30	24								
1604 TS/TF	16	4	2	2.5X1	0	63	51	10	34	24	5.5	9.5	5.5	8	4	265	735	500
1605 TS/TF		5	3.175						35	25						539	1 274	
2005 TS/TF	20	5	3.175	2.5X1	44	67	55	12	37	25	5.5	9.5	5.5	8	4	588	1 666	650
2006 TS/TF		6	3.969		48	71	59		42	30						833	2 058	
2505 TS/TF	25	5	3.175	2.5X2	50	73	61	12	52	40	5.5	9.5	5.5	8	4	1 274	4 312	700
2506 TS/TF		6	3.969		53	76	64		60	48						1 715	5 292	
3205 TS/TF	32	5	3.175	2.5X2	58	85	71	12	52	40	6.6	11	6.5	8	4	1 372	5 586	1 000
3206 TS/TF		6	3.969		62	89	75		60	48						1 862	6 860	
3208TS/TF		8	4.763		66	100	82	16	76	60						2 401	8 134	
3210 TS/TF		10	6.350		74	108	90		91	75	9	14	8.5			3 528	10 780	
3605 TS/TF	36	5	3.175	2.5X2	62	89	75	12	52	40	6.6	11	6.5	8	4	1 470	6 272	1 500
3606 TS/TF		6	3.969		66	100	82	16	64	48	9	14	8.5			2 009	7 938	
3608 TS/TF		8	4.763		70	104	86		76	60						2 700	9 800	
3610 TS/TF		10	6.350		75	120	98	18	93	75						3 773	12 250	
4005 TS/TF	40	5	3.175	2.5X2	67	101	83	16	56	40	9	14	8.5	8	4	1 519	7 056	2 000
4006 TS/TF		6	3.969		70	104	86		64	48						2 107	8 722	
4008 TS/TF		8	4.763		74	108	90		76	60						2 646	10 290	
4010 TS/TF		10	6.350		82	124	102	18	93	75	11	17.5	11			3 969	13 720	

Note: 1) The basic dynamic load rating and basic static load rating are for ball screws ion-plated with Ag.

Remark: Ball screws other than those described in the above Table are also available at KOYO. Please contact KOYO for further details.

11. Application Examples of Ceramic Bearings and EXSEV Bearings

In response to the rapid progress of technologies, research and development has been carried out actively in all industrial fields. The most recent activities are usually conducted in extremely high vacuums, extremely low temperatures, clean environment, or other extreme special atmospheric conditions. The equipment, devices, and parts to be used for these activities must function satisfactorily under all applicable conditions. Introduced in the following pages are some examples of KOYO ceramic bearings and EXSEV bearings in actual use in various fields.

CONTENTS

1. High-speed Rotation

1.1 Spindle for Machine Tools

Example of Application to High-speed Rotation

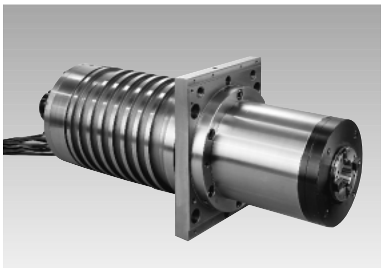
The bearings assembled into machine tool spindles are driven at high speeds. Ceramic rolling elements improve temperature characteristics, seizure resistance, and other high-speed performances of the bearings.

- **Use conditions**

Rotation speed : 5 000 to 20 000 rpm
Temperature : Room temperature to 60˚C

- **Bearing specifications**

Type : Angular ball bearing and cylindrical roller bearing
Lubricant : Grease or oil/air
Material : ① Outer ring and inner ring: Bearing steel
② Ball: Ceramics



1.2 Turbocharger

Example of Application to High-speed Rotation

Bearings for use in turbochargers should have a high-speed rotation performance (low torque, low vibration, and low temperature rise), high acceleration response, and high durability. Owing to the higher heat resistance, higher abrasion resistance, better seizure resistance, and light weight, of ceramic materials, ceramic bearings exhibit better performances than steel bearings.

- **Use conditions**

Rotation speed : 250 000 rpm
Temperature : Up to 350˚C

- **Bearing specifications**

Type : Angular ball bearing
Lubricant : Oil jet
Material : ① Outer ring and inner ring: Heat resistant steel
② Ball: Ceramics
③ Retainer: Polyimide resinp-99

1.3 Automotive Wheel — Example of Application to High-speed Rotation

In the Paris-Dakar Rally held in January, 1998, the "PAJERO T2" model vehicles took the first three places. The front and rear wheels of these vehicles were fitted with ceramic ball bearings. Ceramic bearings were at first considered to have a shorter life in such severe environments as a desert. However, their higher durability and reliability were demonstrated.

- **Paris-Dakar Rally**

Race distance : 6 388 km
Winning time : 65 h 25 min
Average vehicle speed : 97.7 km/h

1.4 HDD Spindle Motor — Example of Application to High-speed Rotation

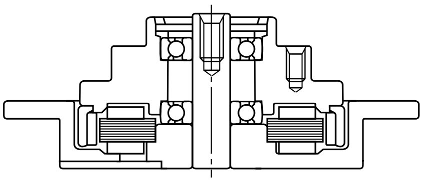
Lower noise and higher non-reproducible run-out (NRRO) accuracy are required of HDD spindle motors, when driven at high speeds. Ceramic bearings meet such severe conditions.

- **Use conditions**

Rotation speed : 10 000 rpm and over
Temperature : Up to 80˚C

- **Bearing specifications**

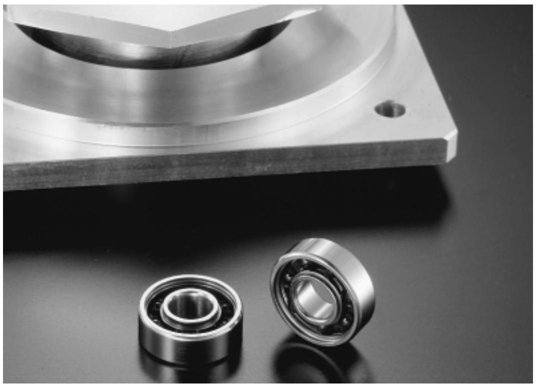
Type : Deep groove ball bearing
Lubricant : Grease
Material : ① Outer ring and inner ring: Bearing steel
② Ball: Ceramics
③ Retainer: Polyamide resin



(1. High-speed Rotation)

1.5 Polygon Scanner Motor — Example of Application to High-speed Rotation

High-speed polygon scanner motors have ceramic bearings that exhibit superior high-speed performances.



- **Use conditions**

Rotation speed : 26 000 rpm and over

- **Bearing specifications**

Type : Deep groove ball bearing
Lubricant : Grease
Material : ① Outer ring and inner ring: Bearing steel
② Ball: Ceramics
③ Retainer: Polyamide resin

1.6 SR Motor — Example of Application to High-speed Rotation

High-speed, high-efficiency SR (Switched Reluctance) motors, for which no coil or permanent magnet is necessary, are fitted with ceramic bearings.

- **Use conditions**

Rotation speed : 30 000 rpm

- **Bearing specifications**

Type : Deep groove ball bearing
Lubricant : Grease
Material : ① Outer ring and inner ring: Bearing steel
② Ball: Ceramics
③ Retainer: Polyamide resin

1.7 Steel Wire Stranding Machine — Example of Application to High-speed Rotation

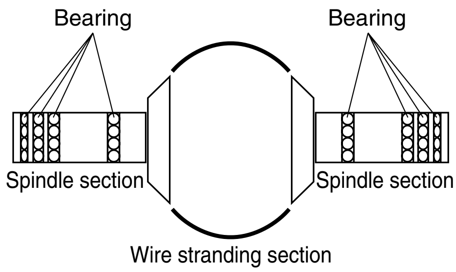
The reinforcing in radial tires is made by stranding steel wires to attain the required strength. The steel wire stranding machines are driven at high speeds. Ceramic bearings are used in the machines to maintain an improved, reliable life span.

- **Use conditions**

Rotation speed : 6 000 rpm and over

- **Bearing specifications**

Type : Angular ball bearing and deep groove ball bearing
Lubricant : Grease
Material : ① Outer ring and inner ring: Bearing steel
② Ball: Ceramics
③ Retainer: Polyamide resin



1.8 High-speed Jet Electrostatic Coating Machine — Example of Application to High-speed Rotation

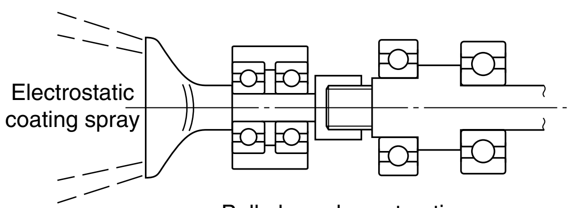
In an electrostatic coating machine, the air motor ejects the grease from the spray nozzle section. This grease affects the quality of the paint to be coated. To resolve this problem, ceramic bearings are used, as no liquid lubricants are required.

- **Use conditions**

Rotation speed : 20 000 rpm

- **Bearing specifications**

Type : Deep groove ball bearing
Lubricant : Special polymeric fluoride
Material : ① Outer ring and inner ring: Bearing steel
② Ball: Ceramics



Bell-shaped construction

(1. High-speed Rotation)

1.9 Inline Skates (sports and leisure equipment) / Example of Application to High-speed Rotation

Inline skating has become very popular, and there are an increasing number of skaters. Because of their high durability and low running torque characteristics, ceramic bearings are assembled into the speed skates. These skates have achieved satisfactory results.

- **Required performance**

Durability
Quick acceleration (low running torque)

- **Use conditions**

Speed : 80 km/h
Rotation speed : 10 000 rpm

- **Bearing specifications**

Type : Sealed type deep groove ball bearing
Lubricant : Oil or grease
Material : ① Outer ring and inner ring: Bearing steel
② Ball: Ceramics
③ Retainer: Reinforced polyamide resin

2. Clean Environment

2.1 Transfer Robot for Semiconductor and Liquid Crystal Production Facilities

Example of Application in a Clean Environment

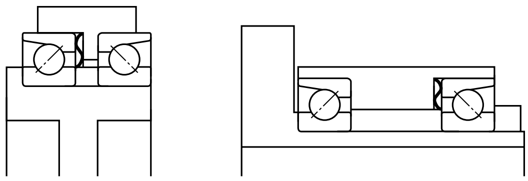
Bearings having low dust generation and long life characteristics are required for the transfer robots used in semiconductor and liquid crystal production facilities. In some cases, these bearings are delivered after being assembled into robot arms or other units to enable easier assembly and higher maintainability.

- **Use conditions**

Temperature : Room temperature to 350˚C
Vacuum : 10^{-3} Pa

- **Bearing specifications**

Type : Super thin section ball bearing, K-series (full complement ball type)
Lubricant : Low dust generation, vacuum grease or special polymeric fluoride coating
Material : ① Outer ring and inner ring: Martensite stainless steel
② Ball: Ceramics

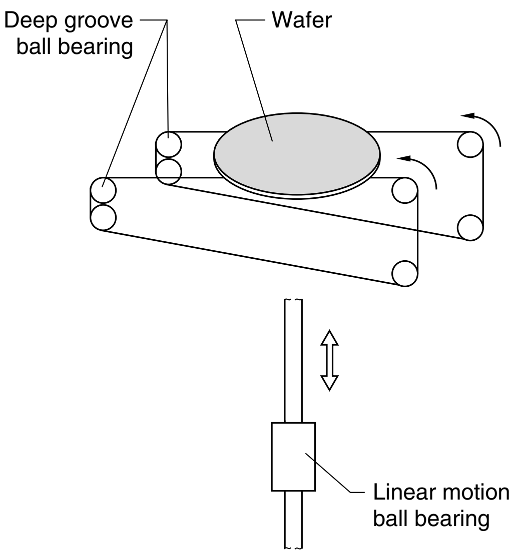


Bearing unit for application to transfer robot

2.2 Conveyor for Spattering Machine

Example of Application in a Clean Environment

"Clean PRO" linear motion ball bearings are used for the conveyors used in spattering machines.



- **Use conditions**

Stroke : 20 mm
Travel speed : 10 mm/s
Temperature : 200˚C
Vacuum : Atmospheric pressure to 10^{-5} Pa

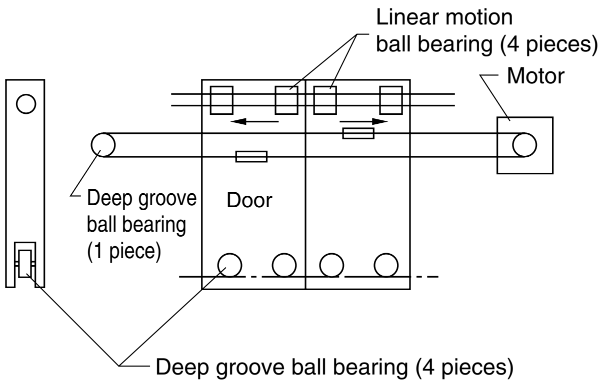
- **Bearing specifications**

Type : Linear motion ball bearing
Lubricant : Special polymeric fluoride coating
Material : ① External cylinder and ball: Martensite stainless steel
② Retainer: Austenitic stainless steel

(2. Clean Environment)

2.3 CVD Machine — Example of Application in a Clean Environment

Ceramic bearings and "Clean PRO" linear motion bearings are used for the doors of CVD machines.



• **Use conditions**
Rotation speed : 10 to 200 rpm
Temperature : 300˚C
Vacuum : Atmospheric pressure to 10^{-4} Pa

• **Bearing specifications**
Type : Deep groove ball bearing and linear motion ball bearing
Lubricant : Special polymeric fluoride coating
Material : ① Outer ring and inner ring: Martensite stainless steel
② Ball: Ceramics

2.4 CVD Machine — Example of Application in a Clean Environment

"Clean PRO Cross Roller Way" linear motion bearing units are also used in CVD machines, due to their low gas and dust generation characteristics.

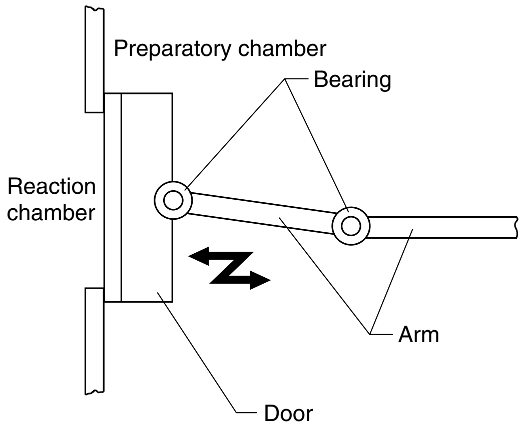
• **Use conditions**
Stroke : 100 mm
Temperature : 200˚C
Vacuum : Atmospheric pressure to 10^{-3} Pa

• **Bearing specifications**
Type : Cross Roller Way linear motion ball bearing
Lubricant : Special polymeric fluoride coating
Material : ① Race way base and roller: Martensite stainless steel
② Retainer: Austenitic stainless steel

2.5 Etching Machine

Example of Application in a Clean Environment

Bearings for use in etching machines must be resistant to halogen, hydrofluoric acid, and other corrosive gases. In addition, they should not generate dust. To meet these requirements, ceramic ball bearings coated with PTFE are used.



- **Use conditions**

Load : 10 N
Temperature : Normal temperature to 60°C
Vacuum : Atmospheric pressure to 10^{-2} Pa

- **Bearing specifications**

Type : Deep groove ball bearing
Lubricant : PTFE coating
Material : ① Outer ring and inner ring: Martensite stainless steel + PTFE coating
② Ball: Ceramics
③ Retainer: Austenitic stainless steel + PTFE coating

2.6 CMP Machine

Example of Application in a Clean Environment

A CMP machine is used for flattening the surfaces of the wafers in a semiconductor multi-layer forming process. Ceramic bearings are assembled into the cleaner attached to the CMP machine.

- **Use conditions**

Rotation speed : 100 rpm
Temperature : Normal temperature
Other : Corrosive solvents are splashed.

- **Bearing specifications**

Type : Deep groove ball bearing
Lubricant : Special polymeric fluoride
Material : Outer ring, inner ring, and ball: Ceramics

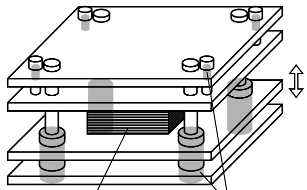
(2. Clean Environment)

2.7 Liquid Crystal Panel Sealing Machine / Example of Application in a Clean Environment

Substrate bonding press jigs for use in furnaces must not generate dust and they should maintain a long service life under high temperature conditions. The "Clean PRO" ceramic linear motion ball bearings are used for these jigs.

• Use conditions
Travel speed : 5 mm/s
Temperature : 200˚C
Vacuum : Atmospheric pressure

• Bearing specifications
Type : Linear motion ball bearing
Lubricant : Special polymeric fluoride coating
Material : ① External cylinder: Martensite stainless steel
② Ball: Ceramics
③ Retainer: Austenitic stainless steel

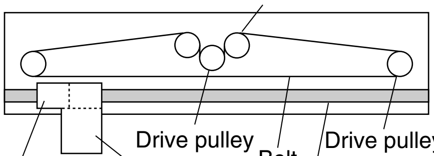


2.8 Wafer Transfer Device / Example of Application in a Clean Environment

Not only low dust generation performance but also corrosion resistance to splashed cleaning agents are required for the wafer transfer devices. For such devices, "Clean PRO Linear Way" bearings and deep groove ball bearings are used.

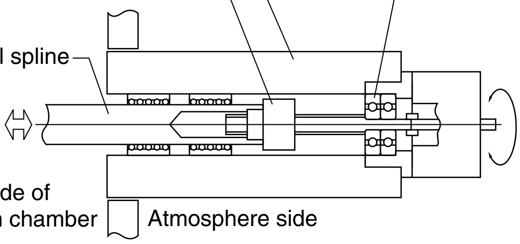
• Use conditions
Travel speed : 350 mm/s
Temperature : Room temperature
Vacuum : Atmospheric pressure
(with splashes of cleaning agent)

• Bearing specifications
Type : Linear Way and deep groove ball bearings
Lubricant : Special polymeric fluoride coating
Material : ① Casing and track rail: Martensite stainless steel
② Ball: Ceramics



2.9 Linear Motion Unit — Example of Application in a Clean Environment

The dollies and positioner transfer mechanisms for use in liquid crystal production facilities require various units consisting of ball screws, ball splines, support bearings, etc. Linear motion mechanisms are designed for such units.



• **Components and their specifications**

① Ball screw : Whole surface of nut, screw, and tube is coated with PTFE.
② Ball spline : Whole surface of outer ring and shaft is coated with PTFE.
③ Support bearing : Outer ring, inner ring, and retainer are coated with special polymeric fluoride.
④ Housing : Stainless steel

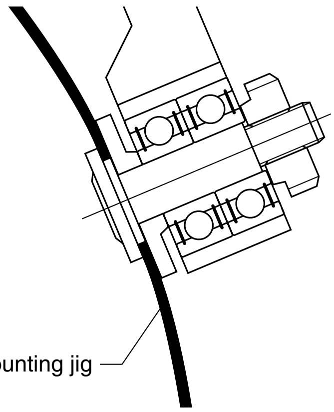
• **Performance**

High vacuum : 10^{-5} Pa
High temperature : 200˚C
Corrosion resistance : Whole surfaces coated with PTFE
Low dust generation : PTFE coating and special polymeric fluoride coating

3. Vacuum Environment

3.1 Vacuum Evaporation Equipment — Example of Application in a Vacuum Environment

High durability under high-temperatures and large loads (moment) is required of bearings for use in the planetary section of vacuum evaporation equipment. To improve the bearing life under high temperature conditions, composite bearings consisting of ceramic balls and high-speed tool steel rings are used.



- **Use conditions**

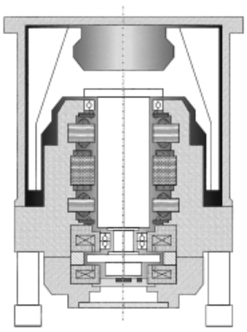
Rotation speed : 1 to 30 rpm
Temperature : 200 to 400˚C
Vacuum : 10^{-6} to 10^{-8} Pa

- **Bearing specifications**

Type : Deep groove ball bearing
Lubricant : Molybdenum disulfide or silver coating
Material : ① Outer ring and inner ring: High speed tool steel
② Ball: Ceramics and martensite stainless steel
③ Retainer: Austenitic stainless steel

3.2 Turbo Molecular Pump — Example of Application in a Vacuum Environment

Magnetic bearings are used in turbo molecular pumps driven at extremely high speeds. To protect the blades from fracture during power cuts or magnetic failure, touchdown bearing units are used. Touchdown bearing units are comprised of ceramic bearings to elongate life span under severe conditions.



- **Use conditions**

Rotation speed : 20 000 to 60 000 rpm
Vacuum : 1 Pa

- **Bearing specifications**

Type : Full complement type deep groove ball bearing and angular ball bearing
Lubricant : Molybdenum disulfide or silver coating
Material : ① Outer ring and inner ring: Martensite stainless steel
② Ball: Ceramics and martensite stainless steel

3.3 X-ray Tube

Example of Application in a Vacuum Environment

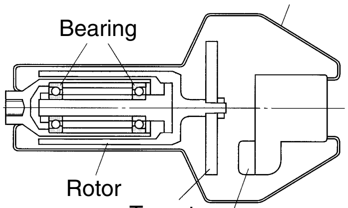
Integral bearing units are used in rotation anode X-ray tubes. Comprised of an inner ring shaft with a flange, each of these bearing units is resistant to high vacuum, high-speed rotation, heat, and high loads.

- **Use conditions**

Rotation speed : 3 000 to 10 000 rpm
Temperature : 250 to 500˚C
Vacuum : 10^{-5} Pa

- **Bearing specifications**

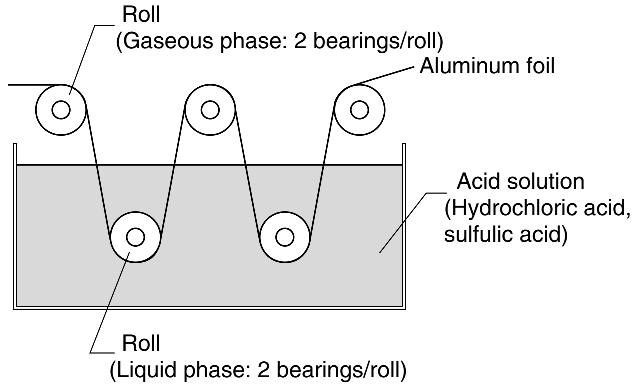
Type : Full complement ball type bearing unit
Lubricant : lead or silver coating
Material : Outer ring, shaft and ball: High speed tool steel



4. Corrosion Resistance

4.1 Aluminum Foil Electrolytic Capacitor Production Facility — Example of Application in Corrosive Environments

In an aluminum foil electrolytic capacitor production facility, a strong acid solution is used to treat the aluminum foils. Highly corrosion-resistant ceramic bearings are used in such high corrosive environments.

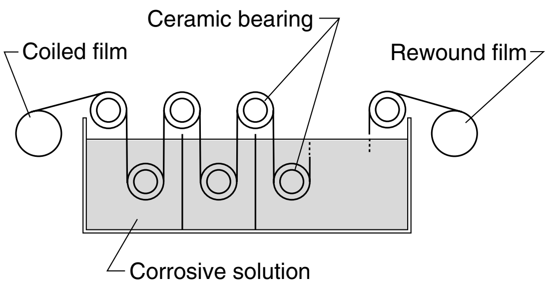


• Use conditions
Rotation speed : 50 rpm
Temperature : 90˚C

• Bearing specifications
Type : Deep groove ball bearing
Lubricant : Solution for foil treatment
Material : ① Outer ring, inner ring, and ball: High corrosion resistant ceramics
② Retainer: Special polymeric fluoride
③ Spacer: Austenitic stainless steel

4.2 Liquid Crystal Polarizing Film Production Facility — Example of Application in Corrosive Environments

Acid solution, alkali solution, dying solution, distilled water, and other solutions are used in liquid crystal polarizing film production facilities. In such corrosive environments, bearings of ceramic components and other components made of corrosion resistant materials are used.

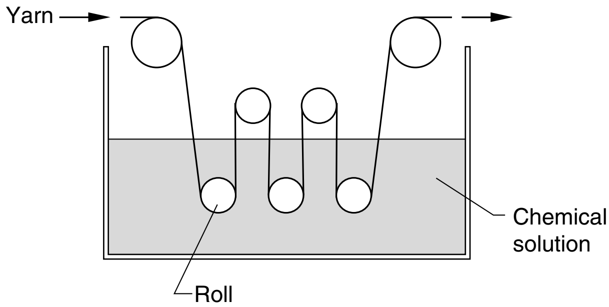


• Use conditions
Rotation speed : 80 rpm
Temperature : Normal temperature to 80˚C

• Bearing specifications
Type : Deep groove ball bearing
Lubricant : Solvent for foil treatment
Material : ① Outer ring and inner ring: High corrosion resistant stainless steel
② Ball: High corrosion resistant ceramics
③ Retainer: Special polymeric fluoride or no retainer (full complement ball type)

4.3 Synthetic Fiber Production Facility / Example of Application in Corrosive Environments

Acid solution, alkali solution, water, and other liquids are used in synthetic fiber yarn reinforcing processes. Highly corrosion resistant ceramic bearings are used in such corrosive ambient conditions.



- **Use conditions**

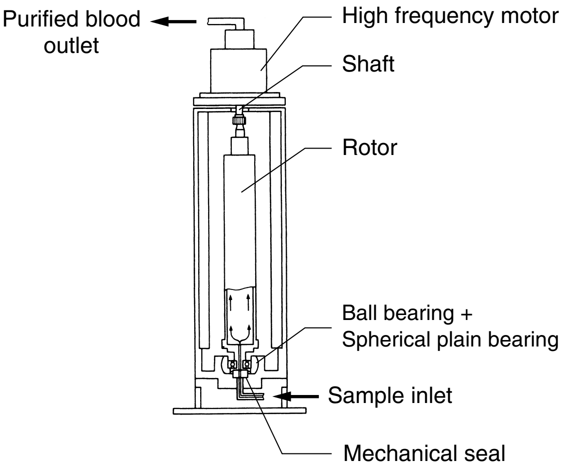
Rotation speed : 20 to 100 rpm
Temperature : Normal temperature to 90˚C

- **Bearing specifications**

Type : Deep groove ball bearing
Lubricant : Solution for foil treatment
Material : ① Outer ring and inner ring: High corrosion resistant stainless steel
② Ball: High corrosion resistant ceramics
③ Retainer: Special type of polymeric fluoride or no retainer (full complement ball type)

4.4 Centrifugal Separator for Blood Purification / Example of Application in Corrosive Environments

Corrosion resistance is required of bearings to be used in the centrifugal separator used in blood purification, because of splashes of physiological saline. Ceramic bearings with bearing rings coated with a corrosion resistant film are used in such corrosive environments.

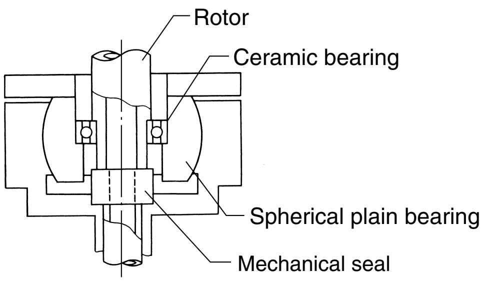


- **Use conditions**

Rotation speed : 20 000 rpm
Temperature : –10 to 10˚C

- **Bearing specifications**

Type : Deep groove ball bearing
Lubricant : Grease
Material : ① Outer ring and inner ring: Stainless steel + Corrosion resistant film
② Ball: Ceramics



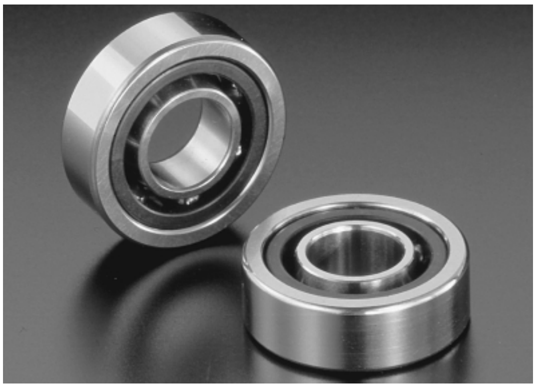
Detail of the section into which bearing is assembled

(4. Corrosion Resistance)

4.5 Cleaner (Spin Dryer)

Example of Application in Corrosive Environments

In semiconductor wafer cleaning processes, the wafers are cleaned in a chemical solution, cleaning agent, distilled water, and other liquids and then dried. Because of their high corrosion resistance, ceramic bearings are used.

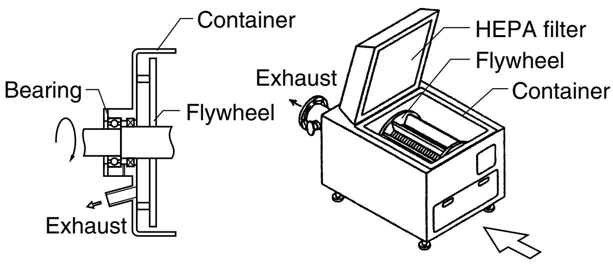


- **Use conditions**

Rotation speed : 2 000 to 3 000 rpm
Temperature : Room temperature (clean room)

- **Bearing specifications**

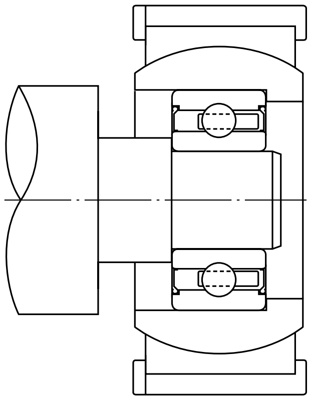
Type : Deep groove ball bearing
Lubricant : Low dust generation grease
Material : ① Outer ring and inner ring: Corrosion resistant stainless steel
② Ball: Ceramics
③ Retainer: Special polymeric fluoride



5. High Temperature

5.1 Conveyors Installed inside Kilns — Example of Application in High-temperature Environments

Conveyors are installed inside kilns that bake Teflon resin onto the heat rollers of copying machines. The bearings for use in such conveyors must not generate dust under high temperatures. Since this type of conveyor is constructed with lower assembling accuracies, ceramic bearings consisting of an outer aligning ring are used.

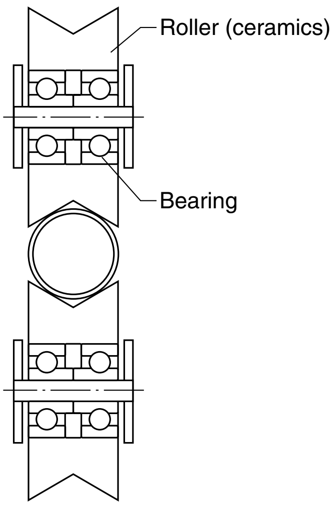


• Use conditions
Rotation speed : 3 to 10 rpm
Temperature : 400 to 500˚C

• Bearing specifications
Type : Deep groove ball bearing (with outer aligning ring)
Lubricant : Graphite
Material : ① Outer ring and inner ring: High speed tool steel
② Ball: Ceramics

5.2 Guide Roll for Tube Annealing Furnaces — Example of Application in High-temperature Environments

The guide roll bearings installed inside tube annealing furnaces are driven in high temperature conditions without lubricants. Ceramic bearings are used in such applications.



• Use conditions
Rotation speed : 300 rpm
Temperature : 300˚C

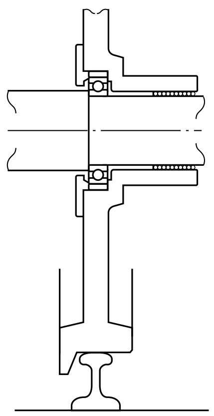
• Bearing specifications
Type : Deep groove ball bearing
Lubricant : Molybdenum disulfide coating
Material : ① Outer ring and inner ring: Martensite stainless steel
② Ball: Ceramics
③ Retainer: Austenitic stainless steel

(5. High Temperature)

5.3 Dollies in Furnaces

Example of Application in High-temperature Environments

The dollies, conveyors, and other material handling equipment used in furnaces are exposed to high temperatures. Because of their high heat resistance, ceramic bearings are used in such applications.



- **Use conditions**

Rotation speed : 10 to 500 rpm
Temperature : 500˚C

- **Bearing specifications**

Type : Deep groove ball bearing
Lubricant : Graphite
Material : ① Outer ring and inner ring: High speed tool steel
② Ball: Ceramics

6. Non-magnetism

6.1 EB Exposing Machine — Examples of Non-magnetic usage

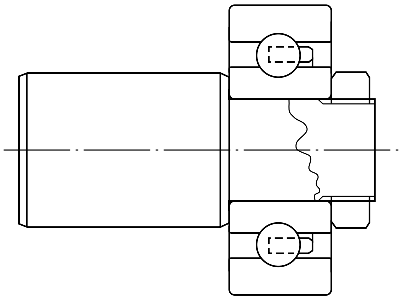
EB exposing machines used in semiconductor production facilities are exposed to a strong magnetic field. Because of their non-magnetic characteristics, ceramic bearings are used in such machines.

- **Use conditions**

Rotation speed : 100 rpm
Temperature : Normal temperature
Vacuum : 10^{-5} Pa

- **Bearing specifications**

Type : Deep groove ball bearing
Material : ① Outer ring, inner ring, and ball: Ceramics
② Retainer: Polyamide resin
③ Shaft: Non-magnetic stainless steel or beryllium copper



6.2 Ultrasonic Motor — Examples of Non-magnetic usage

The motors installed in magnetic resonance instruments (MRI) use magnetism-insensitive ceramic bearings.

- **Use conditions**

Rotation speed : 500 rpm
Temperature : Room temperature
Others : For use in strong magnetic fields

- **Bearing specifications**

Type : Deep groove ball bearing
Lubricant : Special purpose grease
Material : ① Outer ring, inner ring, and ball: Ceramics
② Retainer: Special polymeric fluoride

7. Insulation

7.1 Motor — Example of Applications for Insulation Purposes

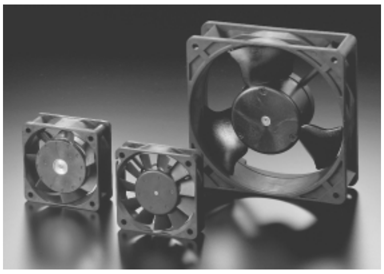
Electric pitting often causes bearing failure in various types of motors. Owing to their insulation characteristics, ceramic bearings are used to eliminate such failures.

- **Use conditions**

Rotation speed : 5 000 rpm
Temperature : –10 to 120˚C

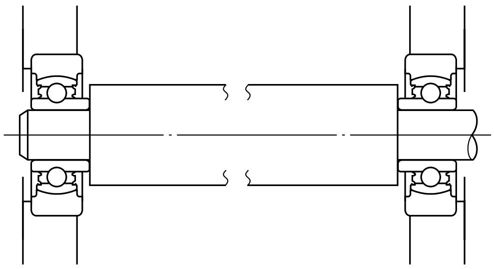
- **Bearing specifications**

Type : Deep groove ball bearing
Lubricant : Grease
Material : ① Outer ring and inner ring: Bearing steel
② Ball: Ceramics
③ Retainer: Stainless steel sheet



7.2 Photographic Film Production Facilities — Example of Applications for Insulation Purposes

A high voltage current is applied to film surfaces when treated in a photographic film production facility. Because of their high insulation characteristics, ceramic bearings are used in such environmental conditions.



- **Use conditions**

Rotation speed : 200 rpm
Temperature : Normal temperature

- **Bearing specifications**

Type : Deep groove ball bearing
Lubricant : Grease
Material : ① Outer ring: Bearing steel
② Inner ring and ball: Ceramics
③ Housing: Cast iron

12. Introduction to KOYO Products

• Ceramic bearings, EXSEV bearing series

• Ceramic bearings for machine tool application

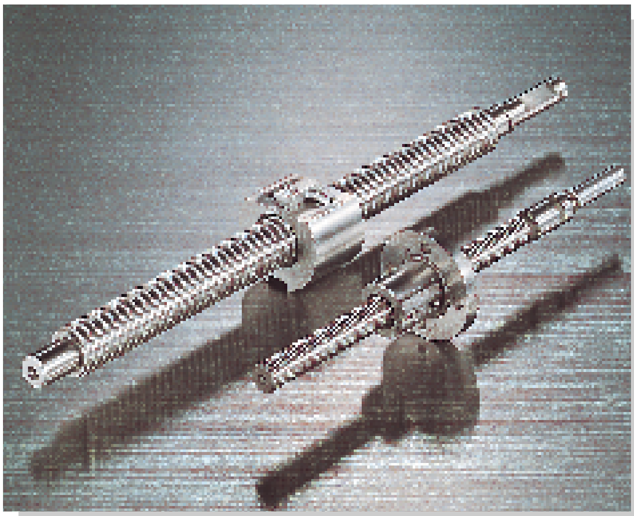
• Insulation bearings for motors

● Super thin section ball bearings, K-series, for use in extreme special environments

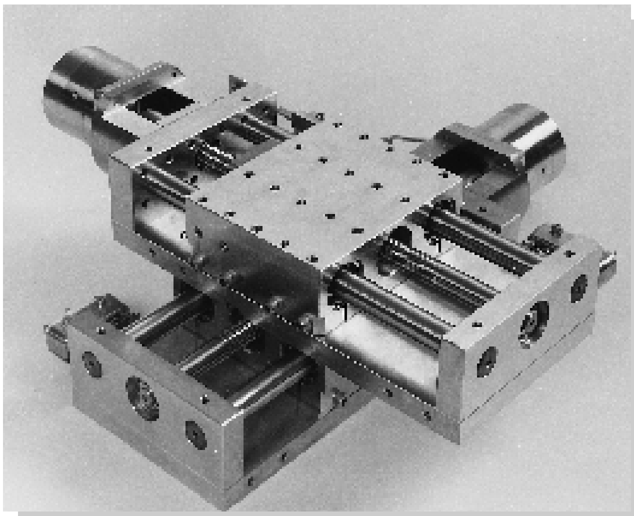
● Bearing units for X-ray tubes

● Ceramic balls

● Linear motion bearings for use in extreme special environments



● Ball screws for use in extreme special environments



● X-Y table unit for use in a vacuum environment

Supplementary table 1 Shaft tolerances (deviation from nominal dimensions)

Nominal shaft diameter (mm)		Deviation classes of shaft diameter															
over	up to	d6	e6	f6	g5	g6	h5	h6	h7	h8	h9	h10	js5	js6	js7	j5	j6
3	**6**	−30 −38	−20 −28	−10 −18	−4 −9	−4 −12	0 −5	0 −8	0 −12	0 −18	0 −30	0 −48	± 2.5	± 4	± 6	+3 −2	+6 −2
6	**10**	−40 −49	−25 −34	−13 −22	−5 − 11	−5 −14	0 −6	0 −9	0 −15	0 −22	0 −36	0 −58	± 3	± 4.5	± 7	+4 −2	+7 −2
10	**18**	−50 −61	−32 −43	−16 −27	−6 −14	−6 −17	0 −8	0 −11	0 −18	0 −27	0 −43	0 −70	± 4	± 5.5	± 9	+5 −3	+8 −3
18	**30**	−65 −78	−40 −53	−20 −33	−7 −16	−7 −20	0 −9	0 −13	0 −21	0 −33	0 −52	0 −84	± 4.5	± 6.5	±10	+5 −4	+9 −4
30	**50**	−80 −96	−50 −66	−25 −41	−9 −20	−9 −25	0 −11	0 −16	0 −25	0 −39	0 −62	0 −100	± 5.5	± 8	±12	+6 −5	+11 −5
50	**80**	−100 −119	−60 −79	−30 −49	−10 −23	−10 −29	0 −13	0 −19	0 −30	0 −46	0 −74	0 −120	± 6.5	± 9.5	±15	+6 −7	+12 −7
80	**120**	−120 −142	−72 −94	−36 −58	−12 −27	−12 −34	0 −15	0 −22	0 −35	0 −54	0 −87	0 −140	± 7.5	±11	±17	+6 −9	+13 −9
120	**180**	−145 −170	−85 −110	−43 −68	−14 −32	−14 −39	0 −18	0 −25	0 −40	0 −63	0 −100	0 −160	± 9	±12.5	±20	+7 −11	+14 −11
180	**250**	−170 −199	−100 −129	−50 −79	−15 −35	−15 −44	0 −20	0 −29	0 −46	0 −72	0 −115	0 −185	±10	±14.5	±23	+7 −13	+16 −13
250	**315**	−190 −222	−110 −142	−56 −88	−17 −40	−17 −49	0 −23	0 −32	0 −52	0 −81	0 −130	0 −210	±11.5	±16	±26	+7 −16	±16
315	**400**	−210 −246	−125 −161	−62 −98	−18 −43	−18 −54	0 −25	0 −36	0 −57	0 −89	0 −140	0 −230	±12.5	±18	±28	+7 −18	±18
400	**500**	−230 −270	−135 −175	−68 −108	−20 −47	−20 −60	0 −27	0 −40	0 −63	0 −97	0 −155	0 −250	±13.5	±20	±31	+7 −20	±20
500	**630**	−260 −304	−145 −189	−76 −120	–	−22 −66	–	0 −44	0 −70	0 −110	0 −175	0 −280	–	±22	±35	–	–
630	**800**	−290 −340	−160 −210	−80 −130	–	−24 −74	–	0 −50	0 −80	0 −125	0 −200	0 −320	–	±25	±40	–	–
800	**1 000**	−320 −376	−170 −226	−86 −142	–	−26 −82	–	0 −56	0 −90	0 −140	0 −230	0 −360	–	±28	±45	–	–

Note 1) Δ_{dmp} : single plane mean bore diameter deviation

Unit μm (Refer.)

k5	k6	k7	m5	m6	m7	n5	n6	p6	r6	r7	Nominal shaft diameter (mm) over	up to	Δd_{mp} [1] of bearing (class 0)
+6 +1	+9 +1	+13 +1	+9 +4	+12 +4	+16 +4	+13 +8	+16 +8	+20 +12	+23 +15	+27 +15	**3**	**6**	0 − 8
+7 +1	+10 +1	+16 +1	+12 +6	+15 +6	+21 +6	+16 +10	+19 +10	+24 +15	+28 +19	+34 +19	**6**	**10**	0 − 8
+9 +1	+12 +1	+19 +1	+15 +7	+18 +7	+25 +7	+20 +12	+23 +12	+29 +18	+34 +23	+41 +23	**10**	**18**	0 − 8
+11 +2	+15 +2	+23 +2	+17 +8	+21 +8	+29 +8	+24 +15	+28 +15	+35 +22	+41 +28	+49 +28	**18**	**30**	0 − 10
+13 +2	+18 +2	+27 +2	+20 +9	+25 +9	+34 +9	+28 +17	+33 +17	+42 +26	+50 +34	+59 +34	**30**	**50**	0 − 12
+15 +2	+21 +2	+32 +2	+24 +11	+30 +11	+41 +11	+33 +20	+39 +20	+51 +32	+60 +41	+71 +41	**50**	**65**	0 − 15
									+62 +43	+73 +43	**65**	**80**	
+18 +3	+25 +3	+38 +3	+28 +13	+35 +13	+48 +13	+38 +23	+45 +23	+59 +37	+73 +51	+86 +51	**80**	**100**	0 − 20
									+76 +54	+89 +54	**100**	**120**	
+21 +3	+28 +3	+43 +3	+33 +15	+40 +15	+55 +15	+45 +27	+52 +27	+68 +43	+88 +63	+103 +63	**120**	**140**	0 − 25
									+90 +65	+105 +65	**140**	**160**	
									+93 +68	+108 + 68	**160**	**180**	
+24 +4	+33 +4	+50 +4	+37 +17	+46 +17	+63 +17	+51 +31	+60 +31	+79 +50	+106 +77	+123 +77	**180**	**200**	0 − 30
									+109 +80	+126 +80	**200**	**225**	
									+113 +84	+130 +84	**225**	**250**	
+27 +4	+36 +4	+56 +4	+43 +20	+52 +20	+72 +20	+57 +34	+66 +34	+88 +56	+126 +94	+146 +94	**250**	**280**	0 − 35
									+130 +98	+150 +98	**280**	**315**	
+29 +4	+40 +4	+61 +4	+46 +21	+57 +21	+78 +21	+62 +37	+73 +37	+98 +62	+144 +108	+165 +108	**315**	**355**	0 − 40
									+150 +114	+171 +114	**355**	**400**	
+32 +5	+45 +5	+68 +5	+50 +23	+63 +23	+86 +23	+67 +40	+80 +40	+108 +68	+166 +126	+189 +126	**400**	**450**	0 − 45
									+172 +132	+195 +132	**450**	**500**	
–	+44 0	+70 0	–	+70 +26	+96 +26	–	+88 +44	+122 +78	+194 +150	+220 +150	**500**	**560**	0 − 50
									+199 +155	+225 +155	**560**	**630**	
–	+50 0	+80 0	–	+80 +30	+110 +30	–	+100 +50	+138 +88	+225 +175	+255 +175	**630**	**710**	0 − 75
									+235 +185	+265 +185	**710**	**800**	
–	+56 0	+90 0	–	+90 +34	+124 +34	–	+112 +56	+156 +100	+266 +210	+300 +210	**800**	**900**	0 − 100
									+276 +220	+310 +220	**900**	**1 000**	

Supplementary table 2 Housing bore tolerances (deviation from nominal dimensions)

Nominal bore diameter (mm)		Deviation classes of housing bore diameter														
over	up to	E6	F6	F7	G6	G7	H6	H7	H8	H9	H10	J6	J7	JS5	JS6	JS7
10	18	+43 +32	+27 +16	+34 +16	+17 +6	+24 +6	+11 0	+18 0	+27 0	+43 0	+70 0	+ 6 − 5	+10 −8	± 4	± 5.5	± 9
18	30	+53 +40	+33 +20	+41 +20	+20 +7	+28 +7	+13 0	+21 0	+33 0	+52 0	+84 0	+ 8 − 5	+12 −9	± 4.5	± 6.5	±10
30	50	+66 +50	+41 +25	+50 +25	+25 +9	+34 +9	+16 0	+25 0	+39 0	+62 0	+100 0	+10 −6	+14 −11	± 5.5	± 8	±12
50	80	+79 +60	+49 +30	+60 +30	+29 +10	+40 +10	+19 0	+30 0	+46 0	+74 0	+120 0	+13 −6	+18 −12	± 6.5	± 9.5	±15
80	120	+94 +72	+58 +36	+71 +36	+34 +12	+47 +12	+22 0	+35 0	+54 0	+87 0	+140 0	+16 −6	+22 −13	± 7.5	±11	±17
120	180	+110 +85	+68 +43	+83 +43	+39 +14	+54 +14	+25 0	+40 0	+63 0	+100 0	+160 0	+18 −7	+26 −14	± 9	±12.5	±20
180	250	+129 +100	+79 +50	+96 +50	+44 +15	+61 +15	+29 0	+46 0	+72 0	+115 0	+185 0	+22 −7	+30 −16	±10	±14.5	±23
250	315	+142 +110	+88 +56	+108 +56	+49 +17	+69 +17	+32 0	+52 0	+81 0	+130 0	+210 0	+25 −7	+36 −16	±11.5	±16	±26
315	400	+161 +125	+98 +62	+119 +62	+54 +18	+75 +18	+36 0	+57 0	+89 0	+140 0	+230 0	+29 −7	+39 −18	±12.5	±18	±28
400	500	+175 +135	+108 +68	+131 +68	+60 +20	+83 +20	+40 0	+63 0	+97 0	+155 0	+250 0	+33 −7	+43 −20	±13.5	±20	±31
500	630	+189 +145	+120 +76	+146 +76	+66 +22	+92 +22	+44 0	+70 0	+110 0	+175 0	+280 0	–	–	–	±22	±35
630	800	+210 +160	+130 +80	+160 +80	+74 +24	+104 +24	+50 0	+80 0	+125 0	+200 0	+320 0	–	–	–	±25	±40
800	1 000	+226 +170	+142 +86	+176 +86	+82 +26	+116 +26	+56 0	+90 0	+140 0	+230 0	+360 0	–	–	–	±28	±45
1000	1 250	+261 +195	+164 +98	+203 +98	+94 +28	+133 +28	+66 0	+105 0	+165 0	+260 0	+420 0	–	–	–	±33	±52

Note 1) ΔD_{mp} : single plane mean outside diameter deviation

Unit µm

K5	K6	K7	M5	M6	M7	N5	N6	N7	P6	P7	R7	Nominal bore diameter (mm) over	Nominal bore diameter (mm) up to	(Refer.) ΔD_{mp} 1) of bearing (class 0)
+2 −6	+2 −9	+6 −12	−4 −12	−4 −15	0 −18	−9 −17	−9 −20	−5 −23	−15 −26	−11 −29	−16 −34	**10**	**18**	0 − 8
+1 −8	+2 −11	+6 −15	−5 −14	−4 −17	0 −21	−12 −21	−11 −24	−7 −28	−18 −31	−14 −35	−20 −41	**18**	**30**	0 − 9
+2 −9	+3 −13	+7 −18	−5 −16	−4 −20	0 −25	−13 −24	−12 −28	−8 −33	−21 −37	−17 −42	−25 −50	**30**	**50**	0 − 11
+3 −10	+4 −15	+9 −21	−6 −19	−5 −24	0 −30	−15 −28	−14 −33	−9 −39	−26 −45	−21 −51	−30 −60	**50**	**65**	0 − 13
											−32 −62	**65**	**80**	
+2 −13	+4 −18	+10 −25	−8 −23	−6 −28	0 −35	−18 −33	−16 −38	−10 −45	−30 −52	−24 −59	−38 −73	**80**	**100**	0 − 15
											−41 −76	**100**	**120**	
+3 −15	+4 −21	+12 −28	−9 −27	−8 −33	0 −40	−21 −39	−20 −45	−12 −52	−36 −61	−28 −68	−48 −88	**120**	**140**	(up to150) 0 − 18 (over 150) 0 − 25
											−50 −90	**140**	**160**	
											−53 −93	**160**	**180**	
+2 −18	+5 −24	+13 −33	−11 −31	−8 −37	0 −46	−25 −45	−22 −51	−14 −60	−41 −70	−33 −79	−60 −106	**180**	**200**	0 − 30
											−63 −109	**200**	**225**	
											−67 −113	**225**	**250**	
+3 −20	+5 −27	+16 −36	−13 −36	−9 −41	0 −52	−27 −50	−25 −57	−14 −66	−47 −79	−36 −88	−74 −126	**250**	**280**	0 − 35
											−78 −130	**280**	**315**	
+3 −22	+7 −29	+17 −40	−14 −39	−10 −46	0 −57	−30 −55	−26 −62	−16 −73	−51 −87	−41 −98	−87 −144	**315**	**355**	0 − 40
											−93 −150	**355**	**400**	
+2 −25	+8 −32	+18 −45	−16 −43	−10 −50	0 −63	−33 −60	−27 −67	−17 −80	−55 −95	−45 −108	−103 −166	**400**	**450**	0 − 45
											−109 −172	**450**	**500**	
–	0 −44	0 −70	–	−26 −70	−26 −96	–	−44 −88	−44 −114	−78 −122	−78 −148	−150 −220	**500**	**560**	0 − 50
											−155 −225	**560**	**630**	
–	0 −50	0 −80	–	−30 −80	−30 −110	–	−50 −100	−50 −130	−88 −138	−88 −168	−175 −255	**630**	**710**	0 − 75
											−185 −265	**710**	**800**	
–	0 −56	0 −90	–	−34 −90	−34 −124	–	−56 −112	−56 −146	−100 −156	−100 −190	−210 −300	**800**	**900**	0 −100
											−220 −310	**900**	**1 000**	
–	0 −66	0 −105	–	−40 −106	−40 −145	–	−66 −132	−66 −171	−120 −186	−120 −225	−250 −355	**1 000**	**1 120**	0 −125
											−260 −365	**1 120**	**1 250**	

Supplementary table 3 Numerical values for standard tolerance grades IT

Basic size (mm)		Standard tolerance grades (IT)																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14 1)	15 1)	16 1)	17 1)	18 1)
over	up to	Tolerances (μm)											Tolerances (mm)						
–	3	0.8	1.2	2	3	4	6	10	14	25	40	60	0.10	0.14	0.26	0.40	0.60	1.00	1.40
3	6	1	1.5	2.5	4	5	8	12	18	30	48	75	0.12	0.18	0.30	0.48	0.75	1.20	1.80
6	10	1	1.5	2.5	4	6	9	15	22	36	58	90	0.15	0.22	0.36	0.58	0.90	1.50	2.20
10	18	1.2	2	3	5	8	11	18	27	43	70	110	0.18	0.27	0.43	0.70	1.10	1.80	2.70
18	30	1.5	2.5	4	6	9	13	21	33	52	84	130	0.21	0.33	0.52	0.84	1.30	2.10	3.30
30	50	1.5	2.5	4	7	11	16	25	39	62	100	160	0.25	0.39	0.62	1.00	1.60	2.50	3.90
50	80	2	3	5	8	13	19	30	46	74	120	190	0.30	0.46	0.74	1.20	1.90	3.00	4.60
80	120	2.5	4	6	10	15	22	35	54	87	140	220	0.35	0.54	0.87	1.40	2.20	3.50	5.40
120	180	3.5	5	8	12	18	25	40	63	100	160	250	0.40	0.63	1.00	1.60	2.50	4.00	6.30
180	250	4.5	7	10	14	20	29	46	72	115	185	290	0.46	0.72	1.15	1.85	2.90	4.60	7.20
250	315	6	8	12	16	23	32	52	81	130	210	320	0.52	0.81	1.30	2.10	3.20	5.20	8.10
315	400	7	9	13	18	25	36	57	89	140	230	360	0.57	0.89	1.40	2.30	3.60	5.70	8.90
400	500	8	10	15	20	27	40	63	97	155	250	400	0.63	0.97	1.55	2.50	4.00	6.30	9.70
500	630	–	–	–	–	–	44	70	110	175	280	440	0.70	1.10	1.75	2.80	4.40	7.00	11.00
630	800	–	–	–	–	–	50	80	125	200	320	500	0.80	1.25	2.00	3.20	5.00	8.00	12.50
800	1 000	–	–	–	–	–	56	90	140	230	360	560	0.90	1.40	2.30	3.60	5.60	9.00	14.00
1 000	1 250	–	–	–	–	–	66	105	165	260	420	660	1.05	1.65	2.60	4.20	6.60	10.50	16.50
1 250	1 600	–	–	–	–	–	78	125	195	310	500	780	1.25	1.95	3.10	5.00	7.80	12.50	19.50
1 600	2 000	–	–	–	–	–	92	150	230	370	600	920	1.50	2.30	3.70	6.00	9.20	15.00	23.00
2 000	2 500	–	–	–	–	–	110	175	280	440	700	1 100	1.75	2.80	4.40	7.00	11.00	17.50	28.00
2 500	3 150	–	–	–	–	–	135	210	330	540	860	1 350	2.10	3.30	5.40	8.60	13.50	21.00	33.00

Note 1) Standard tolerance grades IT 14 to IT 18 (incl.) shall not be used for basic sizes less than or equal to 1 mm.

Supplementary table 4 Inch/millimeter conversion

Inch		Inches										
		0	1	2	3	4	5	6	7	8	9	10
		mm										
0	0	**0**	**25.4000**	**50.8000**	**76.2000**	**101.6000**	**127.0000**	**152.4000**	**177.8000**	**203.2000**	**228.6000**	**254.0000**
1/64	0.015625	0.3969	25.7969	51.1969	76.5969	101.9969	127.3969	152.7969	178.1969	203.5969	228.9969	254.3969
1/32	0.03125	0.7938	26.1938	51.5938	76.9938	102.3938	127.7938	153.1938	178.5938	203.9938	229.3938	254.7938
3/64	0.046875	1.1906	26.5906	51.9906	77.3906	102.7906	128.1906	153.5906	178.9906	204.3906	229.7906	255.1906
1/16	0.0625	1.5875	26.9875	52.3875	77.7875	103.1875	128.5875	153.9875	179.3875	204.7875	230.1875	255.5875
5/64	0.078125	1.9844	27.3844	52.7844	78.1844	103.5844	128.9844	154.3844	179.7844	205.1844	230.5844	255.9844
3/32	0.09375	2.3812	27.7812	53.1812	78.5812	103.9812	129.3812	154.7812	180.1812	205.5812	230.9812	256.3812
7/64	0.109375	2.7781	28.1781	53.5781	78.9781	104.3781	129.7781	155.1781	180.5781	205.9781	231.3781	256.7781
1/8	0.125	**3.1750**	**28.5750**	**53.9750**	**79.3750**	**104.7750**	**130.1750**	**155.5750**	**180.9750**	**206.3750**	**231.7750**	**257.1750**
9/64	0.140625	3.5719	28.9719	54.3719	79.7719	105.1719	130.5719	155.9719	181.3719	206.7719	232.1719	257.5719
5/32	0.15625	3.9688	29.3688	54.7688	80.1688	105.5688	130.9688	156.3688	181.7688	207.1688	232.5688	257.9688
11/64	0.171875	4.3656	29.7656	55.1656	80.5656	105.9656	131.3656	156.7656	182.1656	207.5656	232.9656	258.3656
3/16	0.1875	4.7625	30.1625	55.5625	80.9625	106.3625	131.7625	157.1625	182.5625	207.9625	233.3625	258.7625
13/64	0.203125	5.1594	30.5594	55.9594	81.3594	106.7594	132.1594	157.5594	182.9594	208.3594	233.7594	259.1594
7/32	0.21875	5.5562	30.9562	56.3562	81.7562	107.1562	132.5562	157.9562	183.3562	208.7562	234.1562	259.5562
15/64	0.234375	5.9531	31.3531	56.7531	82.1531	107.5531	132.9531	158.3531	183.7531	209.1531	234.5531	259.9531
1/4	0.25	**6.3500**	**31.7500**	**57.1500**	**82.5500**	**107.9500**	**133.3500**	**158.7500**	**184.1500**	**209.5500**	**234.9500**	**260.3500**
17/64	0.265625	6.7469	32.1469	57.5469	82.9469	108.3469	133.7469	159.1469	184.5469	209.9469	235.3469	260.7469
9/32	0.28125	7.1438	32.5438	57.9438	83.3438	108.7438	134.1438	159.5438	184.9438	210.3438	235.7438	261.1438
19/64	0.296875	7.5406	32.9406	58.3406	83.7406	109.1406	134.5406	159.9406	185.3406	210.7406	236.1406	261.5406
5/16	0.3125	7.9375	33.3375	58.7375	84.1375	109.5375	134.9375	160.3375	185.7375	211.1375	236.5375	261.9375
21/64	0.328125	8.3344	33.7344	59.1344	84.5344	109.9344	135.3344	160.7344	186.1344	211.5344	236.9344	262.3344
11/32	0.34375	8.7312	34.1312	59.5312	84.9312	110.3312	135.7312	161.1312	186.5312	211.9312	237.3312	262.7312
23/64	0.359375	9.1281	34.5281	59.9281	85.3281	110.7281	136.1281	161.5281	186.9281	212.3281	237.7281	263.1281
3/8	0.375	**9.5250**	**34.9250**	**60.3250**	**85.7250**	**111.1250**	**136.5250**	**161.9250**	**187.3250**	**212.7250**	**238.1250**	**263.5250**
25/64	0.390625	9.9219	35.3219	60.7219	86.1219	111.5219	136.9219	162.3219	187.7219	213.1219	238.5219	263.9219
13/32	0.40625	10.3188	35.7188	61.1188	86.5188	111.9188	137.3188	162.7188	188.1188	213.5188	238.9188	264.3188
27/64	0.421875	10.7156	36.1156	61.5156	86.9156	112.3156	137.7156	163.1156	188.5156	213.9156	239.3156	264.7156
7/16	0.4375	11.1125	36.5125	61.9125	87.3125	112.7125	138.1125	163.5125	188.9125	214.3125	239.7125	265.1125
29/64	0.453125	11.5094	36.9094	62.3094	87.7094	113.1094	138.5094	163.9094	189.3094	214.7094	240.1094	265.5094
15/32	0.46875	11.9062	37.3062	62.7062	88.1062	113.5062	138.9062	164.3062	189.7062	215.1062	240.5062	265.9062
31/64	0.484375	12.3031	37.7031	63.1031	88.5031	113.9031	139.3031	164.7031	190.1031	215.5031	240.9031	266.3031
1/2	0.5	**12.7000**	**38.1000**	**63.5000**	**88.9000**	**114.3000**	**139.7000**	**165.1000**	**190.5000**	**215.9000**	**241.3000**	**266.7000**
33/64	0.515625	13.0969	38.4969	63.8969	89.2969	114.6969	140.0969	165.4969	190.8969	216.2969	241.6969	267.0969
17/32	0.53125	13.4938	38.8938	64.2938	89.6938	115.0938	140.4938	165.8938	191.2938	216.6938	242.0938	267.4938
35/64	0.546875	13.8906	39.2906	64.6906	90.0906	115.4906	140.8906	166.2906	191.6906	217.0906	242.4906	267.8906
9/16	0.5625	14.2875	39.6875	65.0875	90.4875	115.8875	141.2875	166.6875	192.0875	217.4875	242.8875	268.2875
37/64	0.578125	14.6844	40.0844	65.4844	90.8844	116.2844	141.6844	167.0844	192.4844	217.8844	243.2844	268.6844
19/32	0.59375	15.0812	40.4812	65.8812	91.2812	116.6812	142.0812	167.4812	192.8812	218.2812	243.6812	269.0812
39/64	0.609375	15.4781	40.8781	66.2781	91.6781	117.0781	142.4781	167.8781	193.2781	218.6781	244.0781	269.4781
5/8	0.625	**15.8750**	**41.2750**	**66.6750**	**92.0750**	**117.4750**	**142.8750**	**168.2750**	**193.6750**	**219.0750**	**244.4750**	**269.8750**
41/64	0.640625	16.2719	41.6719	67.0719	92.4719	117.8719	143.2719	168.6719	194.0719	219.4719	244.8719	270.2719
21/32	0.65625	16.6688	42.0688	67.4688	92.8688	118.2688	143.6688	169.0688	194.4688	219.8688	245.2688	270.6688
43/64	0.671875	17.0656	42.4656	67.8656	93.2656	118.6656	144.0656	169.4656	194.8656	220.2656	245.6656	271.0656
11/16	0.6875	17.4625	42.8625	68.2625	93.6625	119.0625	144.4625	169.8625	195.2625	220.6625	246.0625	271.4625
45/64	0.703125	17.8594	43.2594	68.6594	94.0594	119.4594	144.8594	170.2594	195.6594	221.0594	246.4594	271.8594
23/32	0.71875	18.2562	43.6562	69.0562	94.4562	119.8562	145.2562	170.6562	196.0562	221.4562	246.8562	272.2562
47/64	0.734375	18.6531	44.0531	69.4531	94.8531	120.2531	145.6531	171.0531	196.4531	221.8531	247.2531	272.6531
3/4	0.75	**19.0500**	**44.4500**	**69.8500**	**95.2500**	**120.6500**	**146.0500**	**171.4500**	**196.8500**	**222.2500**	**247.6500**	**273.0500**
49/64	0.765625	19.4469	44.8469	70.2469	95.6469	121.0469	146.4469	171.8469	197.2469	222.6469	248.0469	273.4469
25/32	0.78125	19.8438	45.2438	70.6438	96.0438	121.4438	146.8438	172.2438	197.6438	223.0438	248.4438	273.8438
51/64	0.796875	20.2406	45.6406	71.0406	96.4406	121.8406	147.2406	172.6406	198.0406	223.4406	248.8406	274.2406
13/16	0.8125	20.6375	46.0375	71.4375	96.8375	122.2375	147.6375	173.0375	198.4375	223.8375	249.2375	274.6375
53/64	0.828125	21.0344	46.4344	71.8344	97.2344	122.6344	148.0344	173.4344	198.8344	224.2344	249.6344	275.0344
27/32	0.84375	21.4312	46.8312	72.2312	97.6312	123.0312	148.4312	173.8312	199.2312	224.6312	250.0312	275.4312
55/64	0.859375	21.8281	47.2281	72.6281	98.0281	123.4281	148.8281	174.2281	199.6281	225.0281	250.4281	275.8281
7/8	0.875	**22.2250**	**47.6250**	**73.0250**	**98.4250**	**123.8250**	**149.2250**	**174.6250**	**200.0250**	**225.4250**	**250.8250**	**276.2250**
57/64	0.890625	22.6219	48.0219	73.4219	98.8219	124.2219	149.6219	175.0219	200.4219	225.8219	251.2219	276.6219
29/32	0.90625	23.0188	48.4188	73.8188	99.2188	124.6188	150.0188	175.4188	200.8188	226.2188	251.6188	277.0188
59/64	0.921875	23.4156	48.8156	74.2156	99.6156	125.0156	150.4156	175.8156	201.2156	226.6156	252.0156	277.4156
15/16	0.9375	23.8125	49.2125	74.6125	100.0125	125.4125	150.8125	176.2125	201.6125	227.0125	252.4125	277.8125
61/64	0.953125	24.2094	49.6094	75.0094	100.4094	125.8094	151.2094	176.6094	202.0094	227.4094	252.8094	278.2094
31/32	0.96875	24.6062	50.0062	75.4062	100.8062	126.2062	151.6062	177.0062	202.4062	227.8062	253.2062	278.6062
63/64	0.984375	25.0031	50.4031	75.8031	101.2031	126.6031	152.0031	177.4031	202.8031	228.2031	253.6031	279.0031

Supplementary table 5 (1) SI units and conversion factors

Mass	SI units	Other Units[1]	Conversion into SI units	Conversion from SI units
Angle	rad [radian(s)]	° [degree(s)] * ' [minute(s)] * " [second(s)] *	1° = π/180 rad 1' = π/10 800 rad 1" = π/648 000 rad	1 rad = 57.295 78°
Length	m [meter(s)]	Å [Angstrom unit] ** μ [micron(s)] in [inch(es)] ft [foot(feet)] yd [yard(s)] mile [mile(s)]	1Å = 10^{-10} m = 0.1 nm = 100 pm 1μ = 1μm 1 in = 25.4 mm 1 ft = 12 in = 0.304 8 m 1 yd = 3 ft = 0.914 4 m 1 mile = 5 280 ft = 1 609.344 m	1 m = 10^{10}Å 1 m = 39.37 in 1 m = 3.280 8 ft 1 m = 1.093 6 yd 1km = 0.621 4 mile
Area	m^2 [square meter(s)]	a [are(s)] ha [hectare(s)] acre [acre(s)]	1 a = 100 m^2 1 ha = 10^4 m^2 1 acre = 4 840 yd^2 = 4 046.86 m^2	 1 km^2 = 247.1 acre
Volume	m^3 [cubic meter(s)]	ℓ, L [liter(s)] cc [cubic centimeters] gal (US) [gallon(s)] floz (US) [fluid ounce(s)] barrel (US) [barrels(US)]	1 ℓ = 1 dm^3 = 10^{-3} m^3 1 cc = 1 cm^3 = 10^{-6} m^3 1 gal (US) = 231 in^3 = 3.785 41 dm^3 1 floz (US) = 29.573 5 cm^3 1 barrel (US) = 158.987 dm^3	1 m^3 = 10^3 ℓ 1 m^3 = 10^6 cc 1 m^3 = 264.17 gal 1 m^3 = 33 814 floz 1 m^3 = 6.289 8 barrel
Time	s [second(s)]	min [minute(s)] * h [hour(s)] * d [day(s)] *		
Angular velocity	rad/s			
Angular acceleration	rad/s^2			
Velocity, speed	m/s	kn [knot(s)] **	1 kn = 1 852 m/h	1km/h = 0.539 96 kn
Acceleration	m/s^2	G	1 G = 9.806 65 m/s^2	1 m/s^2 = 0.101 97 G
Frequency	Hz [hertz]	c/s [cycle(s)/second]	1 c/s = 1 s^{-1} = 1 Hz	
Rotation speed	s^{-1}	rpm [revolutions per minute]	1 rpm = 60 s^{-1}	1 s^{-1} = 1/60 rpm
Mass	kg [kilogram(s)]	t [ton(s)] lb [pound(s)] gr [grain(s)] oz [ounce(s)] ton (UK) [ton(s) (UK)] ton (US) [ton(s) (US)] car [carat(s)]	1 t = 10^3 kg 1 lb = 0.453 592 37 kg 1 gr = 64.798 91mg 1 oz = 1/16lb = 28.349 5 g 1 ton (UK) = 1 016.05 kg 1 ton (US) = 907.185kg 1 car = 200mg	 1kg = 2.204 6 lb 1 g = 15.432 4 gr 1kg = 35.274 0 oz 1 t = 0.984 2 ton (UK) 1 t = 1.102 3 ton (US) 1 g = 5 car

Note 1) * : Unit can be used as an SI unit.
** : Unit can be used as an SI unit for the time being.
No asterisk : Unit cannot be used.

Supplementary table 5 (2) SI units and conversion factors

Mass	SI units	Other Units [1]	Conversion into SI units	Conversion from SI units
Density	kg/m^3			
Linear density	kg/m			
Momentum	kg · m/s			
Moment of momentum, angular momentum	kg · m^2/s			
Moment of inertia	kg · m^2			
Force	N [newton(s)]	dyn [dyne(s)] kgf [kilogram-force] gf [gram-force] tf [ton-force] lbf [pound-force]	1 dyn = 10^{-5} N 1 kgf = 9.806 65 N 1 gf = 9.806 65×10^{-3} N 1 tf = 9.806 65×10^{3} N 1 lbf = 4.448 22 N	1 N = 10^{5} dyn 1 N = 0.101 97 kgf 1 N = 0.224 809 lbf
Moment of force, torque	N · m [Newton meter(s)]	gf · cm kgf · cm kgf · m tf · m tf · lbf	1 gf · cm = 9.806 65×10^{-5} N · m 1 kgf · cm = 9.806 65×10^{-2} N · m 1 kgf · m = 9.806 65 N · m 1 tf · m = 9.806 65×10^{3} N · m 1 ft · 1bf = 1.355 82 N · m	1 N · m = 0.101 97 kgf · m 1 N · m = 0.737 56 ft · 1bf
Pressure, stress	Pa [Pascal(s)] or N/m^2 {1 Pa = 1 N/m^2}	gf/cm^2 kgf/mm^2 kgf/m^2 lbf/in^2 bar [bar(s)] at [engineering air pressure] mH_2O, mAq [meter water column] atm [atmosphere] mHg [meter mercury column] Torr [torr]	1 gf/ cm^2 = 9.806 65×10 Pa 1 kgf/mm^2 = 9.806 65×10^{6} Pa 1 kgf/m^2 = 9.806 65 Pa 1 lbf/in^2 = 6 894.76 Pa 1 bar = 10^{5} Pa 1 at = 1kgf/cm^2 = 9.806 65×10^{4} Pa 1 mH_2O = 9.806 65×10^{3} Pa 1 atm = 101 325 Pa 1 mHg = $\frac{101\ 325}{0.76}$ Pa 1 Torr = 1mmHg = 133.322 Pa	1 Pa = 0.101 97 kgf/m^2 1 MPa = 0.101 97 kgf/mm^2 1 Pa = 0.145×10^{-3} lbf/in^2 1 Pa = 10^{-2} mbar 1 Pa = 7.500 6×10^{-3} Torr
Viscosity	Pa · s [pascal second]	P [poise] ** kgf · s/m^2	10^{-2} P = 1 cP = 1 mPa · s 1 kgf · s/m^2 = 9.806 65 Pa · s	1 Pa · s = 0.101 97 kgf · s/m^2
Kinematic viscosity	m^2/s	St [stokes] **	10^{-2}St = 1 cSt = 1 mm^2/s	
Surface tension	N/m			

Note 1) * : Unit can be used as an SI unit.
** : Unit can be used as an SI unit for the time being.
No asterisk : Unit cannot be used.

Supplementary table 5 (3) SI units and conversion factors

Mass	SI units	Other Units[1]		Conversion into SI units	Conversion from SI units
Work, energy	J [joule(s)] W · s [watt(s) second] {1 J = 1 N · m, 1 W · s = 1 J}	eV [electron volt(s)] erg [erg(s)] kgf · m ft · lbf	✻	1 eV = (1.6021892 ± 0.0000046)X10 $^{-19}$ J 1 erg = 10 $^{-7}$ J 1 kgf · m = 9.806 65 J 1 ft · lbf = 1.355 82 J	1 J = 10 ^{7} erg 1 J = 0.101 97 kgf · m 1 J = 0.737 56 ft · lbf
Power	W [watt(s)] {1 W = 1 J/s}	erg/s [ergs per second] kgf · m/s ps [French horse-power] HP [horse-power (British)] ft · lbf/s		1 erg/s = 10 $^{-7}$ W 1 kgf · m/s = 9.806 65 W 1 PS = 75 kgf · m/s = 735.5 W 1 HP = 550 ft · lbf/s = 745.7 W 1 ft · lbf/s = 1.355 82 W	1 W = 0.101 97 kgf · m/s 1 W = 0.001 36 PS 1 W = 0.001 34 HP
Temperature	K [kelvin(s)]	˚C [degree(s) Celsius] ˚F [degree(s) Fahrenheit]	✻	t˚C = (t+273.15) K t˚F = $\frac{5}{9}$ (t - 32)˚C	t K = (t - 273.15)˚C t˚C = ($\frac{9}{5}$ t+32)˚F
Temperature difference	K [kelvin(s)]	˚C [degree(s) Celsius]	✻	1˚C = 1 K	1 K = 1 ˚C
Linear expansion coefficient	K $^{-1}$ [per kelvin]	˚C $^{-1}$ [per degree]	✻		
Heat	J [joule(s)] W · s [watt(s) second] {1 J = 1 W · s}	erg [erg(s)] kgf · m cal [calories] cal $_{15}$ [15 degree calories] cal $_{IT}$ [I. T. calories]		1 erg = 10 $^{-7}$ J 1 cal = 4.186 05 J (when temperature is not specified) 1 cal $_{15}$ = 4.185 5 J 1 cal $_{IT}$ = 4.186 J 1 Mcal $_{IT}$ = 1.163 kW · h	1 J = 10 ^{7} erg 1 J = 0.238 89 cal 1 kW · h = 0.86X10 ^{6} cal
Thermal conductivity	W/ (m · K)	W/ (m · ˚C) cal/ (s · m · ˚C)	✻	1 W/ (m · ˚C) = 1 W/ (m · K) 1 cal/ (s · m · ˚C) = 4.186 05 W/ (m · K)	
Coeffcient of heat transfer	W/ (m ^{2} · K)	W/ (m ^{2} · ˚C) cal/ (s · m ^{2} · ˚C)	✻	1 W/ (m ^{2} · ˚C) = 1 W/ (m ^{2} · K) 1 cal/ (s · m ^{2} · ˚C) = 4.186 05 W/ (m ^{2} · K)	
Heat capacity	J/K	J/˚C	✻	1 J/ ˚C = 1 J/K	
Specific heat capacity	J/ (kg · K)	J/ (kg · ˚C)	✻		

Note 1) ✻ : Unit can be used as an SI unit.
✻✻ : Unit can be used as an SI unit for the time being.
No asterisk : Unit cannot be used.

Supplementary table 5 (4) SI units and conversion factors

Mass	SI units	Other Units [1]	Conversion into SI units	Conversion from SI units
Electric current	A [ampere(s)]			
Electric charge, quantity of electricity	C [coulomb(s)] {1 C = 1 A · s}	A · h ✻	1 A · h = 3.6 kC	
Tension, electric potential	V [volt(s)] {1 V = 1 W/A}			
Capacitance	F [farad(s)] {1 F = 1 C/V}			
Magnetic field strength	A/m	Oe [oersted(s)]	1 Oe = $\frac{10^3}{4\pi}$ A/m	1 A/m = $4\pi\times10^{-3}$ Oe
Magnetic flux density	T [tesla(s)] {1 T = 1N/(A · m) = 1Wb/m² = 1V · s/m²}	Gs [gauss(es)] γ [gamma(s)]	1 Gs = 10^{-4} T 1γ = 10^{-9} T	1 T = 10^{4} Gs 1 T = 10^{9}γ
Magnetic flux	Wb [weber(s)] {1 Wb = 1 V · s}	Mx [maxwell(s)]	1 Mx = 10^{-8} Wb	1 Wb = 10^{8} Mx
Self inductance	H [henry (– ries)] {1 H = 1 Wb/A}			
Resistance	Ω [ohm(s)] {1Ω = 1 V/A}			
Conductance	S [siemens] {1 S = 1 A/V}			
Power	W {1 W = 1 J/s = 1 A · V}			

Note 1) ✻ : Unit can be used as an SI unit.
✻✻ : Unit can be used as an SI unit for the time being.
No asterisk : Unit cannot be used.

Supplementaty table 6 Steel hardness conversion

Rockwell	Vicker's	Brinell		Rockwell		Shore
C-scale 1471.0 N {150 kgf}		Standard ball	Tungsten carbide ball	A-scale 588.4 N {60 kgf}	B-scale 980.7 N {100 kgf}	
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		73.1		60
44	434	409		72.5		58
43	423	400		72.0		57
42	412	390		71.5		56
41	402	381		70.9		55
40	392	371		70.4	–	54
39	382	362		69.9	–	52
38	372	353		69.4	–	51
37	363	344		68.9	–	50
36	354	336		68.4	(109.0)	49
35	345	327		67.9	(108.5)	48
34	336	319		67.4	(108.0)	47
33	327	311		66.8	(107.5)	46
32	318	301		66.3	(107.0)	44
31	310	294		65.8	(106.0)	43
30	302	286		65.3	(105.5)	42
29	294	279		64.7	(104.5)	41
28	286	271		64.3	(104.0)	41
27	279	264		63.8	(103.0)	40
26	272	258		63.3	(102.5)	38
25	266	253		62.8	(101.5)	38
24	260	247		62.4	(101.0)	37
23	254	243		62.0	100.0	36
22	248	237		61.5	99.0	35
21	243	231		61.0	98.5	35
20	238	226		60.5	97.8	34
(18)	230	219		–	96.7	33
(16)	222	212		–	95.5	32
(14)	213	203		–	93.9	31
(12)	204	194		–	92.3	29
(10)	196	187			90.7	28
(8)	188	179			89.5	27
(6)	180	171			87.1	26
(4)	173	165			85.5	25
(2)	166	158			83.5	24
(0)	160	152			81.7	24

Supplementary table 7 Viscosity conversion

Kinematic viscosity mm²/s	Saybolt SUS (second)		Redwood R (second)		Engler E (degree)
	100 °F	210 °F	50 °C	100 °C	
2	32.6	32.8	30.8	31.2	1.14
3	36.0	36.3	33.3	33.7	1.22
4	39.1	39.4	35.9	36.5	1.31
5	42.3	42.6	38.5	39.1	1.40
6	45.5	45.8	41.1	41.7	1.48
7	48.7	49.0	43.7	44.3	1.56
8	52.0	52.4	46.3	47.0	1.65
9	55.4	55.8	49.1	50.0	1.75
10	58.8	59.2	52.1	52.9	1.84
11	62.3	62.7	55.1	56.0	1.93
12	65.9	66.4	58.2	59.1	2.02
13	69.6	70.1	61.4	62.3	2.12
14	73.4	73.9	64.7	65.6	2.22
15	77.2	77.7	68.0	69.1	2.32
16	81.1	81.7	71.5	72.6	2.43
17	85.1	85.7	75.0	76.1	2.54
18	89.2	89.8	78.6	79.7	2.64
19	93.3	94.0	82.1	83.6	2.76
20	97.5	98.2	85.8	87.4	2.87
21	102	102	89.5	91.3	2.98
22	106	107	93.3	95.1	3.10
23	110	111	97.1	98.9	3.22
24	115	115	101	103	3.34
25	119	120	105	107	3.46
26	123	124	109	111	3.58
27	128	129	112	115	3.70
28	132	133	116	119	3.82
29	137	138	120	123	3.95
30	141	142	124	127	4.07
31	145	146	128	131	4.20
32	150	150	132	135	4.32
33	154	155	136	139	4.45
34	159	160	140	143	4.57
35	163	164	144	147	4.70
36	168	170	148	151	4.83
37	172	173	153	155	4.96
38	177	178	156	159	5.08
39	181	183	160	164	5.21
40	186	187	164	168	5.34
41	190	192	168	172	5.47
42	195	196	172	176	5.59
43	199	201	176	180	5.72
44	204	205	180	185	5.85
45	208	210	184	189	5.98
46	213	215	188	193	6.11
47	218	219	193	197	6.24
48	222	224	197	202	6.37
49	227	228	201	206	6.50
50	231	233	205	210	6.63
55	254	256	225	231	7.24
60	277	279	245	252	7.90
65	300	302	266	273	8.55
70	323	326	286	294	9.21
75	346	349	306	315	9.89
80	371	373	326	336	10.5
85	394	397	347	357	11.2
90	417	420	367	378	11.8
95	440	443	387	399	12.5
100	464	467	408	420	13.2
120	556	560	490	504	15.8
140	649	653	571	588	18.4
160	742	747	653	672	21.1
180	834	840	734	757	23.7
200	927	933	816	841	26.3
250	1 159	1 167	1 020	1 051	32.9
300	1 391	1 400	1 224	1 241	39.5

Remark: 1 mm²/s=1 cSt (centi stokes)

KOYO SEIKO CO., LTD.

Company name ______ Division, department, and section ______

Name of staff member in charge ______ Phone ______ FAX ______

Extreme Special Environments
Specifications Sheet for Ceramic Bearings and/or EXSEV Bearings

Note: For the selection of the most suitable bearing this sheet must be completed in as much detail as possible. Date

<table>
<tr><td>Bearing size and bearing number</td><td colspan="6"></td></tr>
<tr><td>Application</td><td colspan="6">a. For new design b. For repair</td></tr>
<tr><td>Required performance</td><td colspan="6">a. Life b. High speed c. Low dust generation d. Vacuum e. Corrosion resistance f. High temperature g. Non-magnetism h. Insulation i. Others ( )</td></tr>
<tr><td rowspan="10">Operating condition</td><td>Operation</td><td>a. Dual-directional b. Continuous c. Intermittent</td><td rowspan="2">Running time</td><td colspan="3" rowspan="2">· 24 h/day
· h/day
· Other ( )</td></tr>
<tr><td>Rotation speed, rpm</td><td>a. Inner ring rotating b. Outer ring rotating
min. :
max. :
Normal :</td></tr>
<tr><td rowspan="3">Load N</td><td rowspan="3">Radial:
Axial:
Moment:</td><td rowspan="3">Fitting</td><td></td><td>Material</td><td>Tolerance</td><td>Surface roughness</td></tr>
<tr><td>Shaft</td><td></td><td></td><td></td></tr>
<tr><td>Housing</td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Environment</td><td colspan="2">Temperature: Normal , max.</td><td colspan="2">Humidity:</td><td colspan="2">Cleanness:</td></tr>
<tr><td colspan="6">Pressure: Pa a. Atmospheric b. Atmospheric ⇔ vacuum c. Vacuum d. Other ( )</td></tr>
<tr><td colspan="6">Corrosive gas:</td></tr>
<tr><td colspan="6">Corrosive liquid:</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="4">Present condition</td><td colspan="6">Bearing material:</td></tr>
<tr><td colspan="2">Lubrication:</td><td colspan="4">Lubricant:</td></tr>
<tr><td colspan="6">Bearing life:</td></tr>
<tr><td colspan="6">Failure condition:</td></tr>
<tr><td>Rough sketch of bearing mounting section and/or other remarks</td><td colspan="6"></td></tr>
</table>

● By this sheet, the ceramic and/or EXSEV bearings most suitable to operating conditions can be created.

KOYO SEIKO CO., LTD.

Company name ______ Division, department, and section ______

Name of staff member in charge ______ Phone ______ FAX ______

Extreme Special Environments
Specifications Sheet for Linear Motion Bearings

Note: For the selection of the most suitable bearing this sheet must be completed in as much detail as possible. Date

Bearing size and bearing number					
Application	a. For new design b. For repair				
Required performance	a. Life b. High speed c. Low dust generation d. Vacuum e. Corrosion resistance f. High temperature g. Non-magnetism h. Insulation i. Others ( )				
Operating condition	Linear motion speed, mm/sec	min.: max.: Normal: Start-up time:	Running time	· 24 h/day · h/day · Other ( )	
	Stroke, mm		Drive system		
	Load N	Bearing loaded: Moment: Other:			
	Environment	Temperature: Normal , max.	Humidity:	Cleanness:	
		Pressure: Pa a. Atmospheric b. Atmospheric ⟺ vacuum c. Vacuum d. Other ( )			
		Corrosive gas:			
		Corrosive liquid:			
Present condition	Bearing material:				
	Lubrication:		Lubricant:		
	Bearing life:				
	Failure condition:				
Rough sketch of bearing mounting section and/or other remarks					

● By this sheet, the linear motion bearings most suitable to operating conditions can be created.

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