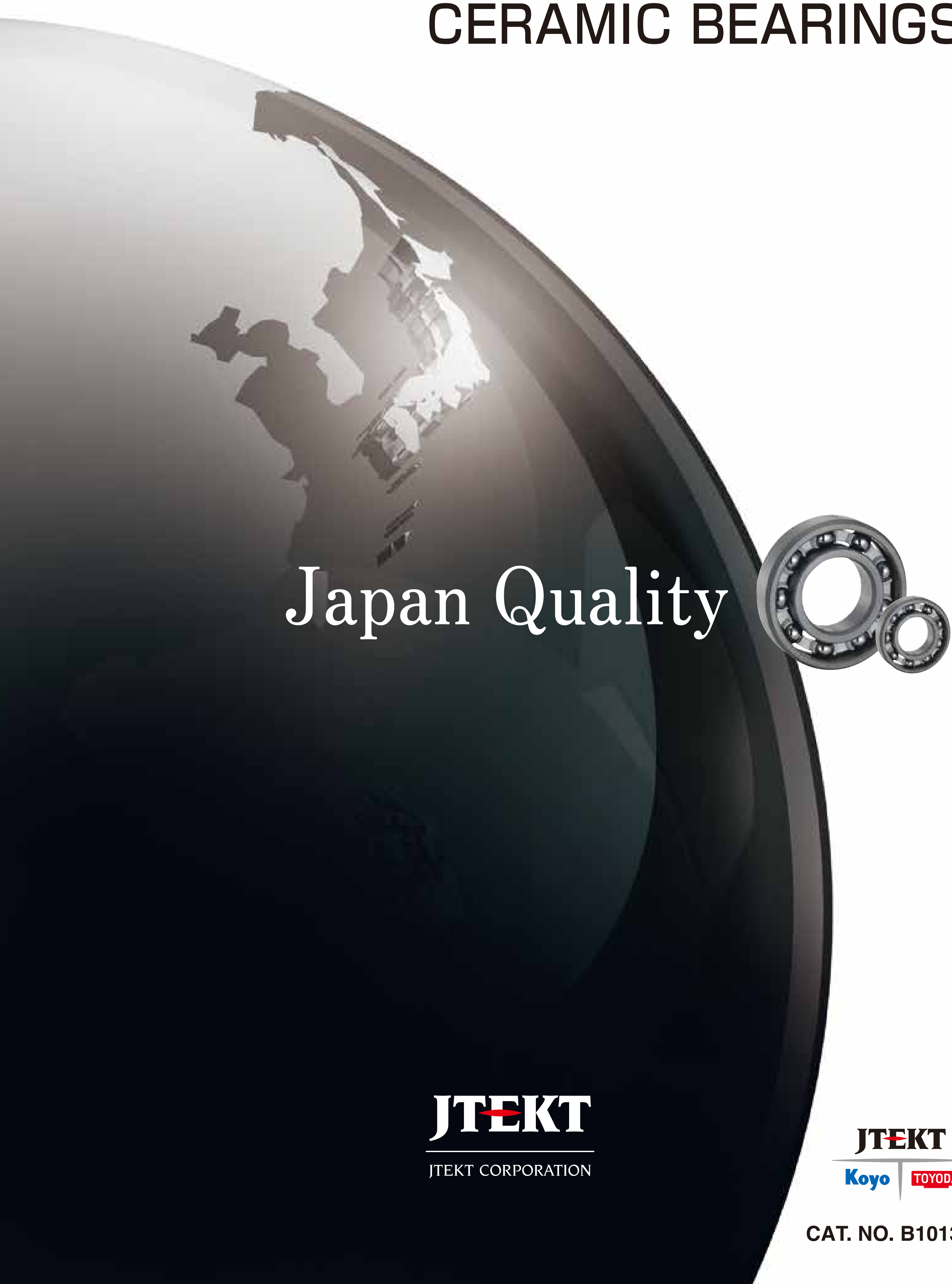
Koyo®

EXSEV

FOR EXTREME SPECIAL ENVIRONMENTS

CERAMIC BEARINGS



JTEKT
Koyo TOYODA

CAT. NO. B1013E

World's first successful practical application of ceramic bearings

"Aren't there any bearings that can be used in seawater?"

…One of our customers asked this question,
triggering our efforts to develop the ceramic bearing.

Initially, we attempted to use alumina as the raw material,
but **it split quickly and cracks developed…**

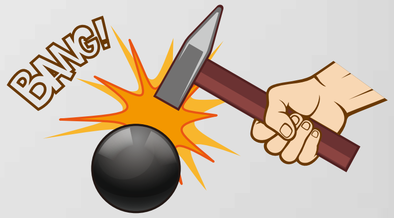
Following this, research stalled and ended after approximately five years.

Research resumed again in 1978;
this time with the development team consisting of five members.

Additionally, **a material manufacturer known for leading ceramics research was invited to join the effort.**

Starting with silicon nitride as the raw material,
strength was reinforced using a sintering additive and
a hot pressing process eliminated cracking.

As a result, the first ceramic bearings were commercialized in 1984.



Some of our customers had doubts about strength in the beginning,
stating "If ceramic cracks, it will surely split in two!"

At that time, **customers would hit the bearings with a hammer to test their strength.**

Doing this, **the concrete below the bearing was the only thing that cracked!**

Finding practical applications was initially difficult,
but **their strength and high-speed performance were gradually recognized,** and
ceramic bearings began to be utilized for the main spindles of machine tools.

Next, **they began receiving attention from semiconductor manufacturers owing to the characteristics of not using oil and not producing waste.**

Ceramic bearings were then **utilized in a section of experimental equipment on the space shuttle Colombia,** expanding their range of applications.

As productivity improved, ceramic bearings began being used in the
mass production of computer HDDs and automobile engines.

Their excellent performance has been recognized and
applications have received various awards, such as the Japan Fine Ceramics Award.

And now…

"For ceramic bearings, the answer is KOYO"

Introduction to Application Examples

Features

Properties of ceramic materials

Production Process

Ceramics Production Process

Product Details

Ceramic Bearing Product Details

Performance

Ceramic Bearing Capacities

Product Introduction

1 Machine tools

CERAMIC BEARINGS

1 Spindle (Angular Contact Ball Bearing)

Product : Hybrid Ceramic Bearings

Machine tool spindle bearings are required to have superior rotational performance at extremely high speeds, quick acceleration/ deceleration, high rigidity, and reduced temperature rises.
Hybrid Ceramic Bearings, which satisfy these requirements, are widely used in this application.

Vacuum | Clean | High temperature | Corrosive | Electric field | Magnetic field | **High speed** | Abrasion resistance | Low torque

- 20% to 30% reduction in temperature rise
- Upper limit of rotational speed range is 1.2-1.5 times higher (compared to Koyo steel bearings)

Use Conditions

Rotational speed: 25 000 min⁻¹ ($d_m n$ = 2.75 × 10^6)
Lubrication: Oil or Grease
Spindle power: 75 kW

2 Spindle (Cylindrical Roller Bearing)

Product : Hybrid Ceramic Bearings

Seizure resistance performance under unbalanced load conditions due to misalignment improved at the Vertical Spindle Machining Center.

Vacuum | Clean | High temperature | Corrosive | Electric field | Magnetic field | **High speed** | Abrasion resistance | Low torque

- 20% to 30% reduction in temperature rise
- Upper limit of rotational speed range is 1.2-1.5 times higher (compared to Koyo steel bearings)

Use Conditions

Rotational speed: 12 000 min⁻¹
Lubrication: Grease

2 Film manufacturing equipment

CERAMIC BEARINGS

1 Liquid Crystal Polarizing Film Manufacturing Equipment

Product : Corrosion Resistant Hybrid Ceramic Bearings

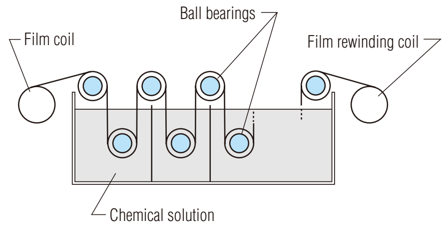
Liquid crystal polarizing film manufacturing equipment use acid solution, alkaline solution, dying solution, distilled water, and other solutions.
In such corrosive environments, Corrosion Resistant Hybrid Ceramic Bearings are widely used.

Vacuum | Clean | High temperature | **Corrosive** | Electric field | Magnetic field | High speed | **Abrasion resistance** | Low torque

- Corrosion resistance to solutions such as acid solution, alkaline solution, dying solution, and distilled water

Use Conditions

Rotational speed: 80 min⁻¹
Temperature: Room temp. to 80°C
Lubrication: Chemical solution



2 Photographic Film Manufaturing Equipment

Product: Hybrid Ceramic Bearings (with special features)

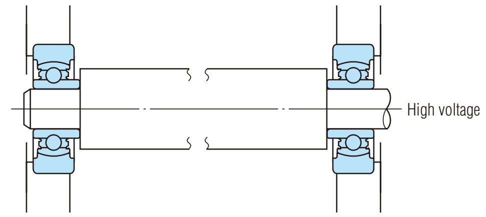
A photographic film production line treats film surfaces by applying a high voltage.
Hybrid Ceramic Bearings are widely used in such environments, because the ceramic inner ring and balls serve as insulators.

Vacuum | Clean | High temperature | Corrosive | **Electric field** | Magnetic field | High speed | Abrasion resistance | Low torque

- Insulation under high voltage environments

Use Conditions

Rotational speed: 200 min⁻¹
Temperature: Room temp.
Lubrication: Grease



3 Power generation equipment

CERAMIC BEARINGS

1 Wind Turbine Generator

Product: Hybrid Ceramic Bearings

Wind Turbine Generator are strongly required to operate for extensive periods of time without the need of maintenance.
However, bearings used in generators are subject to electrical pitting, which may cause the bearings to break down.
Hybrid Ceramic Bearings, which have superior durability and reliability, are widely used in such aerogenerators.

Vacuum | Clean | High temperature | Corrosive | **Electric field** | Magnetic field | High speed | Abrasion resistance | Low torque

- Prevention of electrical pitting
- Extension of grease service life (three times longer than Koyo steel bearings)

Use Conditions

Rotational speed: 2700 min⁻¹
Temperature: Below freezing point to approx. 60°C
Lubrication: Grease

2 Micro Gas Turbine Generator

Product: Hybrid Ceramic Bearings

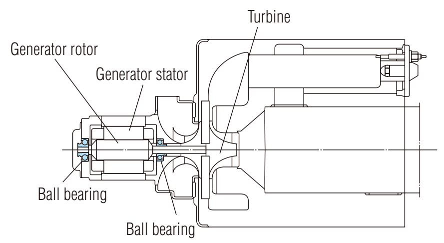
The world's smallest gas turbine generators emit clean exhaust emissions and hence are friendly to the environment.
Hybrid Ceramic Bearings are used in these generators because they are low in vibration and noise generation, and have excellent high speed performance.

Vacuum | Clean | High temperature | Corrosive | Electric field | Magnetic field | **High speed** | Abrasion resistance | Low torque

- Improved reliability in high speed rotation

Use Conditions

Rotational speed: 10 000 min⁻¹ ($d_m n$ = 2.22 × 10^6)
Temperature: 200°C
Lubrication: Oil



4 Industrial furnaces

CERAMIC BEARINGS

1 Liquid Crystal Panel Bonding and LC Sealing Furnace

Product : Hybrid Ceramic Linear Motion Ball Bearings

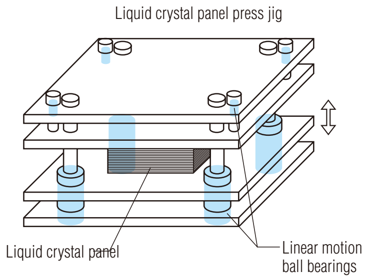
Substrate bonding press jigs for use in furnaces must be low in particle emissions and have a long service life under high temperature conditions.
The Clean Pro Hybrid Ceramic Linear Motion Ball Bearings are widely used for such jigs.

Vacuum | **Clean** | **High temperature** | Corrosive | Electric field | Magnetic field | High speed | Abrasion resistance | Low torque

- Suitable for clean environments thanks to low particle emissions

Use Conditions

Stroke speed: 5 mm/s
Temperature: 200°C
Ambient pressure: Normal pressure
Lubrication: Clean pro coating



2 Furnaces Cars

Product: High Temperature Hybrid Ceramic Bearings

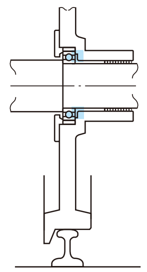
The bogies, conveyers and other carrier systems used in furnaces are exposed to high temperatures.
Because of their high heat resistance, High Temperature Hybrid Ceramic Bearings are used in such applications.

Vacuum | Clean | **High temperature** | Corrosive | Electric field | Magnetic field | High speed | Abrasion resistance | Low torque

- Applicable to high temperature environments

Use Conditions

Rotational speed: 10 to 500 min^{-1}
Temperature: 500°C
Lubrication: Graphite



3 Baking Furnace Cars

Product: High Temperature Hybrid Ceramic Bearings

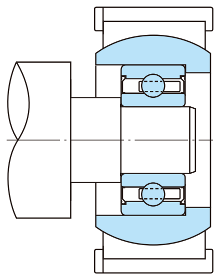
In the kiln that bakes fluorine resin onto the heat rollers of copying machines, conveyor bearings must be low in particle emissions under high temperatures. Because it is structurally difficult to mount bearings accurately, High temperature Hybrid Ceramic Bearings are used for this application, along with aligning rings.

Vacuum | Clean | **High temperature** | Corrosive | Electric field | Magnetic field | High speed | Abrasion resistance | Low torque

- Compatible with high temperature environments

Use Conditions

Rotational speed: 3 to 10 min^{-1}
Temperature: 400 to 500°C
Lubrication: Graphite



4 Tube Annealing Furnace Guide Rolls

Product: Hybrid Ceramic Bearings

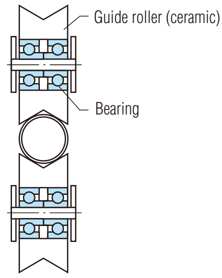
The guide roll bearings installed inside tube annealing furnaces are used under high temperatures without lubrication.
Hybrid Ceramic Bearings are suitable for such applications.

Vacuum | Clean | **High temperature** | Corrosive | Electric field | Magnetic field | High speed | Abrasion resistance | Low torque

- Compatible with high temperature environments

Use Conditions

Rotational speed: 300 min^{-1}
Temperature: 300°C



5 Diffusion Furnace Dolly

Product: Full-complement Ceramic Ball Bearings

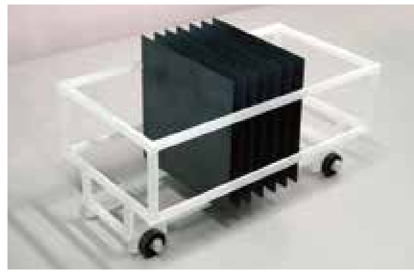
Conditions in a diffusion furnace are harsh, including not only high temperature, but also corrosive gas.
Incorporating a rolling mechanism for the conveyor dolly in the furnace enables smooth conveyance to be obtained, thereby leading to improvements in product quality and productivity.

Vacuum | Clean | **High temperature** | **Corrosive** | Electric field | Magnetic field | High speed | Abrasion resistance | Low torque

- Compatible with high-temperature environments
- Corrosion-resistant against corrosive gases
- Contributes to improved productivity

Use Conditions

Temperature: 800°C or higher
Ambient pressure: Corrosive gas atmosphere
Load: 5N



5 Production equipment

CERAMIC BEARINGS

1 Aluminum Electrolytic Capacitor Manufacturing Equipment

Product: High Corrosion Resistant Ceramic Bearings

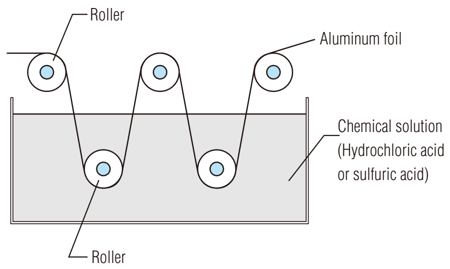
In an aluminum foil electrolytic capacitor manufacturing equipment, a strong acid solution is used to treat the aluminum foils. High Corrosion Resistant Ceramic Bearings are widely used in such highly corrosive environments.

Vacuum	Clean	High temperature
Corrosive	Electric field	Magnetic field
High speed	**Abrasion resistance**	Low torque

- Corrosion resistance to strong acid solution

Use Conditions

Rotational speed: 50 min^{-1}
Temperature: 90°C
Lubrication: Chemical solution (hydrochloric acid and sulfuric acid)



2 Synthetic Fiber Manufacturing Equipment

Product: Corrosion Resistant Hybrid Ceramic Bearings

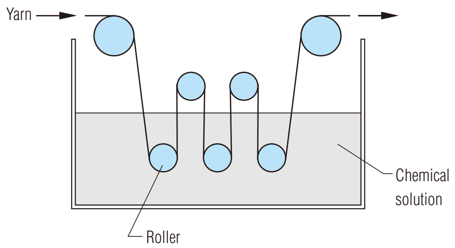
Acid solution, alkaline solution, water, and other liquids are used in synthetic fiber yarn reinforcing processes. Corrosion Resistant Hybrid Ceramic Bearings are applied in such corrosive environments.

Vacuum	Clean	High temperature
Corrosive	Electric field	Magnetic field
High speed	**Abrasion resistance**	Low torque

- Corrosion resistance under acid solution, alkaline solution and water

Use Conditions

Rotational speed: 20 to 100 min^{-1}
Temperature: Room temp. to 90°C
Lubrication: Chemical solution



3 DVD Sputtering Equipment

Product: Hybrid Ceramic Bearings

To improve reliability further, Hybrid Ceramic Bearings are used.

Vacuum	Clean	High temperature
Corrosive	**Electric field**	Magnetic field
High speed	Abrasion resistance	Low torque

- Insulation

Use Conditions

Rotational speed: 300 min^{-1}
Temperature: Room temp.
Lubrication: Grease

4 Steel Wire Stranding Machine

Product: Hybrid Ceramic Bearings

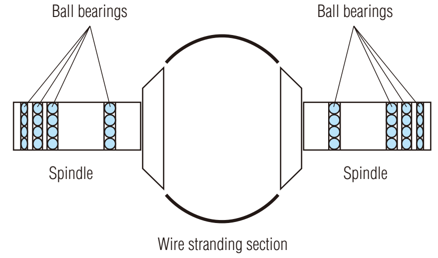
Steel wires for radial tires are produced by stranding steel wires to attain the required strength. In steel wire stranding machines, which involve high speed rotation, Hybrid Ceramic Bearings are used for improved service life and stability.

Vacuum	Clean	High temperature
Corrosive	Electric field	Magnetic field
High speed	Abrasion resistance	Low torque

- Reduced temperature rises
- Reliable durability

Use Conditions

Rotational speed: 6 000 min^{-1} or higher
Lubrication: Grease



5 Jet Electrostatic Coating Machine

Product: Hybrid Ceramic Bearings

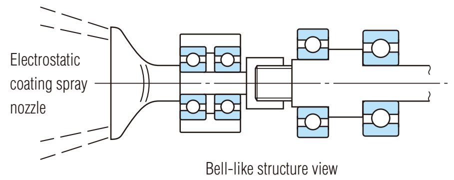
In a jet electrostatic coating machine, grease may escape from the spray nozzle due to the air motor, affecting the quality of the paint to be coated.
To resolve this problem, Hybrid Ceramic Bearings that do not use grease are used.

Vacuum	Clean	High temperature
Corrosive	Electric field	Magnetic field
High speed	Abrasion resistance	Low torque

- Prevention of grease scattering
- Prevention of paint contamination

Use Conditions

Rotational speed: 20 000 min^{-1}
Lubrication: Fluorine polyme



6 Blister Packaging Equipment

Product: High-temperature Hybrid Ceramic Bearings

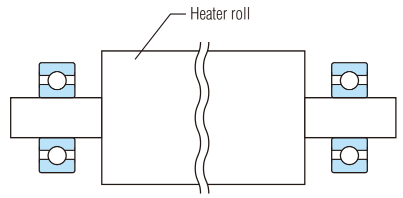
As heater roll bearings used in processing reach high temperatures during operation, conventional bearings are quickly damaged.
Incorporating high-temperature ceramic bearings extends the bearing replacement cycle and improves productivity.

Vacuum	Clean	**High temperature**
Corrosive	Electric field	Magnetic field
High speed	Abrasion resistance	Low torque

- Applicable to high-temperature environments
- Contributes to improved productivity

Use Conditions

Temperature: 250°C
Load: 900N
Lubrication: Grease



6 Semiconductor manufacturing equipment

CERAMIC BEARINGS

1 Transfer Robot for Semiconductor and LCD Manufacturing Equipment

Product: K Series Full-Complement Hybrid Ceramic Ball Bearings

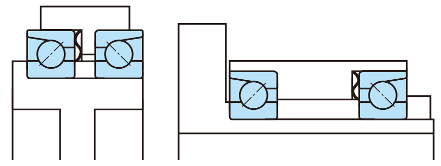
Vacuum | **Clean** | **High temperature** | **Corrosive** | Electric field | Magnetic field | High speed | Abrasion resistance | **Low torque**

For application in transfer robots for semiconductor and liquid crystal manufacturing equipment, bearings are required to be low in particle emissions and have a long service life.
Bearings may be delivered incorporated in arm units for improved assemblability and maintainability.

- Applicable to vacuum environments and clean environments
- Optimal for machine size reduction

Use Conditions

Temperature: Room temp. to 200°C
Ambient pressure: 10^{-3} Pa
Lubrication: Grease or clean pro coating



Bearing unit for application to transfer robots

2 Electron Beam Lithography

Product: Non-magnetic Hybrid Ceramic Bearings

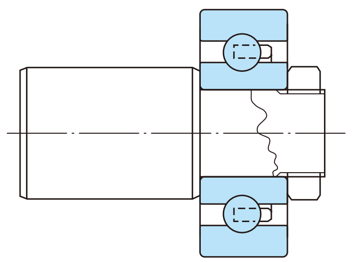
Vacuum | Clean | High temperature | Corrosive | Electric field | **Magnetic field** | High speed | Abrasion resistance | Low torque

The bearings in semiconductor production electron beam lithography are exposed to strong magnetic fields.
Because of their non-magnetic characteristics, Hybrid Ceramic Bearings are used in such machines.

- Compatible with vacuum, strong magnetic field environments

Use Conditions

Rotational speed: 100 min^{-1}
Temperature: Room temp.
Ambient pressure: 10^{-5} Pa
Lubrication: Grease



3 Gates in Chemical Vapor Deposition Equipment

Product: Hybrid Ceramic Ball Bearing Clean Pro Linear Motion Ball Bearings

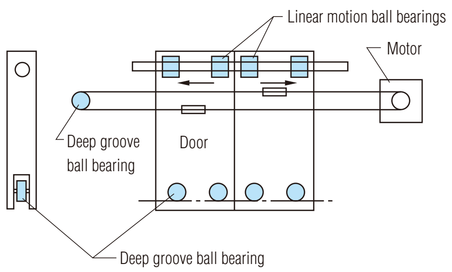
Vacuum | **Clean** | **High temperature** | Corrosive | Electric field | Magnetic field | High speed | Abrasion resistance | Low torque

Hybrid Ceramic Ball Bearings and Clean Pro Linear Motion Ball Bearings are widely used for the doors of the chemical vapor deposition (CVD) equipment.

- Applicable to high temperature, vacuum and clean environments

Use Conditions

Rotational speed: 10 to 200 min^{-1}
Temperature: 200°C
Ambient pressure: Normal to 10^{-4} Pa
Lubrication: Clean pro coating



4 Etching Equipment

Product: Hybrid Ceramic Bearings (with special features)

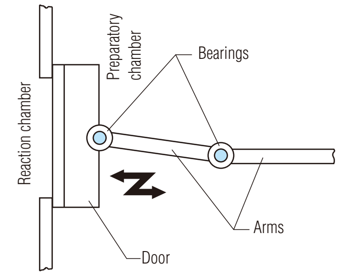
Vacuum | **Clean** | **High temperature** | **Corrosive** | Electric field | Magnetic field | High speed | Abrasion resistance | Low torque

Bearings used in etching machines must be resistant to halogen, hydrofluoric acid, and other corrosive gasses, as well as low in particle emissions. To meet these requirements, PTFE coated Hybrid Ceramic Bearings are used.

- Resistant to corrosive ambient gases such as halogen and hydrofluoric acid
- Suitable for clean environments thanks to low particle emissions

Use Conditions

Temperature: Room temp. to 60°C
Ambient pressure: Normal to 10^{-2} Pa
Load: Radial load of 10 N
Lubrication: PTFE coating



5 Vacuum Evaporator

Product: High Temperature Hybrid Ceramic Bearings (with special features)

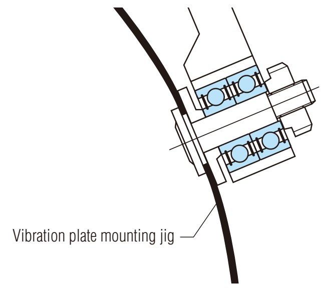
Vacuum | Clean | **High temperature** | Corrosive | Electric field | Magnetic field | High speed | Abrasion resistance | Low torque

Bearings used in the planetary section of vacuum evaporator are required to be high in durability under high temperatures, high load (moment) conditions. To ensure a long bearing life under high temperature conditions, High temperature Hybrid Ceramic Bearings with special features are used.

- Improved reliability in vacuum and high temperature environments

Use Conditions

Rotational speed: 1 to 30 min^{-1}
Temperature: 200 to 400°C
Ambient pressure: 10^{-6} to 10^{-8} Pa
Lubrication: Molybdenum disulfide or silver



6 Spin-dryer for Wafer Cleaning Equipment

Product: Corrosion Resistant Hybrid Ceramic Bearings

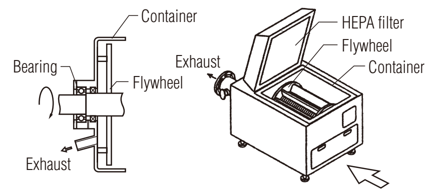
Vacuum | **Clean** | High temperature | **Corrosive** | Electric field | Magnetic field | High speed | Abrasion resistance | **Low torque**

In semiconductor wafer cleaning processes, wafers are cleaned in cleansing chemicals, rinsing liquids, distilled water, and other liquids before drying.
Because of their high corrosion resistance, Corrosion Resistant Hybrid Ceramic Bearings are widely used in wafer cleaners.

- Corrosion resistance to solutions such as cleaning chemicals, rinsing liquids, and distilled water

Use Conditions

Rotational speed: 2 000 to 3 000 min^{-1}
Temperature: Room temp.
Lubrication: Grease



6 Semiconductor manufacturing equipment

CERAMIC BEARINGS

7 Wafer Transfer Equipment

Product: Hybrid Ceramic Linear Way Bearing Units (with special features)

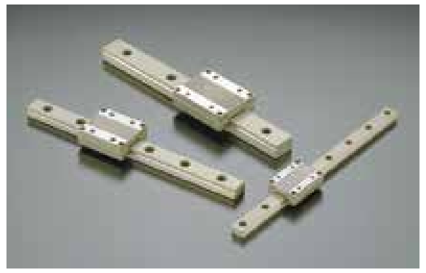
For application in wafer transfer equipment, low particle emissions performance is required.
For such devices, Clean Pro Hybrid Ceramic Linear Way Bearing Units are widely used.

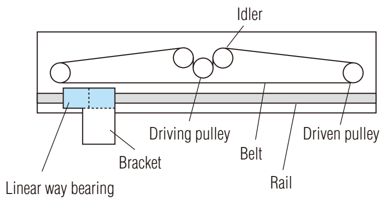
Vacuum | **Clean** | High temperature | Corrosive | Electric field | Magnetic field | High speed | Abrasion resistance | Low torque

- Suitable for clean environments thanks to low particle emissions
- Corrosion resistant to cleaning agent splashes

Use Conditions

Stroke speed: 350 mm/s
Temperature: Room temp.
Ambient pressure: Normal pressure
Lubrication: Clean pro coating





8 Wafer Cleaning Equipment for Chemical Mechanical Polishing System

Product: Corrosion Resistant Ceramic Bearings

In the semiconductor multilayer production process, each wafer surface should be treated to maintain evenness. This process uses chemical mechanical polishing equipment, and the cleaner attached to the equipment uses Corrosion Resistant Ceramic Bearings.

Vacuum | Clean | High temperature | **Corrosive** | Electric field | Magnetic field | High speed | **Abrasion resistance** | Low torque

- Corrosion resistance to corrosive solutions

Use Conditions

Rotational speed: 100 min^{-1}
Temperature: Room temp.
Lubrication: Fluorine polymer

9 Turbo Molecular Pump

Product: Full-Complement Hybrid Ceramic Ball Bearings (with special features)

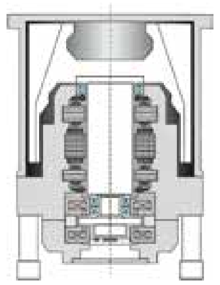
Magnetic bearings are used in turbo molecular pumps driven at extremely high speeds. To protect the blades from fracture in case of a power failure or magnetic failure, touchdown bearing units are used. As touchdown bearings, Full-Complement Hybrid Ceramic Ball Bearings are used to increase the service life of the touchdown bearings under severe hostile conditions.

Vacuum | Clean | High temperature | Corrosive | Electric field | Magnetic field | **High speed** | **Abrasion resistance** | Low torque

- Improved reliability in vacuum environments

Use Conditions

Rotational speed: 20 000 to 60 000 min^{-1}
Ambient pressure: 1 Pa
Lubrication: Molybdenum disulfide or silver



7 Motor, Industrial machinery

CERAMIC BEARINGS

1 Polygon Scanner Motor

Product: Hybrid Ceramic Bearings

Hybrid Ceramic Bearings, which exhibit superior high speed performance, are widely used in high speed polygon scanner motors.

Vacuum | Clean | High temperature | Corrosive | Electric field | Magnetic field | **High speed** | Abrasion resistance | Low torque

- Excellent reliability in high speed rotation

Use Conditions

Rotational speed: 26 000 min^{-1} or higher
Lubrication: Grease

2 Ultrasonic Motor in Magnetic Resonance Imagers

Product: Ceramic Bearings

The motors installed in magnetic resonance imagers (MRI) use magnetism insensitive Ceramic Bearings.

Vacuum | Clean | High temperature | Corrosive | Electric field | **Magnetic field** | High speed | Abrasion resistance | Low torque

- Compatible with strong magnetic field environments

Use Conditions

Rotational speed: 500 min^{-1}
Temperature: Room temp.
Lubrication: Grease

3 Switched Reluctance Motor

Product: Hybrid Ceramic Bearings

For high speed, high efficiency switched reluctance (SR) motors, which do not use coils or permanent magnets, Hybrid Ceramic Bearings are applied.

Vacuum | Clean | High temperature | Corrosive | Electric field | Magnetic field | **High speed** | Abrasion resistance | Low torque

- Excellent reliability in high speed rotation

Use Conditions

Rotational speed: 30 000 min^{-1}
Lubrication: Grease

8 Medical equipment

CERAMIC BEARINGS

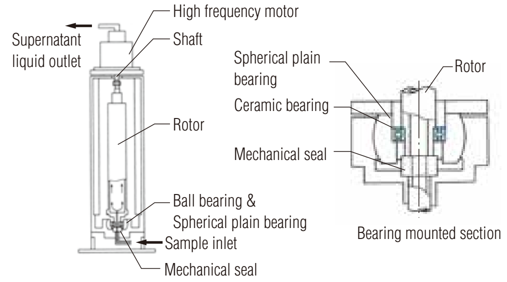
1 Blood Centrifuge

Product: Hybrid Ceramic Bearings (with special coating)

Corrosion resistance is required of bearings to be used in blood centrifuge especially to physiological saline.
Hybrid Ceramic Bearings with bearing rings coated with a corrosion resistant film are suitable for such corrosive environments.

Vacuum | Clean | High temperature | **Corrosive** | Electric field | Magnetic field | **High speed** | Abrasion resistance | Low torque

● Corrosion resistance to physiological saline



Use Conditions

Rotational speed: 20 000 min^{-1}
Temperature: –10 to 10°C
Lubrication: Grease

2 Ultrasonic Motor in Magnetic Resonance Imagers

Product: Ceramic Bearings

The motors installed in magnetic resonance imagers (MRI) use magnetism insensitive Ceramic Bearings.

Vacuum | Clean | High temperature | Corrosive | Electric field | **Magnetic field** | High speed | Abrasion resistance | Low torque

● Compatible with strong magnetic field environments

Use Conditions

Rotational speed: 500 min^{-1}
Temperature: Room temp.
Lubrication: Grease

9 Home electrical appliances

CERAMIC BEARINGS

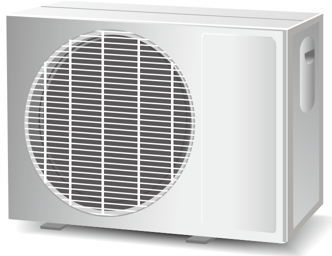
1 Air-conditioner motors

Product : Hybrid Ceramic Bearings

When using motors equipped with inverter control such as air-conditioner motors, there is a possibility of electric pitting defects occurring on motor bearings.
Using a ceramic — which is an insulator — as the rolling elements eliminates electric pitting.

Vacuum | Clean | High temperature | Corrosive | **Electric field** | Magnetic field | High speed | Abrasion resistance | Low torque

● CElectric pitting prevent through insulation performance



Use Conditions

Rotational speed: 3 000 min^{-1}
Load (preload): 1.5% C
Lubrication: Grease

2 Fan Motor

Product : Hybrid Ceramic Bearings

Bearing defects occur due to electric pitting in various motors.
Hybrid ceramic bearings are utilized as a measure against electric pitting.

Vacuum | Clean | High temperature | Corrosive | **Electric field** | Magnetic field | High speed | Abrasion resistance | Low torque

● Prevention of electrical pitting

Use Conditions

Rotational speed: 5 000 min^{-1}
Temperature: –10 to 120°C
Lubrication: Grease

10 Outer space, Leisure

CERAMIC BEARINGS

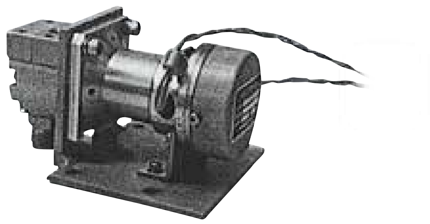
1 Outer Space Experimentation Equipment

Product: Ceramic Bearings

Utilized in experimental equipment on a space shuttle.
Stainless-steel bearings using fresh water as the lubricant experience abrasion and do not reach the required service life.
Using general ceramic bearings enables the required service life to be attained.

Vacuum | Clean | High temperature | **Corrosive** | Electric field | Magnetic field | High speed | **Abrasion resistance** | Low torque

● Long Service Life under Freshwater Lubricating Conditions



Use Conditions

Rotational speed: 10 000 min^{-1}
Temperature: 30°C
Load: Radial 5N, Axial 10N
Lubrication: Fresh water

2 Inline Skates

Product : Hybrid Ceramic Bearings

Because of their low running torque and high durability, Hybrid Ceramic Bearings are widely used in speed skates.

Vacuum | Clean | High temperature | Corrosive | Electric field | Magnetic field | **High speed** | Abrasion resistance | **Low torque**

● Low torque and improved durability

Use Conditions

Rotational speed: 10 000 min^{-1}
Lubrication: Oil or grease

11 Automobiles, Motorcycles

CERAMIC BEARINGS

1 Turbocharger

Product: Hybrid Ceramic Bearings

Bearings supporting the main shaft of the turbocharger are responsive during acceleration and durable when using low-viscosity, dirty oil.
Hybrid ceramic bearings with superior reliability are utilized.

Vacuum | Clean | **High temperature**
Corrosive | Electric field | Magnetic field
High speed | Abrasion resistance | Low torque

- Service life three times longer than that of ordinary bearings
- Acceleration response improved 20%
- Oil quantity reduced 80%

Use Conditions

Rotational speed: 180 000 to 210 000 min^{-1}
Temperature: 350°C
Lubrication: Oil

2 Fuel Injection System Control Valve

Product: Ceramic Ball

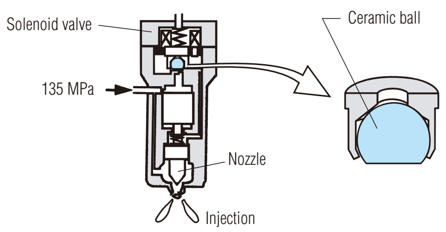
The common rail system (fuel injection system), which enables diesel engines to feature high power, good fuel economy and low emissions, is equipped with Ceramic Balls in the control valves.

Vacuum | Clean | High temperature
Corrosive | Electric field | Magnetic field
High speed | **Abrasion resistance** | Low torque

- Compatible with high pressure fuel injection thanks to improved wear resistance and seizure resistance

Use Conditions

Maximum pressure: 135 MPa



3 Wheel Bearings for Solar Cars

Product: Hybrid Ceramic Bearings

Stable operation of the motor section under severe open conditions of running eight hours or more per day. Improvements in weight reduction, durability and reliability.
Suppressing spinning resistance and efficiently transferring the driving force to the wheels contributes to saving power.

Vacuum | Clean | High temperature
Corrosive | Electric field | Magnetic field
High speed | Abrasion resistance | **Low torque**

- Australia: Covered over 3,000km vertically
- South Africa: Covered over 4,000km

Use Conditions

Rotational speed: 1 000 min^{-1}
Lubrication: Grease

Photo: Courtesy of Tokai University

4 Rally Car Hub Units

Product: Hybrid Ceramic Bearings

Excellent abrasion resistance even under severe environmental conditions has improved durability and reliability.

Vacuum | Clean | High temperature
Corrosive | Electric field | Magnetic field
High speed | **Abrasion resistance** | Low torque

- Utilized in the car entered in the Paris-Dakar Rally in 1997 and 1998
- Rigidity improved
- Unsprung weight reduced

Photos: Courtesy of Mitsubishi Motors Corporation

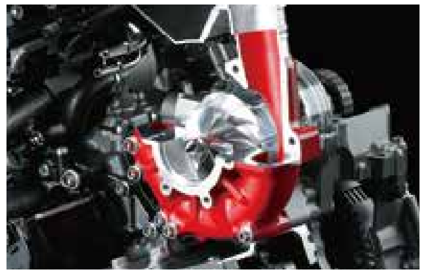
5 Motorcycle Superchargers

Product: Hybrid Ceramic Bearings

The new superchargers for large motorcycles utilize lightweight, high-strength ceramic balls capable of high-speed rotation. The incorporation of ceramic balls has achieved bearings with excellent high-speed performance, heat resistance and abrasion resistance. Additionally, when using hybrid ceramic bearings, high output is achieved even for race-specification motors operating under harsh conditions.

Vacuum | Clean | **High temperature**
Corrosive | Electric field | Magnetic field
High speed | **Abrasion resistance** | **Low torque**

- High-speed performance, heat resistance and abrasion resistance improved
- Contributes to achieving high output supporting race specifications



Photos: Courtesy of Kawasaki Heavy Industries, Ltd.

Properties of ceramic materials

CERAMIC BEARINGS

1 Material characteristics

Table 1 below lists the mechanical and physical properties of major ceramic materials used as bearing materials. Table 2 compares silicon nitride and high carbon chromium bearing steel.

Table 1 Mechanical and physical properties of ceramic materials used as bearing materials

Property (Ceramic Material)	Unit	Silicon Nitride Si_3N_4	Zirconia ZrO_2	Silicon Carbide SiC
Density	g/cm³	3.2	6.0	3.1
Linear expansion coefficient	K^{-1}	3.2×10^{-6}	10.5×10^{-6}	3.9×10^{-6}
Vickers hardness	HV	1 500	1 200	2 200
Module of longitudinal elasticity	GPa	320	220	380
Poisson's ratio		0.29	0.31	0.16
Three point bending strength	MPa	1 100	1 400	500
Fracture toughness	$MPa\cdot m^{1/2}$	6	5	4
Heat resistance (in atmospheric air)	℃	800	200	1 000 or higher
Thermal shock resistance	℃	750 or higher	350	350
Coefficient of thermal conductivity	W/(m·K)	20	3	70
Specific heat	J/(kg·K)	680	460	670

Table 2 Comparison of characteristics of silicon nitride and high carbon chromium bearing steel

Property	Unit	Silicon Nitride Si_3N_4	High Carbon Chromium Bearing Steel SUJ2	Advantages of Ceramic Bearings
Density	g/cm³	3.2	7.8	Decrease in centrifugal force induced by rolling elements (balls or rollers) → Longer service life and reduced bearing temperature rises
Linear expansion coefficient	K^{-1}	3.2×10^{-6}	12.5×10^{-6}	Decreased internal clearance change due to reduced bearing temperature rises → Lowered vibration and reduced preload changes
Vickers hardness	HV	1 500	750	Less deformation in rolling contact areas → Higher rigidity
Module of longitudinal elasticity	GPa	320	208	
Poisson's ratio		0.29	0.3	
Heat resistance	℃	800	180	Retention of superior load carrying characteristics under high temperature
Corrosion resistance		High	Low	Useful in acid or alkaline solutions
Magnetism		Non-magnetic	Ferromagnetic	Decreased rotational fluctuation in ferromagnetic field due to non-magnetization
Conductivity		insulator	conductor	Prevents electrical pitting
Bond		Covalent bond	Metallic bond	Decrease in adhesion (or material transfer) due to oil film thinning in rolling contact areas

2 Rolling fatigue of ceramic materials

The individual ceramic materials were tested for rolling fatigue under oil lubrication and under water lubrication, to evaluate their applicability as bearing material. Figs. 1 and 2 show the results of the tests.
The figures indicate that each ceramic material has a certain level of rolling fatigue strength and that silicon nitride has the highest fatigue strength among the ceramic materials tested.

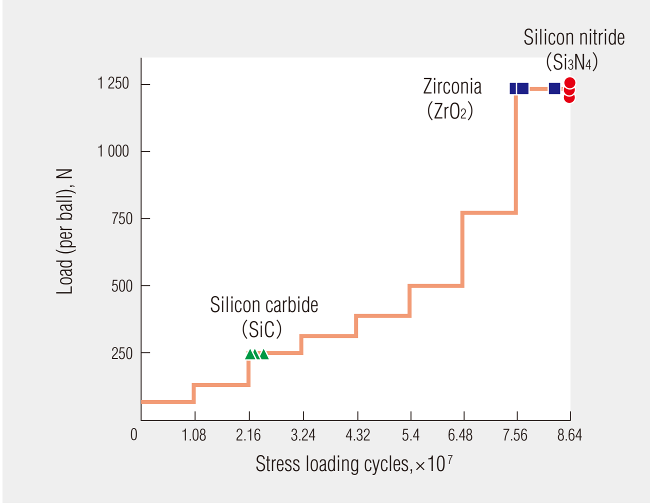


Fig. 1 Comparison in rolling fatigue life under oil lubrication

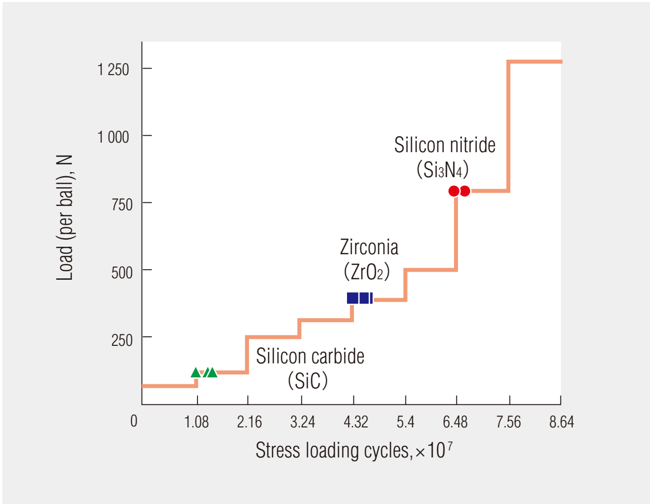
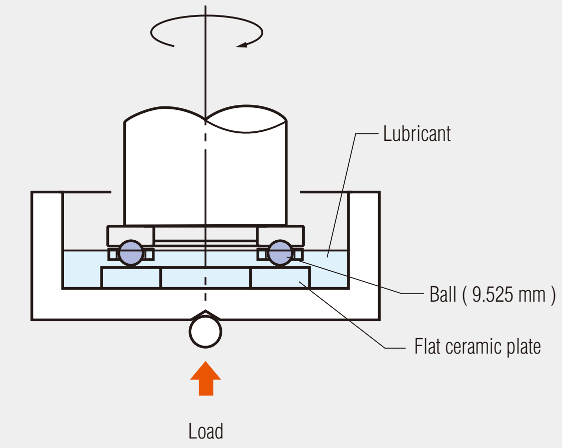


Fig. 2 Comparison in rolling fatigue life under water lubrication

Test conditions

	Oil lubrication	Water lubrication
Lubricant	Spindle oil	City water
Ball	Bearing steel	Ceramic
Load	Increased in stages at every 1.08×10^7 cycles	
Rotational speed	1 200 min^{-1}	

Test equipment



Test equipment appearance

Fig. 3 Rolling fatigue life test conditions and test equipment

3 Ceramic materials suitable for rolling bearings

Table 3 shows the results of evaluating the ceramic materials in terms of their characteristics and the rolling fatigue strength. Among the ceramic materials tested, silicon nitride is the most suitable as rolling bearing material.
JTEKT uses the silicon nitride produced by the hot isostatic pressing (HIP) method as the standard ceramic material for bearings.

Table 3 Ratings of ceramic materials as rolling bearing materials

	Application to rolling bearings		
	Rating	Performance and use	Characteristics
Silicon nitride Si_3N_4	◎	･Comparable to bearing steel in load carrying capability and service life ･Suitable for high performance applications	･High speed ･High vacuum ･Corrosion resistant ･Heat resistant ･Non-magnetic ･High rigidity
Zirconia ZrO_2	○	･Useful under a limited load ･Applicable in highly corrosive chemicals	･Highly corrosion resistant
Silicon carbide SiC	○	･Useful under a limited load ･Applicable in highly corrosive chemicals	･Highly corrosion resistant ･Highly heat resistant

4 Composition of ceramic bearings

Koyo ceramic bearings are divided into Full Ceramic Bearings (with all components, namely, the outer ring, inner ring and rolling elements, made of ceramic) and Hybrid Ceramic Bearings (with only the rolling elements made of ceramic). The outer ring and inner ring of the Hybrid Ceramic Bearings are made from special steel, including high carbon chromium bearing steel. The cage may be made of a metallic material, resin, or composite material, depending on the intended operating conditions of the bearing.

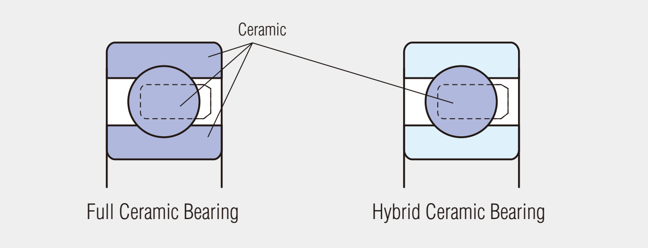


Fig. 4 Composition of ceramic bearings

Ceramics Production Processes

CERAMIC BEARINGS

1 Production processes

With silicon nitride, characteristics such as density and strength can vary greatly depending on the manufacturing method and manufacturing conditions. Therefore, it is necessary to strictly control items such as shape, sintering and other processes when manufacturing silicon nitride for ball and roller bearings.
The general manufacturing process is shown in Fig. 5.

Raw materials — The raw materials used are silicon nitride (Si_3N_4) fine powder and a sintering additive.

Preparation — The raw material powder is wet blended using a solvent. During this process, the silicon nitride powder and sintering additive are mixed evenly in the slurry state.

Drying and granulation — A binder is placed in the mixed slurry and a sprayer device is used to produce spherical particles with a fixed granularity from the slurry state.

Molding — The granulated powder is poured into a mold and compacted into the proper shape by compression.

Machining — Bearing components are machined until a state close to the final form taking shrinking and layer alteration caused by contraction during sintering into consideration.
(May be omitted depending items such as shape and accuracy of the compact.)

Degreasing — Compact is heated in the degreasing furnace to remove organic matter such as binders.

Sintering — In the next process of hot isostatic pressing (HIP), a sealed sintered form without openings is created by applying sufficient gas pressure to the compact.

HIP — A detailed sintered form is attained in a high- temperature, high-pressure gas environment.

Grinding process — The sintered form attained in the HIP process is ground to the dimensions and surface state of the final product.

Inspection — The surface is checked after processing to ensure it does not contain cracks or pinholes.

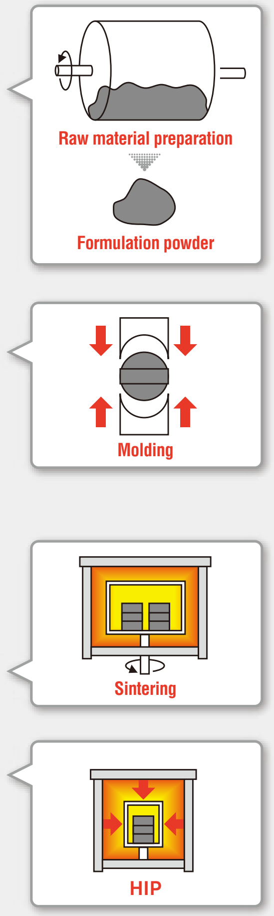


Fig. 5 Ball and roller Bearing Silicon Nitride Manufacturing Process

Ceramic Bearing Product Details

CERAMIC BEARINGS

Silicon nitride, a ceramic material, is more rigid than high carbon chromium bearing steel; therefore, a bearing including silicon nitride components is subject to a higher contact stress on the area of contact between bearing raceways and rolling elements. Accordingly, to estimate the service life of ceramic bearings, whether the rolling bearing theory is applicable or not is critical.

Basic dynamic load rating

The ISO standard defines the basic dynamic load rating as the pure radial load (for radial bearings), constant in magnitude and direction, under which the basic rating life of 1 million revolutions can be obtained, when the inner ring rotates while the outer ring is stationary or vice versa. The basic dynamic load rating represents the resistance of a bearing against rolling fatigue.

Basic static load rating

The basic static load rating is defined as the static load which corresponds to the calculated contact stress shown below, at the center of the most heavily loaded raceway/rolling elements.

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

JTEKT defines the dynamic load rating and static load rating of ceramic bearings based on the results of their service life tests, the maximum allowable static load of the ceramic materials, the elastic deformation test results of high carbon chromium bearing steel, and other related data, as shown in Table 4.

Table 4 Load ratings of ceramic bearings

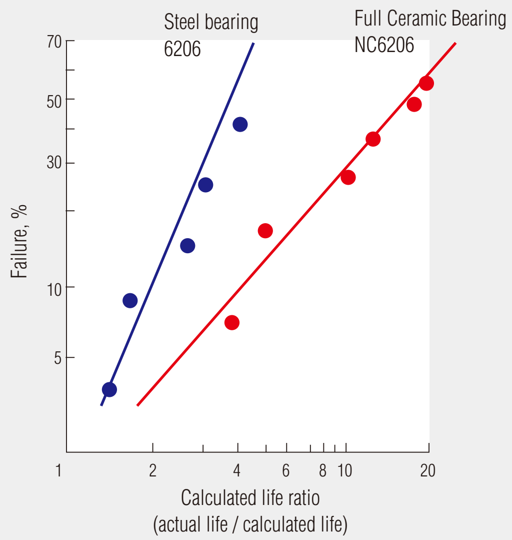
	Full Ceramic Bearing	Hybrid Ceramic Bearing
Dynamic load rating C_r	Comparable to steel bearings	Comparable to steel bearings
Static load rating C_{0r}	Comparable to steel bearings	85% that of steel bearings

Note) The steel bearings here refer to bearings consisting of rings and rolling elements both made of high carbon chromium bearing steel.

1 Rolling fatigue life of ceramic bearings

A typical service life test for Ceramic Bearings and steel bearings was performed under the conditions specified in Fig. 7.
The test results showed that the service life of Ceramic Bearings was equal to or longer than that of steel bearings, exceeding the calculated life.
The Ceramic Bearings were found to exhibit flaking (Fig. 6) when their service life terminated. The same phenomenon was observed on the steel bearings whose service life terminated.
Based on these findings, as the dynamic load rating of a Ceramic Bearing, that of a steel bearing of the same dimensions can be used.

Fig. 6 Flaking on ceramic ball and inner ring



Rolling fatigue test conditions

Bearing number	Material (outer/inner rings and balls)	Dimensions, mm
NC6206	Silicon nitride (Si_3N_4)	30 × 62 × 16 (bore × outside dia. × width)
6206	Bearing steel (SUJ2)	

Specification	Condition
Load	5 800 N
Rotational speed	8 000 min^{-1}
Lubrication oil	AeroShell Turbine Oil 500
Temperature	70 ± 2 ℃

Fig. 7 Rolling fatigue life of Full ceramic bearings and steel bearings

2 Static load rating of ceramic bearings

The basic static load rating of a steel bearing represents a load that produces a localized permanent deformation in the rolling element/raceway contact area, impeding smooth rotation.
However, ceramic materials, which are highly rigid, produce little permanent deformation. Therefore, the theory of the basic static load rating for steel bearings is not applicable to ceramic bearings.

Static load rating of Full Ceramic Bearings

When exposed to continuous excessive loads, ceramic materials may break down; however, before breakdown occurs, the materials develop cracking.
Fig. 8 compares the load measurements at which ceramic balls developed cracking with the basic static load ratings of steel bearings. Fig. 9 shows the measurement system.
As these results show, the loads at which cracks develop on the Full Ceramic Bearing are far higher than that of the basic static load rating of steel bearings. This means that the basic load ratings specified in the ISO standard can be used as the allowable static loads of the Full Ceramic Bearing.

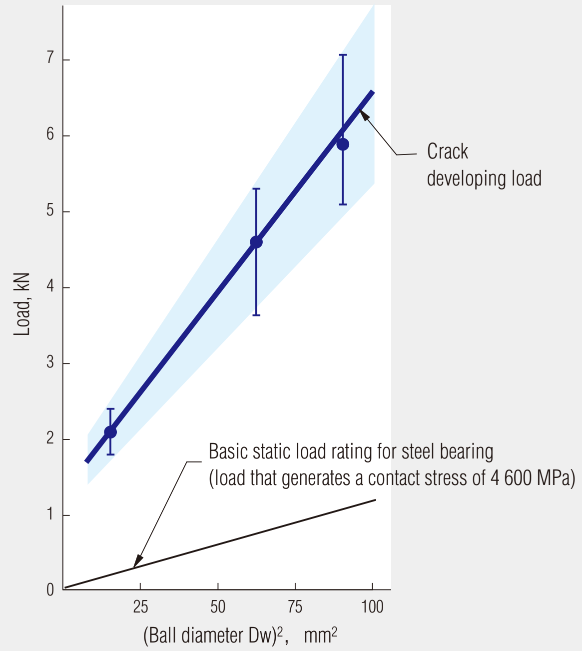


Fig. 8 Crack developing loads for Full Ceramic Bearings

Static load rating of Hybrid Ceramic Bearings

The theory of the static load rating for steel bearings is applicable to Hybrid Ceramic Bearings because their outer and inner rings are made of steel and accordingly any deformation is permanent.
Table 5 shows the results of a test for which a high carbon chromium bearing steel ball and ceramic ball were pressed against a flat plate of high carbon chromium bearing steel and the resulting permanent deformations (indentation depths) on the flat plate and balls were measured.

Table 5 Measurements of permanent deformation produced on flat steel plate and balls

	Load kN	Permanent deformation (average), mm: Flat plate (bearing steel)	Permanent deformation (average), mm: Ball	Permanent deformation (sum of averages), mm
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

These results indicate that ceramic balls do not suffer permanent deformation and that the permanent deformation produced on the flat steel plate by the ceramic balls is approximately 1.2 times the sum of the deformation produced on the flat plate by steel ball and the deformation that the steel ball undergo.
Accordingly, the static load rating of Hybrid Ceramic Bearings can be determined based on the permanent deformation of their bearing steel rings. JTEKT uses the load equal to 85% of the static load rating of steel bearings as the static load rating of the Hybrid Ceramic Bearings.

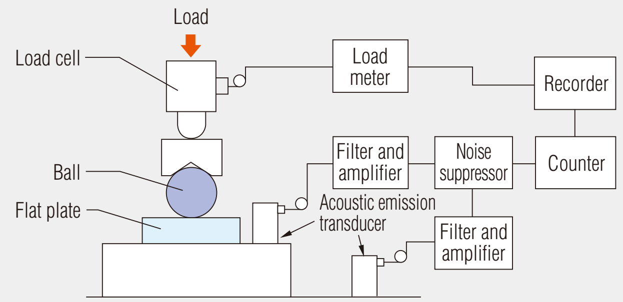


Fig. 9 Crack generating load measurement system

3 Impact strength of ceramic bearings

To evaluate the impact strength of ceramic bearings, ceramic balls were crushed by two methods: by a static load and an impact load. The test results are shown in Fig. 10. Fig. 11 shows the testing methods.

This figure shows that the impact strength of the ceramic bearings is almost equal to the static load strength, which means the bearings possess sufficient impact strength.

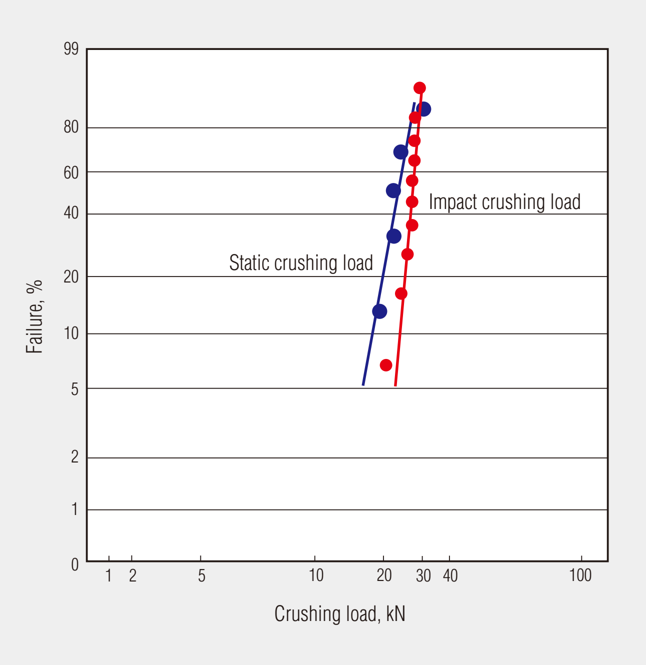


Fig. 10 Comparison of static load and impact load that crush ceramic balls

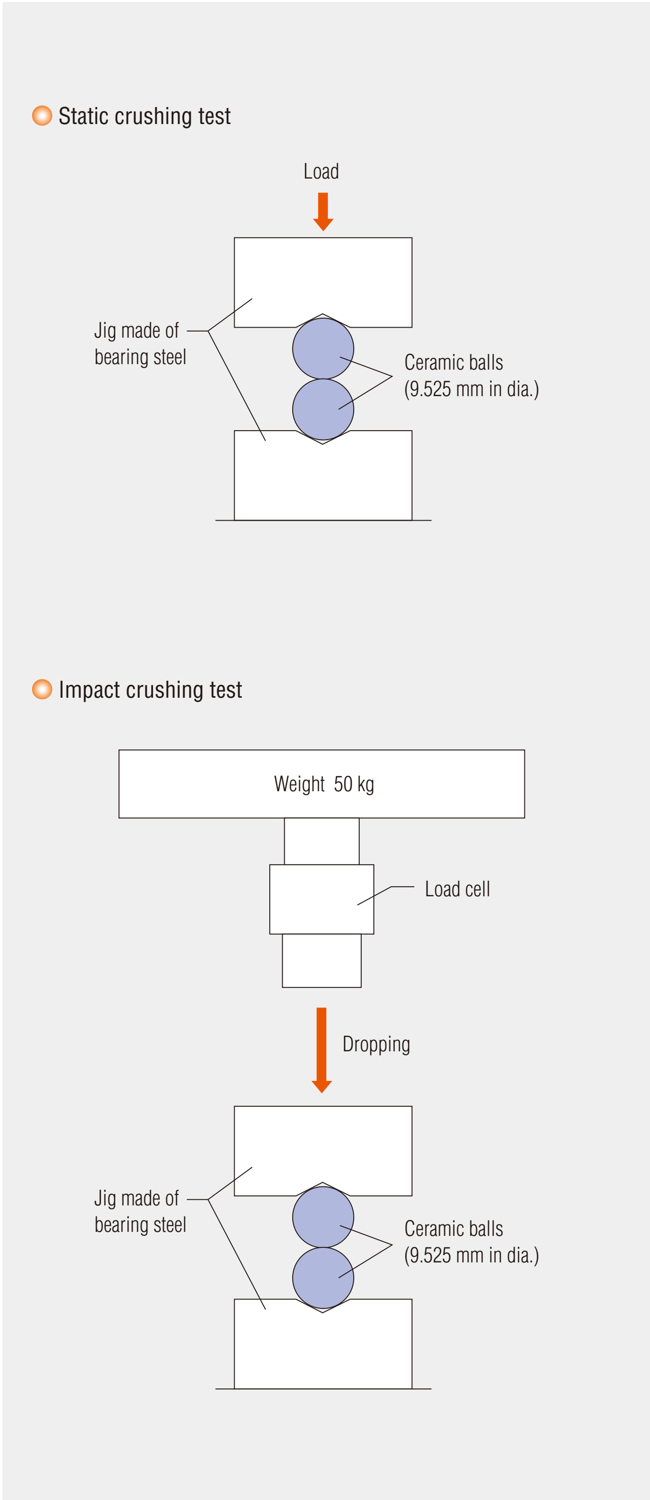


Fig. 11 Ceramic ball crushing test method

4 Fitting of ceramic bearings

When using ceramic bearings, it should be noted that ceramic materials are largely different from steel materials in the coefficient of linear expansion. Attention should therefore be paid to fitting stresses and temperature rises.

The following are the results of evaluating the fitting of a Ceramic Bearing on a stainless steel shaft.

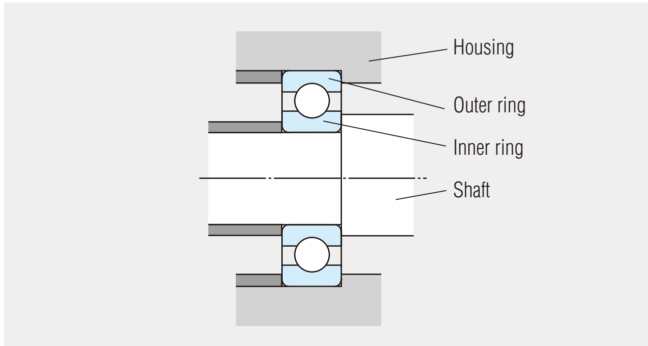


Fig. 12 Bearing fitting

Maximum stress produced by fitting

Table 6 shows the results of a static strength test conducted on a ceramic ring fitted on a stainless steel shaft. Table 7 shows the results of a dynamic strength test (running test) conducted on a ceramic ring fitted on a stainless steel shaft.

Based on the results of these tests, JTEKT makes it a rule for the maximum stress produced by interference to be no greater than 150 MPa when a ceramic inner ring is fitted on a stainless steel shaft.

Consult JTEKT for applications requiring tighter fitting.

Table 6 Typical results of static strength test on ceramic bearing shaft fitting

	Interference, L_{10} μm	Ring's fracture stress MPa
Solid shaft	50	399
Hollow shaft	68	332

Table 7 Typical results of dynamic strength test on ceramic bearing shaft fitting

	Max. allowable interference μm	Max. allowable stress for ring MPa
Solid shaft	31	243
Hollow shaft	43	204

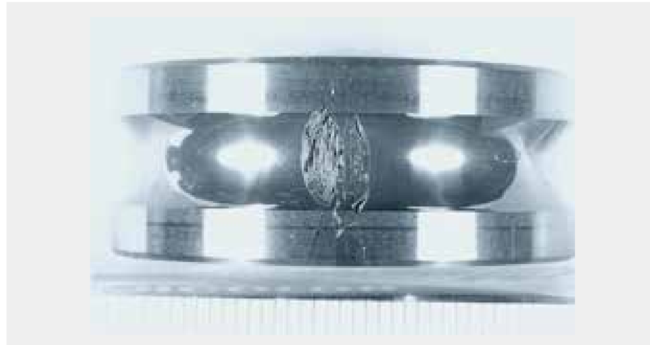


Fig. 13 Ceramic inner ring damaged by dynamic strength test

Influence of temperature

During operation, bearing temperature exceeds the ambient temperature. When a ceramic bearing is operated on a stainless steel shaft or in a stainless steel housing, the interference with the shaft increases due to the difference in linear expansion coefficient while the interference with the housing decreases. (When the outer ring is loose-fitted, the clearance increases.)

To determine the class of fit for a ceramic bearing, the maximum temperature during operation should be assessed carefully.

■ The maximum stress generated on the inner ring due to the interference with the shaft can be determined from the following equation:

$$\sigma = P_m \cdot \frac{D_i^2 + d^2}{D_i^2 - d^2}$$

$$P_m = \Delta_{deff} \left[\frac{d}{E_B} \left(\frac{D_i^2 + d^2}{D_i^2 - d^2} + \nu_B \right) + \frac{d}{E_S} \left(\frac{d^2 + d_0^2}{d^2 - d_0^2} - \nu_S \right) \right]^{-1}$$

σ : Maximum circumferential stress to interference (MPa)

P_m : Pressure of contact on fitting surface (MPa)

d, D_i : Inner ring bore diameter and outside diameter (mm)

Δ_{deff} : Effective interference of inner ring (mm)

d_0 : Bore diameter of hollow shaft (mm)

E_B, ν_B : Bearing's modulus of longitudinal elasticity and Poisson's ratio (MPa)

E_S, ν_S : Shaft's modulus of longitudinal elasticity and Poisson's ratio (MPa)

Ceramic Bearing Capacities

CERAMIC BEARINGS

1 Corrosion resistance

Table 8 shows the corrosion resistance of ceramic materials. Silicon nitride, which is used as the standard material of the ceramic bearings, is excellent in corrosion resistance. However, it may develop corrosion in a highly corrosive chemical, a high temperature, or other highly corrosive ambient condition.

Table 8 Corrosion resistance of ceramic materials

◎ : Fully resistant ○ : Almost resistant △ : Slightly susceptible × : Susceptible

Corrosive solutions \ Ceramic materials	Silicon nitride (standard) Si_3N_4	Corrosion resistant silicon nitride Si_3N_4	Zirconia ZrO_2	Silicon Carbide SiC
Hydrochloric acid	△	○	○	◎
Nitric acid	△	○	○	◎
Sulfuric acid	△	○	○	◎
Phosphoric acid	○	○	○	◎
Fluorine acid	△	△	×	◎
Sodium hydroxide	△	△	○	△
Potassium hydroxide	△	△	△	△
Sodium carbonate	△	△	△	△
Sodium nitrate	△	△	△	△
Water and saltwater	◎	◎	◎	◎

Note) The corrosive natures of individual solutions differ largely depending on the concentration and temperature. Note that mixing two or more chemicals may increase the corrosivity.

There are two types of ceramic corrosion: One is the corrosion of the alumina-yttria system sintering aid (Al_2O_3-Y_2O_3), which is used to bake ceramic materials. To avoid this type of corrosion, corrosion resistant silicon nitride treated with a spinel sintering aid ($MgAl_2O_4$) should be used. Fig. 14 shows the mass reduction and bending strength deterioration of corrosion resistant silicon nitride dipped in an acid or alkaline solution for a given period of time.

The other type of corrosion is the corrosion of the silicon nitride itself. For use in a highly corrosive solution, bearings made of zirconia (ZrO_2) or silicon carbide (SiC) may be effective.

To select a ceramic bearing for use in a highly corrosive environment, its corrosion resistance to the specific condition should be carefully examined.

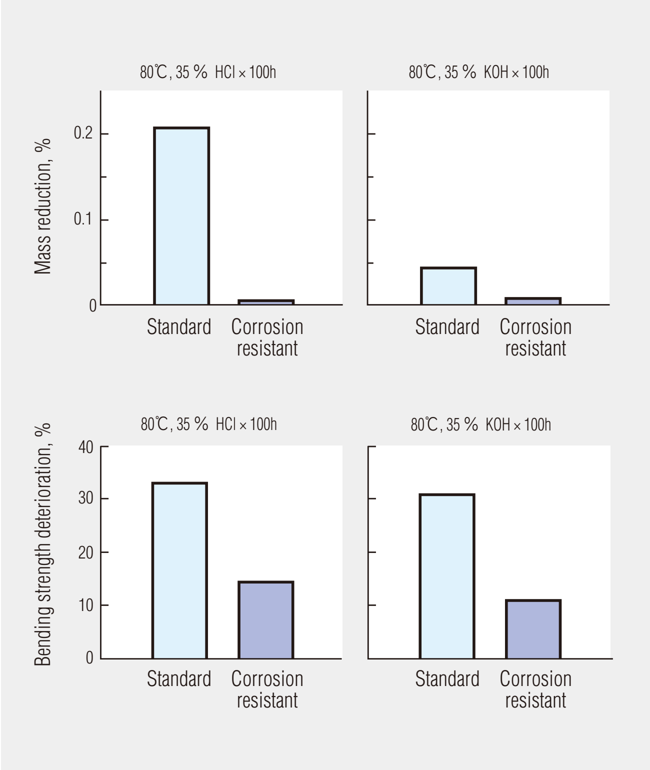


Fig. 14 Anticorrosive performance of corrosion resistant silicon nitride

Service life of corrosion resistant bearings

Table 9 lists the bearings suitable for applications requiring corrosion resistance, along with their major applications.

Table 9 Typical corrosion resistant Ceramic Bearings

	Applications	Bearing Materials	
		Bearing Rings	Balls
Corrosion Resistant Hybrid Ceramic Bearing	In water, alkaline environment and reactive gas	SUS630	Silicon nitride
Ceramic Bearing	In a slightly acidic environment, alkaline environment and reactive gas	Silicon nitride	Silicon nitride
Corrosion Resistant Ceramic Bearing	In a strongly acidic environment, strongly alkaline environment and reactive gas	Corrosion resistant silicon nitride	Corrosion resistant silicon nitride
High Corrosion Resistant Ceramic Bearing	In a strongly acidic environment, strongly alkaline environment and corrosive gas	Silicon carbide	Silicon carbide

When Ceramic Bearings are operated in a solution, the solution serves as a lubricant. This means the solution is closely associated with the service life of the bearings. Fig. 15 shows the service life evaluation results for three types of Ceramic Bearings under water.

The Ceramic Bearings terminate their service life due to the flaking on the bearing ring or ball surfaces.

In case of the Hybrid Ceramic Bearings, ceramic balls do not develop flaking or wear. Their service life ends due to wear attributed to the minute corrosion of stainless steel bearing rings.

When bearings are used in a solution whose lubrication performance is not enough, such as in water, it is important to evaluate in advance the susceptibility of the bearings to corrosion and the relationship between the bearing load and wear in the solution.

SUS440C has a longer service life than SUS630; however, the former steel is not suitable for use in water because it may rust and cause contamination.

Ceramic Bearings may develop wear at an early stage of use depending on the characteristics of the solution, temperature, and load. Please contact JTEKT before using Ceramic Bearings in solutions.

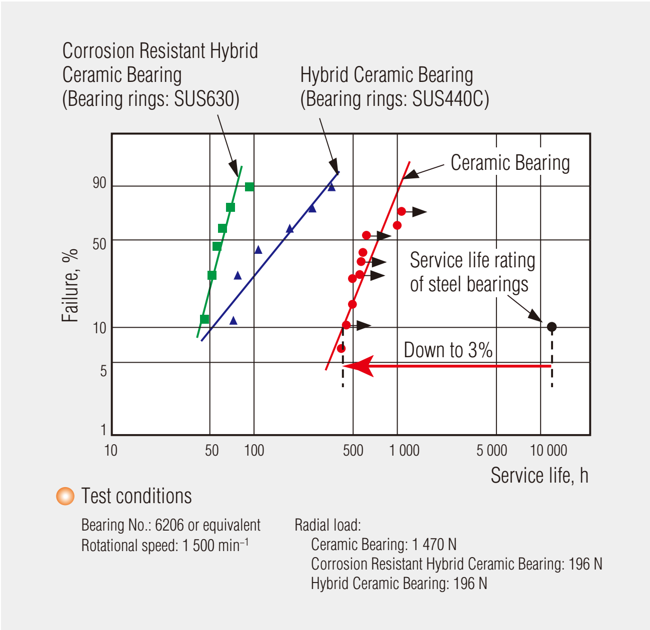


Fig. 15 Comparison in underwater service life of Ceramic Bearings

2 Non-magnetic performance

Bearings may be exposed to magnetic fields in some applications, including equipment associated with super conductivity, semiconductor production facilities and medical examination facilities. If steel bearings are used for such applications, the running torque may fluctuate or the magnetic field may be disturbed . Non-magnetic bearings should be used for such applications. As a non-magnetic material for such bearings, beryllium copper has conventionally been used. However the use of beryllium copper should be avoided since it contains beryllium, a substance of environmental concern.

For such applications, JTEKT supplies Hybrid Ceramic Bearings, whose rings are made of non-magnetic stainless steel and rolling elements are made of a ceramic material, or the full ceramic bearings.

Table 10 Non-magnetic bearings and relative permeability

	Relative permeability
Non-magnetic Hybrid Ceramic Bearings	1.01 or lower
Ceramic Bearing	1.001 or lower
(Ref.) Beryllium copper	1.001 or lower

Fig. 16 shows a rolling fatigue strength evaluation result for various non-magnetic materials. As can be seen from the figure, non-magnetic stainless steel is superior to beryllium copper in rolling fatigue strength.

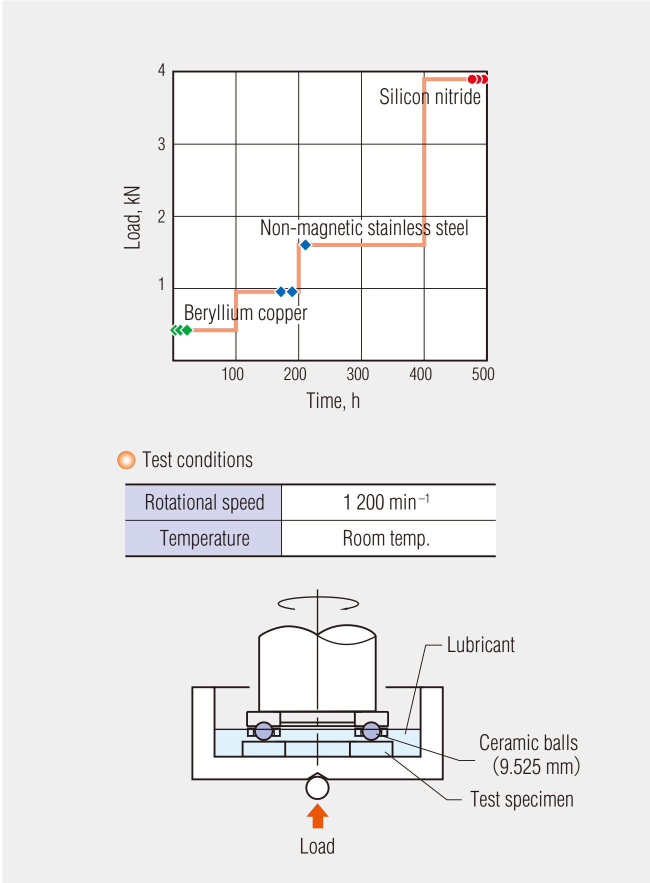


Fig. 16 Comparison of non-magnetic materials in rolling fatigue strength

3 Insulation

A cause of bearing failure in motors or generators is electric pitting. Electric pitting occurs when a surface in rolling contact is locally molten due to sparks produced over the very thin lubricating oil film on the surface when electricity passes through the bearing in operation.
Electric pitting appears as a series of pits or a series of ridges on the surface in rolling contact, which is shown in Fig. 17 and Fig. 18.
An estimation of the mechanism that causes electric pitting on a bearing is shown in Fig. 19.

Fig. 17
Electric pitting generated on general purpose bearings (pits)

Fig. 18
Electric pitting generated on general purpose bearings (ridges)

To avoid such pitting, a bypass is provided to ensure that no electric current passes through the bearing. Another method is to use an insulating bearing that can block electric current.
Since ceramic materials exhibit an excellent insulation performance, Hybrid Ceramic Bearings consisting of ceramic rolling elements can be used as insulating bearings.
Hybrid Ceramic Bearings prevent electric pitting, also reduce bearing temperature rise, and lengthen grease service life. For these reasons, Hybrid Ceramic Bearings assure long term maintenance free operation and high speed equipment operation.

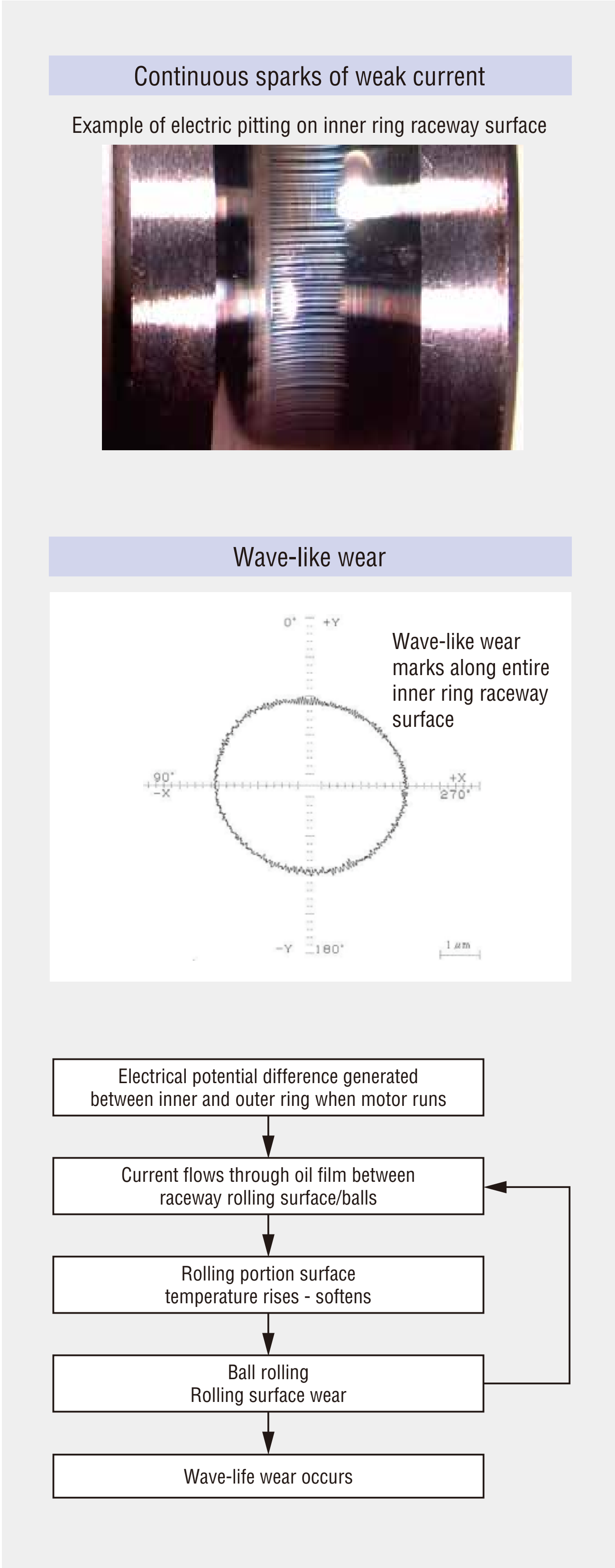


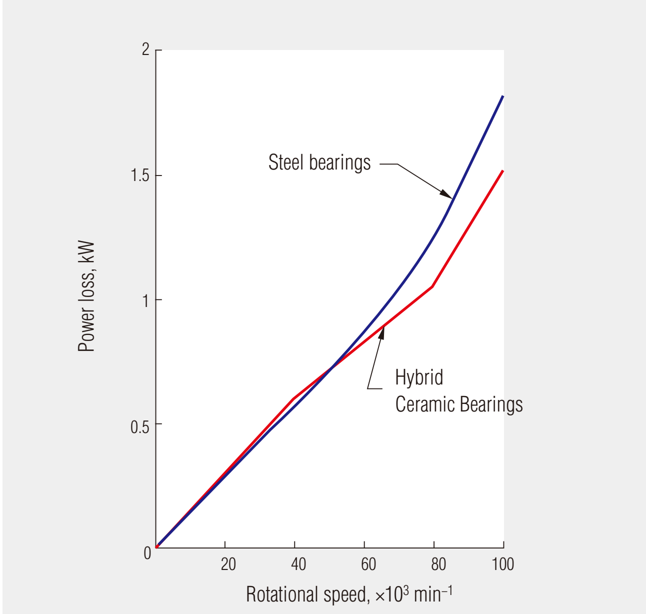
Fig. 19 Estimation of electric pitting (wave-like wear) occurrence mechanism

4 High-speed performance

Hybrid Ceramic Bearings, whose rolling elements are made of a ceramic material with a density lower than that of bearing steel, are most suitable for high speed applications. This is because reduced mass of rolling elements suppresses the centrifugal force of the rolling elements, as well as slippage attributable to the gyro-moment, when the bearings are in operation.
Thanks to their superior high speed performance, Hybrid Ceramic Bearings are used in turbochargers and on machine tool spindles.

Power losses at high speed

Fig. 20 compares power losses between the Hybrid Ceramic Bearings and steel bearings.
When compared to steel bearings, the Hybrid Ceramic Bearings lose smaller power during high speed operation. The power loss decreases with increasing rotational speed.
The Hybrid Ceramic Bearings also have superior antiseizure characteristics, which means that they consume smaller amount of lubrication oil and thereby reduce rolling resistance (power loss).



		Hybrid Ceramic Bearings	Steel bearings
Bearing rings		High speed tool steel (M50)	
Balls	Material	Ceramic (Si_3N_4)	High speed tool steel (M50)
	Dia.	6.35 mm	
	Number of balls	9	
Cage		Polyimide resin	

Condition	Specification
Axial load	200 N
Rotational speed (max.)	100 000 min^{-1}
Lubricating oil	AeroShell Turbine Oil 500
Ambient temperature	Room temp.

Fig. 20 Comparison in power loss between Hybrid Ceramic Bearings and steel bearings

Seizure limit at high speed

Fig. 21 shows the seizure limits of Hybrid Ceramic Bearings and steel bearings. The limits were measured by gradually reducing lubricating oil feed rate.
Compared with general purpose steel bearings, Hybrid Ceramic Bearings consume smaller amount of lubricating oil under the same speed condition, while they can run at a higher speed under the same luburicating oil feed rate condition.

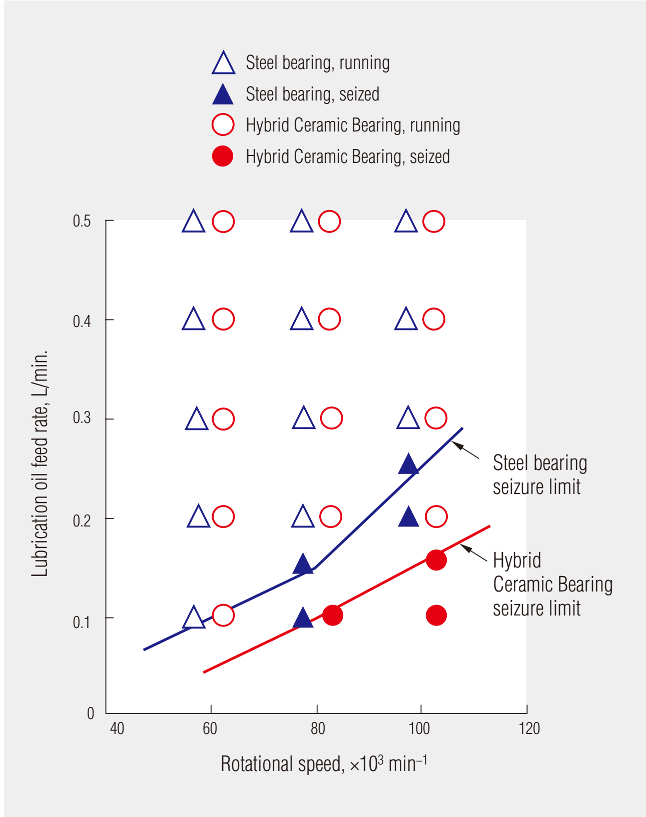


Fig. 21 Comparison between Hybrid Ceramic Bearings and steel bearings in seizure limit

1 Ceramic balls

CERAMIC BEARINGS

JTEKT also supplies Ceramic Balls (silicon nitride), which have excellent resistance to wear and seizure, and are usable in corrosive environments and ultrahigh vacuums. Other major features of these balls are excellent heat resistance (up to 800°C), high rigidity, lightweight (40% compared to bearing steel), non-magnetic, and have insulating characteristics.
The Ceramic Balls are useful in many applications such as jigs, tools, gauges, solenoid valves, check valves, other valve varieties, high grade bicycle parts, automotive parts, and machine components.

Table of Dimensions and Masses

Nominal dimension mm	Nominal dimension inch	Nominal outside diameter mm	Precision grade [1]	Mass [2] (per piece)
0.8		0.800 00	3 and 5	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	5	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
	13/32	10.318 75		1.858 2 g

Nominal dimension mm	Nominal dimension inch	Nominal outside diameter mm	Precision grade [1]	Mass [2] (per piece)
	7/16	11.112 75	5 and 10	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	40	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	60	54.1 g
	1 5/16	33.337 50		62.7 g
	1 1/2	38.100 00		93.5 g

Notes 1) For the grades, those specified in JIS B 1501 shall apply.
2) The masses are calculated on the basis of 3.23 g/cm³ in density.

Numbering System

5/32 G5 NCR

- NCR — Material code: silicon nitride ceramic
- G5 — Precision grade code
- 5/32 — Nominal dimension

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