Technical Trends and R&D Efforts Regarding Industrial Rolling Bearings

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Rolling bearings used throughout the industry are required to be adaptable to many applications. At JTEKT, we promote the development of such bearings, further increasing their added value in order to ensure the satisfaction of our customers.

This report introduces our activities for improving product competitiveness of bearings used in wind power generation, machine tools, steel production equipment, agricultural and construction machinery, and special environments, and indicates the future trend of development within our company.

***Key Words**: industrial bearing, trend, bearing technology*

1. Introduction

Rolling bearings, which support the rotational axes of machines, are an important machine element widely used within all industries. In recent years, demands for bearings have diversified along with the increasing severity of application environments and conditions for all types of machines.

To respond to these demands, JTEKT strengthens and improves fundamental technology such as materials and heat treatment, lubrication, evaluation and analysis. JTEKT is also progressing ahead with developmental improvements for products consisting of existing bearings integrated with maintenance-free technology through longevity, lightweight technology through systemization, ultra-high speed technology through low torque and high reliability technology through robustness.

This report introduces the technological trends and endeavors of JTEKT in (industrial) bearings used within industrial fields (industries) unrelated to the automotive field, namely wind power generation, machine tools, steel production equipment, agricultural and construction machinery, and special environments.

2. Trends of industrial bearings

Although bearings are standardized by the ISO, within industry in general, the application of standard products may not be possible due to the unique environment or conditions of application, and therefore a demand has arisen for performance suited to application conditions. The following applications in particular require special approach.

- Wind power generation: Approach for design life exceeding 20 years
- Machine tools: Approach for ultra-high speeds and ultra-high accuracy
- Steel production equipment: Approach for harsh application environments including subjection to cooling water or heat
- Construction machinery: Approach for robustness and toughness

In addition, special environments may require approaches to cleanliness, vacuums, high temperature or corrosion resistance.

JTEKT strives to respond to these demands not only by cultivating the technologies of bearing design, material heat treatment, lubrication and precision machining, but also by enhancing bench tests, actual evaluations, and the utilization of CAE technology. Examples of activities for each application are shown below, and future development trends are shown in **Fig. 1**. As seen in **Fig. 1**, the keywords of future development are longevity, improved robustness, ultra-high speed, suppression of temperature rise, and high accuracy.

3. Improved reliability of main shaft bearings for wind turbine generators

As the focus on renewable energy increases throughout the world, the introduction of wind power generation has been accelerating since the year 2000, in areas such as Europe, the United States and China. In recent multi-megawatt turbines, the effective utilization ratio has been raised for onshore wind turbines due to the widening of blade diameter, and offshore wind turbines are shifting

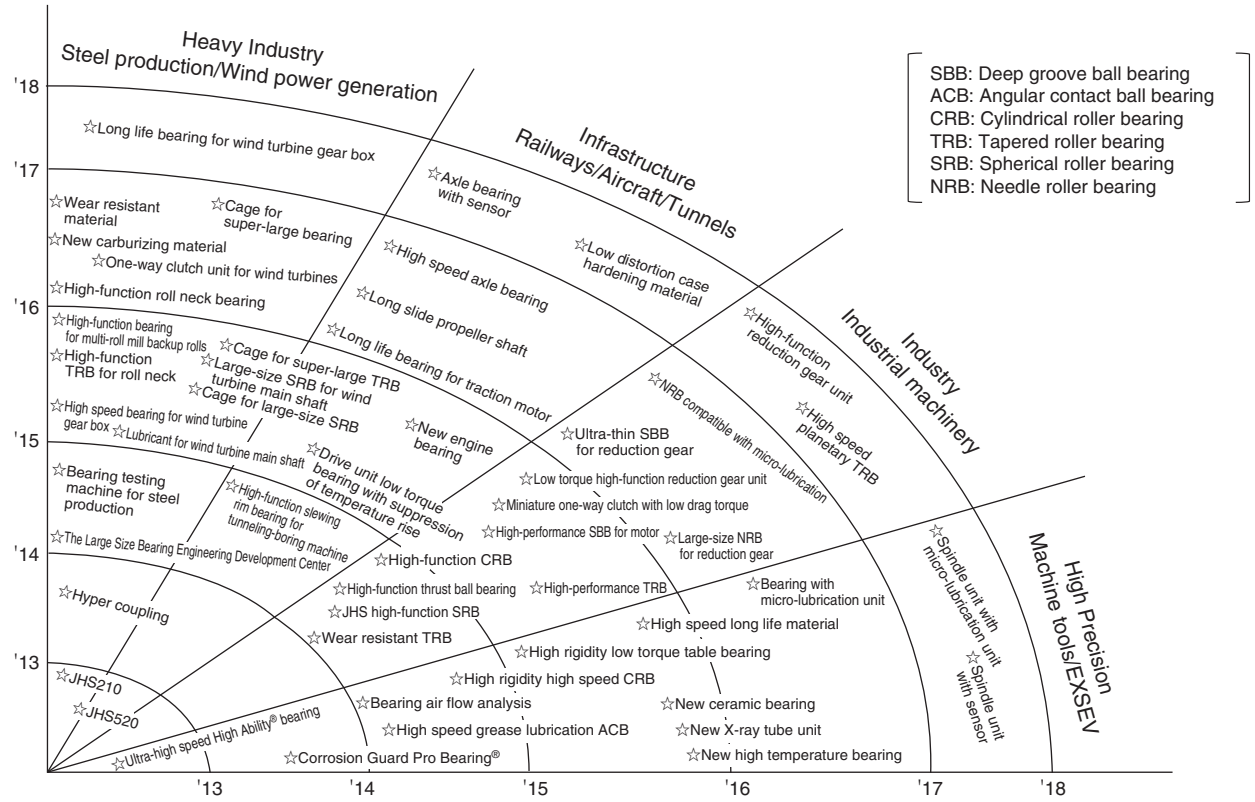

Fig. 1 Trends of industrial bearing development

capacity to high power generation (large-size wind turbines) [1, 2].

This requires large-size bearings with higher load capacity and high rigidity which respond to larger main shafts of wind turbines.

JTEKT has developed a method for selecting optimum bearings for the main shafts of multi-megawatt wind turbines using FEM analysis (**Fig. 2**). With this method, rolling element load distribution closely resembling actual operation conditions can be calculated through analysis considering running torque in addition to the rigidity of peripheral components.

To verify the reliability of the FEM analysis method, measurement of rolling element load distribution was conducted on a scale size model testing machine (**Fig. 3**). The results demonstrated close congruency between the FEM analysis results and measured results, confirming the high reliability of FEM analysis. Additionally, the amount of housing deformation of an actual wind turbine was measured and confirmed to be consistent with FEM analysis results.

Furthermore, JTEKT has recently introduced testing machines to be able to evaluate an actual bearings size used in multi-megawatt wind turbines, because of increasing requests for evaluations of all bearing types using them.

Using the FEM method and the actual size bearing evaluation testing machine (**Fig. 4**), JTEKT will continue contributing to the improvement of reliability and reduced development time of multi-megawatt wind turbines.

4. Activities for machine tool bearings

Performance demands for machine tools are becoming increasingly stringent with each passing year, due to the creation of products with high added value and the reduction of manufacturing costs.

Of the many units comprising a machine tool, the spindle is the most important as it influences machine tool performance. It is therefore essential that the machine tool spindle be high performance.

As the spindle bearing greatly affects spindle performance, high performance of the spindle bearing is extremely important as well. One of the most critical technologies to the spindle bearing is the suppression of temperature rise, which contributes to the improvement of machining accuracy.

Based on this situation, JTEKT has developed an ultra-high speed angular contact ball bearing (dmN value: 4 000 000) and ultra-high speed cylindrical roller bearing (dmN value: 3 000 000), shown in **Fig. 5**.

Further improvement of robustness and actual machine evaluation is necessary to help reduce production lead time through a faster spindle, improve machining accuracy through suppression of spindle thermal displacement, and improve machining ability through higher spindle rigidity. Therefore, JTEKT is promoting the establishment of a bearing internal temperature measurement system using high sensitivity thermography (**Fig. 6**), development of a behavior analysis system for the internal air flow

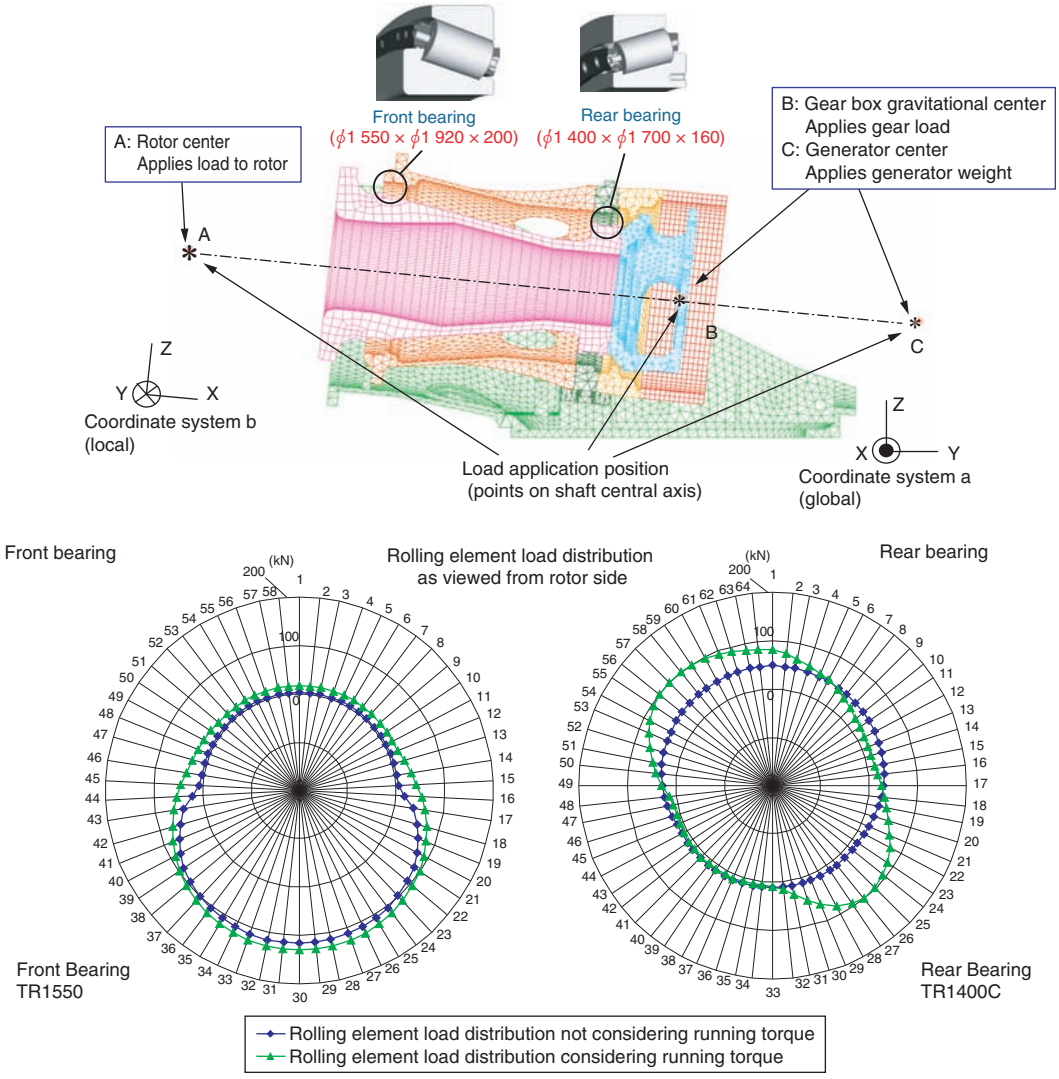

Fig. 2 Structure and results of FEM analysis

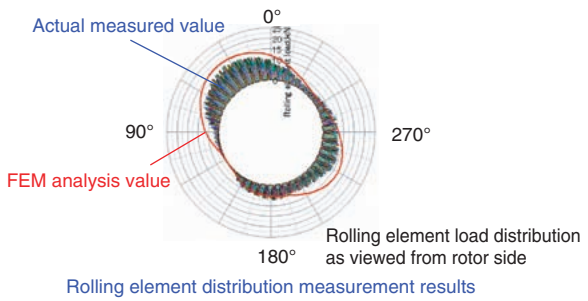

Fig. 3 Comparison of measurement results and calculation results of rolling element load

Fig. 4 Actual size bearing evaluation testing machine

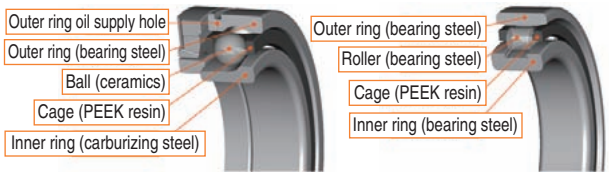

Fig. 5 Ultra-high-speed angular contact ball bearing and cylindrical roller bearing

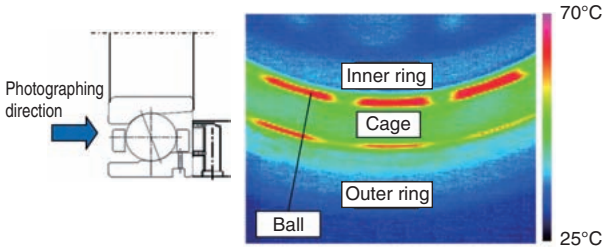

Fig. 6 Example of bearing inner temperature

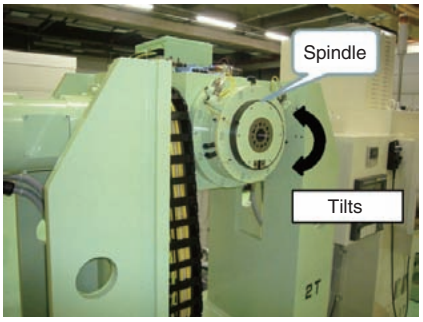

Fig. 7 High-speed tilt testing machine

of bearings through high accuracy fluid simulation technology, as well as evaluation utilizing a high speed tilt testing machine (**Fig. 7**) imitating actual machines.

5. High-function product technology for steel production equipment

Steel production equipment must have reliability, which requires further efficiency improvement and stable operation. JTEKT provides bearings and related products for steel production equipment to improve reliability. In particular, our company has been engaged in the development of product technologies focused on application within the many environments and conditions of use of steel production equipment. **Table 1** and **Fig. 8** show examples of developed products and the concepts of these products.

Suppression of temperature rise and low torque are currently being introduced into products as technologies for stable equipment operation.

For example, JTEKT is promoting the development of technology tapered roller bearings for roll neck to suppress temperature rise, the cause of seizure. The results of a speed test reveal an improvement of approximately four times higher axial load performance (**Fig. 9**) than conventional bearings.

Moreover, our company is working to improve the technologies that suppress temperature rise and low torque within spherical roller bearings as well, which are used widely within steel production equipment [3, 4].

Spherical roller bearings consist of an asymmetrical roller type and symmetrical roller type [5]. Conventionally, the symmetrical roller type had a large load capacity compared with the asymmetrical roller type, although unstable roller movement led to the problem of high temperature rise. From this, JTEKT elucidated the balance of forces influencing roller movement and

Table 1 Examples of developed products

Developed product	Roll neck bearing in rolling mill, "JHS520"	Back-up roll bearing in multi-roll mill, "JHS210"	Oil-air lubrication unit for continuous casting equipment
Concept	Longer life of bearing in corrosive environments	Longer life of bearing under poor lubrication	Prevention of accidental equipment damage through improved lubrication

Fig. 8 Roll neck bearing in rolling mill <JHS520> and back-up roll bearing in multi-roll mill <JHS210>

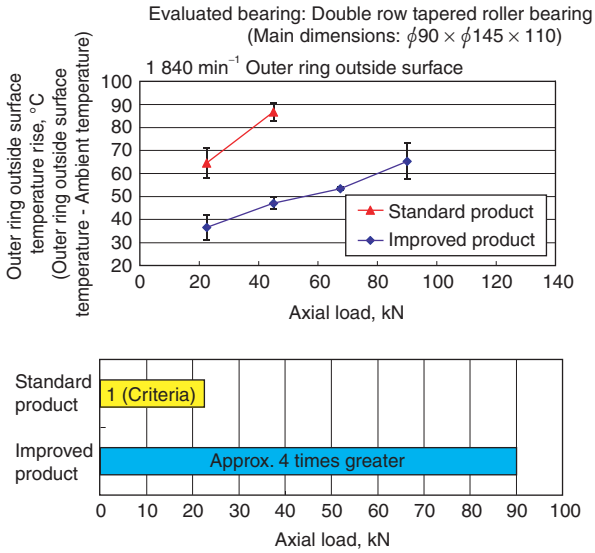

Fig. 9 Axial loading performance at a high speed (1 840 min^{-1})

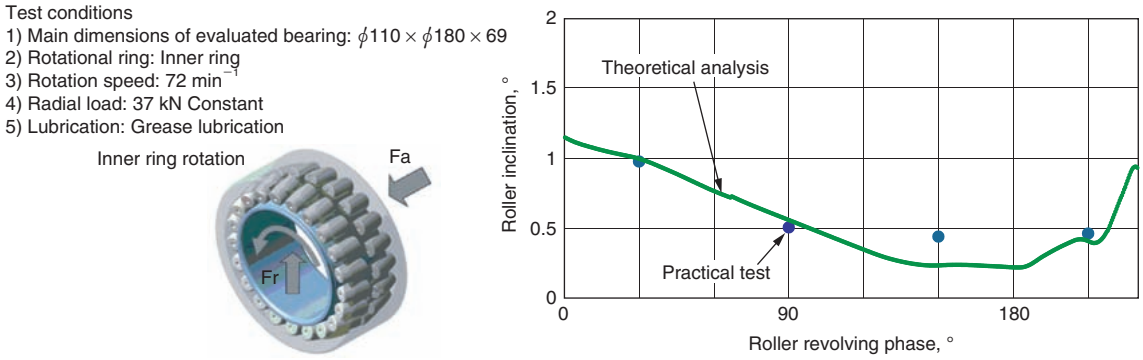

Fig. 10 Results of comparison of practical test and theoretical analysis

verified these forces through an actual evaluation and an analysis method utilizing CAE (**Fig. 10**).

As a result of this evaluation, our company has enabled the stabilization of roller movement and developed a symmetrical roller type spherical roller bearing with both suppression of temperature rise and high load capacity.

The safety unit, which minimizes damage to equipment when an operational abnormality occurs, is another important technology that contributes to stable equipment operation. As the main drive train of rolling equipment is comprised of a motor and reduction gear, considerable loss, including production loss, occurs if it is damaged. **Figure 11** shows the "JHS Hyper Coupling", a safety unit product for releasing excessive torque that occurs within the drive train. This safety unit was developed using technologies cultivated by JTEKT, one of the top manufacturers of drive shafts for rolling mills.

6. Activities for improving the reliability of rolling bearings and drive shafts for agricultural and construction machinery

Due to the demands of infrastructure improvement and resource development accompanying economic expansion, industrial machinery such as agricultural machines have undergone continuous growth in both size and performance. The rolling bearings and drive shafts used within these machinery require high reliability as functional components of the drive train, and JTEKT is continuing efforts to achieve such a goal.

6. 1 High-performance tapered roller bearing

The demand for tapered roller bearings is especially high within construction machinery, as these bearings can receive radial load and axial load at the same time. However, failure in the field at an early stage is a problem with this bearing type as it is used in extremely harsh conditions. JTEKT promotes the development and market introduction of high-performance tapered roller bearings (**Fig. 12**) with improved robustness under harsh conditions.

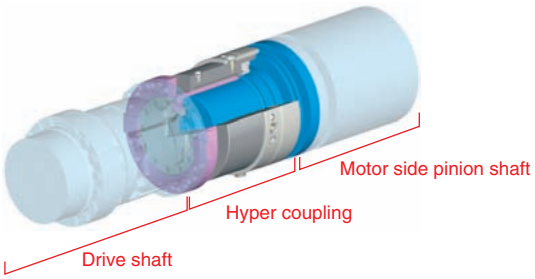

Fig. 11 Hyper coupling

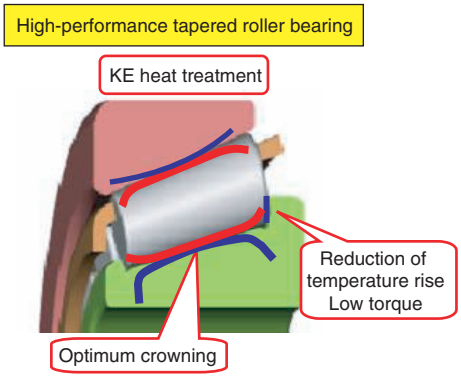

Fig. 12 High Performance Tapered Roller Bearings

The typical failure mode of bearings in the field and details of countermeasures using high-performance tapered roller bearings are shown below.

(1) Damage caused by edge load

Bearings used in misaligned conditions have short lives due to excessive edge load on the raceway surface.

The bearing life of high-performance tapered roller bearings was lengthened by reducing edge load through internal design using shaft system analysis software, developed by JTEKT, and crowning optimization [6].

Figures 13 and **14** show the results of contact stress analysis and results of an evaluation of endurance life against raceway inclination.

(2) Damage caused by foreign materials

Foreign materials in the lubricant cause peeling on the surface layer through brinelling, which significantly lowers bearing life. Surface hardness of the material

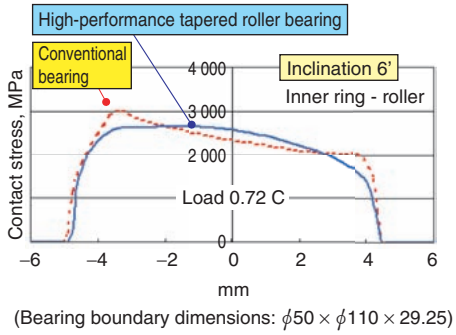

Fig. 13 Contact stress calculation results

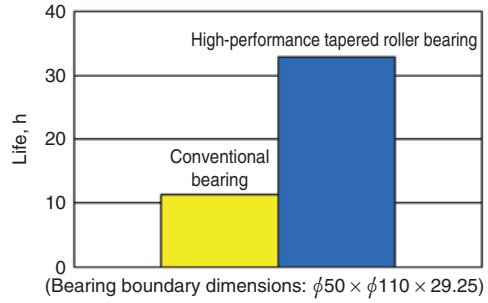

Fig. 14 Life test results in misalignment condition

and optimization of residual austenite are effective in improving bearing life amidst foreign materials in the lubricant. KE heat treatment [7, 8] using these technologies was applied to the high-performance tapered roller bearing to improve life in lubricant with foreign contamination.

(3) Damage caused by lack of oil film

Temperature rise and low viscosity of the lubricant caused by high vehicular performance considerably worsens the condition of the bearing oil film.

LFT (Low Friction Torque) bearing [9, 10] technology has been adopted in the high-performance tapered roller bearing in order to prevent the lack of oil film on the raceway surface. This technology can be expected to improve oil film thickness by reducing oil temperature rise and reducing power loss through low torque.

6. 2 Drive shafts for construction machinery

JTEKT holds the top share in drive shafts for construction machinery (**Fig. 15**), which are operated in severe environments. Our company is therefore engaged in activities to improve the reliability of the cross bearing with a long greasing interval (**Fig. 16**), which raises drive shaft maintainability by improving seal performance and bearing life, and the cover tube type spline seal (**Fig. 17**), which improves muddy water resistance.

Fig. 15 Drive shaft for construction machinery

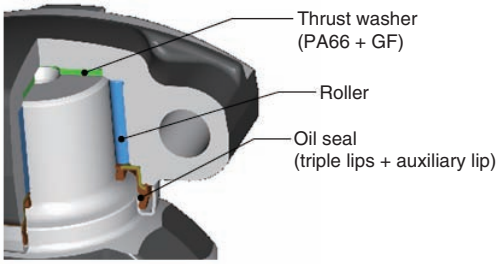

Fig. 16 Cross bearing with long greasing interval

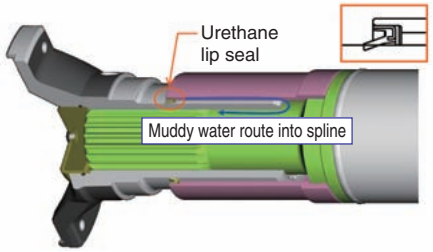

Fig. 17 Cover tube type spline seal

In this way, JTEKT contributes to the improved reliability of agricultural and construction machinery by promoting product development which meets the demands required for the application of such machinery.

7. Activities focused on bearings for special environments

In line with recent technological advances, the environments and conditions in which rolling bearings are used are becoming increasingly more sophisticated and diverse each year. A great number of special environments exist within various industrial manufacturing processes. These environments include those with corrosive factors, vacuums, clean environments, and those with high temperatures. JTEKT has commercialized each type of bearing used in special environments in the EXSEV® (Extreme Special Environment) bearing series.

In special environments, during processes such as chemical treatment and cleaning, bearings are used in tough corrosive environments which include water, cleaning solutions and chemical solutions. Bearings used in such environments especially require corrosion resistance. **Figure 18** shows the relationship between corrosive environments and industries.

Ordinary oil and grease cannot be used in corrosive environments, and bearing steel often lacks sufficient corrosion resistance. Therefore, it is important to select materials that are resistant to corrosion and can withstand usage in conditions with insufficient lubrication. **Figure 19** shows the main materials and applicable parts for corrosion-resistant bearings.

Resins, metals and ceramics are the main materials which constitute corrosion-resistant bearings.

Resins, used for cages, include fluorocarbon resin, which has excellent self-lubrication, and PEEK (polyether ether ketone) resin, which has higher durability.

Metals are used for bearing rings and rolling elements, and include martensitic stainless steel (SUS440C), which has corrosion resistance superior to that of bearing steel, and precipitation hardening stainless steel (SUS630), which has excellent corrosion resistance in environments with cleaning solutions and chemical solutions.

Ceramics, although high in cost, are used for bearing rings and rolling elements as they have excellent corrosion resistance and wear resistance, and can withstand most corrosive environments. On one hand, SUS630 is advantageous in cost in comparison with ceramics, and therefore often used for corrosion-resistant bearings. However, as the hardness level of SUS630 is lower than SUS440C, wear progression on the raceway surface is higher, leading to problems with bearing durability.

This issue is also present in the film manufacturing equipment shown in **Fig. 20**. JTEKT has developed a long life bearing with high corrosion resistance through the use of steel with high hardness and high corrosion resistance, shown in **Fig. 21**. **Figure 22** shows the results of the thrust rolling service life test for the high hardness, high corrosion resistance steel and SUS630. Our company will continue to develop bearings more suitable for corrosive environments in order to respond to market demands within the field of special environments.

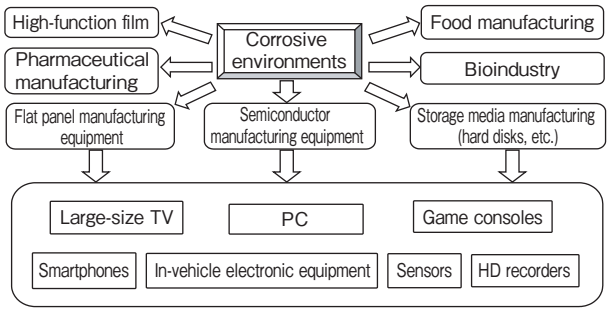

Fig. 18 Relationship between corrosive environments and industries

	Material	Bearing component of application
Resins	Fluorocarbon resin	Cage
	PEEK resin	
Metals	Martensitic stainless steel	Bearing ring, rolling element
	Precipitation hardening stainless steel	Bearing ring
Ceramics	Silicon nitride	Bearing ring, rolling element

Fig. 19 Main materials and applicable parts for corrosion-resistant bearings

8. Conclusion

Besides those introduced, there are still many technical challenges to improve competitiveness of bearings used in industrial fields such as railway axles, aircraft jet engines, electric motors and reduction gear. Based on technical scenarios directing what products should be provided to fulfill customer needs and what technologies are necessary, and development trends shown in **Fig.1**, JTEKT will persevere in developing products attracting customers more and more.

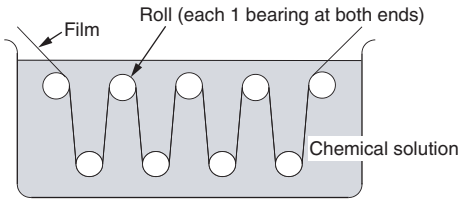

Fig. 20 Schematic illustration of film manufacturing equipment

(Main dimensions: $\phi 25 \times \phi 60 \times 15$)

Fig. 21 Long life and highly corrosion-resistant bearing

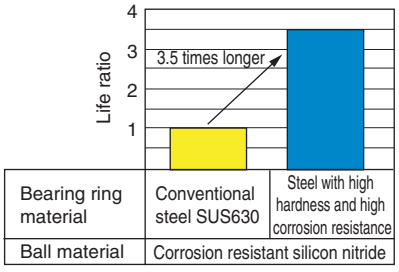

Fig. 22 Results of thrust rolling service life test

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