Prospects

Efforts for Service & Solution Business in NTN

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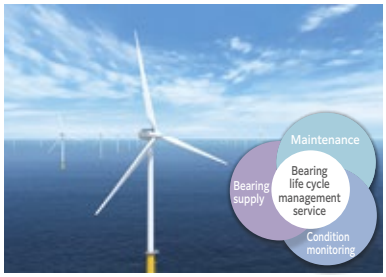

Rolling bearings are fundamental mechanical parts working in various equipment that support our life activities. The failures on mechanical parts in the industrial equipment cause a stop of the equipment and induce a considerable amount of profit loss. It is important to monitor the condition of temperature or vibration around the bearings, in order to prevent the unexpected stop of the equipment. **NTN** develops bearings with sensing functions and provides condition monitoring service of the bearings. We are willing to provide the service & solution, which is valuable to solve the customer's problems by using the sensing data.

1. Introduction

Machinery and equipment that have rotating mechanisms support the abundant lives of people today. Many of the machines and equipment used to manufacture transport machinery such as automobiles and railroads, as well as air-conditioning equipment and household electrical appliances are equipped with rotating mechanisms. Rolling bearings (hereafter, bearings) are one of the major components used in these rotating mechanisms. Bearings must rotate smoothly while supporting the rotating shaft and be able to operate in a stable manner for long periods of time. Although improvements in bearing performance continue, it is said that bearings are the cause of 30 % of all machinery and equipment failures[1)].

Since profit is lost when equipment stops due to defects in machine parts at the production site, it is important to monitor the temperature and vibration around the bearing to prevent defects from occurring. Furthermore, in the automotive sector, bearing condition monitoring will become essential as growth in autonomous driving results in people moving from ownership of automobiles to sharing them, in addition to the development of infrastructure to support autonomous vehicles.

As mentioned above, it is necessary to develop a method (providing services) to use bearings in a stable manner for extended periods of time, not just develop technology (providing products) for the bearings themselves. In response to this, **NTN** provides solutions that combine both products and services that focus on bearing technology:

- High-performance products that integrate sensing functions with bearings (products)
- Services that provide users with information such as bearing condition diagnosis, appropriate methods of use, and replacement periods (services)

Here, I will introduce an overview of the service and solution business that **NTN** is working on and discuss the future prospects. More detailed information about the technology and applicable products will be introduced separately in other articles in this technical review.

2. Sensing around the bearing

NTN has developed a bearing with a sensor that combines bearing and sensing functions with the aim of responding to the following customer needs:

(1) Integrated multi-functions for bearings
(2) Improved reliability for machinery, equipment, and parts as well as support for maintenance

(1) Implementation within compact machines such as motors and pumps. Incorporating a sensing function in the bearing provides an effective method of saving space and reducing the person-hours for assembly, etc. Sensing functions are used to measure such things as the rotational speed, rotational angle, and load around the bearing, and are used to control the operation of machinery.

(2) Implementation within large equipment that must operate in a stable manner and run for long consecutive periods of time. Sensors embedded into the bearing are used to monitor the bearing's operating conditions, and to provide information about bearing condition diagnosis such as whether it is damaged. This aims to prevent unforeseen problems and minimize stoppage time due to failure. To diagnose the condition of a bearing, it is necessary to sense such factors as its temperature, vibration (noise) and lubrication conditions (oil film thickness, grease degradation, foreign object contamination).

If production equipment or infrastructure-related equipment suddenly stops operating, this will have a significant impact on business operators and society. Therefore, there is a strong demand in these sectors for a bearing that will not fail, or at the very least an understanding of a suitable replacement period. **NTN** provides technical services that achieve a high level of accuracy in predicting and detecting when a failure will occur. These services prove useful to customers in preventing equipment-related problems and production downtime.

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3. Implementation example of a bearing with a sensor

3.1 Rotation sensor bearing

The rotation sensor bearing is constructed by incorporating a magnetic sensor and magnetic encoder in the bearing as shown in **Fig. 1**, and **NTN** has created a lineup of several standard deep groove ball bearing numbers. Since a magnetic sensor is used, it is resistant to contamination compared with general optical sensors and can also be used in high-temperature environments. This type of bearing is used to control the drive motor on forklifts and for wheel slip prevention control.

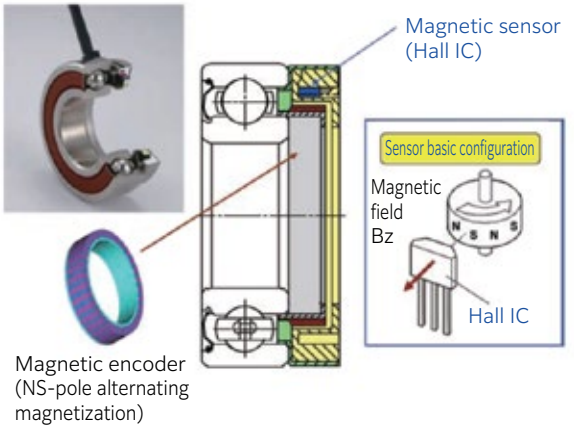

Fig. 1 Rotation sensor bearing[2)]

3.2 Automobile wheel speed sensor

A magnetic sensor to detect the wheel speed is fitted onto the bearings of automobile wheels (hub bearings) and used for controlling ABS (anti-lock braking system). The seal on the hub bearing has a built-in rubber magnetization ring, which provides high durability and prevents deterioration around the wheel over an extended period even in harsh environments. **NTN** has also developed the Hub Bearing with an Integrated High-Resolution Rotation Sensor[2)] that uses a magnetic sensor provided with an interpolation function **(Fig. 2)**.

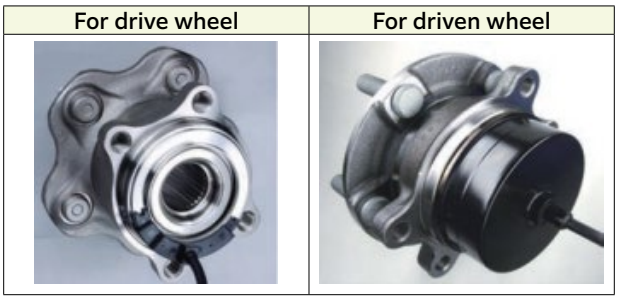

Fig. 2 Hub Bearing with an Integrated High-Resolution Rotation Sensor[2)]

Wheel rotation signals include the impact of tire conditions (such as the air pressure) and road conditions. Analyzing high resolution rotation signals makes it possible for us to detect the differences in tire conditions and road conditions with a greater level of accuracy. For example, when passing over a section of asphalt road covered in gravel, the rotational speed changes spectrum varies[2)] as shown in **Fig. 3**. Using this type of high-resolution signal can further enhance the functionality of automotive control.

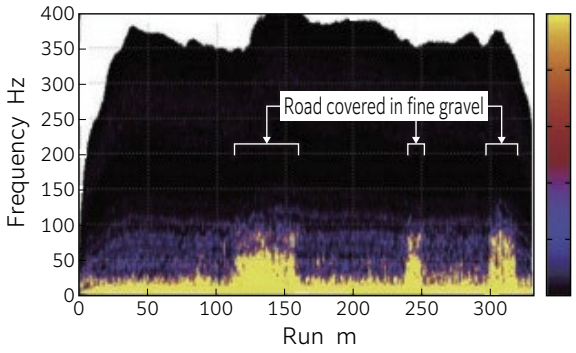

Fig. 3 Variance in speed change spectrum while driving[2)]

3.3 Multi Track Magnetic Ring for absolute angle sensing

NTN has developed the Multi Track Magnetic Ring[3)] as shown in **Fig. 4**. This magnetic ring is sold as a detection target for use in combination with a magnetic sensor for absolute angle detection. The magnetic sensor's advanced interpolation function and Multi Track Magnetic Ring's highly accurate magnetic pattern make it possible to detect a single revolution (360 degrees) with an angle resolution of over 100 thousand divisions. Since it is magnetic, it has superior environmental resistance when compared to optical sensors, and its compact configuration is suitable for saving space. It is used as a control sensor on robot joints and various types of motors.

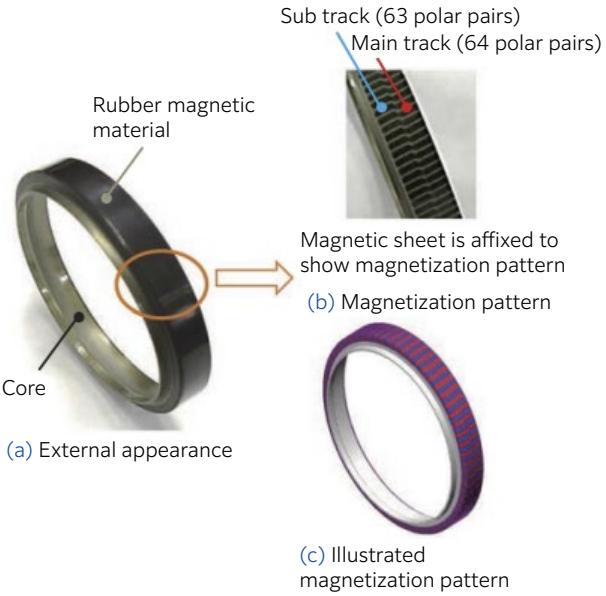

Fig. 4 Multi Track Magnetic Ring: Radial magnetization type[3)]

3.4 Sensor Integrated Bearing Unit for Machine Tool Spindles

The main shaft unit on a machine tool must support condition monitoring and IoT in addition to having the fundamental ability of high speed, high rigidity, and high accuracy, etc. **NTN** has developed the "Sensor Integrated Bearing Unit" for Machine Tool Spindles, which has various sensors integrated into the outer ring spacer adjacent to the bearing to monitor the conditions inside the bearing and has a load detection function and wireless communication function **(Fig. 5)**[4]. These sensors detect deteriorating lubrication conditions and signs of damage from vibration and temperature sensing information to prevent defects. Alternatively, they have been proposed for use in adjusting machining conditions by monitoring such factors as forming load and bearing pre-load amount.

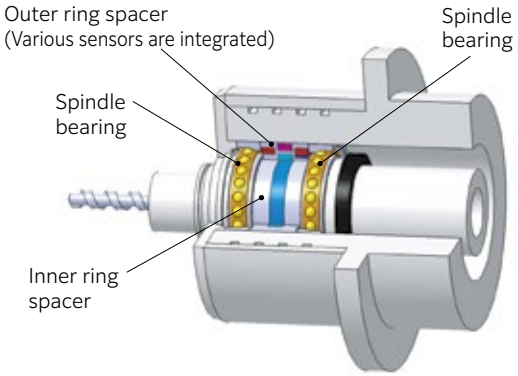

Fig. 5 "Sensor Integrated Bearing Unit" for Machine Tool Spindles[4]

3.5 Talking Bearing™

NTN has developed a "Talking Bearing™" as the ultimate form of a bearing integrated with sensing functions **(Fig. 6)**[5]. This bearing has the same external dimensions as a standard number bearing but also has vibration, temperature, and rotation sensors as well as a power generator, signal processing circuit and wireless communication unit incorporated into the bearing. The bearing generates power as it rotates and results from sensors are sent wirelessly, allowing the bearing to "talk" and convey information.

Currently, space is required to incorporate the electronic circuit and power generator so there is a limit to the viable bearing size. However, the progress being made in miniaturizing sensor devices and the improvements in power saving will lead to the implementation of much smaller diameter bearings that use this concept in the future.

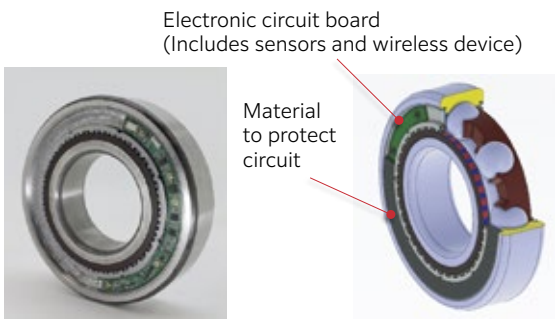

Fig. 6 Talking Bearing™

4. Efforts for condition monitoring services

4.1 Trends in condition monitoring

In recent years, the concept of assessment management, which targets the maintenance management and operation of infrastructure such as roads and buildings, is also being expanded to the machinery and equipment sector, and extensively applied to areas from machine condition monitoring to part procurement control. In terms of the equipment maintenance method, there has been a shift towards CBM (condition-based maintenance, predictive maintenance) from the conventional TBM (time-based maintenance, preventive maintenance) method **(Fig. 7)**.

Under such circumstances, efforts to monitor bearing conditions during operation, detect signs of defects and then provide measures before problems arise have attracted a great deal of interest.

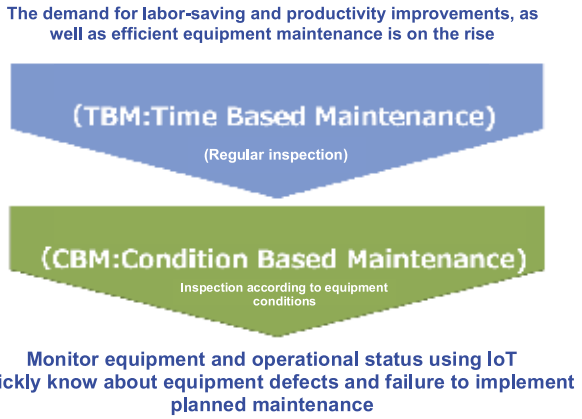

Fig. 7 From time-based maintenance to condition-based maintenance.

4.2 Introducing a condition monitoring system for factory equipment

To operate large machinery and equipment, continuous operation pumps and generators, etc., in a stable manner for extended periods of time it is vital to conduct suitable maintenance work based on bearing condition monitoring, diagnosis technology and the conditions. At large-scale equipment and important production lines, comprehensive condition monitoring systems are introduced while regular inspection and daily maintenance work is conducted constantly together with records for operation and maintenance. In this manner, all companies have established a condition monitoring and operation management system for their entire factory to prevent problems with large equipment.

In contrast, operation management is often conducted individually for each machine when looking at small-scale equipment. This creates the problem of making it difficult to introduce condition monitoring machinery and connect it to a unified system for operation because factories with small-scale equipment use a mix of partially optimized systems throughout the factory.

An IoT platform has been proposed to solve this type of problem. The IoT platform is introduced to each piece of equipment and then applications such as measurement software are run on the equipment

to make it easier for data and communication to be sent between equipment as well as stored data to be managed at a central location and facilitate mutual use of such stored data.

NTN has developed a bearing diagnostic application **(Fig. 8)** that runs on Edgecross[6], which is an IoT platform. This application is provided as a condition monitoring tool that requires no internet connection or detailed settings[7]. See the commentary section for more information about this application.

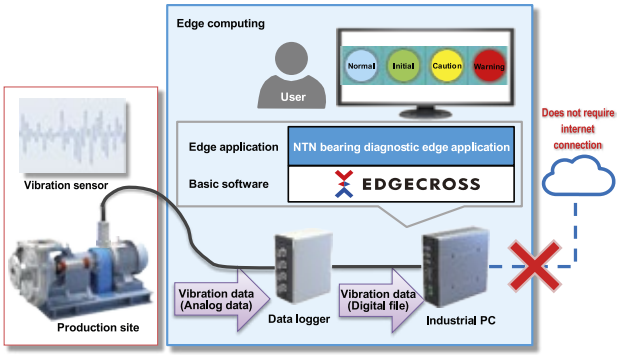

Fig. 8 Bearing diagnostic application

4.3 Portable Vibroscope

When personnel regularly take measurements at fixed points on equipment as they patrol and monitor their worksite where TBM (time-based maintenance) is performed, there is a demand for a measuring instrument that is easy to carry around and that can easily record data. The **NTN** Portable Vibroscope[8], as shown in **Fig. 9**, is a useful tool for this type of application.

Personnel can connect the device to a tablet PC or a smartphone, then measure and record vibrations at the equipment to determine the conditions based on predefined criteria or analyze condition trends. If the observed data needs to be analyzed in more detail, a frequency analysis function is used to enable such things as coupling damage and bearing damage to be diagnosed.

Fig. 9 **NTN** Portable Vibroscope

4.4 Trends in condition monitoring with large wind turbines

Large wind turbines, as shown in **Fig. 10**, are installed at a height of over 60 meters above ground level and are often operated in difficult to access locations such as along the coast and in mountainous areas. Weather conditions can also restrict work on wind turbines so it is not easy to know the equipment conditions and maintenance work cannot be conducted easily. For this reason, remote monitoring using a condition monitoring system (CMS) is necessary, and the use of this type of system has spread throughout Japan.

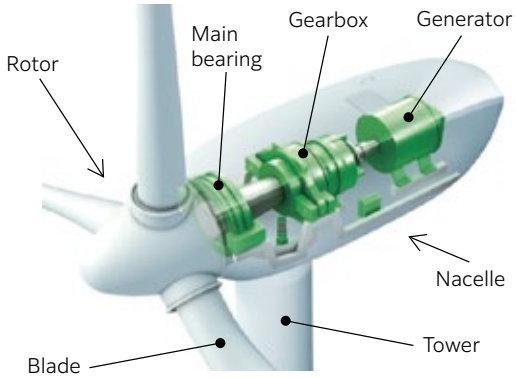

Fig. 10 Large wind turbine structure

Plans are underway in Japan to introduce large wind turbines with the aim of creating offshore wind turbine projects in the region of 10 GW by 2030 and 30 to 45 GW by 2040. One of the technical challenges in this area is reducing the cost of power generation, and targets were indicated to achieve 8 to 9 yen per kWh using seabed-mounted offshore wind turbines. To achieve this, significant importance has been placed on reducing the cost of operation and maintenance (O&M), which accounts for 36 % of the lifetime cost of wind turbines **(Fig. 11)**.

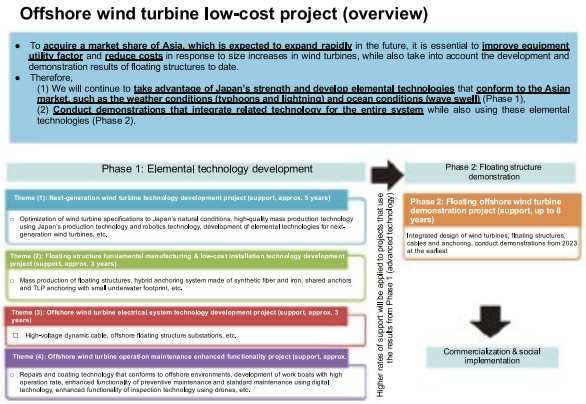

Fig. 11 Lowering the cost of offshore wind turbines (Source: Found in documentation from the Ministry of Economy, Trade and Industry[9])

4.5 Wind Doctor™, a condition monitoring system for wind turbines

NTN released Condition Monitoring System (CMS) for Wind Turbines "Wind Doctor™" for sale in 2012. Currently, this system is in operation at around 300 wind turbines throughout Japan[10) 11]. Wind Doctor™ provides a monitoring service as shown in **Fig. 12**. Sensors installed on the wind turbine are used to remotely collect and store data such as vibrations on a regular basis for monitoring purposes. If an abnormality or change is detected, the system will promptly send information to the customer.

Customers using this monitoring service can use this information for operation management and maintenance work on their wind turbines.

As discussed above, offshore wind turbines are more difficult to access than those built on land, and remote condition monitoring of key components such as bearings is particularly important for offshore wind turbines. Furthermore, it is believed necessary to evolve and support condition monitoring systems so that they can adapt to the weather conditions unique to Japan, such as typhoons and winter storms over the Sea of Japan, which are said to be the strongest in the world.

NTN has selected the two projects of "next-generation wind turbine technology development" and "offshore wind turbine operation maintenance enhanced functionality" for NEDO Green Innovation Fund Projects[12] and started activities on these projects from FY2022[13]. These projects promote technological research and development from both sides of "products" and "services" in terms of developing improvements for bearings and enhancing the functionality of CMS.

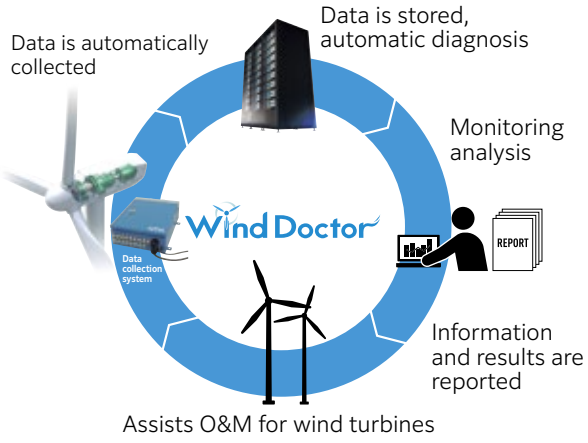

Fig. 12 Wind Doctor™ monitoring service

5. Efforts for the solution business

5.1 Using sensing data

Generally, condition monitoring systems diagnose equipment conditions using diagnosis parameters derived from such things as vibration data measured around bearings. It is possible to calculate many diagnosis parameters, but it is difficult to select parameters that are viable for diagnosis because they are different for each piece of equipment.

If diagnosis parameters have previously been selected through observation and experience, and a large volume of data has been stored that shows the relationship between the measured data and damage, then it is possible to teach an AI system to automatically select viable diagnosis parameters. Also, analyzing cases of observed damage and defects can also improve the design of machinery and equipment and their operation method. The more we can store actual data from the machine, the greater we can improve accuracy in assessing the conditions relating to the equipment.

NTN continues to build a system that stores and uses observed data from the actual machine and is working on the continuous operation of this system. At the same time, we are focusing on developing sensor devices for collecting sensing information centered on bearings, as well as providing measurement tools, which we consider to be especially important.

5.2 Solutions provided by NTN

The following types of information are required by equipment operation sites to monitor the conditions and sense around the bearing.

(1) The decision about whether operating conditions are suitable or not

(2) The estimated progress of damage if it has occurred

Technology shown below is required to provide this information and requires a great deal of time and effort such as expert level training and much experience.

- Fundamental knowledge of bearings and condition diagnosis technology
- Sensing technology and signal processing technology
- Technology to automate condition assessment, such as AI diagnosis
- Expertise in issues unique to bearings

Business operators who run equipment need condition diagnosis information for the entire machine, not just for the bearing condition. Therefore, comprehensive assessment technology that incorporates information from around the machine is required. Furthermore, depending on the unique characteristics of the operated equipment, we may also be able to consider operations that combine information from a wide range of fields. For example, we may be able to use various data such as weather data, financial data, social events, or currency exchange information and apply it to data analysis for equipment operation management through tasks such as considering procurement costs and the timing of repairs.

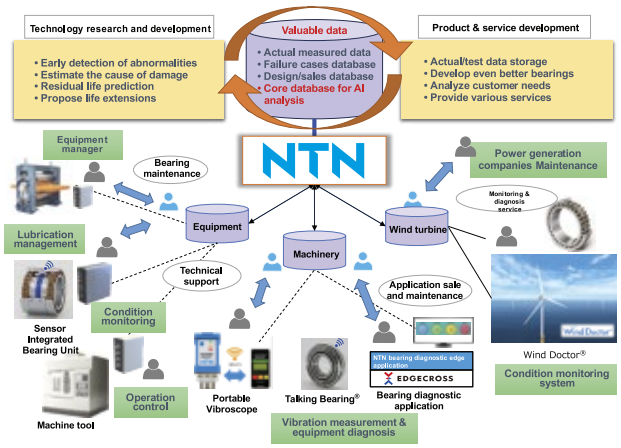

Fig. 13 Service & Solution Business in **NTN**

Many business operators feel it is important to focus on operation and management that uses collected data rather than spending the effort to build and maintain a monitoring system. As shown in **Fig. 13**, **NTN** will continue to develop services that provide solutions that can be used in business

operations, such as equipment maintenance planning, by extracting information beneficial to the customer and information required to resolve problems through activities such as monitoring the condition of bearings incorporated in equipment.

5.3 Development of wind turbine maintenance business

In addition to condition diagnosis based on CMS for wind turbines, **NTN** is working to optimize operation and maintenance and its use in operation control. In the long term, we will develop long operating life bearings by analyzing CMS data and cases of bearing damage, while promoting the provision of a total service for aftermarket bearings and inspection maintenance to reduce O&M costs for offshore wind turbines.

In the wind turbine sector, **NTN** has started an initiative[14] in the maintenance business in collaboration with Hokutaku Co., Ltd. By optimizing the operation and maintenance of wind turbines based on CMS information (smart maintenance) and collaborating on the development and procurement of bearings, and operation and maintenance services, as shown in **Fig. 14**, **NTN** will achieve bearing life cycle management and continue to contribute to society.

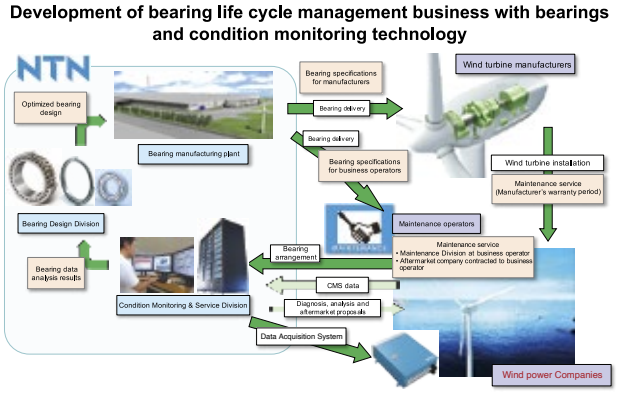

Fig. 14 Bearing life cycle management

6. Summary

NTN not only sells products but also provides services to resolve customer problems. Efforts in this area will be focused on developing software that analyzes sensor signals and software that controls machinery to create new value. Additionally, we will provide aftermarket bearings and develop improvements in new bearings based on collected information and build life cycle management for bearings centered on bearings and their monitoring information.

In the future, we will build a business model that uses this big data and promote service and solution business that will lead to improved **NTN** brand value.

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