# Development of Technologies Contributing to the Stable Operation of Steelmaking Steel Production Equipment

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*A high percentage of steel production equipment mainly consists of rotating bodies, such as rolling mills and continuous casting machines. The performance of mechanical parts that support such rotating bodies is extremely important in steel production equipment.*

*For many years, JTEKT has contributed to the stable operation of steel production equipment through the provision of bearings, oil seals, universal joints and other products. In recent years, we are making efforts not only in the area of product technology, but also development of lubrication technologies such as oil seals and lubrication equipment, optimum design of bearings by bearing diagnosis using actual equipment, and appropriate repair methods for long-term use of products. JTEKT aims not only to offer customers our products, but also to provide comprehensive technology including how to use such products. This report introduces some concrete examples of our efforts.*

***Key Words**: rolling mill, continuous casting, long life, maintenance free, technical trend*

## 1. Introduction

For many years, JTEKT has exerted efforts to offer products such as bearings, oil seals and universal joints (UJ) for steel production equipment, as well as engage in technological developments for each product. This is why we have been able to maintain a significant share of the market in the steelmaking domain. However, there are many cases where it is impossible to sufficiently address customers' various concerns through providing products alone. JTEKT aims to contribute to customers through comprehensive technological proposals suited to a product's application and usage environment.

In regards to bearings, for example, we have extended bearing life by improving lubrication through efforts such as enhancing oil seal functionality and developing an oil/air lubrication system. Moreover, in relation to steel production equipment, there is the potential for bearings to be subjected to loads unforeseen at the design stage, therefore an effective way of identifying the cause of failure is load measurement on the actual equipment. By leveraging our proprietary load measurement and analysis technologies, JTEKT has elucidated the relationship between the load status of the bearing interior and the operating conditions of the bearing in equipment to achieve optimum bearing design. Moreover, as an initiative to maximize the life of bearings, UJs, and other products, we are proposing appropriate repair methods. Against such a backdrop, this report introduces activities aimed at the stable operation of steel production equipment.

## 2. Initiatives for Longer Bearing Life

The rolling process of steel production equipment is a crucial process determining the quality of steel products, therefore high reliability is required. Bearings used in the roll necks of rolling mills, in addition to the common failure type relating to rolling fatigue life, also entail the issue of early-stage failure caused by foreign matter penetrating from outside, and rust occurring in the bearing interior due to the rolling water used in the rolling process and scale generated from the slab. **Figure 1** shows bearing failure types. JTEKT is exerting effort to elucidate the causes of failure and establish countermeasures from both material and lubrication perspectives.

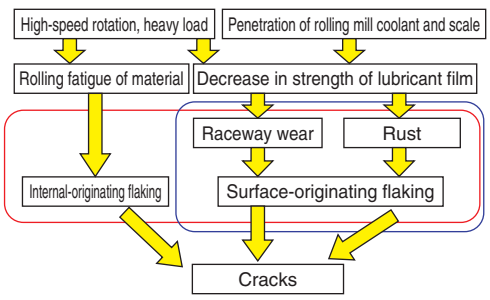



**Fig. 1** Bearing failure types

### 2. 1 Material Development

There are two types of bearings for use in the roll necks of rolling mills; the backup roll bearing and work roll bearing. JTEKT developed JHS520* a long-life high corrosion resistant bearing using high-performance material with the aim of making the abovementioned bearings more robust against failures. The roll neck bearing (**Fig. 2**) and bearing features (**Table 1**) are shown below. For details on material development, please refer to page 22 of this report.

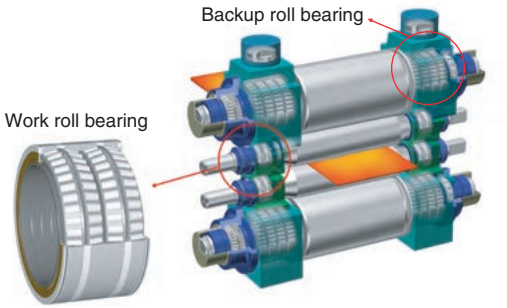



**Fig. 2** Rolling mill structure and roll neck bearing

**Table 1** Features of roll neck bearing material development

| | Features |
|---|---|
| ① | Adopts long-life, high-corrosion resistant steel with an optimized amount of Cr and Mo |
| ② | JTEKT's original carbonitriding heat treatment improving corrosion resistance and wear resistance |

Moreover, multi-roll mills are used to produce the electromagnetic steel sheets essential as material for the iron cores of hybrid car motors, and the generators and transformers used in wind power generation. The backup roll bearings used in these multi-roll mills should have durability to operate in environments with insufficient lubricant oil film formation due to heavy loads. JTEKT has developed JHS210 as a backup roll bearing for use in multi-roll mills aimed at improving robustness in such an operating environment. This bearing (**Fig. 3**) along with its features (**Table 2**) are shown below.

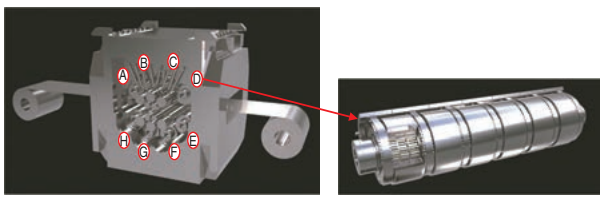



**Fig. 3** Structure of bearings for multi-roll mills backup roll

**Table 2** Features of material development for bearings for multi-roll mills backup roll

| | Features |
|---|---|
| ① | Secured shock resistance on the outer ring by forming sufficient internal-softening layer. In addition to securing rigidity on the deep surface-hardening layer, increased re-grinding allowance of the outer diameter surface. |
| ② | Adopted case hardened steel for inner ring to improve rolling life in conditions where lubricant oil film formation is insufficient. |

In addition to the above material developments, the following sections will introduce our latest initiatives for lubrication improvement by enhancing oil seal functionality and developing an oil/air lubrication system.

### 2. 2 Development of a High-sealability Oil-seal

(1)Development concept

Work roll bearings are supposed to operate in extremely harsh environments exposed to high temperatures, rolling water and scale. The four-row tapered roller bearing used as the work roll bearing should be capable of heavy-load and high-speed rotation. Moreover, the oil seals used in this bearing should have excellent sealability in harsh environments (**Fig. 4**). The development concept for this was to fully revise the cross-section profile of the lip portion and maximize the pump capacity to push back influx of water, foreign matter, etc. from lubrication retention and outside of the bearing. Moreover, lips were placed intermittently on the inter-inner ring seal, making it possible to control the negative pressure inside the bearing.

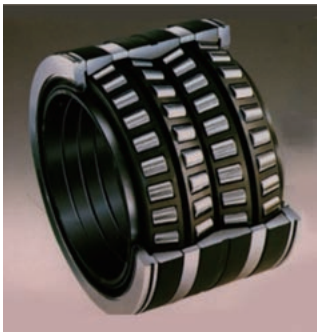


**Fig. 4** Sealed-type four-row tapered roller bearing for roll neck

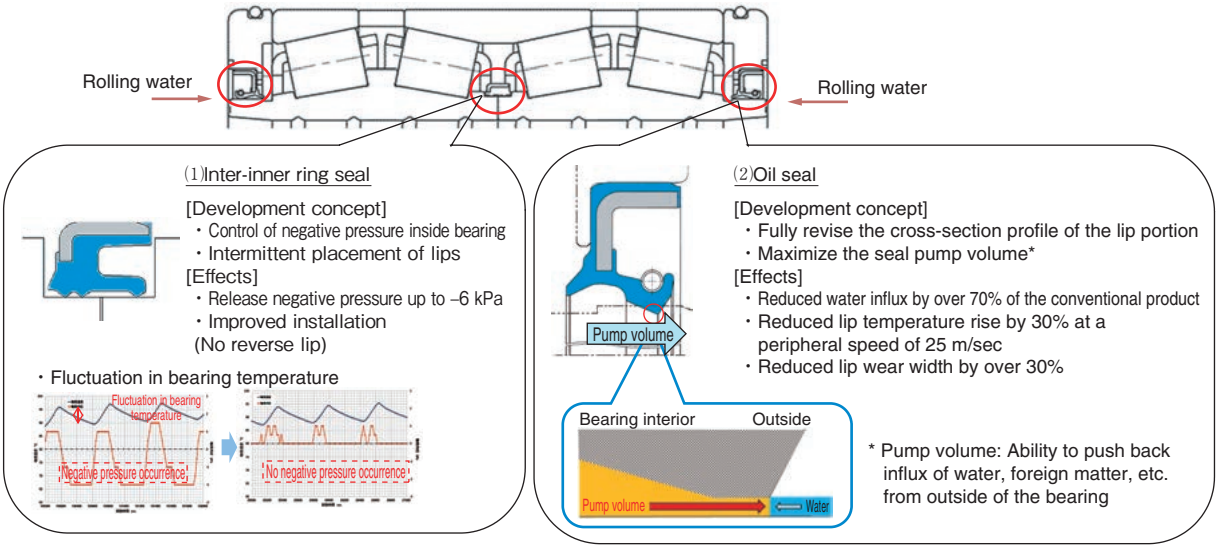



**Fig. 5** Sealed bearing for work roll neck and seal development concept and effects

(2)Features

**Figure 5** shows a sealed-type bearing for work rolls as well as the concept and effects of oil seal development.

We succeeded at developing a high-performance sealed-type bearing for work rolls by leveraging the synergistic effects of the developed oil seal and inter-inner ring seal.

①Improved robustness through enhanced sealability

Succeeded in reducing water influx into the bearing by over 70% compared to the conventional product, thus minimizing sudden bearing failure caused by deteriorated lubrication (**Fig. 6**).

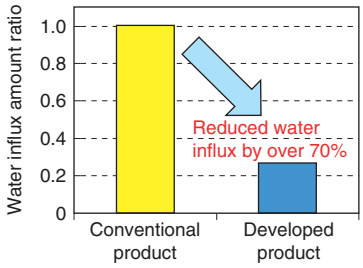



**Fig. 6** Water influx test result

②Extended the applicable scope of conventional material (NBR: nitrile rubber)

Through reducing lip temperature rise by around 30% of the conventional product, we have extended the applicable scope of NBR as material for the oil seals of rolling mill bearings within the operating temperature range of common NBR (**Fig. 7**).

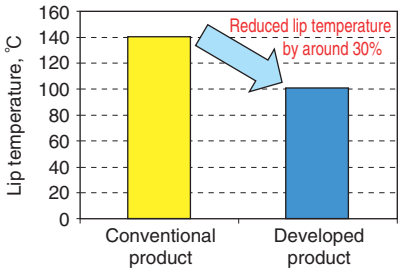



**Fig. 7** Temperature increase test result

## 2. 3 Development of the Oil/air Lubrication System

In recent years, there has been growing demands for steel production equipment to offer stable operation and environmental-friendliness. As such, there is a constant expectation to improve the lubrication of steel production equipment. One countermeasure is oil/air lubrication. JTEKT began mass production of the oil/air lubrication system in 1994 and, since then, has accumulated a strong track record of applications in bearings for various steel production equipment, such as continuous casting machines, hot and cold rolling mills. As a result, JTEKT is contributing to our customers' stable operations as a system supplier of oil/air lubrication systems, bearings, oil seals and bearing housings.

(1)Principle and features of oil/air lubrication

**Figure 8** shows the transport principle of oil/air lubrication while **Fig. 9** shows the basic layout. Oil inside the pipe is transported to the final lubrication point by the friction force of compressed air. Also, there is minimal discharge of oil mist that does not contribute to lubrication, therefore oil consumption is minimized. Moreover, because compressed air, which is the force that transports the oil, is supplied to the bearing, the interior of the bearing has positive pressure, preventing influx of

foreign matter from outside of the bearing.

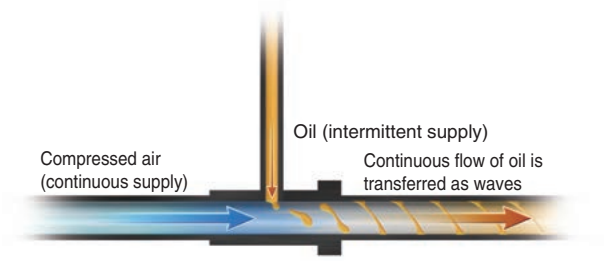



**Fig. 8** Transport principle of oil/air lubrication

JTEKT's oil/air lubrication system offers our customers the below benefits.

①Significant improvement of wear and failure in harsh environments

· High sealability through positive pressurization of the bearing housings

· High lubrication performance through the application of high-viscosity oil and extreme-pressure oil

②Improvements in equipment maintenance

· Improved operating costs through lubrication with minimal oil

· Improved environment surrounding equipment due to oil recovery

③Easy application

· Easy to design piping through adopting small-diameter pipes

· System design with a high-degree-of-freedom from minimal to numerous oil supply points

(2)Applications

The below section introduces cases where the lubrication method was changed from oil mist to oil/air for steel rolling equipment, and oil/air lubrication was used to replace grease lubrication on continuous casting machines.

■Application to steel rolling equipment

①Easy to design piping through adopting small-diameter pipes

②Reduction of running costs (one-third of oil mist lubrication)

③High lubrication performance through the application of high-viscosity oil and extreme-pressure oil

**Figure 10** shows the consumption ratio of oil mist lubrication and oil/air lubrication.

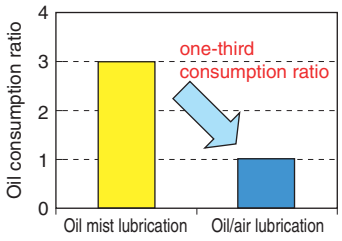



**Fig. 10** Lubricant consumption amount

■Application for continuous casting machines

①Significant reduction of wear specific to self-aligning roller bearings (one-tenth of grease lubrication)

②Reduction of bearing replacement frequency caused by wear, flaking and rust

③Reduction of sudden incidents through longer life bearings

④Reduction of man-hours required for bearing washing during maintenance work

**Figure 11** shows the race wear ratios of grease lubrication and oil/air lubrication.

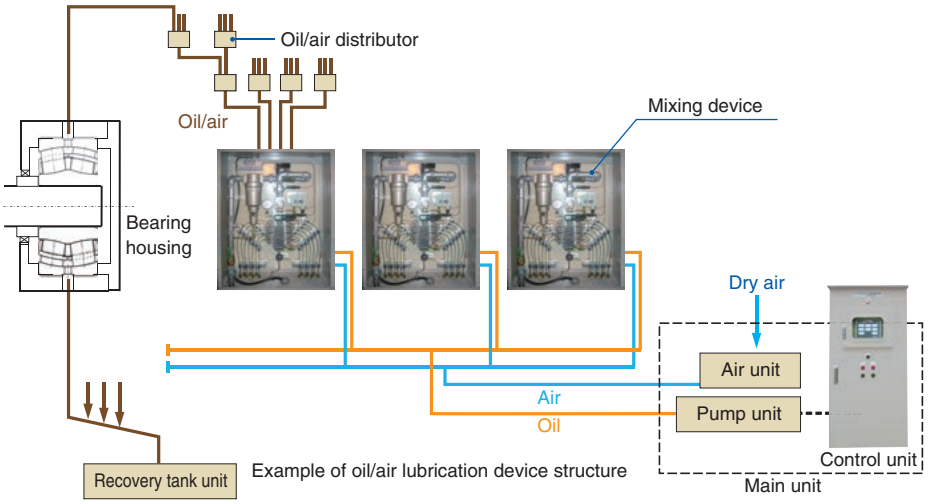



**Fig. 9** Basic layout for oil/air lubrication

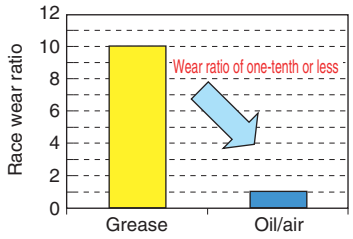



**Fig. 11** Comparison of bearing wear amounts

(3)Development of a multi-point oil supply distributor

Furthermore, amongst the various types of steel production equipment, equipment with a high number of oil supply points such as continuous casting machines entails issues such as the number of pipes and securing space for various devices. In order to solve this issue, JTEKT has developed a block-type distributor able to distribute oil/air to multiple points (**Fig. 12**), thus simplifying equipment. The developed product has no moving parts, therefore can distribute oil in an oil/air state in many directions, enabling installation in environments subjected to heat and water.

**Fig. 12** Block-type oil/air distributor

Furthermore, we also support constant management systems in regards to oil/air lubrication through the use of a monitoring panel which enables the visualization of operational status. JTEKT is further advancing the oil/air lubrication as a means of lubricating the bearings used in steel production equipment with the aim of offering engineering solutions including peripheral devices such as bearings, oil seals and bearing housings.

## 3. Initiatives for Longer Life Bearings through Bearing Diagnosis

In steel mill equipment, bearings can be subjected to load unforeseen at the design stage. Some feasible causes of load are factors relating to operational status and factors relating to equipment aging, however measuring load on the actual equipment is effective in identifying the true cause of load. JTEKT wishes to leverage its independent load measurement and analysis technologies to ascertain the relationship between the load status of the bearing interior and operating conditions, then propose optimum bearing design to our customers.

### 3. 1 Introduction of an Actual Size Testing Machine

Previously, it was extremely difficult to reproduce the severe conditions of actual equipment in a bench testing machine. As such, it was difficult to evaluate large bearings at actual size therefore the common practice was to make evaluations using scaled-down bearings. In recent years, there have been growing requests to evaluate the various actual size bearings, therefore, JTEKT introduced the bearing testing machine for steelmaking equipment as shown in **Fig. 13**. This testing machine is capable of reproducing the various environmental conditions of an actual machine, such as rolling water scatter, high temperature, high speed and high load.

This testing machine can accommodate an actual size bearing used on a rolling mill, the main piece of equipment used in steel mill, making it the world's first testing machine to enable evaluation under actual equipment operating conditions. This section introduces cases of using this testing machine to measure load applied to actual size bearings.

**Fig. 13** Bearing test rig for steelmaking equipment

### 3. 2 Measurement of Rolling Element Load for a Radial Bearing

Generally, four-row tapered roller bearings are used as radial bearings for work rolls. Focusing on the fact that this bearing uses a hollow rolling element, we attached a strain gauge to the inner face of this hollow rolling element and measured the load that occurred. However, initial calibration between rolling element load and strain value was performed on a single row tapered roller bearing under axial load condition.

**Figure 14** gives an overview of the method used to measure rolling element load. The output of the strain gauge attached to the interior of the hollow rolling element is recorded in an ultra-small data logger integrated with the rolling element through a fixture, then, after measurement, data is removed with the bearing

in a static state, and analyzed. Examination of load is performed by applying only pure axial load in a vertical test rig and correlating the rolling element load and strain.

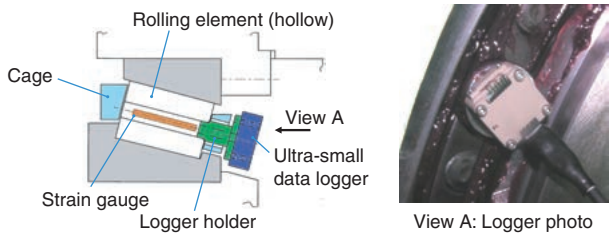



**Fig. 14** Summary of measurement method of rolling element load

Regarding rolling element load, **Fig. 15** shows a comparison of results measured on the testing machine and results calculated from FEM analysis. We confirmed that rolling element load distribution is bimodal due to the effect of housing rigidity and that the measured load distribution and load distribution value obtained through FEM analysis has good consistency. JTEKT utilizes this method to measure the radial load of work roll bearings on actual equipment.

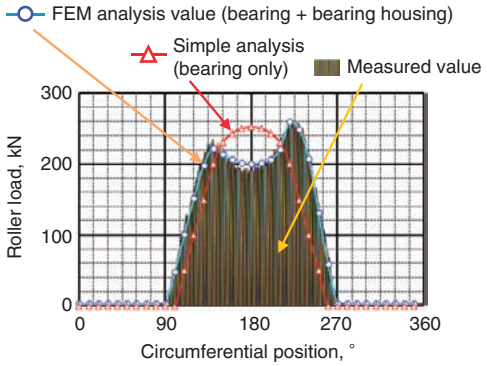



**Fig. 15** Comparison between measured and analysis value of rolling element load

### 3. 3 Measurement of Axial Load for a Thrust Bearing

Thrust bearings have a large contact angle which makes mounting of the abovementioned small logger difficult. As such, we machined a notched groove on the outer ring, which is the fixed ring, mounted a strain gauge to this groove, then performed measurement by detecting the strain on the fixed ring when the rolling element passed the notched groove on the outer ring.

**Figure 16** shows the method used to measure axial load. Examination of load is performed in the same way as with the abovementioned radial bearing, by applying only pure axial load in a vertical test rig and preparing a relationship diagram for the rolling element load and strain in advance.

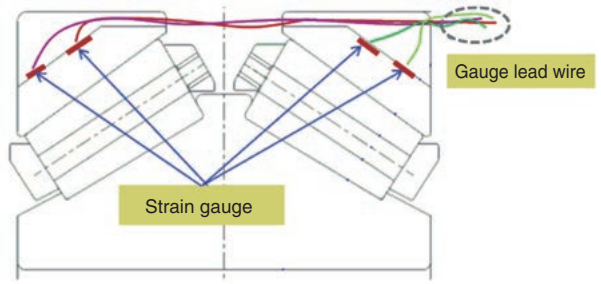



**Fig. 16** Measurement method of axial load

**Figure 17** shows the measured waveform for fixed ring strain. From the measurement result, we were able to measure the axial load from the P-P waveform of the rolling element passing frequency of each row. This result was consistent with the result of the testing machine input load, thus we were able to confirm the reliability of the measurement method, and that actual equipment measurement is an extremely effective measurement method.

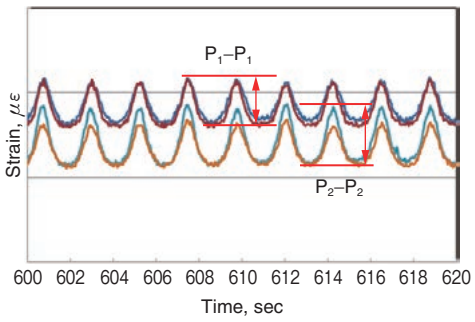



**Fig. 17** Measurement results of strain amount

This time, in a testing machine for steel mill equipment, we were able to confirm the effectiveness of the radial and axial load measurement method used on actual size bearings. In addition to these measurement technologies, by combining temperature and vibration measurement, we can achieve visualization of the bearing operating status under actual equipment conditions.

Leveraging our proven track record of performing multiple measurements using this technology, JTEKT wishes to continue load measurement on our customers' actual equipment and offer a technical service to solve customer concerns. Moreover, in addition to achieving optimum design of bearings for steel production equipment based on the data obtained here, we would also like to offer a service for monitoring the operational status of steel mill equipment.

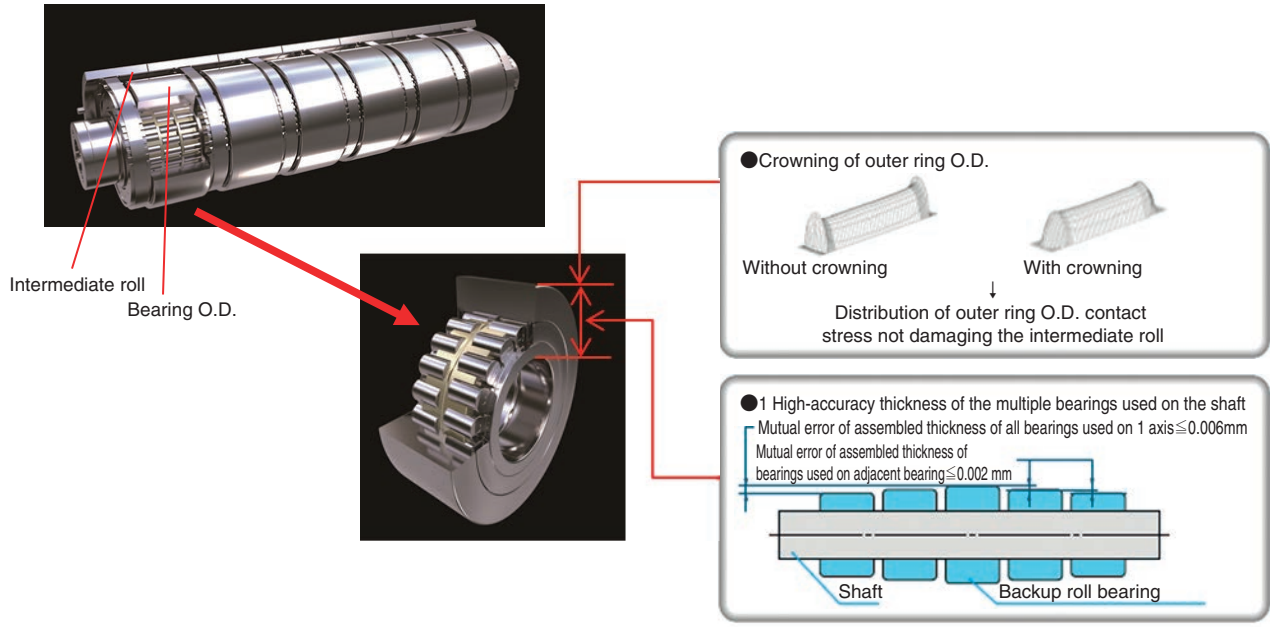



**Fig. 18** The backup rolls bearings of multi-roll mills

## 4. Initiatives for Long-term Stable Use through Appropriate Repairs

For many years, JTEKT has been offering customers bearings and UJs for steel production equipment. Amidst this, as initiatives to use our products for even longer, we offer proposals for the establishment of a maintenance support system for rolling mill bearings and repair method for the UJ main unit. The details of these initiatives are introduced in the following sections.

### 4. 1 Establishment of a Maintenance Support System for Multistage-type Rolling Mill Bearings

(1)Required bearing performance

As seen in **Fig. 18**, several of the backup roll bearings used in multi-roll mills are mounted on one shaft, the bearing outer diameter makes direct contact with the intermediate roll, and the outer ring rotates while being subjected to rolling force load. As such, the outer ring should have sufficient rigidity and be strong against rolling fatigue, in addition to offering a high-accuracy finish.

This bearing is required to exhibit the below performances.

①Crowning of outer ring outer diameter

Crowning considering contact stress distribution is performed on the outer diameter of the bearing outer ring in order to prevent damage to the intermediate roll caused by concentrated load on the edges (**Fig. 18**).

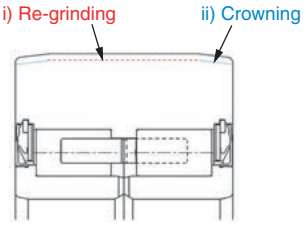



**Fig. 19** Re-grinding support

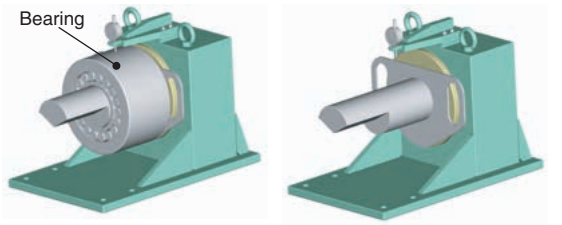



**Fig. 20** Device for measuring thickness


**Fig. 21** Polishing jig

②High-accuracy thickness and rotational accuracy of the numerous bearings used on one shaft

In regards to the high-accuracy thickness and rotational accuracy of bearings, optimum contact stress distribution is achieved in order to prevent damage to the intermediate roll (**Fig. 18**).

(2)Establishment of a maintenance support system

When our customers re-grind the outer diameter of the bearing outer ring as part of maintenance work, JTEKT first measures the half-value width using X-ray diffraction then proposes optimum grinding amount (**Fig. 19**). We also provide maintenance tools for our customers to use (**Fig. 20**). This contributes to stable operation and reduced maintenance man-hours of our customers.

Moreover, we have established a system whereby JTEKT collects the bearings with outer diameters re-grinded by customers, confirms quality, then re-delivers (**Fig. 21**).

### 4. 2 Initiatives for Rolling Mill Universal Joints

The universal joints (UJ) that drive rolling mill rolls have an extremely high torque load and are limited in size due to equipment space limitations. As such UJs are often used in operating regions with high loads relative to their load capacity. JTEKT has proactively engaged in efforts to increase UJ capacity, and by implementing the countermeasure shown in **Fig. 22**, achieved the major accomplishment of improving fatigue limit torque. Moreover, regarding response to excessive torque, we developed the Hyper Coupling as a product that instantly releases the torque transfer working on UJs and are building up our track record with this (**Fig. 23**). The preceding sections of this paper have introduced initiatives to improve UJ strength and life, however maintenance for environmental and aging-related changes is also an important issue.

In the past, we performed inspections and repairs upon receiving requests from customers, however we believe we can contribute to stable operations by establishing regular maintenance through sharing of customer maintenance plans and UJ repair history. As such, JTEKT engages in the following activities.

(1)Strengthening of UJ inspection/repairs acceptance system

**Figure 24** shows the UJ repair system chart. It proposes strengthening of inspection/repair acceptance and an efficiency maintenance cycle.

(2)Formation of a repair performance database

JTEKT has conducted a high number of repairs so we are able to utilize such performance data to propose a suitable time for consumable part replacement, and maintenance work content. We will propose maintenance management by individual parts based on a database of repairs performed at our customer's site.

(3)Development of a history management method

To date, the following issues have prevailed.

①It was difficult to confirm product history after actual equipment usage.

Conventionally, product history was confirmed by scanning the product number or serial number stamped into the product surface however scanning was difficult due to the build-up of dust after usage and dust removal required a high number of man-hours.

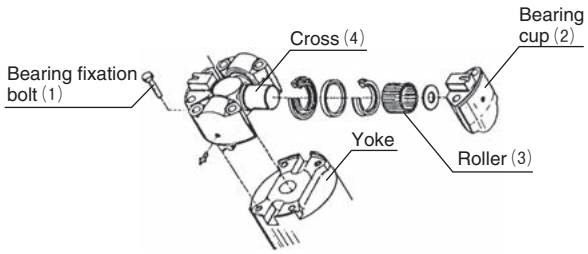
②Repair history management was not being achieved.

The history of products themselves, such as periodic repairs, etc. was not being maintained.

To solve these issues, we introduced a product history management system adopting RFID tag* and this is introduced in **Fig. 25**.

This system enables product history to be confirmed easily and swiftly. Moreover, it is easy to register repair history and usage history, therefore history management is also easy, which can help predict product life and replacement timing.

*RFID tag: A system for the non-contact reading and writing of data saved on an RF tag using electromagnetic waves.




| | Bolt strength improvement | Flaking life improvement | Description |
|---|---|---|---|
| (1) | ○ | – | Rolling of the fixation bolt thread |
| (2) | ○ | ○ | Spraying of the bearing cup key |
| (3) | – | ○ | Adoption of bearing portion with varying-diameter rollers |
| (4) | – | ○ | Varnishing of the cross race |

**Fig. 22** Proposal for improving fatigue strength

**Fig. 23** Device for releasing excess load: Hyper Coupling

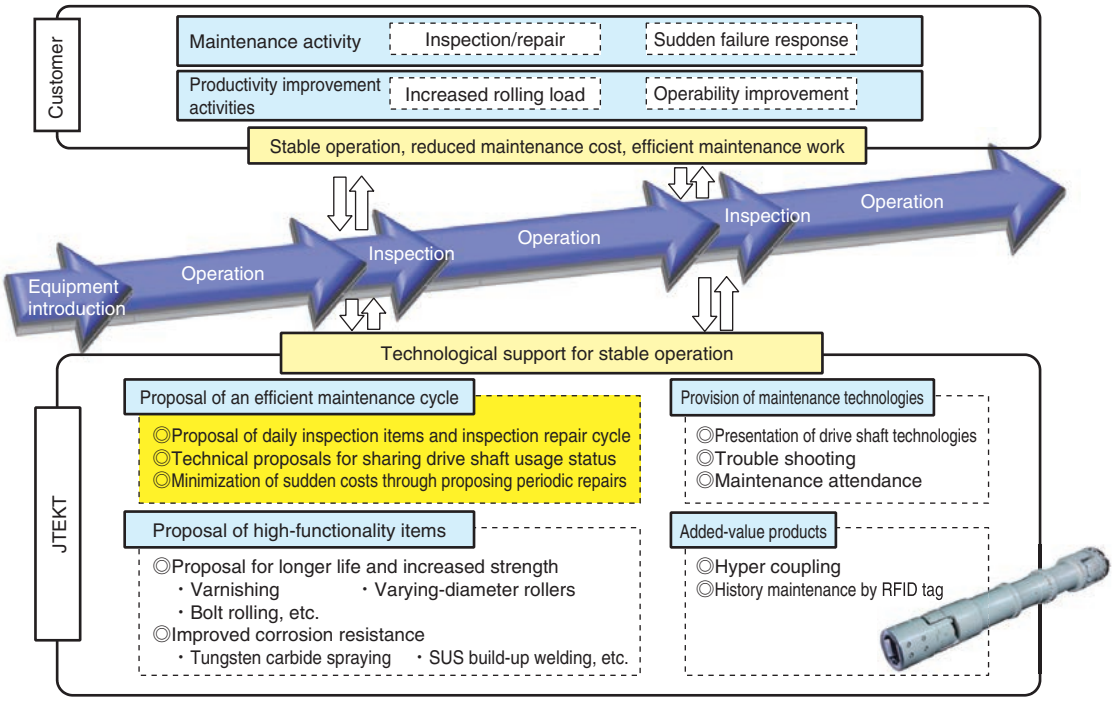



**Fig. 24** UJ repair system chart

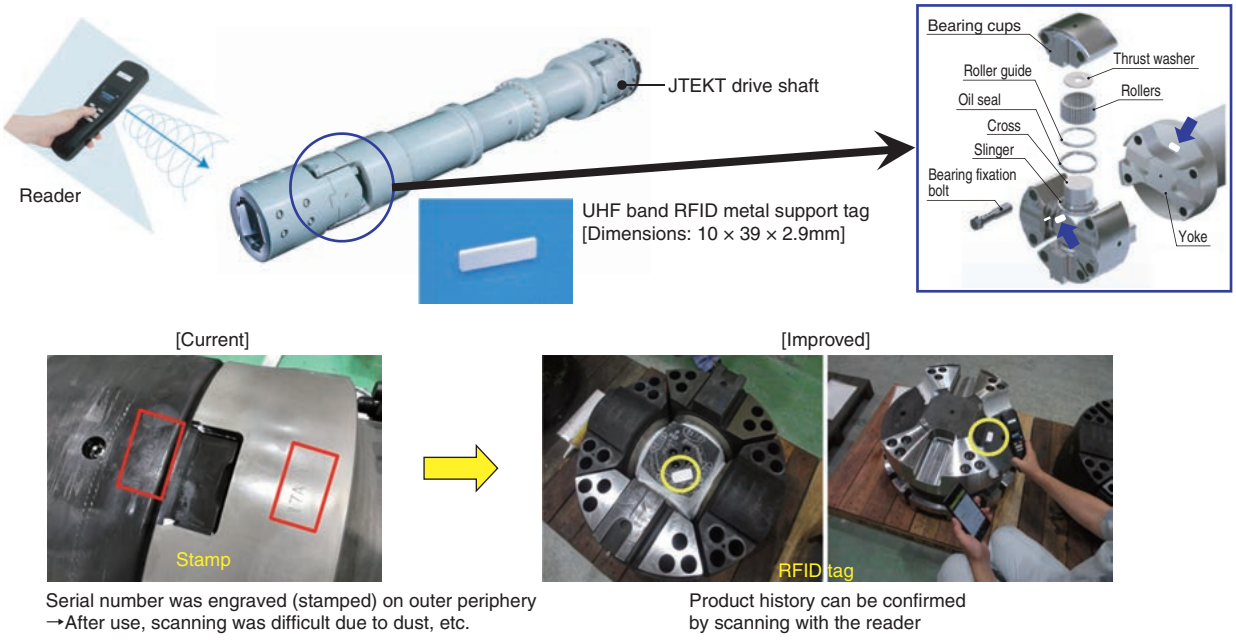



**Fig. 25** Product history management system

## 5. Conclusion

JTEKT has contributed to the stable operations of steel production equipment for many years by providing products such as bearings, oil seals and universal joints. Moreover, as indicated in this report, in recent years there has been a focus not only on product technology, but also the shift from “mono” to “koto”, with some examples being ①development of lubrication technologies such as lubrication devices ②optimized bearing design through bearing diagnosis using actual equipment, and ③ appropriate repair methods to ensure long-term product use. JTEKT wishes to continue exerting efforts towards the development and provision of new products to suit market trends aimed at the stable operations of steel production equipment, and the relevant services thereof.

*1 JHS is a registered trademark of JTEKT Corporation.

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