Technical Trends and Vision for Industrial Bearings and Units — Activities Relating to the Shift from "Mono" to "Koto" —

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In the industrial field, there is a need to tailor product development and activities to each specific industry due to the differences in usage environment, usage conditions and required functions. Furthermore, recently the demand for not only "mono" (product value), but also "koto" (the value obtained by using a product - i.e. "added value") has intensified.

This report introduces the future trend of development for steel production equipment, agricultural and construction machinery, machine tool spindles and printing machinery, as well as our activities relating to mono and koto.

***Key Words**: industrial bearing, bearing technology, mono, koto, universal joint, traction drive*

1. Introduction

In recent years, activities to migrate from "*mono*" to "*koto*" are accelerating. We have entered an age where we cannot earn our customers' satisfaction by simply providing products ("mono"), and rather than the functional value of "*mono*", we must instead offer "*koto*" - value obtainable through using a product. In the past, it sufficed if bearings could rotate for a long period of time without breaking, however it has become difficult to offer customers originality with that alone, and the commoditization of "*mono*" is progressing. Originality in "*koto*" aspects will become of increasing importantance moving forward. In addition, the rapid progress of IoT is accelerating the speed of "*koto*" development. JTEKT is pushing ahead with "*koto*" aspects of failure detection through the visualization of bearing condition, and optimizing machining conditions through visualization of machining status.

Furthermore, in regards to steel production equipment, large agricultural/construction vehicles, etc., a reduction of life cycle cost* (LCC) has become a key activities to improving business profitability, and efforts toward both "*mono*" and "*koto*" aspects are necessary.

This report introduces the technical trends of "*mono*" and "*koto*" regarding the rolling bearings which are major mechanical elements supporting the rotating axes of steel production equipment, agricultural and construction machinery, machine tool spindles and industrial fields of printing machinery, and also regarding the traction drive units which are no-backlash reduction gears. This report also introduces examples of JTEKT's relevant activities.

* The total required running costs throughout all the processes after purchase of a vehicle; namely maintenance, management and disposal.

2. Trends of Industrial Bearings & Units

The operating environments, operating conditions and required functions of bearings and units differ depending on the industrial type, therefore product development and activities must be tailored to the respective domain. **Table 1** shows the requirements relating to "mono" and "*koto*" by industry type. First, in order to respond to "*mono*" requirements, there is a need for technological developments in the areas of design, material, heat treatment, surface treatment, lubrication, machining, etc.[1] In addition, to respond to "*koto*" requirements, the visualization of bearing condition, in other words sensing technology, will become important. JTEKT is pushing ahead with the failure detection/prediction through visualization of bearing condition (sensing)[2]. Moreover, bearings are subjected to all external loads, therefore are the most affected when abnormal load occurs. By sensing bearing load condition, we believe it is possible to detect abnormal operation and abnormal work. In other words, we believe it is possible to perform equipment diagnosis through the visualization of bearing condition. **Figure 1** shows a conceptual image of this. Achieving this would require further improvements in experimental technology, analysis technology and sensing technology.

Below is an introduction of our activities for each application, as well as the development trends for future industrial bearing products, as per **Fig. 2**. **Figure 2** shows

that not only "*mono*" such as long life, high robustness, high-speed, low-temperature-rise, sensing and so on but also the development of "*koto*" is important.

Table 1 Requirements relating to product function (mono) and added value (koto) by industry type

Industry type	"Mono" (product value)	"Koto" (value obtained by using a product)
Steel production equipment	Durability in harsh environments such as high temperature, water and scale	Failure detection/prediction
Agricultural/ construction machinery	Robustness in all work environments	Failure detection/prediction Design considering repairs (LCC reduction)
Machine tools	Supports ultra-high-speed, high-rigidity	High-accuracy, high-efficiency machining
Printing machinery	Reduced rotational unevenness of rotating drum, quietness	New development area

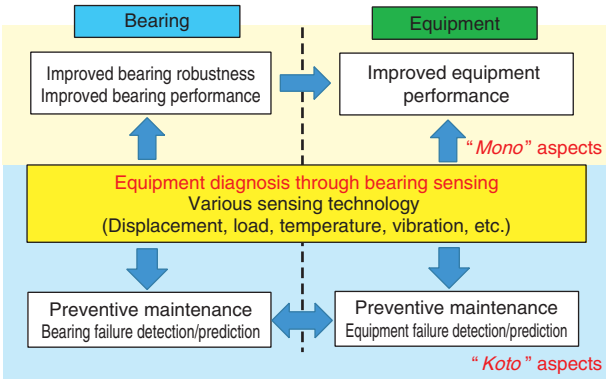

Fig. 1 Conceptual image for control of equipment with bearing sensing

3. Development of Contributing Technologies to the Stabilization of Steel Production Equipment Operation

Steel production equipment must operate in extremely harsh environments exposed to high temperature, water and scale. The bearings used in steel production equipment must also be capable of supporting heavy loads and high-speed rotation, and not only support by the bearing itself, but also support through integration with peripheral parts. **Figure 3** shows the various bearing failure types. **Figures 4** and **5** show examples of the JTEKT HYPER STRONG (JHS) as bearings supporting operation in harsh environments.

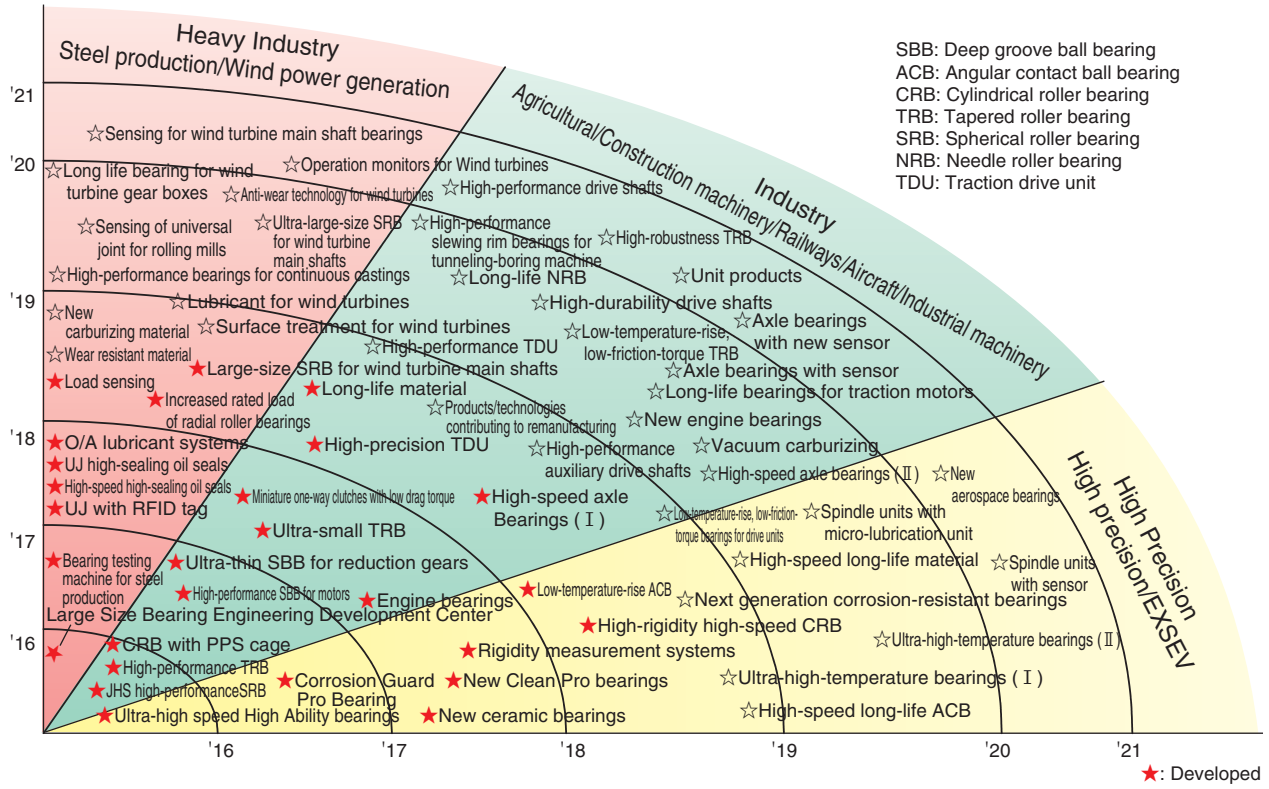

Fig. 2 Trends of industrial bearing development

Figure 4 shows a sealed-type, four-row tapered roller roll neck bearing for rolling mill (JHS520). This bearing has excellent sealing performance, speed and load resistance. **Figure 5** shows a back-up roll bearing for multi-roll mill (JHS210). This bearing has excellent load resistance and robustness even when operating in diluted lubricant[3)-5)].

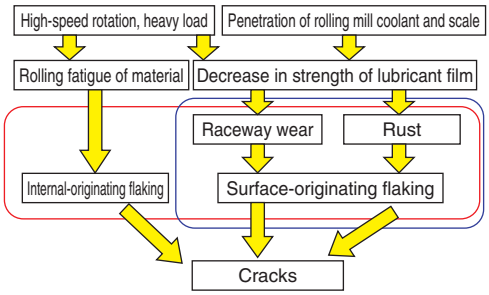

Fig. 3 Bearing failure types[3)-5)]

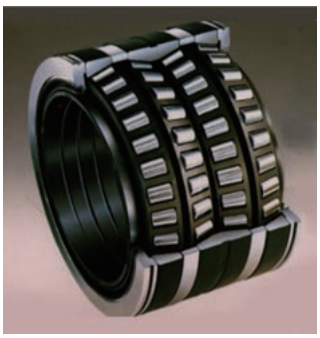

Fig. 4 Sealed-type four-row tapered roller bearing for roll neck (JHS520)

Fig. 5 Bearing for multi-roll mill backup roll (JHS210)

Sometimes steel production equipment can be subjected to loads exceeding design specifications, and this leads to bearing failure. A variety of factors could cause this, including operating conditions, maintenance or equipment deterioration. As "*koto*" activities, JTEKT would like to propose optimal design to our customers through leveraging proprietorial load measurement and analysis technologies to measure and analyze the relationship of the bearing use conditions with the internal load status and performing equipment diagnosis based on actual measurements.

Table 2 shows the load measurement method for rolling elements of radial bearings and thrust bearings for work roll.

Figure 6 shows a bearing test rig for steelmaking equipment, **Fig. 7** shows a summary of the measurement method for rolling element load, and **Fig. 8** shows a comparison of measured values for rolling element load and FEM analysis values. The measurement results confirm that the rolling element load distribution has two peaks due to the impact of housing rigidity, moreover it is clear that there is good consistency with the FEM analysis values. Using this method, JTEKT performs measurement of radial load for roll neck bearings.

Table 2 Measurement method for rolling element load

	Radial bearings for work rolls	Thrust bearings for work rolls
Measurement item	Rolling element load	←
Required item	Radial load (conversion from rolling element load)	Thrust load (conversion from rolling element load)
Gauge mounting position	Hollow interior diameter of roller	Notch part of Outer ring
Measurement method	Accumulate strain gauge output in ultra-small data logger → Take out it upon stopping	Take out strain gauge output by wire

Fig. 6 Bearing test rig for steelmaking equipment[6)]

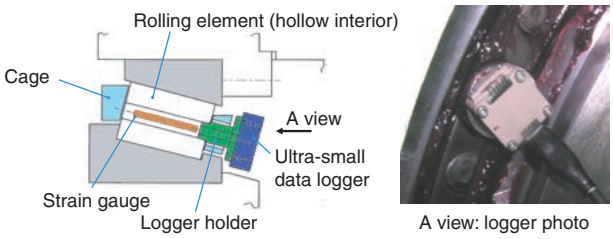

Fig. 7 Summary of measurement method of rolling element load

Moreover, in regards to universal joints for rolling mill roll drive (UJ, **Fig. 9**), JTEKT proposes a repair for UJ and a method for history maintenance by RFID tag[*2] to customers in order to reduce LCC. **Figure 10** shows a UJ repair system chart.

We wish to contribute to the stable operation of steel production equipment through these "*mono*" and "*koto*" activities.

*2 A system for the non-contact reading/writing of data recorded within RF tags using electromagnetic waves

4. Contributing Technologies to Reduce the LCC of Agricultural/Construction Machinery

LCC is an important indicator for a user when purchasing agricultural/construction machinery (vehicles). For this reason, vehicle manufacturers are exerting efforts in development, proposals and services to reduce LCC. JTEKT is developing technologies and services that can contribute to reduce LCC by focusing on six keywords and experimental analysis technology.

Figure 11 shows the needs of agricultural/construction vehicles and JTEKT's development keywords.

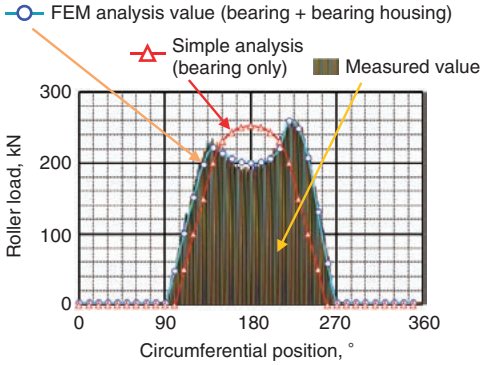

Fig. 8 Comparison between measured and analysis value of rolling element load

Fig. 9 Universal joint for rolling mills

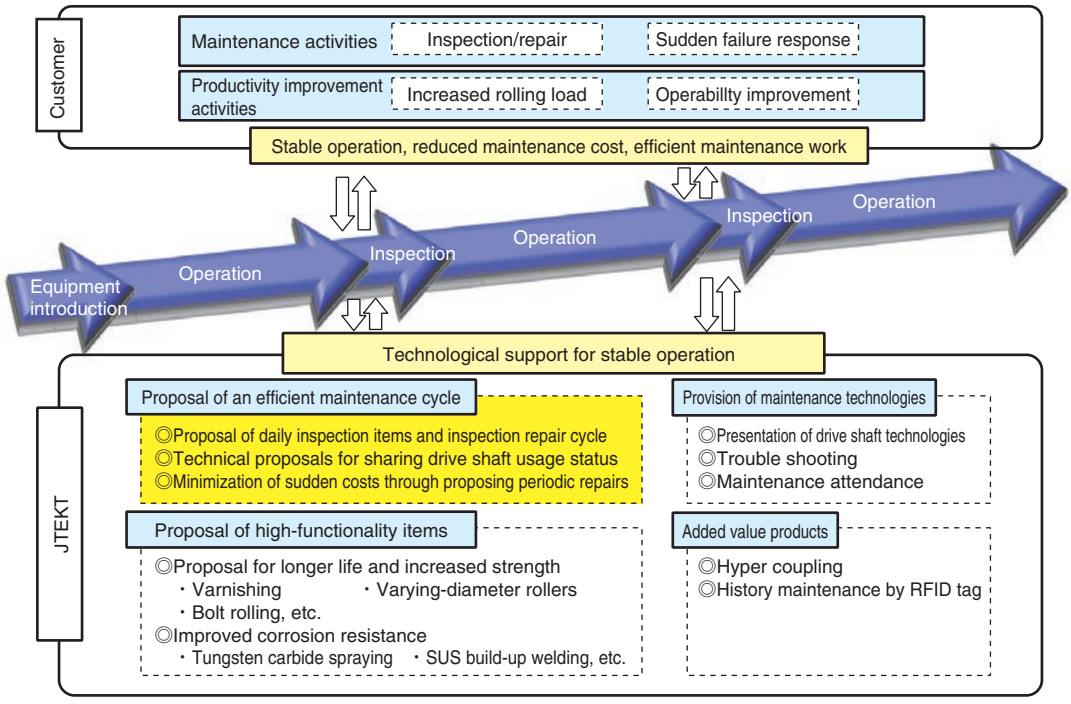

Fig. 10 UJ repair system chart

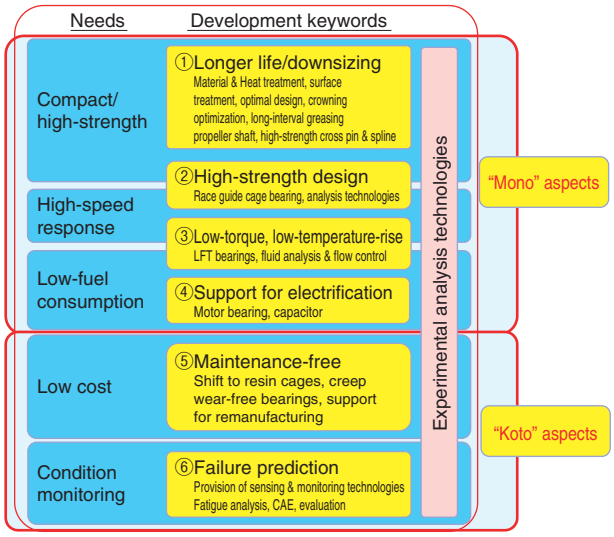

Fig. 11 Agricultural and construction machinery need and JTEKT's development keywords

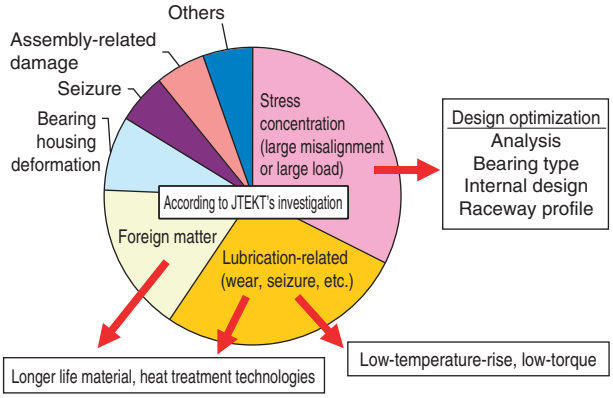

Fig. 12 Failure mode analysis (as investigated by JTEKT) of agricultural and construction machinery bearings and bearing support technology

Moreover, **Fig. 12** shows the failure modes of bearings used in agricultural and construction machinery (according to analyses of bearings returned to JTEKT) as well as supporting technologies. 75% of all failures are caused by either edge stress due to large misalignment or large load, or inappropriate lubrication. An important part of helping to solve these issues are "mono" activities of developing products focused on ①longer life/downsizing, ②high-strength design, ③low-torque, low-temperature-rise, etc. as well as optimization of internal specifications through analysis considering operating conditions and the rigidity of peripheral parts. These activities directly contribute to better vehicle performance, higher robustness and higher fuel efficiency. Moreover, ④ technologies supporting electrification are also of importance in regards to EV shift of vehicle.

"*Koto*" aspects of ⑤maintenance-free technologies and ⑥failure prediction technologies do not directly contribute to improved vehicle performance, etc. however are believed to significantly contribute to reducing the number of man-hours involved in disassembly work and part repair costs through technologies preventing damage (wear) to the shaft and housing, which are bearing peripheral parts, as well as through development of easy-to-disassemble bearings. In regards to ⑥ failure prediction technologies, **Fig. 13** shows JTEKT's conceptual image for vehicle condition monitoring. By combining the sensing technologies currently used on vehicles with JTEKT's bearing sensing technologies, customers can not only appropriately appraise the timing of vehicle overhauls and improve operating rate, but also reduce maintenance costs through failure prediction. This makes it possible to reduce LCC. Moreover, with optimized bearing design through grasping the status on actual equipment, it is also possible to shorten the overall vehicle development period, etc.

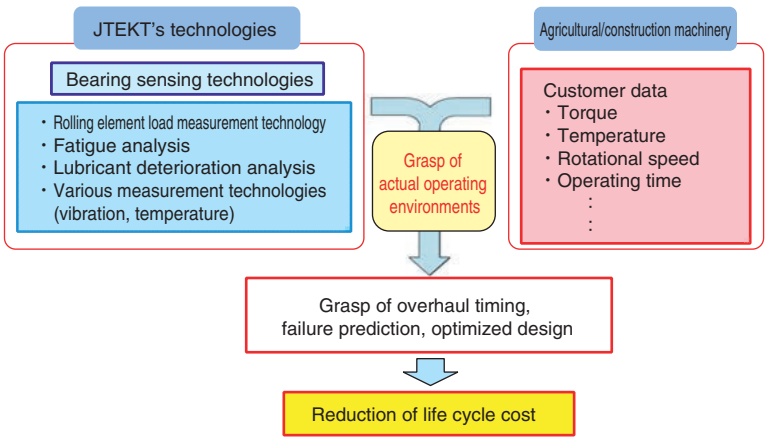

Fig. 13 Conceptual image for vehicle status monitoring

JTEKT wishes to contribute to reducing vehicle LCC through these "*mono*" and "*koto*" activities.

5. Activities for High-Performance Bearings for Machine Tool Spindles

Each year, the demands placed on machine tools are becoming increasingly stringent, and consumers are seeking even higher speed, higher rigidity and lower temperature rise. In recent years, there has been a growing need for combined processing machines from the perspective of high-efficiency machining, therefore the market demands that equipment offers both high-speed and high-rigidity. Moreover, out of the two lubrication methods, grease and oil-air, the latter is adopted in high-speed regions, however from the perspective of protecting the environment against the negative impact of oil scattering, there is a growing need to expand the application of grease lubricant[7), 8)].

The performance of spindle bearings used in the spindle unit plays an extremely important role in high-speed performance. At JTEKT, we have achieved even greater high-speed in our cylindrical roller bearing with high rigidity, low temperature rise and grease lubrication are used in lathes, which require high-rigidity (**Fig. 14**) as well as our angular ball bearing with low temperature rise and grease lubrication (**Fig. 15**). We are also expanding the application of grease lubricant, and these efforts are contributing to produce more eco-friendly machine tools.

Moreover, even in regards to machine tools, JTEKT exerts efforts for the visualization of machining conditions, which is "*koto*" aspects, in order to contribute to high-accuracy and high-efficiency machining. The rigidity of the spindle unit, which greatly affects workpiece machining accuracy, is affected itself by bearing precompression, rotational speed, temperature rise, spindle posture, etc., therefore, conventionally, dynamic measurement was difficult. Here, we'd like to introduce JTEKT's recent activities; the development of a dynamic rigidity measurement system.

Figure 16 shows a schematic of a dynamic rigidity measurement system. This system uses a vibrator adopting magnetic bearing[9)] technology to vibrate the arbor mounted on the spindle at different frequencies to detect the displacement at that time using a sensor. **Figure 17** shows an example of dynamic rigidity measurement with a rotational speed of 5 000 min^{-1}, and when the spindle is vibrated in a radial direction. The horizontal axis of the graph shows input frequency, while the vertical axis shows dimensionless quantity responding to rigidity, and was able to confirm that rigidity decreases when frequency is around 900 Hz. JTEKT aims to use these results to both enable optimization of machining conditions and bearing specifications and achieve development of status monitoring technology for the spindle unit in the future.

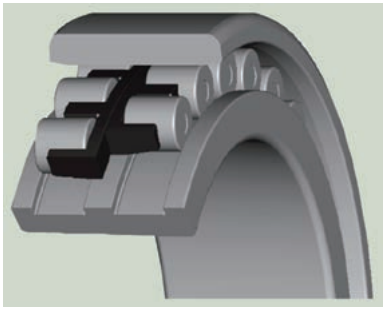

Fig. 14 Cylindrical roller bearing with high rigidity, low temperature rise and grease lubrication

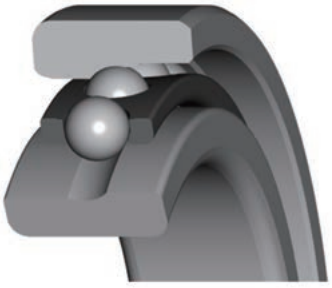

Fig. 15 Angular ball bearing with low temperature rise and grease lubrication

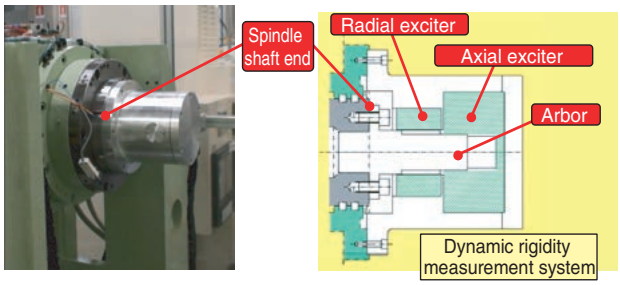

Fig. 16 Schematic of a dynamic rigidity measurement system

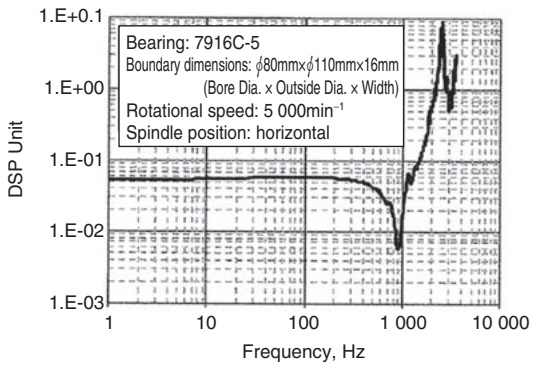

Fig. 17 Outline of dynamic rigidity measurement system

6. Higher Performance Traction Drive Units for Printing Machinery

The traction drive unit is a power transmission device using the rolling contact of rotating bodies, and has been used for some time as a smooth, play-free gearbox. In terms of smooth power transmission, there are no mechanisms that surpass the quality traction drive offers, and it is still used for printing machinery, however now there are demands for further reduction of rotation speed unevenness and longer life. **Figure 18** shows the planetary roller-type traction drive unit used in printing machinery. This drive unit is comprised of a high-accuracy, high-strength roller and was developed by JTEKT utilizing our bearing core technology accumulated over many long years[10), 11)]. Its features are extremely minimal rotational speed unevenness, no backlash, and excellent quietness due to no vibration or noise caused by gear meshing. **Figure 19** shows noise comparison results of a planetary gear versus a traction drive unit.

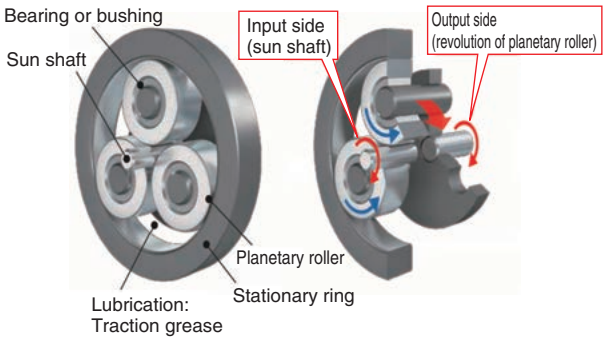

Fig. 18 Structure of a planetary-type traction drive unit

As the measurement method, we used the same stepping motor and measured noise pressure while continuously increasing rotational speed, then performed frequency analysis. The result of this measurement showed that, while rotational noise still existed in the drive motor of the traction drive unit, the noise that had occurred on the planetary gear in a high number of degrees had disappeared. Conventionally, traction drive units were primarily only used in applications which benefits from its feature of having extremely minimal rotational speed unevenness, however in recent years, traction drive units are being used for new applications focused on quietness, for example, there are an increasing number of cases where their application is being considered in devices for investigating natural environments and animal ecology. Through application in these new fields, JTEKT wishes to work on the development of new "*koto*" aspects.

7. Conclusion

Apart from the content introduced this time, JTEKT will promote product development responding to customers' needs and problems for a broad range of industries, including power generation equipment, rolling stock, transportation machinery and tunneling-boring machine, as well as further strengthen "*koto*" activities. So that our customers will ultimately think "I'm so glad because I chose JTEKT", we will continue offering No.1 & Only One products and technologies, and contributing to the stable operation of equipment and vehicles as well as LCC reduction.

*1 JHS (JTEKT HYPER STRONG) is a registered trademark of JTEKT Corporation.
*2 LFT is a registered trademark of JTEKT Corporation.

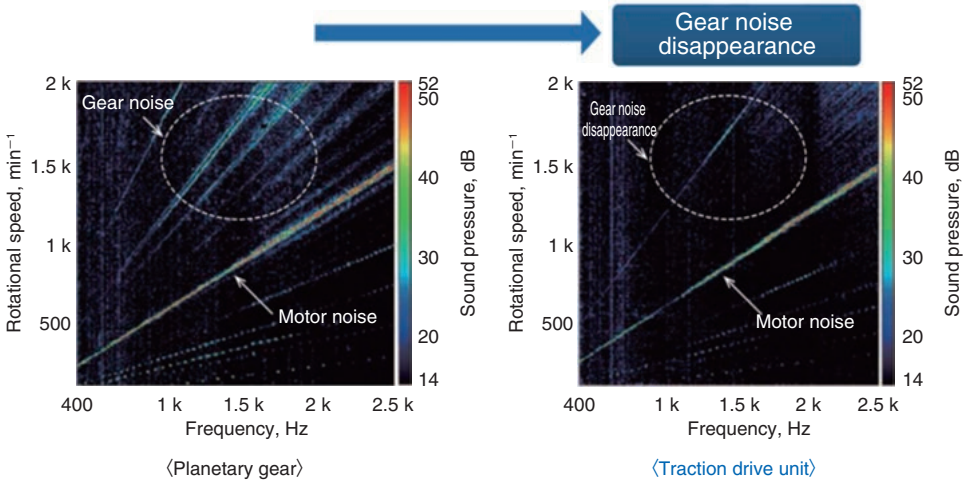

Fig. 19 Noise comparison results of a planetary gear versus a traction drive unit

References

1) K. HAYASHIDA, H. MATSUYAMA: JTEKT ENGINEERING JOURNAL, No. 1015E (2018) 17.
2) R. HOSAKA, S. MATSUDA: JTEKT ENGINEERING JOURNAL, No. 1012E (2015) 32.
3) R. HOSAKA, N. YASUDA: JTEKT ENGINEERING JOURNAL, No. 1004E (2008) 42.
4) J. KUBO, M. KAWATA: JTEKT ENGINEERING JOURNAL, No. 1012E (2015) 43.
5) JTEKT CORPORATION: Ball & Roller Bearings, CAT. No. B2001E-7 (2017) A152.
6) JTEKT CORPORATION: JTEKT ENGINEERING JOURNAL, No. 1012 (2014) 114 (in Japanese).
7) T. MURAKI, H. YAMAMOTO: Current State and Outlook of the Multi-tasking Machine, Journal of the Japan Society for Precision Engineering, vol. 78, No. 9 (2012) 740 (in Japanese).
8) JTEKT CORPORATION: Precision Ball & Roller Bearings for Machine Tools, CAT. No. B2005E-3 (2016), 35.
9) H.UEYAMA: Koyo Engineering Journal, No. 163E (2003) 24.
10) R. NAKATA: Koyo Engineering Journal , No. 149 (1996) 31 (in Japanese).
11) A. KAWANO: Koyo Engineering Journal, No. 165E (2004) 59.

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