Application Examples of PRECILENCE Ultra-high Precision Bearings — Minimization of Electrode Slurry Coating Roll Runout —

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The runout of electrode slurry coating rolls in battery manufacturing equipment have been reduced to 0.65 µm using ultra-high-precision bearings and minimizing the roundness of the rolls, as well as by optimizing the distance between the bearings that support rolls.

***Key Words**: bearing, high precision, slurry coating roll, PRECILENCE, roll runout*

1. Introduction

As global warming has progressed in recent years, there is steadily growing demand for development of environmentally friendly products. Bearings must deliver high performance when installed in any kind of equipment. As a bearing supplier, JTEKT is not only developing bearings by the usual process, but is also actively participating in actual equipment evaluations at the customers. It is necessary to optimize bearings for the actual service conditions and environment, and we are convinced that JTEKT should proceed with initiatives to maximize the performance of that equipment in parallel with this development.

This report will introduce the use of the PRECILENCE[1)] ultra-high precision bearings developed by our company as bearings that support electrode slurry coating rolls in the battery manufacturing process, and examples of contributions toward achieving carbon neutrality.

2. PRECILENCE Ultra-High Precision Bearings

PRECILENCE ultra-high precision bearings (hereafter “PRECILENCE”) were developed for use in machine tools and other equipment that require higher levels of machining accuracy and efficiency. PRECILENCE is a term created by combining “Precision” and “Silence,” and it has the following features.

[Features of PRECILENCE]
1) Small tolerances for bore diameter and outside diameter (**Fig. 1**)
2) Small runout (**Fig. 2**)
3) High cleanliness
In order to prevent intrusion of foreign matter after precision washing, the bearings are inserted into vacuum packs in a clean room (ISO standard: class 1) before they are shipped (**Fig. 3**).

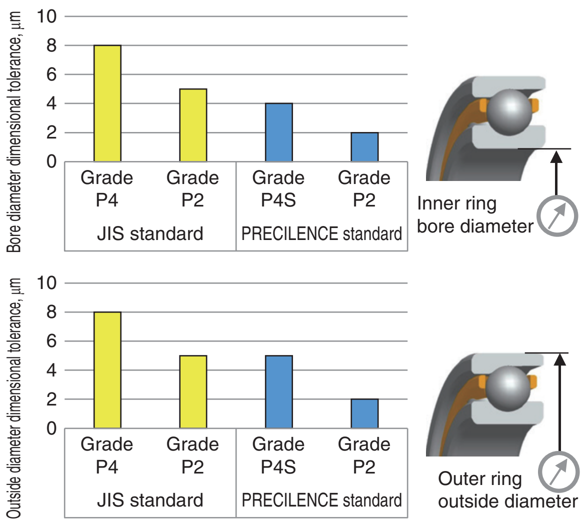

Fig. 1 Comparison of dimensional tolerance (7020[*1])

*1: Bore diameter × Outside diameter × Width: ϕ100 mm × ϕ150 mm × 24 mm

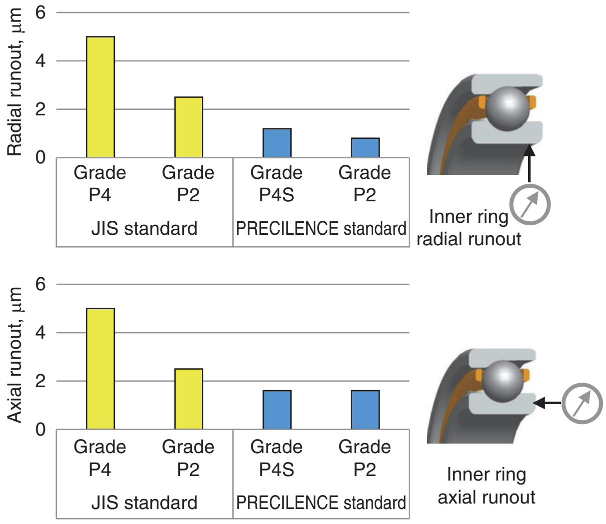

Fig. 2 Comparison of bearing runout (7020)

Fig. 3 Vacuum pack

3. Selection of Target Industries

3. 1 Development Contents

The industries which require ultra-high precision bearings span a wide range, and there is no single bearing specification that can meet the operating conditions of all machines and equipment. We therefore selected the target industries where the features of PRECILENCE could be put to maximum use, and optimized the bearing operating conditions. The goal was to improve the performance of the product where the bearing is installed, not the bearing itself.

3. 2 Current Trends

The most recognizable keyword describing current trends is "carbon neutrality." In FY2021, the net amount of carbon dioxide and other greenhouse gases emitted and absorbed in Japan alone was 1.12240 billion tons, with emissions greatly exceeding absorption (**Fig. 4**).

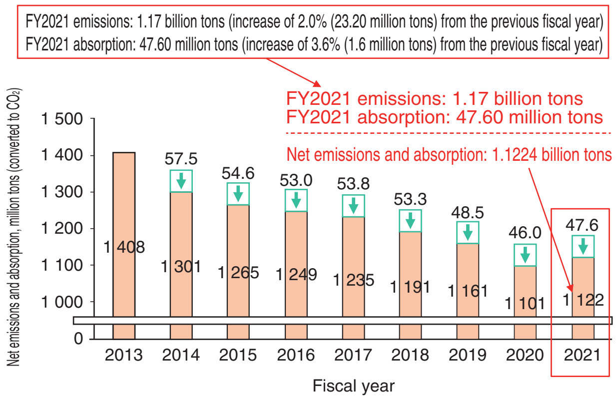

Fig. 4 Trend in greenhouse gas emissions and absorption in Japan[2)]

In the automobile industry where JTEKT operates, the shift from engine vehicles to battery electric vehicles (BEV) is being carried out in order to contribute to carbon neutrality. The lithium-ion batteries that are installed in a BEV have higher energy density than nickel-hydrogen batteries and other rechargeable batteries. Demand for these batteries is expected to continue growing, and they will be produced in larger numbers. The market also expects higher capacities, higher quality, and higher levels of safety. If PRECILENCE can help in resolving these market issues, it can play a part in achieving carbon neutrality.

3. 3 Battery Manufacturing Equipment

As shown in **Fig. 5**, the manufacturing process for ordinary lithium-ion batteries begins from blending the materials for the cathode and anode, and contains numerous processes including coating, drying, rolling, assembly, fluid injection, and charging and discharging. Among these, this report focused on the electrode material coating process which has a large effect on battery performance (**Fig. 6**). In the process that applies paste-like electrode material called slurry to the foil, reducing variation in the application and applying the slurry evenly will reduce variation in the battery lifetime, and will in other ways help to improve quality and the yield rate.

By using PRECILENCE for the bearings that support the coating roll at the slurry coating process, and optimizing the installation method according to the preload and other bearing designs, we worked to reduce roll runout to the minimum possible and achieve a more even electrode film thickness.

Because the requested roll runout from the equipment manufacturer was 1.0 to 3.0 µm, the target value was set at 1.0 µm or less.

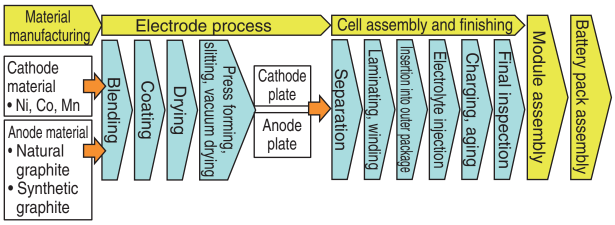

Fig. 5 Battery manufacturing process[3]

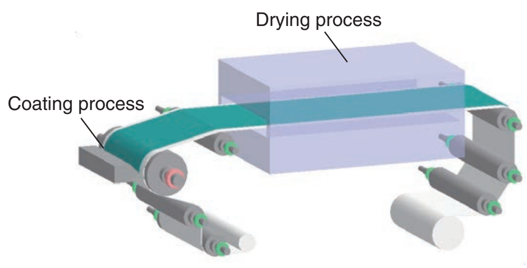

Fig. 6 Image of coating and drying process[4]

4. Optimization of the Coater Bearings

4. 1 Optimization Contents

We made two improvements in order to reduce roll runout to the minimum possible and create a more even film thickness. One was to minimize the roll deflection, and the other was to minimize roll runout.

4. 2 Minimizing Roll Deflection

An image of the slurry coating part is shown in **Fig. 7**. Ordinarily when the coating width is large, this improves equipment productivity. However if the coating width is simply expanded, the roll width also becomes larger, and deflection increases as a result of the roll's own weight. When roll deflection increases, it becomes difficult to adjust the coating clearance between the die and roll at the roll center and edges, and there is the risk of increasing variation in film thickness in the width direction.

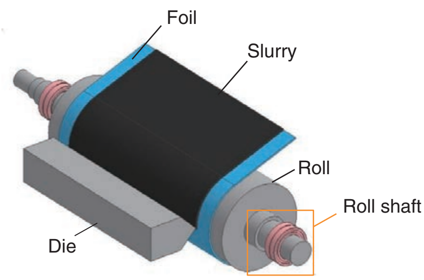

Fig. 7 Image of coating part (roll and die)[4]

Roll deflection changes not only based on the internal specifications of the angular contact ball bearing that supports the roll, but also according to the mounting positions, preload, interference, and other elements of the operating environment. However if preload and interference are increased too much, this will adversely affect the bearing service life. As shown in **Fig. 8**, of the four rows of bearings that support the roll, we fixed the mounting positions of the two rows of bearings on the inside on the left and right of the roll, and conducted a parameter study analyzing the mounting positions of the two rows of bearings on the outside in order to study a method to minimize roll deflection.

The results are shown in **Fig. 9**. We learned that when the mounting positions of the outside bearings are closer to the inside bearings, roll deflection is reduced.

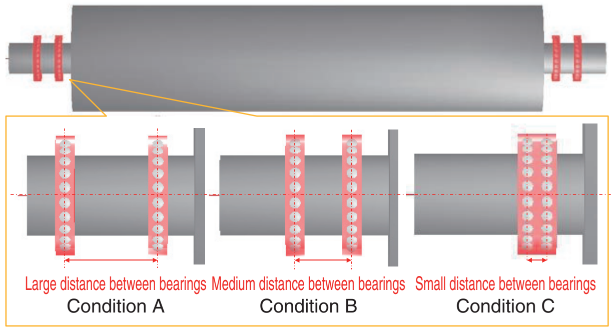

Fig. 8 Bearing mounting position test conditions

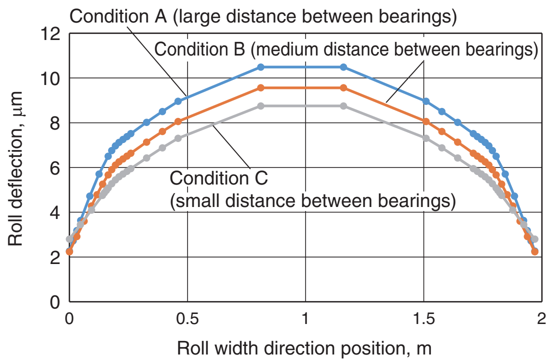

Fig. 9 Deflections along roll width direction

4. 3 Minimizing Roll Runout

Generally roll runout after bearing fitting is considered to be the sum of the runout of the roll itself and the radial runout of the bearing inner ring. However when bearings are actually fitted onto a roll and runout is measured, variation occurs between individual parts. The reason is considered to be that shape variation in the fitting sections of the bearing and roll shaft produces different interference in the peripheral direction. This then increases the shape change of the inner ring raceway after bearing fitting.

We therefore prepared roll shafts with different roundness and bearing inner rings. As shown in **Fig. 10**, we observed the change in inner ring raceway roundness before and after bearing fitting. The results are shown in **Fig. 11**. We found that the inner ring raceway shape after bearing fitting depended on the roundness of the roll shaft.

This means that in order to reduce runout of the roll coating surface, it is necessary to pay careful attention to the shaft roundness.

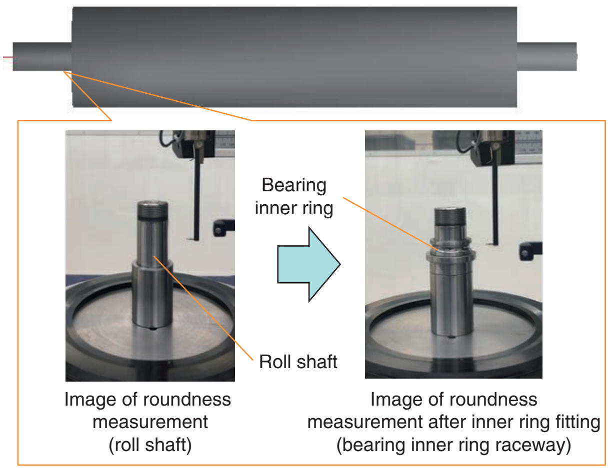

Fig. 10 Roundness measurement of roll shaft and inner ring raceway

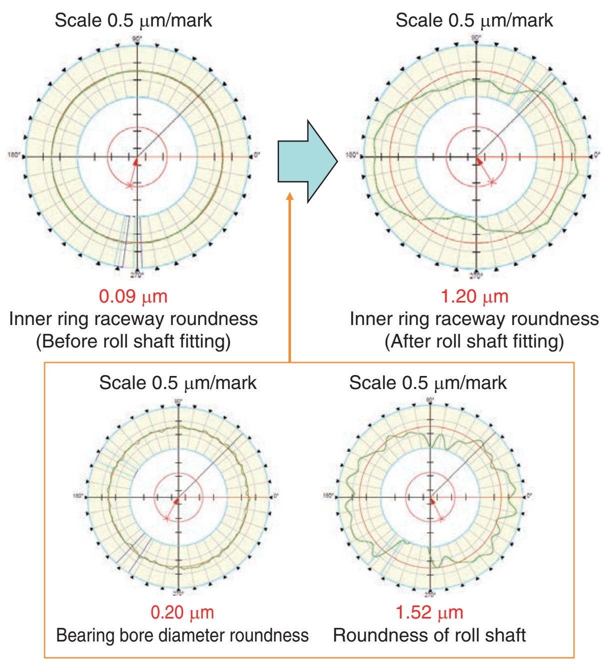

Fig. 11 Comparison of inner ring raceway roundness before and after shaft fitting

5. Verification of Effects with Test Machine

Based on the countermeasures described above, we optimized the specifications and evaluated roll runout using a test machine that we produced.

5. 1 Evaluation Samples and Environment

A schematic diagram of the test machine is shown in **Fig. 12**, and the evaluation conditions are shown in **Table 1**. PRECILENCE bearings were used back-to-back on both ends of the shaft, and the roll was rotated by means of a belt drive in the same manner as the actual equipment. Non-contact displacement sensors were installed at three locations on the roll to measure roll runout.

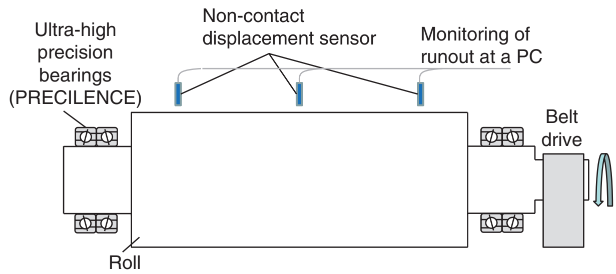

Fig. 12 Measurement system of test machine

Table 1 Test conditions of test machine

Roll dimensions		ϕ200 mm (roll diameter) × 1 200 mm (surface length)
Sample bearing		7010C (ϕ50 mm × ϕ80 mm × 16 mm) Back-to-back
Material	Bearing ring	SUJ2
	Balls	Ceramic
	Cage	PEEK
Rotation speed		3 min^{-1}
Temperature		Room temperature
Test item		Roll runout

5. 2 Evaluation Results

The results of measurement performed under the conditions described in **Section 5. 1** showed that roll runout was reduced to 0.65 μm at the center—the location where runout is largest, achieving the target of 1.0 μm or less (**Fig. 13**).

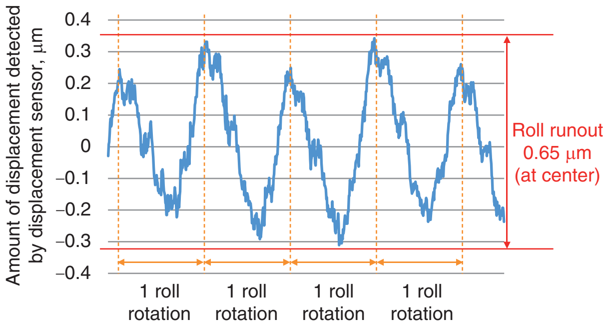

Fig. 13 Roll center runout measurement result

6. Conclusion

This report introduced an example of using the PRECILENCE bearings developed by JTEKT as electrode coating roll support bearings in the battery manufacturing process. In order to reduce roll runout to the minimum possible, we minimized the distance between the bearings supporting the roll on the same side, and minimized the roundness of the roll shaft. As a result, roll runout was reduced to 0.65 μm. This result can deliver higher capacity, higher quality, and higher safety of lithium-ion batteries to the customers, and can also contribute to achieving carbon neutrality.

Bearing performance changes significantly depending on the mounting method and operating conditions. In the future, we believe that perfecting the final product through cooperation among engineers from different companies will be the way to create a shortcut to carbon neutrality in various industrial fields.

* PRECILENCE is a registered trademark for the ultra-high precision bearings developed by JTEKT Corporation and JTEKT Precision Bearing Corporation.

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