High Load Capacity Cylindrical Roller Bearings

1. Introduction

The gearbox on wind turbines is located high off the ground and is therefore difficult to access for service. Therefore, the bearings in the gearbox must provide long life with a high degree of reliability. Even though the size of wind energy farms has been growing in recent years, demand for smaller, lighter nacelles have been on the rise in order to mitigate loads on towers. Given this, compact bearings for gearbox applications that boast greater load carrying capacity are greatly needed.

In response to these needs, NTN has developed a unique high load capacity cylindrical roller bearing product (Fig.1) that incorporates keystones in place of a cage. As a result, our new cylindrical roller bearing product boasts a greater load bearing capacity without loss in running performance. The rated life of the new product is more than 1.5 times longer than that of conventional caged cylindrical roller bearings.

2. Structure and Features

In the new NTN design, resin-made keystones are situated between the rollers to prevent roller-to-roller contact. Since these keystones are independent of each other, tensile stress otherwise resulting from roller-to-roller contact and separation does not affect them. As a result, the size and number of the rollers can be increased because the keystones can be thinner (Fig. 2).

In Table 1, the performance of the new design is compared with that of a conventional design.

- **Longer life**
  
The size and the number of the rollers are optimized to enhance the load carrying capacity of the bearing. As a result, a rated life that is more than 1.5 times as long as that of a conventional caged bearing design.

- **Higher speed**
  
  Roller-to-roller contact occurring on full complement roller bearings is avoided by use of a unique keystone design. Through optimization of the shape and roller guiding scheme with the keystones, limiting speed and smearing resistance equivalent to a caged design have been achieved.

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3. Evaluation Test (1)

The following tests were performed by assuming that each test bearing was used on the output shaft of a gearbox for a wind turbine.

3.1 Test bearings

In general, the non-locating bearing on the output shaft is often an NU or NJ cylindrical roller bearing type, in the case the test bearings used were NJ2324E. The new design tested is a prototype identical to a conventional design, but that has an increased number of rollers compared to the conventional design.

In Table 2, the technical data for the conventional design (with a cage) is compared to that of the new design.
3.2 Temperature increase comparison test

The running performance of the new design was compared with that of the conventional design in terms of temperature increase.

As shown in Fig. 3, the temperature increase pattern with the keystone design closely matches that of the conventional design, and the new bearing was capable of trouble-free operation up to 3500 min⁻¹ (dn/dmn = 420,000/670,000).

3.3 Acceleration/deceleration test

To evaluate resistance to the smearing that can occur in non-load operation, the keystone bearing was subjected to an acceleration/deceleration test under a set of low-load conditions.

As can be seen from the test results plotted in Fig. 4, the temperature rise on the outer ring was limited to a stable level of approximately 15˚C. (Additionally smearing did not occur during the test.)

3.4 Oil-resistance test with separator pieces

To determine oil resistance resin test pieces made of the same material as that used for the keystones were immersed in the lubricating oils that are used in wind turbine gearboxes. The tensile stress of the test pieces was taken and plotted in Fig. 5.

As can be seen from the data, the test pieces immersed in each of the two lubricating oils did not exhibit significant losses in mechanical strength.
4. Evaluation Test (2)

Additional tests were performed with an N-type cylindrical roller bearing (a type that has a double-ribbed inner ring). This type of bearing is often used in planetary gear applications.

On certain planetary gears, the bore surface of the gear may be used as a raceway surface for the outer ring. With this type of arrangement, an N-type cylindrical roller bearing that lacks an outer ring is often used (Fig. 6). Bearings for planetary gearing are usually used with their outer rings allowed to rotate. However, for the these tests, the inner ring was allowed to rotate.

4.1 Test bearings

In Table 3, the technical data for the conventional design (full complement roller bearing) is compared with that for the new keystone design.

![Table 3 Test bearings](image)

![Fig. 5 Oil resistance of separator](image)

![Fig. 6 Example of using N type](image)
4.2 Temperature rise comparison test

To evaluate the running performance of the keystone design, the temperature increase characteristics were compared to those of the conventional design.

As shown in Fig. 7, the temperature increase of the keystone design was limited compared to the conventional design. There was an approximately 10°C maximum difference in temperature increase between the new and conventional designs. In addition, after undergoing the test. The conventional design exhibited smearing, something not apparent in the keystone design (Fig. 8).
5. Conclusion

A unique high-load capacity cylindrical roller bearing design incorporating keystones has been described, and the results from evaluation tests with this new design have been discussed. The author believes that this new bearing design, which features the advantages not only of bearings with cages but also those of full complement roller bearings, will contribute significantly to longer bearing life and improved reliability for transmission systems.

The new high-load capacity cylindrical roller bearing design can be applied to systems other than gearboxes, so NTN will market this design as a high load capacity bearing product line.