ULTAGE Standard Angular Contact Ball Bearings, 79U/70U type

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Machine tool bearings require high speed capability, long life, and consideration of the operating environment. To meet such needs, **NTN** has developed a new standard angular contact ball bearing, the 79U/70U type, which has superb performance and adds rich variation to our ULTAGE Series product line. This paper describes the features of **NTN**'s standard angular contact ball bearings that have created a new epoch in the areas of high-speed, load resistance, and lubrication performance. These improvements make the 79U/70U ULTAGE Series worthy of the title "The New World Standard."

1. Introduction

Machining centers and machine tools are becoming faster, more efficient, and more precise. Today, the machining centers that are used primarily for mold fabrication have reached a $d_m n$ value of 3.5 million (d_m: ball pitch circle diameter of bearing rolling elements mm, n: rotating speed min^{-1}) [1]. In addition, increased productivity (higher efficiency achieved through reducing the non-processing time) is actively sought by consolidating multiple machining processes, including the cutting process, into a single machine. Recently, environmentally friendly technologies have become commercially available, which include "dry machining" where no cutting oil is used and "semi-dry machining" where an extremely small amount of cutting oil is used in the processes. The key words in this field are "High-speed", "Compound", and "Eco-conscious technology."

To meet such market trends, **NTN** created the "ULTAGE" series machine tool bearings and introduced them at JIMTOF (Japan International Machine Tools Fair) in 2002. Since then, **NTN** has been expanding this series mainly by adding angular contact ball bearings and cylindrical roller bearings which have superb high-speed performance to be suitable for the machine tool main spindles. More recently, **NTN** has improved the functionality of the standard angular contact ball bearing and added it to the "ULTAGE" series product line as a new series in the bearing family. (**Photo 1**)

Photo 1 ULTAGE standard angular contact ball bearing 79U/70U type

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2. Optimization of internal design

2.1 Adoption of optimal design for high-speed, high-rigidity performance

Standard angular contact ball bearings are superior to high-speed angular contact ball bearings utilizing small diameter balls in terms of rigidity and load capacity (a parameter that indicates resistance to rolling fatigue life). On the other hand, applications of these bearings are limited by speed. The recent design change was aimed at improving high-speed performance, thereby expanding its application. **NTN** reviewed the internal design and solved the conflicting high-speed performance and high rigidity at the same time (establishing the specifications that achieve high-speed performance while retaining rigidity of the current bearing).

More specifically, impact of the designs of the rolling elements and raceways on rigidity were assessed. Effort was made to change the design of the areas that had less impact on rigidity to improve high-speed performance. However, changes to those areas that have definite impact on rigidity were kept at a minimum. "ULTAGE" 79U/70U type standard angular contact ball bearings utilized the above approach and accomplished both high-speed and high rigidity. Furthermore, this bearing uses a new resin cage, described later, and attained the $d_m n$ value of 0.95 million with grease lubrication, about 1.5 times that of the current bearing, and 1.5 million with air-oil lubrication, about 1.8 times that of the current bearing (both bearings used a contact angle of 15° and steel balls).

Figs. 1 and **2** compare rigidity in the current and new designs. The new design has a slight decrease in rigidity, but maintains the rigidity at nearly the same level.

2.2 Improvement in load resistance

The bearings for machine tool main spindles can be subject to large axial loads during tool change while machine is stopped. If the load exceeds the allowable limit of the bearing, it can cause dents or other damage to the raceways. Such characteristics that indicate limitations to axial loads are called "allowable axial loads." **NTN** defines these as follows:

- The end of contact ellipse on the raceway surface reaches the shoulder of either an inner or outer ring (contact ellipse formed between the rolling element and the raceway protrudes out of the raceway: **Fig. 3**).
- The contact surface pressure on the raceway surface reaches 3650MPa in either the inner or outer ring raceway.

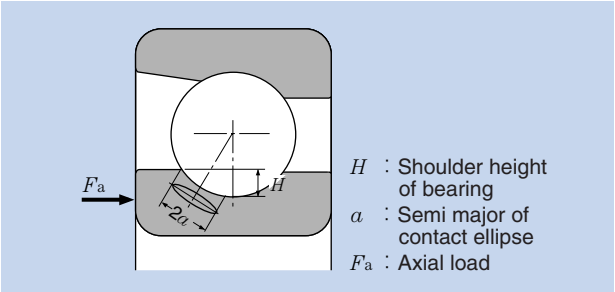


Fig.3 Rolling elements protrude over the raceway shoulder

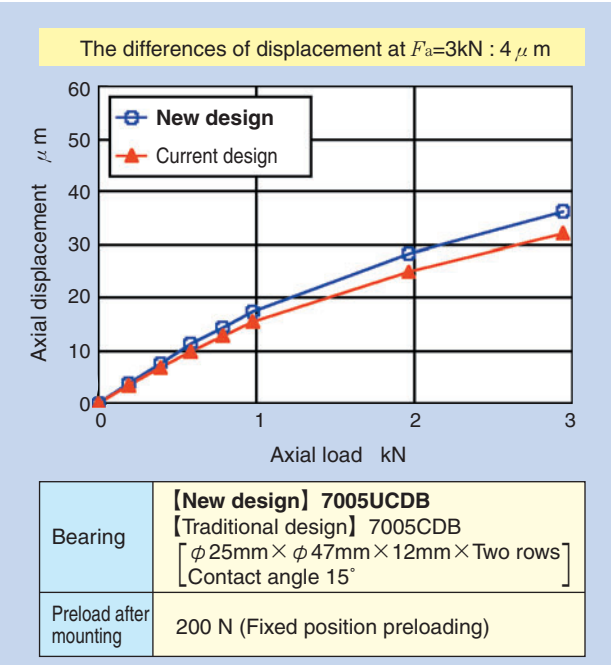


Fig.1 Axial rigidity (7005CDB)

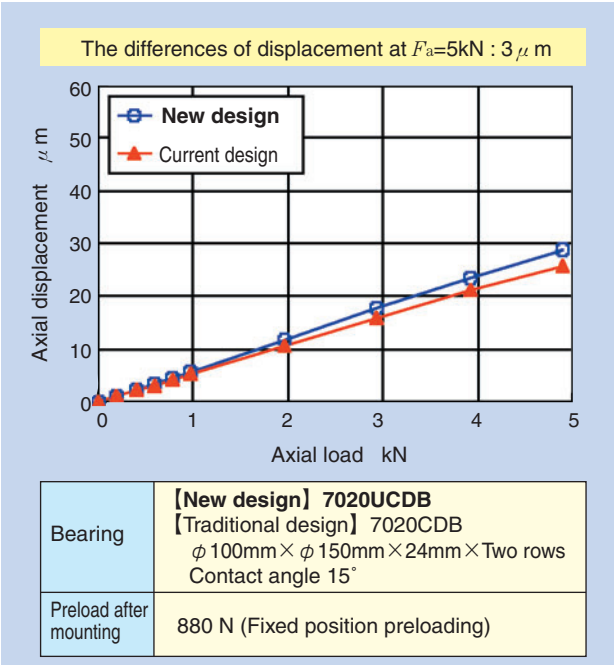


Fig.2 Axial rigidity (7020CDB)

With ULTAGE 79U/70U type standard angular contact ball bearings, optimization of the internal design (described earlier) took these characteristics, into consideration. The review included the shoulder height and attained allowable axial load far greater than (about 2.5 times) that of the current design. (**Figs. 4** and **5**)

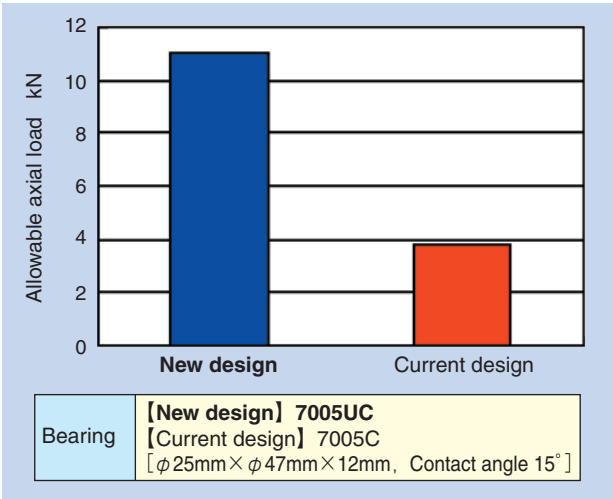


Fig.4 Allowable axial load (7005CDB)

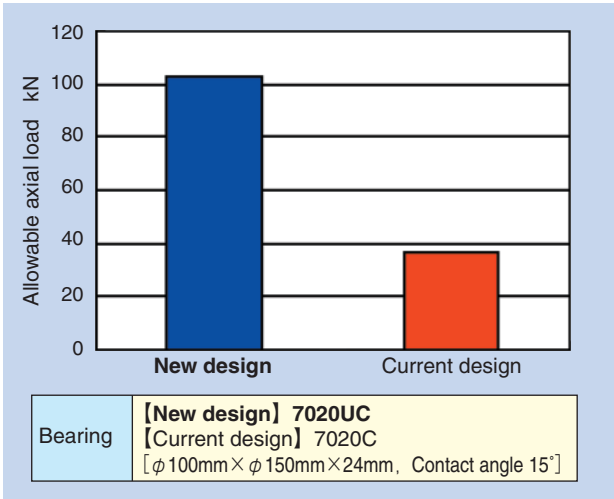


Fig.5 Allowable axial load (7020CDB)

2.3 Optimal design for lubrication

In air-oil lubrication, oil delivery into the bearing is important, as is the discharge of used oil (exhaust of air-oil). Unless there is a smooth discharge of used oil, lubricant can collect inside the bearing, which increases stirring resistance and results in temperature rise or seizure [1]. Consequently, attention must be paid not only to optimization of the rolling elements, raceway profile, or other internal design but also to the above issue in order to establish stable temperatures under high-speed operation.

In grease lubrication, deterioration of grease by heat and lubrication life are critical. For this reason, internal structures having excellent grease retention have an advantage.

ULTAGE 79U/70U type standard angular contact ball bearings, have adopted designs that increase reliability of lubrication both in air-oil and grease lubrication. The following sections describe the key designs.

2.3.1 Molded cage with new profile (Polyamide resin: Figs. 6 (a) and (b))

(a) Characteristics in air-oil lubrication

To ease delivery of lubricant to the rolling element and the raceway contact area (aiming) and to promote the discharge of used oil outside the bearing (purging), the bore of the cage was tapered and the spaces for lubricant delivery and discharge inside the bearing were expanded.

In addition, slits were created at four corners of the ball pockets (where rolling elements are located) to secure oil passage from the inner to the outer ring (flow of lubricant created by centrifugal force).

These measures will prevent stirring resistance caused by stagnant lubricant.

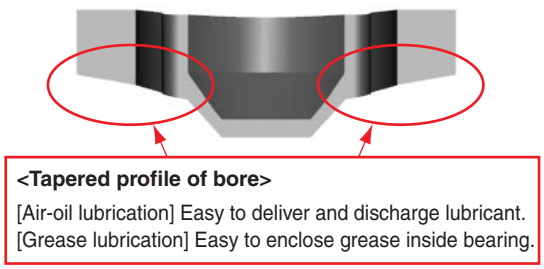


Fig.6(a) New resin cage (section of the ball pocket)

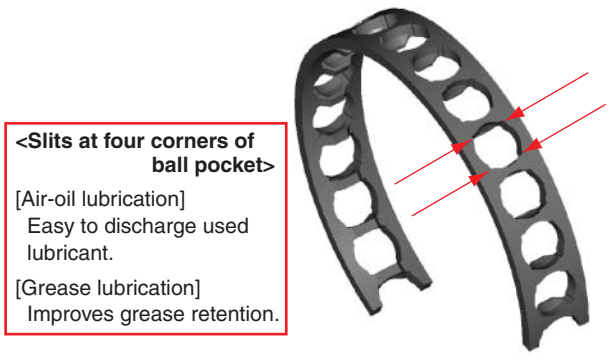


Fig.6(b) New resin cage (appearance)

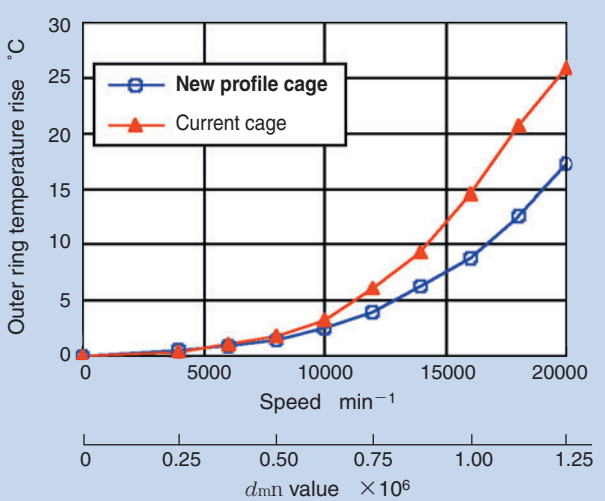
Fig. 7 compares the current cage to the new profile cage in a high-speed operation test (air-oil lubrication). The graph shows less bearing temperature rise with the new profile cage than with the current cage.

(b) Characteristics in grease lubrication

In grease lubrication, the slits at the pockets function to retain grease. Adoption of the tapered profile increases the bearing space (increases opening at bearing width), which makes it easy to enclose grease inside the bearing. Thus, this profile improved lubrication reliability and simplified grease handling.

Fig. 8 compares the current cage to the new profile cage in a high-speed operation test (grease lubrication). The graph shows equal or less bearing temperature rise with the new profile cage than with the current cage.

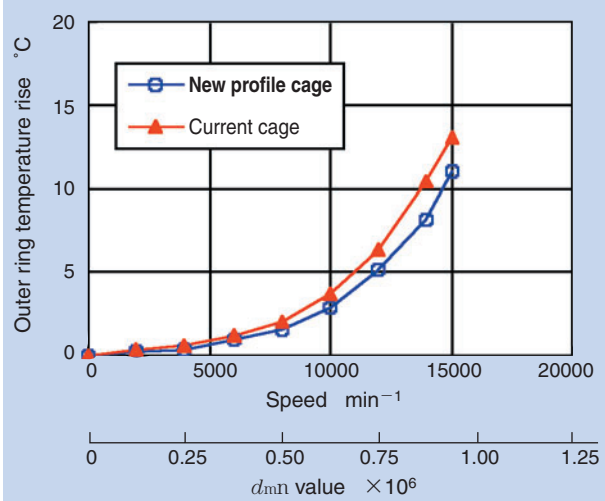
ULTAGE 79U/70U type standard angular contact ball bearings, with applications reaching the $d_m n$ value of 1.05 million use this new cage profile as standard, whereas those for high-speed application (air-oil lubrication) beyond this speed use phenol machined cages that have been field proven in many super high-speed applications.



【Test conditions】

Bearing	7010UCDB [φ50mm×φ80mm×16mm×Two rows Contact angle 15˚]
Preload after mounting	200 N (Fixed position preloading)
Lubrication method Air supply rate Oil supply rate Oil type	Air-oil lubrication 40 NL/min 0.03 mL/5 min/shot ISO VG32
Jacket cooling	None

Fig.7 High-speed test (air-oil lubrication)



【Test conditions】

Bearing	7010UCDB [φ50mm×φ80mm×16mm×Two rows Contact angle 15˚]
Preload after mounting	200 N (Fixed position preloading)
Lubrication method Brand name	Grease lubrication ISOFLEX NBU15
Jacket cooling	None

Fig.8 High-speed test (grease lubrication)

2.3.2 Changes in inner ring profile (Fig. 9)

The lubricant delivery space was expanded by designing the outer diameter of the inner ring of the back side, or non-load side, lower than that of the current bearing and combining it with the above mentioned new cage profile. This structure allows for easier oil delivery to the cage-inner ring gap suitable for high-speed operation (with excellent oil delivery in air-oil lubrication) and allows oil delivery (aim of nozzle) at an angle. This reduces the dimensional restriction on the spacer with respect to the nozzle and improves freedom of design for the bearing peripheral structure.

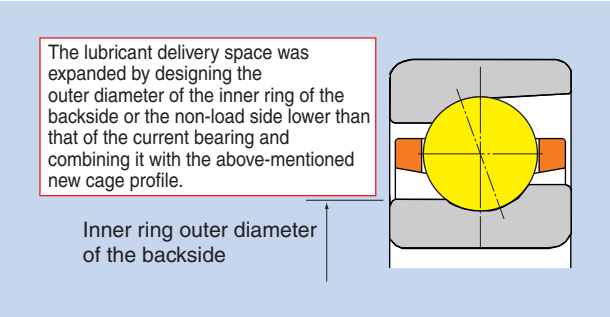
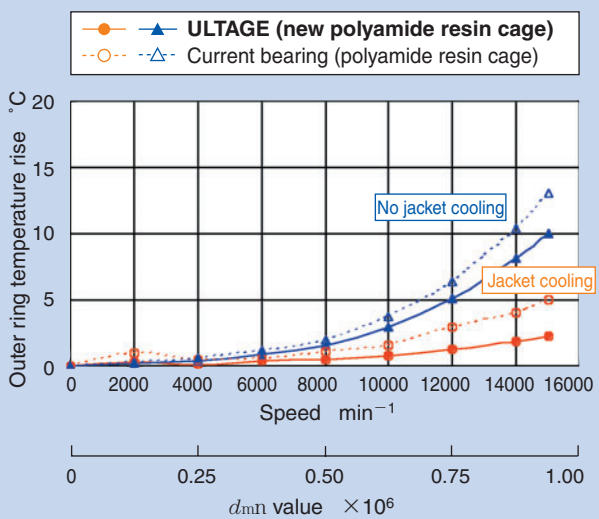


Fig.9 Section of 79U/70U type

4. High-speed operation test results

The test results (grease lubrication) of ULTAGE 79U/70U type standard angular contact ball bearings, are shown in **Fig. 10**. The temperature rise with the new series is lower than that of the current bearings with or without jacket cooling, and the speed reached a $d_m n$ value of 0.95 million.

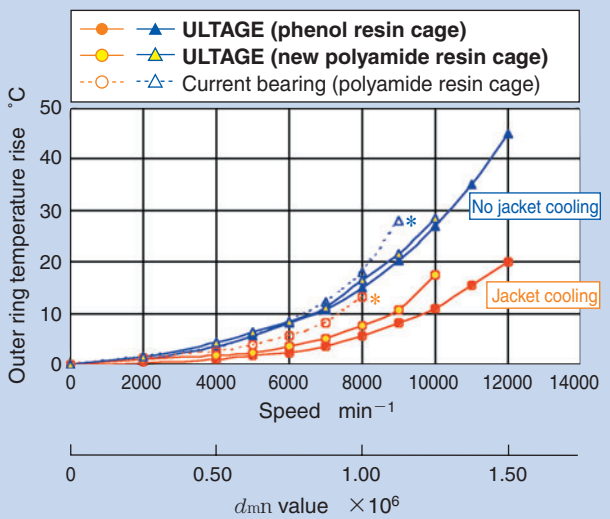
Like grease lubrication, air-oil lubrication evaluation (**Fig. 11**) also found lower temperature rise in the new series with or without jacket cooling than that of the current bearing. The current bearing showed unstable temperature rise at around a $d_m n$ value of 1.05 million (indicated by ○*, △*), while the new series showed stable temperature rise at a $d_m n$ value of 1.5 million.



【Test conditions】

Bearing	【ULTAGE】7010UCDB 【Current bearing】 7010CDB [φ50mm×φ80mm×16mm×Two rows Contact angle 15°]
Preload after mounting	200 N (Fixed position preloading)
Lubrication method Brand name	Grease lubrication INSOFLEX NBU15
Jacket cooling	Provided, Not provided

Fig.10 High-speed test (grease lubrication)



【Test conditions】

Bearing	【ULTAGE】7020UCDB 【Current bearing】 7020CDB [φ100mm×φ150mm×24mm×Two rows Contact angle 15°]
Preload after mounting	150 N (Fixed position preloading)
Lubrication method Air supply rate Oil supply rate Oil type	Air-oil lubrication 40 NL/min 0.03 mL/5 min/shot ISO VG32
Jacket cooling	Provided, Not provided

Fig.11 High-speed test (air-oil lubrication)

5. Series

ULTAGE 79U/70U type standard angular contact ball bearings, series configuration is shown in **Table 1**. The bearing models are either 0 series or 9 series, and each series has three different contact angles (15˚, 25˚, 30˚). The bearing sizes (bore diameter) for these series are ϕ 10mm ~ ϕ 130mm (common to all series). In addition to the current steel balls, the materials for rolling elements include ceramic balls to provide ample variation.

Table 1 79U/70U Series

Steel ball series	Contact angle 15˚	79xxUC/70xxUC
	Contact angle 25˚	79xxUAD/70xxUAD
	Contact angle 30˚	79xxU/70xxU
Ceramic ball series	Contact angle 15˚	5S-79xxUC/5S-70xxUC
	Contact angle 25˚	5S-79xxUAD/5S-70xxUAD
	Contact angle 30˚	5S-79xxU/5S-70xxU

Available bearing size (shaft diameter):
ϕ 10mm ~ ϕ 130mm (common to all series)

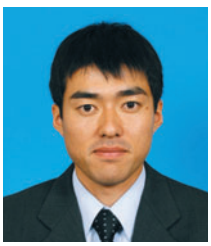
6. Conclusion

ULTAGE 79U/70U type standard angular contact ball bearings, are products suitable for machine tools that are used under more and more severe environments. **NTN** will continue to improve and develop machine tool bearings under the fundamental philosophy of "people and environment-friendly bearing technology" and "more advanced functionality and ease of use."

Reference

1) Keiichi Ueda, THE TRIBOLOGY No.188 (2003), 19 (in Japanese)

Photos of author



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