History of Development of Bearings for Automobiles Aiming at Low Fuel Consumption

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Hybrid vehicle/Electric vehicles (HEV/EV) that represent the next-generation vehicles, future expansion are expected.

On the other hand, in emerging countries such as Asia and Africa, there is still high demand for conventional vehicles (engine type) on a global basis due to population growth. In addition, from the point of environmental regulation, each automotive manufacturer is focusing on the development of vehicles with low environmental impact. We will introduce the history of the development as a bearing for automobiles, about “Low Fuel Consumption” required for automobiles.

1. Introduction

Since the structure of bearings for automotive use are simple, specification differences are not often noticeable by appearance. However, a look at the history of bearing specifications from the 1980’s till present reveal that basic performance continued to evolve ahead of market needs. In this article the transition of automotive bearing technology (deep groove ball bearing and tapered roller bearing) is introduced up to the latest specification in regards to low fuel consumption (low torque).

2. History of Development of Bearings for Automotive Use

2.1 Deep Groove Ball Bearing

In response to the market demands of high efficiency multi-stage AT and CVT, the functionality of the deep groove ball bearing, mainly used for transmission, has been improved. This includes high-speed use and lower torque. In addition to requirements of being compact, lightweight and a long operating life, bearings for driving motors of electric vehicles also face similar specification demands.

The demand for lower torque is met with a compact and lightweight design. This is achieved with the material and thermal treatment, change of internal design specification and improvement of components such as the seal, cage and grease **(Fig. 1)**.

Table 1 shows the characteristics of the structure and performance of each specification of deep groove ball bearings. **Fig. 2** shows the history of technology since the 1980s comparing the running torque.

The deep groove ball bearings used for transmission were generally the open type without a shield or seal. However, contact seals (LU seal/LH seal) are now adopted to prevent reduction of operating life due to penetrating hard foreign objects contained in the oil.

Bearings with contact seals have higher torque than the open type due to the sliding nature of the seal so the open type is used when the requirement for lower torque is critical. Improvements of material and thermal treatment have been made to achieve longer operating life even in an environment where foreign objects may penetrate.

The latest specification (LE Seal) developed has improved seal material and seal lip geometry achieving low torque while maintaining the seal performance. These improvements result in lower torque equivalent to non-contact type seal under oil lubrication.

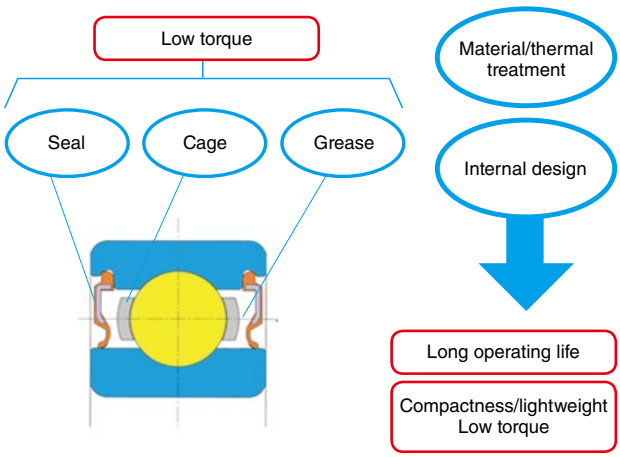

Fig. 1 Deep groove ball bearing and characteristics

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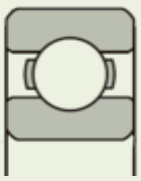
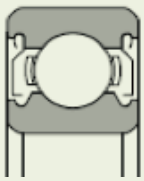
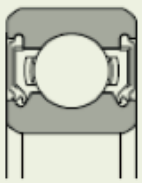
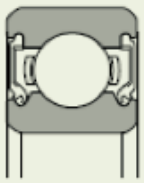
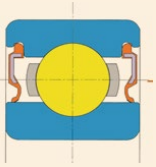
Table 1 Characteristics of deep groove ball bearing[1)]

		Specification of standard type				Specification of developed product
Type and code		Open type	Shield type	Seal type		Seal type
			Non-contact type ZZ	Contact type LU	Low torque type LH	Low torque type LE
Structure						
		No shield or seal to seal the bearing.	Metallic shield is fixed on the outer ring to form labyrinth seal with the seal groove of the inner ring.	Seal of steel plate with synthetic rubber adhered by vulcanization is fixed to the outer ring and the tip of the seal is in contact with the seal groove of the inner ring for sealing the bearing.	The same basic structure as LU with improved seal tip to reduce the contact force and achieve low torque by providing slits for avoiding absorption.	Low torque is achieved with non-contact seal by creating a wedge film effect of fluid under the oil lubrication environment by providing multiple arc-shaped micro convexes on the sliding surface of the seal tip.
Comparison of performance	Low torque	☆☆☆	☆☆☆	☆	☆☆	☆☆☆
	Dust proof	—	☆	☆☆☆	☆☆☆	☆☆☆
	High speed	☆☆☆	☆☆☆	☆	☆☆	☆☆☆

Order of superiority: excellent ☆☆☆>☆☆>☆ poor

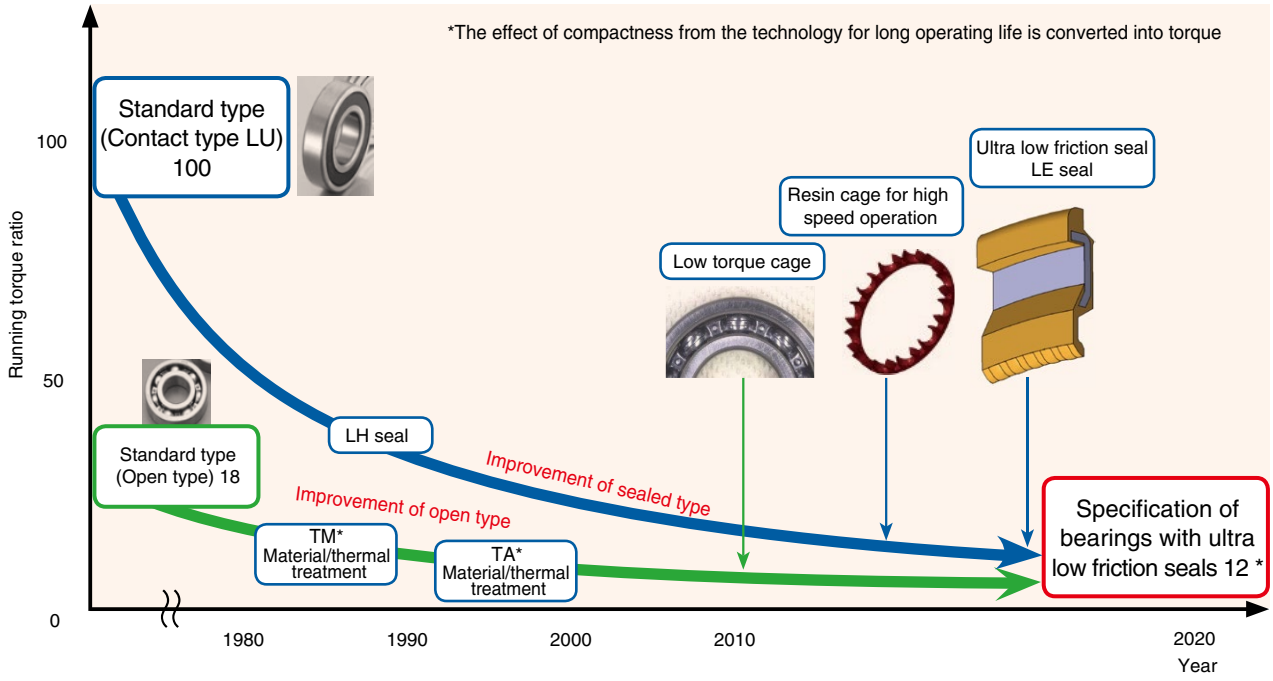


Fig. 2 Transition of development of deep groove ball bearings[2)]

2.2 Tapered Roller Bearing

Tapered roller bearings used for transmission and differential gears have more design elements than deep groove ball bearings. As a result, various characteristics brought by the design parameters have been explored. In addition to lower torque, improvements on materials and thermal treatment as well as long operating life has been achieved **(Fig. 3)**.

In this Section, improvements on the internal design and material/thermal treatment are discussed in the transition to lower torque. The ST specification, which reduced the torque by improving the sliding characteristics of the rollers, was established for the improvement of internal design. This is primarily accomplished with special shape and processing of the inner ring collar. As for the improvement of the material/thermal treatment, special thermal treatment was applied to the carburized steel as the base. This contributes to long operating life due to an increase in retained austenite on the surface of the raceway. (The torque calculation result due to compactness is shown in **Fig. 4.**)

The ECO-Top specification was later established with improvements to micro curvature (crowning) of inner/outer ring raceway and development of products which integrated this technology and other material/thermal treatment technology. Furthermore, the stirring resistance of oil was significantly reduced by changing the design of steel plate cage. In the latest specification, ULTAGE*1 Tapered Roller Bearing for Automotive Application was developed with improved design of crowning and establishing of volume production processing technology. This also addresses the needs for being lightweight and compact for the recent application of HEVs/EVs.

In addition, the long-life thermal treatment “FA process” was developed based on the bearing steel globally available for procurement. The ULTAGE Tapered Roller Bearing has achieved an increased operating life and a significant torque reduction compared to the standard specification **(Fig. 4)**. Improvements such as optimization of contact stress distribution, which is mentioned later, contribute to the longer life.

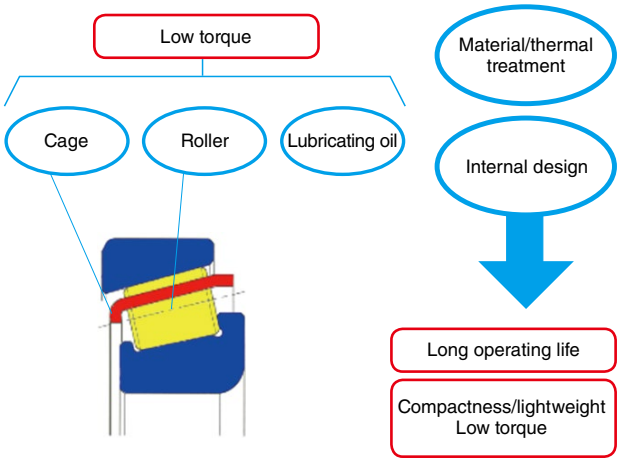


Fig. 3 Tapered roller bearing and characteristics

*1 ULTAGE® is a name created from the combination of “ultimate,” signifying refinement, and “stage,” signifying **NTN**’s intention that this series of products be employed in diverse applications. Additionally, ULTAGE® is also the general name for **NTN**’s new generation of bearings that are noted for their industry-leading performance.

Tapered roller bearings

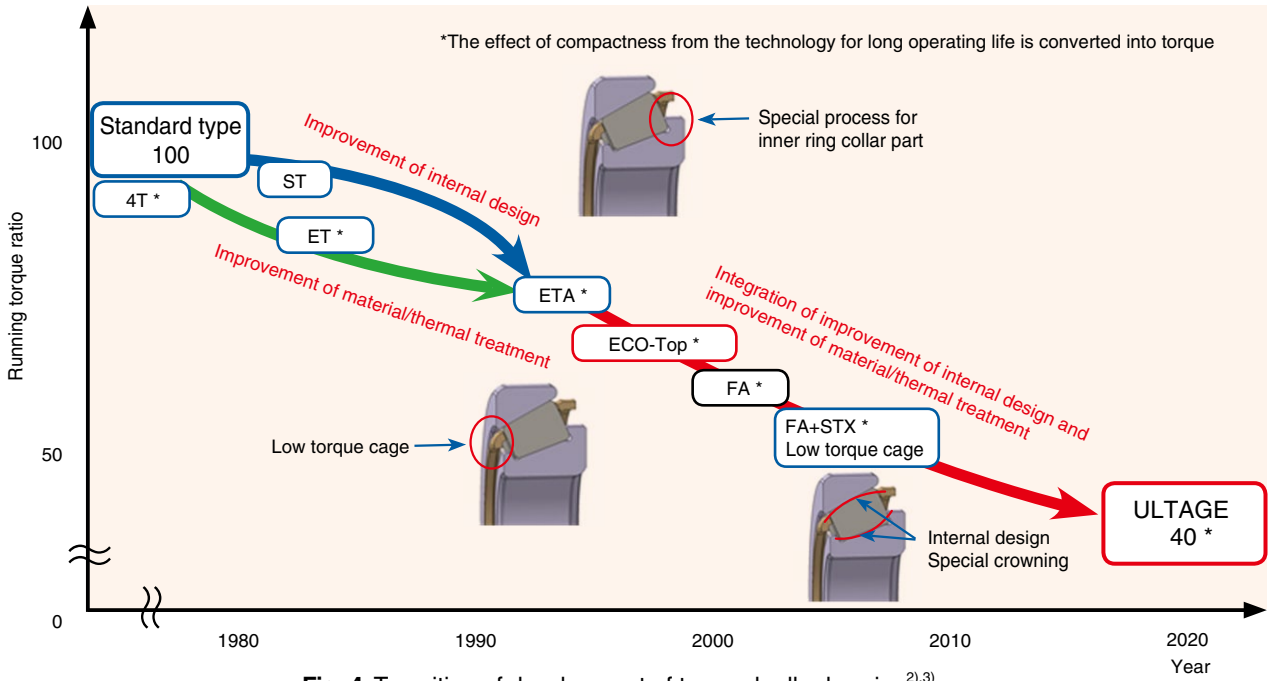


Fig. 4 Transition of development of tapered roller bearing[2),3)]

3. Introduction of Next-Generation Bearings for Automotive Use

The following is the introduction of the next-generation deep groove ball bearings for automotive use for “low fuel consumption” and the latest development of tapered roller bearings.

3.1 Ultra Low Friction Sealed Ball Bearing[4)]

In order to prevent reduction of operating life due to severe environments where hard foreign objects are present in the transmission lubrication oil, contact type seals are generally used. Contact type seals increase resistance to foreign objects such as the wear particles from gears. However, bearings with contact seals have larger torque due to the sliding resistance of the seal. The LE Seal optimizes the shape and material of the seal to achieve low torque while maintaining the sealing effect of the contact seal. This seal successfully reduces running torque and raises the circumferential speed limit. It accomplishes this by promoting formation of oil film between the seal lip and the sliding surface of the bearing inner ring for fluid lubrication condition, from the pressure wedge effect of the arc-shaped (half-cylindrical shaped) micro convexes **(Fig. 5)** placed on the sliding contact section of the seal lip **(Table 2, Fig. 6)**.

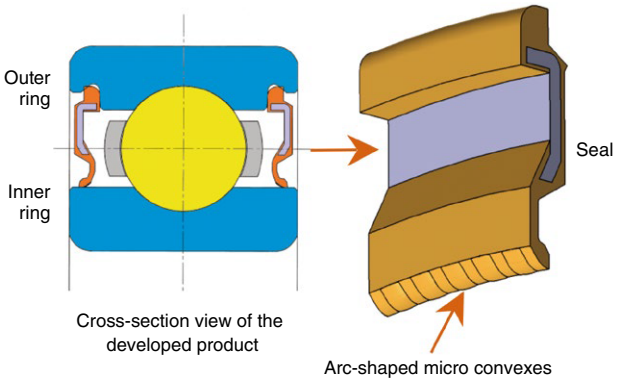


Fig. 5 Characteristics of ultra low friction sealed ball bearing

Features of developed product

(1) Reduction of 80% or more of running torque (compared to contact type seal)
(2) Support of high circumferential speed of 50 m/s or more
(3) Prevention of harmful foreign objects from penetrating

Table 2 Test condition

Item	Condition
Radial load	0.05 C (C: dynamic load rating)
Rotational speed (min^{-1})	1,500
Lubricating oil	CVT fluid
Bearing temperature (°C)	35-120

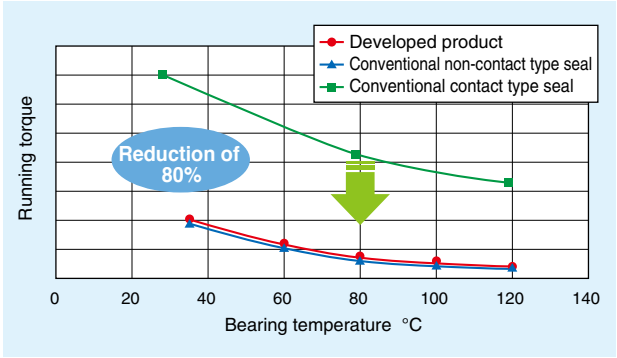


Fig. 6 Relation between bearing temperature and running torque

3.2 ULTAGE Tapered Roller Bearing for Automotive Application[5)]

Tapered roller bearings used in the power train such as the transmission and differential gears are required to be small and light, in addition to having long operating life and low torque.

ULTAGE Tapered Roller Bearing for Automotive Application is introduced in the following, which delivers the world’s highest standard of high-load capacity and high-speed rotational performance with robust crowning optimization technology to maximize the rolling fatigue life of bearing **(Fig. 7)**.

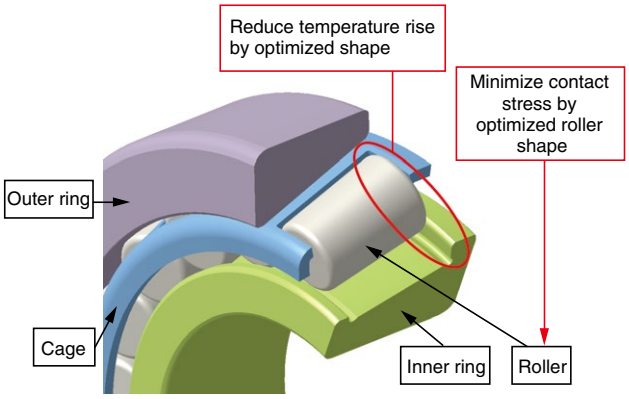


Fig. 7 Structure of ULTAGE tapered roller bearing for automotive application

Features of developed product

(1) World’s highest standard of high-load capacity
  • Basic dynamic load rating - 1.3 times*
(2) Long operating life (compared with the basic rating life)
  • Standard type (bearing steel; standard quenching) 2.5 times or more*
  • High-functionality type (FA process) 3.8 times or more*
(3) High speed rotational performance at the world’s highest level
  • Permitted rotational speed - approx. 10% improvement*
(4) Permitted inclination (magnitude of misalignment)
  • Permitted inclination - max. 4 times*

* Comparison of standard catalog values

The contact stress at the rolling contact area of the tapered roller bearing was minimized and a special crowning shape to reduce the excessive pressure on the edge of the contact area (edge load) was applied to the rollers. **Fig. 8** shows an example of calculation of contact stress distribution at the axial cross section of raceway. With ULTAGE Tapered Roller Bearing for Automotive Application, the bearing operating life is improved by suppressing the edge load at the edge of the contact area and equalizing the overall contact stress distribution by the adoption of special crowning.

In addition, because of the long operating life effect due to equalized contact stress distribution, the bearing can be designed for smaller and lighter form factor under the same operating life. Using a compact and lightweight design while maintaining operating life and the restriction of contact pressure, the bearing running torque was reduced by 60% compared to the standard bearing **(Fig. 9)**.

Furthermore, superior seizure resistance property was confirmed with the temperature rise of 1/3 of the standard bearing in the temperature rising test, as shown in **Fig. 10.** Optimization of the shape of the collar and the roller end surface shown in **Fig. 7** resulted in the superior seizure resistance property.

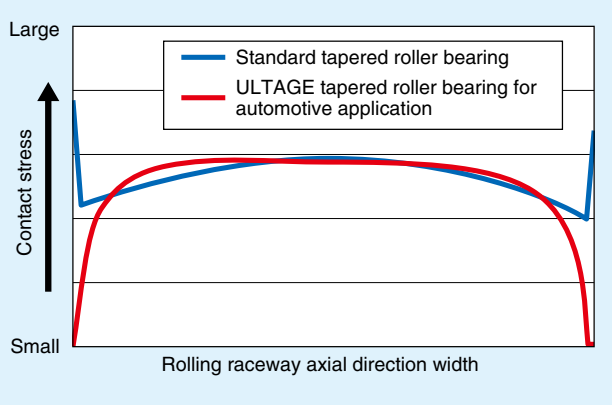


Fig. 8 Contact stress distribution on the raceway

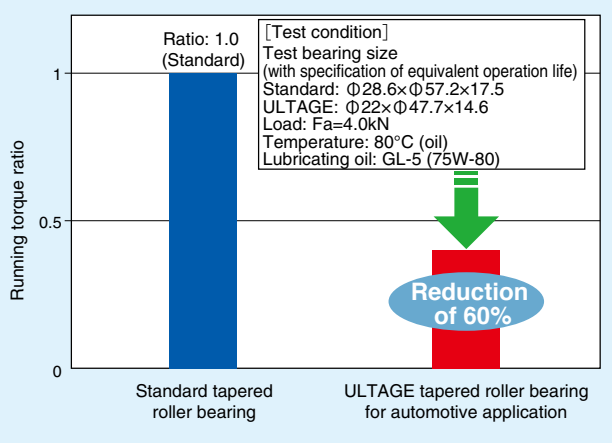


Fig. 9 Running torque ratio of bearings

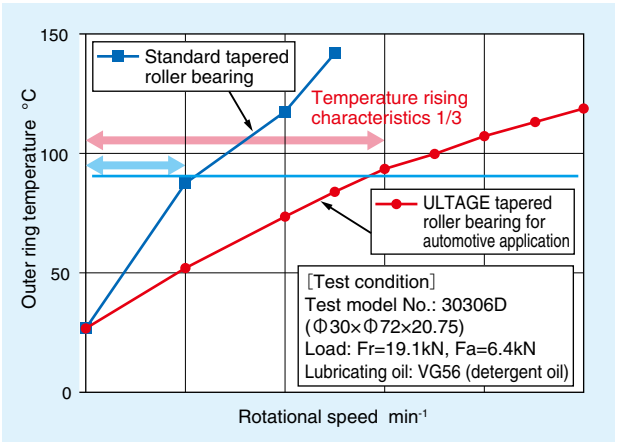


Fig. 10 Seizure resistance test (temperature rising test)

4. Conclusion

The development history of bearings for automotive application was reviewed from the viewpoint of reducing torque. As we have been proposing products ahead of market needs through the development of various technologies, we intend to support the coming stricter and rapidly changing demands. We hope we can continue to contribute to society, so that we will continue to be indispensable in the quest for development of more environmentally friendly, more comfortable and more useful next-generation vehicles.

References

1) NTN Catalog CAT. No. 3015- Ⅳ , P2
2) Hirokazu Nakashima, Trends in Materials and Heat Treatments for Rolling Bearings, NTN TECHNICAL REVIEW, No. 76 (2008), 10-16.
3) Chikara Ohki, Development of High Performance Bearing with Strengthened Grain Refinement, NTN TECHNICAL REVIEW, No. 78 (2010), 128.
4) Katsuaki Sasaki, Takahiro Wakuda, Tomohiro Sugai, Ultra-low Friction Sealed Ball Bearing for Transmission, NTN TECHNICAL REVIEW, No. 85 (2017), 62-66.
5) Yasuhito Fujikake, Takanori Ishikawa, Susumu Miyairi: ULTAGE Tapered Roller Bearing for Automotive Application, NTN TECHNICAL REVIEW, No. 85 (2017) 51-55.

Photo of author

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