History of Axle Unit Bearings for Automobile

1. Introduction

While rolling bearings for general use are standardized by organizations such as ISO and JIS, rolling bearings for supporting vehicle wheels (hereinafter "axle unit bearings") have gone through significant transitions over the years on their types/materials and design specifications.

In addition, as environmental issues have become the focus of the entire automotive industry, size, weight and fuel efficiency of vehicle components are strongly required to improve these environmental concerns. In parallel with the development of technologies to address these market requirements, the production/technology centers of NTN’s axle unit bearings have expanded globally (Fig. 1), which I would like to review with its history and market needs.

2. Market needs

The design specifications of axle unit bearings are diverse based on automotive manufacturer needs (mounting methods, allowable space and bearing size, bearing load carrying capacity, friction, sealing capability, rigidity and strength, etc.). Their historical and current requirements can be categorized as follows:

- Ease of assembly
- Simplification or elimination of bearing clearance adjustment
- Compactness and lightweight and large bearing load carrying capacity
- Maintenance-free
  (Particularly, elimination of greasing operation and external seals for sealed bearings)
- Reduction of components
- Reduction of total cost including bearing units, peripheral components and labor

Fig. 1 Axle unit bearing global production and R&D location

*Automotive Unit Engineering Dept., Automotive Business Headquarters
NTN has been developing and marketing volume production of GEN1, GEN2 and GEN3 successfully for approximately 40 years, responding to the above requirements 2).

3. Transition of axle unit bearings

3.1 From standard bearings to GEN1

Until the 1970s, standard bearings conforming to the ISO Standard were mainly used for axle unit bearings, placing two deep groove ball bearings or conical rolling bearings on an axle and appropriately selecting spacer rings and nut tightness to adjust the assembly clearance.

This method of using standard bearings had limitations in weight and size; therefore, the market needs for sealed/integrated bearings with potential for a compact and light form factor increased, which provided ease of assembly onto vehicles and did not require clearance adjustment. In the late 1970s, sealed double-row angular contact ball bearings (angular unit) and sealed double-row conical roller bearings (taper unit), called GEN1, were introduced into the market, and are still widely used as the axle unit bearings for passenger cars even in the 21st century. NTN produces GEN1 axle unit bearings in domestic plants, as well as overseas.

3.2 From GEN2 to GEN3

In the 1980s, the requirements for lightweight and compact vehicle components increased. As a result, the peripheral components of axle unit bearings, such as hub and housing (knuckle) were integrated as a unit, evolving into GEN2 (GEN2 and later products as units are called hub bearings at NTN, among the axle unit bearings). NTN started development of GEN2 hub bearings in 1979 and volume production in 1983, the first being produced in Japan. GEN2 hub bearings required integration of the hub flange and outer ring raceway surface as a unit. This was achieved by applying high frequency heat treatment to the raceways, ensuring rolling fatigue life required for bearings, rotating bending fatigue strength required for hub flanges, and fracture strength for expected large load bearings from the road surface were met. Adoption of GEN2 bearings by the automotive manufacturers increased from the 1980s to 2000s as its advantages are well recognized in the market.

Later, GEN2 evolved into GEN3 by integrating the inner ring, which improved ease of assembly of hub bearings in the vehicle assembly line 1).

NTN started volume production of GEN3 in the mid-1980s, the first being produced in Japan. Then, full adoption of GEN3 started in the latter half of the 1990s and its wave rapidly propagated throughout the world up until today.

In this case, GEN3 continued to evolve with superior specifications such as shaft-end tightening to facilitate pre-load control and improving ease of assembly in the vehicle assembly lines, as well as improving reliability by integrating wheel velocity sensors in the anti-lock brake system which prevents damage from pebbles and corrosion from muddy/salty water.

<table>
<thead>
<tr>
<th>Table 1 Characteristics of NTN axle unit bearings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generation</strong></td>
</tr>
<tr>
<td>Volume production start time</td>
</tr>
<tr>
<td>Structure</td>
</tr>
<tr>
<td>Feature</td>
</tr>
<tr>
<td>Ease of assembly to vehicles</td>
</tr>
<tr>
<td>Compactness</td>
</tr>
<tr>
<td>Rigidity</td>
</tr>
<tr>
<td>Pre-load control</td>
</tr>
<tr>
<td>Running torque</td>
</tr>
</tbody>
</table>

Superiority: ★★★★★ > ★★★★★ > ★★★ > ★★
NTN has been responding to the demand of axle unit bearings from the market based on specific technology accumulated over the years.

Table 1 on the previous page shows the transition and features of NTN’s axle unit bearings by generation, including the period when two standard bearings were used before integration.

### 3.3 Evolution of raceway material, grease and seals

#### (1) Raceway material

NTN used high carbon chromium bearing steel for inner/outer ring raceway materials for GEN1 axle unit bearings. For outer rings and hub rings of GEN2 and GEN3, carbon steel with high frequency heat treatment is used on the raceway, which contribute to increased rolling operating life and forgeability. For inner rings of GEN2 and GEN3, high carbon chromium bearing steel is used, similar to GEN1.

Axle unit bearings use grease lubrication which is easy to handle, contributes to simplified design of sealing device and is most economical. Internal grease for axle unit bearings is required to have the following features:

1. Reduction of friction and wear
2. Extension of bearing life
3. Prevention of corrosion
4. Prevention of foreign materials from entering
5. Prevention of fretting wear

#### (2) Grease

Table 2 shows features of grease used in NTN’s axle unit bearings. NTN originally used highly refined mineral oil as the base oil and urea-based organic compound as thickener. Then, grease with improved anti-corrosion properties was used as the standard product. In addition, grease with improved low-temperature tolerant properties was introduced for volume production by blending additives to prevent fretting wear when used for long-haul freight car transportation in cold regions. Furthermore, with stricter fuel efficiency regulation planned to be implemented by 2021 in Japan, U.S. and Europe, due to the recent increase of fuel cost and environmental issues such as global warming, low-torque specification is required for axle unit bearings. To meet the low torque requirements, NTN has developed low-torque grease by modifying the base oil/kinematic viscosity and consistency. This low torque grease is currently in volume production.

#### (3) Seals

Seals for axle unit bearings are required to have air-tightness and low torque properties preventing muddy water from penetrating from the operating environment. Table 3 shows characteristics of seals used in NTN’s axle unit bearings. It shows the evolution from 2-lip seal that consist of only radial lips to Hipack seals which improved sealing properties.

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**Table 2 Characteristics of NTN axle unit greases**

<table>
<thead>
<tr>
<th>Performance</th>
<th>Conventional grease</th>
<th>Standard grease</th>
<th>Grease with improved fretting resistance</th>
<th>Low-torque grease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anti-corrosion property</td>
<td>★★★★★</td>
<td>★★★★★</td>
<td>★★★★★</td>
<td>★★★★★</td>
</tr>
<tr>
<td>Fretting resistance</td>
<td>★★★★★</td>
<td>★★★★★</td>
<td>★★★★★</td>
<td>★★★★★</td>
</tr>
<tr>
<td>Torque</td>
<td>★★★★★</td>
<td>★★★★★</td>
<td>★★★★★</td>
<td>★★★★★</td>
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</tbody>
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against muddy water by adding side lips, as well as significant anti-corrosion properties of the seal land by adding stainless steel slingers. Additionally, it achieved low-torque properties responding to the aforementioned low-torque requirement, by optimizing seal lip sliding surfaces and developing grease dedicated for seal lips. Furthermore, NTN has extended volume production of value-added seals by integrating magnetic encoders, vulcanizing magnetic rubber on the side of the slinger.

3.4 Next generation hub joint

After the development of GEN3 for volume production, NTN completed development of the next generation hub bearings, GEN4, integrating constant velocity joints (hereafter “CVJ”). This technology has not been adopted since it requires significant modification to the vehicle assembly lines at the automanufacturers.

Therefore, NTN developed a new joint method for CVJ and hub bearings which can be assembled without changing the assembly lines at the automanufacturers and has achieved a significant reduction in weight. The following is the introduction of Press Connect Spline Hub Joint (PCS-H/J) (Fig. 2).

Conventionally, CVJ and hub bearings are engaged with a spline and tightened with a nut. The spline teeth are generally designed for interference fit with the helix angle to eliminate backlash, which requires long spline fit length ($L_1$ in Fig. 3 (a)). The new press connect fit method finishes forming the spline by tightening a bolt, which results in a tighter interference fit than the CVJ stem spline on the inner diameter of the hub bearings. This enables the torque to be applied to the entire spline area, resulting in significant reduction of spline fit length ($L_2$ of Fig. 3 (b)).

Adopting the press connect method, PCS-H/J achieves approx. 65% reduction in CVJ stem length, 12% reduction in weight (max) and no spline fit backlash.

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**Fig. 2 Structure of PCS-H/J**

**Fig. 3 Example of The Application and Spline Cross Section of PCS-H/J**
4. Summary

NTN has been leading the evolution of axle unit bearings for approximately 40 years, and through expansion of market share with the merger of NTN-SNR in 2008, it has acquired the top share today.

This paper reviewed the history of axle unit bearings on the occasion of the 100th anniversary of NTN. This development is the result of efforts of the forerunners which we are very proud of, and we strive to continue this spirit of development while continuing to achieve vehicles with higher functionality and better comfort, setting our eyes on the next 100 years.

References