Activities and Achievements for Automotive Market Trends CASE

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In this article, we explain our considerations and actions of research & technological development for fuel economy regulations, autonomous driving and car sharing, in the change of business conditions represented by “CASE”. In other words, we introduce our development of technologies and products which meet the needs of the market.

Today, automobile industry is facing a great change. We are to develop in advance of the market trends, improving efficiency and accuracy with high speed. We also mention our CAE simulation technologies that support the research & technological development based on our core competence.

1. Introduction

Europe implements the strictest fuel efficiency regulations, and it will be necessary to further improve fuel efficiency by approximately 15 % in 2025 versus 2021 regulations. Automobile manufacturers will continue to improve fuel efficiency into the future by decreasing vehicle weight, improving aerodynamics, engine downsizing, and further shifting from mild hybrids to strong hybrids and fully electric vehicles. **(Fig. 1)**

Furthermore, as shown in **Table 1**, we know that the level of autonomous driving can be divided into 4 to 5 stages. Current mainstream autonomous driving systems are considered to be very effective in reducing traffic congestion at level 1, reducing road accidents due to human error at level 2, and reducing the environmental impact at level 3 due to the fact that they reduce the burden on the driver. However, it is necessary to closely monitor industrial trends for level 4 and 5 until transportation system management has been established a little further in the future.

Recently, car sharing has been increasing mainly in urban areas. The current utilization rate per hour for passenger cars is said to be around 5 %. If this utilization rate increases due to car sharing, there will be a demand to improve the durability of all parts, including **NTN** parts, or provide vehicles with various types of sensor functionality such as failure detection.

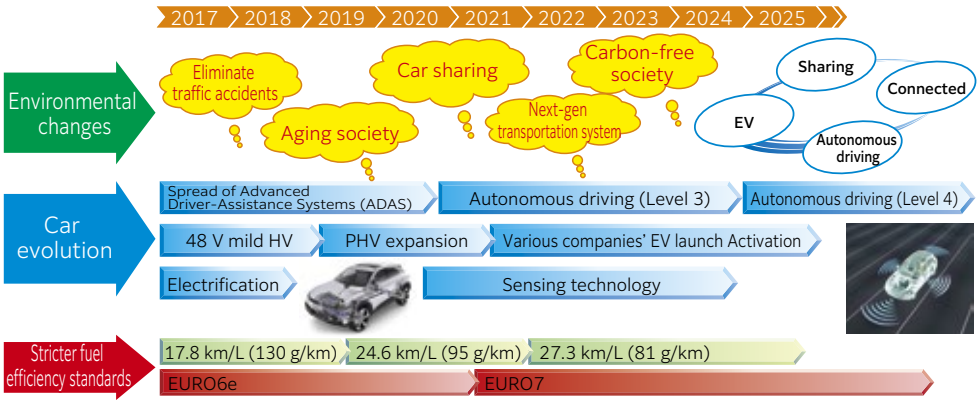

Fig. 1 Market trend of automobile

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Table 1 Issues and measures for each level of autonomous driving

Level	Challenges	Measure
1	Reduce traffic congestion	Can reduce traffic congestion by managing the transportation system
2	Reduce traffic accidents	Reduce accidents due to human error by controlling the vehicle with a autonomous driving system
3	Reduce environmental impact	Reduce unnecessary acceleration or deceleration and reduce environmental impact by reducing traffic congestion
4	Movement assist for the elderly and disabled	Assisted movement for people who are unable to drive using autonomous driving vehicles
5	Labor-saving	Resolve driver shortages using unmanned driven vehicles

2. Market Needs and Responding to These Needs with NTN's Research and Development

There is a strong demand from the market to produce lighter and more compact bearings that have a lower friction and such from the perspective of reducing fuel consumption and saving energy **(Table 2)**. **NTN** has been making progress in developing high-performance products and deploying them to the market more than our competitors based on our accumulated technology and knowledge. We have also established the **NTN** Next Generation Research Alliance Laboratories at Osaka University (in 2017) to conduct research into next-generation technology that cannot be achieve through corporate research alone, and have continued to incorporate findings from this research into **NTN** technology.

For example, we took up the challenge of producing an axle bearing that has approximately 60 % lower friction than conventional products and achieved a product to meet this goal. Grease-filled bearings have a seal to prevent the grease from leaking and prevent muddy water from penetrating from outside the bearing. It was necessary to establish an optimal design for the sealing characteristics and friction characteristics, which was the root of the challenge concerning friction. We were also successful in reducing the friction of transmission ball bearings by 80 %. In the past, a contact-type seal was used to prevent hard foreign objects, such as gear debris generated inside the transmission, from entering the bearing. However, after coming up with a bold new design for the seal we achieved an 80 % reduction in friction.

The electrification of auxiliary equipment driven by the internal combustion engine is also making progress due to the electrification of drivetrains. Therefore, low friction, lightweight and compact bearings are required for the purpose of achieving further energy reduction. It is necessary to also respond to speed increases that accompany motors becoming faster. **NTN** has explored solutions for these issues as it has continued to do so in the past. Our core competencies lie in technologies that include multi-material technology, heat treatment technology, high-precision machining technology, measurement technology, surface processing technology, and simulation technology. **NTN** has a dedicated team of researchers and engineers who excel in these core competencies in our Research and Engineering Division. We believe the time has come to contribute towards the automotive industry by using these core competencies and various human resources to further expand the playing field to meet market needs such as improved fuel efficiency.

We have also received many requests for high-performance module products, beginning with bearings, utilizing these core competencies. All of which have the goal of reducing traffic accidents, providing freedom of movement in a safe and secure manner, bringing convenience to users, and establishing environmental measures. **NTN** has been developing electric module products by integrating such things as motors and controllers through collaboration with other companies and in-house development. Some of these products have already entered the preliminary stage of mass production. More specifically, products such as electric oil pumps, electric water pumps, and electric parking locks for which demand is increasing. This also includes products such as Hub Bearing with Motor Generator Function (eHUB) and Hub Bearing with Steering Assist Function (sHUB™), which provide multi-functionality to the axle bearing, a bearing that has taken the top global share.

Table 2 Market trend and needs

	Market trend	Market needs
1	Environmental technology (Low fuel and power consumption)	・Electric module products ・Lower friction ・Higher speed ・More compact and lightweight ・Greater efficiency ・Greater reliability
2	Car sharing	・Greater reliability ・Durability
3	Comfort	・Low-noise profile
4	Safety and autonomous driving	・Sensors, control technology (linearity)

3. Developed Products

3.1 Electric Module and Actuator Development and Application Examples

We have developed an electric module and actuator constructed from a motor, sensor and mechanical body that utilizes such as motor design technology and bearing/ball screw product technology, which are some of our core competencies. More specifically, the BIII-series **(Fig. 2)** combines a hollow high power output brushless DC motor and a ball screw, with a linear motor mechanism arranged in the hollow section of the motor. The SP-series **(Fig. 3)** is also available for use in applications that require a thin and high torque rotational actuator by incorporating a reducer in the hollow section of the BIII-series.

The following are application examples proposed to the market, beginning with the electric module and actuator.

(1) Electric hydraulic brake (BIII-series)
Applying the coaxial type BIII-series with built-in ball screw to the master cylinder shaft can create a more compact electric hydraulic brake system.
(2) Electric variable valve timing control (SP-series)
Incorporating the SP-series into the camshaft can achieve a more compact and highly efficient electric variable valve timing mechanism.
(3) Electric oil pump (SP-series)
Incorporating a thin and highly efficient SP motor and integrating it with a controller can create a more compact electric oil pump.

- Compact design due to coaxial arrangement
- Optimized size, torque and output using a polymerized structure for the magnet and core
- Shares the magnet and coil, which are the main components of a motor
- Built-in non-contact linear position sensor

Fig. 2 BⅢ series

- Brushless DC motor series
- Hollow structure based on the motor unit from the BIII-series
- Can be applied as a thin and high torque rotational actuator by incorporating a reducer in the hollow section
- Built-in rotation angle sensor

Fig. 3 SP series

3.2 Axle Bearing Low Friction and Modular Products

3.2.1 60 % Reduction in Friction “Low Friction Hub Bearing III” (Fig. 4)

“Low Friction Hub Bearing III” is constructed with seals, grease and an internal bearing design in pursuit of lowering the friction, reduces the rotational torque by about 60 % when compared to conventional products, and has improved vehicle fuel efficiency by approximately 0.53 % **(Fig. 5)**. This product has already been proposed to several automobile manufacturers and is undergoing prototype evaluation and being ordered by customers.

(1) Low friction due to the seal
Approximately 50 % of rotational torque from a hub bearing is friction due to sliding with the seal. The seals ability to resist muddy water is an important characteristic and the following two points are challenges in maintaining this characteristic and lowering the friction. The friction was reduced for both the outer seal and inner seal making full use of each element test and simulation technology.
① Labyrinth structure, lip shape and material
② Optimal design for lip contact surface, lip application dedicated grease

(2) Low friction due to grease inside the bearing
The following 3 points are challenges present for resistance and friction that accompany grease agitation and such. Low friction was achieved by optimizing the thickening agent and additive and lowering the viscosity and friction of the base oil.
① Rolling viscous resistance between the rolling element and raceway surface
② Friction due to micro slips at the rolling contact zone of the rolling element and raceway
③ Resistance due to grease shearing between the rolling element and cage pocket surface

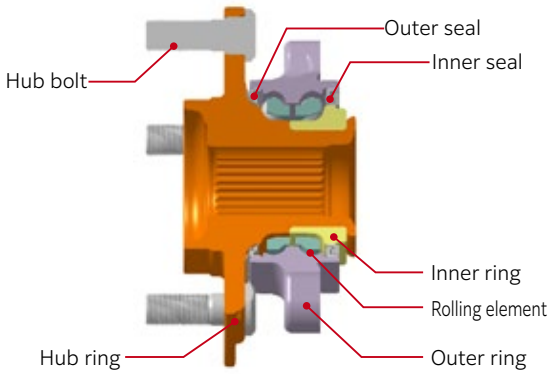

Fig. 4 Low Friction Hub Bearing Ⅲ

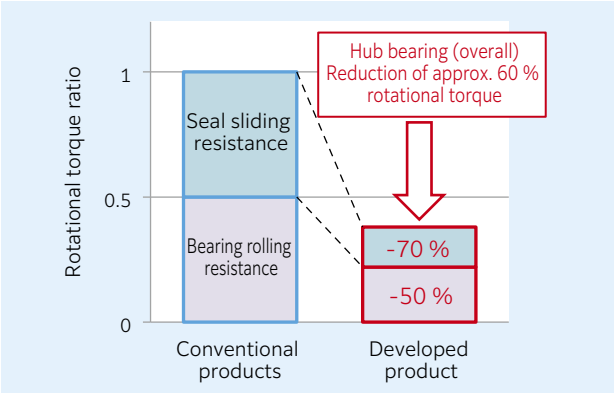

Fig. 5 Performance of Low Friction Hub Bearing Ⅲ

3.2.2 Hub Bearing with Steering Assist Function "sHUB ™" (Fig. 6)

Since the steering device arranged at the front wheels of a vehicle is mechanically connected to the tires on both sides (left and right) of the vehicle, the steering angle for the left and right tire is uniquely determined against the steering angle of the steering wheel. When making a large turn at low speed, the turning radius of the path through which each of the left and right wheel passes through is different. Therefore, it is necessary that Ackermann geometry (a setup in which the steering angle for the inside wheel is large and the outside wheel is small) is used for the left and right wheel to ensure the vehicle turns smoothly in theory. Furthermore, the turning center of a vehicle changes depending on the vehicle speed in a medium to fast speed range so the ideal left and right wheel angle will also change.

NTN developed the "Hub Bearing with Steering Assist Function" (hereafter, sHUB™), which grants the hub bearing with a function that can control steering geometry depending on the conditions.

sHUB™ achieves reliable and comfortable driving by controlling the angle of the left and right wheel separately according to the vehicle driving conditions. This product is a module system that improves straight running stability and driving reliability when cornering and also contributes towards avoiding dangers during an emergency such as when a vehicle wheel slips while driving on a low coefficient of friction road. It can also save energy when driving by reducing cornering drag when turning the vehicle normally. It is a module that achieves vehicle maneuverability and a comfortable driving experience with the aim of applying it to such things as avoidance operation in future autonomous driving technology. The following are its features.

(1) assembled on both left and right wheels to separately set the left and right steering angle
(2) Ideal angle control that matches driving conditions at each wheel separately
  ・Energy-saving driving with reduced cornering drag
  ・Stabilizes the vehicle attitude even during emergencies such as to avoid dangers
(3) Can be assembled regardless of the type of suspension system
  Can be assembled without significant modification to the existing vehicle's driven wheels (front and rear)
(4) Provides a compact and lightweight solution using an optimal internal bearing design

Furthermore, sHUB™ for the rear wheels described in this paper was designed for the purpose of further improving vehicle maneuverability and achieving safe, comfortable, and energy-saving driving by assembling it on the vehicle's rear driven wheels to control them. We have also received many inquiries about its application on front-wheel-drive vehicles.

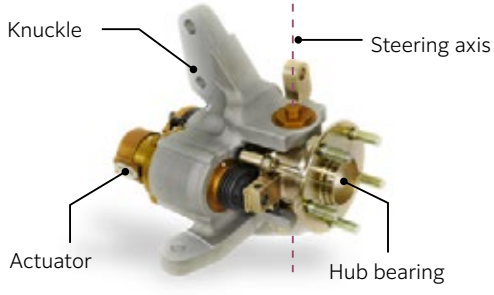

Fig. 6 Structure of sHUB™

3.3 Support for Next-Generation Mobility with World's Highest Level in Low Temperature Rise and Low Torque "Low Temperature Rise and Low Torque Tapered Roller Bearing" (Fig. 7)

Within this revolutionary period typified by CASE (Connected, Autonomous, Shared & Services, Electric) and against the backdrop of such things as the increase in vehicle travel distance due to vehicle electrification and car sharing, the move to higher efficiency power transmission devices is underway. Furthermore, due to reduction in the amount of lubricating oil in devices and the switch to low-viscosity oil, there has been a greater need for bearings to work under harsh lubrication conditions and for bearings with lower torque.

To fill this need, we developed the "Low Temperature Rise and Low Torque Tapered Roller Bearing" for automobile transmissions and differentials. By optimizing the newly designed plastic cage and the internal bearing design, we achieved the world's highest level in low temperature rise (capability for protecting against seizure) and low torque performance. The following are this product's features.

(1) Low temperature rise:
  10 times improvement in comparison with **NTN** standard type (world's highest level)
  ・Reduces temperature rise even under harsh lubrication conditions due to decreasing amount of lubricating oil and reducing lubricating oil viscosity
  ・The concave shape of the plastic cage enables oil to be supplied to the roller end face when there is insufficient lubrication to reduce temperature rise
  ・Reduces temperature rise with a design that improves the lubricity of sliding contacts between the roller end face and inner ring cone back face rib surface
(2) Low torque:
  66 % reduced torque compared to **NTN** standard type (world's highest level)
  ・Plastic cage reduces excessive lubricant inflow into the bearing, reduces rotational torque due to lubricant stirring resistance
  ・Smaller bearing size with longer operating life due to optimized internal bearing design and roller bearing design
  ・Reduces rotational torque due to reduction in rolling contact length between rolling elements (rollers) and raceway (inner and outer rings)

Since we were able to create a compact bearing size with this product, it contributes to making devices more compact and lightweight, and further increasing the amount of space inside the vehicle as well as improving driving comfort, in addition to providing greater efficiency for power transmission devices, and making vehicles more fuel and power efficient.

Fig. 7 Low Temperature Rise and Low Torque Tapered Roller Bearing

4. CAE Simulation Technology

In order to quickly launch competitive products on the market that meet market needs, it is essential to make research and technology development work more sophisticated and efficient. We have introduced CAE simulation technology as a means of this achievement. This technology allows to verify the performance of products including peripheral components at the design stage. This makes it possible to optimize design variables before creating a prototype, and reduce the number of prototype builds and tests. These factors can achieve improved work efficiency, reduce development costs, and shorten development lead times.

To ensure that designers can easily use CAE simulation technology required to develop products, we have been developing our own CAE system and program, and part of it is introduced here.

(1) FEM analysis automated system **(Fig. 8)**

FEM analysis is used when designing axle bearings to evaluate the stress and rigidity. In the past, this work was performed by dedicated CAE personnel but after developing a system that automates model creation, calculation, and results processing required for the analysis, it is now possible for designers to perform this analysis by themselves. This has enabled us to reduce the time needed to hold meetings between designers and dedicated CAE personnel and the time waiting for analysis to begin, and also speed up design changes influenced by the calculation results.

(2) Engineering calculation program for transmission bearings **(Fig. 9)**

Progress is being made for multi-stage and increasingly complex transmissions to respond to environmental requirements. To design bearings used in such products, we have developed an engineering calculation program that enables designers to easily create a model of the entire transmission and simulate it. This has enabled us to perform batch calculations for the bearing operating life and the load acting on each bearing's rolling element inside the transmission, a task that was traditionally performed using a combination of several programs. Further using a dynamic analysis system[1] for the bearing alone enables us to calculate stress generated at the cage as well[2) 3)]. Using these programs has enabled us to efficiently perform advanced optimal design for bearings that match the characteristics of transmissions.

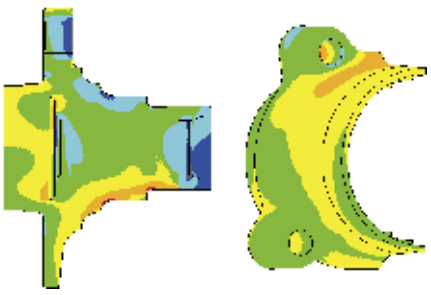

Fig. 8 FEM analysis sample of axle bearing

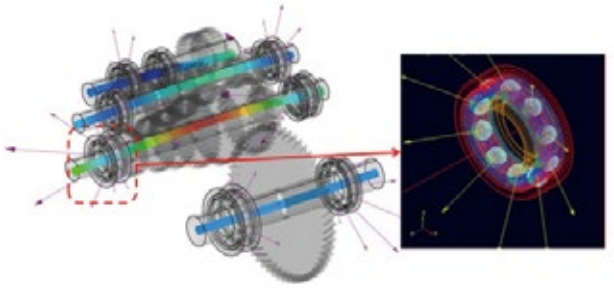

Fig. 9 Simulation sample of transmission bearing

5. Conclusion

This paper describes **NTN**'s views and how the company will proceed concerning research and technology development with regards to fuel efficiency regulations, autonomous driving technology and car sharing amid environmental changes typified by CASE.

We believe that the information contained here has provided you with an understanding of our product development and market expansion that is superior to our competitors based on **NTN**'s accumulated technology and knowledge.

All developed products introduced here are the results of improving and incorporating elemental technology. We will continue to provide global proposals as specifications that can apply these products to next-generation mobility.

We sincerely hope that by providing products that resolve the various issues related to automobiles into the future will enable us to contribute to achieving a NAMERAKA smart mobility society.

References

1) Mariko Sekiya, Integrated Bearing Dynamic Analysis System (IBDAS), NTN TECHNICAL REVIEW,No.79, (2011)119-123.
2) Tomoya Sakaguchi, Kazuyoshi Harada, Sadatsune Kazama, Advancement of Cage Stress Analysis of Rolling Bearings, Tribology Congress Spring 2012 Tokyo, (2012) 233.
3) Tomoya Sakaguchi, Kazuyoshi Harada, Sadatsune Kazama, Advancement of Cage Stress Analysis of Rolling Bearings, NTN TECHNICAL REVIEW, No.80, (2012) 92.

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