NTN's Approach and Effort for CASE

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Currently, it is said that automotive industry enters a phase of major change which comes “once in a century”.
One of the representative development trends is CASE.
"CASE" consists from initials of Connected (External connection), Autonomous (Autonomous driving), Shared & Services (Car sharing and service or Car sharing only) and Electric (Electrical vehicles).
CASE is advocated by Dr. Dieter Zetsche (ex-CEO of Daimler AG) at Paris Motor Show 2016.
This paper introduces our developing activities with this major trend which we are greatly concerned with.

1. Introduction

Automobiles are a useful means of transportation, but a significant change to electrification is now underway due to recent environmental issues. Autonomous driving is another area of research for a safer and more efficient transportation system. Research of autonomous driving involves both control of a single vehicle and a safe and highly efficient autonomous driving system that incorporates various types of information. Particularly in Japan, with a large aging society, autonomous driving should be effective means in avoiding accidents.

In addition, the car sharing system is also expanding, particularly in urban environments where automobiles are being shared instead of owned.

As such, the automobile industry is in an era of transformation so-called “once in a century”, which is driving an alliance among automobile manufacturers in order to reduce the burden of development expenses. As new entrants are making strides into autonomous driving from outside the automobile industry, such as communication companies, it is not clear from the consumers who the decision makers of the automotive industry will be in the future.

The impact of these large trends on product development is significant for **NTN**, and as a result we have been developing electric module products. We have also conducted development of energy saving features on the existing products.

This paper describes our approach for development of new electric module products to support CASE, which is depicted in **Fig. 1**, as well as an overview of new development to our existing products for faster, more reliable, quieter and more durable operation in addition to our continuous efforts to reduce size/weight and lower friction.

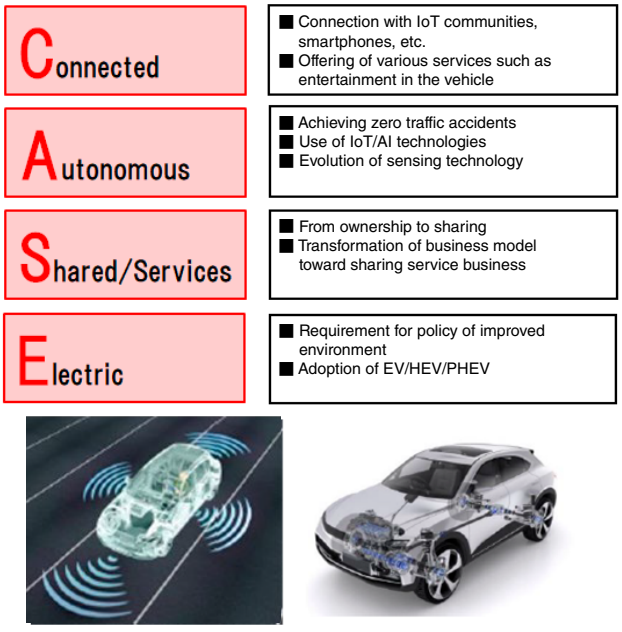

Fig. 1 Overview of CASE for automobile

2. Approach to Support CASE

2.1 Development of the Electric Actuator and Its Applications

NTN has developed the “Electric Motor and Actuator” series, which is essential for by-wire control that is expected to be widely used for vehicle drive and control.

Significant electrification is now underway in the

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automotive industry, particularly with by-wire control as the core technology along with the various systems that support drive and control, in response to the requirements needed for autonomous driving and improved fuel efficiency.

To address such market trends, **NTN** developed the "Electric Motor and Actuator" series shown in **Table 1** and **Fig. 2**, combining its core technology of bearings and ball screws with motor design and electronic control technology for controlling vehicles. The product line-up features common components and specifications with a variety of shapes and sizes, which eliminates the need for individual designs and reduces development time.

The developed products can be applied to various on-board applications, but should be applicable for a wider range of fields in the future that is beyond automotive. **NTN** is aiming to establish early volume production and promote global distribution for on-board applications first, and then expand applications to other devices that use actuators.

Table 1 Types of electric actuators

	Type	Feature
1	Parallel shaft Type B II	• Lightweight with resin housing • Can be equipped with a reverse input rotation prevention unit that can be used for parking brakes, etc. • Add-on reducer unit that can be used for high-thrust applications • Integrated non-contact linear position sensor
2	Coaxial Hollow Shaft Type B III **(Fig. 2)**	• Compact design with coaxial configuration • Optimum size, torque and output by layering the magnet and core • Common magnets and coils that are the core components of motors • Integrated non-contact linear position sensor

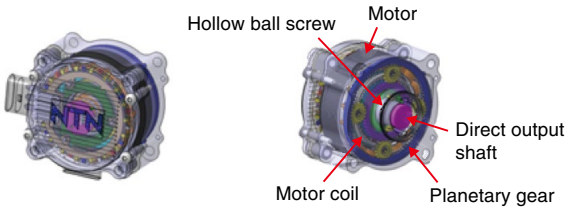

Fig. 2 External view and configuration of Coaxial Hollow Shaft Type B III

2.1.1 Electric Oil Pump for Transmission

An example of this development is the electric oil pump for idling stop function. Idling stop is provided as one of the methods to reduce fuel consumption and requires a lightweight/compact, more efficient and higher energy savings electric oil pump, which requirement is met by the pump that uses **NTN**'s "Electric Motor and Actuator."

In addition, the ZEV (Zero Emission Vehicle) regulations in the U.S. and China, for example, require EV mode driving of approx. 50 km or more for HEVs and PHEVs, which is only met by electric oil pumps with higher output than those for idling stop.

2.2 Module Product with Added Functionality for Axle Bearings

2.2.1 Hub Bearing with Motor Generator Function "eHUB"

"eHUB **(Fig. 3)**" is a product already developed which combines a motor generator with a hub bearing to support wheel rotation. As improvement of fuel efficiency of vehicles progresses and regulation of CO_2 emission is strengthened, the adoption of the "48V Mild Hybrid System" (hereafter, 48V MHEV), which improves fuel efficiency by adding power at start or acceleration of vehicles, has increased.

The "48V MHEV" is a system that uses the engine as the main power source and provides additional power using a small motor while driving the engine when starting and accelerating. Also, the energy can be recovered as electric power in deceleration (regeneration) resulting in even better fuel efficiency.

When "eHUB"s are used for front-wheel drive vehicles they are also mounted on the rear wheels (non-driven wheels) to provide driving assist power with the motor in order to reduce engine load and also act as power generators to regenerate energy into electric power when decelerating. When "eHUB" is combined with the "48V MHEV" already in use (such as starter generators), an improvement of up to 25% in fuel efficiency is expected compared to conventional vehicles with only engines. It can also be used for EV creep and vehicle stability control on slippery roads (low friction roads).

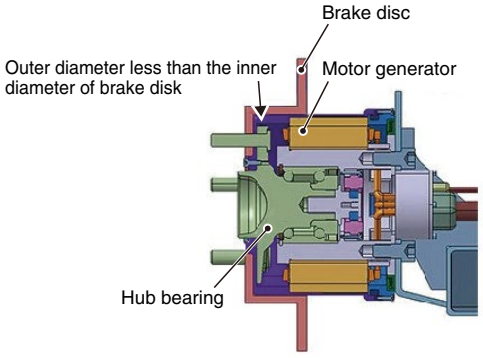

Fig. 3 Cross-section of Hub Bearing with Motor Generator Function

2.2.2 Hub Bearing with Steering Assist Function "sHUB"

NTN has developed a hub bearing with a steering assist function, "sHUB", which integrates the hub bearing and steering angle adjustment mechanism. "sHUB" combines motor and motion control technology with the design and manufacturing technology that has been acquired over many years with the development of the hub bearing, which **NTN** has the No. 1 global share.

With conventional vehicles, the tires and the steering device placed on the front wheels are mechanically connected and therefore the turning angles of both front tires are fixed to the angle of the steering wheel being operated. While driving it was not possible to change to an optimal setting for each driving condition, such as driving straight or cornering.

"sHUB" (shown in **Fig. 4**) is a module product that can correct the steering angle at the left and right wheels separately and be installed onto a vehicle's front wheel steering and the suspension system without replacing the existing steering device. Optimum correction of the turning angles of each tire based on the data on the speed and steering wheel operating angle while driving improves the cornering performance and high-speed stability, as well as vehicle stability in emergency against skidding, for example, and fuel efficiency.

It is expected that "sHUB" will be used as part of a system to provide a safer risk avoidance performance in full-autonomous driving vehicles and it is anticipated that this product will expand in the market in the future.

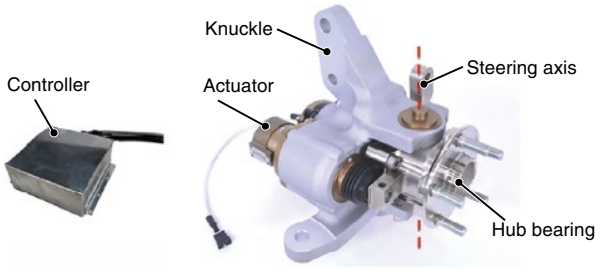

Fig. 4 General structure of Hub Bearing with Steering Assist Function

3. Improvement of the Existing Products for Reduced Size/Weight and Lower Friction

3.1 "Ultra-low Friction Sealed Ball Bearing" for Transmission

NTN developed the "Ultra-low Friction Sealed Ball Bearing" for automotive transmissions that reduces rotating torque by 80% compared to the conventional contact sealed type bearing by adopting a proprietary shape of the ultra-low friction seal.

Lower torque is required for better fuel efficiency in addition to a longer life for transmission bearings used for automobiles. Use of the contact sealed type was standard for longer operating life by preventing hard foreign objects, such as wear debris from the gears in the transmission, to penetrate the bearings. However, this resulted in drag torque due to the seal contacting the inner ring when rotating. Furthermore, in applications where high-speed rotation is required, such as recent EVs and HEVs, use of the contact sealed type was difficult due to the restriction of the peripheral speed limit of the seal.

"Ultra-low Friction Sealed Ball Bearing" has achieved an 80% rotating torque reduction compared to conventional products and provides a low torque effect equivalent to that of the non-contact sealed type. This is achieved by adopting a newly developed contact type seal which arranges arc-shaped (half-cylindrical) micro convexes at evenly spaced intervals on the sliding contact section of the seal lip, as shown in **Fig. 5**. During rotation an oil film is formed between the sliding surfaces of the seal and inner ring due to the wedge film effect of the micro convexes. This significantly reduces the drag torque of the seal, even if it is a contact sealed type. Also, because the seal lip convexes are microscopic, they allow lubricant to pass through but prevent harmful hard foreign matter from entering the bearing, which contributes to longer bearing life.

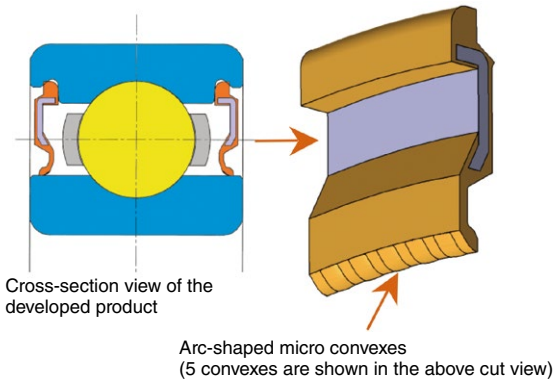

Fig. 5 General structure of "Ultra-low Friction Sealed Ball Bearing" for Transmission

3.2 ULTAGE Tapered Roller Bearings for Automotive Application

"ULTAGE Tapered Roller Bearing for Automotive Application **(Fig. 6)**" is introduced in the following paragraphs, which delivers the world's highest standard load capacity and rotational speed performance by optimizing the internal design of the bearing.

Tapered roller bearings for automobiles are used in components such as transmissions and differentials, and need to have a high-load capacity in order to operate in conditions that are becoming increasingly more harsh, including greater loads due to a higher power output, as well as greater unbalanced loads caused by the lower rigidity due to lightweight housings. The bearings also need to provide the low torque required for lower fuel consumption and high-efficiency and high-speed rotational performance with a low temperature rise.

"ULTAGE Tapered Roller Bearing for Automotive Application" improved on the optimal design technology that maximizes the rolling operating life developed for the Large Size Tapered Roller Bearing and applied it to the compact series lineup. This was done to realize the maximum potential of the bearing operating life even under increased and high unbalanced loads by making the contact stress even between the rolling elements (rollers) and the raceways (inner/outer rings).

This developed product has realized a load capacity 1.3 times higher and a rated life over 2.5 times longer than the conventional product. In addition, the permitted rotational speed increased by approximately 10% to offer the world's highest level in load capacity and rotational speed performance by optimizing the sliding contact zone between the rollers, inner ring and cage.

Fig. 6 ULTAGE Tapered Roller Bearing for Automotive Application

3.3 "Low Friction Hub Bearing III" Reducing Rotational Friction by 62%

"Low Friction Hub Bearing III" reduces rotational friction by 62% compared to the conventional product and is introduced in the following paragraphs.

Hub bearings that support wheel rotation are now being required to further reduce rotational friction in addition to satisfying the basic performance, such as operating life and strength.

NTN has been researching and developing hub bearings for many years in pursuit of lighter weight, longer operating life, and higher efficiency. We have also promoted to unitize bearings and components (GEN1 to GEN3) to improve fuel efficiency and ease of assembling by making them smaller and lighter. We also developed hub bearings with longer operating life and lower friction by improving materials, greases, seals, and other items, for use in the global market. Today, **NTN** has the world's largest market share in hub bearings.

"Low Friction Hub Bearing III" reduces rotational friction by 62% compared to the conventional product and improves the fuel efficiency by approximately 0.53%, by developing a low friction grease as shown in **Fig. 7**. The newly developed product has improved operating life and resistance to fretting wear in low temperature. In addition, by optimizing the preload inside the hub bearing, the developed product reduces the rotational friction of the bearing itself while still maintaining the required performance.

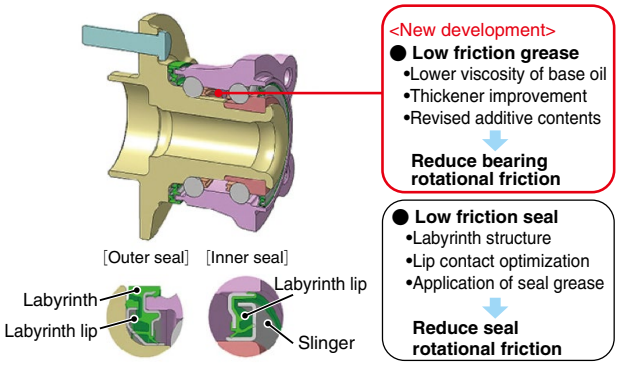

Fig. 7 Low Friction Hub Bearing III

3.4 Compact Plunging Type Constant Velocity Joint for Propeller Shafts "HEDJ-P"

"HEDJ-P" **(Fig. 8)** is a plunging type constant velocity joint for propeller shafts that achieves the world's highest level of compactness and lightweight with 17% weight reduction and 6% decrease in outer ring outer diameter when compared to conventional products.

Propeller shafts are used on vehicles, such as ones with 4WD, and take the role of transferring transmission rotation to the front and rear of the vehicle, as shown in **Fig. 9**. Also, constant velocity joints for propeller shafts have increased in application as there is now an increase emphasis on NVH (Noise, Vibration and Harshness) for luxury passenger vehicles as well as SUVs (Sports Utility Vehicle).

The conventional HEDJ, which this development was based on, provides excellent balanced NVH

characteristics, as well as easy mounting ability on a vehicle since a greater slide amount and operating angle can be used, which improves the flexibility of vehicle layout and is suitable for use on SUVs which use large angles.

NTN has been widely distributing HEDJ's, which have been adopted by a great number of users around the world since the first product roll out. The newly developed "HEDJ-P" is redesigned based on the conventional HEDJ in order to make the outer ring even more compact and the inner ring thinner for dedicated use with propeller shafts. As a result, it achieved 17% weight reduction and 6% reduction in the size of the outer diameter while maintaining the same performance as the HEDJ.

Fig. 8 Compact Plunging Type Constant Velocity Joint for Propeller Shafts HEDJ-P

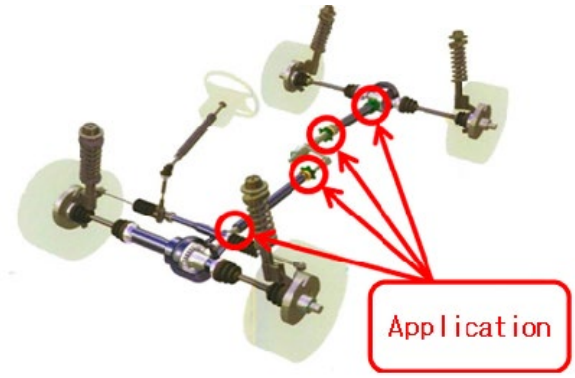

Fig. 9 Application of Compact Plunging Type Constant Velocity Joint for Propeller Shafts HEDJ-P

4. Conclusion

This paper introduced **NTN**'s current development and products regarding one of the main development trends, CASE (Connected, Autonomous, Shared & Services, Electric), which represents a "once in a century" transformation of the automotive industry.

We described our approach for development of new electric module products, as well as an overview of new development items to our existing products for faster, more reliable, quieter and more longer life operation in addition to our continuous efforts to reduce size/weight and lower friction.

Numerous items in development are based on **NTN**'s core competency of tribology technology, high-precision processing technology, high-precision measurement technology and analytical technology such as simulation, as well as our alliance with external agencies in view of increased speed and expansion of fields of application.

We hope to provide a major contribution to the development of the automotive industry and to the community at large through our technologies and products.

Photo of author

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