Technical Trends of Automotive Wheel Bearings

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As automotive wheel bearings, double-row angular contact ball bearings (DAC) and hub units are widely used because of their advantages in compactness, higher reliability and easy handling. However requirements for automotives have been remarkably changed by environmental requirements and various customer's needs, so that high performance pulser and high functional sensor integrated hub units for automotive wheel bearings have been developed. This report presents the recent technical trend and problems for automotive wheel bearings.

Key Words*: automotive wheel bearing, environmental requirement, technical trend*

1. Preface

Compactness, lightweight, and high-reliability are demanded as required performance for automotive wheel bearings. Furthermore, in order to simplify assembly work at customer's plant, double-row angular contact ball bearings (hereinafter referred to as DAC) and hub units are now applied to many automobiles. Meanwhile, the situation over automobiles is remarkably changing since global warming has become a serious issue caused by exhaust gas and customer needs have much diversified. These trends are considered to continue for a long time.

In order to comply with such radical changes in social circumstances, a large number of new developments such as bearings with high-performance pulser ring and multifunctional sensor-integrated hub unit have made progress in automotive wheel bearings other than basic improvement in their performance.

Figure 1 shows examples of needs for automotive wheel bearings and their solutions in bearing technology.

Here presents the latest technical trend and problems for automotive wheel bearings, followed by the paper in the previous edition, "Trends and Future Prospects for Rolling Bearing Technologies."[1)]

Figure 2 shows an example of an axle including a wheel bearing.

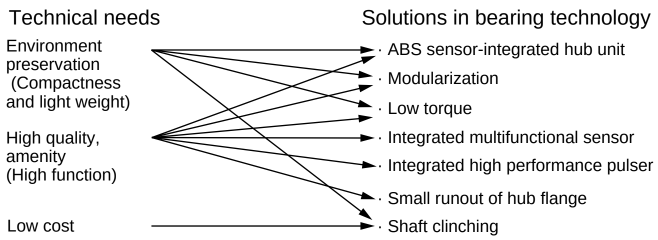


Fig. 1 Needs for automotive wheel bearings and solutions in bearing technology

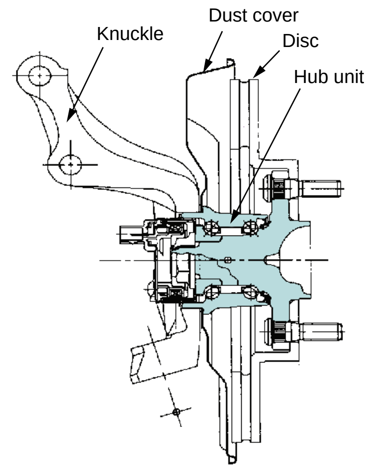


Fig. 2 Structure of axle

2. Structure of Automotive Wheel Bearings[2)]

In conventional wheels, two radial ball bearings or tapered roller bearings were used. As automotive production has increased, unit products have been increasingly used, and now, the 3rd generation hub units have been developed and put into practical use.

The 4th generation hub unit, which integrates a constant velocity joint with a bearing is now under development though it has not yet been mass-produced.

2. 1 The 1st Generation Wheel Bearings

The 1st generation wheel bearing is composed of two single-row bearings with their outer rings integrated, where grease is filled with seals.

Many DAC and double-row tapered roller bearings (DU) are used for driving wheel bearings.

Typical configurations are shown in **Fig. 3**.

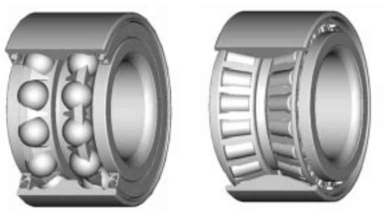


Fig. 3 1st generation wheel bearings

2. 2 The 2nd Generation Hub Unit

The 2nd generation hub unit has integrated flange into the outer ring of 1st generation wheel bearing. There are two types depending on the rotation ring.

The outer-ring rotation type is that wheel is directly attached to the outer ring. This type is used for driven wheel.

The inner-ring rotation type is that hub shaft is attached to the inner ring. It is used both for drive and driven wheels.

The typical configurations are shown in **Fig. 4**.

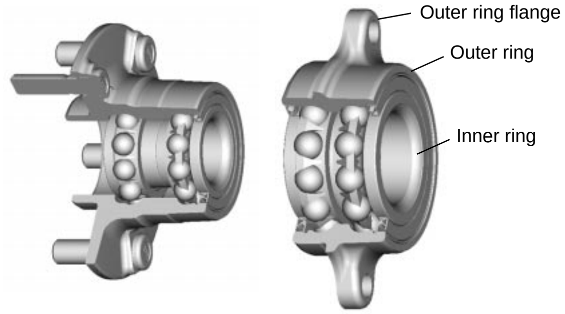


Fig. 4 2nd generation hub units

2. 3 The 3rd Generation Hub Unit

The 3rd generation hub unit is an advanced type of the 2nd generation, which the outboard inner ring of the inner-ring rotation type hub unit and hub-shaft are integrated. In this generation hub unit, number of built-in high-performance sensor type has increased.

As for driven wheel, a hub shaft and an inner ring are usually tightened by a nut, but Koyo is switching to shaft end clinching method for weight and cost reduction.

The typical configuration is shown in **Fig. 5**.

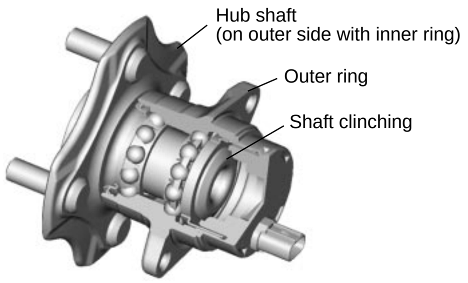


Fig. 5 3rd generation hub unit

3. Accommodation to ABS Systems

Recently, there is a growing demand for automobile safety, where the adoption of antilock brake systems (hereinafter referred to as ABS) has been increased.

An ABS system is a brake control system that prevents wheel lock on braking, and maintains maneuverability and direction stability even on such slippery road as wet, frozen or snowed road. The system is composed of a wheel speed sensor, hydraulic control system, and ECU. ABS system processes a signal transmitted from wheel speed sensor in ECU and controls the braking force by a hydraulic control system.

Hub units that accommodate the above ABS system have been developed and mass-produced with two types: one that a pulser ring for wheel speed sensor is assembled to the hub unit, and another that a wheel speed sensor is integrated in the hub unit.

3. 1 Hub Unit with Pulser Ring

A pulser ring is made of magnetic material formed into gear shape. It generally detects gear movement during rotation with a magnetic sensor and calculates the rotational speed of wheel.

In hub unit for driven wheel, such a structure as shown in **Fig. 6**, has been widely adopted, where the gear-shape pulser ring made of sintered alloy is press-fit on the rotation ring. Moreover, in order to reduce cost and weight, various types have been developed. There are: a ladder type, which steel plate is formed into ladder-shape by press-blanking process; a wave type, which gear is formed by drawn process as shown in **Fig. 7**; and an outer-ring-integrated type, which gear is formed into such shape, simultaneously with outer ring of hub unit forging as shown in **Fig. 8**.

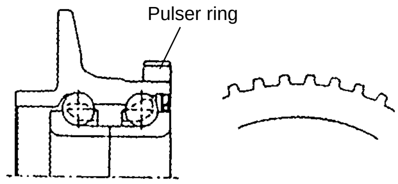


Fig. 6 Sintered metal pulser ring

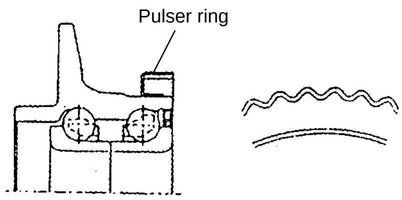


Fig. 7 Stamped steel pulser ring

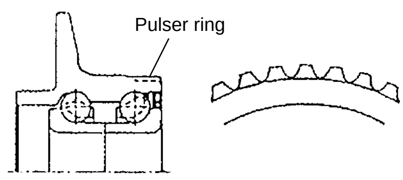


Fig. 8 Outer-ring-integrated pulser ring

3. 2 Hub Unit with Magnetized Pulser Ring

In order to fully utilize the magnetic characteristic, the magnetized pulser ring has been developed as shown in **Fig. 9**, in which a multipolar magnet is used for the pulser ring.

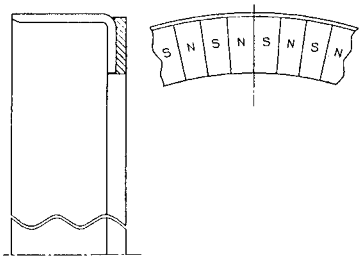


Fig. 9 Example of magnetized pulser ring

The multipolar magnet consists of vulcanized bonded magnet, made from magnetic powder filled in rubber material, and is magnetized consecutively on circumference with N pole and S pole placed alternately. The sensor detects movement of each magnetic pole caused by wheel rotation and computes the rotation speed of the wheel. **Figure 10** shows an application example of a magnetized pulser ring and sensor.

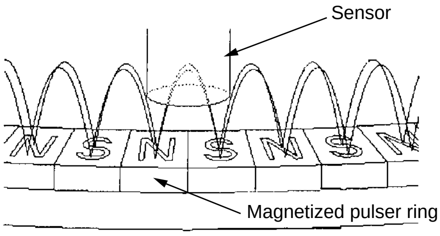


Fig. 10 Example of magnetized pulser ring

Using a magnetized pulser ring will make it possible to gain steady detection even if the clearance between sensor and pulser ring (hereinafter referred to as air gap) may become large, and is possible to simplify the air gap control when assembling to a vehicle. In addition, application of a magnetized pulser ring will make it possible to downsize and reduce the weight of the sensor and pulser ring, and to simplify the structure by integration with a pack seal as shown in **Fig. 11**.

When the pulser ring is changed from the sintered metal type to the magnetized type, the weight of hub unit is decreased by 50～100 g per hub unit.

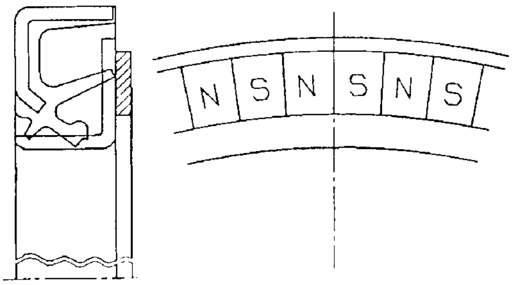


Fig. 11 Example of magnetized pulser ring with pack seal

There are two types in magnetized pulser rings. One is the axial type which the sensor is in close proximity to the axial direction. Another is the radial type which the sensor is in close proximity to the radial direction.

Variation of magnetic flux density between N pole and S pole of the magnetized pulser ring is detected by a sensor using a semiconductor element such as Hall element, magnetic resistance element, etc.

3. 3 Passive-sensor-integrated Hub Unit (Fig. 12)

The above-mentioned hub unit with pulser ring is further developed to the one that integrates ABS sensor into the hub unit so that it enables improvement in reliability of the sensor output and in productivity by simplifying assembly process at customers.

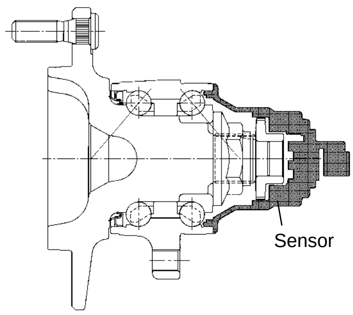


Fig. 12 Passive-sensor-integrated hub unit

A sensor that perceives the voltage as a signal, which is generated in the coil depending on the principle of electromagnetic induction, is called a passive sensor. Passive sensor is composed of a magnet, coil and iron core and is combined with gear type pulser ring. This passive sensors integrated into 3rd generation hub units are now widely used.

As passive sensor uses electromotive force generated from coil as a signal, it does not need power source. Also, in order to restrain the affect to output caused by dispersion in pitch error of pulser ring, it is possible to face the core of plural-toothed coil with each tooth of the pulser ring, that is, to make it a multipolar sensor. On the other hand, the problem to be solved is that passive sensor requires high control of air gap precision because the coil and magnet become large and it cannot gain enough output voltage in the range of ultra-low speed rotation.

3. 4 Active-sensor-integrated Hub Unit

A sensor using a semiconductor element such as a Hall element and magnetic resistance element (MR element) is generally called an active sensor. An active sensor is applicable to various vehicle control systems including ABS systems that are expected to be improved from now on. It is expected that in the future, a hub unit with a built-in active sensor (**Fig. 13**) will be mainly adopted in vehicles. An active sensor has features described as follows.

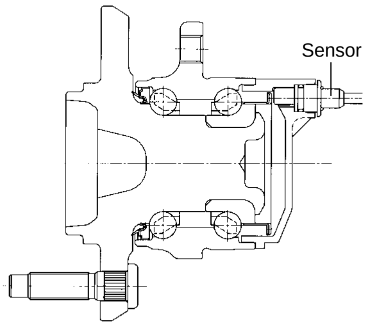


Fig. 13 Active-sensor-integrated hub unit

① It is capable of providing steady output because the output signal is converted to square-wave-treated digital signal in a semiconductor.
Comparison of output signals generated from active type and passive type is shown in **Fig. 14**.

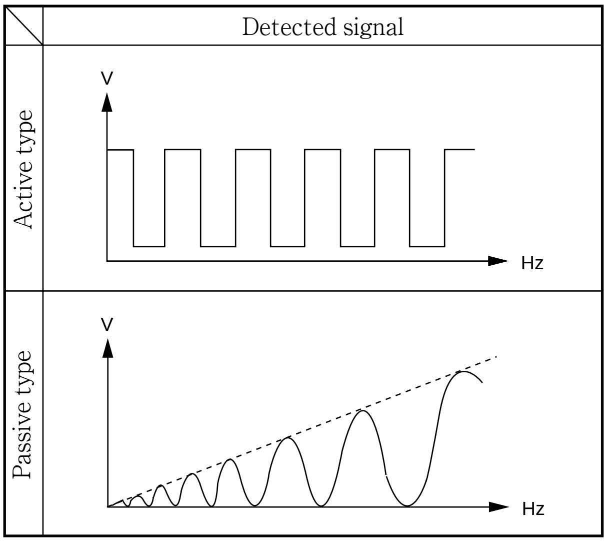


Fig. 14 Comparison of output signals

② It is applicable to systems other than ABS systems since it would be possible to detect the rotation direction and calculate the rotation angle earned by placing plurality of elements on the sensor.
③ Downsizing and weight-reduction are possible.

4. Shaft Clinching[3)]

Recently, adoption of shaft end clinching is growing at high speed for the purpose of complying with the required demand of weight-reduction and compactness in hub units. The shaft end clinching is a technique that deforms the end part of hub shaft by rocking die forging in which inboard of inner ring is pressed, and that gives stability of inboard inner ring and proper shaft force by this deformation.

Figures 15 and **16** show examples of 3rd generation type clinched shaft hub units for a driven wheel and drive wheel respectively.

In addition, this technique is also applicable to the inner ring rotation type 2nd generation hub units.

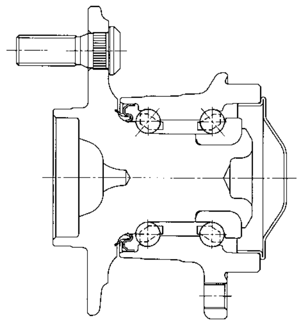


Fig. 15 Shaft clinching hub unit for driven wheel

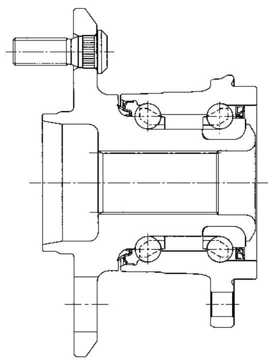


Fig. 16 Shaft clinching hub unit for drive wheel

Required functions for tightening of shaft end are described as follows.
1) Fixing hub shaft and its separate inner rings
2) Maintaining proper preload
(Preventing the creeping between a hub shaft and inner ring, improve rotation precision, maintain rigidity)

Switching from a nut-tightening type to shaft-end-clinching type enables us to earn the following effects of ①~③ for the driven wheel, and those of ② and ③ for the drive wheel without losing the above functions.
① Cost reduction: It is possible to eliminate the nuts that were indispensable to tighten the inner ring to the hub shaft.
② Compactness and weight reduction: It is possible to make the tightening part compact.
③ Improved reliability: Shaft clinching process is capable to perfectly comply with the problem of "loosening of tightening" that was impossible to be solved for the nut tightening.

5. Small Runout of Hub Flange

As for the countermeasure against brake judder on a vehicle, Koyo is coping with reducing the runout of a disk rotor. According to this, small runout of the flange face is the countermeasure for the hub unit. For an example, controlling the flange runout within a certain amount would make it possible to reduce the occurrence of brake judder on a vehicle.

For move improvement, there is a way of grinding not only the hub flange surface but also the rotor surface after the hub unit and rotor are assembled. In this way, it would be possible to further reduce the runout on the rotor surface.

6. Development of Low Torque Seal

There are more and more needs for energy efficiency and low fuel consumption these days. In order to cope with these needs, We are trying to reduce the torque of hub unit.

Figure 17 shows that the large contribution from the seal to torque in a typical hub unit. Therefore it is imperative to reduce the rotational torque of seals for low-torque hub unit.

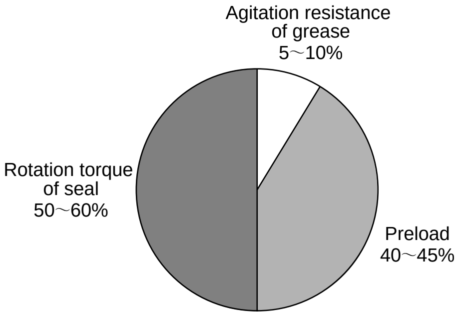
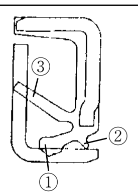
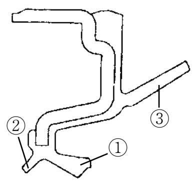


Fig. 17 Torque contribution of each factor in hub unit

Table 1 shows the seal designs of hub unit and their contribution of each lip to the seal torque. The effective way to reduce the torque is to reduce the lip interference of the radial main lip and the radial auxiliary lip, which greatly contribute to the rotation torque. Meanwhile, there may be reverse affect of decline in the anti-mud water resistance by reducing the lip interference. However, a new design that covers this reverse affect has been developed.

Table 1 Seal designs of hub unit and contribution of each lip to seal torque

	Pack seal	Shaft seal
Seal design		
① Radial main lip	40～50%	
② Radial auxiliary lip	30～40%	
③ Axial lip	10～30%	

7. Conclusion

This paper presented the outline of the latest technical trend and problems of wheel bearings corresponding to the rapid change in social environment.

We would do our utmost to develop such products for which automotive makers in the world would crave as to coping with improvement in vehicle's fuel consumption to prevent global warming by weight reduction and low torque, advanced navigation systems made possible by a multifunctional sensor-integrated hub unit with a high-performance pulser ring, development of ITS (intelligent transport system) like advanced vehicle control and safety systems, and changes in supplying systems.

References

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