HUBLFT Ⅱ: HUB Unit for Low Friction Torque

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Hub units are used worldwide as automobile wheel bearings. We have carefully examined the function and performance of the labyrinth seal and completed development of a low torque hub unit called "HUBLFT Ⅱ" which has improved sealing performance. This paper will introduce the technology of this development.

Key Words: *axle bearing, hub unit, low torque, labyrinth structure, gutter lip*

1. Introduction

The automotive industry is entering a period of innovation seen only once per century. A major shift is taking place toward electrification and automated driving, as typified by BEVs (electric vehicles) and FCEVs (fuel cell electric vehicles). In particular, there is an urgent need to reduce the rotation torque of hub units, partly due to society's shift towards carbon neutrality. In the case of BEVs, it is important to reduce vehicle running resistance so that per-charge travel ranges can be extended, which will in turn enable reductions in battery weight. Such improvements may also enable battery costs to be reduced, which is directly linked to user running costs. For these reasons, stakeholders such as vehicle manufacturers have expressed a strong desire for reductions in the rotation torque of hub units. In the past, JTEKT launched its HUBLFT Ⅰ[1], which features 44% less rotation torque than conventional products. "HUBLFT," which stands for "HUB unit (bearing) for Low Friction Torque," is the name of JTEKT's series of hub unit bearings for low friction torque.

In creating this evolved version of HUBLFT Ⅰ, we have developed seals for the inboard and outboard sides[2] that employ a labyrinth structure and gutter lip by utilizing fluid analysis to simulate the flow of muddy water around the hub unit. This paper describes how we used these methods to successfully develop the HUBLFT Ⅱ, which features 58% less rotation torque than conventional hubs.

2. How Hub Units Are Used and Our Efforts to Reduce Torque

As shown in **Fig. 1**, the hub unit is placed inside the vehicle wheel and supports the weight of the vehicle to enable the wheels to rotate smoothly. It is a unit bearing that consists of a bearing with rolling elements and inner and outer ring raceways, and a flange used to fasten it to the vehicle. The hub unit protects the bearing by blocking muddy water kicked up by the tires on both the inboard and outboard sides of the bearing, and is equipped with seals that prevent lubricating grease from leaking out. It

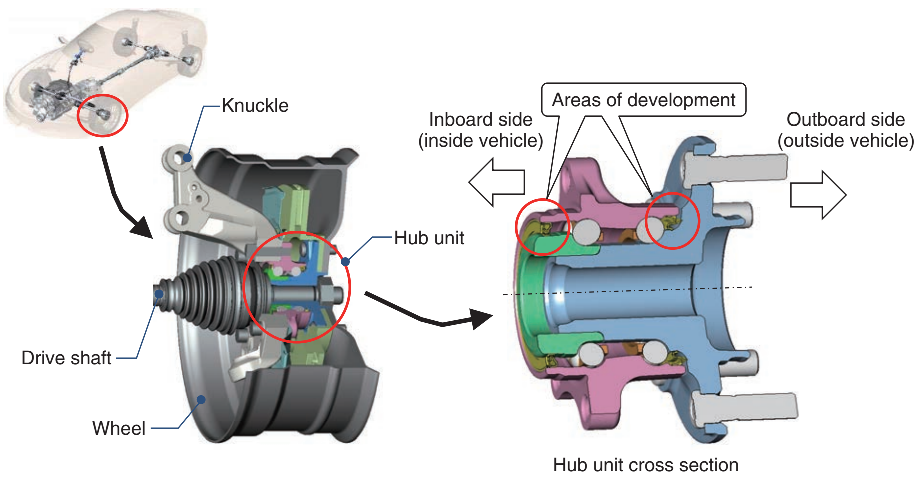


Fig. 1 Placement and cross section of hub unit

is also maintenance-free, enabling the bearing to rotate smoothly for the life of the vehicle.

Figure 2 shows a performance comparison between conventional hubs and HUBLFT Ⅰ, and the development goals of HUBLFT Ⅱ. The friction loss of the hub unit is divided between the bearing and seals, while the torque ratio is approximately 50% for the bearing and 50% for the seals. Compared to conventional hubs, the HUBLFT Ⅰ uses low torque grease for the bearing, while a different shape has been used for the lip portion of the seals. Furthermore, low torque grease is also used for the seals, and the lip sliding part has undergone surface modifications. These improvements have resulted in the hub unit assembly having 44% less rotation torque than conventional hubs.

In our development of HUBLFT Ⅱ, we aimed to achieve 58% less rotation torque than conventional products through further reductions in seal torque. Also, when settings targets, we used the same CO_2 reduction rates as those used in Europe where environmental regulations are strict. Accordingly, this report compares the performance of HUBLFT Ⅱ with that of conventional hub seals.

3. Breakdown of Seal Rotation Torque and Environments in Which Hub Units and Seals Are Used

As mentioned above, hub units are a component of the vehicle's undercarriage and employ seals for preventing the intrusion of muddy water from the outside. In our attempt to reduce torque, we focused on these seals. Formula (1) is a formula for calculating seal rotation torque (Ts).

$$\mathrm{Ts} = \mu \mathrm{Pr} \frac{D}{2} \qquad (1)$$

μ: Coefficient of friction, Pr: Lip reaction force,
D: Diameter of lip sliding part

As shown by formula (1), torque can be reduced by reducing the coefficient of friction and lip reaction force. In the case of the above-mentioned HUBLFT Ⅰ, we reduced the coefficient of friction by using low torque grease for the seals and by modifying the surface of the lip sliding part. In developing the HUBLFT Ⅱ, we are focused on achieving further reductions in lip reaction force.

As shown in **Fig. 3**, market return products are suffering rust and corrosion. Rusting of the seal sliding part of the steel hub unit is promoted by muddy water kicked up by the tires and wheels, which may contain road salt or calcium chloride used for deicing in cold regions. It may also be caused by flooding when the tires, wheels,

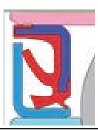
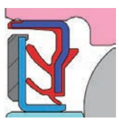
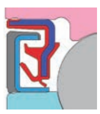
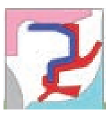
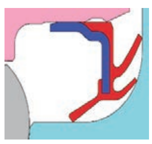
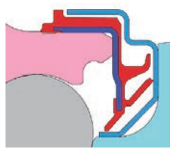
Conventional hub	HUBLFT Ⅰ (development completed)			HUBLFT Ⅱ (target values)		
	Low torque technology	Reduction rate (single unit)	Reduction rate (assembly)	Low torque technology	Reduction rate (single unit)	Reduction rate (assembly)
Hub unit assembly (100%)	—	—	–44%	—	—	–58%
Bearing (torque ratio: 50%)	・Low torque grease for bearings	–40%	–20%	←	–40%	–20%
Inboard side seal (torque ratio: 25%) 	・Lip shape modification ・Low torque grease for seals ・Lip sliding part surface modification 	–55%	–14%	・Lip reaction force reduction ・Lip quantity reduction ・Low torque grease for seals ・Lip sliding part surface modification 	–75%	–19%
Outboard side seal (torque ratio: 25%) 	・Lip shape modification ・Low torque grease for seals 	–40%	–10%	・Lip reaction force reduction ・Lip quantity reduction ・Low torque grease for seals ・Lip sliding part surface modification 	–75%	–19%

Fig. 2 Performance comparison between conventional HUB and HUBLFT Ⅰ, and development goals of HUBLFT Ⅱ

and hub units become submerged. Countermeasures for such muddy water environments must be taken if torque is to be reduced.

Fig. 3 Market return products and environment used

4. Specific Methods of Reducing Torque and Contradictory Breakthrough Methods

We will now provide a detailed description of the methods we used to reduce rotation torque by looking at the inboard and outboard sides separately. **Figure 4** shows our development concept. The inboard side seal is placed on the side inside the wheel. Previously, a two-piece seal, also known as a “pack seal,” had been used. However, in order to reduce lip reaction force, which is one cause of rotation torque, the conventional configuration in which contact is made by two axial lips (see the information for HUBLFT II shown in **Fig. 2**) has been changed to a configuration in which contact by one axial lip is combined with a contactless gutter lip. Although there are concerns that this configuration may result in a loss of the sealing performance necessary for blocking muddy water from the outside, we aimed to utilize a labyrinth effect in compensating for that loss. Specifically, our analysis results showed that changing the slinger shape from a conventional L-shaped cross section to a U-shaped cross section greatly enhances this labyrinth effect. For details, see the fluid analysis results in **Section 5**.

The same concept is generally employed for the seal on the outboard side. Conventionally, the same type of carbon steel for machine structures as that used for the shaft has been used for the sliding part. However, by adding the same type of stainless-steel slinger as that used on the inboard side and press-fitting it to the shaft, we have succeeded in creating a labyrinth configuration while improving the rust resistance of the seal lip sliding part.

5. Verification of the Labyrinth Effect’s Ability to Compensate for Sealing Performance: Fluid Analysis Method and Results

As discussed above, the number of axial lips that come in contact with the sliding part has been reduced from two to one as a method of reducing torque, while the use of a labyrinth effect has been employed as a method of compensating for the loss in sealing performance caused

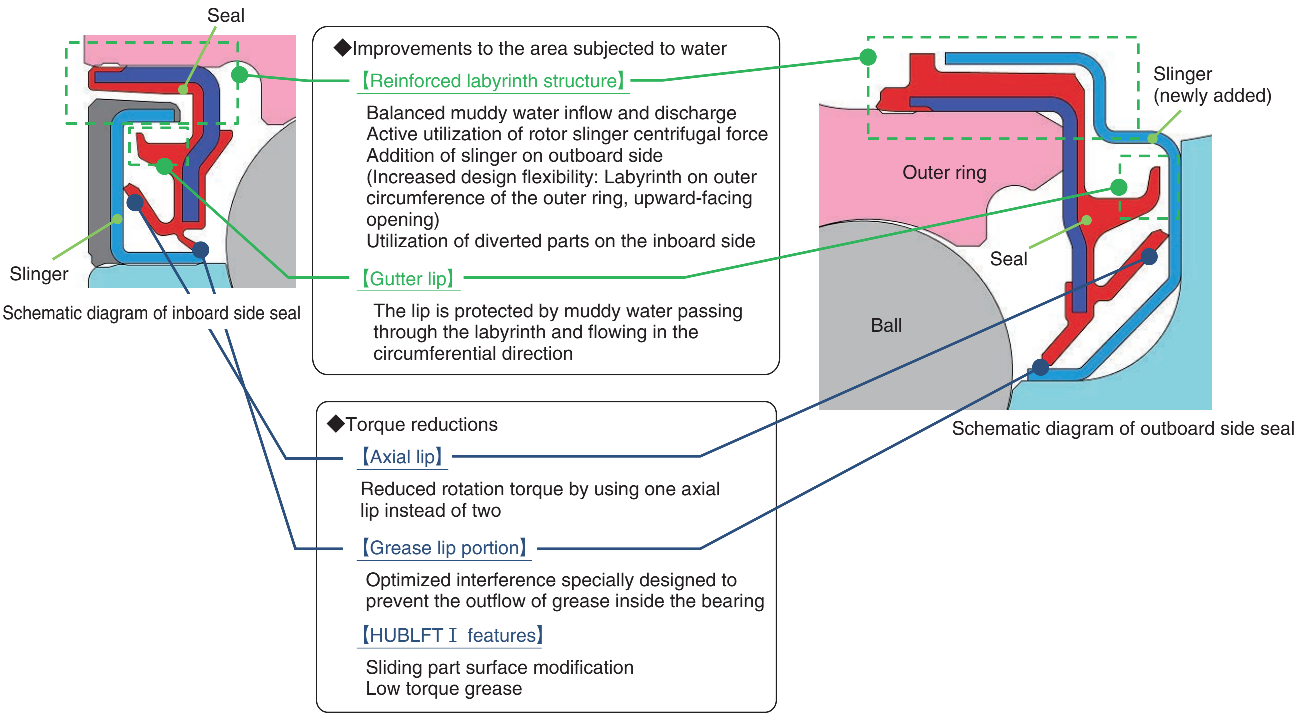


Fig. 4 Development concept

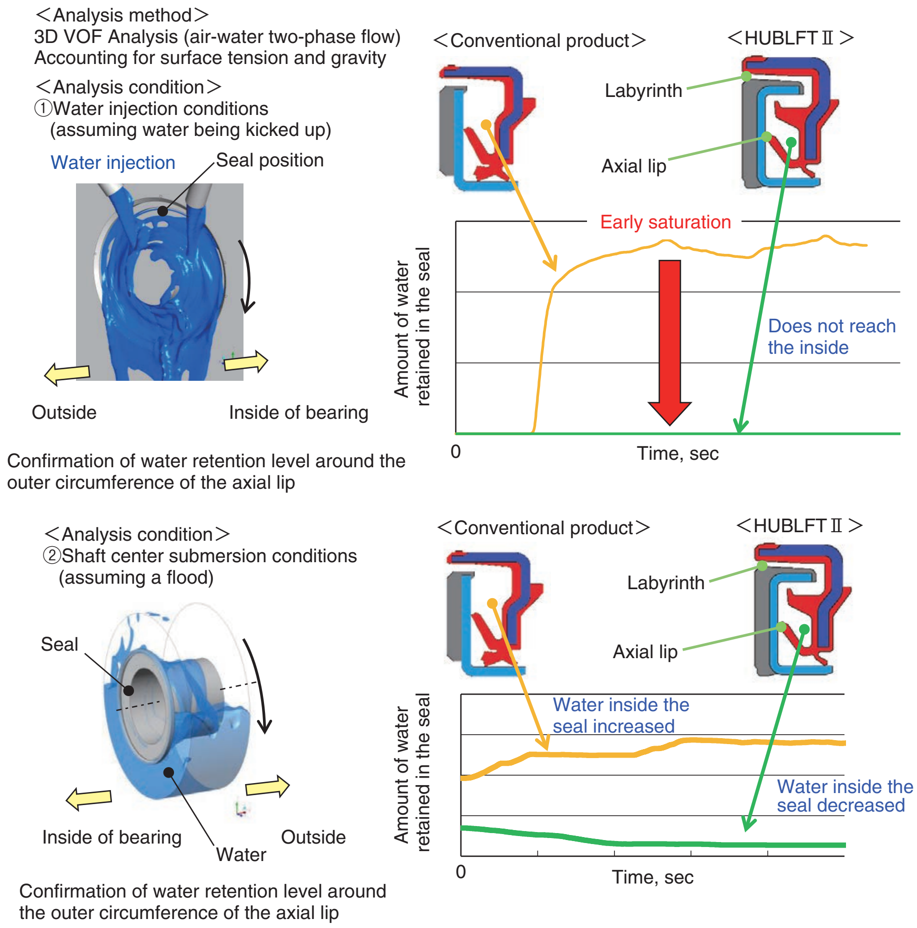


Fig. 5 Comparison of fluid analysis results

by this reduction. In this section, we will examine the fluid analysis method used to simulate the flow of muddy water, as well labyrinth effect based on those results. Conditions under which the seals on both sides of the hub unit are exposed to water are ① conditions assuming muddy water being kicked up by tires and wheels, and ② conditions assuming flooding or submersion when crossing a river. **Figure 5** shows fluid analysis results in which water retention levels within the seal are compared. In the case of the conventional product, water reaches the inside of the seal immediately after water injection starts and fills the area around the lip sliding part. However, in the case of HUBLFT Ⅱ, water does not reach the vicinity of the lip sliding part. This is thought to be largely due to the narrowing of the passage through which muddy water enters, as well as due to the labyrinth effect created by that passage being made longer. Furthermore, under ② shaft center submersion conditions assuming a flood, which starts when the hub unit is submerged in water up to the center of the shaft, the amount of muddy water around the lip increased immediately after rotation was started in the case of the conventional product. However, in the case of HUBLFT Ⅱ, a decrease in the amount of water inside the seal was observed. It is thought that the centrifugal force generated by rotation of the slinger acts on the muddy water, causing an effect in which the muddy water flows out of the space inside the seal. Because the results of this analysis showed that there was no muddy water around the lip, we can expect that lip abrasion caused by mud particles will be reduced and that sealing performance will be improved. Furthermore, although the details of the analysis results for the outboard side are omitted, because the mechanism is almost the same as the above-mentioned inboard side, results showed that the amount of muddy water remaining around the lip is reduced, which leads us to expect that sealing performance is improved over that of the conventional product.

6. Evaluation and Verification

6. 1 Verification of Torque Reduction Effects

Figure 6 shows the rotation torque comparison results for a single seal. Our newly developed seal for the HUBLFT Ⅱ achieved a 74% reduction in the case of the inboard side seal and a 77% reduction in the case of the outboard side seal (both compared to the conventional product). Although these results are for a rotation speed of 1 000 min^{-1}, equivalent reductions in rotation torque are observed under any condition between zero and 1 000 min^{-1}, leading us to believe that this seal can sufficiently contribute to reductions in vehicle fuel and electricity consumption even under the various driving conditions of actual vehicles.

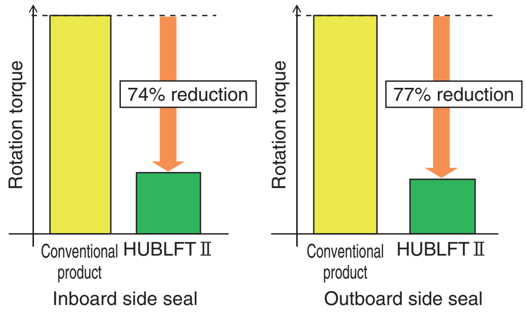


Fig. 6 Comparison of rotation torque

6. 2 Sealing Performance Test Results: Muddy Water Evaluation Results and Considerations

In order to confirm sealing performance, a bench simulation test machine was used to conduct life comparisons with the conventional product under two conditions: ①Water injection conditions assuming muddy water being kicked up by tires and wheels and ②Shaft center submersion conditions assuming a flood. Results are shown in **Fig. 7**. These results are for evaluations performed on a single seal. We were able to confirm that both the inboard side seal and outboard side seal have a life (sealing performance) equal to or greater than that of the conventional product under any conditions.

Furthermore, we also conducted testing using water injection conditions in which the hub unit assembly was subjected to both saltwater conditions and muddy water conditions. The results of these tests also enabled us to confirm that sealing performance was equal to or greater than that of the conventional product. Noteworthy of mention are the seal observation results following durability testing (see photos at bottom of **Fig. 7**). Observation results of the grease applied to the outermost seal lip of the inboard side seal showed that the grease maintained the same appearance as newly applied grease. As mentioned in the fluid analysis of **Section 5**, this indicates that muddy water was unable to reach the area around the seal lip and attack the lip. Although the details of evaluation results for the outboard side seal have been omitted, it was confirmed that the grease on the outermost seal lip of the outboard side showed the same appearance as newly applied grease.

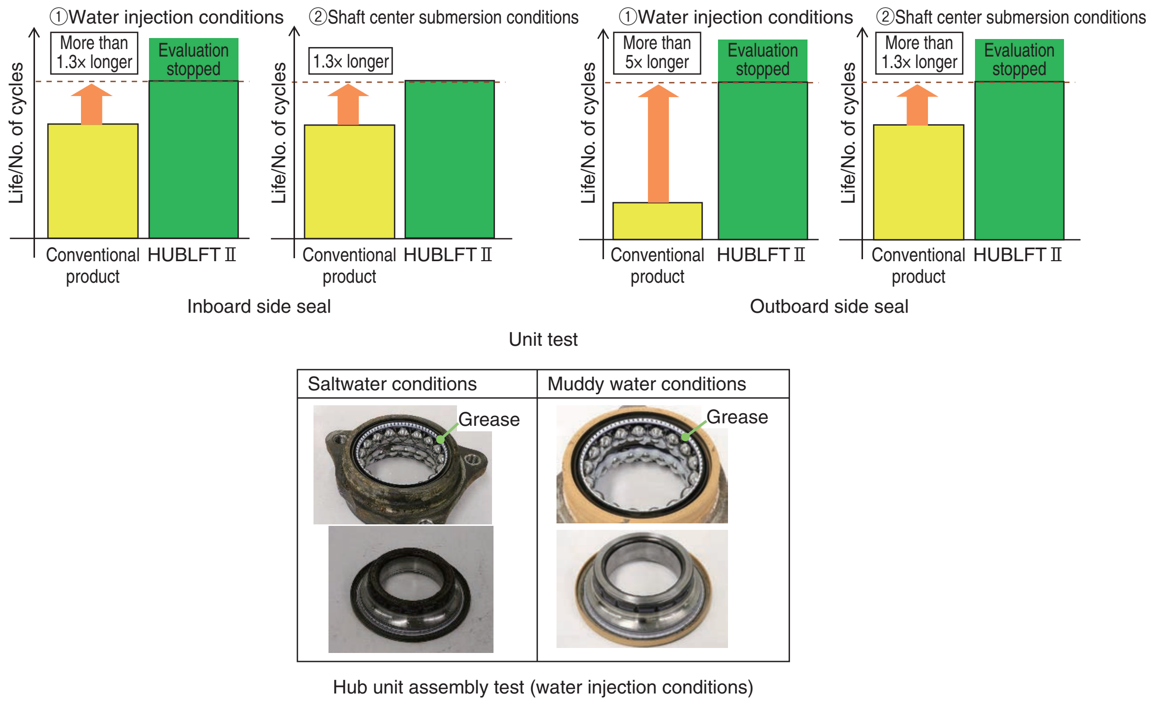


Fig. 7 Comparison of sealing performance

7. Conclusion

The torque reduction effects of the hub unit assembly are shown in **Fig. 8**. These results show that the development targets outlined in **Fig. 2** have been achieved. In order to compensate for the loss in seal performance caused by the reduction in the number of lips that make contact, the seal structure has been modified to optimize its labyrinth effect. We feel that both the torque reductions and improved sealing performance brought about by this modification represent major technological advances.

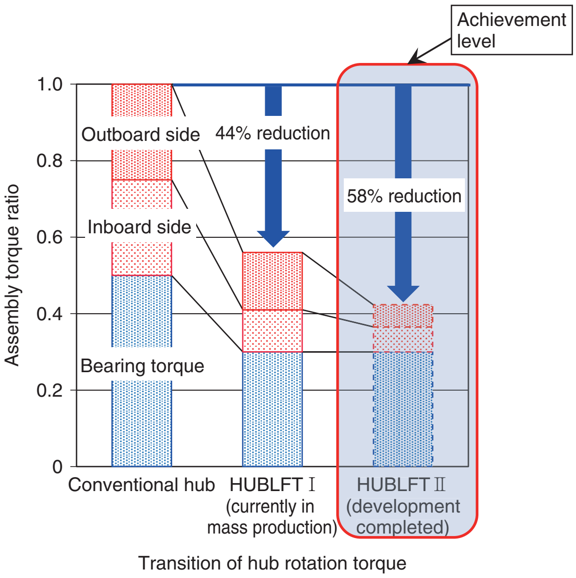


Fig. 8 Achievement level of HUBLFT Ⅱ

In the case of engine vehicles (4-wheeled), the hub unit is generally believed to account for 1% of the fuel consumption rate, which means that halving the rotation torque of the hub units can contribute a 0.5% improvement in fuel efficiency. Because electrification results in lower energy consumption by the engine and transmission, the ratio of overall vehicle friction loss accounted for by the hub unit will tend to increase. By continuing to improve upon our torque reduction technology, we hope to contribute to carbon neutrality and the realization of a low-carbon society.

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