2.5th Generation Double-Row Tapered Roller Bearing Hub Unit for SUVs and Pickup Trucks

K. FURUKAWA

Generally-speaking, passenger cars use double-row angular contact ball bearing hub units as wheel bearings, while heavy vehicles such as a sport utility vehicles (SUV) and pickup trucks use a pair of tapered roller bearings (TRB) or 1st or 2nd generation double-row TRB hub units. Recently, there is an increased demand for 2.5th and 3rd generation double-row TRB hub units with integrated hub shafts, particularly for front wheel application. This report describes the characteristics and design points of the 2.5th generation double-row TRB hub unit, which is gradually becoming a main product in SUVs and pickup trucks.

***Key Words**: wheel bearing, integrated hub shaft, the 2.5th generation double-row tapered roller bearing hub unit, SUV, pickup truck*

1. Introduction

Double-row angular contact ball bearing hub units are mainstream as wheel bearings for passenger cars, but for heavy vehicles such as sport utility vehicles (SUV) and pickup trucks, a pair of tapered roller bearings (TRB), or 1st or 2nd generation double-row TRB hub units, are used.

Recently, there is an increased demand for the 2.5th and 3rd double-row generation TRB hub units with integrated hub shafts, particularly with regards to front wheel application. JTEKT developed the 2.5th generation double-row TRB hub unit in 2004 for pickup trucks, and ever since commencing mass production, have enjoyed increased sales. JTEKT is currently completing technical development for the 3rd generation double-row TRB hub unit.

Figure 1 shows the sales performance of the 2.5th generation product. One of the reasons for the heightened demand is that it can be used together with the 2nd generation product on small TRB hub units for which the market scale is small, and by changing hub shaft specifications, can readily respond to diverse customer needs as well as offer performance equivalent to that of the 3rd generation at a lower cost.

This report will introduce the characteristics and design points of the 2.5th generation double-row TRB hub unit, which is gradually becoming a main product in SUVs and pickup trucks.

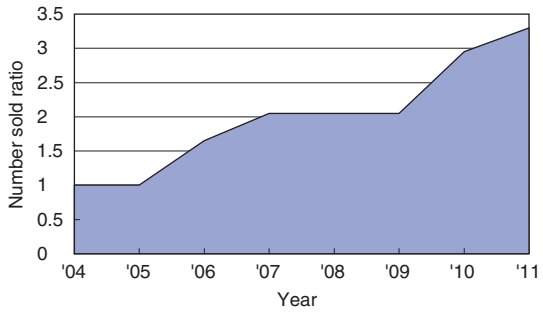


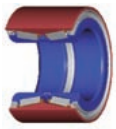
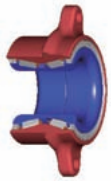
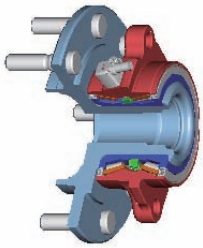
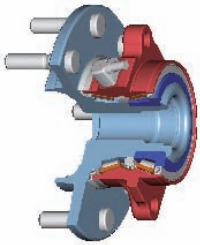
Fig. 1 2.5th generation double-row TRB hub unit sales

2. Trends in TRB Hub Units

TRB hub units are grouped by generation depending on component parts and type, and currently JTEKT mass produce the 1st, 2nd and 2.5th generations.

Table 1 shows a comparison of respective generation double-row TRB hub unit characteristics. As is the case with ball bearing hub units, the more advanced the TRB hub unit generation is, the greater the number of component parts and the more modularized it becomes, therefore offering the customer more advantages.

Tabel 1 Comparison of respective generation double-row TRB hub unit characteristics

		1st generation	2nd generation	2.5th generation	3rd generation
Schematic view					
Performance	Life	△	△	○	○
	Rigidity	△	△	○	○
	Rotational torque	◎	◎	◎	○
	Flange run-out	×	△	○	◎
Lightweight/compactness		×	△	○	◎
Cost		×	△	○	○
Total evaluation		×	△	○	○

◎ : Excellent, ○ : Good, △ : Average, × : Poor

2. 1 Configuration of the 1st and 2nd Generation Double-Row TRB Hub Units

The 1st and 2nd generation of double-row TRB hub units are of a back-to-back, double-row configuration, and are available in both inner-ring and outer-ring rotation type. The 1st generation uses an identical design for both inner and outer-ring rotation and is highly versatile. The 2nd generation integrates a flange into the outer ring of the 1st generation, and the inner-ring rotation type has the outer ring flange mounted on the knuckle. The outer-ring rotation type is used with the outer ring flange mounted on the wheel.

2. 2 Configuration of the 2.5th Generation Double-Row TRB Hub Unit

Figure 2 shows a cut model example of the 2.5th generation double-row TRB hub unit which is recently being used in an increasing number of applications.

The 2.5th generation TRB double-row hub unit is configured from the inner-ring rotation type 2nd generation TRB hub unit integrated with a hub shaft, also with an in-built ABS sensor. This new design offers customers better ease of assembly.

Moreover, shaft clinching is used on the drive wheels to suppress variation in axial tension caused by nut tightening.

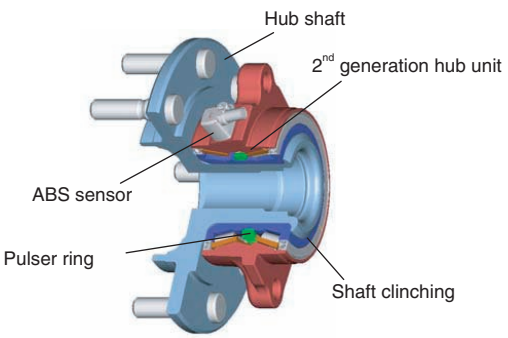


Fig.2 Cut model example of 2.5th generation double-row TRB hub unit

3. Design Points

Table 2 shows the design points necessary to secure functions demanded of bearings used in SUV and pickup truck wheels.

The following section introduces the activities involved in the design of the 2.5th generation double-row TRB hub unit.

Table 2 Functions demanded of SUVs and pickup trucks and double-row TRB hub unit design points

Design element	Impact on performance	Design point
Life	Flaking	Life performance satisfying required vehicle body life
Rigidity	Drive stability	Rigidity satisfying required vehicle body properties
Reduced friction	Consumption	Internal design with reduced friction
Reduced weight (hub shaft, outer ring strength)	Fatigue failure of hubs and outer rings	Repeated stress load

4. Activities Involved in the Design of 2.5th Generation Double-Row TRB Hub Units

4. 1 Life and Rigidity

SUVs and pickup trucks are heavier than passenger cars and are required to last longer. For these reasons, the TRB hub unit, with its large basic dynamic load rating, is used.

Sufficient rigidity must also be secured in order not to lose driveability of the vehicle when travelling at high speeds or cornering, therefore the appropriate axial clearance must be found with consideration to accomplishing both life and rigidity, which are often at trade-offs with each other. **Figure 3** shows one example of results from a life study for each generation, and here the emphasis was placed on safety during vehicle travel, therefore the axial clearance was set near the lower limit of the range satisfying the life requirement. On the 2.5th generation, it is possible to set the axial clearance to be advantageous for securing rigidity in order to suppress axial clearance variation caused by engagement.

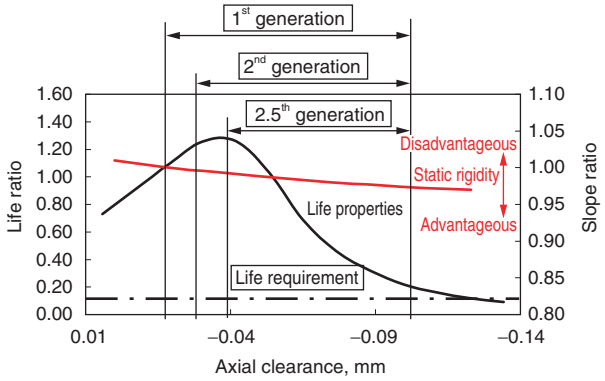


Fig. 3 Relation of axial clearance to bearing life and rigidity

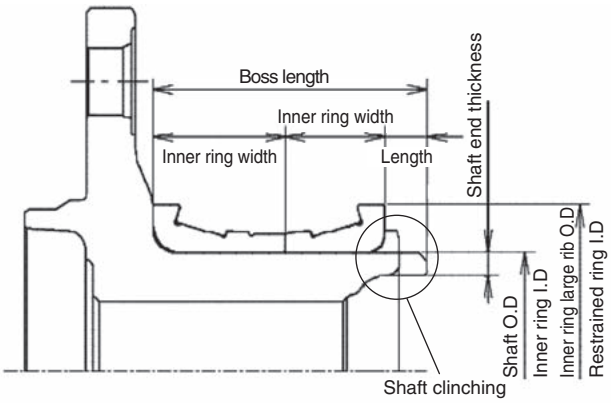


Fig. 4 Dimensions of the hub shaft clinching section

Furthermore, as the 2.5th generation uses a shaft clinching and nut tightening design, the nut tightening torque can be made reduced, meaning that variation in axial force can be suppressed. In shaft clinching, so as to provide more stable axial force, optimal conditions of clinching length, thickness and clinching setting pressure are established, as shown in **Fig. 4**.

4. 2 Reduced Friction

There is also a high demand to reduce friction in bearings for wheels.

Figure 5 shows the characteristics of a low torque TRB. Low friction is achieved by crowning the inner and outer ring raceways, machining the sliding contact surface of the large rib into a curved shape, and reducing surface roughness. **Figure 6** is an example of torque measurement on the low torque TRB and demonstrates that torque can be reduced by approximately 25% in a rotational speed area equivalent to normal vehicle speed.

Figures 7 and **8** show comparisons of temperature rise and bearing seizure limit load in standard and low torque TRBs under a rotational speed equivalent to a vehicle speed of 170 km/h. These comparisons prove that low torque TRB had approximately 16% less temperature rise and approximately 25% higher bearing seizure limit load than those of standard TRBs. It can therefore be stated that adopting low torque TRB will improve reliability in regards to seizure.

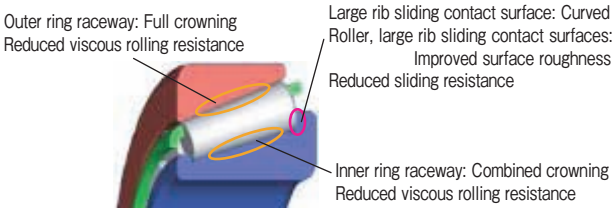


Fig. 5 Characteristics of low torque TRB

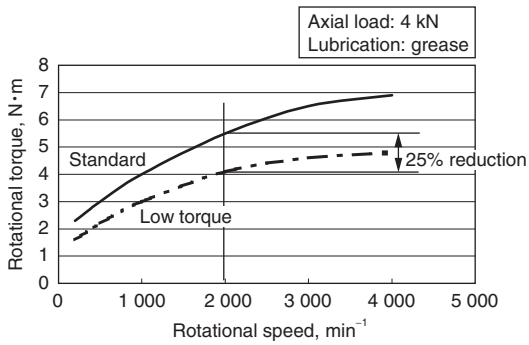


Fig. 6 Torque properties of low torque TRB

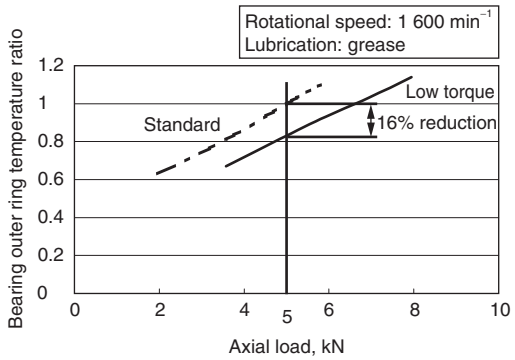


Fig. 7 Temperature rise properties of low torque TRB

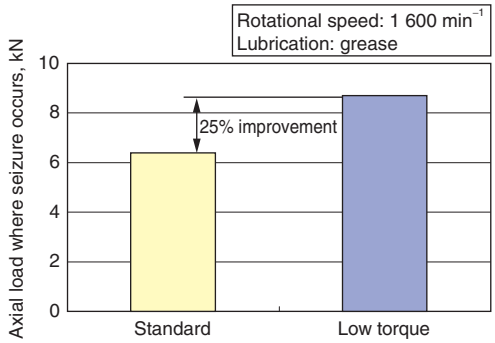


Fig. 8 Bearing seizure limit load of low torque TRB

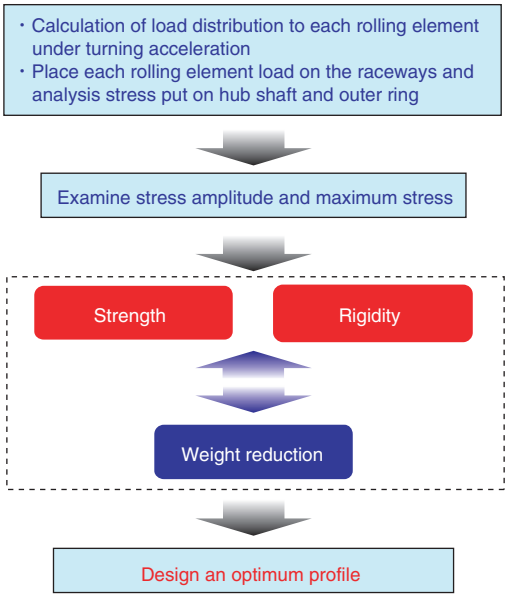


Fig. 9 Strength and rigidity analysis method

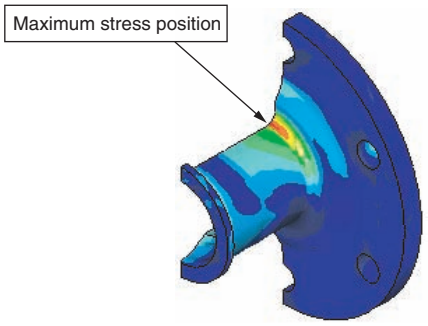


Fig. 10 Example of hub shaft strength analysis

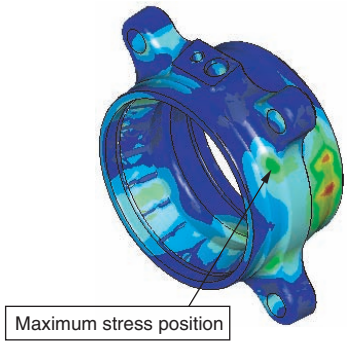


Fig. 11 Example of hub outer ring strength analysis

4. 3 Weight Reduction (Hub Shaft, Outer Ring Strength)

There is a great need to reduce the weight of wheel bearings. However, breakages such as splits due to insufficient hub shaft strength could ultimately lead to serious accidents such as tires falling off. Therefore designers must sufficiently confirm that the stress which occurs in the base of the hub shaft is suppressed to a level that will not lead to breakages under high turning acceleration conditions. **Figure 9** shows strength and rigidity analysis using CAE, while **Figs. 10** and **11** show an example of strength analysis for the hub shaft and outer ring respectively in the case of the 2.5th generation double-row TRB hub unit. JTEKT has developed this model to offer as weight reduction a design as possible while suppressing the stress at the maximum stress position on both the hub shaft and the outer ring to a level within the material's fatigue limits.

5. Conclusion

In line with the enhanced performance and improved reliability of vehicles, an integrated unit design is being adopted for wheel bearings.

Until now, the majority of hub units were custom designed to suit individual vehicle types based on customer needs however, JTEKT would like to continue creating an optimized series through integration of specifications and joint use of components in order to offer customers a low-cost product while ensuring the desired level of functions and performance.

References

1) M. Takeuchi: LFT Tapered Roller Bearings, Koyo Engineering Journal, No. 127 (1985) 52.
2) M. Takeuchi: Change of Wheel Bearing Design, Koyo Engineering Journal, No. 131 (1987) 16.
3) M. Kawamura: Design Trends of Automotive Wheel Hub Units, Koyo Engineering Journal, No. 147 (1995) 51.
4) T. Numata: Latest Technical Trend of Hub Unit Bearing, Koyo Engineering Journal, No. 168 (2005) 8.

K. FURUKAWA*

* *West JAPAN Technical Center, Bearing & Driveline Operations Headquarters*