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

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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 1\textsuperscript{st} or 2\textsuperscript{nd} generation double-row TRB hub units. Recently, there is an increased demand for 2.5\textsuperscript{th} and 3\textsuperscript{rd} 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 2.5\textsuperscript{th} 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 2.5\textsuperscript{th} 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 1\textsuperscript{st} or 2\textsuperscript{nd} generation double-row TRB hub units, are used.

Recently, there is an increased demand for the 2.5\textsuperscript{th} and 3\textsuperscript{rd} double-row generation TRB hub units with integrated hub shafts, particularly with regards to front wheel application. JTEKT developed the 2.5\textsuperscript{th} 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 3\textsuperscript{rd} generation double-row TRB hub unit.

Figure 1 shows the sales performance of the 2.5\textsuperscript{th} generation product. One of the reasons for the heightened demand is that it can be used together with the 2\textsuperscript{nd} 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 3\textsuperscript{rd} generation at a lower cost.

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

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 1\textsuperscript{st}, 2\textsuperscript{nd} and 2.5\textsuperscript{th} 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.
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.

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

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<th>1st generation</th>
<th>2nd generation</th>
<th>2.5th generation</th>
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<td>Cost</td>
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○ : Excellent, ○ : Good, △ : Average, × : Poor

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

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. 3 Relation of axial clearance to bearing life and rigidity

Fig. 4 Dimensions of the hub shaft clinching section

Fig. 5 Characteristics of low torque TRB

Fig. 6 Torque properties of low torque TRB
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