Hub Bearings for Automobiles that Conserve Resources

1. Preface

One of the leading environmental issues today is global warming. To help in the prevention of global warming it is necessary to reduce the emissions of greenhouse gases - in particular, CO2. Therefore, in the auto industry around the world there is an ever increasing need for light-weight, low friction designs that will lead to lower energy consumption on cars during travel as well as a reduction in the amount of materials consumed during car manufacturing.

Believing that coexistence with the global environment is its most urgent challenge, NTN has long been committed to efforts for designing lighter, lower-friction car components. We have developed a unique hub bearing, which is one of the underbody car components. In this paper we are going to present information about this novel “resource-saving automotive hub bearing design” that features a reduction in the amount of materials consumed in production while boasting functions and characteristics equivalent to or better than those of conventional hub bearing products.

2. Structure and features

In developing our “resource-saving automotive hub bearing design”, we have adopted the Gen3 hub bearing for non-driven wheels (rear wheels on front drive vehicles) as a model case. In this development work we have attempted to meet the following targets:

- **Compatibility with conventional designs in terms of mounting dimensions**
- **10% or more weight reduction compared with conventional designs**
- **At least 20% reduction in the materials used for the hub and outer rings whose masses account for a large portion of the bearing product**
- **Functions including rolling fatigue life, mechanical strength and rigidity of our novel hub bearing design are equivalent to or better than those of conventional designs, even though our hub bearing design does not adopt special materials and/or heat treatment technique.**
- **Production cost equivalent to that of conventional designs**

To fulfill these targets, we have improved forging techniques in the manufacturing aspect, and fully utilized structural analysis techniques including FEM in the design aspect. We have optimized the bearing shape so that the amount of material scrapped in the forging process and the amount of material removed in the machining process are minimized, while still...
maintaining functionality of the hub bearing. Thus, we have achieved a light weight hub bearing product as well as a reduction in the amount of materials consumed in production.

2.1 Hub flange

Fig. 1 shows a typical example of the structure of a Gen3 hub bearing for a non-driven wheel. The hub ring as a rotary body has a hub flange that functions as a mount for installing the wheel and brake disk. The most commonly used hub flanges are disk type hub flanges such as a one shown in Fig. 2. Light-weight hub flange products are available; examples of which include a hub flange having lightening holes as shown in Fig. 3 and a cross shaped hub flange (non-common shape) shown in Fig. 4.

A hub ring is prepared by obtaining a work blank from a round steel bar and then subjecting the blank to forging, turning, heat treatment and grinding processes. The ratio of the mass of the steel blank work loaded into the forging process to the mass of the finished hub ring is known as “material yield”.

The lightening holes shown in Fig. 3 are formed by punching during the forging process. Despite its lightening effect, this technique leads to deteriorated material yield. When a cross shaped hub flange is manufactured, a work blank is first forged into a shape somewhat larger than the flange design, and then the work piece is punched to the final flange shape, and this technique also leads to deteriorated material yield.

In order to achieve not only improved material yield but also a lighter hub ring, we have developed a hub bearing shape shown in Fig. 5. In finalizing this shape, we have adopted an FEM analysis technique to optimize the mechanical strength and forgeability of the hub flange. More specifically, concaves of a larger radius are included in the outer circumference of the hub flange so that the convexes on the outer circumference are readily formed during the forging process and the number of portions which can later develop intermittent cutting during the turning process (which means deteriorated workability).
2.2 Hub pilot

The hub ring is provided with a hub pilot that serves as a guide for the wheel and brake disk installation on the hub. Previously, the outer circumference of the hub was machined to generate a hub pilot in the form of a cylindrical-sectioned belt as shown in Fig. 6, and the mass removed by the machining process was scrapped as chips.

In the case of our newly developed hub bearing, to achieve lightweighting as well as reduce the portion removed by machining, the previous pilot (cylindrical-sectioned belt) has been superseded with an intermittent hub pilot shown in Fig. 7 that consists of a plurality of teeth formed by forging.

An intermittent pilot shape can contribute to lightweighting as well as improved material yield owing to a reduction in surface being machined. However, this feature necessitates intermittent cutting, which leads to shorter tool life. At the same time, because this pilot shape involves an increased number of edges on the work piece, a chamfering process is needed to remove burrs.

To address this problem, ramps are formed during the forging process at both ends on each pilot tooth along the circumferential direction as shown in Fig. 8. This arrangement helps not only mitigate the impact that occurs when the cutting tool comes into contact with the pilot teeth but also inhibits the occurrence of burrs, thereby extending the life of the cutting tool and decreasing the number of machining steps.

Furthermore, as can be understood from Fig. 7, the pilot is situated in a location whose phase is the same as that of a concave on the outer circumference of our hub flange; consequently, the difference in cross-sectional area between a convex and a concave on the outer circumference of our hub flange is minimized and forgeability of the hub flange is improved.

2.3 Outer ring pilot

When a hub bearing is installed to the car body (suspension), the outer ring of the hub bearing offers a mounting point to the car body. The outer ring has a ring pilot that serves as a guide.

We have again chosen an intermittent configuration for the outer ring pilot on our hub bearing in order to reduce the area being machined and realize a lighter outer ring design. However, unlike the hub pilot, the inner bore of the outer ring pilot is fitted with a seal that prevents ingress of water and dust into the hub bearing. Therefore, as can be understood from the views given in Fig. 9, the inner edge of the outer ring pilot is continuous while the outer edge features a discontinuous form.

Incidentally, we have adopted a continuous machined surface around the flange of outer ring pilot in order to improve accuracy for installing the hub bearing and prevent corrosion of the flange surface due to the ingress of muddy water. Like in the case of the hub pilot, areas subject to intermittent cutting on
2.4 Lightening and reduced material consumption

As a result of the reduction in material consumption and improved material yield, our new design has achieved the following improvements over conventional designs: approximately 10% weight reduction of the hub bearing, approximately 20% reduction in material consumption with the hub ring and outer ring, and approximately 30% reduction in the total amount of material scrapped as a result of machining for the hub ring and outer ring.

3. Evaluation test

We first performed the theoretical review by FEM analysis technique of our novel “resource-saving automotive hub bearing design” that reflects the previously mentioned lightening technique and material consumption reduction technique. Then, we have subjected the prototype to a bench test looking at five characteristics, whereby we can verify that our new design is equivalent to the conventional design in terms of functionality:

1. Bearing rolling fatigue life: life (durability) test for bearing subjected to turning load on the car
2. Fatigue strength of hub flange: fatigue strength test
3. Rigidity of hub bearing: rigidity measurement
4. Mechanical strength of hub bearing: static strength test
5. Rotational balance of non-common shape flange: unbalance measurement

3.1 Bearing life (durability) test for bearing subjected to turning load on the car

The findings from the bearing life test are given in Table 1. The measured rolling fatigue life of our new design is more than six times as long as the targeted rating life. Thus, it has been proven that our new bearing design has sufficient durability.

<table>
<thead>
<tr>
<th>Subject of evaluation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional design</td>
<td>At least six times as long as rating life</td>
</tr>
</tbody>
</table>

3.2 Fatigue strength test

As summarized in Table 2, the samples have been run for a number of revolutions in excess of a target number. Though having undergone a test whose run time was longer than that of a conventional hub flange design, our newly developed hub flange has not developed any fractures, thereby we have determined that our new design has sufficiently high fatigue strength.

<table>
<thead>
<tr>
<th>Subject of evaluation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>New design</td>
<td>Number of revolutions at least 1.9 times as many as the targeted value. No fracture on flange</td>
</tr>
<tr>
<td>Conventional design</td>
<td>Number of revolutions at least 1.7 times as many as the targeted value. No fracture on flange</td>
</tr>
</tbody>
</table>
3.3 Rigidity measurement

Table 3 summarizes the results of the rigidity measurement. The rigidity of our newly developed hub flange is virtually equivalent to that of a conventional design.

<table>
<thead>
<tr>
<th>Subject of evaluation</th>
<th>Rigidity of tilted hub flange kN/˚</th>
</tr>
</thead>
<tbody>
<tr>
<td>New design</td>
<td>21</td>
</tr>
<tr>
<td>Conventional design</td>
<td>22</td>
</tr>
</tbody>
</table>

3.4 Static strength test

The mechanical strength required for our bearing in the static strength test is that the bearing does not develop a fracture when subjected to a lateral G load of 2.0 in the vehicle turning mode (side collision situation where the wheel has hit a curb). As can be understood from the information given in Table 4, our new bearing design satisfies the load requirement and has mechanical strength equivalent to that of conventional bearing designs.

Table 4 Result of static strength test

<table>
<thead>
<tr>
<th>Subject of evaluation</th>
<th>Lateral G in turning mode equivalent to fracture load</th>
</tr>
</thead>
<tbody>
<tr>
<td>New design</td>
<td>2.4</td>
</tr>
<tr>
<td>Conventional design</td>
<td>2.4</td>
</tr>
</tbody>
</table>

3.5 Unbalance measurement

To be able to determine the magnitude of effects of a non-common hub flange shape on the rotational balance of the hub ring, the unbalance of the hub ring needs to be measured. The resultant unbalance is of this design is better than G16 per JIS B 0905 and this level well satisfies G40, which is the level recommended by the same JIS (Japanese Industrial Standard) for quality of balance with automotive wheels.

From these findings, we are sure that our novel “resource-saving automotive hub bearing design” has functions equivalent to those of conventional hub bearing designs. The chart in Fig. 10 provides a comparison between our new hub bearing design and conventional design in terms of functionality and advantages in manufacture.

4. Afterword

To be able to contribute to the reduction of CO₂ emissions, NTN has designed a unique hub bearing product that boasts lighter weight through improved design as well as a reduction in materials consumed through an improved forging technique.

The applicable specification for individual NTN hub bearings can vary depending on the vehicle type and/or location of use. It is possible that all the considerations described in this document may not be applicable for the intended usage; notwithstanding, NTN will as necessary expand the scope of applicability of this product line. NTN is going to integrate its already proven “hub bearing with built-in high-sealing low-torque seal” technology with its novel “resource-saving automotive hub bearing” technology described above. Through these efforts, NTN will promote the reduction in weight and friction for hub bearings and thereby will further contribute to reductions in energy consumption by cars in travel as well as proceeding with development of novel eco-conscious technologies.

References


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