The Introduction of Sintered New Products for Automobile

1. Introduction

The use of sintered machine parts in vehicles has grown in recent years. Domestic production grew by 20% from approximately 70,000 tons in 1998 to 84,000 tons in 2012. Total weight of sintered parts in a vehicle also grew by 50% from approximately 6 kg in 1998 to approximately 9 kg in 2011. In this article, we would like to introduce high-density and high-strength sintered machine parts which can be used in a variety of vehicle applications along with sintered bearings, which can be used in corrosive or poorly lubricated environments.

2. High-density/high-strength sintered materials

Sintered materials are used in automotive applications in engine and drivetrain components where high strength is required in addition to high reliability and quality are required. In this section, we will describe the development of high-density and high-strength sintered materials.

2.1 High-strength sintered materials by high-density process

Sintered compacts, which contain internal pores, have inferior mechanical properties compared to the materials made by the melting and forging cast process. Therefore, various methods for strengthening sintered materials by increasing density are being proposed. Fig. 1 shows the relation between density and cost of the representative methods.

Powder forging, shown in Fig. 1, is a method to increase the density of sintered compacts by hot forging with the intent of completely eliminating the internal pores. Copper infiltration is a method wherein the internal pores of sintered compacts are filled with melted copper. Warm compacting is a method to increase the density by heating the powder and mold and using a special lubricant. These conventional high-density methods listed require special processes which lead to higher costs.

Therefore, we aimed for obtaining high-density sintered compacts with a similar method as the ordinary sintering process of the past. This was done by optimizing manufacturing conditions, such as material composition, forming conditions, heat treatment, etc.

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and high-density/high-strength sintered materials were developed.

2.2 Mechanical properties

Fig. 2 shows the relation between the density of various materials, including the developed material, and Young’s modulus. The density of the developed product is 7.5 g/cm³. This achieves more than 95%, in true density ratio, of the density of iron, which is 7.85 g/cm³. Young’s modulus is 180 - 190 GPa, which is equivalent to high carbon chromium bearing steel, SUJ2. Adding cold working further increases both density and Young’s modulus.

Fig. 3 shows the radial crushing strength. Radial crushing strength is obtained by the following equation, applying compressive stress on the annular test piece, as shown in Fig. 4. The developed material showed a radial crushing strength of 2,000 MPa or more, compared to 1,300 MPa of the conventional high-density materials.

Fig. 5 shows the fatigue limit of the developed material obtained from the ring compression fatigue test. The ring compression fatigue strength is obtained from a test of finding the fatigue limit by repeating a load of stress ratio 0.1 (the ratio between the maximum and minimum compression load is 10:1) on the annular test piece, as shown in Fig. 6. The result of the ring compression fatigue test is, in general, experimentally known to be around 0.8 times the fatigue strength obtained by the ordinary bending fatigue test.

The fatigue limit of the developed material is 300 MPa, about twice the fatigue limit of the conventional high-density material of 150 MPa.

Therefore, the developed material can be used in areas with a high repetitive load, where the conventional sintered parts could not be used.
3. Corrosion resistant sintered bearings

In general, bronze series sintered bearings are used for motor-based fuel pumps of automobiles. Corrosion by sulfur and organic acid contained in the fuel has recently been observed in the conventional bronze series sintered bearings due to the use of inferior quality fuel used mainly in developing countries. To cope with this issue, cupronickel-based sintered bearings with superior corrosion resistance are used. However, this material is very expensive as it contains nickel. This led to the development of the less costly sintered bearings, adopting aluminum bronze as the material, which has equivalent or better corrosion resistance as the cupronickel material.

3.1 Features and challenges of aluminum bronze

Although aluminum bronze exhibits superior corrosion resistance, it was considered inadequate for the sintering process of powder metallurgy because of surface oxidation under high temperature. It also has a higher friction coefficient than the ordinary bronze series material.

To solve this issue, the material composition and manufacturing method were optimized, especially the sintering method to improve its properties. This achieved aluminum bronze with corrosion resistance equivalent to or better than that of the cupronickel material. In addition, friction and anti-wear properties were significantly improved by optimizing the blending of graphite.

3.2 Corrosion resistance

Table 1 shows the test results of corrosion resistance against organic acid and sulfur. Cupronickel material was also tested for comparison purposes.

<Test conditions>
(1) Corrosion resistance test against organic acid
   - Test fluid: Organic acid with 2% concentration
   - Temperature: 50°C
   - Test time: 100 hours
(2) Corrosion resistance test against sulfur
   - Test fluid: Gasoline with 300 ppm of sulfur
   - Temperature: 80°C
   - Test time: 300 hours

The test results showed that the developed material was equivalent in corrosion resistance against organic acid and superior in corrosion resistance against sulfur.

3.3 Friction/wear properties

Table 2 shows the friction coefficient and specific wear amount.

<Test conditions>
(1) Friction test
   - Load: 35N
   - Rotation speed: 3,160 min⁻¹
   - Test piece size: ID 5 × OD 10 × Width 7 mm
   - Opposite material: SUS304
   - Test time: 30 min.
(2) Wear test
   - Load: 64N
   - Rotation speed: 3,000 min⁻¹
   - Test piece size: ID 6 × OD 12 × Width 6 mm
   - Opposite material: SUS304
   - Test time: 500 hours

The friction coefficient of the developed material was equivalent to that of the cupronickel material. On the other hand, the specific wear amount of the developed material was about 1/10 that of the cupronickel material.

This shows that the developed material has a more superior anti-wear property than the cupronickel material, thus making it a suitable replacement for the latter.

Table 2 Friction coefficient and specific wear rate

<table>
<thead>
<tr>
<th></th>
<th>Developed material</th>
<th>Cupronickel material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friction coefficient</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>Specific wear rate m³/(N·m)</td>
<td>3.2×10⁻¹³</td>
<td>30.0×10⁻¹³</td>
</tr>
</tbody>
</table>

4. Self-lubricating sintered bearings

Sintered oil retaining bearings for automobiles and office equipment may be used in environments with high temperatures or enclosed by a cover, etc. In this case, lubricant oil retained in the bearings may evaporate and contaminate the surroundings. The developed self-lubricating sintered bearings use special graphite as the solid lubricant and are applicable in high temperature environments where oil cannot be used.

Regular graphite is inferior to other kinds of metal powder in fluidity; however, increasing the additive amount causes inferior compactibility preventing formation of complex shapes and low green compact strength.

Therefore, the metal powder mixture was changed to adopt high-fluidity special graphite in an increased...
amount. This achieved the development of self lubricating sintered bearings with excellent sliding and anti-wear properties even when lubricant oil is not used, while maintaining high productivity (Fig. 7).

The friction coefficient of the self lubricating bearings were approximately half that of the bronze series without oil content. The specific wear amount was also about 1/3, showing an excellent anti-wear property. This means they can be used in areas where an anti-wear property is required without oil content.

## 5. Summary

In this article, the newly developed high-density/high-strength sintered machine parts for automobiles and sintered bearings for special environments were introduced. We will promote marketing of the developed products introduced in this article, along with continuing development of higher functionality.

### [High-density/high-strength sintered material]
- Achieved true density ratio of 95% to iron and Young’s modulus equivalent to SUJ2
- Approximately 1.5 times radial crushing strength and 2 times fatigue limit compared with the conventional high-density sintered materials

### [Corrosion resistance sintered bearings]
- Equivalent or better corrosion resistance and friction coefficient and around 1/10 of specific wear amount of the cupronickel sintered bearings

### [Self lubricating sintered bearings]
- Approximately 1/2 the friction coefficient and approximately 1/3 the specific wear amount compared to the bronze series sintered bearings without lubricant content

## References

1) Sokeizai Center, Monthly Bulletin “Sokeizai” May 2013 Vol. 54, No. 5 Special Issue, Sokeizai Yearbook 2012