The Copper-Iron-based Material Equivalent to Bronze-based Material for Sintered, Oil-impregnated Bearings

1. Introduction

Sintered, oil-impregnated bearings are widely used in automobiles and industrial machines and their materials are broadly classified into bronze-based, iron-based and copper-iron-based, which combines the former two materials. When superior sliding performance is required in a bearing application, such as electric parts (power windows, fan motors, etc.), copying machines, or laser printers, bronze-based material is suitable. However, because of the recent increase in the cost of copper, NTN has developed a new material as an alternative to bronze for sintered bearings. In this paper, we present the properties of this copper-iron-based material equivalent to bronze sintered material for sintered, oil-impregnated bearings.

2. Material of Sintered, Oil-impregnated Bearings

Among sintered, oil-impregnated bearings, bronze-based material is superior in its sliding properties, iron-based material is superior in its durability, and copper-iron-based material has both properties.

On the other hand, since the price of iron is less expensive than copper, the sliding properties, durability, and cost are in a trade-off situation. NTN determined the correct composition of copper and iron based on the applicable use and conditions considering the balance between sliding properties, durability, and cost, from the base copper-iron-based material.

3. Features of Special Copper Powder

Table 1 shows the composition of the developed material and Fig. 1 shows the cross section of a bearing using a special copper powder based on this developed material composition. The upper side of the figure is the bearing bore surface, where a thin layer of copper can be observed. The special copper powder tends to aggregate on the surface of the powder compact; therefore, a green compact can be produced in the regular molding process without needing any special processes, such as plating. On the other hand, many general copper and iron powders added in the blending process are contained inside the compact.

Fig. 2 shows the bearing bore surface. Copper is exposed on approx. 60% or more of the bore surface which contributes to the excellent sliding properties.
The friction coefficient of the developed material was the lowest at the beginning of operation and it was the same as the bronze-based material at the time before stabilization. In addition, the friction coefficient 10 minutes later was at the same level as the bronze-based material and even lower than the copper-iron-based material containing an equivalent amount of copper.

From these results, it was found that the developed product has excellent initial fitness and that its friction properties are equivalent or superior to the bronze-based material.

4. Performance of the Developed Bearings

We considered initial fitness, limiting PV value, wear resistance, and low temperature properties when evaluating the performance of the developed products.

4.1 Initial Fitness

The sintered, oil-impregnated bearings have a high friction coefficient at the beginning of operation which gradually decreases. This phenomenon is called initial fitness.

Since motors are required to have stable operation characteristics, a low friction coefficient from the beginning of operation and early stabilization is required. Therefore, we evaluated the initial fitness of the developed product.

In addition to the developed product, we also evaluated bronze-based material and copper-iron-based material containing 20% copper, equivalent to the developed product. The result is shown in Fig. 3.

4.2 Limiting PV Value

PV value, which is an index to determine the operation limit of the bearings, is indicated by the product of the contact pressure applied to the bearings P and peripheral speed V.

The larger the value, the tougher the operation condition.

Fig. 4 shows the measurement results of the limiting PV value of different bearings. This test is conducted by maintaining a constant rotational speed and applying a load on the bearings. After a predetermined time, if the friction coefficient becomes stable, the weight of the load is increased. This is repeated. If the friction coefficient does not stabilize after the predetermined time, the PV value at that time is considered as the limiting PV value.
The friction coefficient of the developed material behaved the same way as the bronze-based material and was lower than the copper-iron-based material containing an equivalent amount of copper. In addition, the limiting PV value of the developed material was significantly higher than the bronze-based product and equivalent with the copper-iron-based material.

From this result, it can be determined that the developed material has an equivalent friction coefficient as the bronze-based material in the low PV value range and maintains a low friction coefficient in the high PV value range, as well. Therefore, it can be used in the broad PV value range.

**<Test condition>*  
- Shaft material: SUS420J2  
- Bearing size: φ6×φ12×6  
- Test temperature: Room temperature

4.4 Low Temperature Properties

When used in an automotive application, a noise may be produced at the beginning of operation in low ambient temperatures - (abnormal noise at a low temperature). The cause of this noise is considered to be the metal-on-metal contact between the shaft and the bearings.

With sintered, oil-impregnated bearings, the rotational shaft is supported by the oil film formed between the shaft and the bearings which may contract in low temperatures, causing less lubrication and resulting in metal-on-metal contact.

**Fig. 6** shows the measurement result of oil film forming rates in low temperature, as an evaluation of oil film forming behavior. As a comparison, the measurement result in room temperature is also shown. The oil film forming rate of 100% indicates non-contact and 0% indicates full contact.

In **Fig. 6 (1)**, it was found that the oil film forming rate of the bronze-based product was poor, indicating metal-on-metal contact even 30 minutes later. On the other hand, the developed product showed a good oil film forming rate right after the beginning of the test, transitioning to a non-contact state in an early stage. As a result, we consider that the developed product has superior oil film forming properties to bronze-based product in low temperatures, contributing to low noise and vibration in a low-temperature environment. In addition, as shown in **Fig. 6 (2)**, the developed product indicates better oil film forming properties than the bronze-based product suggesting superior operational life and wear resistance.

**<Test condition>*  
- Shaft material: S45C  
- Contact pressure: 0.51 MPa  
- Peripheral speed: 93.4 m/min  
- Shaft material: SUS420J2  
- Test time: 30min.  
- Test temperature: room temperature, -40°C

4.3 Wear Resistance

For the evaluation of wear resistance, the wear was estimated from the difference of the bearing bore diameter before and after the operation test. **Fig. 5** shows the evaluation results.

It was found that the wear amount of the developed product is less than that of the bronze-based material and copper-iron-based material, presenting excellent wear resistance.

**<Test condition>*  
- Peripheral speed: 38 m/min  
- Contact pressure: 4.0 MPa  
- Bearing size: φ6×φ12×6  
- Shaft material: SUS420J2  
- Test temperature: Room temperature  
- Test time: 8 hours

*Fig. 4* Result of limiting PV value measurement

*Fig. 5* Result of wear resistant evaluation
5. Expansion of Applications of the Developed Product

The features of the developed product as observed in the evaluation results of the previous section are as follows:

(1) Equivalent friction properties as the bronze-based product
(2) Equivalent limiting PV value properties as the copper-iron-based product
(3) Superior wear resistance
(4) High oil film forming properties in low temperatures

Because of these features, the application of the developed material can be expanded into diverse areas as an alternative to bronze-based material. In particular, its application in electric motors, such as the starter motor, is expected due to its good low-temperature characteristics.

In industrial machines, it can also be applied to the small diameter motors where large loads are applied, such as vibration motors and stepping motors.

6. Conclusion

In this paper, we presented the newly developed copper-iron-based material equivalent to bronze sintered material for sintered, oil-impregnated bearings. We are poised to expand our sales by leveraging the unique features of these products and continue our development aiming at further enhancement.