Introduction of Composite Material Products for Industrial Machinery

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Composite Material Products Division has developed and produced bearings, mechanical parts, and unit module products made of multi materials such as plastic, sintered metal, and magnetic material using tribology as a basic technology. In this article, we introduce composite material products used in various advanced fields of industrial machinery.

1.Introduction

New markets are emerging and growing for products equipped with advanced technology according market trends in the field of industrial machinery. Machine parts with tribological characteristics that are better than existing technologies are required for new products in this advanced field. Creating lightweight or low-friction parts to save energy and control CO_2 emissions are an example of this. The Composite Material Product Division has been using and developing materials such as plastics, sintered metal and magnetic material for products that meet these higher performance requirements, and has been proposing and supplying these products to our customers. This paper introduces examples of applications for composite material products in advanced fields.

2. Hydrodynamic BEARPHITE Bearing for Thin Cooling Fan Motors

There has been a rapid growth in demand for mobile devices such as laptops for use in teleworking and online courses. A superior quietness is required for cooling fans **(Fig. 1)** equipped in these types of devices that covers an extensive range of low to high rotational speed. **NTN**'s Hydrodynamic BEARPHITE **(Fig. 2)** has the reputation of achieving this quietness and reliability, and has been widely adopted in thin cooling fans.

Hydrodynamic BEARPHITE provides non-contact support for the shaft and bearing through oil-film pressure generated within the bearing clearance due to the hydrodynamic effect. Therefore, it is a bearing an excellent quietness. Generally, oil-film pressure increases proportional to the rotational speed for hydrodynamic BEARPHITE bearings. Like when the bearing is rotating at high speeds, it is important to maintain the oil-film pressure required to provide non-contact support even at low speeds when the oil-film pressure drops. By improving the Hydrodynamic BEARPHITE material, we have maintained a quietness at low rotational speed, a requirement of cooling fans.

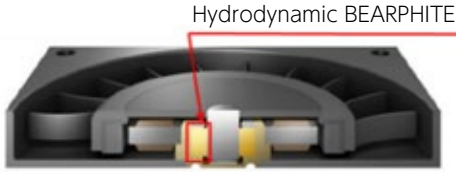

Fig. 1 Fan for cooling

Fig. 2 Hydrodynamic BEARPHITE

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2.1 Features

There are 2 types of Hydrodynamic BEARPHITE: the copper and iron based material EZ06 which is a standard material, and EZ17 with increased oil-film pressure. **Table 1** shows the material composition.

Table 1 Material composition

		Material	
		EZ06	EZ17
Chemical composition %	Cu	Remaining amount	Remaining amount
	Sn	1 - 3	1 - 3
	C	0.5 - 2.5	–
	Fe	38 - 42	38 - 42

Hydrodynamic BEARPHITE is a type of oil-impregnated sintered bearing manufactured using a powder metallurgy method. So it has pores on the bearing surface and interior. While the pores have an important function of maintaining and supplying lubricating oil, they can also be the cause of decreasing of generated oil-film pressure. In order to maintain a quietness at a low rotational speed of 1,000 min^{-1} required for thin cooling fans used in mobile devices, it is important to control the pores to maintain a high oil-film pressure.

In case of EZ17, the pores are micronized to improve the oil-film pressure by optimizing the particle distribution and shape of the material powder. **Fig. 3** shows a comparison of the bearing inner diameter surface. Pores on EZ17 are clearly micronized than EZ06.

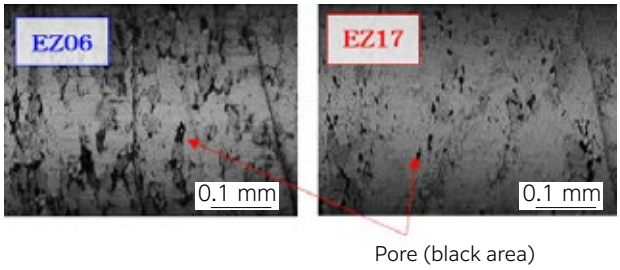

Fig. 3 Enlarged photo of inner surface (Inner diameter 2 mm)

2.2 Performance

We compared the rotational speed at which EZ06 and EZ17 can provide non-contact support for the shaft by determining whether contact occurs between the shaft and Hydrodynamic BEARPHITE using an electrical resistance method. **Fig. 4** shows the results.

EZ17 can reduce the rotational speed at which non-contact support can be provided for the shaft by 30 % compared to EZ06. This shows that it is possible to provide non-contact support even at the low rotational speed of 1,000 min^{-1} required for cooling fans.

< Test conditions >
Shaft material SUS420J2
Bearing dimensions: Inner diameter 2 mm, outer diameter 4 mm, width 3 mm
Surface pressure 0.5 MPa, room temperature, test time of 2 min
Lubricating oil kinematic viscosity (40 ℃) 12 mm^2/s

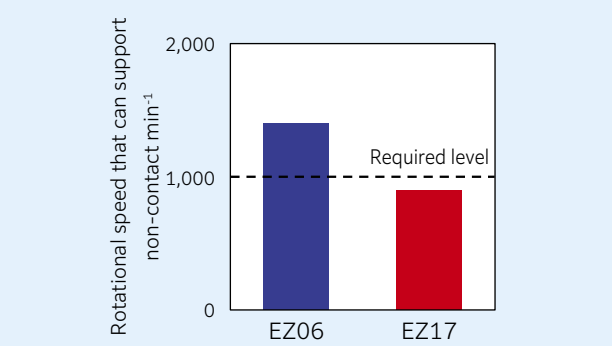

Fig. 4 Test result of contact of shaft and BEARPHITE (Shaft outer diameter 2 mm)

3.Plastic Bearings for Electric Water Pump[1)]

Heat pump water heaters using natural coolant, residential fuel cell cogeneration systems, and water-heated floors are some of the technology used for residential equipment to support ZEH (Net Zero Energy House). Electric water pumps are used for their circulation and cooling systems. **NTN**'s underwater plastic (BEAREE AS5704) sliding bearing is used in these electric water pumps.

3.1 Structure of Electric Water Pump

Fig. 5 shows the structure of a magnetic drive water pump as a typical electric water pump.

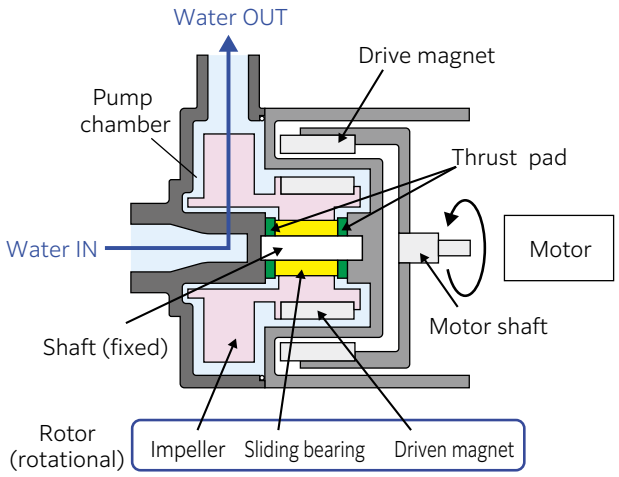

Fig. 5 Structure of magnetic drive electric water pump

A rotor integrated with a plastic impeller, driven magnet and sliding bearing is housed inside the pump chamber and supported by the shaft using a sliding bearing. The drive magnet installed on the motor shaft rotates the rotor by magnetic force to transfer water sucked by the impeller into the pump chamber. Since radial load and axial load occur when the rotor rotates, the bearing surface of inner diameter and shaft, and the bearing end surface and thrust pad slide underwater respectively. Generally, the bearing is inserted into a mold along with the driven magnet and the plastic impeller is integrated using an injection molded composite mold.

3.2 Required Performance and Bearing Material

Low-friction properties and high wear resistance in a liquid are required for bearings to achieve power saving and long-life electric water pumps.

Furthermore, chemical resistance and dimensional stability in water or acidic and alkaline liquids are also required. For magnetic drive water pumps, the bearing is integrated with the impeller using a composite mold, therefore the bearing outer diameter surface must be provided a retainer and rotation lock (D-shaped cut, protrusion, etc.) from the impeller. Therefore, the flexibility of the shape design is also important.

Due to the above requirements, electric water pumps use plastic bearing made of polyphenylene sulfide (PPS), polyether ether ketone (PEEK) and polytetrafluoroethylene (PTFE) or carbon bearing. Among plastic bearing, PPS bearing is less wear and longer operating life than PTFE bearing, and are cheaper than PEEK bearing. PPS bearing also has the benefit of a high flexibility of the shape design since it can be injection molded. Consequently, **NTN**'s "BEAREE AS5704 Bearing" for underwater **(Fig. 6)** which has excellent friction and wear properties, and chemical resistance by combining fillers such as solid lubricants and stiffeners with PPS, is used on electric water pumps.

Fig. 6 BEAREE AS5704 bearings for using in water

3.3 Comparing BEAREE AS5704 Bearing with Other Bearings

PPS have high rigidity and excellent water, chemical and heat resistance, although it is comparatively low cost. PPS lacks the mechanical properties and friction and wear properties by itself, so it is combined with fillers. The friction coefficient and wear resistance change depending on the conditions of use like the environment (the atmosphere, oil, or water), the load, sliding speed, and mating material. Bearings for electric water pumps slide on a soft stainless steel mating material in fluid such as water.

Fig. 7 shows the results from a friction and wear test performed underwater on 4 types of bearings. These bearings are the BEAREE AS5704 bearing, and PPS combined with glass fiber (GF), carbon fiber (CF) and polytetrafluoroethylene (PTFE).

The CF combined bearing has a low specific wear amount but has high dynamic friction coefficient. The PTFE combined bearing has 30 to 40 % lower dynamic friction coefficient than both the GF and CF combined bearings but has less wear resistance. The BEAREE AS5704 bearing has a lower friction coefficient than the PTFE combined bearing and its specific wear amount is under 1/5 of the CF combined bearing.

The BEAREE AS5704 bearing is combined with fillers selected appropriately for using in electric water pumps, so the wear amount of the bearing and mating material is small, and it has excellent friction and wear properties underwater in comparison with PPS bearings combined with other fillers.

< Test conditions >
Ring on disc type testing machine
Mating material SUS304
Surface pressure 0.4 MPa, speed 25 m/min
Underwater, room temperature, test time 50 hours

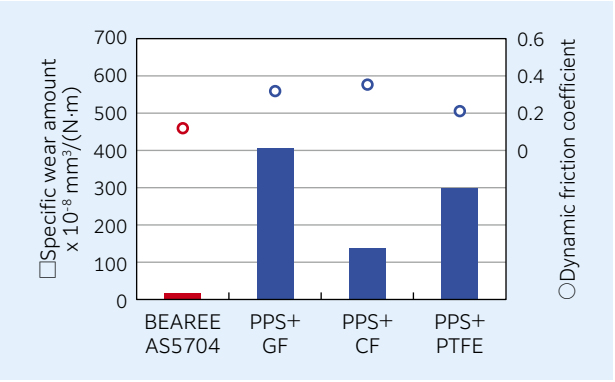

Fig. 7 Results of friction and wear test of PPS bearings

Carbon bearing also used to use in electric water pumps. As shown in **Fig. 8**, the BEAREE AS5704 bearing has the same or greater friction and wear properties as carbon bearing, therefore adoption of BEAREE AS5704 bearing is increasing by replacing from carbon bearing.

Table 2 shows the comparison in performance of the BEAREE AS5704 bearing and carbon bearing.

Since carbon bearing is machined product made from molding material, so it is expensive and has a low flexibility of the shape design. Furthermore, it is fragile and easy to chip due to impact, so it is necessary to be taken care with handling during transportation and fixing them to rotors.

Meanwhile, BEAREE AS5704 bearing is an injection molded product, so the retainer, rotation lock and lubrication grooves on bearing inner diameter surface and end surface can be easily designed. Furthermore, it is cheaper compared to carbon bearing and easy to handle since it is difficult to chip.

< Test conditions >
Ring on disc type testing machine
Mating material SUS304
Surface pressure 1 MPa, speed 125 m/min
Underwater, room temperature, test time 10 hours

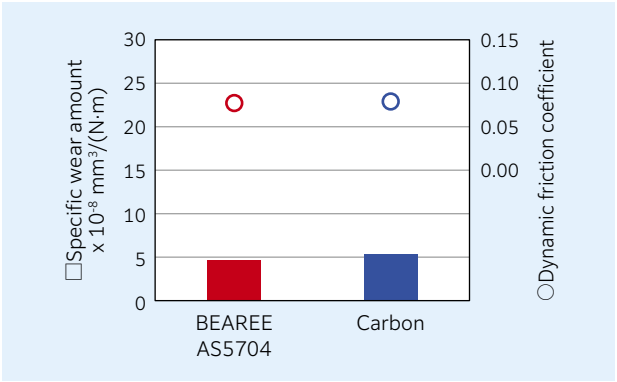

Fig. 8 Results of friction and wear test of BEAREE AS5704 bearing and carbon bearing

Table 2 Comparison between BEAREE AS5704 bearing and carbon bearing

Item	BEAREE AS5704 bearing	Carbon bearings
Processing method	Injection molded	Machined
Friction coefficient (underwater)	◎	◎
Wear resistance (underwater)	◎	○
Water and chemical resistance	◎	◎
Chip due to impact	○	△
Flexibility of shape design	◎	△
Cost	◎	△

◎ : Excellent ○ : Good △ : Acceptable

4. Plastic Sliding Screws for Medical Devices Such as Eye Testers, Dialysis Machines and Anesthesia Apparatus[2)]

Ball screw and sliding screw are available for feed screw that convert the rotational movement of the motor into linear motion, and these screws are used depending on their application and conditions of use. Ball screw have a high allowable load and excellent screw efficiency, but is not suitable for use in environments where grease cannot be used. Meanwhile, plastic sliding screw has a low allowable load but can be used without lubrication, produce low-noise, and is light and compact.

Due to these features, **NTN** plastic sliding screws are also adopted in inspection devices for COVID-19. In terms of other medical devices, these screws have been installed for eye testers, dialysis machines and anesthesia apparatus. In other fields, there are also adopted for such as substrate positioning on semiconductor manufacturing equipment.

4.1 NTN Plastic Sliding Screw Structure and Required Performance

Plastic sliding screw is assembled plastic nut and stainless steel screw shaft. During shaft rotation, the plastic nut and screw shaft slide, so low friction and wear properties are required for the plastic nut. As shown in **Fig. 9**, the plastic nut material of the "**NTN** Plastic Sliding Screw" is "BEAREE AS5000", which has combined with PPS and a special solid lubricant. **NTN** has a lineup of 16 standard types with a screw shaft outer diameter of 4 to 12 mm and leads of 1 to 36 mm.

Generally, polyoxymethylene (POM), polyamide, and PPS are used for the plastic nut material on the plastic sliding screw and are combined with a solid lubricant to provide low friction properties. The durability of plastic sliding screw depends on the wear resistance of the plastic nut which is improved through the use of a filler. However, combining fibrous filler increases the friction coefficient and generates sliding noise.

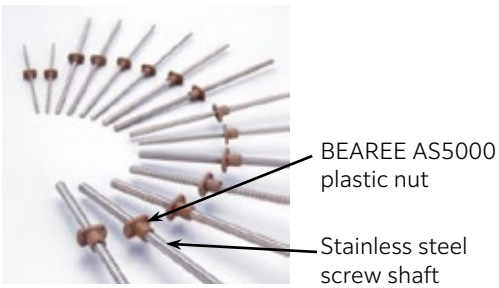

Fig. 9 NTN Plastic sliding screws

4.2 Comparison between NTN Plastic Sliding Screws and Other Sliding Screws

A special fibrous PTFE is combined to BEAREE AS5000 to produce a plastic nut that has low friction and wear properties. **Fig. 10** shows wear properties

without lubrication based on an element test for 3 types of sliding screws: BEAREE AS5000, PPS combined with a general granular PTFE, and PPS combined with granular PTFE and CF. The specific wear amount of BEAREE AS5000 combined with fibrous PTFE is 1/5 lower compared with that of PPS combined with granular PTFE, and half compared with that of PPS combined with granular PTFE and CF as stiffener.

< Test results >
Ring on disc type testing machine
Mating material S45C
Surface pressure 0.4 MPa, speed 25 m/min
Room temperature, no lubrication, test time 50 hours

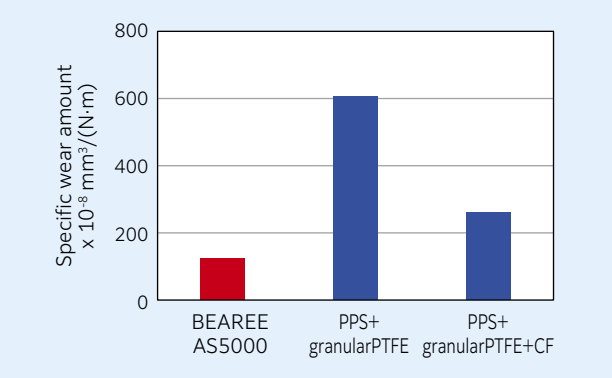

Fig. 10 Result of wear test of PPS

POM plastic sliding screw which is assembled an oil-impregnated POM plastic nut and a stainless steel screw is widely used in the market. **Fig. 11** shows the results of a wear test for this POM plastic sliding screw and the **NTN** plastic sliding screw. Generally, a sliding screw can be used as long as the amount of increase in axial clearance due to operation is 0.3 mm or less. In contrast, the POM plastic sliding screw which exceeds 0.3 mm for the amount of increase in axial clearance at a 60 km of sliding distance, the **NTN** plastic sliding screw is 0.15 mm even at 200 km, so it has a long operating life.

< Screw test conditions >
Screw specification: Shaft diameter 8 mm, lead 24 mm, 6 threads
Load 100 N, rotational speed 500 min^{-1}, room temperature, no lubrication

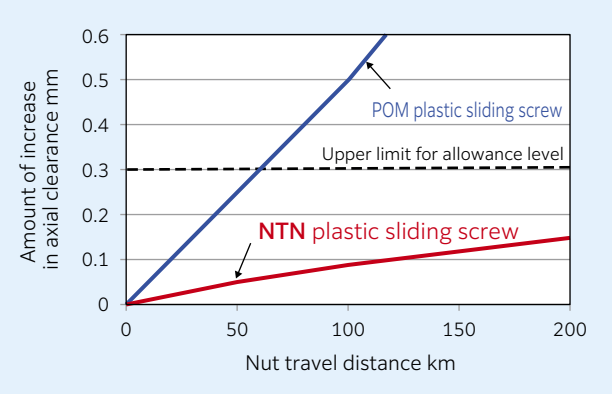

Fig. 11 Result of wear test of plastic sliding screws

5. Conclusion

This paper introduced examples of adopting bearing and element products made of plastics and sintered metal in various fields for the purpose of low-noise, energy-saving, compact design, lightweight and long operating life.

In future, societies will emerge driven by new technologies such as robotics, hydrogenation and IoT.

The Composite Material Product Division contributes developing the industrial machinery field by developing products to further improve functionality and making low friction and element products for growing markets.

References

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2) Naonari Tanigawa, Norio Itou, Tomomi Tonomura, Plastic sliding screws, NTN TECHNICAL REVIEW, No.84, (2016) 69-73.

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