Experimental Study on Material Properties of Bearing Bush of Water Lubricated Bearing

Chen Changsheng, Li Shan, Lu Zhen, Ma Zhenlai, Li Guoping, Zhang Yi
Shanghai Marine Equipment Research Institute, N0.10 Hengshan Rd. Shanghai, China
ccs704@163.com

Abstract. Water lubricated bearings are commonly used equipment in ship and other fields. The friction factors and other parameters of bearing materials have great influence on the performance of Water lubricated bearings. In this paper, a comprehensive bearing test platform was established, the slurry wear test of bearing material was carried out on the MPH corrosion wear tester, and the effects of wear time, sliding speed and load on the friction performance of bearing material were obtained. And then the effects of different additives on the optimization and improvement of the wear resistance and friction coefficient of bearing bushes have been systematically analyzed. The results show that the friction coefficient increases when glass fiber is added into PTFE matrix, but the effect of carbon fiber is not significant. The material composed of PTFE matrix and graphite not only improves the wear resistance, but also reduces the friction coefficient. Rigid additives increase the hardness of PTFE matrix, while soft additives decrease the hardness of PTFE matrix. Almost all kinds of additives can reduce the impact strength of PTFE matrix.

1. Introduction
Water lubricated bearings, which are lubricated by water, are pollution-free, widely sourced, safe and flame-retardant. They can reduce wear, noise and power consumption caused by friction motion. Therefore, water lubricated bearings have great potential in environmental protection and energy saving, especially in mechanical systems such as ships and pumps. Water lubricated bearings need to choose different bearing materials according to different working conditions, which are different from traditional oil lubricated bearings. For example, the working conditions of water lubricated bearings installed in pumps are characterized by high speed and vibration absorption. The elastic modulus, thermal expansion coefficient and water absorption of different materials will have different effects on the characteristics of water lubricated bearings. Therefore, the influence of different materials on lubrication mechanism, support stiffness and other parameters can be obtained by studying the material characteristics of bearing bushes. As an important index to judge wear characteristics of bearing materials and service life of bearings, friction performance has become a research hotspot in this field.
At present, many scholars have done a lot of research on water lubricated bearings, including lubrication mechanism, friction mechanism and the influence of different conditions and material characteristics on tribological behavior. However, to some extent, the research on the influence of working conditions and material additives on the tribological characteristics of bearings is not enough. Therefore, the experimental study on the improvement of bearing materials for water lubricated bearings is an important supplement to the existing research results, which provides support for the practical application of bearing materials for water lubricated bearings and has important engineering practical value.

In this paper, a comprehensive bearing test platform has been established, and a lot of tests have been carried out on the material properties of water lubricated bearing bushes. The effects of different additives on the optimization and improvement of the wear resistance and friction coefficient of bearing bushes have been systematically analyzed. The research results have certain guiding significance for the selection and optimization of the material of water lubricated bearing bushes.

2. Introduction of Test Platform

In this paper, a comprehensive bearing test platform is built. Firstly, the slurry wear test of bearing material was carried out on the MPH corrosion wear tester, and the effects of wear time, sliding speed and load on the friction performance of bearing material were obtained. On this basis, the friction and wear characteristics of bearing material are systematically analyzed, and material improvement is carried out, and the bearing material with improved material performance is studied. Then, the friction and wear characteristics of bearings under water lubrication are studied by using the bearing comprehensive test platform, and the tribological law under this condition is obtained.

Polytetrafluoroethylene (PTFE) was chosen as the base material of bearing bush in this paper. Additives of different proportions and types were added to the base material for experimental study.

![Figure 2. Comprehensive bearing test platform.](image)
3. Wear Behavior of Bearing Material under Dry Friction
In this paper, the PTFE fine-grained resin produced by suspension method was tested, with an average particle size of 50 microns. Because the wear resistance of the bearing material is very outstanding, the friction coefficient can only be measured by ordinary friction and wear testing machine, and the wear amount can only be measured by mortar wear testing method. Therefore, the friction and wear tests were carried out on the friction and wear tester, and the mortar wear tests of bearing materials were carried out on the MPH corrosion and wear tester.

From the curve of Figure 3, it can be seen that the wear of bearing materials can be divided into three stages: wear run-in period, stable wear period and accelerated wear period, while the load and speed remain unchanged. During the wear run-in period (0-5 min), ploughing will be formed on the surface; during the stable wear period (5-20 min), a series of ploughing will disappear and wear is relatively stable; after 20 min, the heat generated during the friction process softens the bearing material, and repeated sliding will cause the tearing and fracture of the bearing material, resulting in serious wear.

Figure 4 shows the effect of load on friction coefficient and wear rate. It can be seen that the friction coefficient of bearing material decreases with the increase of load. This is because of the plasticity of the bearing material, which results in the increase of the actual contact area with the increase of the load. When the contact saturation is reached, the external load increases again, but the friction force does not continue to increase, so the friction coefficient shows a decreasing trend. When the speed of the wear tester is 2.0m/s and the test time is 30 minutes, the wear amount increases with the increase of the load, and when the wear time increases, serious wear will occur under lower load.

Because the bearing material has viscoelasticity, its friction coefficient is dependent on time, speed and temperature. When the load is 300N, the relationship between the friction coefficient of the bearing material and sliding speed and temperature is shown in Fig. 5. It can be concluded that when the velocity increases, the friction coefficient presents a curve change. Below the glass transition temperature, the friction coefficient increases with the increase of temperature; above the glass transition temperature, the friction coefficient decreases with the increase of temperature; when the temperature is high, the surface melting of bearing material will make the friction coefficient very low.
Because the bearing material has viscoelasticity, its friction coefficient is dependent on time, speed and temperature. When the load is 300N, the relationship between the friction coefficient of the bearing material and sliding speed and temperature is shown in Fig. 5. It can be concluded that when the velocity increases, the friction coefficient presents a curve change. Below the glass transition temperature, the friction coefficient increases with the increase of temperature; above the glass transition temperature, the friction coefficient decreases with the increase of temperature; when the temperature is high, the surface melting of bearing material will make the friction coefficient very low.

4. Experimental Study on Material Performance Improvement

In order to develop better bearing material, carbon fibre, glass fibre, graphite, PEEK and MoS2 were added to PTFE matrix respectively, and experimental research was carried out. The specific contents and experimental results are as follows.

The graph below shows the relationship between the proportion of additives and the wear rate. It can be seen that when the proportion of additives is small, the wear rate decreases obviously with the increase of additives, that is, the wear resistance increases. This is due to the addition of inorganic materials in the matrix of PTFE can act as a rigid support point, effectively preventing the embedding and grinding of sand particles, thereby improving the wear resistance. When the proportion of additives reaches a certain value, the wear resistance of bearing material will not increase. This is because when the content of additives exceeds a certain value, the original characteristics of plastics and the continuity of matrix will be destroyed, and the interaction force between polymer molecules will become smaller. Under the action of sand particles, the material will be easy to wear. Therefore, the proportion of additives should not be too large, otherwise, the wear resistance will be reduced.

The Fig. 7 shows the relationship between different additives and friction coefficient. It can be seen that the addition of glass fibre has a great influence on the friction coefficient, and the friction coefficient will increase; the addition of carbon fibre has little effect on the friction coefficient; the addition of MoS2, PEEK and graphite can reduce the friction coefficient. This is because MoS2 and graphite are better solid lubricants, which can greatly reduce the wear of PTFE composites. PEEK has excellent lubrication properties and forms a lubrication film on the surface of the composites, which can reduce the wear and friction coefficient of PTFE composites.

As can be seen from Fig. 8, the effect of additives on the hardness of PTFE varies with the type and proportion of additives. Rigid additives such as carbon fibre and glass fibre increase the hardness of PTFE, while soft fillers such as graphite and MoS2 reduce the hardness of PTFE. PEEK material has little influence on the hardness of PTFE. With the increase of PEEK ratio, the hardness of PTFE decreases slightly.

It can be seen from Fig. 9 that the impact strength of PTFE decreases with the increase of the proportion of additives. This is due to the poor compatibility of additives and PTFE matrix, which
forms stress concentration points in PTFE matrix, resulting in the decrease of impact strength. Therefore, when adding materials to improve the friction performance of PTFE, the proportion of additives should not be too large, otherwise, the impact strength will become very low.

5. Summary
The friction coefficient of PTFE bearing material decreases with the increase of load, and the wear rate increases with the increase of load. The friction coefficient of bearing material varies with the increase of speed. Below the glass transition temperature, the friction coefficient of bearing material increases with the increase of temperature, but above the glass transition temperature, the law is opposite.

Friction factors will increase when glass fibre is added to PTFE matrix, while carbon fibre have little effect on the friction coefficient. MoS2, PEEK, graphite, glass fibre and carbon fibre can reduce the friction coefficient. MoS2, PEEK, graphite, glass fibre and carbon fibre can greatly improve the wear resistance of PTFE matrix when the filler ratio is not more than 20%. Among them, graphite has the best friction reduction effect. The composites composed of PTFE matrix and graphite filler not only improve the wear resistance, but also greatly reduce the friction coefficient. Rigid additives increase the hardness of PTFE matrix, while soft additives decrease the hardness of PTFE matrix. Almost all kinds of additives can reduce the impact strength of PTFE matrix.

References
[1] Yu, H., Yin Z.(2012) Experimental research of temperature rise on water lubricated bearing reinforced with polymer composite materials. Mechanical Research & Application. 01: 50-52.
[2] Zhang X., Wang P., Tian R., Wang W.(2017) Experimental Study on Friction and Wear of Water-lubricated Bearing in High Revolution and Low Specific Pressure. Dongfang Turbine. 12(04): 17-19.
[3] Fan K., Xie Z., Rao Z., Ta N., Yin Z.(2016) Experimental Study on Friction Characteristics of Water-lubricated Composite-material Bearings. Noise and Vibration Control. 2(01): 192-199.
[4] Peng P. (2013) Experimental Study on Tribological Problems in Several Water-Lubricated Stern Tube Bearing Materials. Wuhan University of Technology.
[5] He L., Yang X., Shuai C. (2012) Study on Hardness and Friction Properties of New Type of Low-noise Water-lubricated Material for Ship Propeller Bearing. Noise and Vibration Control. 10(05): 181-184.
[6] Wodtke M.A., Olszewski, M Wasilczuk. (2013) Application of the fluid-structure interaction technique for the analysis of hydrodynamic lubrication problems. Proc. Inst. Mech. Eng.