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Study on tribological and vibration performance of a new UHMWPE/graphite/NBR water lubricated bearing material

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ABSTRACT

The mixture powder of Ultra-high molecular weight polyethylene (UHMWPE) and graphite was blended into nitrile–butadiene rubber (NBR) to be modified to develop a new kind of compound water lubricated rubber bearing with cost-effective, low-friction performance. In order to study the tribological and vibration performance of the new material, a series of experiments were carried out on the test rig SSB-100. Friction coefficient and vibration characteristics under different working conditions: speed, specific pressure and temperature were acquired and analyzed by torque meter and B&K Pulse. The mechanical physical performance of the compound rubber material SPB-N has reached the requirements of Chinese ship standard CB/T769-2008. The results showed that a better tribological performance of the new material met the U.S. military standard (MIL-DTL-17901C (SH)). Stick-slip effect of the new material was induced with critical speed of 0.27 m/s, which showed excellent low-speed performance. Moreover, its friction coefficient reached a minimum value at the speed of 0.54 m/s. Local specific pressure of the new material was 0.7 MPa. The new composite rubber material was served as a kind of water-lubricated bearing material with excellent all-round performances.

1. Introduction

Water lubricated rubber stern bearing (WLRSB) has been widely used in ship propulsion systems because of its good performance of vibration attenuation and shock resistance, as well as its resource conservation and environmentally friendliness, etc. Especially its application on submarines in naval battles during the World War II, made its brilliant performance recognized by the whole world [1]. While it still has several defects such as low design specific pressure, low bearing capacity, and the phenomenon of stick-sliding. These defects will make the submarines exposed to an advanced electronic detecting instrument. Hence, it is urgent to carry out a systemic research on the material development/modification of WLRSB and to investigate the mechanism and influence factors of the stridor to find out a solution for depressing vibration and noise of the WLRSB.

The literature review has shown that after blending modification, the new rubber which is made by adding padding such as UHMWPE and graphite to NBR can effectively reduce the friction and wear of water lubricated stern bearing [2,3]. However, there has been lacking in systemic research on the tribological characteristics and vibration noise of the modified rubber under different working conditions.

Based on the standard formula of NBR, the aim of the study was to develop a water lubricated composite rubber bearing material of low noise and low friction coefficient, i.e. the SPB-N, by adding UHMWPE, graphite and other additives according to a certain proportion and process. Then, its friction performance and vibration noise under different pressure, rotating speed and temperature were investigated, which aims at vibration deduction and noise reduction.

2. Formulation and process

According to the basic formula of NBR(ASTM), SPB-N is as shown in Table 1.

With NBR as the matrix, mixed UHMWPE and a small amount of anti-friction material such as graphite and DOP are filled into the injection molding mold. After heat preservation and vulcanization, the SPB-N with smooth surface will be produced. The manufacturing process of SPB-N is shown in Fig. 1.

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3. Testing apparatus and solution

3.1. Water lubricated stern bearing test-rig

As shown in Figs. 2 and 3, the test was conducted on the marine stern tube bearing test-bed SSB-100, designed by Wuhan University of Technology. The tested spindle paired to the bearing specimen was made of GB steel 45 (ISO steel C45E4; AISI/SAE steel 1045), and the shaft neck was covered by ZCuSn10Zn2 (a kind of cast copper alloy: GB/T 1176-1987) bushing. Clean water was used for lubrication (the water lubrication system can adjust water temperature). The speed of the spindle was measured by tacho-generator, and the horizontal and vertical vibration signals of the bearing were collected by acceleration sensor. The installation method is shown in Fig. 2.

The speed torque meter was used to measure the spindle's friction moment, and then to calculate the friction coefficient. All the signals were transmitted to a computer for display and analysis by the multichannel analyzer.

Table 1
The standard formula of SPB-N.

Formulation constituents	NBR	UHMWPE	Graphite	Other additive
Weight percent	64.725	0.097	0.025	35.153

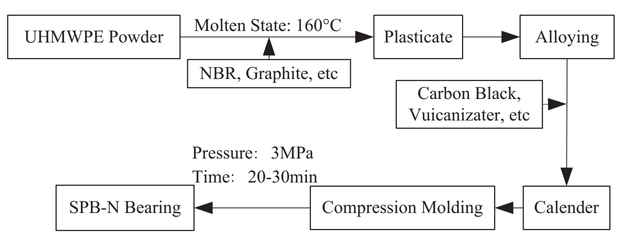


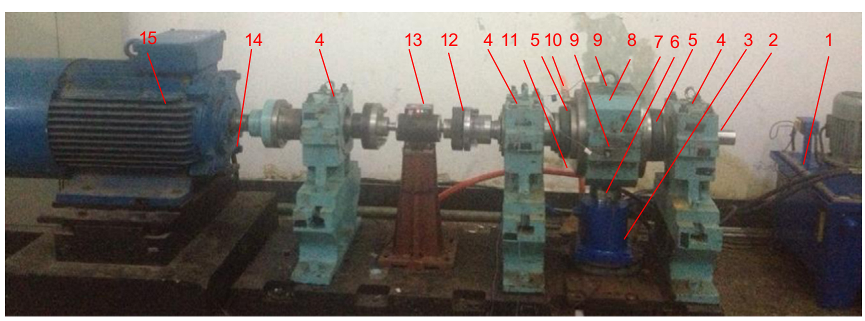
Fig. 1. The process of SPB-N.

3.2. The test specimen

The specimen is a holistic cylindrical plane bearing made of SPB-N, as shown in Fig. 3. This structure is made by a one-injection-compression technology with close organization, small startup friction torque and advantages for establishment of hydrodynamic pressure lubrication, as shown in Fig. 3. The roughness of the bearing inner surface (SPB-N) is less than 0.2 μm, the hardness of the rubber 75 ± 2 A (shore A hardness). The backing material is copper H62 (Brass). To make the bearing get enough water for cooling and lubrication, 12 lubrication grooves are uniformly distributed inside the bearing, and one of the staves must be located beneath the test spindle at the time of installation.

3.3. The test program

The experiment is conducted with the reference to the determination outline of friction coefficient from MIL-DTL-17901C(SH) [4]. The specific pressure is respectively: 0.28, 0.42, 0.56, 0.70, and



1- Hydraulic Pressure Station; 2- Spindle; 3- Vertical Hydraulic Cylinder; 4- Axial Bearing; 5- Sealing Device; 6- Pressure Sensor; 7- Bearing Shell; 8- Stern Tube Bearing; 9- Acceleration Sensor; 10- Water Outlet; 11- Water Inlet; 12- Flexible Coupling; 13- Speed Torque Meter; 14- Tacho-Generator; 15- Converter Motor

Fig. 2. The ship stern bearing test system and the physical map of SSB-100.

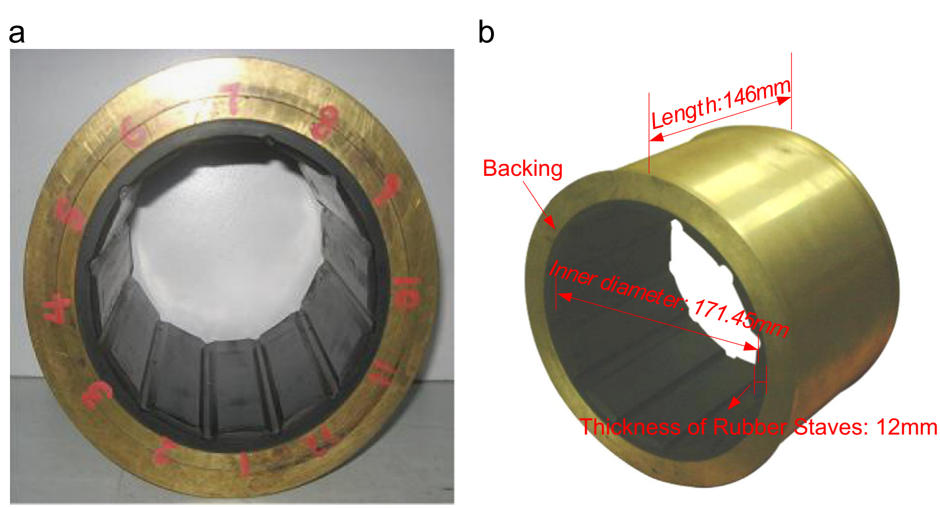


Fig. 3. The SPB-N Bearing (a) and the structure diagram (b).