Wear 376-377 (2017) 920–930

Contents lists available at ScienceDirect

Wear

journal homepage: www.elsevier.com/locate/wear

Influence of both friction and wear on the vibration of marine water lubricated rubber bearing

Huanjie Wang [a,b,*], Zhenglin Liu [a], Li Zou [a], Jun Yang [a]

[a] School of Energy and Power, Wuhan University of Technology, Wuhan, Hubei, China
[b] Wuhan Institute of Shipbuilding Technology, Wuhan, Hubei, China

ARTICLE INFO

Article history:
Received 28 August 2016
Received in revised form
31 January 2017
Accepted 1 February 2017

Keywords:
Water lubricated rubber bearing
Friction
Wear
Vibration
Deformation

ABSTRACT

Marine water-lubricated bearing is the key part of the thrust shafting of underwater vehicles and some surface vessels, that is currently made with rubber, Thordon, Feroform, nylon, lignumvitae materials etc. Because the performance of vibration and noise reduction of the rubber material is better than some materials so that it is usually applied in water-lubricated propeller shaft bearing of submarines and underwater vehicles to improve their stealth, security, performance and reliability. Although the rubber is of better damping effect, it is always easy to cause friction vibration and noise under low speed, heavy load and wear situation, especially at starting or stopping phases. Therefore, it is of important theoretical significance and engineering value to enhance the mute level of the vehicles and alleviate friction vibration and noise.

The tribological properties of water-lubricated rubber bearing such as friction and wear can affect the bearing vibration directly. So the research objective is to explore the influence of both friction and wear of water-lubricated rubber bearing on the bearing vibration under the different rubber materials of the bearing lining and working conditions. In the research, both theoretical analysis and test methods are applied. In theoretical analysis, the finite element model of the bearing is established and the deformation of the bearing lining is analyzed, and in test research, kinds of water-lubricated bearings with different rubber material were tested on the bearing test-bed under different shaft rotary speed, load and cooling water temperature. The research results show that both friction coefficient and wear of water-lubricated rubber bearings are affected with the different rotary speed, load and cooling water temperature, which result in the bearing vibration status changed significantly. With the increase of the load in some range, the deformation of the bearing lining is intensified and the specific pressure of the bearing is decreased due to the augment of contact area of between test shaft and bearing lining so that the friction coefficient and vibration are declined. As cooling water temperature is enhanced, both wear and vibration are aggravated.The higher shaft rotary speed is, smaller friction coefficient is in certain speed range so friction vibration is reduced.

1. Introduction

The friction vibration of marine water lubricated stern bearings is one of the bottleneck problems of underwater vehicles, which seriously affects the concealment, reliability, and occupant comfort of the underwater vehicles. Today's most quiet underwater vehicle isn't easy to be found more than 100 m far from it with the most sensitive acoustic equipment. If vibration noise radiation of the stern bearing is declined by 6 ~ 10 dB, the detecting range of the passive sonar of the enemy can reduce about 50%, and one of our part can increase 1 times or so, thus it can enhance the mute level and survival ability of the underwater vehicles to inhibit the friction vibration of the bearing.

The frictional vibration of the water lubricated stern bearing is a very complex natural phenomenon, which has to do with the friction, wear and lubrication conditions closely. Practice has proved that the frictional vibration mainly appear in low speed (<0.5 m/s), overloading, and starting and stopping conditions. At this time, both shaft and bearing often operate under boundary lubrication or mixed lubrication status so that water film is difficult to establish, which can lead to the abnormal vibration and noise, the rapid wear of both shaft and bearing and the damage of sealing device. These affect the concealment of the underwater vehicle seriously.

Kinkaid. N.M et al. [1–3] indicated that the friction vibration aroused by the water lubricated stern bearing mainly is self-excited

* Corresponding author at: School of Energy and Power, Wuhan University of Technology, Wuhan, Hubei, China.

http://dx.doi.org/10.1016/j.wear.2017.02.006
0043-1648/

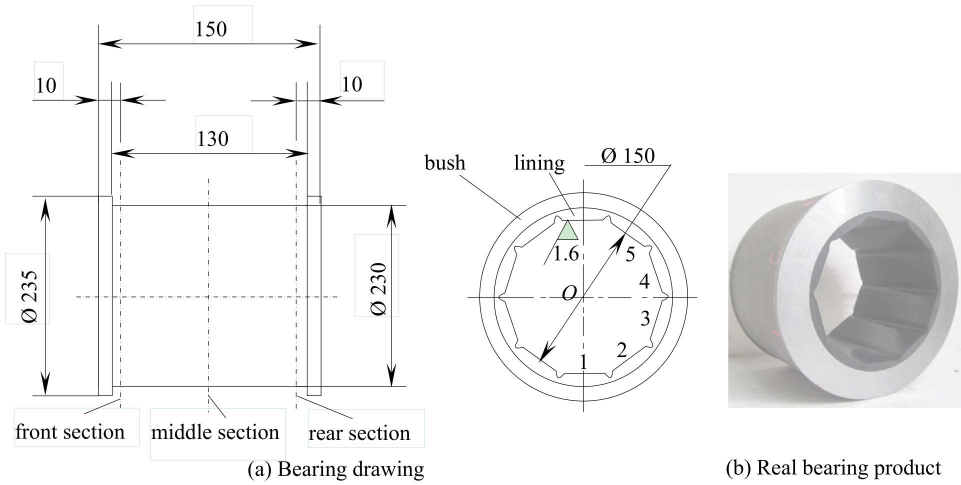

Fig. 1. Water lubricated rubber stern bearing.

vibration. At present, researchers have offered four kinds of the formation mechanism of friction self-excited vibration such as the stick-slip movement, self-locking sliding, the negative slope of friction coefficient-relative sliding velocity and the modal coupling. But the four kinds of friction vibration mechanism can't explain all of frictional vibration phenomena satisfactorily. SUN Di et al. [4] thought that Friction vibration can reflect the change of the running-in wear state of the friction pair, and presented that the change law of characteristic parameter K of vibration signal is consistent with one of friction coefficient, so K can be used to identify the running-in wear state of the friction surface. Zhou Jianhui et al. [5] discussed the tribological mechanism of the marine water lubricated rubber stern bearings. The research results indicate that the friction coefficient of the bearing is decreased with the increment of the shaft rotary linear speed. Zhao Shuhe et al. [6] pointed out that if there is the local interaction of the micro convex body in the working surfaces between the shaft and bearing, then the friction resistance between the shaft and bearing is jointly composed by the shear forces of both fluid film and the micro convex body of the contact surfaces, and the friction coefficient is significantly decreased with the increase of the relative sliding speed between friction surfaces. The friction vibration characteristic of ship shafting depends on the lubrication condition of the bearing. Sudan [7] pointed out that this friction vibration is not resonance phenomenon in linear vibration, but is the self-excited vibration by dry friction. In the nonlinear self-excited vibration caused by this kind of dry friction, now whole sliding motion and both hysteresis stopping and sliding motion can be analyzed [8–11].

Because self-excited vibration equation is much more complex, therefore, more studies are based on the numerical analysis, phase plane analysis and experimental research. R.A. Ibrahim et al. [12] discussed the friction self-excited vibration mechanism of water lubricated radial rubber bearing, and pointed out that under low speed, particularly at starting or stopping moment, the bearing is in dry friction state whose lubrication effect of is very poor, so it is easy to generate self-excited vibration and noise, but with the increase of rotary speed, both vibration and noise are obviously improved. Chen et al. [13,14] found in his experiment that friction vibration may only occur at a part of the test procedure, but it is possible to bring about throughout the whole test procedure, which depends on the test conditions, such as the structure stiffness of the friction system, normal contact force and relative sliding speed, friction pair material, abrasion and some unknown factors. The occurrence of friction vibration is not completely depending on the size of the friction resistance.

Both friction and wear behavior characteristics on the rubber lining surface of water lubricated stern bearing are explored by the experiments in this paper to reveal both friction vibration and noise mechanism and their forming process, performance variation law and implementation condition under low speed, overload and low viscosity (water) and to provide the theoretical support for reducing friction vibration and noise.

2. Test bearing and testing machine

2.1. Water lubricated rubber bearing

The research object in this paper is marine water lubricated rubber bearings (hereinafter referred to as the bearing). This kind of bearing is different from oil lubricated one, especially its structure and lining material.

In this paper, the rubber bearing only is the test specimen used to evaluate the tribological performance of kinds of rubber materials of the bearing such as friction coefficient, wear and vibration. As long as the testing conditions of specimen is the same as one of the service use of marine bearing including specific pressure, shaft rotary speed, cooling water temperature and bearing lining material, and water slot structure is semblable, the size of the bearing such as diameter and length to diameter ratio is not be emphasized in general.

2.1.1. The structure and basic size of bearing

Bearing samples are divided into 5 groups, a total of 15 pieces. Bearing inner diameter D is Ø150 mm, length L is 150 mm, and is decorated with 10 pieces of flat rubber slats to form 10 sinks. The flat slat can preferably improve lubricating performance than circular arc one. The slat thickness δ is 9.5 mm. In the test, one slat of the bearing is installed directly below the test shaft, as shown in Fig. 1.

2.1.2. Bearing material

The bush material of the bearing is brass and the lining one is Buna-N rubber. The main component of Buna-N rubber are butadiene and acrylonitrile (20%∼35%), and graphite or molybdenum disulfide etc. self-lubricating materials. In addition to different acrylonitrile in each bearing, the rest of components are the same. The performance index of the lining material includes tensile strength $\sigma_b > 16$ MPa, Shore Hardness $H_A = 70 \sim 85$.

Although both structure and dimension of all of bearing samples are the same, the individual component ratio difference of the bearing lining material will cause the friction coefficient and the critical speed varied to generate friction vibration and noise, which affect the friction vibration suppression of the bearing.