KSTLE International Journal, Vol. 4, No. 2, December 2003, pp. 43-46

Frictional Characteristics of Stainless Steel Ball Bearings Lubricated with Hot Water

Jae-Seon Lee†, Jong-In Kim, Ji-Ho Kim, Hong-Yune Park and Sung-Qunn Zee

Korea Atomic Energy Research Institute

Abstract: Water-lubricated frictional characteristics of a stainless steel ball bearings are not well known compared to the oil-lubricated frictional characteristics. Furthermore a study on friction at a high temperature is rare because the bearing maintenance strategy for water-lubricated or chemicals-lubricated bearings of equipment is generally based on the replacement of the failed bearings and parts. Ball bearings and ball screw are installed in the power transmission for the newly developing integral reactor and these are lubricated with chemically-controlled pure water at a high temperature and a high pressure. Bearings and power transmitting mechanical elements for an atomic reactor requires high reliability and high performance during the estimated lifetime, and it should be verified. In this paper, experimental research results of the frictional characteristics for water-lubricated ball bearings are presented as a preliminary investigation.

Keywords: Stainless steel ball bearing, rotational tribometer, friction torque, high temperature, water lubrication

Introduction

Generally stainless steel is resistant to water, water vapour, alkaline solutions, photographic developers, or acids, so stainless steel ball bearings are used for poor lubrication condition. Especially STS440C stainless steel can be used in a radiation or vacuum environment because of the low gas emission, and at high temperature even up to 400°C with a light loading.

Because of these merits, STS440C stainless steel ball bearings are used as a load carrying component in the control element drive mechanism of an integral nuclear reactor. Ball bearings are lubricated in a high temperature and a highly pressurized water which is highly purified and chemically controlled in the nuclear reactor because it is impossible to supply lubricating oil. Viscosity of the water goes down to a very low level just about 10 times that of air at a high temperature [1]. The lubrication condition for a ball bearing becomes very poor because the ball bearing is only lubricated with nuclear reactor coolant (water), therefore it can be estimated that its load carrying capacity is drastically reduced and its friction force would be seriously increased in this situation. However there are few research results on the frictional characteristics of the stainless steel ball bearing regarding a temperature rise for an estimating system of the friction loss.

Many former researches focused on the surface coating effect or the effect of a low viscosity of the oil or solid lubricant with composite or ceramic materials [2-5]. Some studies considered the water-lubricated effects with other materials [6]. The reason for very few researches on the water lubrication ball bearing characteristics may be due to the machine elements maintenance strategy which is based on replacing a bearing after damage occurs or a certain period rather than applying an improved ball bearing by considering the frictional and lubricant characteristics of the bearing. However, the reliability and durability of the ball bearings used in the integral nuclear reactor are most important. So the water lubrication characteristics of ball bearings should be verified from a critical design factor. Particularly, the viscosity of the water decreases from 0.997×10^{-3} Pa · s at 20°C to 0.236×10^{-3} Pa · s at 120°C at the operation pressure of the integral nuclear reactor, 14.7MPa (Fig. 1).

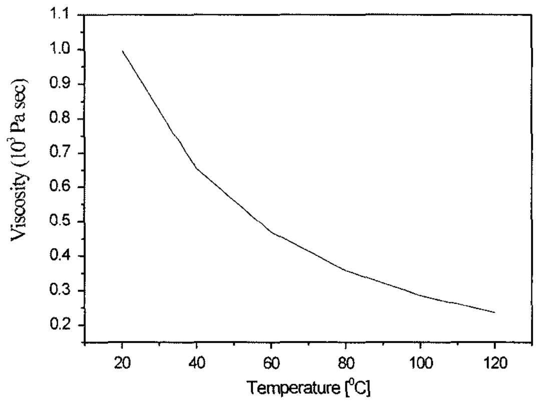

Fig. 1. Viscosity drop according to temperature.

Since the water viscosity is reduced up to 73% at a high temperature, the frictional characteristics of the ball bearing are expected to be influenced by this high temperature. In this paper, experimental results from the frictional characteristics of

†Corresponding author; Tel: 82-42-868-2826, Fax: 82-42-868-8990
E-mail: leejs@kaeri.re.kr

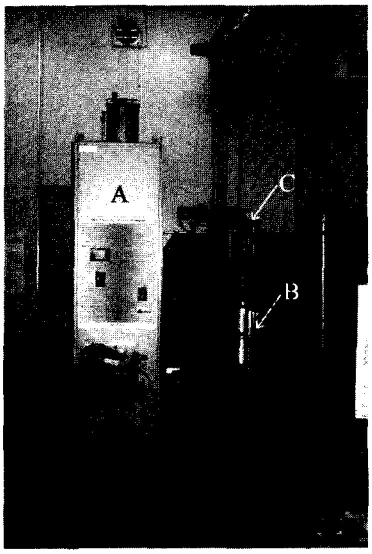

Fig. 2. Photograph of the tribometer system.

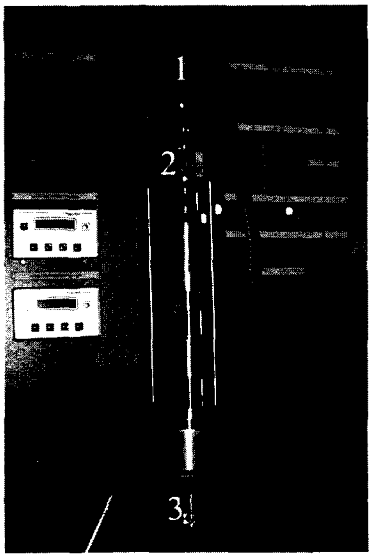

Fig. 3. Photograph of the rotational tribometer.

a ball bearing under the simulated test conditions (high temperature and high pressure) of a nuclear reactor are presented.

Test methods

In this paper, the frictional characteristics of a 440C stainless steel ball bearing at a high temperature is studied with a special tribometer. The tribometer is shown in Fig. 2. The tribometer consists of the water chemistry control and the electrical control panel (A), the autoclave (B) and the rotational tribometer (C). Water as the lubricant in the autoclave can be heated to 350°C and pressurized to 17 MPa and the temperature and the pressure can be controlled separately.

The tester consists of the rotational tribometer (Fig. 3) for the rolling element bearings and the reciprocating tribometer for the evaluation of the friction characteristics of the material itself. Test results with the rotational tribometer are analysed in this paper.

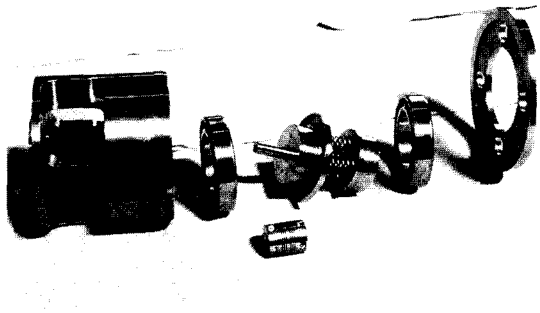

Fig. 4. Test ball bearing Assembly.

Table 1. Water chemical composition

Chemical composition	Value
Ph	9.5~10.6 (25°C)
Ammonia	10 ppm
Dissolved Hydrogen	≤0.5 ppb
Dissolved Oxygen	≤5 ppb
Conductivity	35 microsiemens/cm

Water chemistry is controlled as in Table 1 to simulate the nuclear reactor conditions.

The ball bearings used for the test are commercial normal grade No. 6208 ball bearings made by FAG, and the retainers are changed to plastic retainers.

The test bearings are installed at the No. 3 position in Figure 3, and submerged in the autoclave. Water in the autoclave is pressurized to 14.7 MPa and heated.

Two bearings are assembled in the special equipment and the axial load is applied by the coil springs between the two test bearings as shown in Fig. 4.

Applied axial load is 10 N for consideration of the frictional characteristic of the bearing itself and to remove force effect, and the rotational speed is 300 rpm. Maximum test temperature is 120°C which is less than the tempering temperature of about 150°C of the 6208 inner, outer race and steel ball.

Some previous researches show that the friction force variation of STS440C stainless steel is about 5% that of the normal friction coefficient of 0.5 up to 160°C The reciprocating tribometer was used for the former study [7]. And the test results showed that the friction coefficient of STS440C stainless steel is almost uniform from room temperature up to 120°C (Fig. 5). It could be predicted that the variation of the friction torque of the STS440C stainless steel ball bearing is small with heated water as a lubricant to 120°C, and this estimation shall be confirmed by this research. System torque of the rotational tribometer is measured as 0.07 Nm and this is not affected by the pressure, rotational speed or temperature (Fig. 6). The system torque is subtracted from the measured torque.

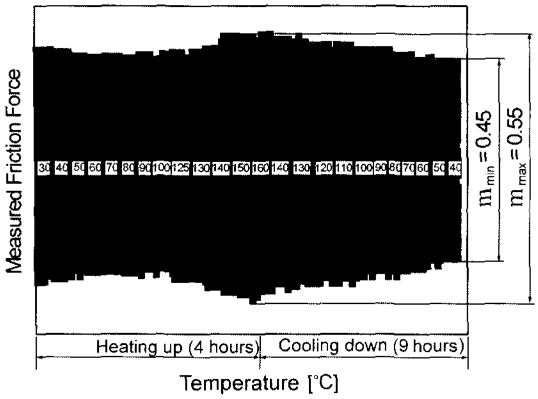

Fig. 5. Thermal friction of STS440C.

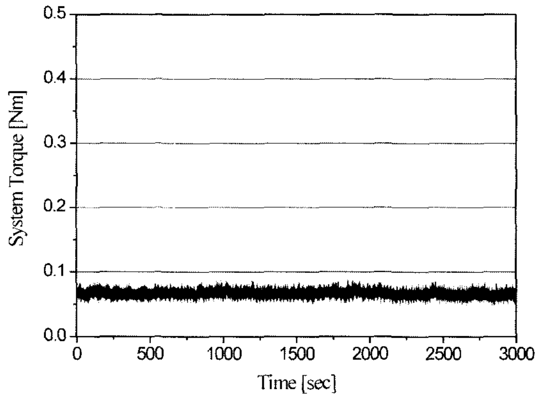

Fig. 6. System friction torque.

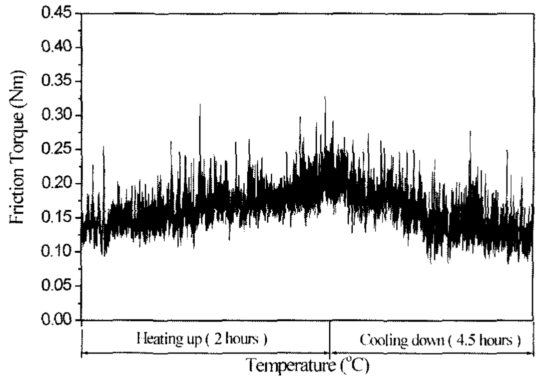

Fig. 7. First test result.

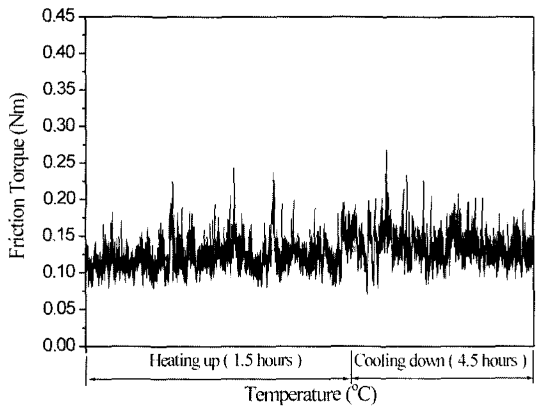

Fig. 8. Second test result.

Test Results

Figure 7 and Figure 8 show the measured bearing torque according to the water heating and cooling for the two tests. Although the friction torque increases to 0.07 Nm at 120°C compared to the value at 30°C by the first test, the torque increment is merely 4% of the normal value. The second test shows an almost uniform torque measurement.

Therefore it can be confirmed that the friction torque and the friction force for the stainless steel lubricated with water have the same characteristics when operated below 120°C. The results show that the temperature does not affect the friction force, seriously. However the application of this result is restricted to a slightly high temperature, 120°C, which is limited by the tempering temperature of the metal.

This result is caused by the unchanged lubrication condition. It is certain that the bearing is operated under a boundary film lubrication regime at room temperature and this lubrication regime is not changed up to 120°C.

Conclusions

1. It is confirmed that the frictional torque of a stainless steel ball bearing which is lubricated with water is not seriously affected by a temperature rise up to 120°C. It shows the same tendency as the test results on the stainless steel itself.
2. Variation of the frictional torque of a stainless steel ball bearing according to a temperature rise is small regardless of the water viscosity at 120°C which decreases to only 27% of that at room temperature. The initial lubrication condition (boundary film lubrication) is also not changed.
3. Study on the thermal frictional characteristics of a ball bearing operating under a realistic load and rotational speed shall be performed and reported, upon.

Acknowledgment

This work has been performed under the nuclear research and development program sponsored by the Ministry of Science and Technology, Korea.

References

1. Daugherty R. L., Franzini J. B. and Finnemore E. J., "Fluid Mechanics with Engineering Applications," 8 ed., McGraw-Hill, 1985.
2. Zhao Xingzhong, Liu Jiajun, Zhu Baoliang and Miao Hezhou, "Sliding wear of ceramic/metal pairs under boundary lubrication of water and oil," Journal of Materials Science and Technology, Vol. 13, No. 5, pp. 409-415, 1997.
3. Vairis A., "Investigation of Friction Behaviour of Various materials under sliding conditions," European Journal of Mechanics, A/ Solid, Vol. 16, No. 6, pp. 929-945, 1997.

4. Ovaert T. C., Cheng H. S. and Shen M. C., "Temperature effects on friction and elevated temperature behaviour of base oil-additive combinations under boundary lubricated conditions," SAE Transanctions, Vol. 100, pp. 1131-1160, 1991.
5. Dumont B., Blau P. J. and Crosbie G. M., "Reciprocating friction and wear of two silicon nitride-based ceramics against type 316 stainless steel," Wear, vol. 238, No. 2, pp. 93-109, 2000.
6. Ko Pak L. and Robertson M. F., "Friction and wear studies of nuclear power plant components in pressurized high temperature water-2," ASME Pressure Vessels and Piping Conference, Aug 1-5. 1999, Boston MA.
7. JaeSeon Lee, JiHo Kim, JongIn Kim, "Frictional Characteristics of Stainless Steel Lubricated with Pressurized Water at High Temperature," Vol. 19, No. 1, pp. 21-25, 2003.