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A Study on Grease Leakage from Rolling Bearings

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Abstract- **The leakage of grease from shielded rolling bearings is usually caused by grease being pushed out by ball or cage motion, centrifugal force, or grease flow due to high temperature. However, we have discovered another mechanism that causes significant leakage: slippage of the grease lump caused by adhesion forces to the shield plate and inner race which typically occurs in case of slippery grease on the surface.**

Keywords- **grease, shielded rolling bearing, leakage, adhesion, PFPE**

I. INTRODUCTION

Grease-packed shielded rolling bearings are probably the most widely used rolling bearings due to the ease of handling and relatively long service life [1]. However, grease will inevitably leak from such bearings because of the gap between the shield plate ring and the inner race. This leakage causes the bearings to deteriorate prematurely and contaminates the environment [2].

Although such leakage of grease causes much trouble in products or manufacturing equipment, few cases of directly investigating the mechanisms involved have been reported, aside from some reports on the behavior, distribution or deterioration of grease in rolling bearing [3-5], as well as several cases of evaluating grease leakage from shielded rolling bearings under systematically arranged conditions [6-11].

In many cases, grease leakage from shielded rolling bearings is believed to be caused by the pushing-out force generated by a rolling element or cage motion, centrifugal force, grease flow due to high temperature, or grease degradation [2, 12]. However, a number of cases could not be sufficiently explained by examining these mechanisms.

The engineers or researchers concerned are well aware of the propensity for significant grease leakage when using PFPE (Perfluoropolyether) grease for bearings coated with rust-inhibiting mineral oil [13]. Similarly, PFPE grease is also known to frequently cause significant leakage when packed into bearings as a replacement for the previously used packed mineral oil grease without sufficiently removing the originally packed grease. In these cases, leakage is deemed attributable to the lack of compatibility between PFPE and mineral oil greases that prevent the strong adhesion of PFPE grease to bearing surfaces, making the grease vulnerable to being pushed out from the bearings by the motion of bearing elements. Given the generally larger extent of this kind of leakage, there should be another mechanism of leakage other than those described above.

In this study, we used a simple test rig to demonstrate that another significant mechanism of leakage exists for above cases, and to explain the large leakage [14, 15].

II. EXPERIMENTAL PROCEDURE

A simple test rig was used to investigate the phenomenon of grease leakage. Fig. 1 shows a schematic of the tester. This tester consisted of a rotating stainless steel disk (JIS SUS 304 stainless steel, 50 mm in diameter) and a glass plate separated by a small gap. In the tester, the circumferential motion of actual bearings was transformed into lateral motion for an easy visualization of grease movement. The disk corresponded to the shield plate of the bearing, and the plate to the inner race. The gap was set to 0.1 mm—the typical gap between the shield plate and inner ring in the shield bearing.

Grease was deposited over the disk and the glass plate, forming a right triangular cross-section of 4.5 mm inside as shown in Fig. 1. This simulated the situation in a bearing where grease lay between the shield plate and inner race, and adhered to both. This situation is common for actual bearings filled with a sufficient amount of grease. A CCD camera placed under the glass plate and a high speed camera above the grease was used to observe grease movement. The seepage of grease into the gap between the disk and glass plate was equivalent to the flow of grease leaking into the gap between the inner race and shield plate of an actual bearing.

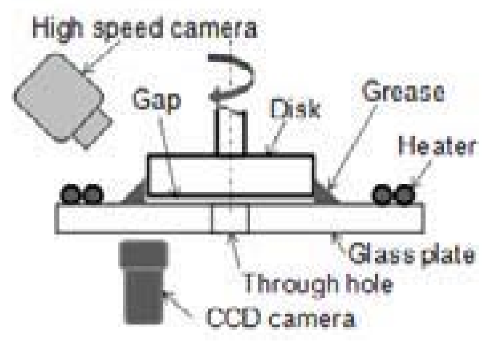

Fig. 1 Schematic and settings of tester

Heaters were used to raise the temperature on the glass plate, and a thermocouple was employed to measure the glass plate surface temperature adjacent to the test grease. The adhesion force of the types of grease to the stainless steel and glass plate were estimated as being relatively similar based on rough measurements of the pushing force necessary to move the lumps of grease placed on the stainless steel and glass plate.

There were apparently no pushing-out forces generated by the rolling elements or cage, and there was no centrifugal force forcibly moving the grease into the gap on the test rig. Centrifugal force only forcibly moved the grease outward from the gap. Airflow in the gap space did not affect grease movement, which was checked by using powdered milk instead of grease. Thus, any grease observed seeping into the gap would mean that the mechanisms of grease leakage did not entail centrifugal force or the pushing-out force generated by the rolling elements or cage motion.

Tables 1 and 2 list the test greases and test conditions, respectively. We investigated two conditions of grease deposition. One involved applying a specific type of grease to the tester; the other involved applying PFPE grease to a thin coating of mineral oil grease (less than 0.1 mm thick) and conversely applying mineral oil grease to a coating of PFPE oil grease (in a test lasting 15 minutes for this case), thereby simulating a case where the bearing is packed with PFPE or mineral oil grease without sufficiently eliminating the previously packed mineral oil or PFPE grease.

Table 1 Test Greases

No.	Thickener	Base oil	Penetration	Apparent Viscosity
1	Urea	Mineral oil	265	34 Pa･s at 0℃, 100 s^{-1}
2	Lithium complex soap	Mineral oil	280	64 Pa･s at 0℃, 100 s^{-1}
3	PTFE	PFPE	280	10 Pa･s at 0℃, 100 s^{-1}

* PTFE: Polytetrafluoroethylene PFPE: Perfluoropolyether

Table 2 Test Conditions

Rotation speed : 900 rpm
Test duration: 30 min
Temperature (at glass plate surface): Room temp., 100℃

III. Experimental Results and Discussion

Fig. 2 shows examples of CCD camera images. As shown in Fig. 2 (a), the mineral oil grease alone showed no seepage into the gap. This was also true for PFPE grease used alone (not shown in Fig. 2). As shown in Fig. 2 (b), however, PFPE grease on the coating of mineral oil grease eventually exhibited seepage into the gap, as did the mineral oil grease on the coating of PFPE grease (not shown in Fig. 3).

Fig. 3 shows the time evolution of seepage depth. These were determined by averaging the seepage distances at three equidistant points along the front line of grease shown in Fig. 2. The tests for lower disk rotation speed (600 rpm) and a larger gap (of 0.2 mm) were additionally conducted, with the results also shown in Fig. 2. The results of each grease alone at room temperature revealed no seepage, and thus are not indicated. The seepage depth of PFPE grease on the coating of

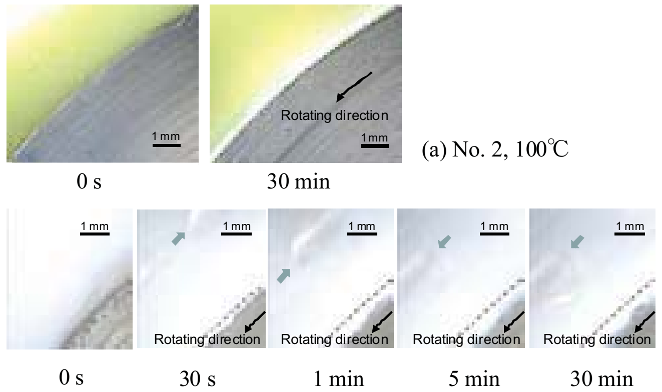

Fig. 2 Examples of CCD images for CASE 1 (Nos.2 and 3 correspond to those in Table 1. The gray sector at the lower right is part of the disk. The broken line indicates the initial boundary between the disk and grease.)

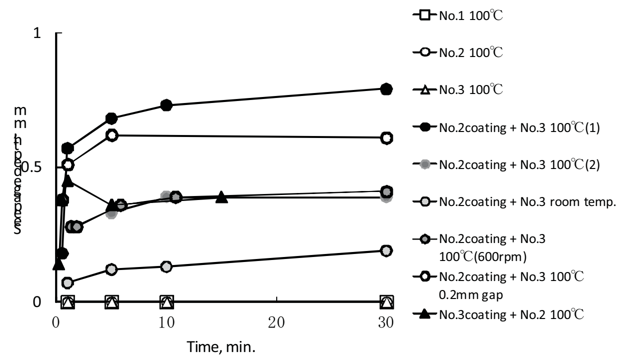

Fig. 3 Time evolution of seepage depth for CASE (Nos.1 to 3 correspond to those in Table 1.)

mineral oil grease increased rapidly within five minutes after starting the test, and then slowly thereafter. The mineral oil grease on the coating of PFPE grease also showed similar results, though it revealed that the one-time decrease in seepage depth was probably due to the effect of centrifugal force.

The mark on the bottom surface of the PFPE grease, indicated by arrows in Fig. 2 (b), showed movement in the disk rotating direction and gradually moved toward the center of the disk. The mark showed relatively rapid movement in the initial five minutes, and then began moving slowly. This movement corresponded to the trend in grease seepage depth and certainly caused grease to seep into the gap.

Fig. 4 shows examples of high speed camera images, taken about 10 seconds after commencing the tests. Mineral oil greases were split into two parts adhering to the disk and glass plate, respectively (as shown in Fig. 4 (a) and (b)). PFPE grease alone and PFPE grease on the coating of mineral oil grease remained in solid form (as shown in Fig. 4 (c) and (d)), although PFPE grease alone showed a thin layer of flow layer along the disk's circumferential surface, probably due to its

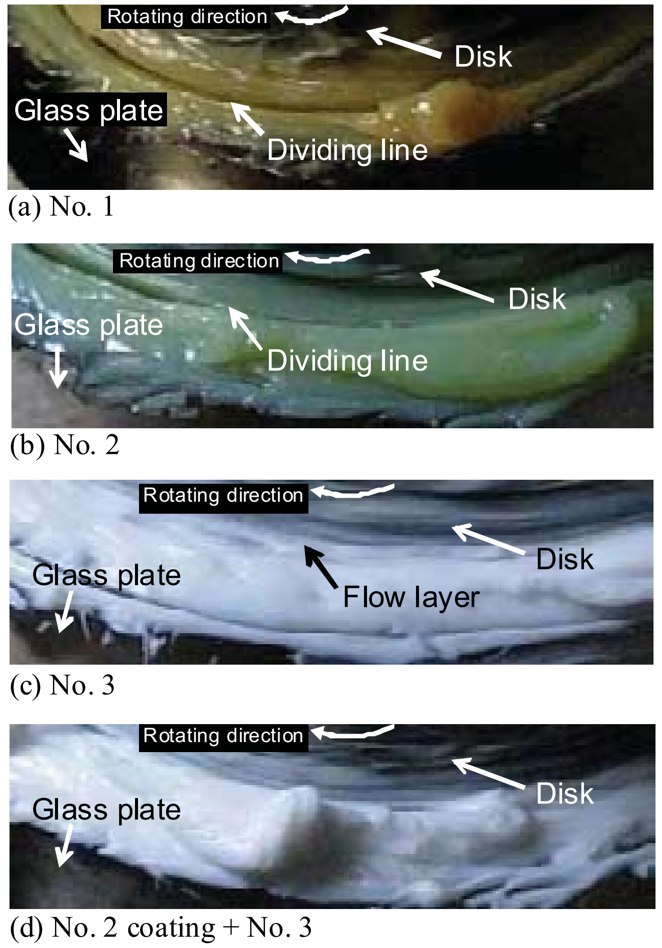

Fig. 4 High speed camera images (Nos. 1 to 3 correspond to those in Table 1.)

low apparent viscosity, which was hardly observed in the mineral oil grease. The mineral oil grease on the coating of PFPE grease ended up being split into two parts, and showed no subsequent seepage (not shown in Fig. 4).

Fig. 5 schematically illustrates the leakage mechanism based on observations shown in Figs. 2 and 4. When solid grease adheres to a surface, it splits into two parts—one adhering to the shield plate (disk) and one to the inner race (glass plate)—and moves with both separately (see Fig. 5 (a-1) and (a-2) for mineral oil grease) or is sheared near the shield plate surface to form a thin flow layer (PFPE grease alone). In these cases, the grease did not cause leakage. If the grease becomes slippery on the surface, however, as in the case of PFPE or mineral oil grease on the coating of mineral oil or PFPE grease, the lump of slippery surface grease will slip due to the torque generated by adhesion force from the disk and glass plate surfaces, thereby forcibly moving the lump of grease into the gap and causing leakage (see Fig. 5 (b-1) and (b-2)).

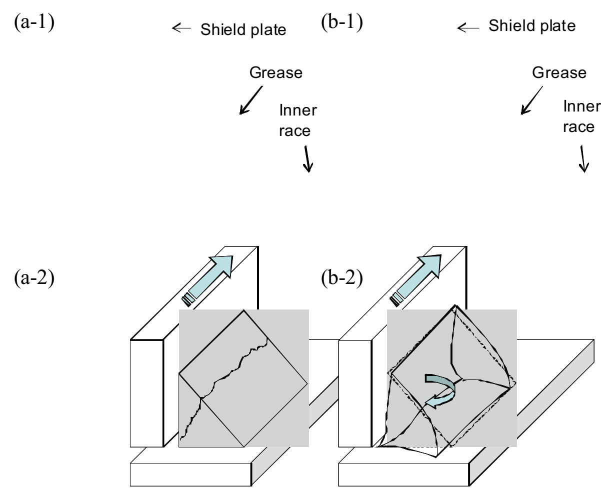

Fig. 5 Schematic illustration of leakage mechanism

IV. Conclusions

We demonstrated newly discovered mechanisms of grease leakage from bearings. One mechanism pushes grease out by using the torque generated by adhesion force from the shield plate and inner race when there is slippery grease on the surface. This situation is apt to occur when grease is applied on incompatible grease film—PFPE or mineral oil grease on the coating of mineral oil or PFPE grease, respectively. .

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