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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 two other mechanisms that cause significant leakage: (1) 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, and (2) the thixotropic flow of grease due to alternate grease deformation which could occur when the shaft has precession motion or inclines against the bearing.

1. 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 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. We also investigated the leakage phenomena that could occur when the shaft is inclined against the bearing or there is precession motion in the shaft-and-bearing assembly.

2. Experimental procedure

A simple test rig was used to investigate the phenomenon of grease leakage [14]. Fig. 1(a) 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(a). 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

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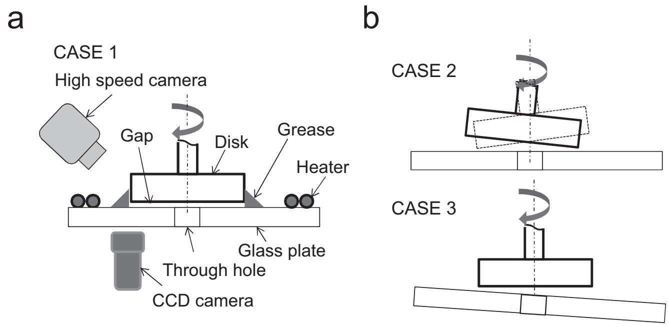

Fig. 1. Schematic and settings of tester.

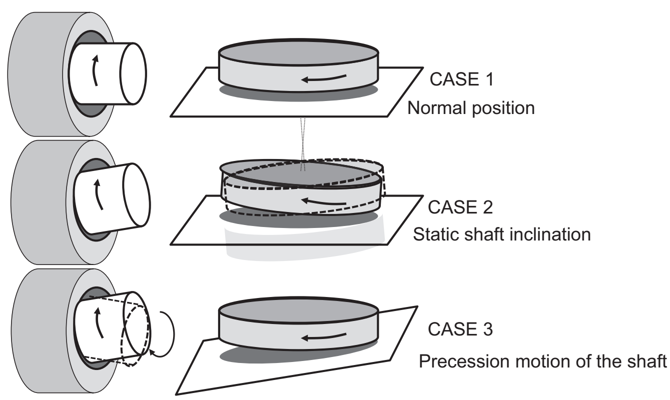

Fig. 2. Shaft conditions and corresponding test conditions.

amount of grease. A CCD camera placed under the glass plate and a high speed camera above the grease were 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.

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 was 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 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.

The disk and glass plate were set in the three positions shown in Fig. 1(a) and (b): the normal position (CASE 1), an inclined disk that leads to disk precession motion (CASE 2), and an inclined glass plate (CASE 3). As shown in Fig. 2, these positions correspond to the correct bearing and shaft positions, shaft inclination against the bearing, and shaft precession motion in the actual bearing-and-shaft assembly, respectively.

Tables 1 and 2 list the test greases and test conditions, respectively. No. 3 PFPE grease was applied for CASE 1 and No. 4 for CASES 2 and 3, in considering the assumed actual application of each type of grease.

The disk rotation speed for CASE 2 was lower than that for CASE 1, in order to avoid vibration due to imbalanced mass. The

Table 1
Test greases.

No.	Thickener	Base oil	Penetration	Apparent viscosity
1	Urea	Mineral oil	265	34 Pa s at 0 °C, 100 s^{-1}
2	Lithium complex soap	Mineral oil	280	64 Pa s at 0 °C, 100 s^{-1}
3	PTFE	PFPE	280	10 Pa s at 0 °C, 100 s^{-1}
4	PTFE	PFPE	266–295	–

PTFE: Polytetrafluoroethylene; PFPE: Perfluoropolyether.

Table 2
Test Conditions.

Rotation speed	900 rpm (CASE 1), 320 rpm (CASES 2 and 3)
Test duration	30 min
Temperature (at glass plate surface)	Room temperature, 100 °C

disk rotation speed for CASE 3 was set the same as that for CASE 2. The tilt angles of the disk or glass plate were 0.06, 0.09, and 0.2°. For CASE 2, the amplitudes of disk swing corresponding to the disk tilt angles were 0.07, 0.11, and 0.24 mm, respectively.

For CASE 1, 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 and conversely applying mineral oil grease to a coating of PFPE oil grease (in a test lasting 15 min 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.

A coating of mineral oil or PFPE grease roughly about 0.1 mm thick was applied to both the glass plate and disk surfaces. After applying the coating, the disk was pressed against the glass plate and then elevated to a height of 0.1 mm, thus revealing that the coating thickness on the glass plate and disk bottom surfaces in the gap was much smaller than 0.1 mm, because the considerably thick grease coating on these surfaces had been pushed out.

3. Experimental results and discussion

3.1. CASE 1 [14]

Fig. 3 shows examples of CCD camera images for CASE 1. As shown in Fig. 3(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. 3). As shown in Fig. 3(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. 4 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. 3. 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. 3. 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 mineral oil grease increased rapidly within 5 min 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. 3(b), showed movement in the disk rotating