DEPENDENCE OF GAS TRANSPORTATION IN RADIAL LIP SEALS ON OIL AND GAS

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ABSTRACT
Experimental studies are made on transportation of gas across radial shaft seals. Gas flow rates are determined with gas chromatography. Gas is pumped in, while gas also leaks at about half of the pump rate. The flow rates increase with shaft speed and oil viscosity, though paraffinic mineral oils allow more gas to move than polyalphaolefin of the same viscosity. The rate also depends on gas. These suggest that gas is conveyed by hydrodynamic flow of oil at the seal lip.

INTRODUCTION
Radial shaft seals prevent oil or grease from leaking by hydrodynamic force to pump the fluids back at narrow gap between a seal lip and a shaft. It is well known that this pumping effect also works to take in surrounding atmospheric gas into the sump side, although little is known about its true mechanism. In many cases, the gas introduced is air, and is usually considered to do little harm. However, there are some cases when the gas contains substance such as hydrogen that may induce failures in machines, and it is necessary to consider not only the sealing function to prevent leakage of lubricants but also behaviors of gases to move across sealed parts.

Nakaoka et al. [1] has recently developed a technique to experimentally determine the volume of gas that moves across a radial lip seal. Their preliminary tests with helium, hydrogen and air demonstrate that the gas pump rates are of the order of 0.1 to 1 ml/h under the test conditions employed, and suggest that the transportation of gas strongly relates with the hydrodynamic flow of oil. The aim of the present study is to confirm the hydrodynamic effect in gas transportation by conducting the experiments with oils of different type and viscosity, and with several different gases.

EXPERIMENTAL
Experiments are conducted by using the same rig and the method as in Ref. 1. Figure 1 shows schematic illustration of a test section. A test seal is inserted between Chambers A and B. Different gases are filled in the chambers, lubricating oil is supplied in Chamber B, and while the shaft is rotated, a small amount of gas is sampled from Chamber A or B, which is analyzed with gas chromatography to determine the amount of gas moved between the chambers. The shaft is 50mm in diameter, and made of 316 stainless steel. The test seal is ISO6194-1 Type 1 plain lip seal made of fluoroelastomer. Further details of the method are described in Ref. 1.

Three polyalphaolefins and three paraffinic mineral oils are used, whose viscosities are shown in Table 1. Chamber B is half filled with the oil, and the shaft is rotated at speeds ranging between 0 and 7.85 m/s for 100 minutes. Gas is sampled every 20 minutes to determine the rate of gas suction from Chamber A to B, or of leakage from Chamber B to A. Oil temperature in Chamber B is continuously monitored.

<table>
<thead>
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<th>Table 1 Viscosities of oils</th>
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<td>Viscosity, mm²/s</td>
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<td>PAO-17</td>
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RESULTS

Figure 2 shows the rate of hydrogen flow from Chamber A to B, and Chamber B to A, where nitrogen is used as reference gas. The rate increase with the shaft speed, and the pump rate of hydrogen from A to B is about twice as much as the leakage rate of hydrogen from B to A.

Experiments are made with the six oils with hydrogen and nitrogen as the test gas and the reference gas. The results demonstrate that the pump rate from Chamber A to B increases with the shaft speed and the viscosity of the oils. Also, the pump rate is larger with the mineral oils than with polyalphaolefins for the same speed and viscosity.

In Figs. 3 and 4 are plotted the hydrogen pump rate with PAOs and mineral oils, respectively, against $\eta^{1/2}u^{3/2}$, where $\eta$ is the oil viscosity in Pa·s and $u$ is the shaft speed in m/s. The parameter $\eta^{1/2}u^{3/2}$ is taken from Kawahara and Hirabayashi’s empirical equation for pumping flow of oil with radial lip seals [2]. They found that the oil flow increased linearly with this parameter by measuring the oil flow when the oil was supplied to the air side of the seal lip. The physical meaning is that the flow is related with the oil film thickness at the lip and the speed. The figures clearly show that the suction of gas also increases linearly with $\eta^{1/2}u^{3/2}$, suggesting that hydrogen is conveyed in the flow of the oil due to the pumping action of the seal lip. In addition, the present results demonstrate that the amount of gas conveyed depends also on the type of oil. Chemical properties of oil contents affect how much hydrogen is entrained and dissolved in the oil.

Figure 5 shows the rate of gas leakage from Chamber B to A for five test gases, with PAO-32. The rate is largest for carbon dioxide and smallest for helium. This can also be ascribed to difference in dissolution of the gases in the oil.

CONCLUSIONS

Gas transportation through the gap between the seal lip and the rotating shaft is caused by hydrodynamic pumping flow of oil, and depends on how much gas is entrained in the oil flow.

ACKNOWLEDGMENTS

This study is funded by the Japanese Ministry of Economy, Trade and Industry, through administration by NEDO as a part of the Development of Basic Technology for the Safe Use of Hydrogen. The authors would like to thank NOK Corporation and Idemitsu Kosan Co. Ltd. for their support.

REFERENCES