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The Effect of Lubricant Type on the Friction Torque Characteristics of Rotary Lip Seals

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Abstract- The effects of lubricant on frictional characteristics of a radial lip seal are investigated by experiments. For this reason a test system has been developed. In this test system a cylinder is placed on four load cells in order to monitor the friction torque generated between seal and counter face. A group of experiments are cried out with nitrile butadiene rubber based radial lip seals. EP gear oil, hydraulic brake fluid and transmission oil are selected as lubricants. The seals are tested under atmospheric pressure, 0.5 and 1 bar for a short period. The friction torque was measured and compared for different lubricants. As a result, it is observed that lubricant types affect seal friction torques in different ratios.

Keywords- *friction torque, leakage, lubrication, NBR , rotary lip seals*

I. Introduction

Radial lip seals are used to prevent lubricants from leaking out of a system which contains mechanical devices that requires lubrication to prevent wear and to supply cooling.

The sealing lip of a radial shaft seal must be lubricated in order to have a good sealing performance for a long period. Lubricating the sealing lip dissipates heat generated by the seal. Also, lubrication reduces friction and wear on the sealing lip and shaft. Lubricants reduce the coefficient of friction and minimize the frictional losses. Lubricants also have internal frictional forces that resist flow. This resistance to fluid flow is known as viscosity. Viscosity of the lubricant is an important parameter which affects the friction characteristics of lip seals. According the researches, friction torque values increases as the viscosity increases. Lubricant for a lip seal must be selected according to operating conditions. It should create a fluid film between sealing lip and shaft. Lubricant should not cause to generate high friction torque values but should form suitable lubrication regimes.

Many researchers investigated effect of lubricants and lubrication regimes both numerically and experimentally. Baart et al. studied on grease lubricated radial lip seals. They examined the difference between oil seals and grease lubricated seals in the terms of lubrication, sealing, and pumping mechanisms [1]. Dawei et al. developed a transient mixed lubrication analysis in order to simulate the effect of operating conditions on lubrication regime [2]. Leeuwen et al. also studied on visco-elastohydrodynamic lubrication in radial lip seals [3]. Bălan et al. examined the influence of the lubricant viscosity on the rolling friction torque. They modeled the rolling friction torque in a lightly loaded thrust ball bearing. An experimental method to determine friction torque was elaborated [4]. A similar study has been carried out by Gül et al. using same test system. In this work, friction and wear characteristics of PTFE seals with elastomer lip have been investigated experimentally [5]. In this study, the effect of lubricant viscosity on frictional torque values of NBR radial lip seals has been examined.

II. Experimental Set-Up

To investigate the effect of lubricants on the frictional characteristics of radial lip seal, a test rig was developed for the systematical experiments (Fig. 1). The test block and the cover were made of aluminum to obtain relatively good thermal properties. The radial lip seals were mounted to the cover on the cylinder block (Fig. 1). To prevent the oil leakage between cover and block, an O-ring was placed to the system as a secondary sealing element. Oils with different viscosities were used as lubricant in the experiments. Test system is driven by a frequency controlled AC motor. A flat belt mechanism was coupled to the motor in order to obtain the desired speeds for experiments. Rotational speed of the disc is measured by an optical tachometer. Radial force of seal due to its design generates a frictional force when shaft starts to rotate. As seen in the Figure 1, four force transducers (load cells) are integrated to the cylindrical test block to measure friction torque occurred between the seal and shaft. The signals received from the force transducer are transmitted to a data acquisition system. The shaft was machined from stainless steel with hardness HRC30 and average surface roughness Ra = 0.5 μm.

For the experiments, radial shaft seals with secondary lip were used. The cross sectional views of seals are shown in Figure 2. Standard lip seals with 40 mm inner diameter were manufactured by SKF. Nitrile butadiene rubber was selected as the elastomeric material of the seals due to it’s extensive use in industrial applications. Nitrile butadiene rubber has good resistance to aging, very good pumping ability and wears resistance.

9 samples were tested at 1, 3 and 5 m/s sliding speeds. Hydraulic brake fluid, transmission oil and gear oil are selected as lubricants. The properties of selected lubricants are shown in Table 1. The seals were tested with three different lubricants under 1 and 0,5 bar and atmospheric pressure for a short period in order to avoid undesired effects resulting from frictional heating. All of the tests were performed at room temperature. During the experiments, the frictional torque values were measured and compared for three different lubricants. The effect of speed, pressure, and viscosity were investigated. Also, oil leakage observation was achieved.

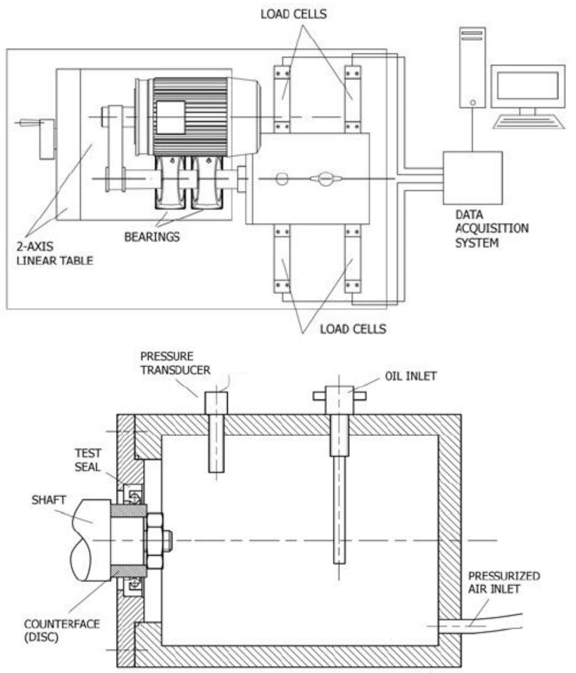

Figure 1. Schematic view of test system and test block

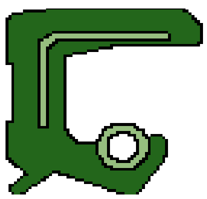

Figure 2. Cross-sectional views of test seals

TABLE I. PROPERTIES OF LUBRICANTS

	Kinematic viscosity at 100^{0}C (mm^2/s)	Kinematic viscosity at 40^{0}C (mm^2/s)	Viscosity index	Density at 15 ^{0}C (kg/l)
Hbf DOT 3 brake fluid	1,9	-	-	1,037
ATF DX II transmission oil	6,9	35,2	161	0,878
EP 90 gear oil	1,7	198	95	0,897

III. Test Results And Discussion

In Fig. 3, the variations of frictional torque of seals with sliding speed is given for different lubricants under atmospheric pressure. As it is seen from the Figure, friction torque values for three different lubricants are very close to each other. A remarkable effect of viscosity on torque values is not observed. On the other hand, friction torque values slightly increase with increase of speed as it is expected.

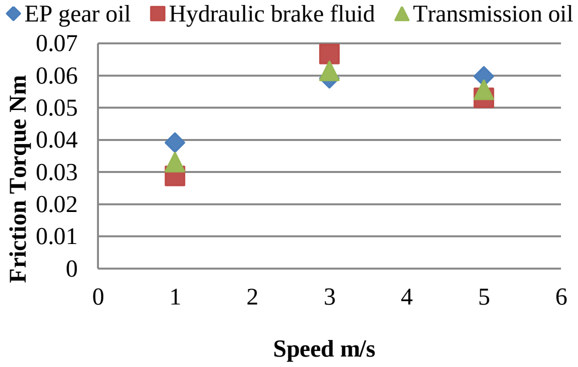

Figure 3. The variations of frictional torque of NBR seals for different lubricants with respect to sliding speed. (p = atmospheric pressure)

In Fig. 4, the variations of frictional torque of seals with sliding speed is given for different lubricants under 0,5 bar pressure. For all speeds, transmission oil gives lower friction torque values. Highest friction torque values generally are observed for EP gear oil which has the highest viscosity. Also, increasing speed increases the friction torques as seen in Figure 3. Variation of pressure from atmospheric pressure to 0,5 bar also increases the friction torque values slightly.

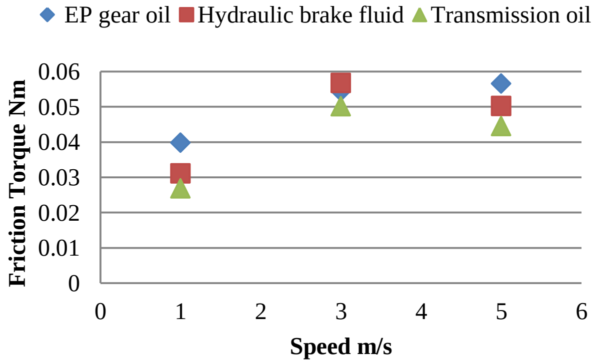

Figure 4. The variations of frictional torque of NBR seals for different lubricants with respect to sliding speed. (p = 0,5 bar)

In Fig. 5, the variations of frictional torque of seals with sliding speed are given for different lubricants under 1 bar pressure. At 1 m/s sliding speed, friction torque values for three different lubricants are very close to each other. At 3 m/s speed, there is not also a significant difference among lubricants as well. However, friction torque value for transmission oil is relatively lower. On the other hand, the effect of lubricant on friction torque values can be seen more remarkably at 5 m/s speed. Highest torque level is observed for hydraulic brake fluid which has the lowest viscosity value. Also, it is observed that radial lip seals which were tested for hydraulic brake fluid give unstable friction torque results. Even in a short period, sudden changes were observed for this lubricant. At 5 m/s, transmission oil gives the lowest friction torque value. Variation of pressure from to 0,5 bar to 1 bar does not affect the results remarkably at low speeds (1 and 3 m/s). However, results for brake fluid changes dramatically at 5 m/s as the pressure increases.

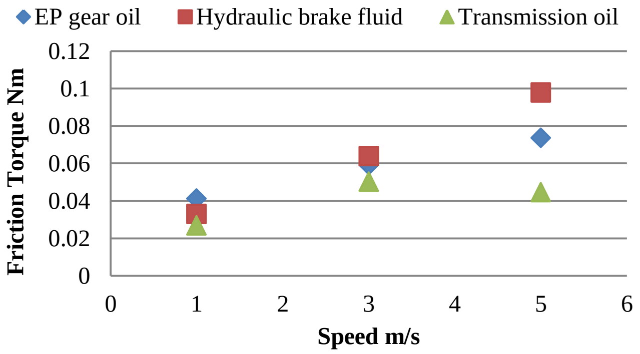

Figure 5. The variations of frictional torque of NBR seals for different lubricants with respect to sliding speed. (p = 1 bar)

IV. CONCLUSION

Regarding to all these experiments, the following conclusions can be drawn from the present study:

- EP gear oil gives stable friction seal torque values for different operating pressures whilst showing a slight increase with increasing sliding speed.
- Transmission oil having a kinematic viscosity of 35,2 cSt at 40^0C gives lower friction torque results especially at high speeds and pressures.
- At high speeds, hydraulic brake fluid is likely to give highest friction torque results in spite of its low viscosity value. Also the friction torque values are likely to be unstable and variations are dramatic for this lubricant at relatively high speeds and pressures. This probably caused by breaking and reformation of fluid film between seal and counter face due to very thin cross section on contact region.
- In many cases, maximum operating pressure for standard NBR lip seals is suggested as 0,5 bar. Changing pressure to 1 bar does not affect the friction torque levels remarkably for all three lubricants at low speeds.
- Leakage is not observed during experiments.

V. ACKNOWLEDGEMENTS

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