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THE INVESTIGATION OF FRICTIONAL CHARACTERISTICS OF NEW DESIGN PTFE SEALS

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ABSTRACT

In this study a new design PTFE (Polythetrafluoroethylene) radial lip seal was experimentally investigated. The purpose of this work is to compare new design seal with respect to commercial elastomer lip seal regarding their frictional torque and seal life. For this purpose, a test system has been developed. In this test system a cylinder block is placed on four load cells to monitor the frictional torque generated between seal and counter face. Seals were tested for 100000 meter sliding distance at 1m/s, 3 m/s, 5 m/s sliding speeds. At the end of many systematic experiments, the characteristics of new design PTFE seal have been obtained.

Keywords: Radial Seals, PTFE, Friction torque

1. INTRODUCTION

For many years various investigations about sealing technology make this field comprehensive day by day. There are many subtitles to examine and gain better sealing such as their counterface surface, sealing geometry, sealing material. Nowadays most used material PTFE is became a popular sealing material because of its distinctive properties such as high chemical and heat resistance, low coefficient of friction and withstands higher pressures. However it can be easily damaged during assembly and has low wear resistance. In order to utilize the advantage of PTFE’s superior properties, the behavior of this material under actual operating conditions should be determined.

It’s known that the lip surface geometry in sealing region significantly affects sealing mechanism. Therefore, many researchers investigated this phenomenon both numerically and experimentally. Salant R.F. and Flaherty A.L. studied on rotary lip seal that has different lip surface geometries and observed the effect of each asperity pattern on leakage [1]. The sealing lip geometry was produced periodically in previous study. Shi F and Salant R. F. used random surface geometry to simulate almost real situation of sealing mechanism. [2]. Bauer F and Haas W. analyzed performance of the PTFE lip seals with spiral grooves and observed flow through the seal to explain sealing mechanism [3]. Kletschkowski et al. studied about PTFE shaft seals. They developed a numerical model for PTFE shaft seal and proved its accuracy [4]. They concluded that the wear of sealing edge was very important for the failure of sealing systems. Weber D and Haas W was investigated wear behavior of PTFE lip seals with different sealing edge by experimentally and numerically [5]. On the other hand seals were investigated for their counterface roughness, shafts peripheral speeds and shaft diameter values. Ozperk and Temiz work on effect of surface roughness and shafts peripheral speeds on the performance characteristics of radial seals [6]. In a similar work, Kerkuklu et al. work on effect

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surface roughness and direction of machining (grinding) on wear and frictional characteristics of the seals. In this experimental work, Kerkuklu et al. concluded that the value of the system oil leakage varies according to grinding direction of the disc surface finishing. [7].

2. EXPERIMENTAL SET-UP

To investigate the effect of the surface roughness, sliding speed and lip geometry on the frictional characteristics of radial lip seals, 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.

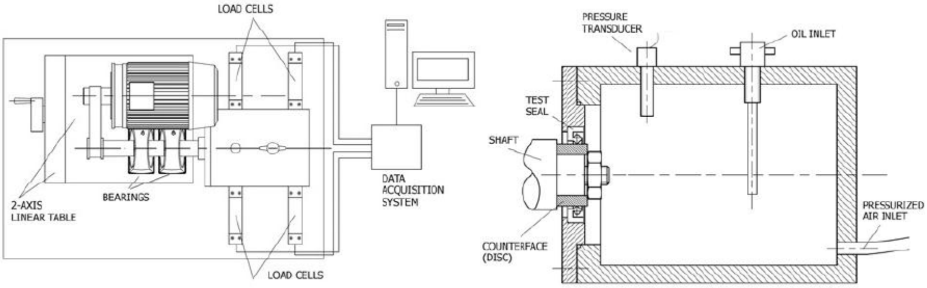

Figure 1. Schematic view of test system and test block

High pressure industrial gear oil with 150 cSt viscosity having a density of 897 kg/m^3 at 15°C was 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 cylinder 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 R_a=0.5 µm. Surface characteristic of shaft is shown in figure 2.

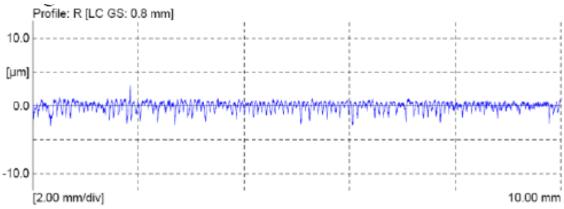

Figure 2 Surface characteristic of shaft

Figure 3 Cross section views of seals

Elastomeric lip seals are used wide variety range of mechanical engineering applications such as automotive industry. The cross sectional views of seals are shown in Figure 3.In figure 3 A shows PTFE lip seal and B shows elastomer lip seal. Elastomeric seal contains a garter spring to provide contact pressure and the helical aids grooves also added to prevent extra sealing. PTFE lip seal has a pattern of small undulation, aligned parallel to the circumferential direction. The main differences between PTFE lip seal and elastomer lip seal is the existence of garter spring. Therefore, radial forces on the shaft exerted by seal are 2125 N/m for PTFE lip seal and 269 N/m for elastomer lip seal.

The experiments were carried out at 18°C…21°C ambient temperature and 40% and 50% relative humidity in indoor laboratory condition. During the shaft installation, the axial eccentricity of shaft was eliminated by means of a dial gauge having ±0.001 mm precision. The mounting of PTFE lip seal on the shaft surface was carried out by means of special adapter sleeve. After the system was assembled, shaft speeds set to 1m/s, 3m/s and 5m/s for each test and frictional torques were recorded during 100000 m (100 km) sliding distance. At the end of each test, seal lips were examined under the optical microscope to observe the surface cracks and deformations.

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3. TEST RESULTS AND DISCUSSION

In the Figure 4 the variation of frictional torque with respect to sliding distance for both seals are shown. A remarkable increase on the frictional torque is observed up to 500 m sliding distance. After that, the frictional torque values reach a nearly constant value for commercial rubber seal. For PTFE lip seal, frictional torque values show a slight increase with sliding distance after 500 m. Kletschkowski T. et. al. stated that this remarkable change in the frictional torque was caused by stress relaxation [5]. Therefore, the sudden change obtained in the experiments before 500 m sliding distance is also caused by stress relaxation. During the experiments it is observed that contact surface temperature of PTFE lip seal was at 30 $_{o}$C at 1 m/s, 50 $_{o}$C at 3 m/s and 60 $_{o}$C at 5 m/s. For rubber based seals contact surface temperature was about 30 $_{o}$C for all peripheral speeds

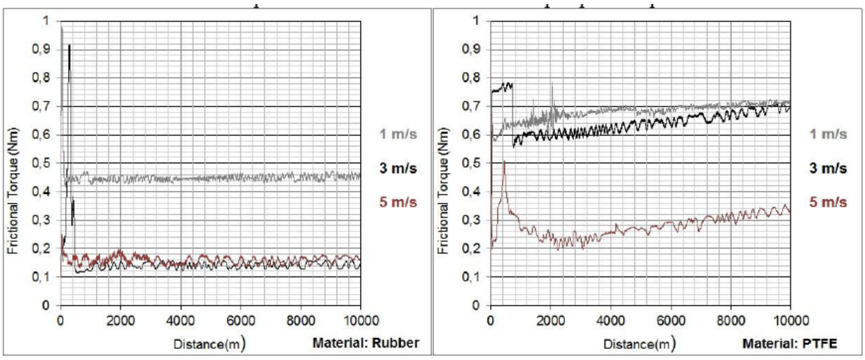

Figure 4 The variation of frictional torque with respect to sliding distance for both seals

In the Figure 5, the variation of frictional torque with sliding speed is shown for both seals. As seen from the Figure, the friction torque decreases with increasing sliding speed. The higher friction torques for PTFE lip seal is mainly caused by remarkably high preload applied during the mounting process. Interference between inner diameter of PTFE seal and shaft was more than 5 mm.

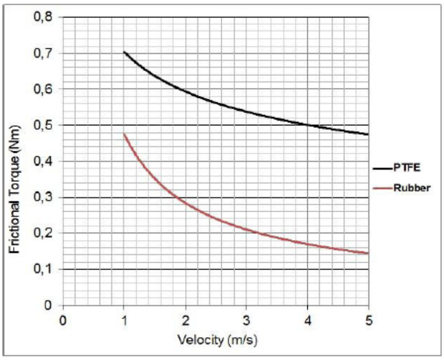

Figure 5 The variation of frictional torques with sliding speed

In Figure 6, the optical micrographs of test seals are shown. The micrographs were taken at the end of the 100 km sliding distance. The right hand side of each micrograph shows oil side and left hand side shows air side. While no remarkable undulation deformation has been observed for PTFE seal at 1 m/s and 3 m/s sliding speeds, for 5 m/s sliding speed it is determined that undulation on the lip region was wear out (Fig. 6.c). For elastomeric lip seal, no remarkable wear evidence has been observed for all test speeds. Further inspections on the micrographs showed that there is no micro cracks perpendicular to the sliding direction due to hardening of seal material. Therefore, no measurable leakage was determined after 100 km sliding distance (about 24 hours).

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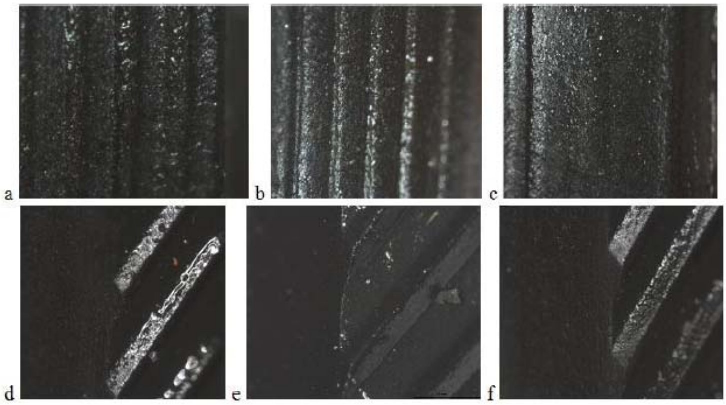

Figure 6 Optical micrographs of seal surfaces at the end of the test: a) PTFE at 1m/s, b) PTFE at 3m/s, c) PTFE at 5m/s, d) Elastomer at 1m/s, e) Elastomer at 3m/s, f) Elastomer at 5m/s

4. CONCLUSION

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

- PTFE lip seal gives higher frictional torque values than that of commercial rubber seals.
- Commercial rubber seals shows more evident start up characteristics (relaxation) than PTFE seals due to the viscoelastic nature of rubber material.
- The frictional torques obtained for 1 m/s and 3 m/s sliding speeds for PTFE seals are nearly identical, whereas at 5 m/s sliding speed the obtained frictional torque values is lower. It can be stated that the friction torques for PTFE seals decreases with increasing speed.
- The frictional torques obtained for 3 m/s and 5 m/s sliding speeds for rubber seals are almost identical, whereas at 1 m/s sliding speed the obtained frictional torque values is higher.
- Contact surface temperatures for PTFE seals give higher values due to the higher preload.
- PTFE seals shows evidence of remarkable wear at relatively higher sliding speeds.

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