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ON THE EFFECTS OF SLIDING VELOCITIY ON THE INTERFACIAL TEMPERATURE GENERATION IN BUNA-N O-RING SEALS

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ABSTRACT

Careful attention must be directed to factors affecting the performance and behavior of elastomeric seals including friction, wear, and temperature generated between the seal rings to meet the stringent environmental requirements and to increase the durability and service longevity of these seals [1]. The performance and reliability of these O-ring seals are dependent on the thermal characteristics of the seal and piston in relative motion with each other [2]. Failure of these dynamic O-ring seals is considered to be responsible for considerable productivity loss in reciprocating and rotating applications in hydraulic and pneumatic industries**.**

Modeling

In the present study, a commercial CFD software FLUENT was used to analyze heat transfer characteristics in the vicinity of the elastomeric seals including the steady state temperatures generated at the contact interface region. Modeling, meshing, and application of boundary conditions for a 2D-axisymmetric model shown in Fig. 1 was done in GAMBIT. A 3D model was also built and analyzed to cross check with the temperature results obtained by 2D model considering the axis symmetry. The energy equations are solved in both solid and liquid domain with the computational model taking into account the heat generated between the interface of the rotating shaft and the stationary seal, heat conduction into the rings and the heat convection into the surrounding fluid in the seal chamber.

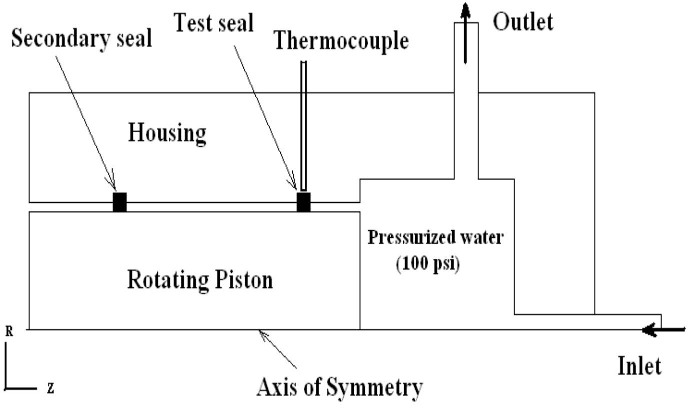

Fig. 1. Schematic of the elastomeric seal installation with temperature sensor.

Experimental Apparatus

Experiments are performed on the seal test rig (STR) composed of a stationary stainless steel cylindrical housing one end of which is closed and the other end exposed to the atmosphere as shown in Fig.2. The housing contained two grooves drilled on the inside diameter for the o-ring seals to be seated. A circular rotating steel piston controlled with an motor and a frequency drive was inserted through the bore of the housing. Pressurized water at 100 Psi was pumped from closed end of the housing with the pump to maintain a pressurized water chamber on one end of the test seal as shown in Fig. 2. A lubricating chamber is maintained in between the test seal and secondary seal. It provides lubrication to the seals at all times during the test. A thermocouple is located closely at the tip of the test seal to be able to monitor the temperature data during the test as shown in Fig. 1

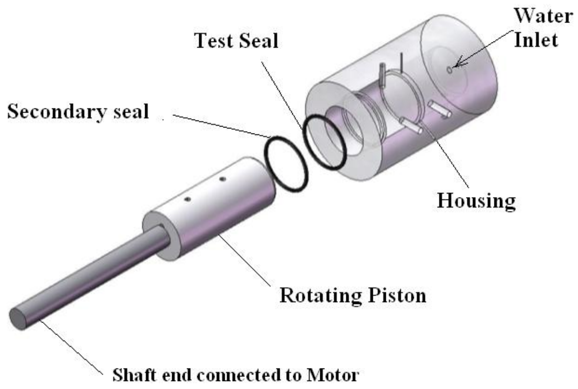

Fig.2 .Exploded view of the Piston and Housing before assembly.

In case of dynamic sealing applications, the O-ring continuously rubs against the same portions of the shaft at the contact interface, thus continuously generating high local friction heat. To determine the heat generated at the rubbing interface between the seal and the piston, the friction coefficient is to be determined. A series of three friction tests was performed using the CETR Universal

Micro-Tribometer with a ball on elastomer configuration lubricated with SAE 30 lubricant under similar conditions as in actual experimental test. The results of the tests showed that the friction coefficient of elastomer rubbing against steel remained independent of the loading conditions. Similar conclusions are reported by Shooter and Tabor [3].

A parametric study was performed taking into consideration the obtained simulation results from a 2D-axisymmetric model considering the effects of both peripheral sliding velocities (v) and interfacial friction coefficient (f) on the rise of temperature (T) at the contact interface of the piston and stationary seal.

Experiments are planned to be carried out in two different regimes. Under the regime-I, a series of experimental tests are planned with clean water as a working fluid in the system. The main focus of this regime is to investigate the effects of rise in interfacial temperature (T) with increase in sliding velocities (v) keeping the other parameters unchanged. The steady-state temperature results of this phase of the regime are to be validated using the CFD codes.

Under the regime–II, a set of experiments are planned with contaminated water as the working fluid. In the first phase the effects of variations in sliding velocity (v) on interfacial temperature rise (T) considering other parameters remaining unchanged are planned to be determined. In the second phase the increase in interfacial temperature (T) due to an increase in local friction heat caused by the increased friction coefficient (f) at the rubbing interface due to the presence of varying contaminant quantity are planned to be evaluated.

Results and Discussion

The results obtained from the parametric study in Fig. 3 show that the interfacial temperatures of the test seal remain low with lower values of peripheral sliding velocities and gradually tend to increase with increased sliding velocities for each case of assumed friction coefficient. For a particular case of friction coefficient of 0.08, the temperatures remain as low as 30.5 °C for sliding velocities of 0.265 m/s and gradually increase with higher values of sliding velocity eventually reaching the maximum temperature of 59 °C for sliding velocity of 1.595 m/s. It can, therefore, be concluded that the peripheral sliding velocities plays a crucial role in influencing the interface temperature generation.

Also a rise in interfacial temperatures of the test seal is observed with increase in friction coefficient (f) for each case of sliding velocity. Considering a particular case of sliding velocity of 1.595 m/s, it can be observed from Fig. 3 that the interfacial temperatures remain at 59°C for friction coefficient case of 0.08 and reach as high as 110°C in case of highest friction coefficient of 0.20 due to the increase in local friction heat at the contact junction which may cause diminishing effects on the performance of seals.

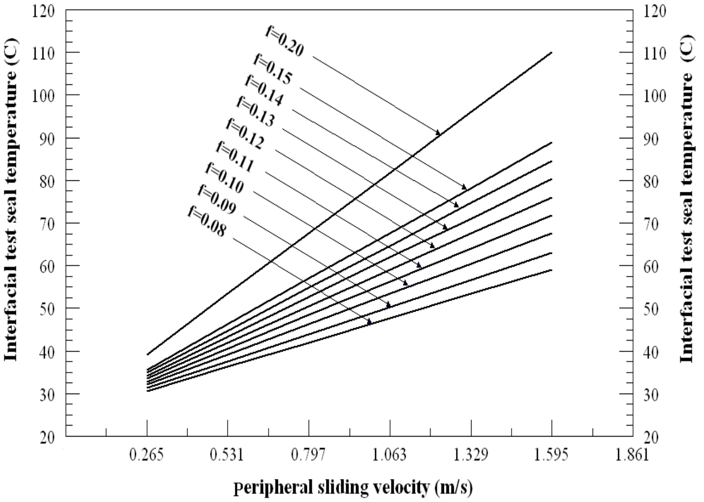

Fig.3. Response of Interfacial test seal temperature (C) with Peripheral sliding velocity (m/s)

A noteworthy observation made from the Fig.3 is that the curves are not parallel to each other and that the slope of the curves increases for each case of friction coefficient in combination with sliding velocity.

It can therefore be concluded that the increased peripheral velocities (v) in combination with high friction coefficients (f) at the rubbing interface of the seal and piston play a crucial role in determining the life of the elastomeric seals.

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References

1. Luan,Z.G, Khonsari,M.M. 2006."Numerical Simulations of the flow field around the rings of mechanical seal". ASME J Tribol; V.128, pp.559-565.
2. Dareing, D.W, 1980. "Factors affecting seal life in down hole motors". Report No.SAND79-7123, Maurer Engineering Inc., Houston, TX. January.
3. Shooter, K and Tabor, D .1952."The Frictional properties of plastics". Proc R Soc. V.65, pp.661-671.