OPTICAL INVESTIGATIONS INTO ROTATING AND OSCILLATING RADIAL LIP SEAL CONTACTS

B Wennehorst* and GWG Poll
*wennehorst@imkt.uni-hannover.de
Institute for Machine Design and Tribology (IMKT), Leibniz Universität Hannover
Welfengarten 1A, D-30167 Hannover, Germany

KEYWORDS
Mixed Lubrication; Surface topography; (soft) EHL; Radial Lip Seal

ABSTRACT

In continuation of earlier work [1, 2], an optical radial lip seal test rig was set up implementing a servo direct drive, a transparent sapphire hollow shaft, and a high resolution high-speed CCD camera attached to a stereo microscope (fig.1). Complementary to the previously used total internal reflection white light illumination approach, the light was now directly and nearly radially fed into the sealing contact via the tilted mirror used for radial redirection of the optical path (i.e., very similar to [3]). Using this technique, the actual elastomer asperity / sapphire contacts appear as dark regions, while cavities within the elastomer contact topography appear as dispersed bright areas and spots; the presence of lubricant leads to a noticeable contrast attenuation within the wetted regions of this contact pattern.

A first series of optical investigations was conducted at room temperature and low sliding speeds up to approx. 0.2 m/s (CW/CCW stationary rotation), and oscillation of ±90° with a frequency up to approx. 2 Hz, respectively. The tested sealing systems were plain FKM radial lip seals lubricated with polyglycol (PG), and NBR seals lubricated with mineral oil (MO). The lubricants were pure base oils without any additives. The test seals had been previously run in on a standard steel shaft (CW stationary rotation at 5 m/s, 36 km sliding distance, 60 °C sump temperature).

In both sealing systems, each during stationary CW/CCW rotation as well as during oscillation, the asymmetric tangential distortion of the elastomer seal lip contact topography could clearly be seen from the contact pattern brightness distributions. In addition, axial oscillations of individual contact spots were consistently observed, clearly indicating the "stretch effects" previously described in [4]. Moreover, during oscillation, the angular positions of zero sliding velocity do not coincide with the angular end positions of the shaft, as could be assumed at first glance. Instead, as soon as the angular position corresponding to maximum sliding speed (and, therefore, corresponding to maximum viscous and contact shear forces) is passed, the circumferentially distorted seal lip starts to deform back; in the meantime, the shaft passes through the angular end position, until, in the reverse direction, at a certain angular position, the shaft surface velocity reaches the surface velocity of the seal lip, thus resulting in zero sliding velocity. Then, the same behavior is seen in the remaining part of the oscillation cycle, i.e., in the reverse direction.

In the constantly CW rotating NBR/MO sealing system, the oil on the air side of the seal lip was pumped to the oil side, until a stationary size of the air side oil meniscus was reached; in the opposite rotation direction, the meniscus slowly increased. No clear oil transport was seen during oscillation. In the constantly CW rotating FKM/PG system with its lower wettability, the entire air side lubricant was quickly pumped to the oil side, i.e., the meniscus was apparently totally ingested into the sealing contact, thus leading to starved lubrication in a large air side portion of the contact beyond the seal lip pressure maximum [5]; in the reverse (CCW) direction, the oil leaked back to the air side. During oscillation, this behavior was cyclically reproduced. Thus, it could be demonstrated that meniscus ingestion strongly depends on the wetting behavior of the entire sealing system, as can be inferred from [5].

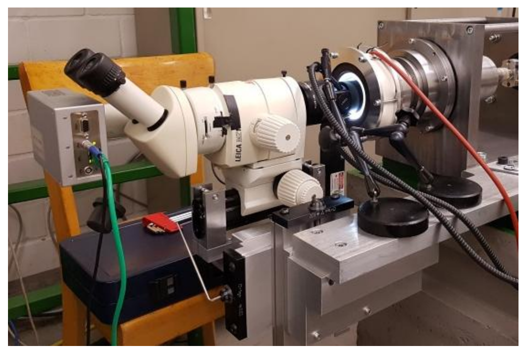

Fig.1: Optical radial lip seal test rig

REFERENCES

[1] Wennehorst B and Poll GWG. Investigations into the tribological characteristics of radial lip seals – LIF and friction measurements. In: Proc. 20th Int. Conf. on Fluid Sealing 2009, pp. 213–229.

[2] Wennehorst B. On Lubrication and Friction in Soft Rough Conformal Sliding Contacts — Experimental and theoretical contributions to the discussion on elastomer shaft seal tribology, Leibniz Universität Hannover, Doctoral Thesis, 2016.

[3] Nakamura K and Kawahara Y. An Investigation of Sealing Properties of Lip Seals through Observations of Sealing Surfaces under Dynamic Condition. In: Proc. 10th Int. Conf. on Fluid Sealing BHRA The Fluid Engineering Centre, BHRA, 1984 – Paper C1.

[4] Leeuwen, H van, Petterson R, Meesters K. Cinderella in fluid film lubrication: stretch effects in radial lip seals. In: Proceedings of the 38th Leeds–Lyon Symposium on Tribology: Energy and Health, Lyon, 2011.

[5] Salant RF. Rotary lip seal operation with an ingested meniscus. In: Journal of Tribology 119 (1997), Issue 1, p. 205–210.