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On friction and surface energy in the tribological contact of rod seals

Oliver Feuchtmüller[1)*], Lothar Hörl[1)] and Frank Bauer[1)]

[1)]University of Stuttgart, Institute of Machine Components, Germany
*Corresponding author: oliver.feuchtmueller@ima.uni-stuttgart.de

In this work, the influence of wetting and surface energy on dynamic friction of reciprocating rod seals is analysed experimentally. Sealing materials made of different polyurethane compounds are used. The polar and dispersive surface energy is determined using sessile drop contact angle measurements and the theories from Wu and OWRK. Friction measurements were carried using multiple rod seals with similar mechanical properties, same geometry but different surface energy. A polished hard-chromed rod and mineral oils with different viscosity classes were used. The measured friction is plotted against the product of speed and dynamic viscosity as a reference curve. Although the geometry and mechanical properties of the rod seals are close to identical, significant differences in measured friction are reported. Rod seals made of low surface energy polymer compounds have significantly lower friction forces.

Keywords: hydraulic rod seals, dynamic friction, surface energy

1. Introduction

Interfacial phenomena influence the tribological behaviour of lubricated machine components [1]. Empirical studies present the correlation between surface energy and the spreading parameter on friction in sliding steel/steel contacts [2]. The influence of interfacial phenomena on the tribological behaviour of radial lip seals is analysed as well [3]. In particular, the pumping rate of radial lip seals and wear on rotating shafts depend on wetting parameters like the work of adhesion and spreading parameter. Wettability and its influence on hard-soft tribological contacts in sealing technology are recognised, but still not fully understood, even though tailor-made sealing materials offer great potential for low friction and innovative sealing systems.
In this work, the influence of surface energy and wettability on the hard-soft contact of reciprocating seals is analysed experimentally. Rod seals with same geometry, similar mechanical properties but made of polymer compounds with different surface energy are used.

2. Methods

Sessile drop contact angle measurements are carried out. The polar and dispersive surface energy is calculated using the theories from OWRK and Wu.
For each sealing material, friction is measured as a function of rod speed and dynamic viscosity using a polished hard-chromed rod and different pure mineral oils.

3. Results

Significant differences of typical sealing materials regarding free surface energy and polarity are revealed, e.g. surface energy values vary from approx. 20 mN/m up to 40 mN/m for different polyurethane compounds.
As expected, the results of the friction measurements show a clear correlation of viscosity and speed on friction. It is noteworthy that the measured friction depends significantly on the sealing material. Figure 1 presents friction measurements of two analysed rod seals as examples.

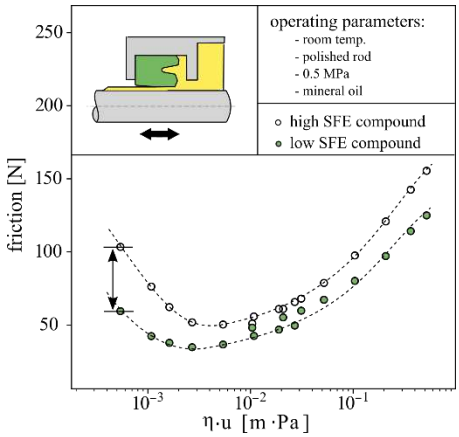

Figure 1: Friction of rod seals made of different polyurethane compounds

4. Discussion

The results show that wetting parameters in the sealing gap of reciprocating rod seals are of great importance. For low rod speeds and low oil viscosity, when the boundary lubrication regime dominates, the influence of interfacial phenomena increases. In this study, polymer compounds with low surface energy and polarity reduce friction significantly. Boundary slip or the apparent oil viscosity in close vicinity to the seal-oil interface may depend on wetting parameters of the seal material.
In any case, results show the potential for low friction dynamic seals quantitively. Furthermore, the study is a step towards better understanding of the tribological behaviour in hard-soft lubricated thin film sliding contacts.

5. References

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