1. Introduction
2. Friction and wear under dry sliding conditions
3. Lubricated sliding friction
4. Two body abrasive wear in lubricated condition
5. Concluding remarks
Introduction

- Reciprocating and rotary seals are widely used in various technological systems
- Elastomers are the preferred choice of materials

Sealing elastomers

Elastomers are the most popular seal materials because of their:

- low modulus of elasticity & high elongation-to-break: can deflect significantly, follow the irregularities and vibration of the sealed surface without giving high contact stresses.
- high Poisson’s ratio (close to 0.5) & low shear modulus G, enabling an elastomeric seal to create its own sealing force automatically in proportion to the pressure.

Unloaded coiled chains

Loaded in tension

Elastomers are polymeric materials with high elasticity and fairly low cross-link density, with links at random intervals, usually of between 500 and 1000 monomers.
Why tribology of elastomeric seals?

- Friction
- Leakage (due to wear)
- Service life (limited by wear)
- Seal-oil interaction (performance deterioration)

*Seals account for major part of bearing friction (~75% of total bearing power loss)*

*Patent, WO 2011/110360 A1

Challenges in tribological testing of elastomers!

- Large elastic deformation
- Low contact pressure, difficult to investigate the tribological behaviour of elastomer in boundary or mixed lubrication
- Edge effects
- Absorption of oil and leaching
- Effect of cleaning agents
- Thermal effect

High frequency tests

Low frequency tests
Dry friction of elastomers under unidirectional sliding conditions

<table>
<thead>
<tr>
<th>Elastomeric materials</th>
<th>Hardness (Shore A)</th>
<th>Tensile strength (MPa)</th>
<th>Elongation at break (%)</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrile rubber (NBR)</td>
<td>76.1</td>
<td>25.4</td>
<td>466</td>
<td>1.31</td>
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<td>Hydrogenated nitrile rubber (HNBR)</td>
<td>71.3</td>
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<td>Acrylate rubber (ACM)</td>
<td>73.4</td>
<td>7.8</td>
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<tr>
<td>Fluoro rubber (FKM)</td>
<td>72.8</td>
<td>15.6</td>
<td>&gt;900</td>
<td>2.03</td>
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Surface roughness of steel rings

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<th>Surface type</th>
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<tr>
<td>Smooth surface</td>
<td>0.17–0.34</td>
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<tr>
<td>Medium surface</td>
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<td>Rough surface</td>
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Dry frictional behaviour at low load *
(Normal load: 1.5 N, Speed: 10 r.p.m.)

• Friction coefficient decreased after a running-in period and the wear was insignificant.
• Longest running-in periods observed during sliding against fine surfaces.

Dry frictional behaviour: Influence of sliding speed
(Normal load: 1.5N, Ra: 0.35 ~ 0.55 μm)

Speed dependence of friction is quite anomalous; different for different elastomers!
Dry friction and wear behaviour*
(Normal load: 10 N, Speed: 10 rpm, Ra: 0.35 ~ 0.55 μm)

- Powdery worn particles observed on the ACM resulted lower friction coefficient but for FKM and HNBR, worn particles with roll shapes have been produced.
- Worn particles of FKM were significantly larger than those of the other tested materials.

Frictional behaviour of sealing elastomers in different lubrication regimes
Experimental materials and lubricant

- Four different types of sealing elastomers NBR, HNBR, ACM and FKM
  (Rectangular sheets of 16 mm x 4 mm x 2 mm thickness)
- Paraffinic oil without any additive
  (Viscosity: 34.1 cSt @40°C)
- Steel counterface
  - AISI 52100 bearing steel
  - Ra ≈ 380 nm, after removing the cylindrical curvature

### Experimental elastomers

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Elastomers' properties

Surface topography of elastomeric samples (Ra ≈ 80 nm)
Test apparatus and configuration

A block on ring test configuration was chosen to simulate radial lip seal operating under unidirectional (rotational) sliding conditions.

Test parameters and procedure

- Running in for 50 minutes at a sliding velocity of 18.33 mm/s to reach more steady results and the sliding
- Tests at both increasing and decreasing speeds of 0.24, 0.33, 0.58, 1.03, 1.83, 3.26, 5.79, 10.30, 18.33, 32.58 mm/s
- Tests run for 10 min at each sliding speed
- Tests performed at room temperature (22 ± 2 °C).
- Experiments carried out at a normal load of 3.5 N (contact pressure ~ 370 kPa)
Friction results

Purple lines show friction coefficients in tests in which oil and elastomers have been in contact for longer duration.

Friction in full film (soft ehl) regime

Friction coefficients for different elastomers are different and this is due to the different viscoelastic behaviour of the elastomers.
Two body abrasive wear and friction of sealing elastomers in unidirectional lubricated sliding

**Materials and test parameters**

**Materials:**
- Four different types of sealing elastomers (NBR, ACM and FKM)
- The lubricant was *monoester*

The samples aged in the lubricant for 2 weeks at 120°C and then the changes in their weights and tear strength were measured.
Influence of lubricant on the abrasive wear, weight change, tear strength and friction coefficient is most for ACM!

Wear particles examination

Wear particles (particularly from ACM) in dry sliding get aggregated but in lubricated sliding dispersed!
• Apart from FKM, presence of the oil resulted in a decrease in friction coefficient as well as the tear strength of the elastomers, especially for ACM.

Concluding remarks

• In boundary lubrication, the ACM and FKM have shown the lowest and highest friction coefficients respectively.
• Friction coefficient of an elastomer in boundary lubrication may decrease or increase with time and it may be due to the oil absorption or extraction of some elastomer’s constituent respectively.
• In EHL regime, the friction coefficients of FKM and HNBR have the lowest and highest values respectively.
• Depending on the wear mechanism and the oil-elastomer compatibility, the presence of lubricant may decrease or increase the wear of elastomers.
Concluding remarks

Tribology of elastomer is highly complex; influenced by several factors such as counterface surface topography, interaction with lubricant etc.

In another study, we have found both leaching (extraction of elastomer constituents by the lubricant) & absorption of lubricant in elastomer material.

Salient publications

- Mofidi, M., Prakash, B., Two body abrasive wear and frictional characteristics of sealing elastomers under unidirectional lubricated sliding conditions, Tribology: Materials, Surfaces & Interfaces, 2010, 4, 1, 26-37.
Thank you for your kind attention!