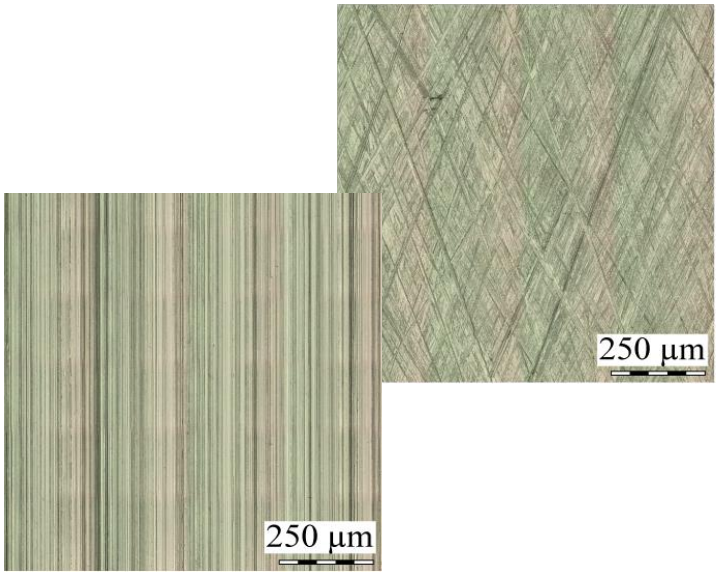
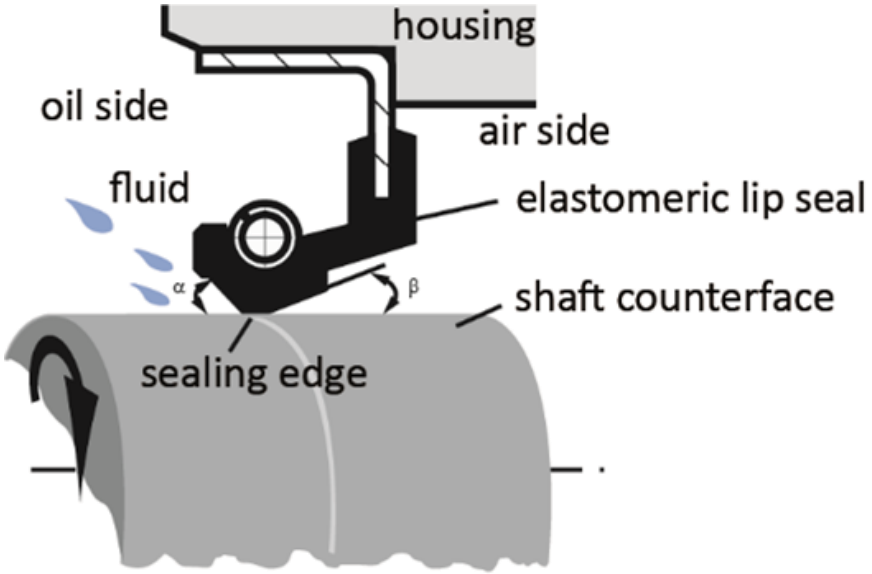
Influence of different shaft surface finishes on the tribological and functional behaviour of radial shaft seals

Schulz, Markus



Outline

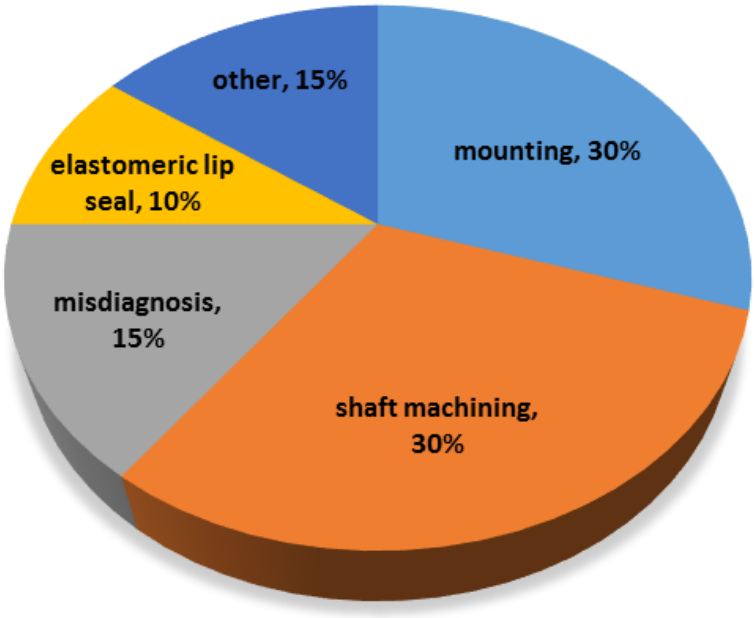
Introduction & Motivation



[5] Baumann, M., Bauer, F., Haas, W. – Messung, Analyse und Bewertung von Dichtungsgegenlaufflächen für das Tribo-System Radial-Wellendichtung, 18th ISC, 2014

- Plunge grinding is the standard manufacturing process
- Alternative manufacturing methods are used more and more often
- Reasons:
  - Time & cost saving
  - Supposed to generate „lead free“ surfaces

Introduction & Motivation



[3] Prem, E., Vogt, R. – Der Simmering, 2008

- Plunge grinding is the standard manufacturing process
- Alternative manufacturing methods are used more and more often
- Reasons:
  - Time & cost saving
  - Supposed to generate „lead free“ surfaces
- Result: Often problems with leakage or increased wear
- Aim: In which limits can belt ground and superfinished surfaces be used as a sealing counterface?

Outline

Shaft Manufacturing

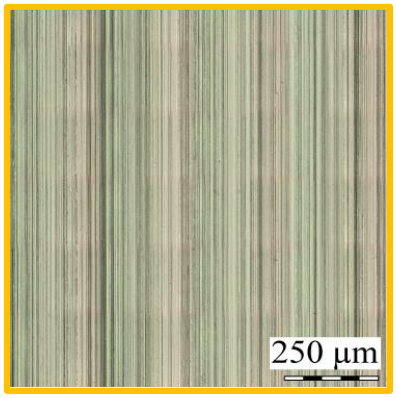
- Shafts were belt ground with or without axial movement

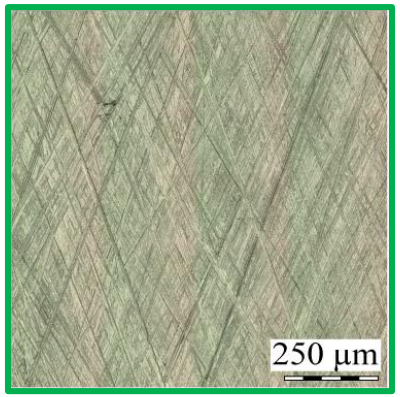
  → Crossed surface structures or circumferentially closed grooves

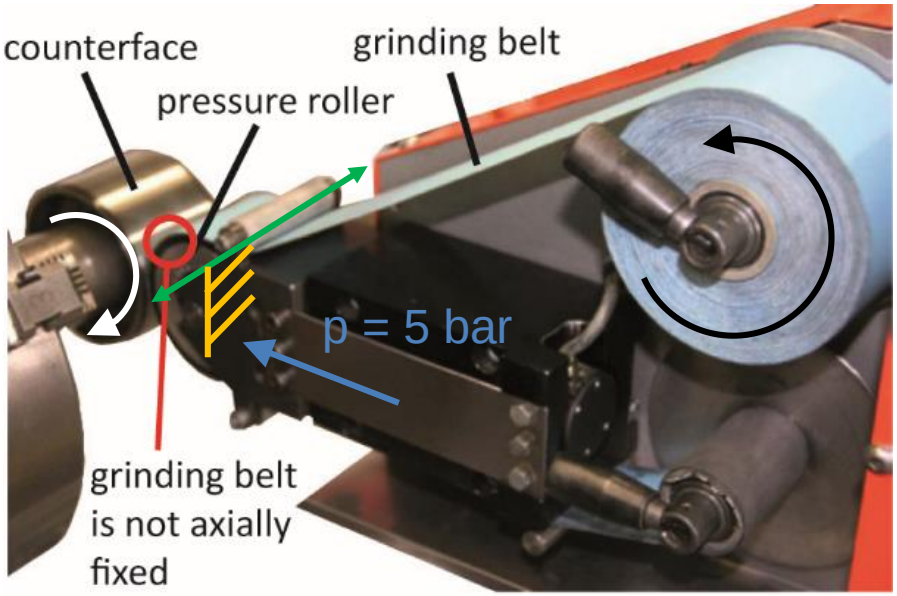
  → In the following named superfinished (S) and beltground (BG)

- 5 grinding belts with different grain sizes

  → Shaft counterfaces with different roughness







Visual Analysis of the Shaft Counterfaces

Reference: Ref

Plunge ground shaft counterface

BG

Belt ground shaft counterface

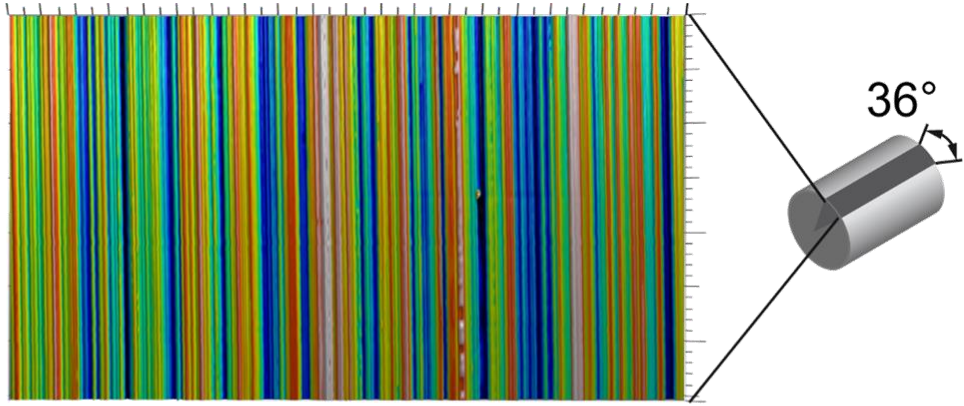
S

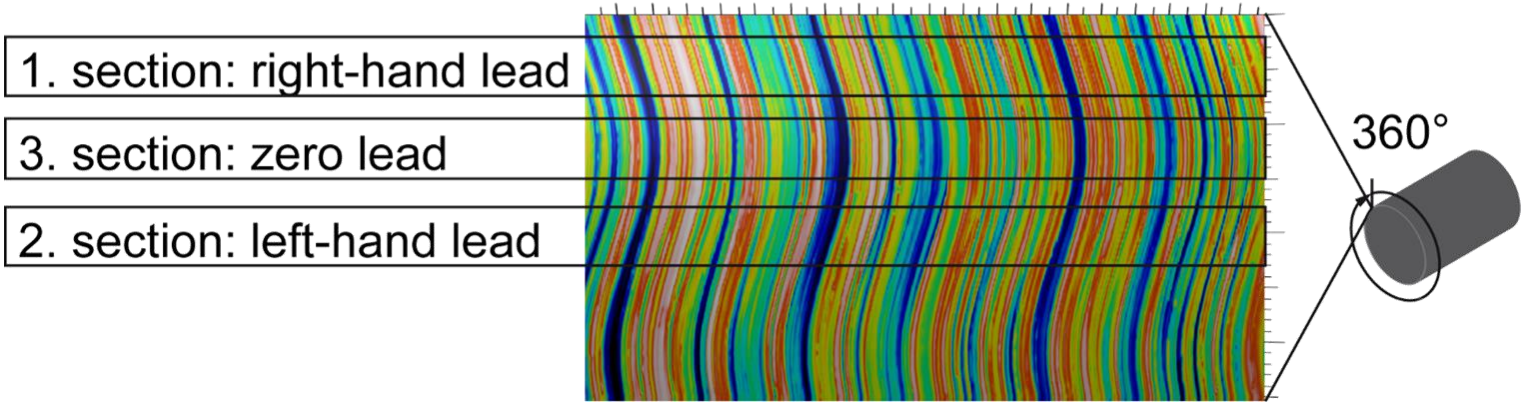
Superfinished shaft counterface

Macrolead Analysis

- According to Daimler MBN 31007-7

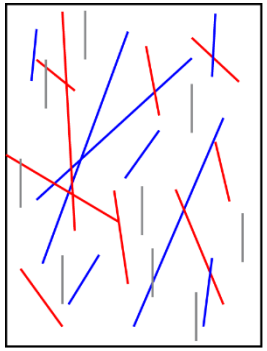
Lead thread	36°-analysis	360°-analysis
Reference	0 and -1	0
Superfinished	-112 and 45	-2 to 5
Belt ground	-1 and 0 (4 shafts -1)	0



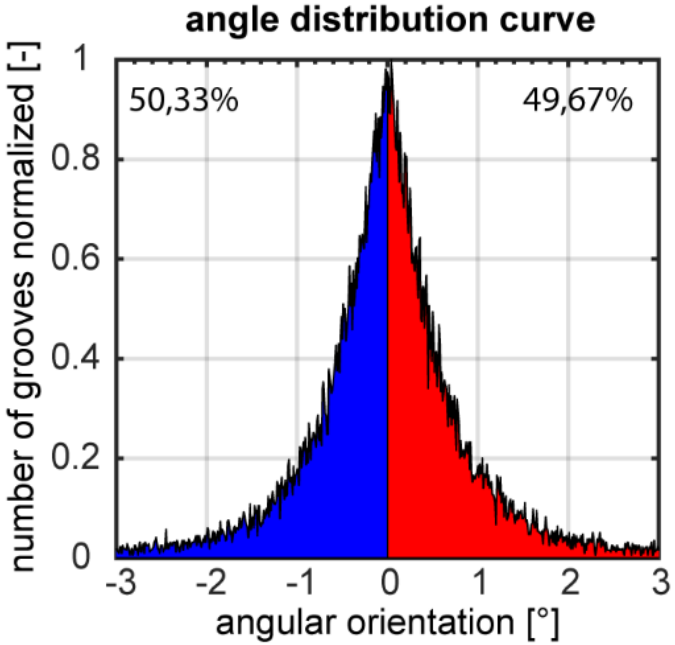


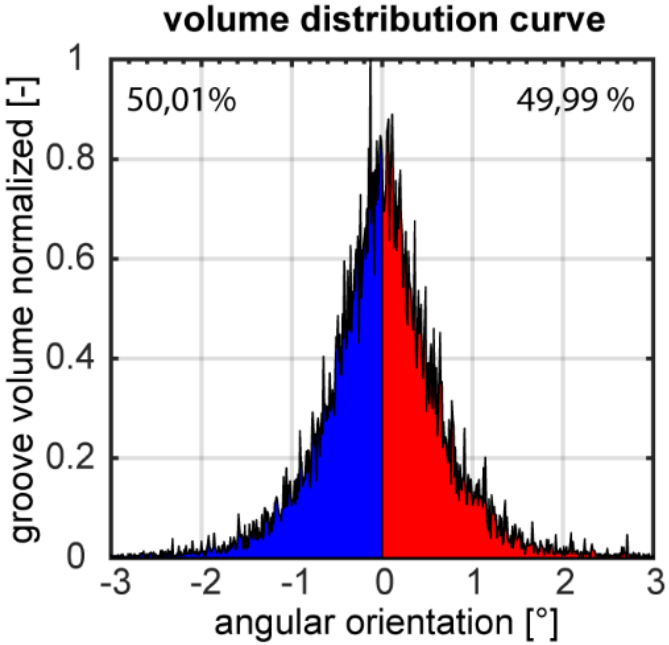
IMA-Microlead® Analysis

- Reference:
  Plunge ground shaft
  counterface Ref 1



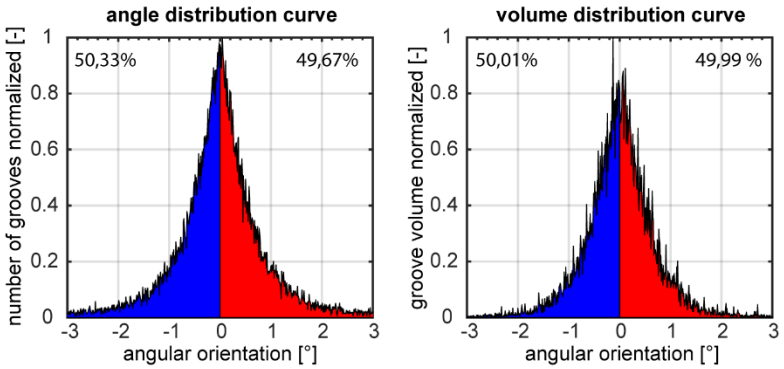
Red: Right-hand lead structures
Blue: Left-hand lead structures
Grey: Structures in circumferential direction

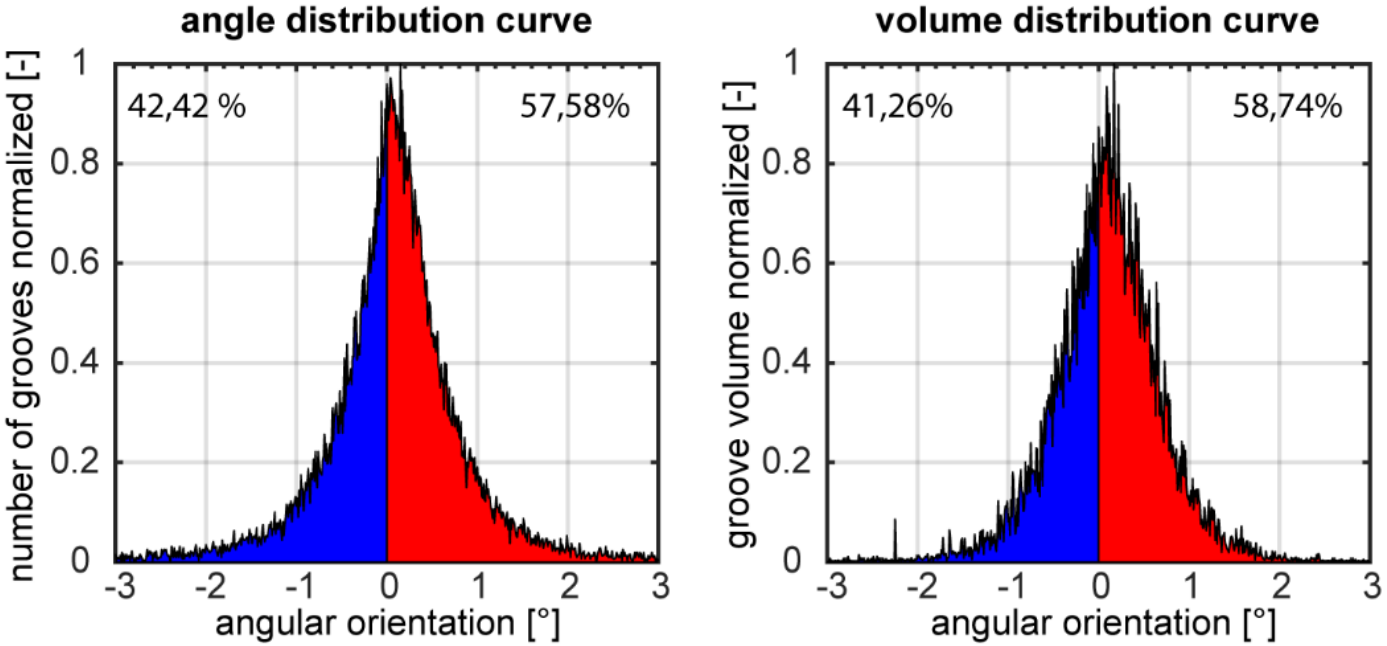




IMA-Microlead® Analysis

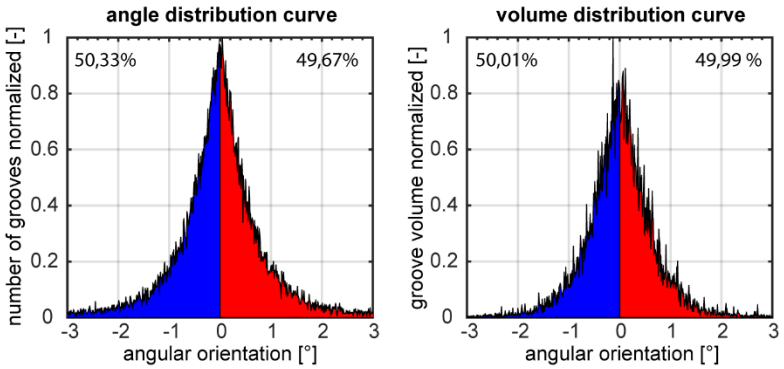
- Plunge ground reference shaft counterface Ref 2

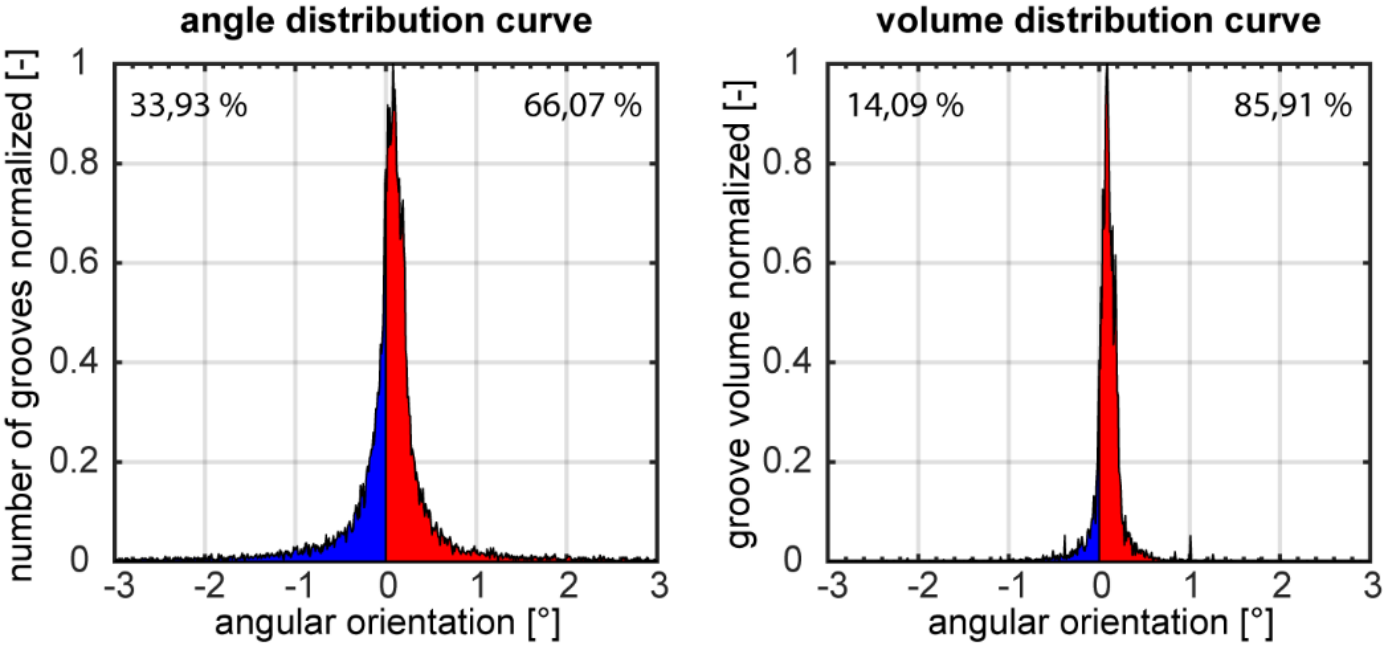




IMA-Microlead® Analysis

- Belt ground shaft counterface BG 5



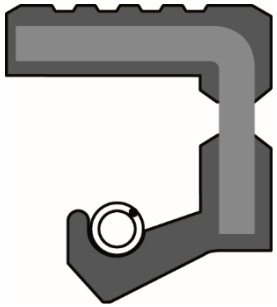


Test Conditions

- Shaft counterfaces

	Belt ground	Superfinished	Reference (Plunge ground)
R_z	2.2 – 6.8 µm	0.4 - 2.5 µm	1.6 µm and 2.8 µm
R_a	0.3 – 1.0 µm	0.03 - 0.3 µm	0.2 µm and 0.3 µm

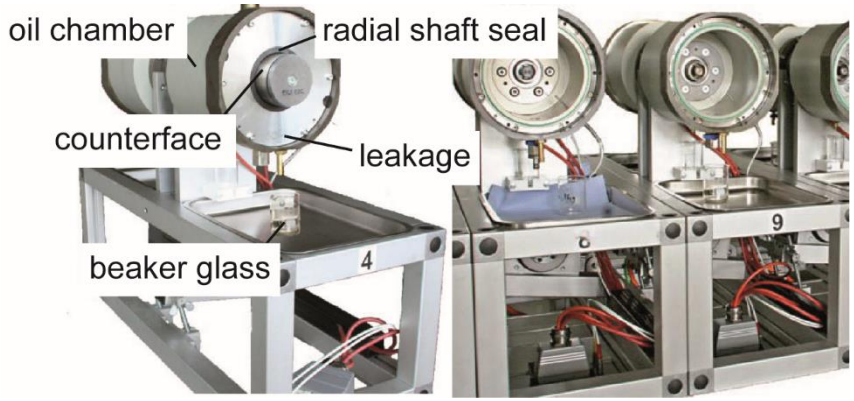
- Elastomeric lip seals: nitrile butadiene rubber



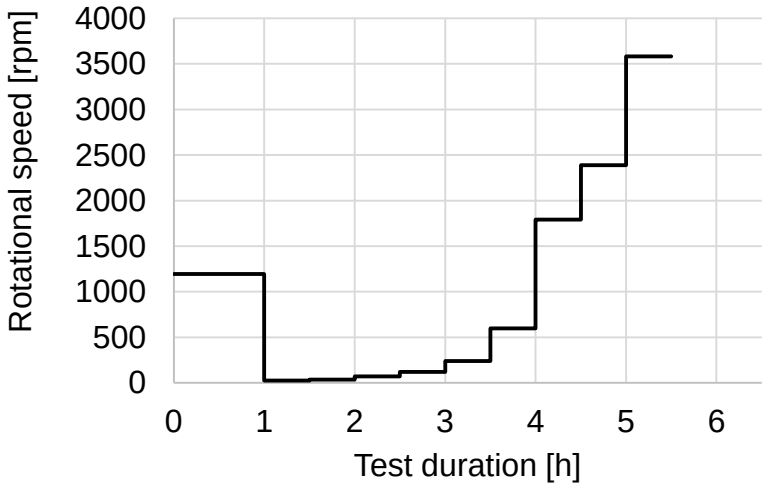
- Oil: Fuchs Titan Supersyn SL SAE 0W-30

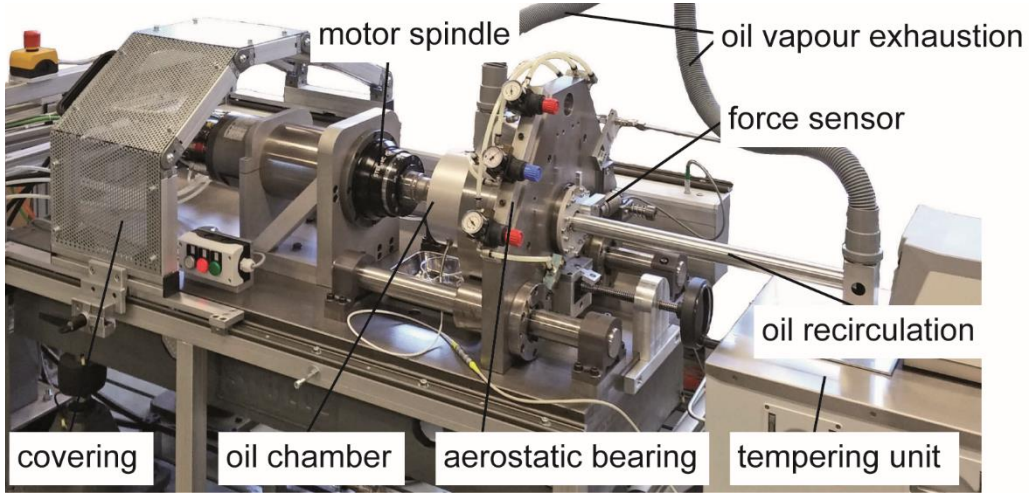
Test Conditions

- Endurance tests
  - Duration 96 h
  - Oil sump temperature 60 °C
  - Circumferential speed 5 m/s



- Friction measurement





Outline

1 Introduction & Motivation

2 Experimental Approach

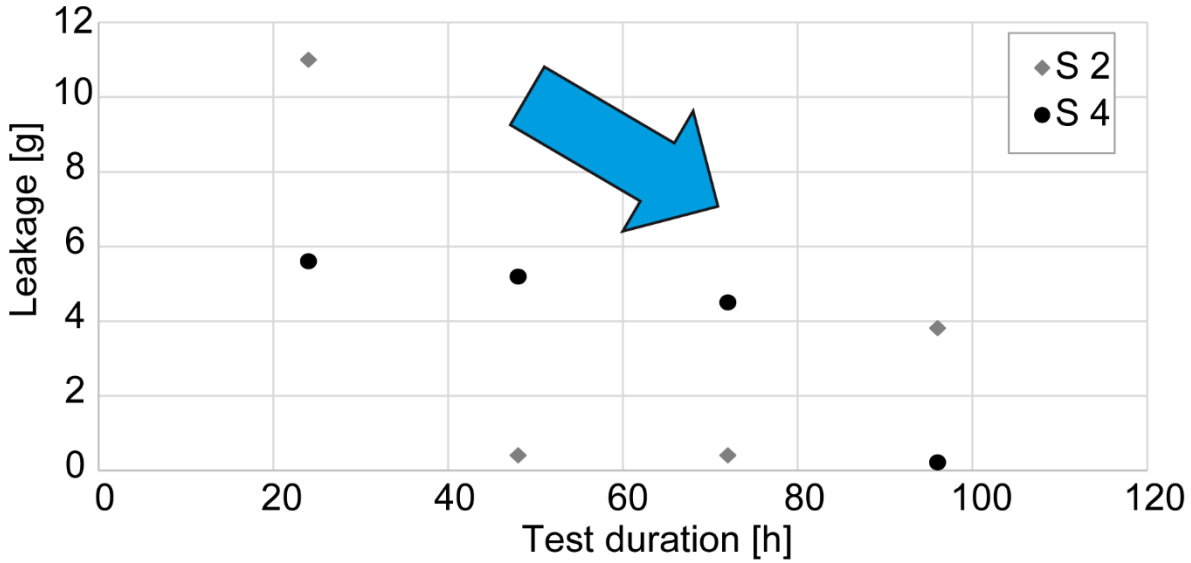
3 Results

Leakage

- Reference plunge ground shaft counterface (Ref)
- Belt ground shaft counterfaces (BG)

} No leakage

- Superfinished shaft counterfaces:
  - Leakage in all test runs
  - Leakage decreased with test duration
  - Remaining test had an oil meniscus at the airside of the sealing lip



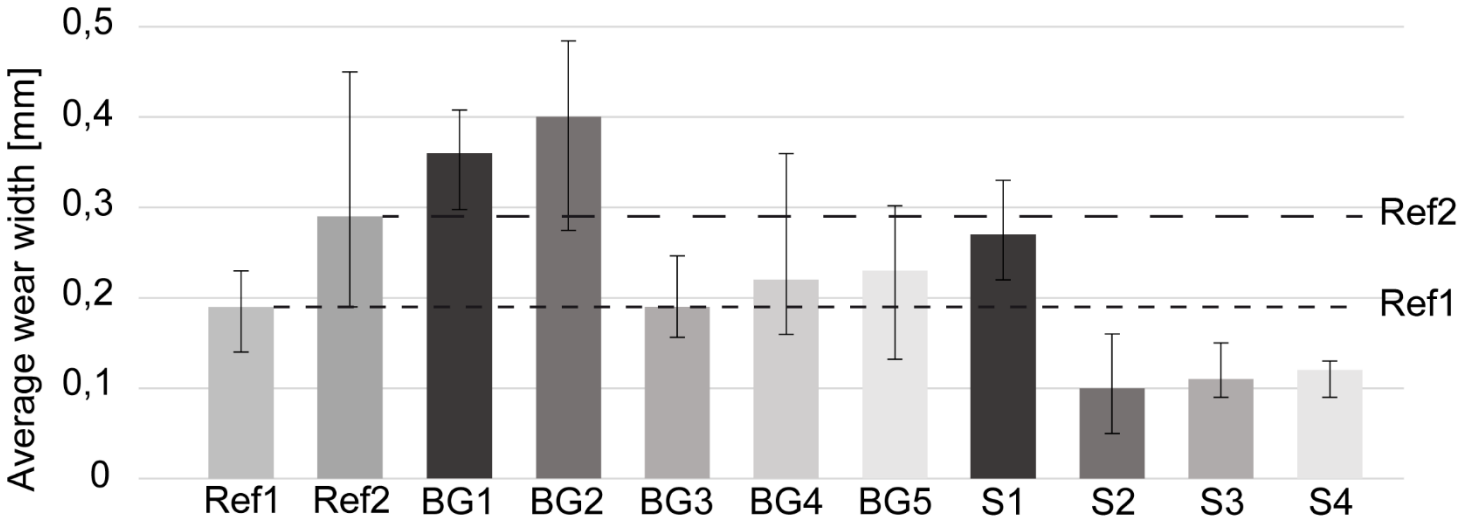
Wear of Elastomeric Lip Seals

- Wear widths vary strong around the circumference → asymmetric wear

→ Partly strong hardening of the sealing edge, thus wear stagnated

→ Hardening influences the sealing mechanism of an elastomeric lip seal

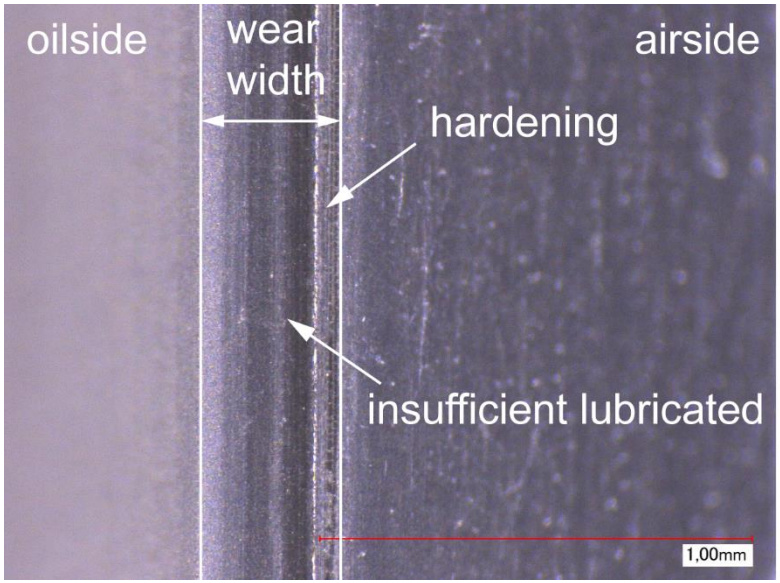
- Reference 2 caused increased wear due to microlead
- Due to leakage and therefore good lubrication, small wear widths with superfinished shaft counterfaces

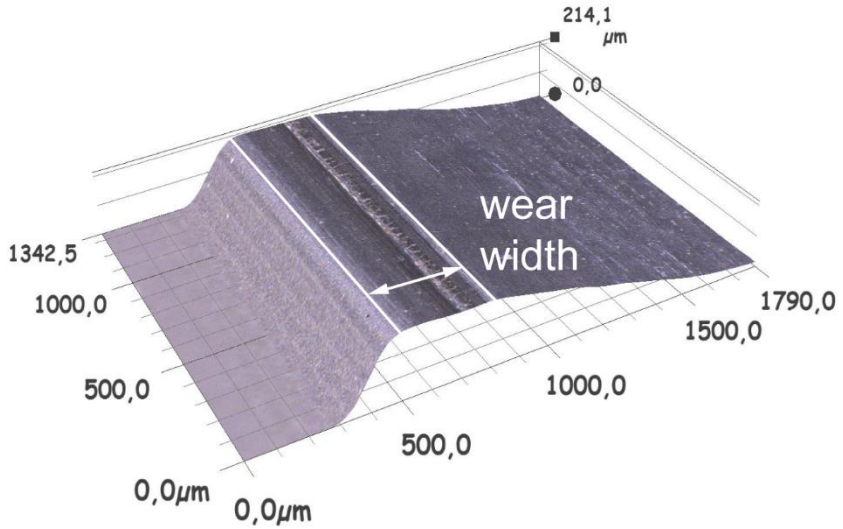


Wear of Elastomeric Lip Seals

Belt ground shaft counterfaces:

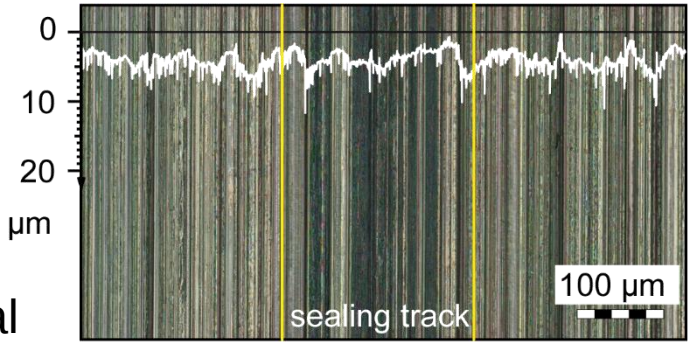
- Grooves in circumferential direction and axial cracks
- Slower increase of the wear widths due to hardening of the sealing edge
- Sections of different lubrication conditions





Wear of Shaft Counterface

BG 1



Belt ground shaft counterfaces:

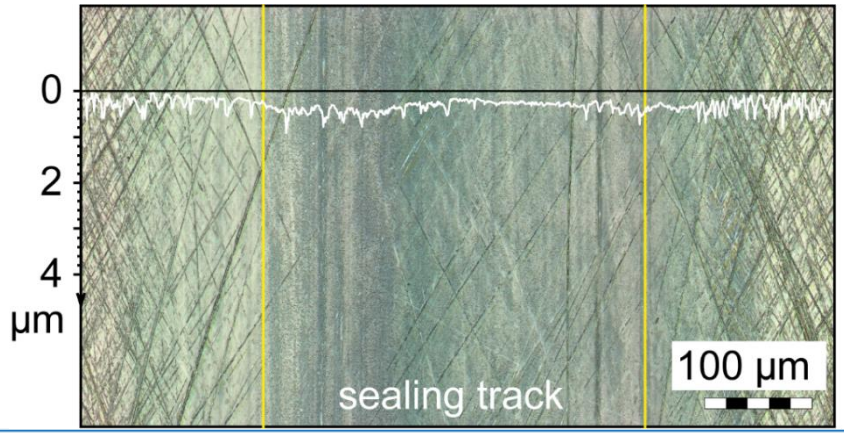
- Sealing track not measurable

Superfinished shaft counterfaces:

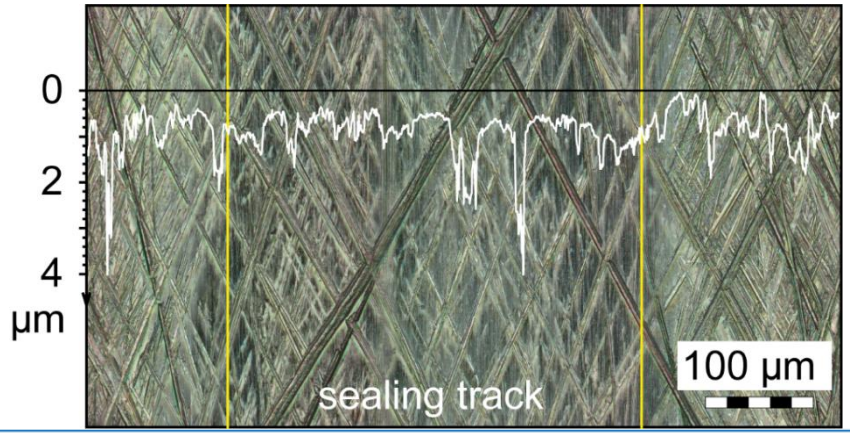
- Strong wear in the area of the elastomeric lip seal
- Rougher surface structures remain (S1), whereas fine surface structures are worn (S4)

→ Possible reason for the leakage behaviour

S 4 (fine surface structures)

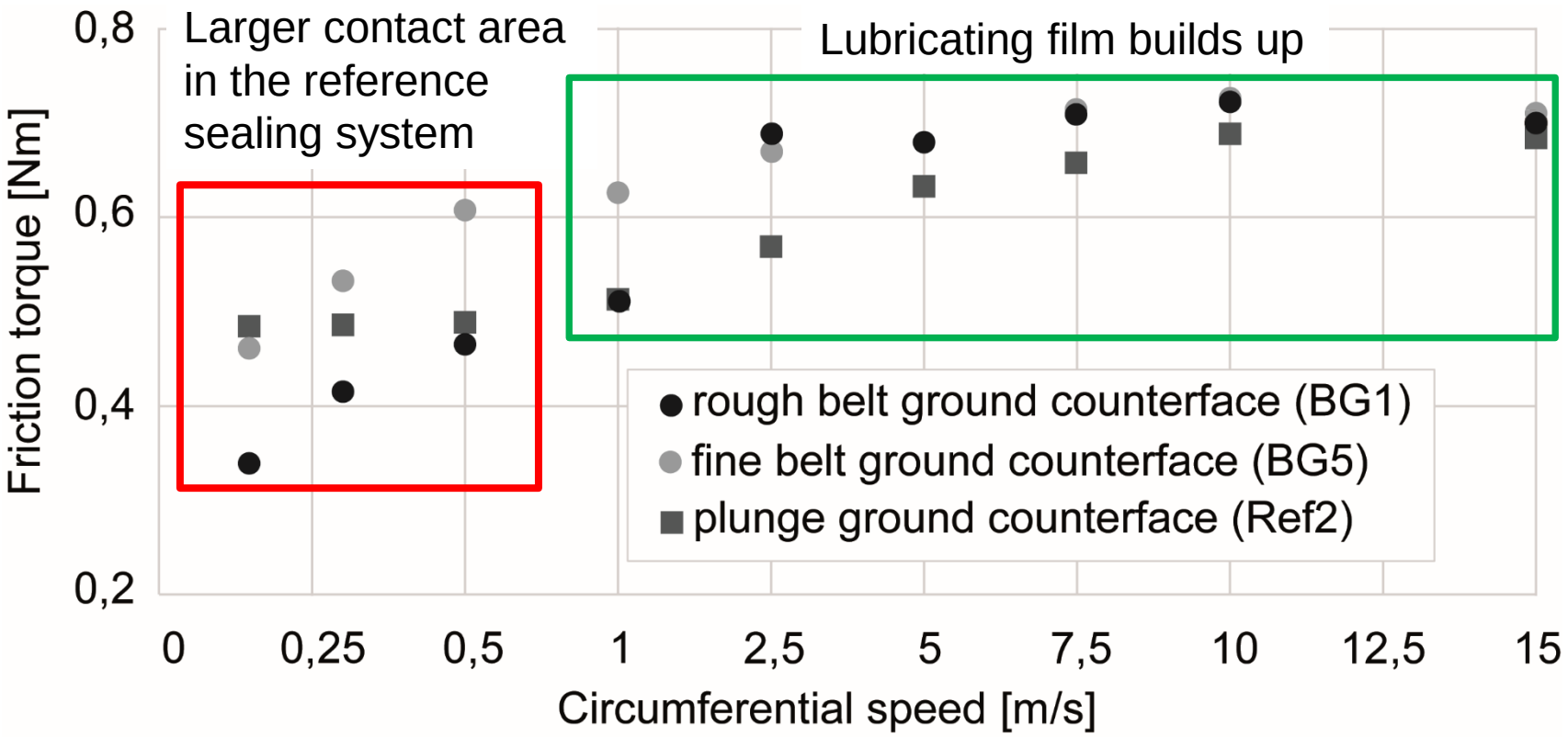


S 1 (rough surface structures)



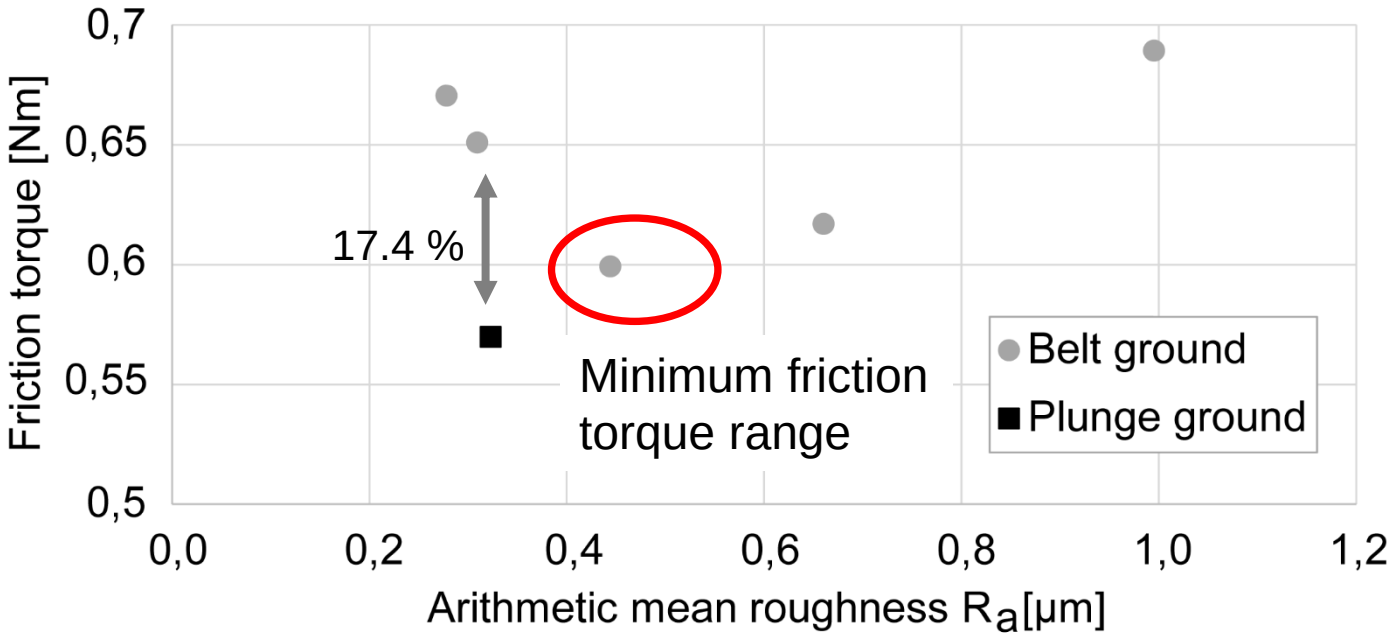
Friction Torque

- Mean values of the last five minutes of every rotational speed level



Friction Torque

- At comparable roughness (R_a about 0.3 µm):
  → Friction torque of the reference sealing system about 17.4 % smaller than with a belt ground shaft counterface



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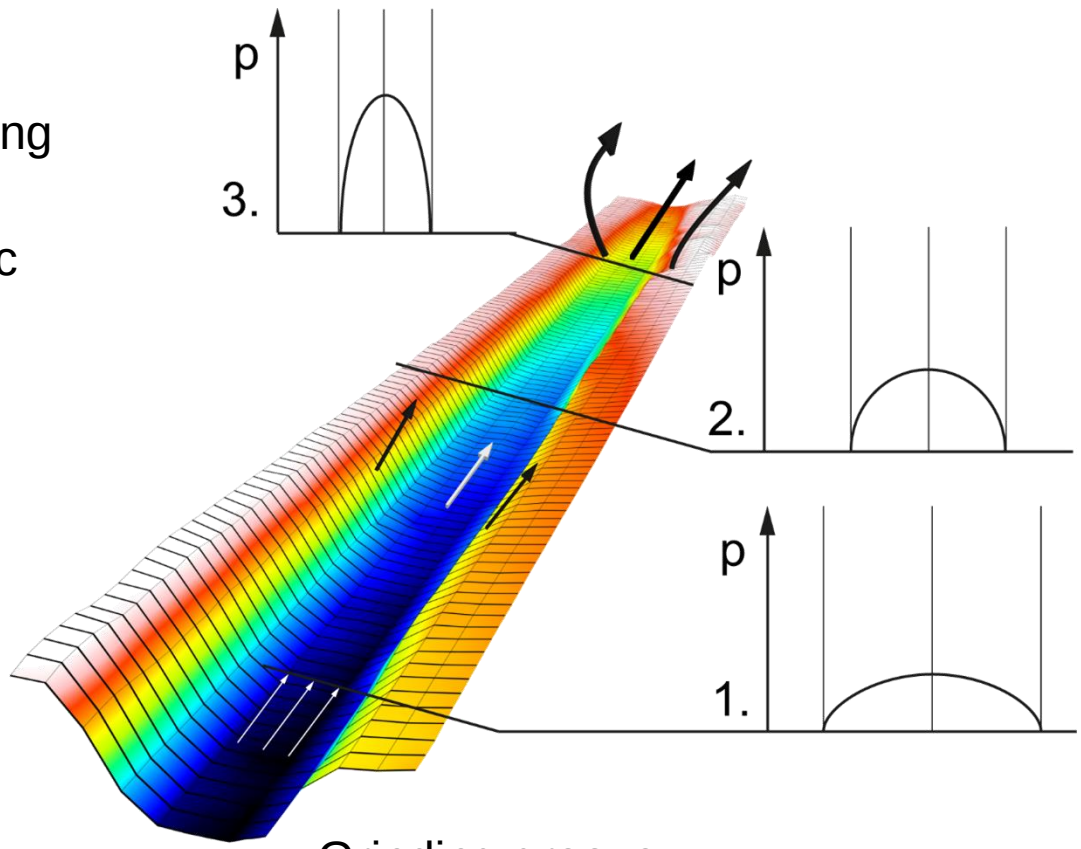
4 Summary & Conclusion

Summary & Conclusion

Reference: Plunge ground shaft counterfaces

- Many double convergent grooves = grooves with varriing depth and width
- This leads to a Hydrodynamic pressure built up
  - → Lubrication film lift off the sealing lip
  - → Well lubricated, low temperature and low wear
  - → Fluid exchange in the sealing gap and thus frictional heat dissipation



Grinding groove

Summary & Conclusion

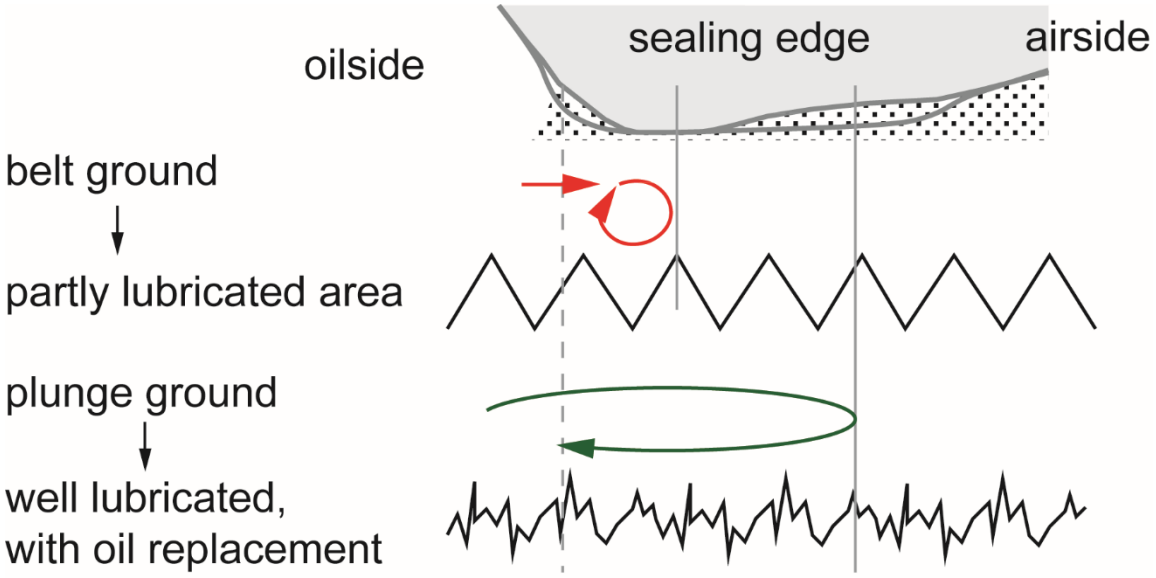
Belt ground shaft counterfaces:

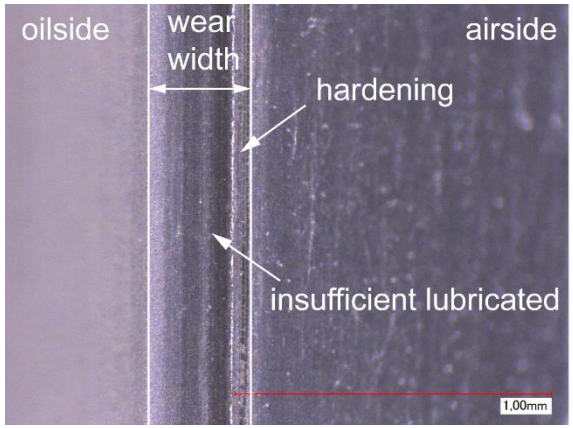
- Disturbed fluid exchange
  - → Insufficient lubrication
  - → Thermal damage

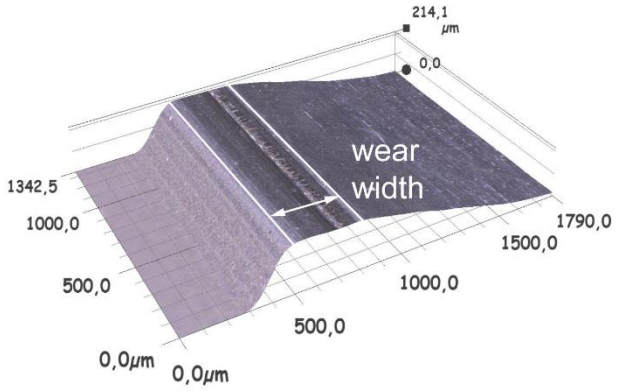
Superfinished shaft counterfaces:

- leakage

  → Reliable sealing with belt ground and superfinished shaft counterfaces not possible







Thank you for your attention!

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