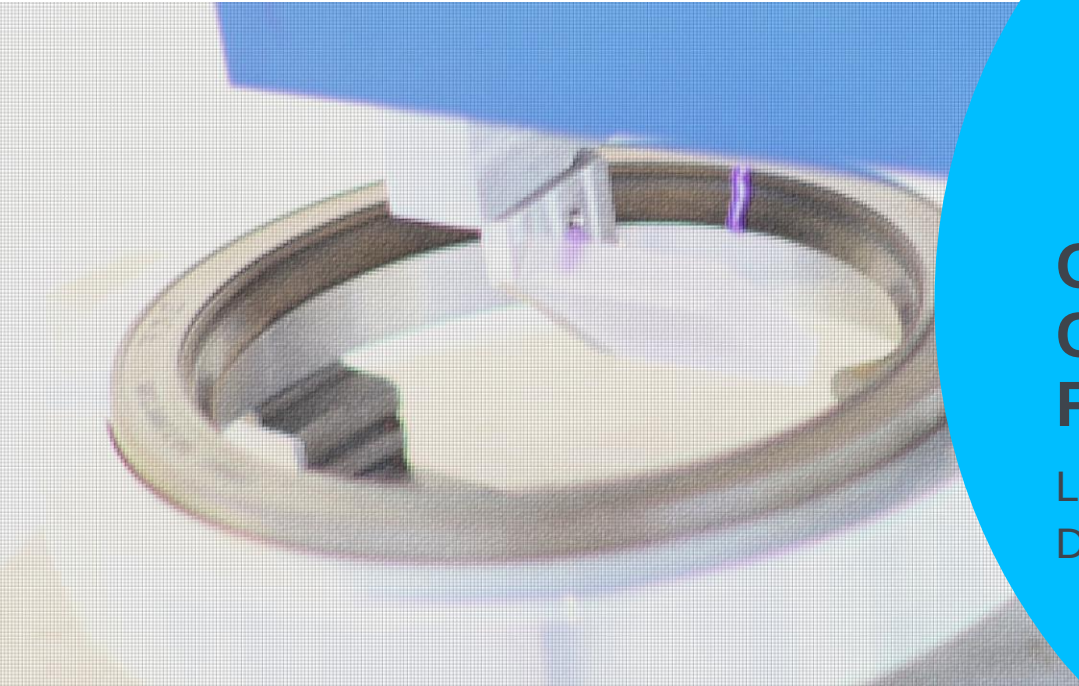


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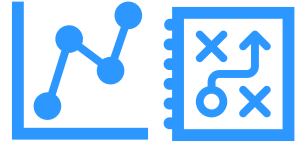


Oil Elastomer Compatibility Testing for Rotary Shaft Seals

Lubricant Expo – Essen, 2022
Dr.-Ing. Matthias Baumann

Motivation

“Why is oil elastomer compatibility testing for seals important?”



- The automotive industry is facing disruptive changes → *EV-Lubricants, high rotational speeds, etc.*
- Economic cycles to become sustainable → *Biogenic and Biodegradable Lubricants*
- We expect to see a variety of newly developed lubricants and, of course, the development will focus on tribological systems such as gears and bearings,

.... but rotary shaft seals are also highly loaded tribological systems!

- Failures of machinery and equipment often start with a seal failure. Newly developed lubricants can therefore only be successful on the market if they can also be sealed.
- Since we do not have reliable models to predict the function or the service life of seals up to now, we only can rely on experiments
- *Today I want to spread information about the basic function mechanisms of rotary shaft seals and how these are affected by oil-elastomer compatibility issues*

Agenda

- 1 Introduction
- 2 Rotary Shaft Seals - Basics and Function
- 3 Oil Elastomer Compatibility Testing
- 4 Conclusion

Agenda

1 Introduction

2 Rotary Shaft Seals - Basics and Function

3 Oil Elastomer Compatibility Testing

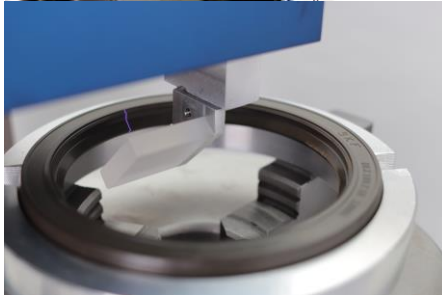
4 Conclusion

Introduction

Who are we?



University of Stuttgart
Institute of Machine Components
Department Sealing Technology



- Construction Technology Institute at University of Stuttgart, Campus Vaihingen
- Research Departments:
 - Sealing Technology
 - Reliability Engineering
 - Drive Technology
 - Rail Vehicle Technology
- We run a Seal Test Laboratory for rotary, translational and static seals with a variety of tools, measurement equipment
- We develop hard- and software for the specific test and analysis of rotary shaft seals

Agenda

1 Introduction

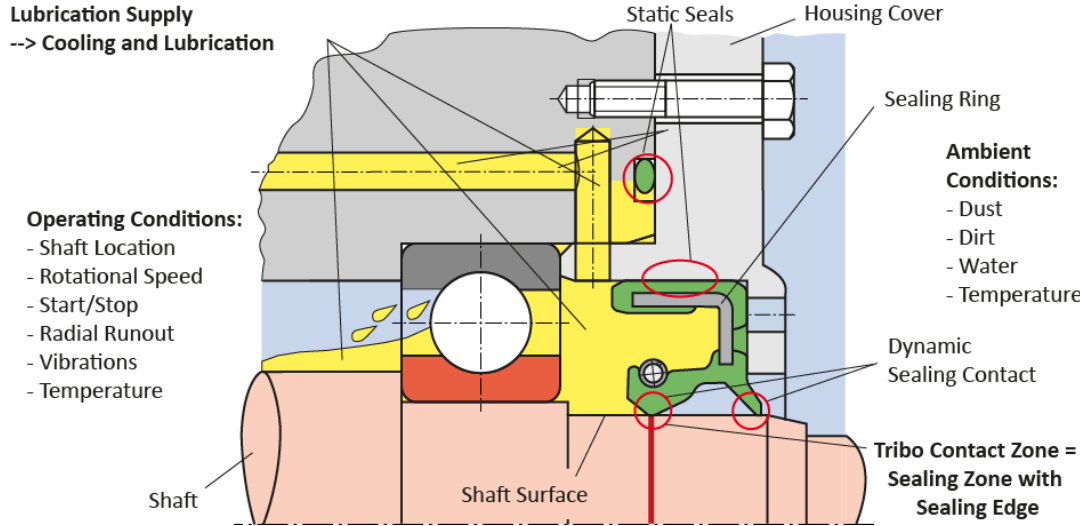
2 Rotary Shaft Seals - Basics and Function

3 Oil Elastomer Compatibility Testing

4 Conclusion

Rotary Shaft Seals – Basics and Function

Tribological Sealing System



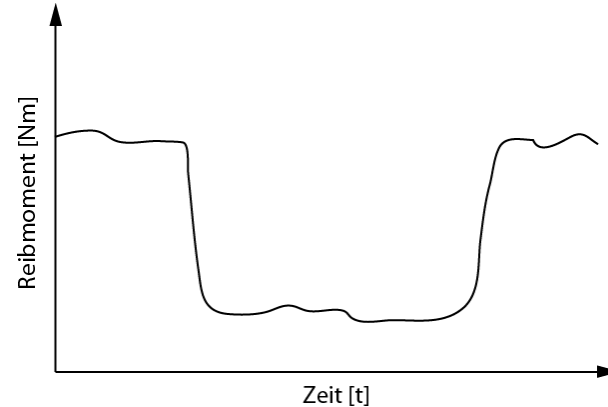
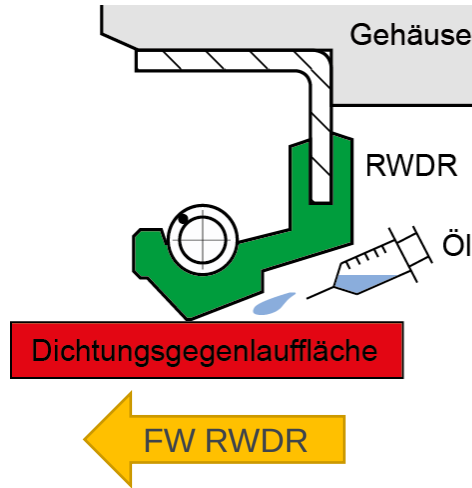
- A radial shaft seal forms a complex tribological system with a high number of interdependencies
- To date, there are no reliable calculation or simulation methods/models to predict the function of a radial shaft seal or its service life with certainty
- Therefore, we still have to rely heavily on empirical tests

Rotary Shaft Seals – Basics and Function

Active Sealing Mechanism – An observation



How does this work?

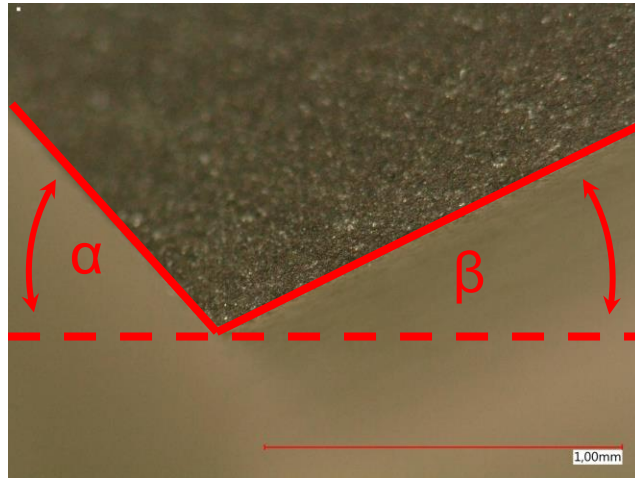


- Active pumping mechanism pumps oil from the air side to the oil side of the seal

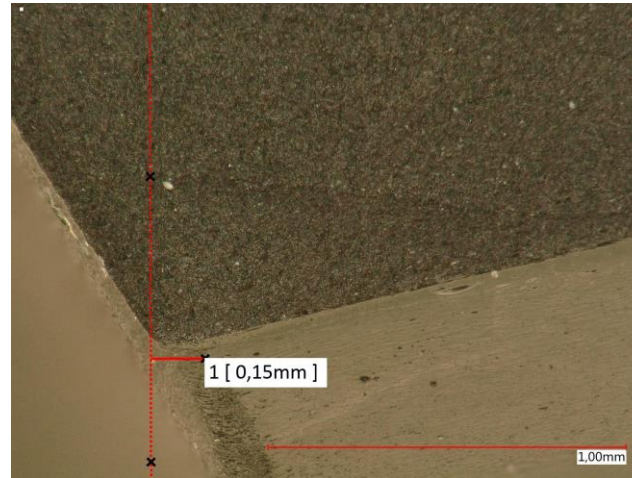
Rotary Shaft Seals – Basics and Function

Active Sealing Mechanism – An observation

Seal in new condition



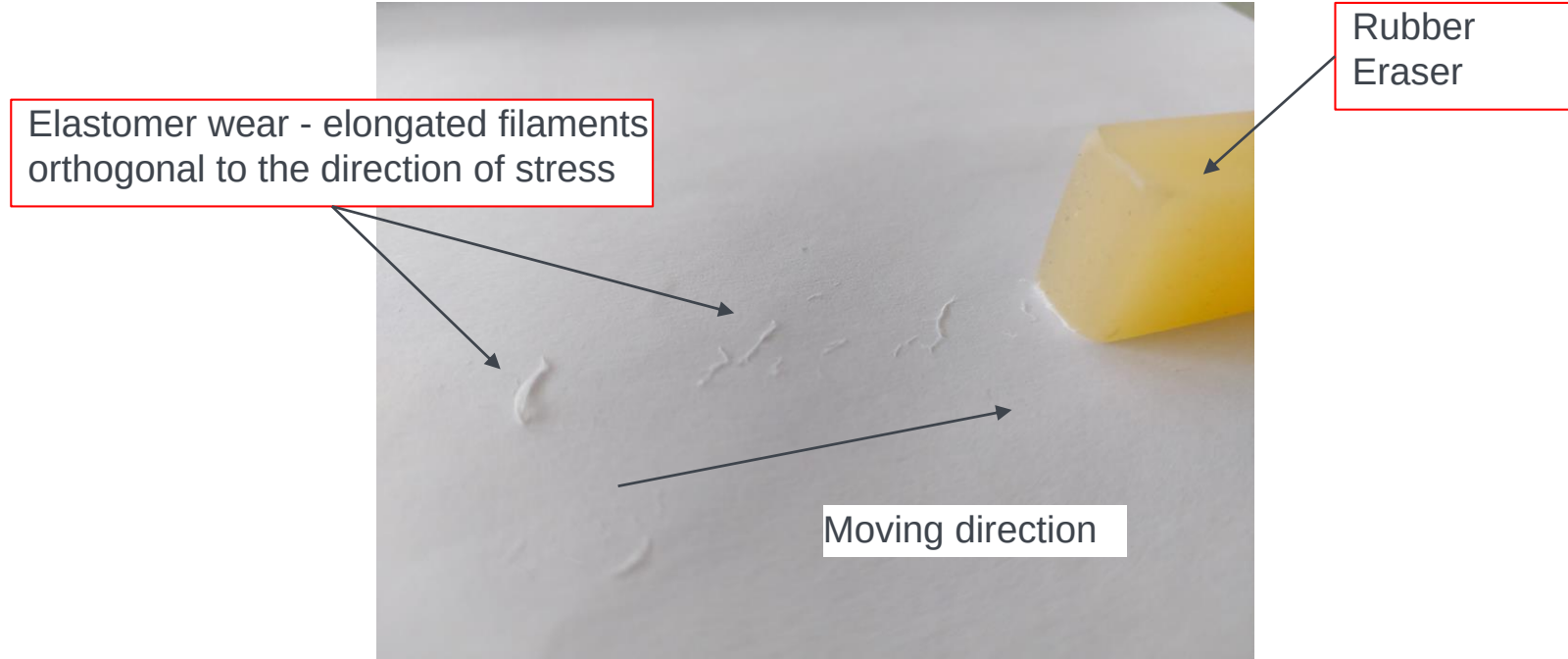
Seal after 48-hour running-in



- Wear structures on the sealing edge and different sealing edge angles are decisive for the sealing effect

Rotary Shaft Seals – Basics and Function

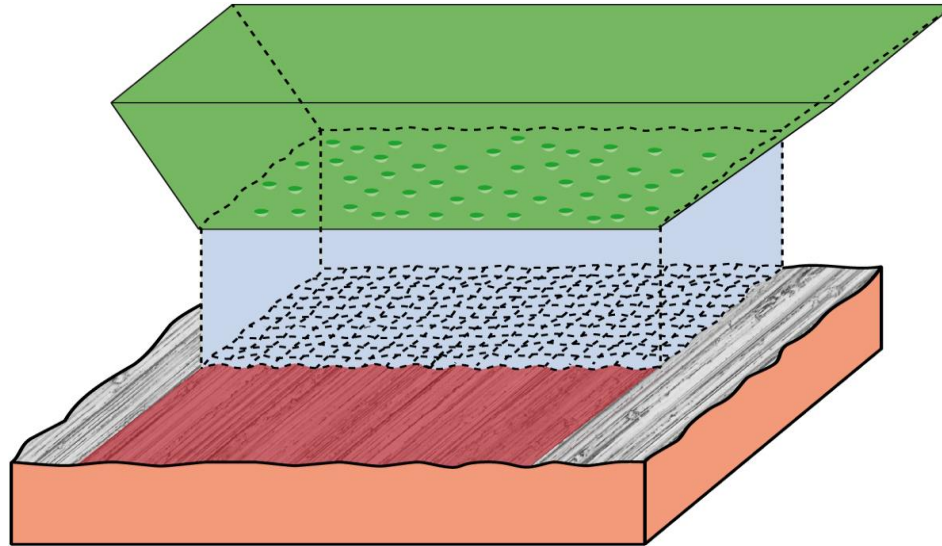
Rubber Experiment



Rotary Shaft Seals – Basics and Function

Distortion Principle

Fluid
Side

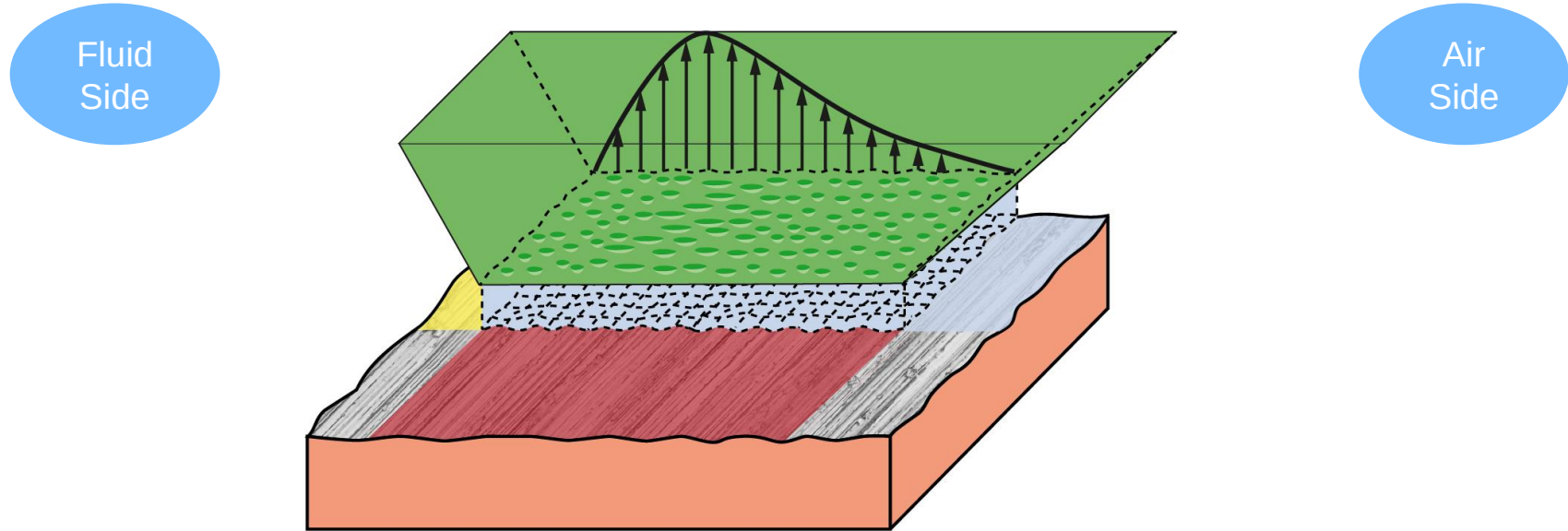


Air
Side

- Run-in sealing edge before assembly
- Roughness structures on the sealing edge

Rotary Shaft Seals – Basics and Function

Distortion Principle



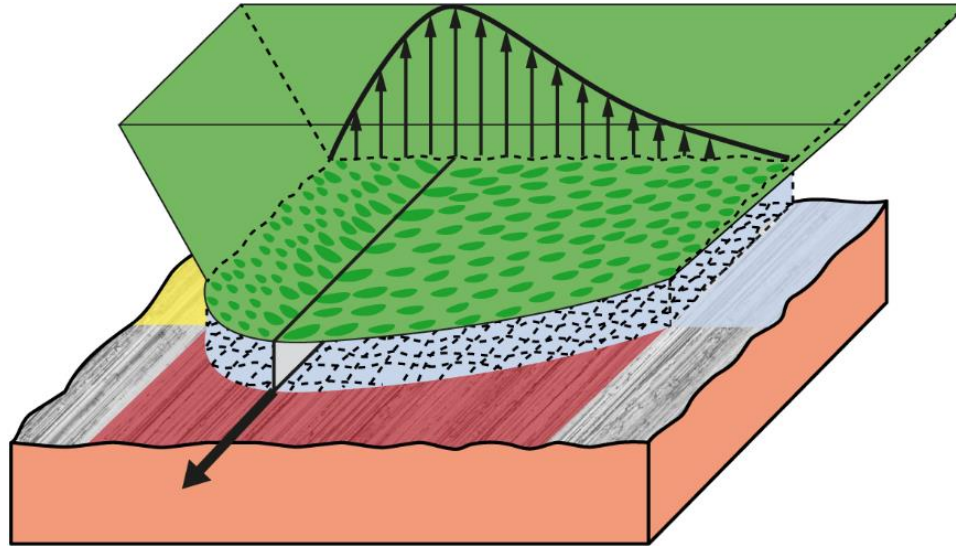
- Through contact with the shaft, the roughness hills are flattened more or less depending on the pressure distribution.

Rotary Shaft Seals – Basics and Function

Distortion Principle

Fluid
Side

Air
Side

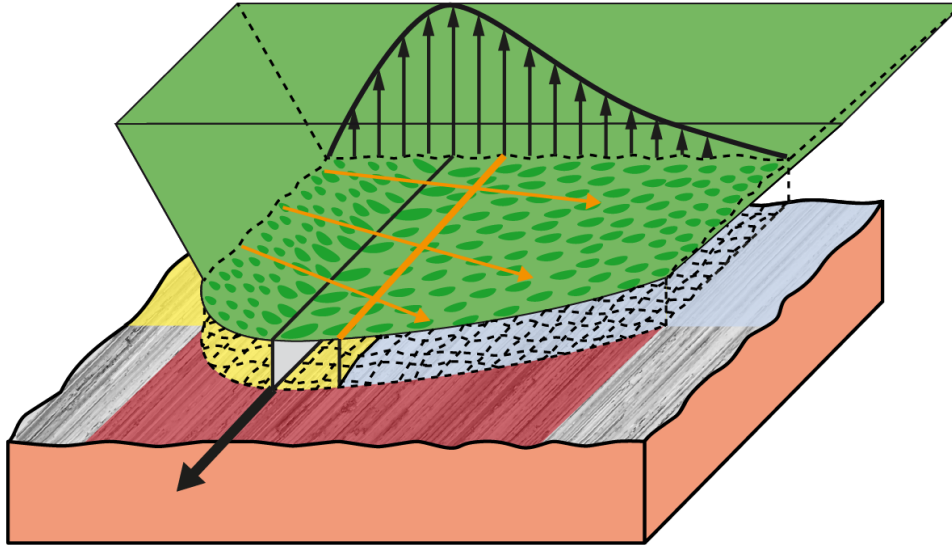


- When shaft rotates: roughness hills are distorted by tangential friction

Rotary Shaft Seals – Basics and Function

Distortion Principle

Fluid
Side



Air
Side

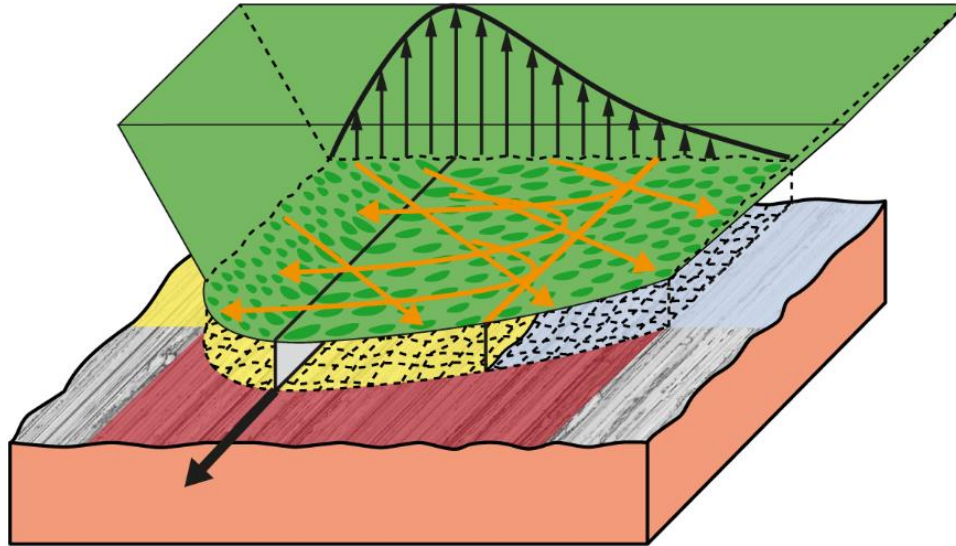
- The fluid is dragged along by the strongly distorted structures in the direction of the air side

Rotary Shaft Seals – Basics and Function

Distortion Principle

Fluid
Side

Air
Side



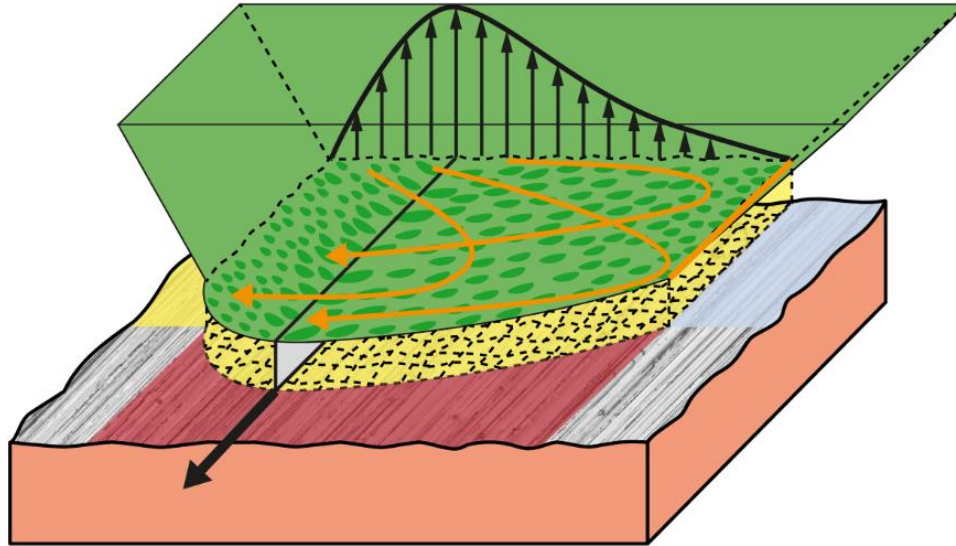
- The fluid flow is axially decelerated, deflected and pumped back by the airside structures

Rotary Shaft Seals – Basics and Function

Distortion Principle

Fluid
Side

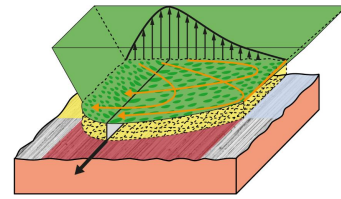
Air
Side



- Up to the limit of the sealing edge, the entire fluid flow is "collected" and pumped back

Rotary Shaft Seals – Basics and Function

Distortion Principle



- **Summary:**

- The sealing function of rotary shaft seals depends on the seal design and the material properties of the elastomers used
- An asymmetric pressure distribution leads to an asymmetric distortion and thus to a fluid pumping effect

- **Conclusion:**

- To remain functional, a sealing edge must remain soft and elastic and the pressure distribution must remain asymmetrical. Any impairment of these two properties will result in a loss of sealing ability.

Agenda

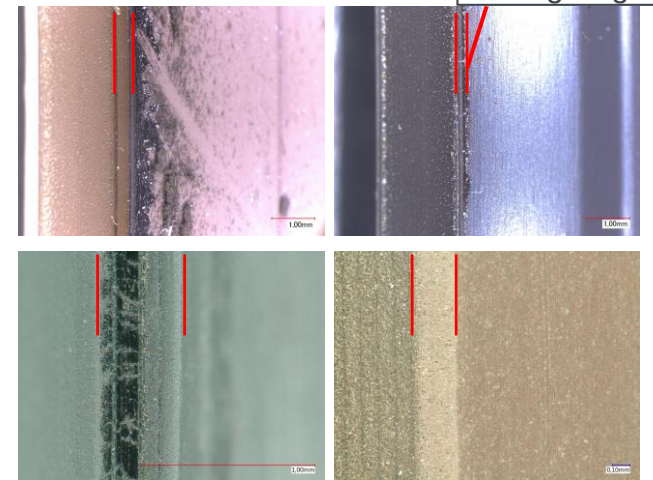
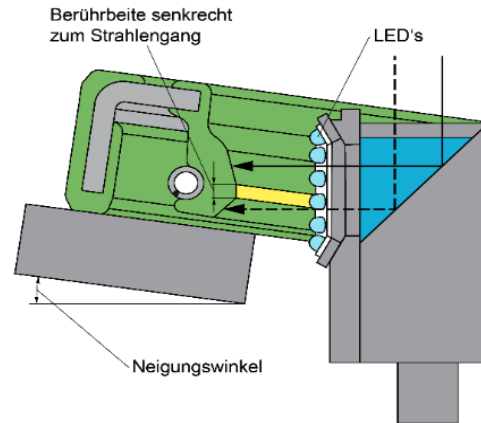
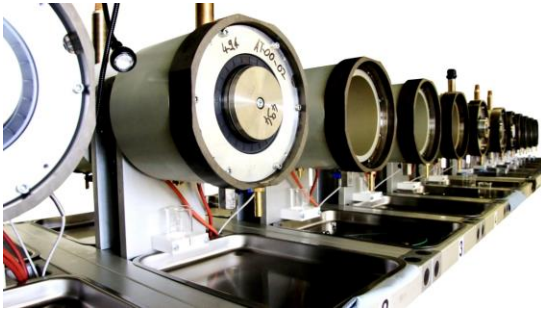
- 1 Introduction
- 2 Rotary Shaft Seals - Basics and Function
- 3 Oil Elastomer Compatibility Testing
- 4 Conclusion

Oil Elastomer Compatibility Testing

Basic Test Procedure

Focus of investigation:

- Functional behavior
 - Oil-Elastomer Compatibility
 - Lifetime Estimation
- Visual inspection with digital microscopy
 - A lot of Pictures
 - uncleaned / cleaned
 - damaged / not damaged

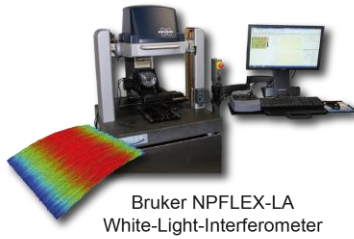


Test Run

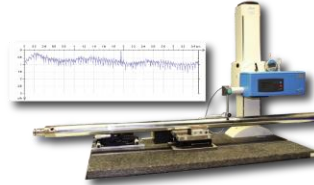
Analysis of Components

Evaluation

Oil Elastomer Compatibility Testing Analysis Equipment



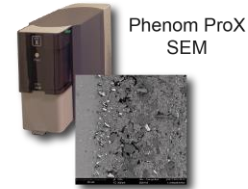
Bruker NPFLEX-LA
White-Light-Interferometer



Hommel T8000
Tactile Profilometer

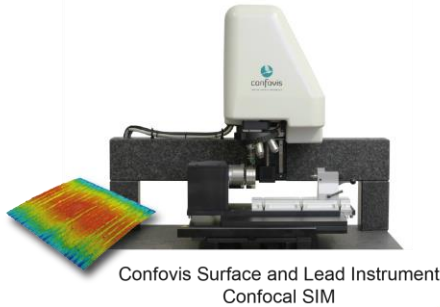


IMA-Sealscanner



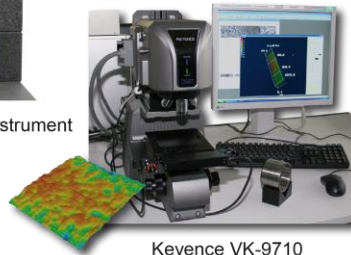
Phenom ProX
SEM

SEM-Image of an
Elastomeric-Sealing Edge



Confovis Surface and Lead Instrument
Confocal SIM

- 3D Characterisation of Surface Geometry
- Damage Analysis of Sealing Rings
- Roughness and Countour Measurement
- Wear Measurement



Keyence VK-9710
Laser-Scanning-Microscope



Keyence
VHX-1000
Digital-Microscope

Optical Analysis
of Sealing Edge



IMA-Sealobserver

Oil Elastomer Compatibility Testing

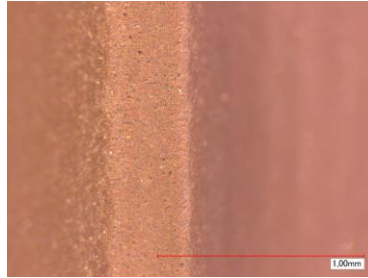
Image Categories

Uncleaned



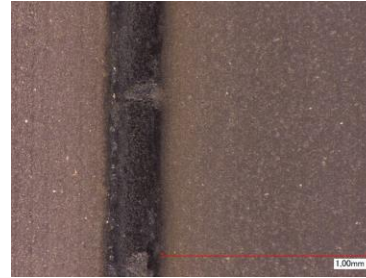
To estimate:
→ wear debris
→ oil carbon deposits

Undamaged



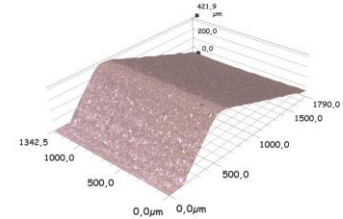
To estimate:
→ mechanical failure
→ chemical attack

Damaged



To estimate:
→ mechanical failure
→ thermal failure
→ chemical attack

3D-View



→ for visualization

Oil Elastomer Compatibility Testing

Matrix for the Advanced Rating of Seals (MARS)

 MARS Matrix for the Advanced Rating of Seals UNI STUTTGART				
Versuchs-Programm:	Schritt	1	20 h	120 °C
	Schritt	2	4 h	RT
	Schrittzahl	10	240 h	
Dauer				
Fluid-Bezeichnung:	Fuchs Titan Supersyn OW30			
-Fluidstand	Wellenmitte			
Dichtring-Bezeichnung	75 FKM 595			
-Innendurchmesser	85 mm			
Dichtring-Nr.		290		291
Prüfkammer Nr.		12-V6		12-H6
Wellen-Nr.		290		291
Drehrichtung		ccw		cw
Radialkraft:				
-Neuzustand	N	31,8		35,2
-Nach Versuch	N	28,2		30,9
-Änderung der Radialkraft	%	-11,4		-12,0
Dichtfunktion:				
-Gesamtleckage	g	0		0
-Erstleckage	h	0		0
-Maximaltemperatur Luftseite Dichtkante	°C	129,8		130,7
Visuelle Analyse der Dichtkante:				
-Verschleißbreite	mm	0,17 - 0,25		0,16 - 0,25
-Mechanische Schadensmechanismen				
Trockene Verschleißpartikel	0 → +++			
Asymmetrischer Verschleiß	0 → +++	+		+
Raue Verschleißoberfläche/ Ausbrüche	Ja/ Nein			
Riefen Umfangsrichtung in weicher Dichtkante	Ja/ Nein			
Hohlkehle auf der Luftseite der Dichtkante	Ja/ Nein			
-Mechano-thermische Schadensmechanismen				
Verfärbung der weichen Dichtkante	0 → +++			
Verhärtung der Dichtkante	Ja/ Nein			
Axiale Risse in der verhärteten Dichtkante	Ja/ Nein			
Riefen Umfangsrichtung in harter Dichtkante	Ja/ Nein			
-Ölkohlebildung				
Löslich	0 → +++			
Anhaftend	0 → +++	+		+
-Physio-chemische Schadensmechanismen				
Quellen	0 → +++			
Deformation	Ja/ Nein			
Risse in der weichen Dichtkante	Ja/ Nein			
Blasenbildung	Ja/ Nein			
Bewertungsvorschlag IMA		Ja/ Nein	Ja: Freigabe	
Legende:	0: Unverändert	+: Irrelevant	++: Grenzwertig	+++: Schadhaf
Änderung:	Nein: Unverändert			Ja: Schadhaf
Nicht ausgefüllt = 0/ Nein				

- Methodology for a reproducible and accurate evaluation of the sealing function within standardized test procedures
- 4 evaluation groups:
 - *Mechanical failure*
 - *Thermal failure*
 - *Oil carbon deposits*
 - *Chemical attack*
- Protocol with all relevant data and evaluation conclusion

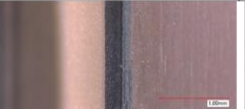
Oil Elastomer Compatibility Testing

Matrix for the Advanced Rating of Seals (MARS)

-Mechanische Schadensmechanismen			
Trockene Verschleißpartikel	0 → +++		
Asymmetrischer Verschleiß	0 → +++	+	+
Raue Verschleißoberfläche/ Ausbrüche	Ja/ Nein		
Riefen Umfangersrichtung in weicher Dichtkante	Ja/ Nein		
Hohlkehle auf der Luftseite der Dichtkante	Ja/ Nein		
-Mechano-thermische Schadensmechanismen			
Verfärbung der weichen Dichtkante	0 → +++		
Verhärtung der Dichtkante	Ja/ Nein		
Axiale Risse in der verhärteten Dichtkante	Ja/ Nein		
Riefen Umfangersrichtung in harter Dichtkante	Ja/ Nein		
-Ölkohlebildung			
Löslich	0 → +++		
Anhaftend	0 → +++	+	+
-Physio-chemische Schadensmechanismen			
Quellen	0 → +++		
Deformation	Ja/ Nein		
Risse in der weichen Dichtkante	Ja/ Nein		
Blasenbildung	Ja/ Nein		

-Thermal attack: Discolouring (soft elastomer)			
0	+	++	+++ (intolerable)
			

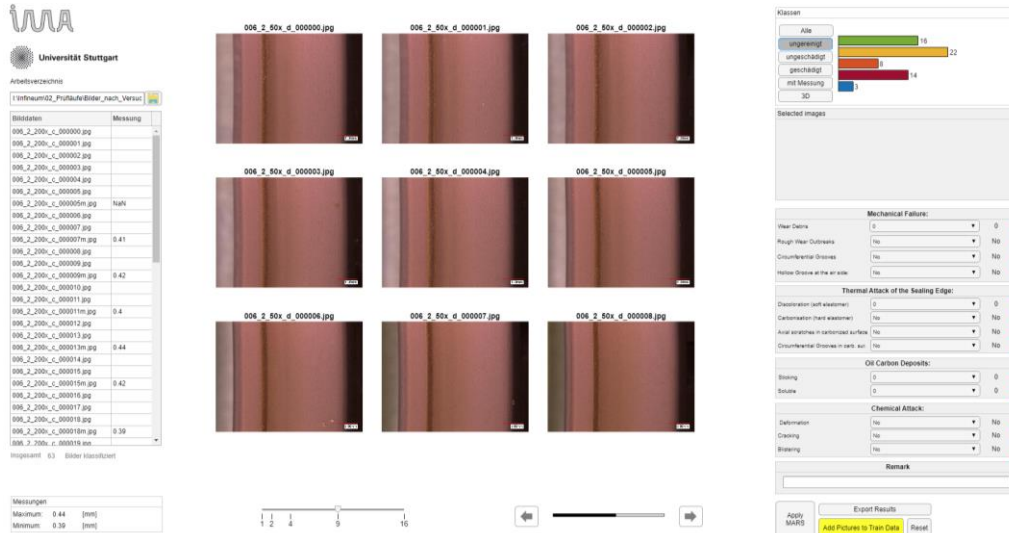
-Thermal attack: Oil carbon deposits: Soluble			
0	+	++	+++ (intolerable)
			

-Thermal attack: Oil carbon deposits: Sticking			
0	+	++	+++ (intolerable)
			



Oil Elastomer Compatibility Testing

Software Supported Rating



- Implementation of an AI support software to assist raters with data handling, data presentation and export of results
- Intuitive handling and presentation of relevant images
- Automatic protocol generation
- Focus on:
Help the rater to get an overview of the large amount of image data and still focus on small details



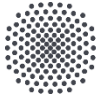
Introduction led to an increase in efficiency of rater meetings, after a learning phase a time saving of approx. 50% and a standardization of the results over e.g. repeated tests and over different users.

Agenda

- 1 Introduction
 - 2 Rotary Shaft Seals - Basics and Function
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-

Conclusion

- Oil Elastomer Compatibility is important for reliable products
- New developed lubricants need to be compatible with sealing materials
- Up to now, there are no predictive models for the suitability of lubricants for sealing, so that we only can rely on testing
- Sealing function of rotary shaft seals bases on the material properties of the elastomers used, an impairment of the material properties at the seal edge lead to seal failure
- Oil-elastomer compatibility tests must be performed with care and must methodically consider damage mechanisms specific to seals and elastomer materials



University of Stuttgart



Thank you!



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