



Attempts for Real Time Sensing in Tribo Contacts - Ways to Digital Tribology

MENSUS Session

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Agenda

1 Motivation

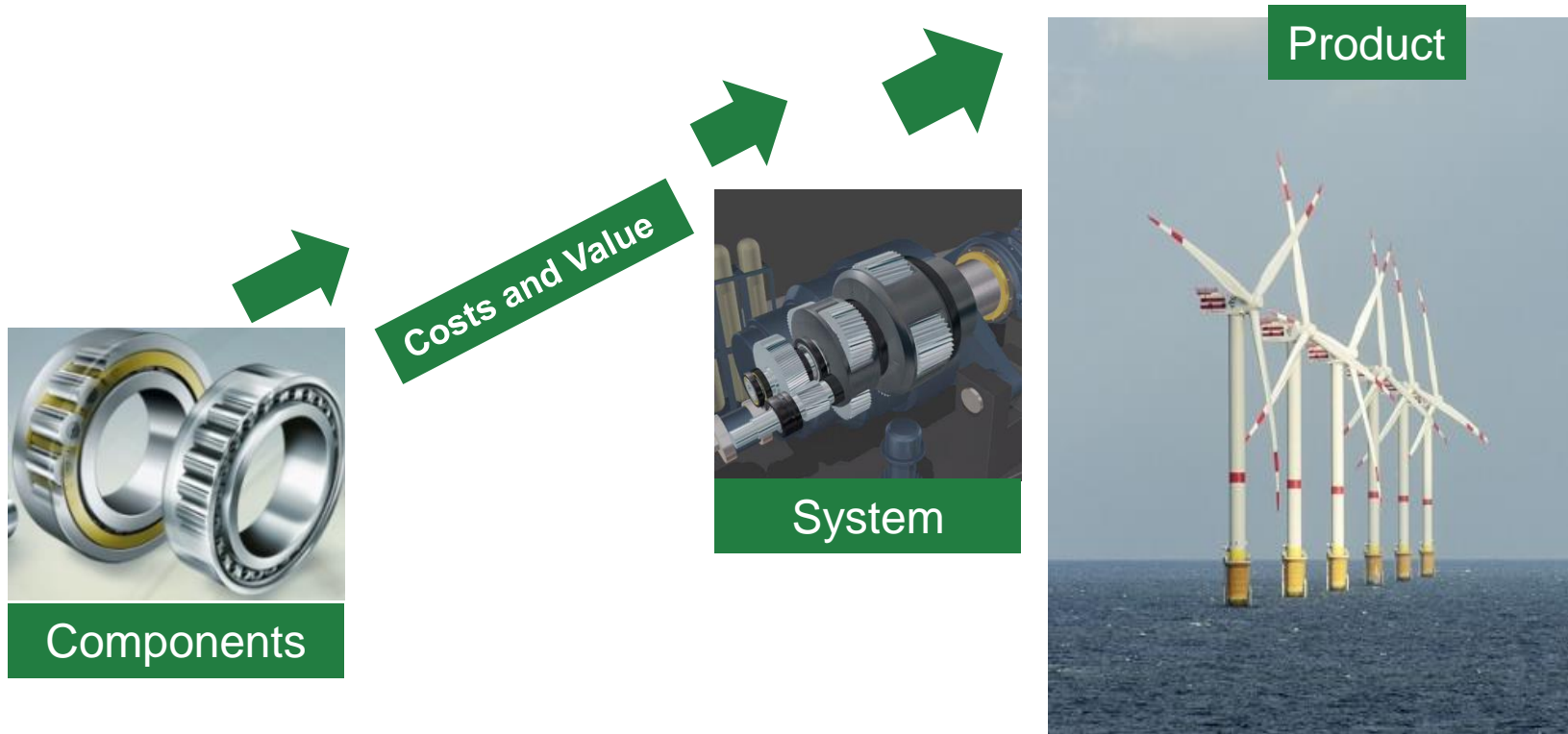
2 Mechanical Sensors –Sensotect®

3 „In Situ“ Chemical Sensors for Life assessment -Principles

4 In Situ“ Chemical Sensors for Life assessment -Results

Summary

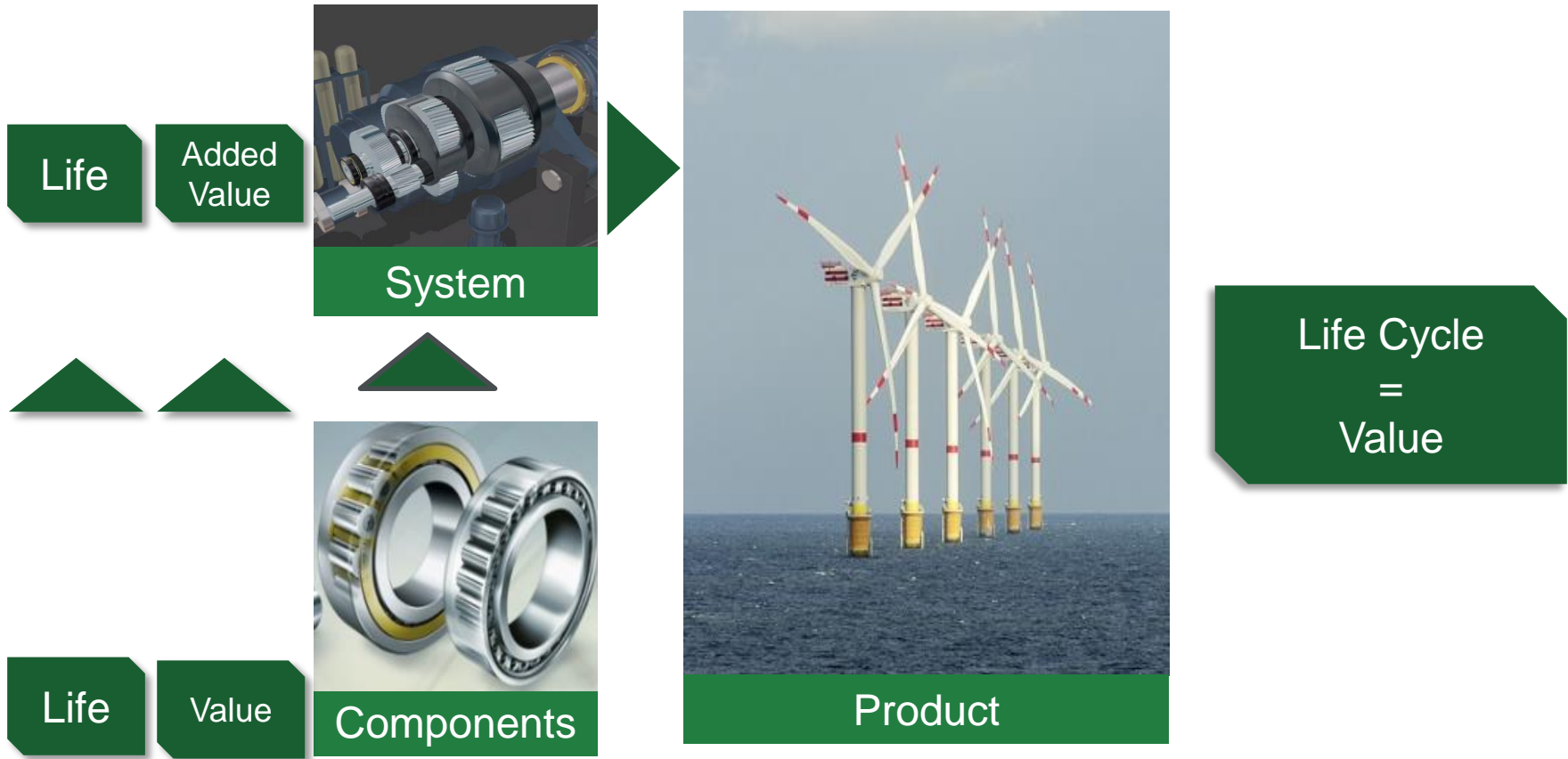
Motivation



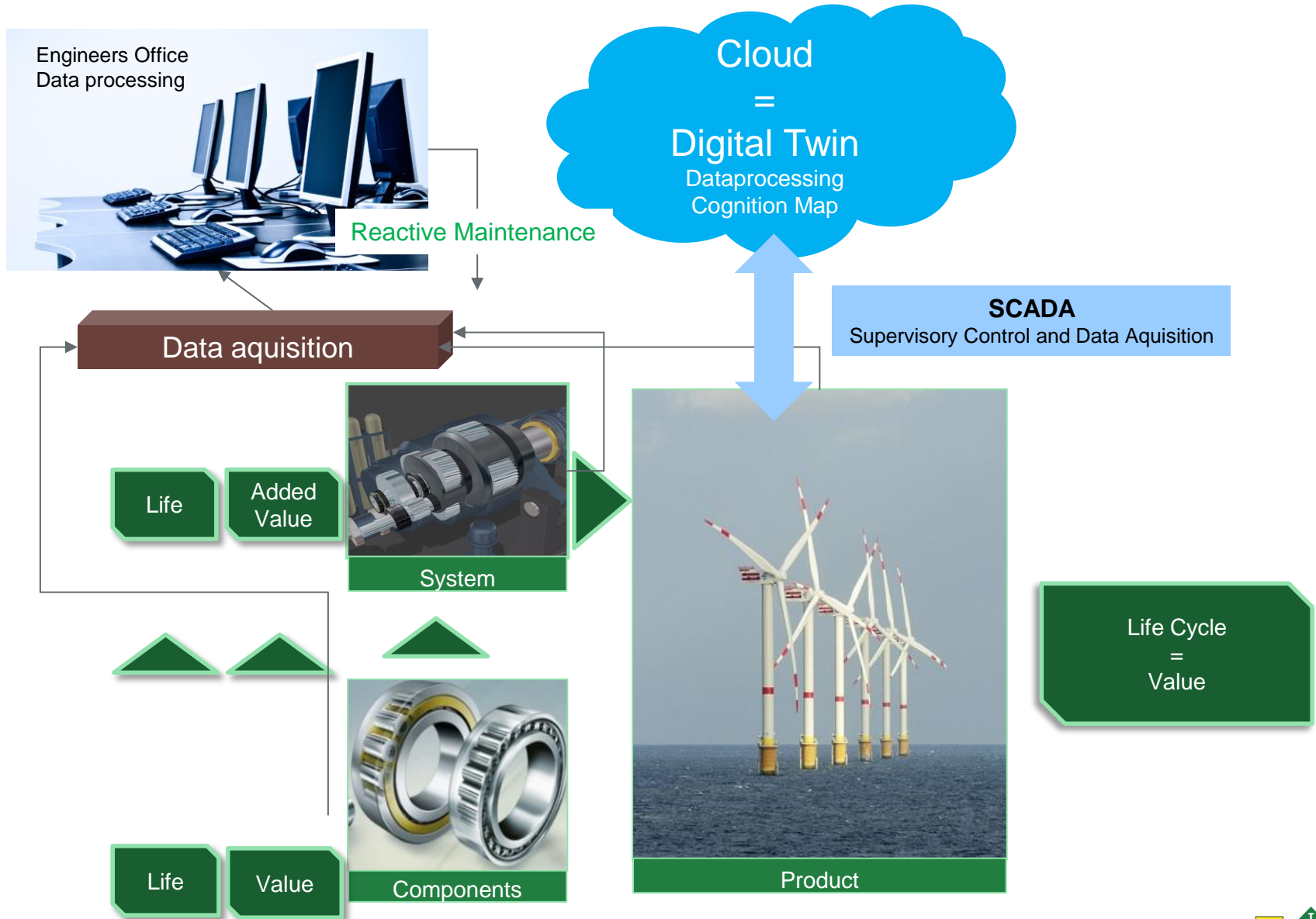
Components add to the System – Life Cycle of the System creates the entire Value

Motivation

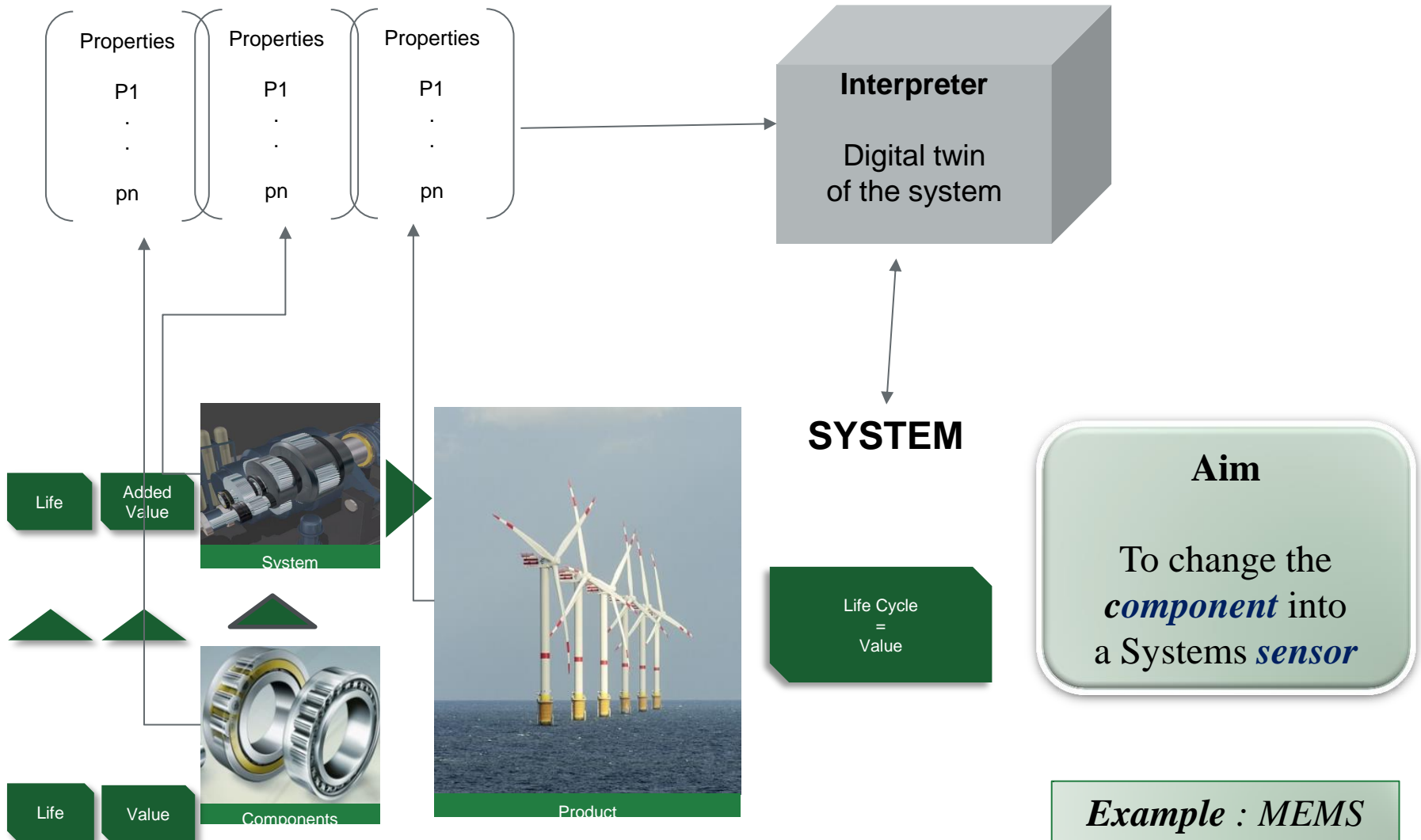
Components add to the System – Life Cycle of the System creates the entire Value



Motivation



Motivation



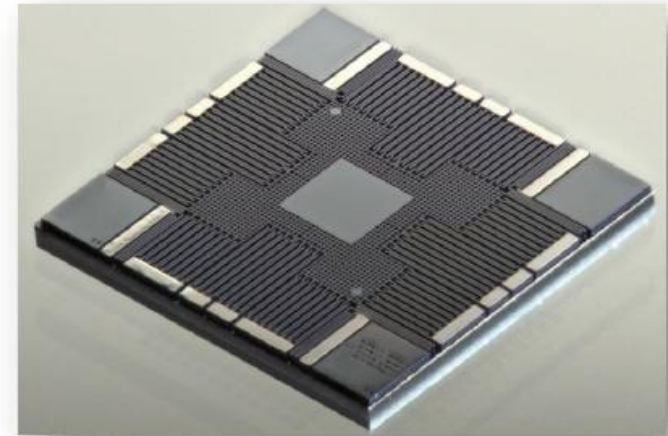
Motivation

Success strategy of microelectronics ...

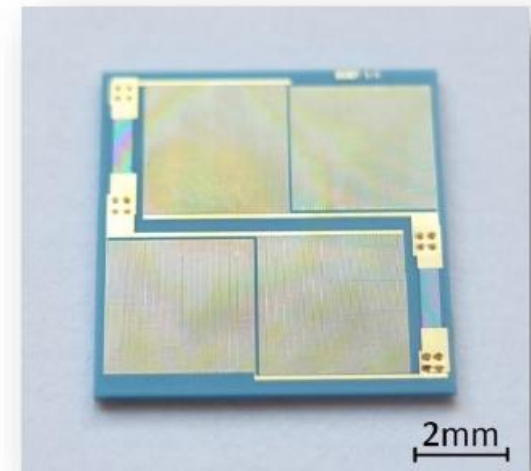
efficiency, miniaturization, integration,
parallelization, functional blocks

... transferred to other technical domains as
disciplines of microsystems technology:

- Classical microsystems technology and micromechanics („MEMS“)
- Microsensor and microactuator technology
- Microoptic („MOEMS“)
- Microfluidics (digital microfluidics, lab-on-a-chip)
- Biology microsystems technology („Bio-MEMS“)
- Technology development
- etc.

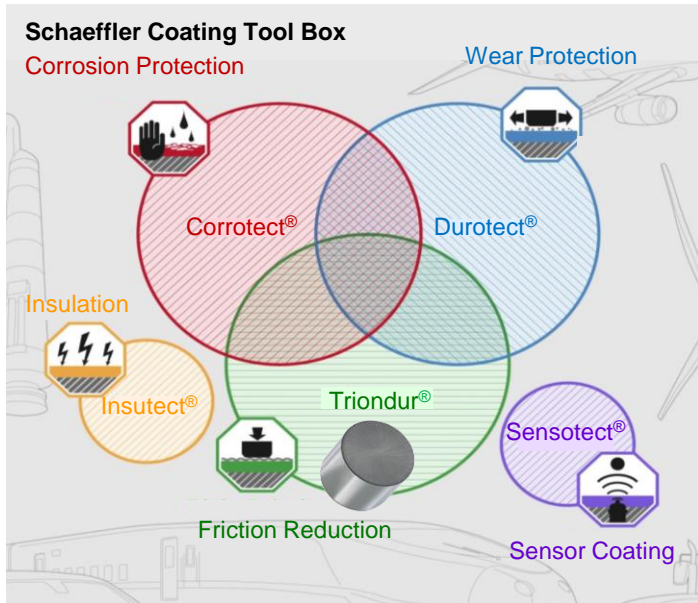


Biaxial positioning stage



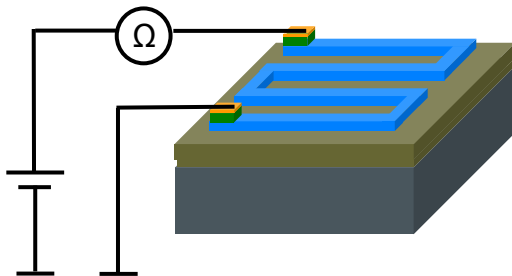
Goj et al. 2014:
Temperature and humidity sensor

Mechanical Sensors – Sensotect®



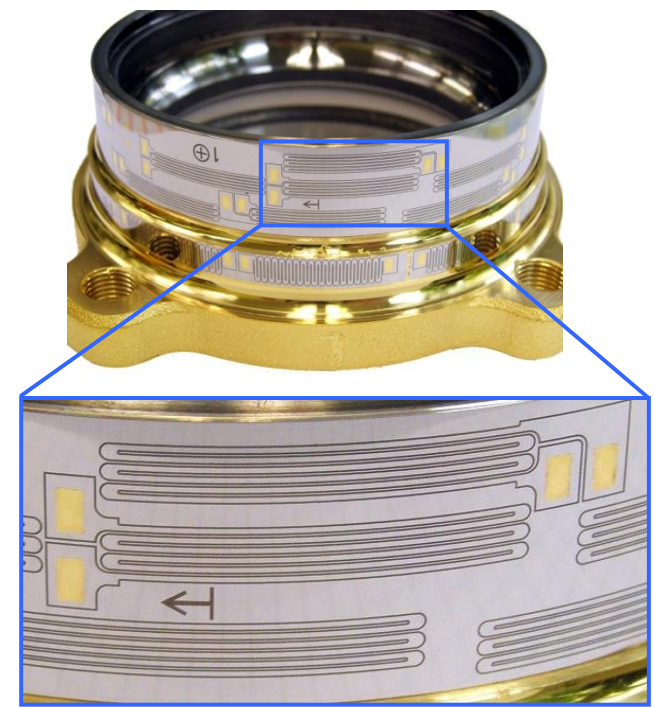
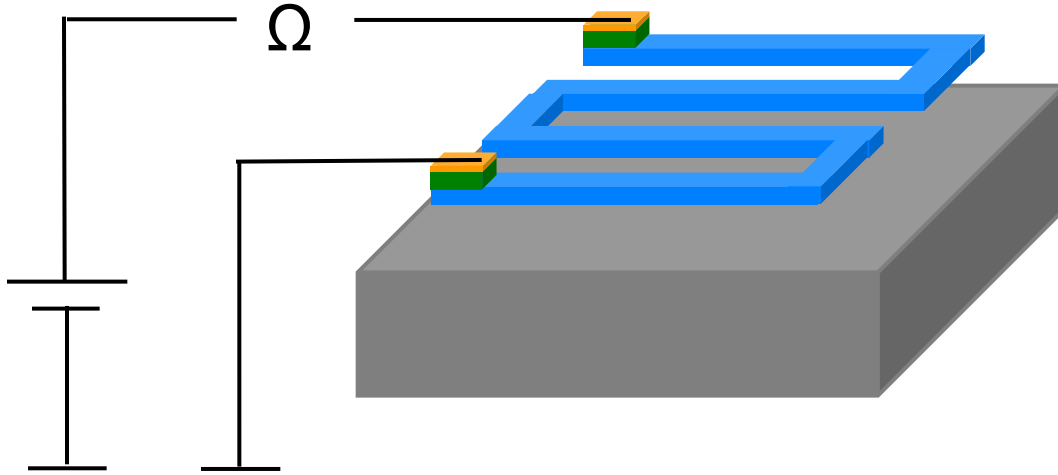
Advantage Sensotect®:

- Directly coated Sensor Layer.
- No adhesives.
- No transfer polymers.
- High strain sensitivity.
- No aging drift.
- No temperature creeping.



The Component acts as Sensor

Mechanical Sensors – Sensotect®



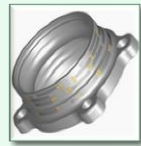
- For strain measurement, a strain sensitive alloy is deposited by advanced PVD (Physical-Vapour-Deposition) technique.
- These structures allow the calculation of the local stress condition, even if they are applied outside of the tribological contact.

Mechanical Sensors –Sensotect®

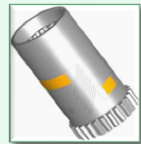
Thrust Bearing
Industrial



Steering shaft
Automotive



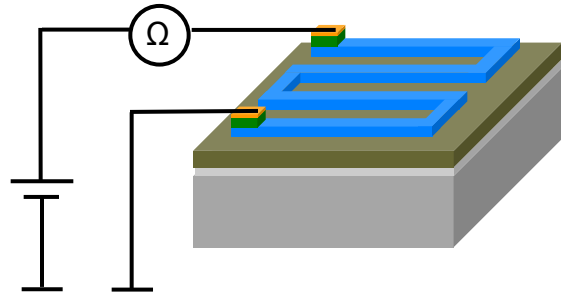
Wheel bearing
Automotive



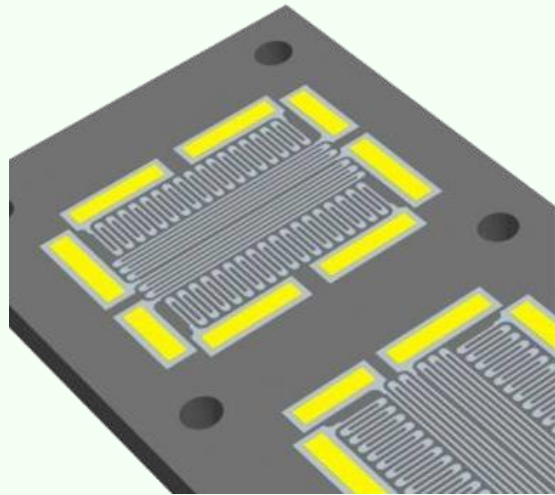
Bicycle
Bottom bracket
Consumer Products

- Application of strain gauges is independent from substrate geometry.
- 3D- as well 2D-applications are state-of-the-art.

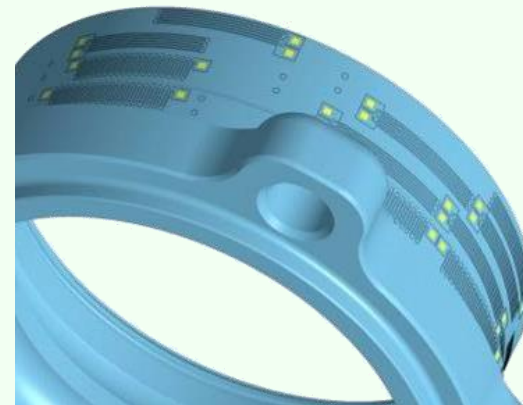
Mechanical Sensors – Sensotect®



2D-Samples



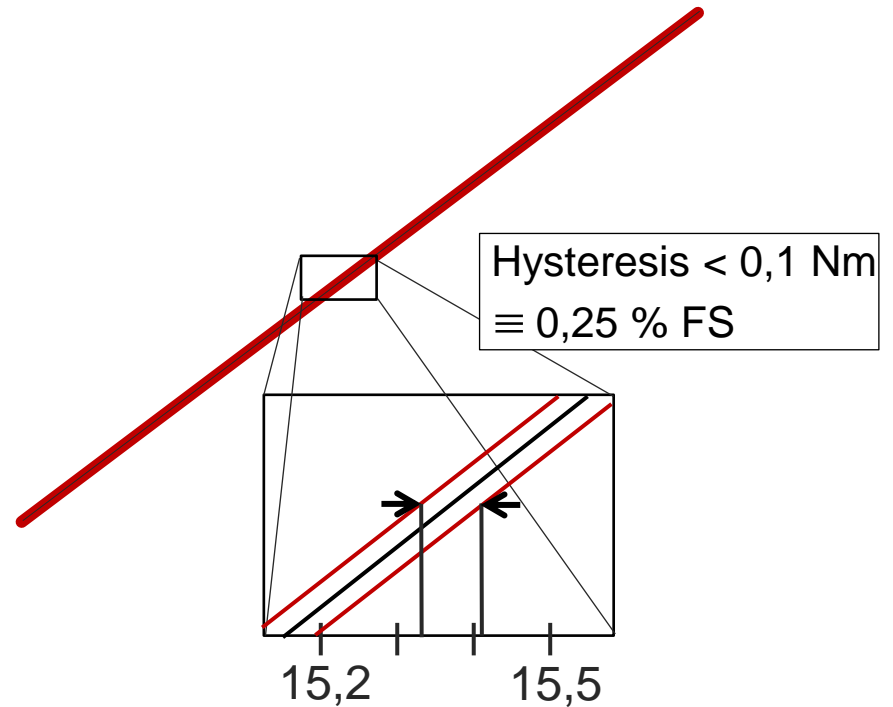
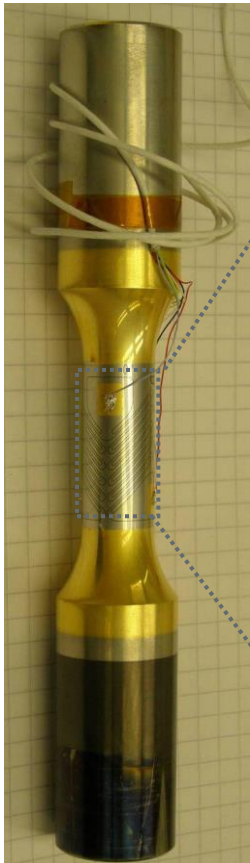
3D-Bearing



- Application of strain gauges is independent from substrate geometry.
- 3D- as well 2D-applications are state-of-the-art.

Mechanical Sensors – Sensotect®

Torque Measuring Steering Shaft

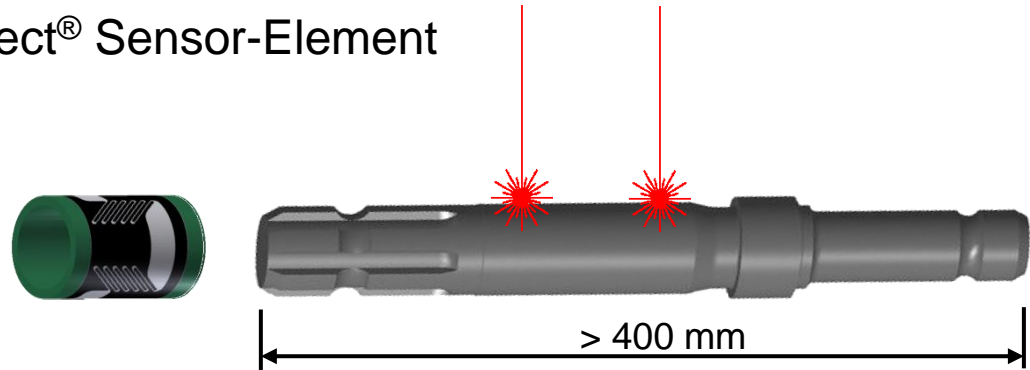
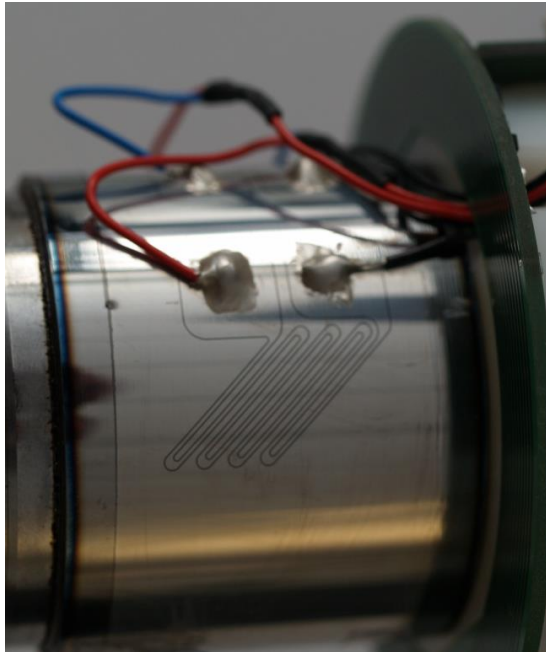


- High Sensitivity.
- Excellent Linearity und low Hysteresis Deviation.

Mechanical Sensors – Sensotect®

Sensor Sleeves for Long Shafts

Sensotect® Sensor-Element



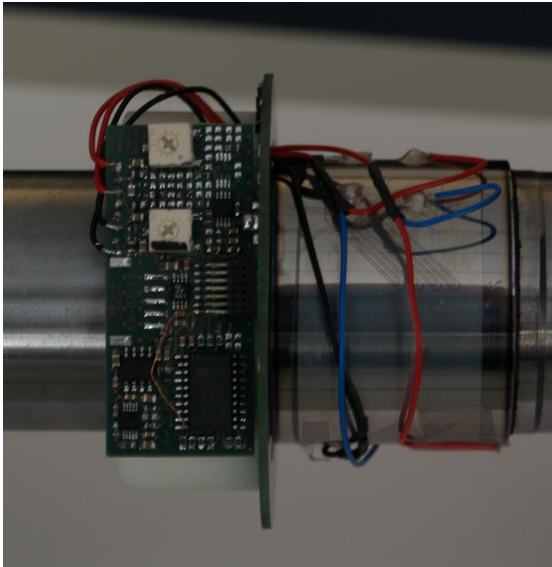
Benefits of Sensotect® Sensor Element:

- Modular, standardized design.
- High output and low geometry-related risk.
- Low unit costs due to low component size.

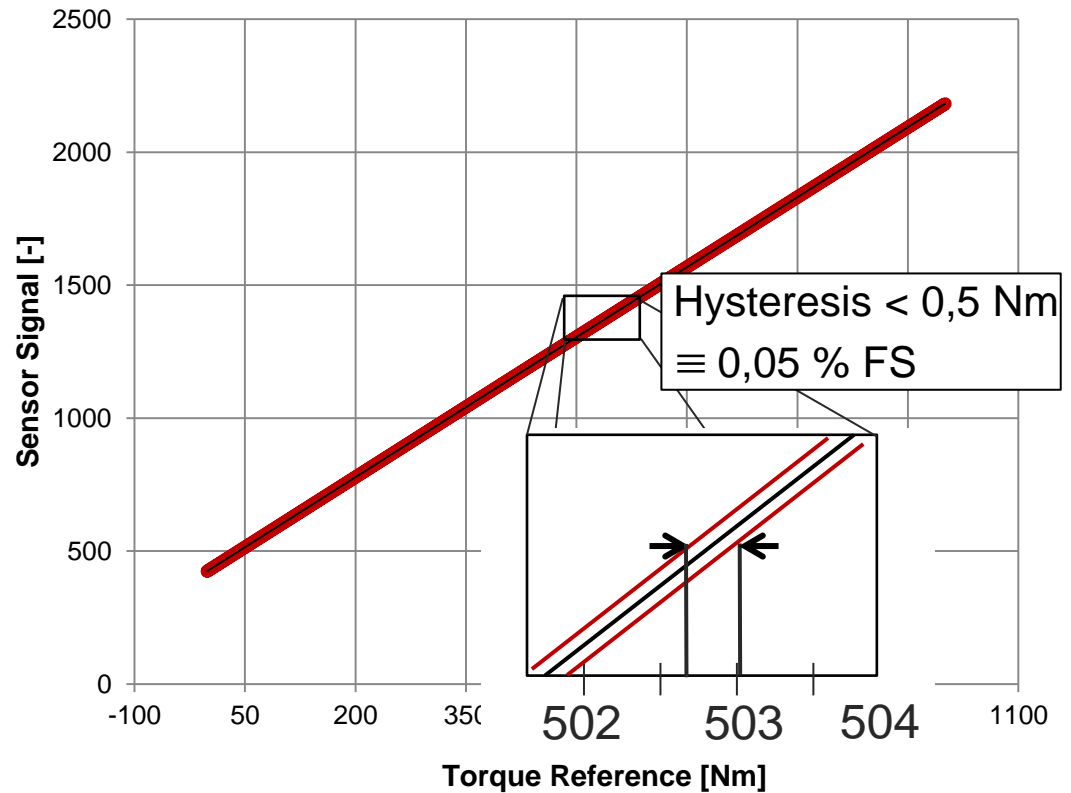
• Cost Reduction by coating small Sensotect® Sensor Elements.

Mechanical Sensors – Sensotect®

Sensor Sleeves for Long Shafts

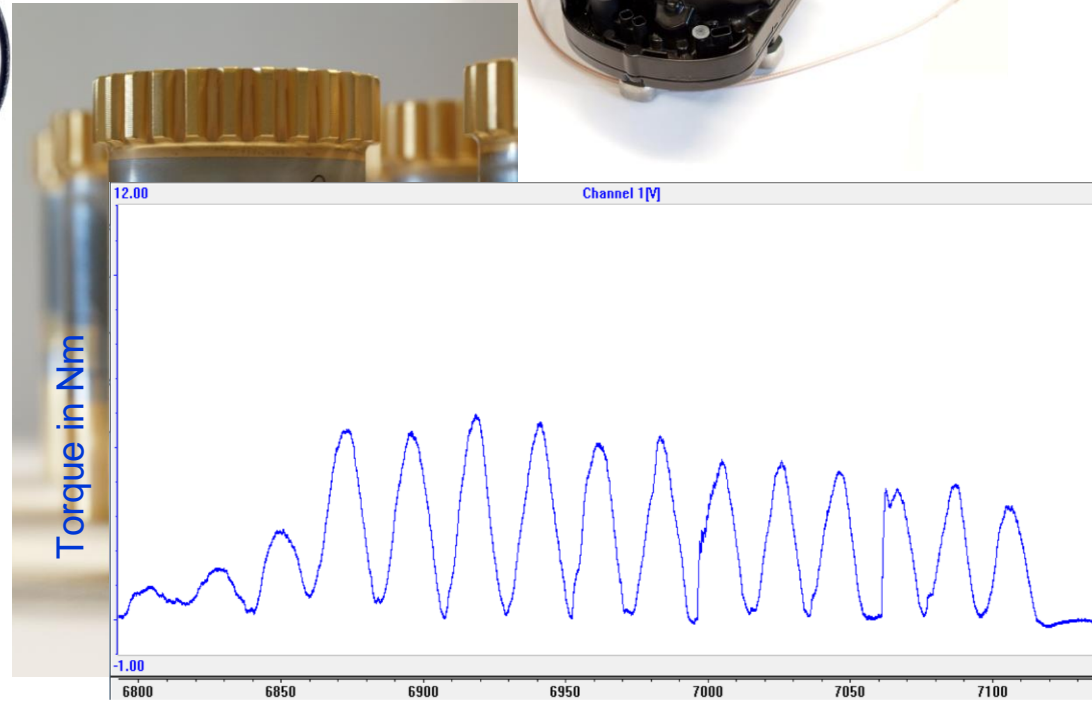


Sensotect® Sensor-Element with wireless Data Transmission.



Mechanical Sensors – Sensotect®

Online Torque-Measurement



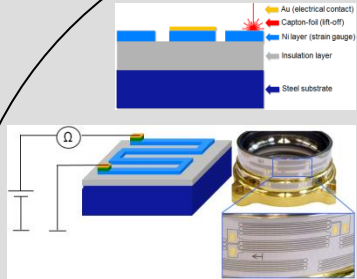
Time in sec.

Mechanical Sensors –Sensotect®

Sensotect® :

Sensor Coating System:

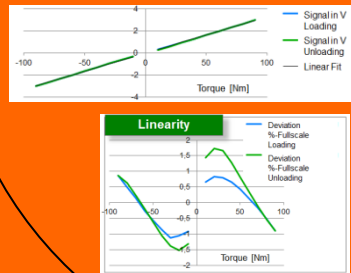
Directly coated strain gauge system without polymer adhesives or transfertape.



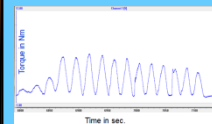
Function is proven for several Schaeffler applications.



Functional Validation performs excellent sensitivity, low linearity- and hysteresis deviation



Sensotect® enables e.g. continuous torque-measurement in e.g. steering shafts or E-Bikes during operation. Complete demonstrator systems are realized.



Next Steps:

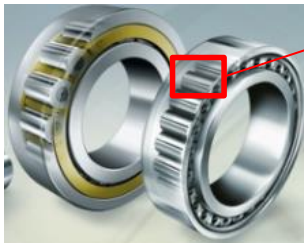
- Ready to be developed for series production; search for pilot customer / application

„In Situ“ Chemical Sensors for Life assessment -Principles

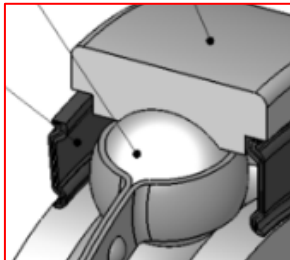
.. And their twins ...



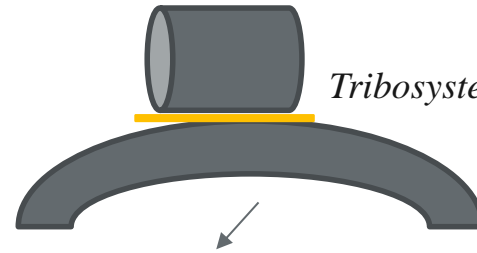
System and it's components



Component



Segment

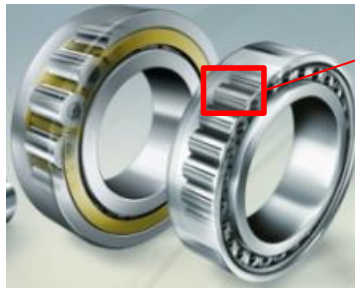


Tribosystem

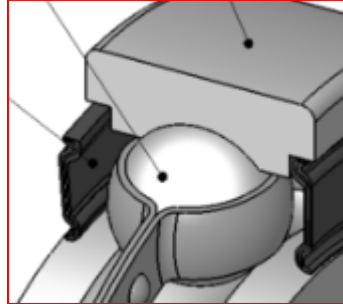
Take the lubricant as a sensor



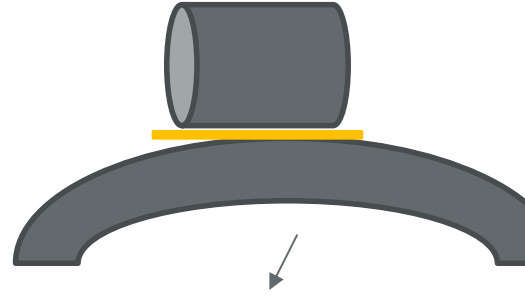
„In Situ“ Chemical Sensors for Life assessment -Principles



Component



Segment



Take the lubricant as a sensor

*Tribosystem
Products p_i
Plus
Environmental
noise Δe*



Lubricant = Components Vector

Interaction = Self Interaction Interaction with Surfaces

Products

Environment

$$\begin{pmatrix} C1 \\ \vdots \\ Cn \end{pmatrix}$$

*Components
(Baseoil, Additives)*

$$\begin{pmatrix} C11 & \dots & C1n \\ \vdots & & \vdots \\ Cn1 & \dots & Cnn \end{pmatrix}$$

*Components
Self Interaction*

$$\begin{pmatrix} C11s & \dots & C1ns \\ \vdots & & \vdots \\ Cn1s & \dots & Cnns \end{pmatrix}$$

Interaction with Surfaces

$$\begin{pmatrix} p1 \\ \vdots \\ pn \end{pmatrix}$$

Products

$$\begin{pmatrix} ev1 \\ \vdots \\ evn \end{pmatrix}$$

Environment

$$\begin{pmatrix} P_1 + \Delta e \\ \vdots \\ P_n + \Delta e \end{pmatrix}$$

„In Situ“ Chemical Sensors for Life assessment -Principles

Life is determined by the distribution of the lubricant within the contact as there are

Cage - Rolling Elements

Rolling Elements toward OR/IR

Life $\sim D(t+1) \sim D(t)$ Life depends on the distribution of the lubricant over time $(t) : D(t) : \text{How much lubricant gets lost} - \text{how much does enter again}$

A



Example : TRB Test stand

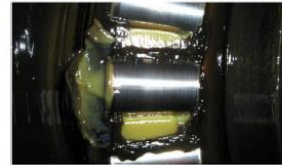
A : Original lubricated

B : After test

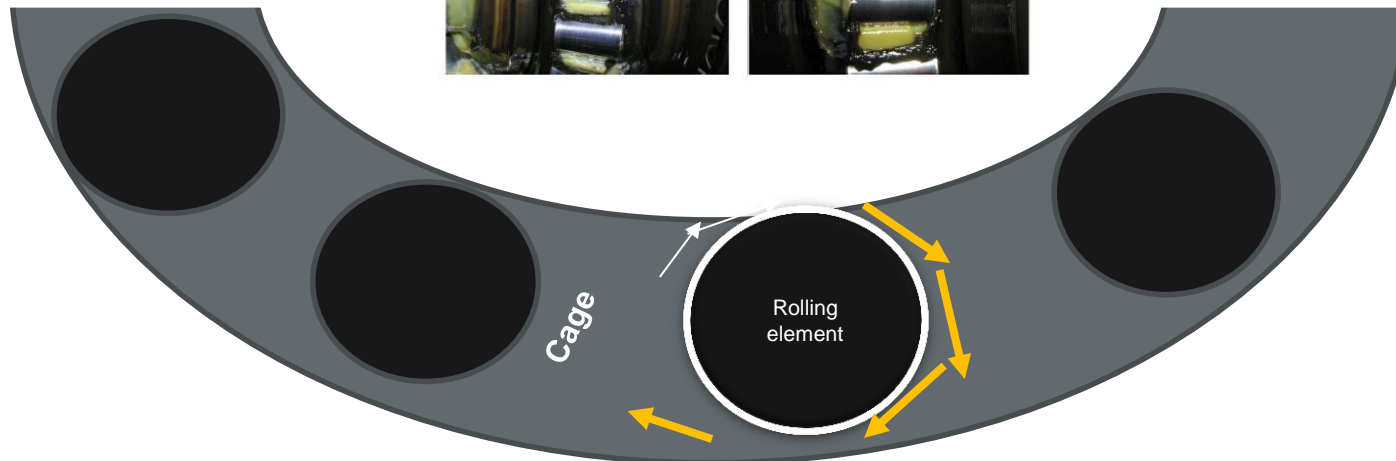
bearing no.: 244



bearing no.: 243

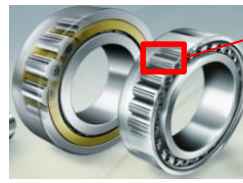


B

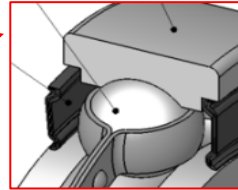


„In Situ“ Chemical Sensors for Life assessment -Principles

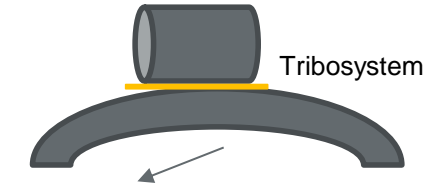
System in time



Component

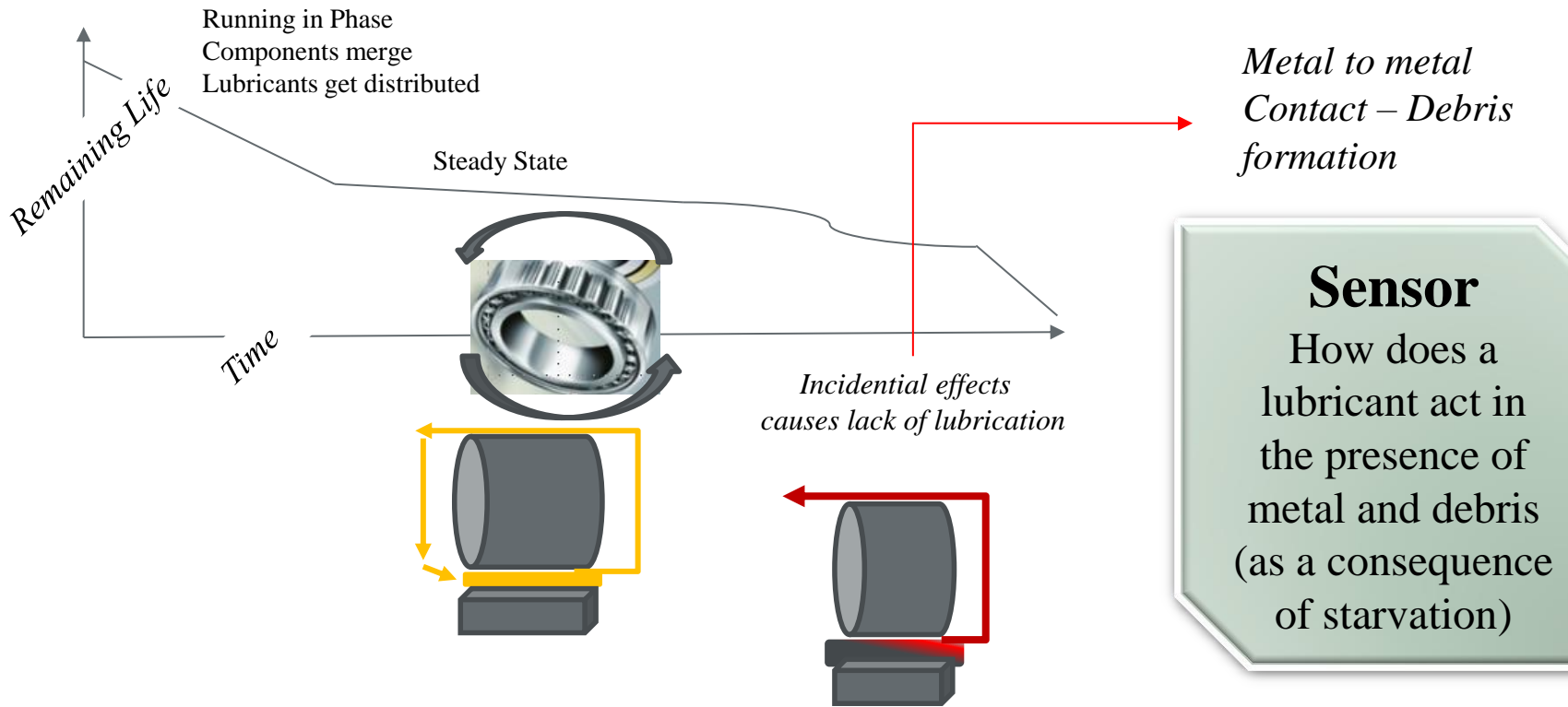


Segment

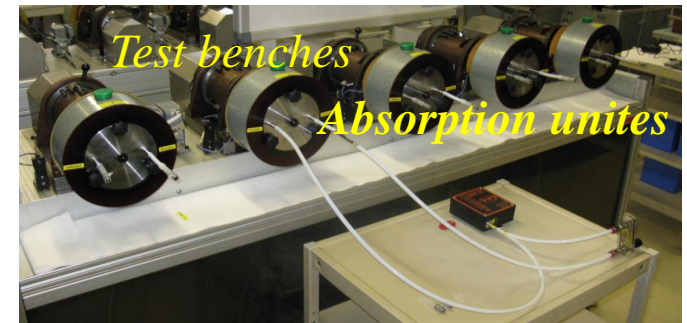
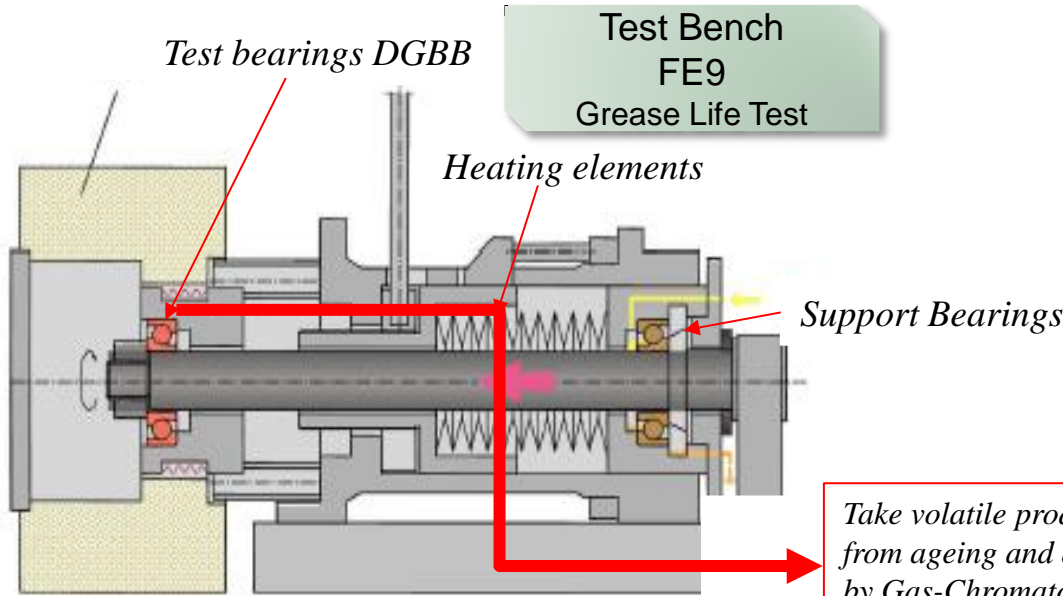


Tribosystem

Take the lubricant as a sensor

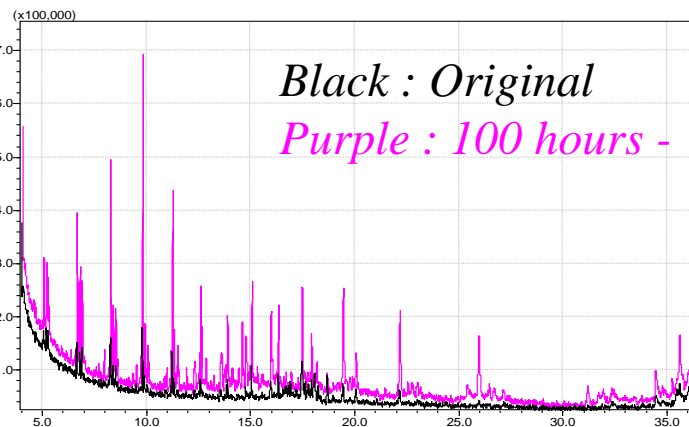
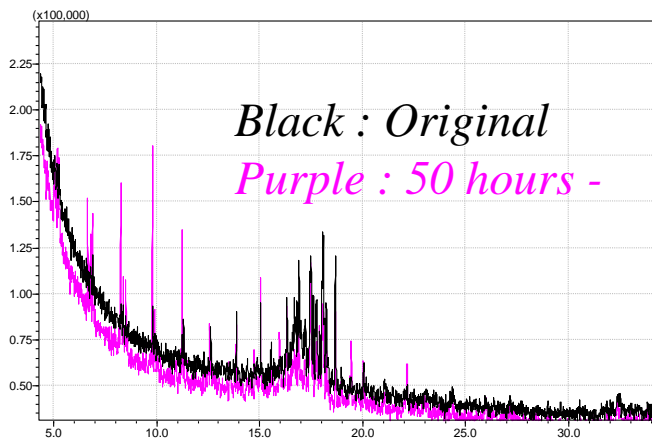
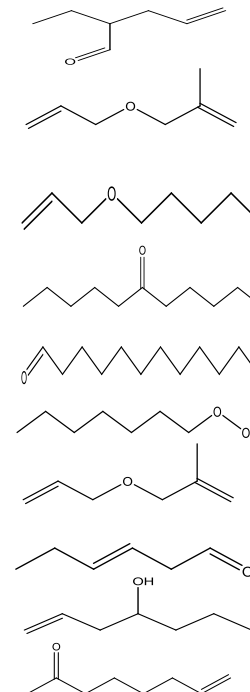


In Situ“ Chemical Sensors for Life assessment -Results



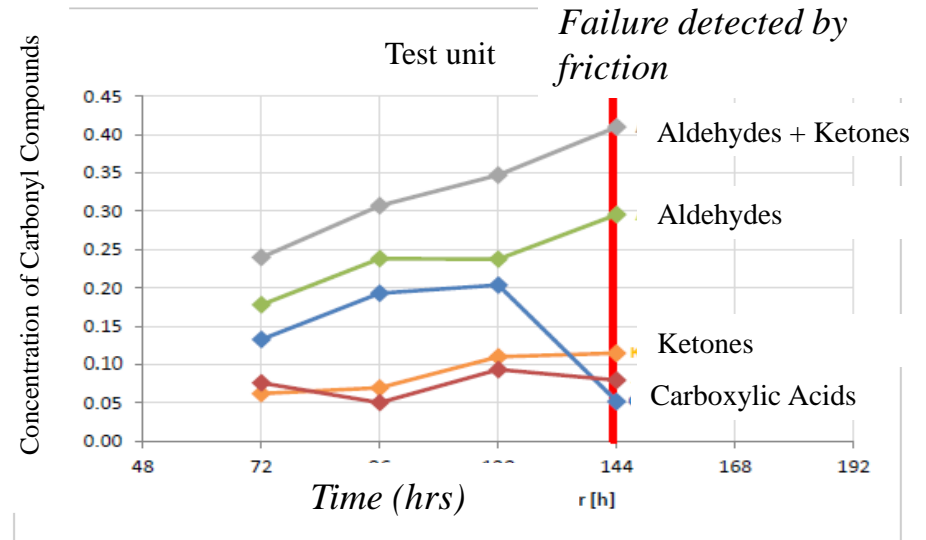
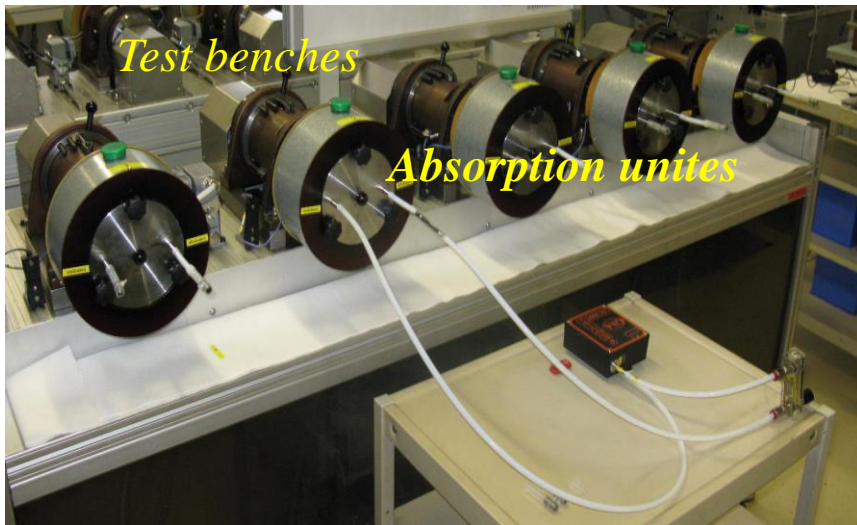
FE 9 Test Bench for Grease Life

Some Products



In Situ“ Chemical Sensors for Life assessment -Results

Adsorption of volatile reaction products



„In-situ“ Detection of **Catalytic Degradation** enables early failure detected by an **increase in friction**

In Situ“ Chemical Sensors for Life assessment -Results

Creation of Digital Twins in Tribosystems

- *Mechanical* by Strain Gauge units at place
- *Chemical* by „in situ“ Spectrometry

Leads to Predictive Reactive Maintenance

Adds to SCADA

*Cloud
Cognition Map*

*Prediction of
Complex Systems
In real time*

THANKS for YOUR ATTENTION

