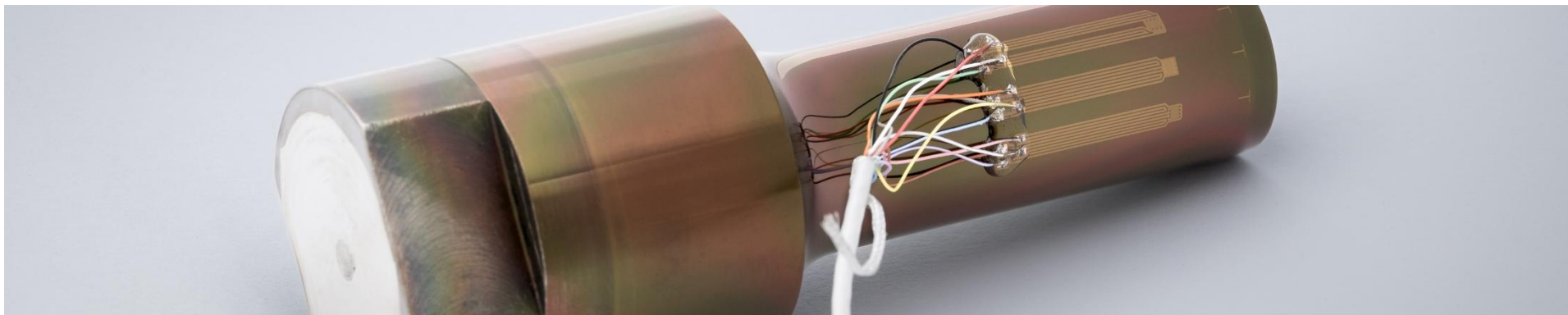




Thin-Film Sensors in Friction-Locking Shaft-Hub Connections: A New Approach to In-Situ Joint Pressure Measurement

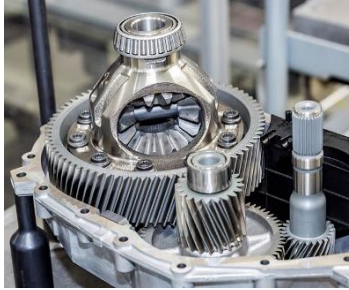
Sensor Integrating Machine Elements Congress

15 – 16 September, 2026 in Darmstadt, Germany

Charlotte Breuning, Marcel Plogmeyer, Christina Pongratz, Markus Wagner, Anna Schott,
Günter Bräuer, Matthias Kreimeyer

The Shaft-Hub connection (SHC) is an important component in drive technology

Gearbox



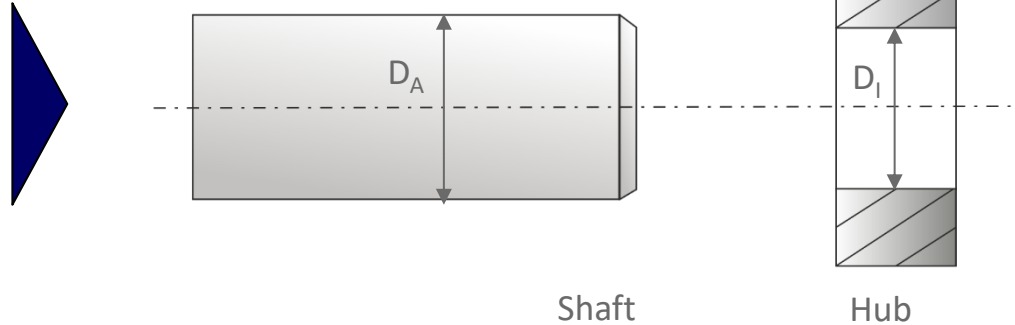
[Ecomento20]

Electric motor



[lcp GmbH26]

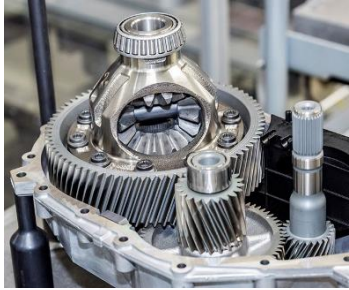
A common example is the **cylindrical interference-fit**



$$D_A > D_I$$

The Shaft-Hub connection (SHC) is an important component in drive technology

Gearbox



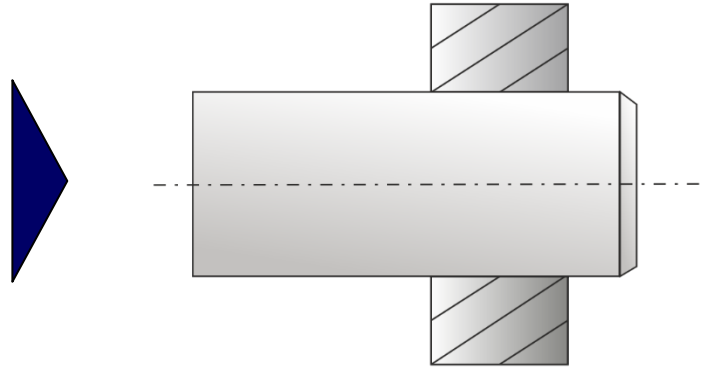
[Ecomento20]

Electric motor



[lcpghmbh26]

A common example is the **cylindrical interference-fit**



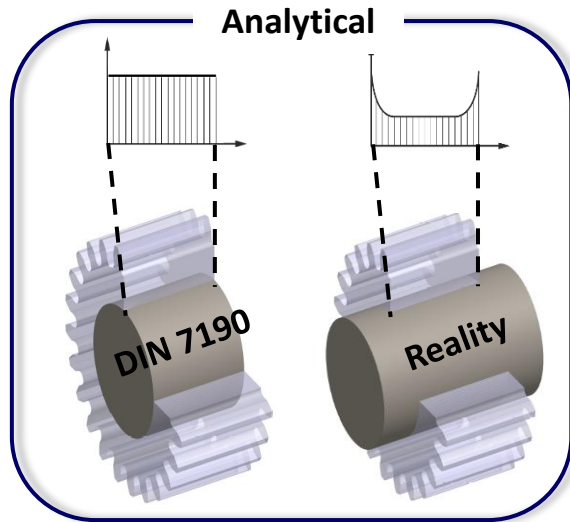
Shaft-hub Connection

$$T = \frac{\pi}{2} \cdot D_f^2 \cdot l \cdot \mu \cdot \frac{p}{s_R}$$

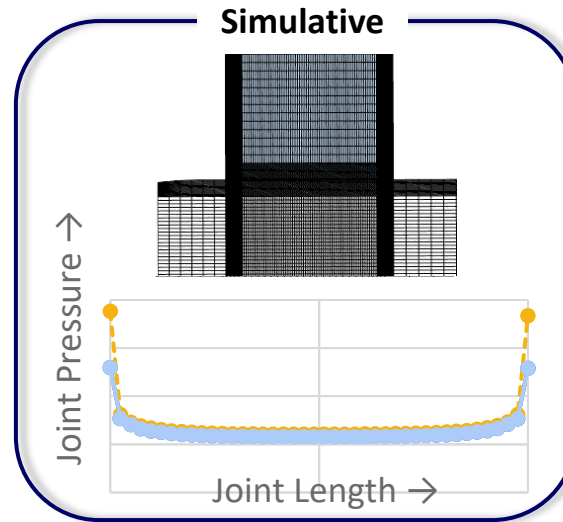
→ The fundamental potential for smartification is present

The current design of the ME is not efficient in terms of resources!

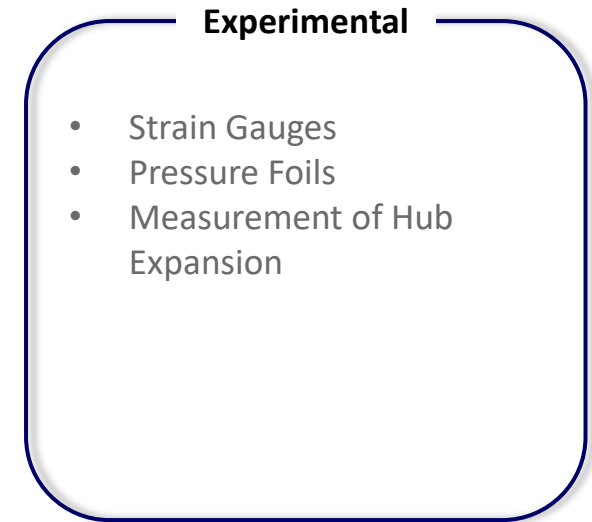
The methods for determining the **joint pressure p** are not sufficiently accurate



The values of the peaks are unknown



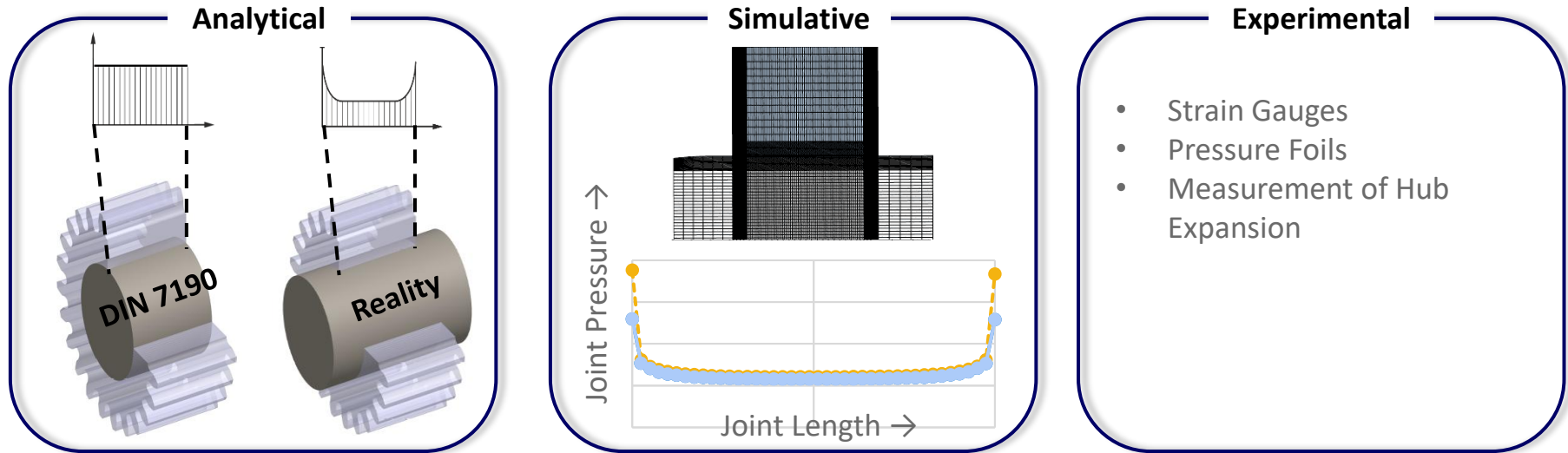
The peaks represent a singularity



Measurement is too imprecise and has a significant impact on the stress state

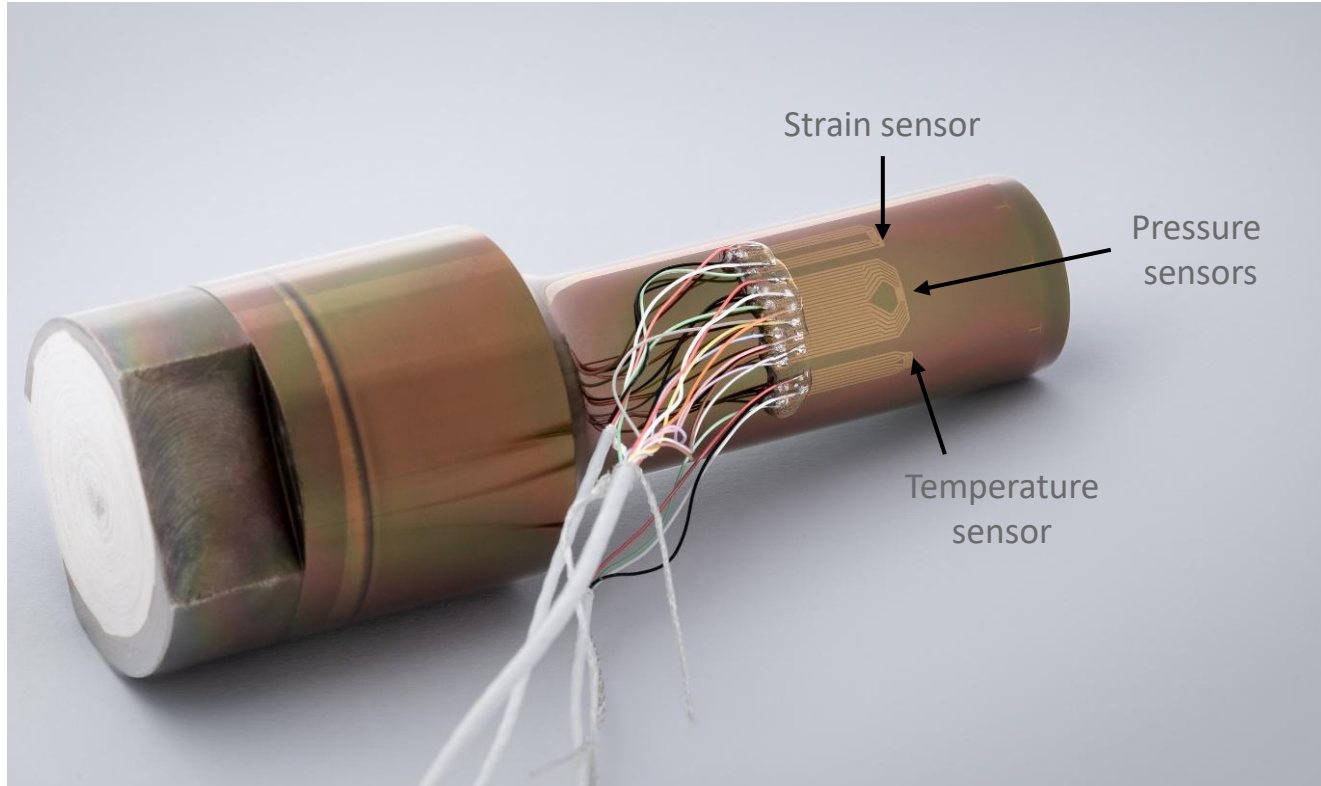
The current design of the ME is not efficient in terms of resources!

The methods for determining the **joint pressure p** are not sufficiently accurate

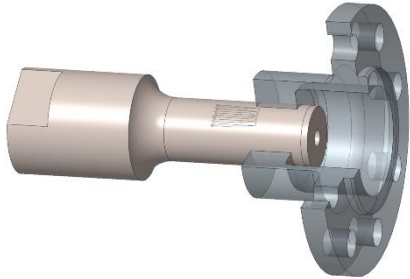


The unknown course of the peaks is compensated for in the design by using high safety factors
→ untapped potential for savings in weight and installation space

The SHC with integrated thin-film sensors as a solution



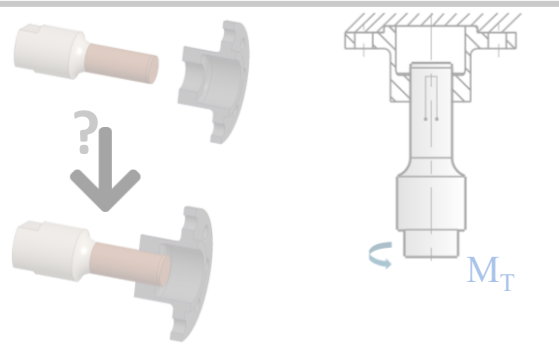
Agenda for today



Concept

- Integration of the sensor into the ME

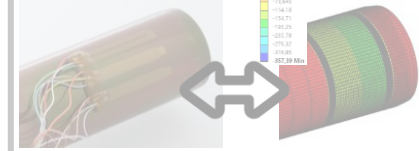
1



Preliminary investigations

- System development & design of the ME
- Impact on Functionality & Feasibility

2



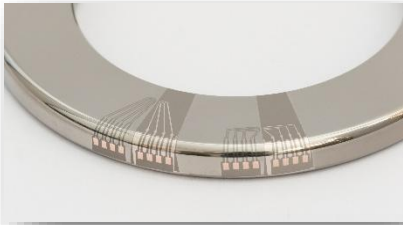
Measurement

- Excerpt from the measurement results

3

Thin-film sensors

- Wear-resistive PVD + PECVD thin-film coatings
- Microstructuring by photolithography or laser for an individual sensor designs
- In situ measurement of pressure, force, strain, or temperature

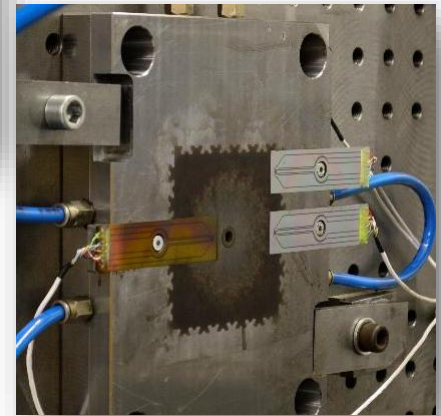


Gears

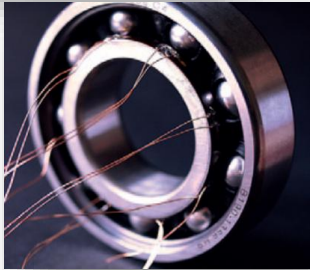


Screws and washers

Production processes



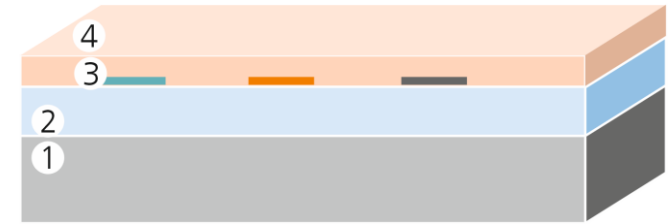
Bearings



Structure and functioning of the SiME

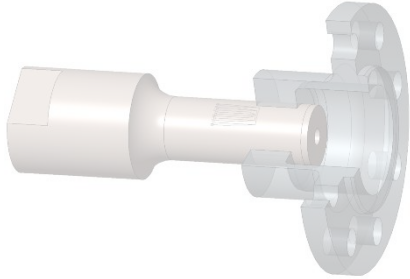
- Benefits in SHC:
 - Minimal impact on shape and interfaces ($t < 10 \mu\text{m}$)
 - Flexible sensor placement
 - No impact on stress state
 - Simultaneous in-situ measurement of
 - Pressure p → Manganin (CuMnNi)
 - Temperature T → Titanium
 - Strain ε → NiCr
- Each sensor is dependent on all parameters

$$\Delta R \approx \alpha_p * p + \alpha_T * T + k * \varepsilon$$



4 Insulation and wear protection layer (SICON® or Al_2O_3) (2-3 μm)
3 Sensor structures (CuMnNi, Ti, NiCr) (0.2 μm)
2 Insulation layer (Al_2O_3) (5 μm)
1 Shaft

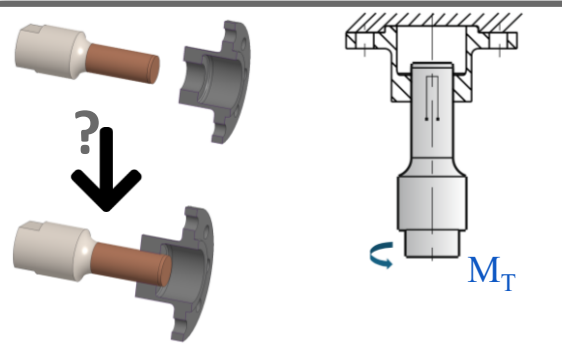
Agenda for today



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- Integration of the sensor into the ME

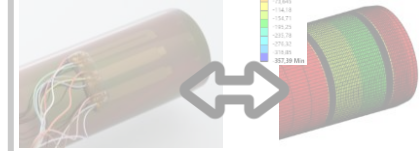
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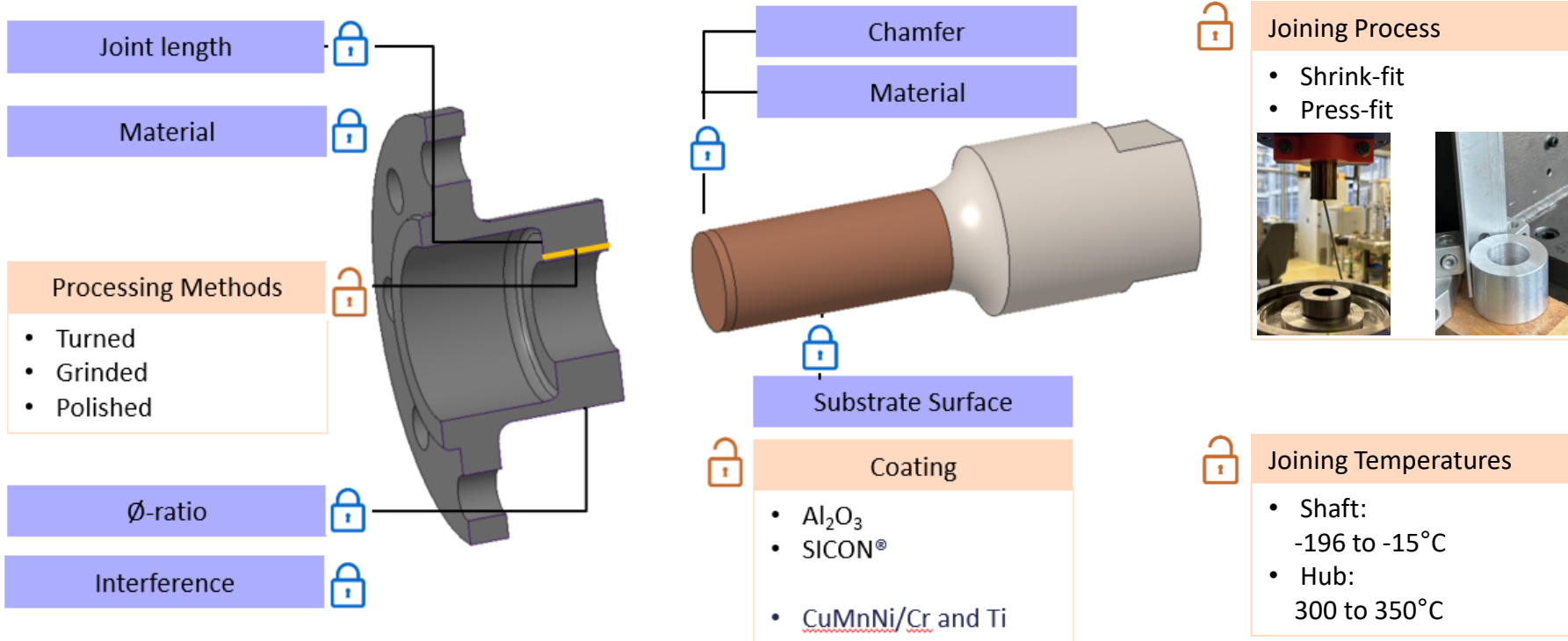


Measurement

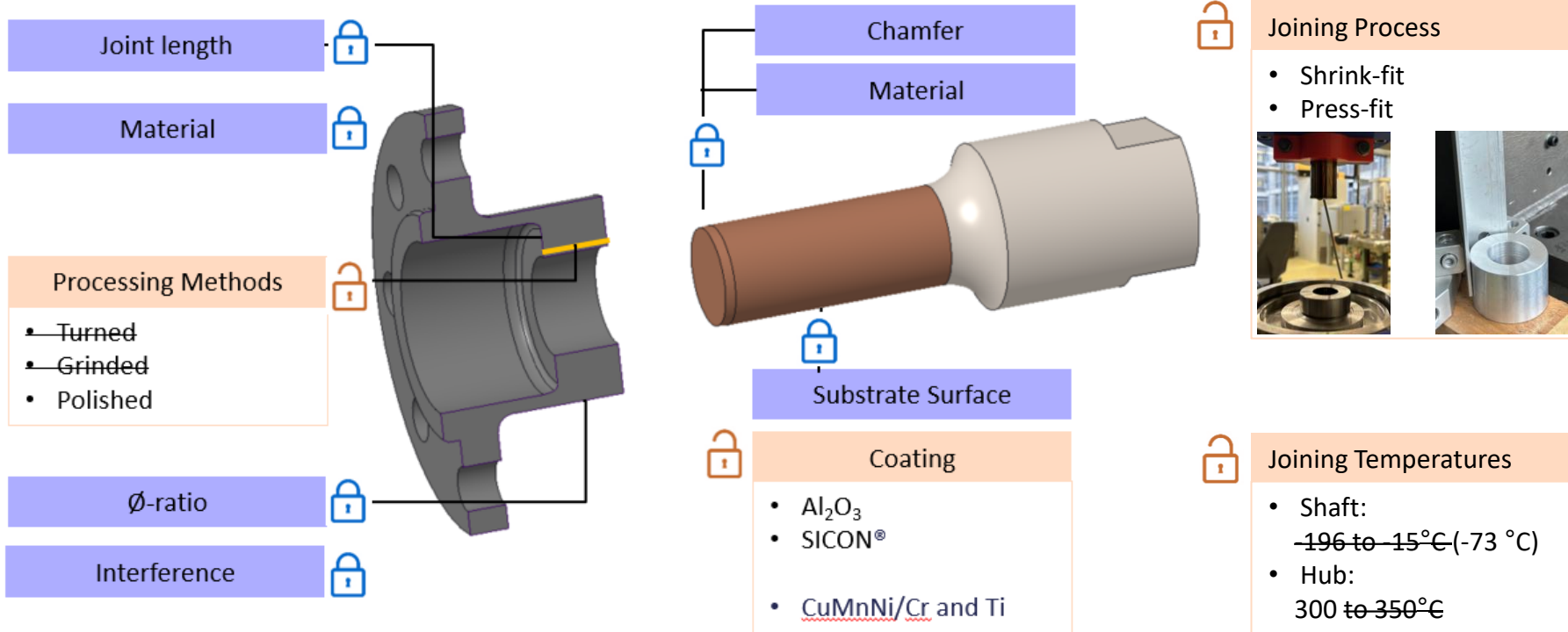
- Excerpt from the measurement results

3

Aim: Joining the SHC without damaging the sensor function



Aim: Joining the SHC without damaging the sensor function

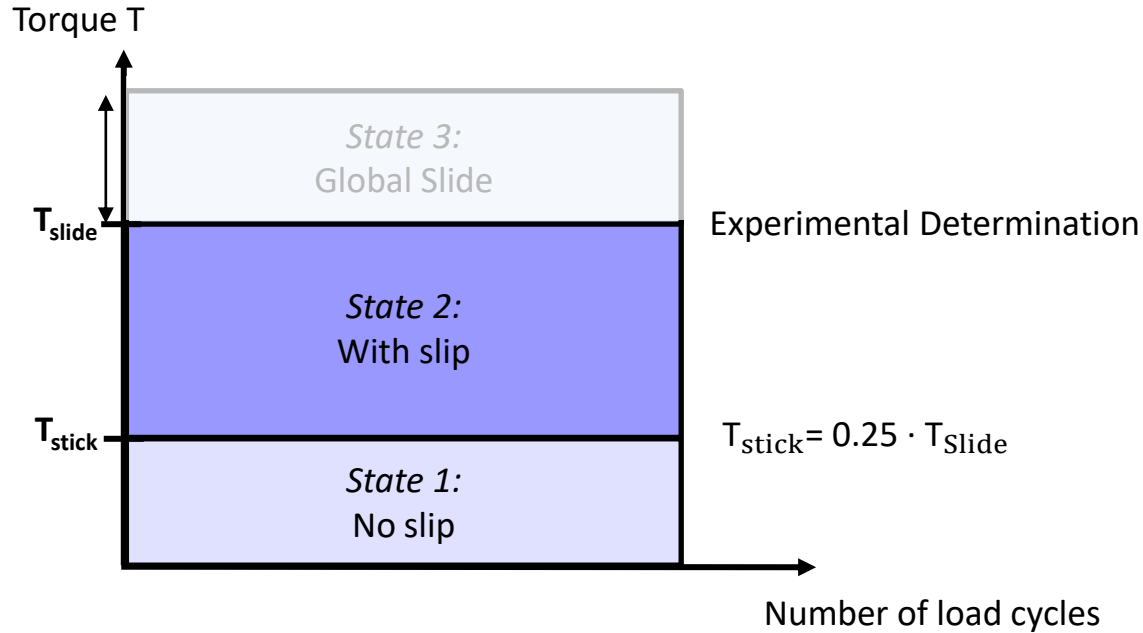


Key Takeaways

1. Damage-free joining using shrink-fits is possible for both coatings, provided certain parameters are observed
2. The joining temperature represents a compromise between joint clearance and induced residual stresses
3. The joint pressure is not affected by the material of the coatings

Influence on function

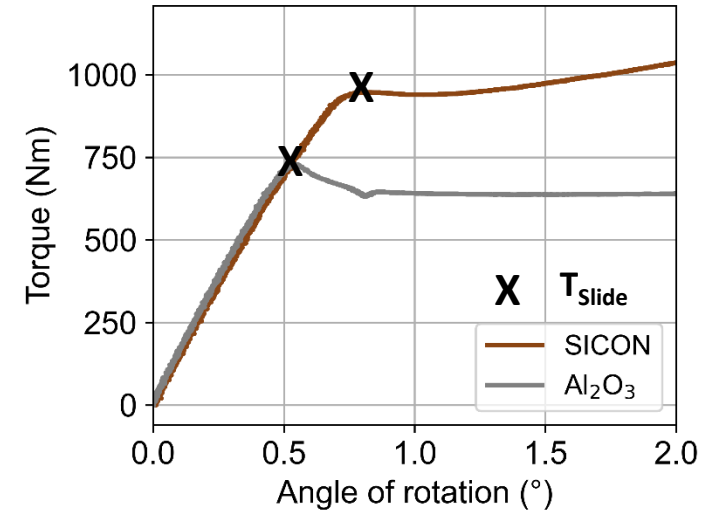
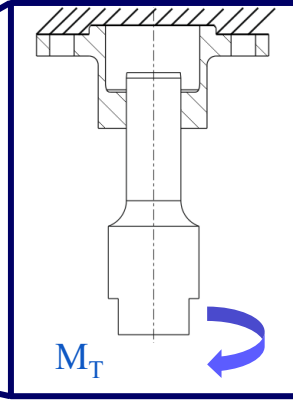
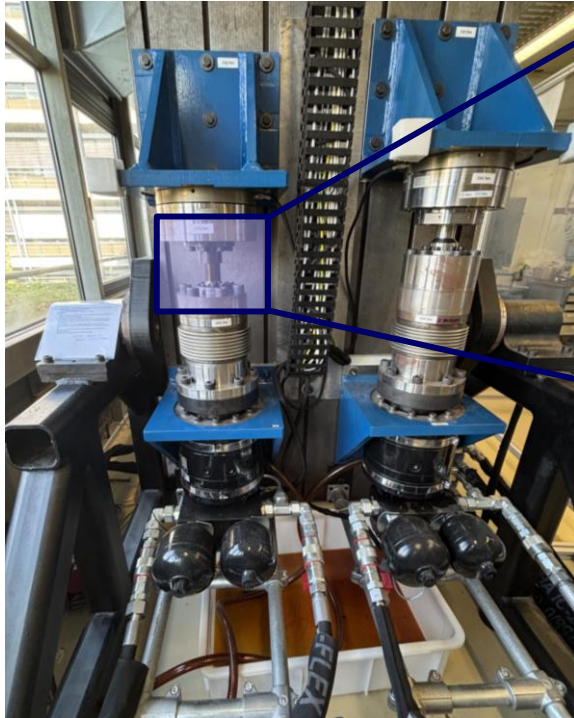
Aim: Determination of the fatigue-resistant torque capacity



First, T_{slide} must be determined

Influence on function

First: Determination of T_{Slide}



$\mu(\text{SICON}^{\circledR}) = 0.23$
 $\mu(\text{uncoated}) = 0.2$

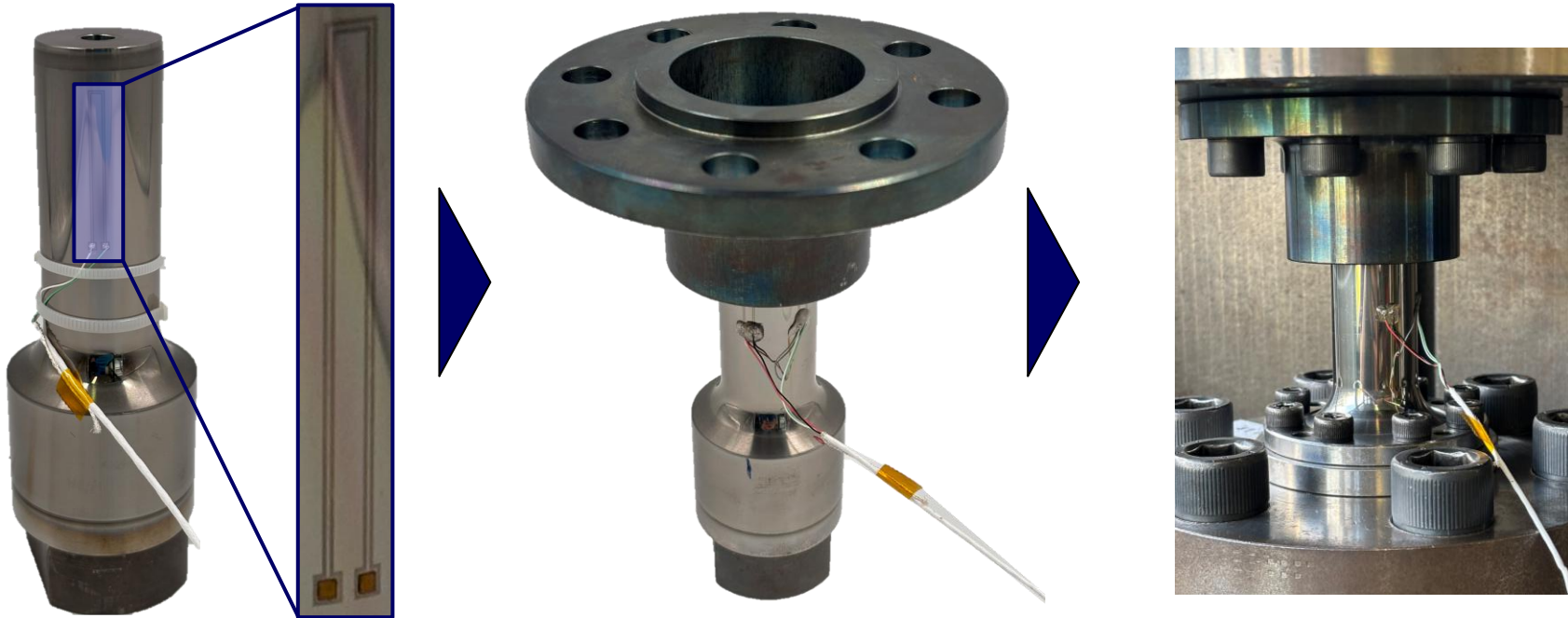
$\mu(\text{Al}_2\text{O}_3) = 0.18$

The SICON-coating can transmit a **higher torque** than uncoated SHC

Influence on function

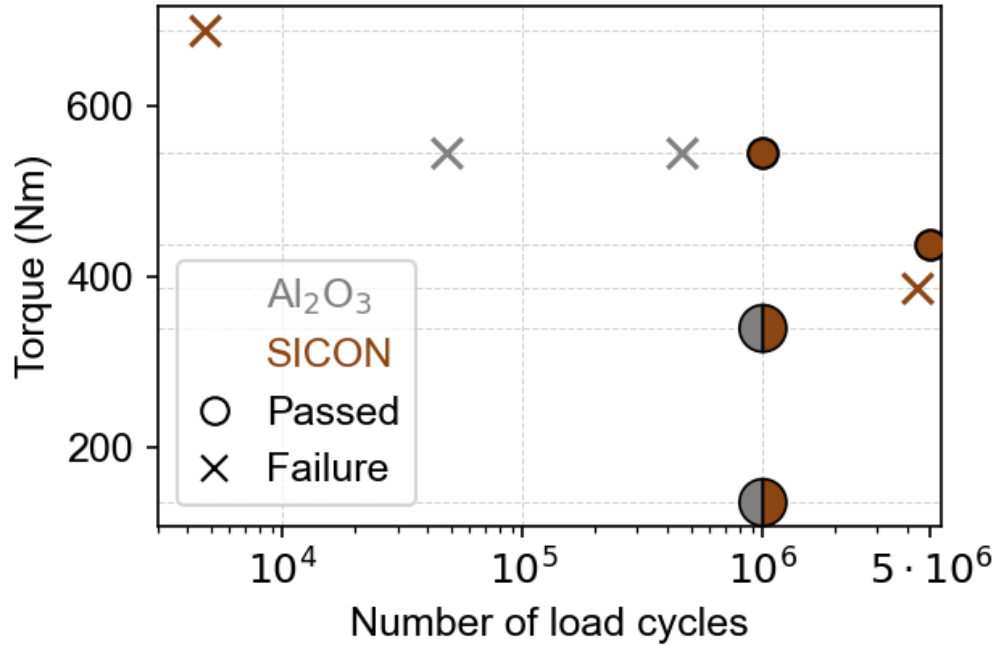
Aim: Determination of the fatigue-resistant torque capacity

→ This requires the implementation of a **wear detection sensor system**



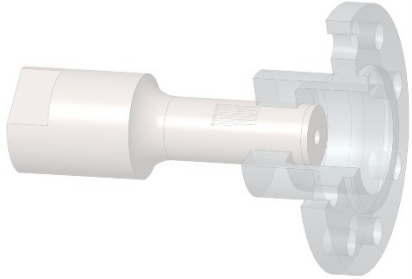
Influence on function

Aim: Determination of the fatigue-resistant torque capacity



- 
1. $T_{\text{fatigue-resistant}} \approx 546 \text{ Nm}$, which allows for the transmission of higher torque than with uncoated SHC
 2. The permissible slip is limited to approximately $7 \mu\text{m}$
 3. A proof of concept for the sensor system has been provided

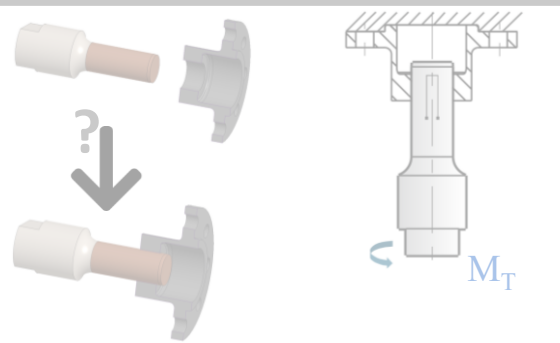
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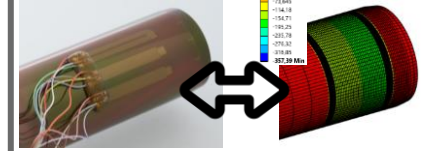
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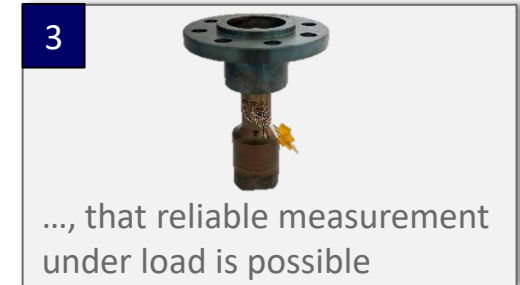


Measurement

- Excerpt from the measurement results

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- First ever joint-pressure measurement in SHC realized which offers additional benefits
 - + In-Situ measurement
 - + Minimal change in the stress state at the joint due to the sensor system
 - + No changes to the interfaces
- Experimental investigations show...



- **The sensor-integrating SHC can optimize the design in numerous applications and also enable real-time monitoring even under load**
- Outlook: Follow-up project with improved calibration and wireless data transmission