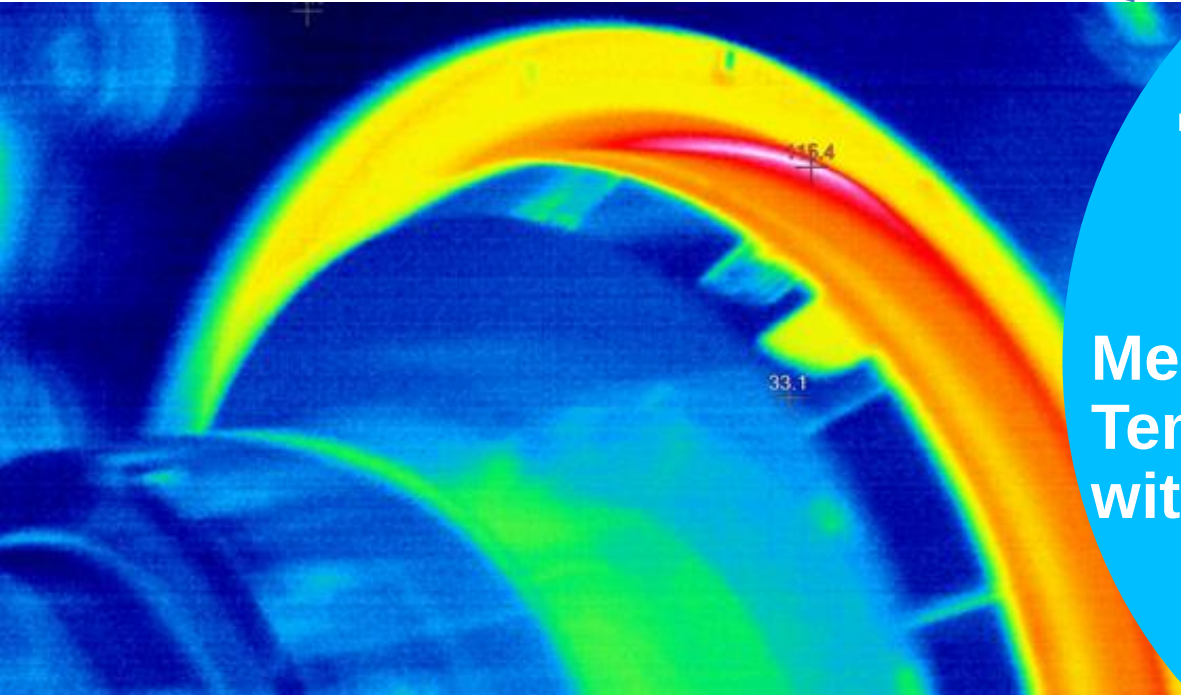


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iWA

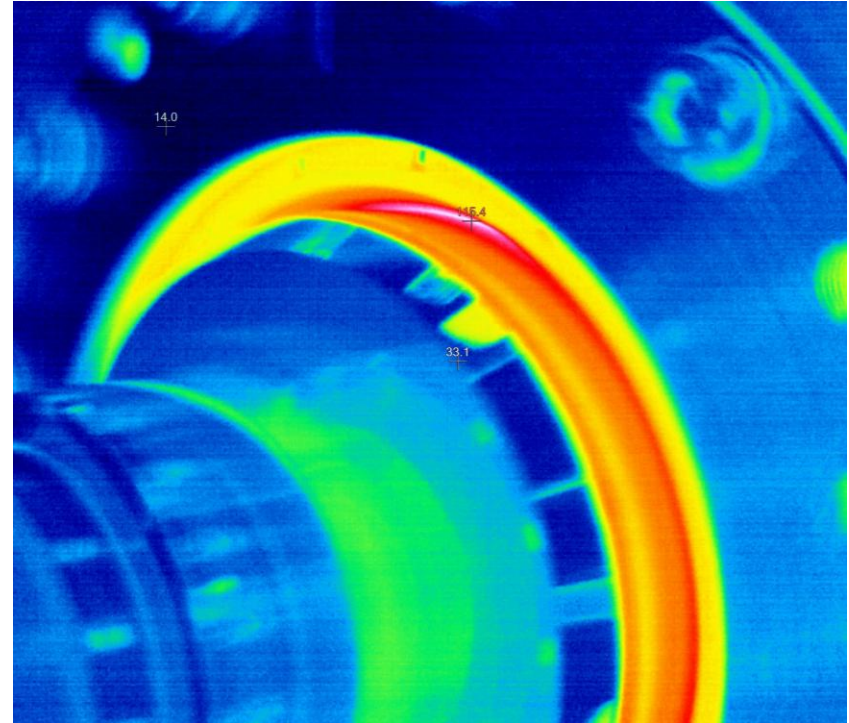
FAPS

Measuring the Contact Temperature of Shaft Seals with a Virtual Sensor

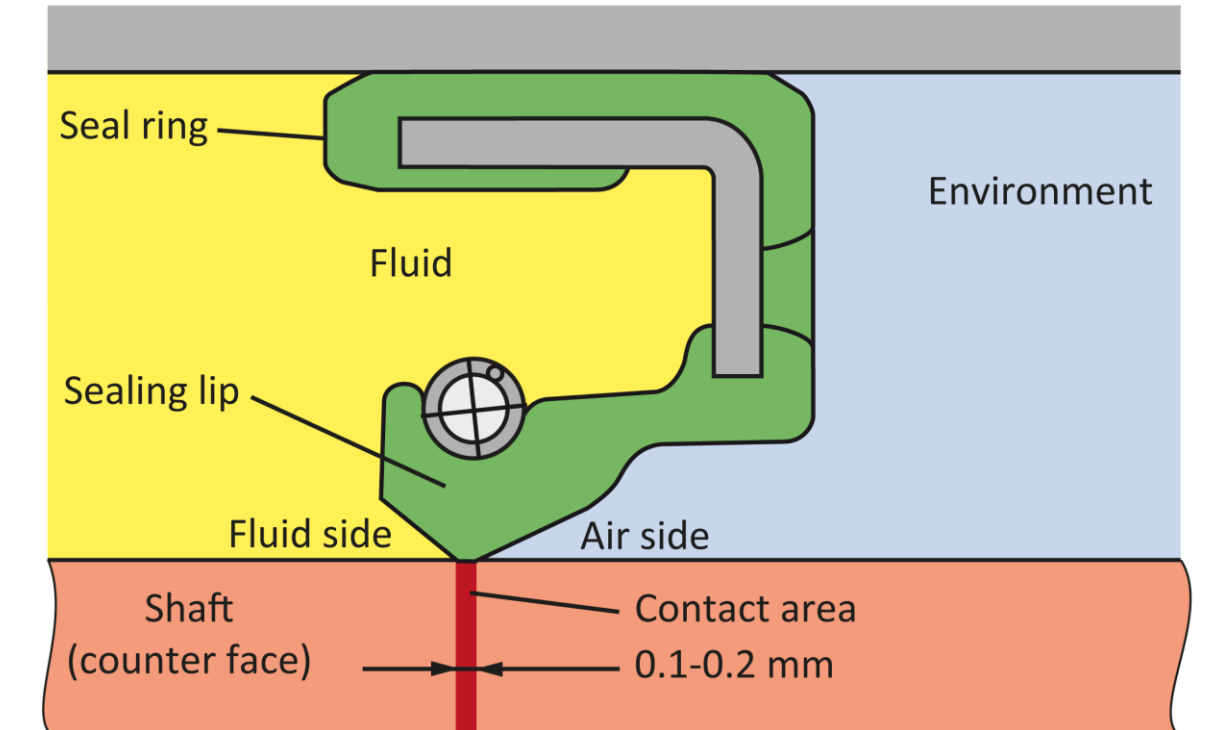
Christoph Olbrich

Agenda

- Problem of overheating
- Options for temperature measurement
- SmartSeal system (contact temperature)
- Conclusion



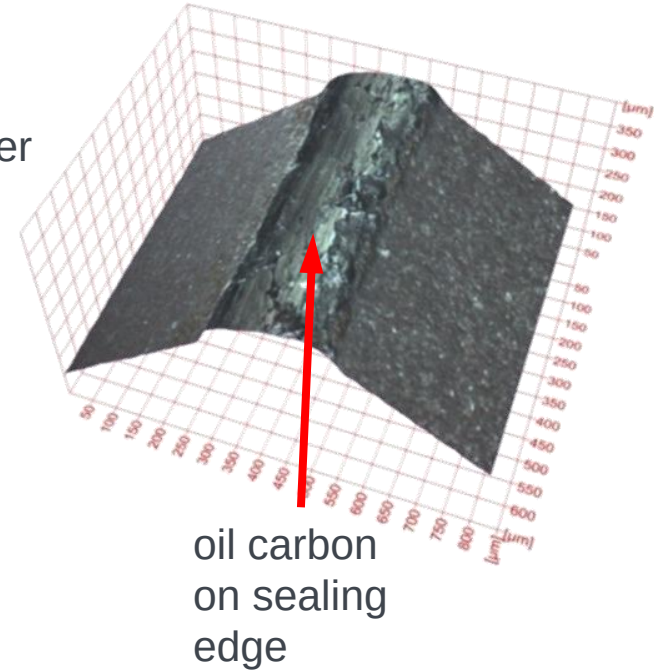
Tribological system rotary shaft seal



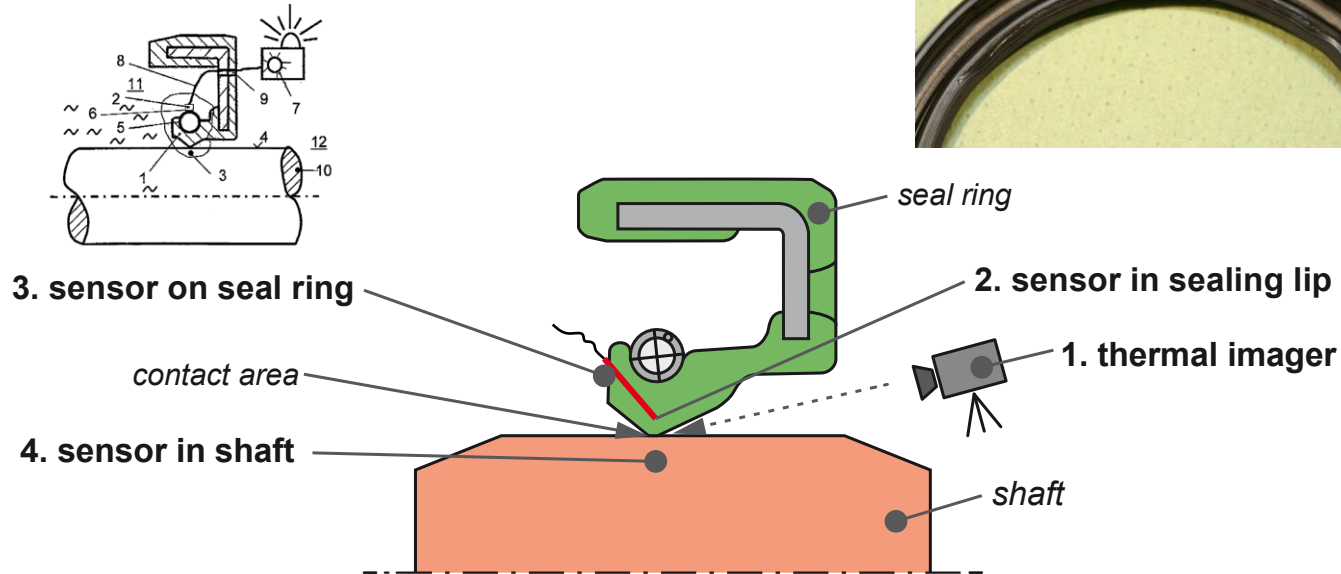
- Frictional power loss in small contact area
- High temperatures in contact area (overheating)
- Contact area not accessible for temperature measurement

Problem

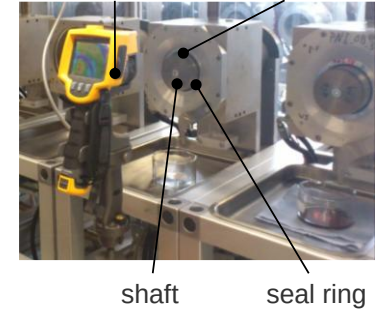
- **Overheating in the contact area**
 - high frictional power and/or inadequate heat transfer
 - hardening of the sealing lip
 - decomposition of the fluid
- **Goal: determination of the contact temperature**
 - better than with current methods
 - without compromising the tribological system
- **Vision**
 - status monitoring during operation
 - adaptive operating strategy + predictive maintenance



Options for temperature measurement



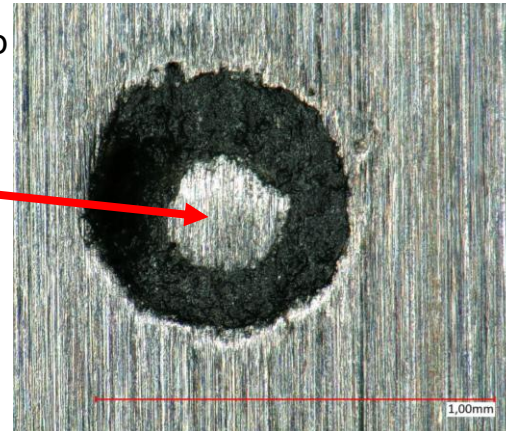
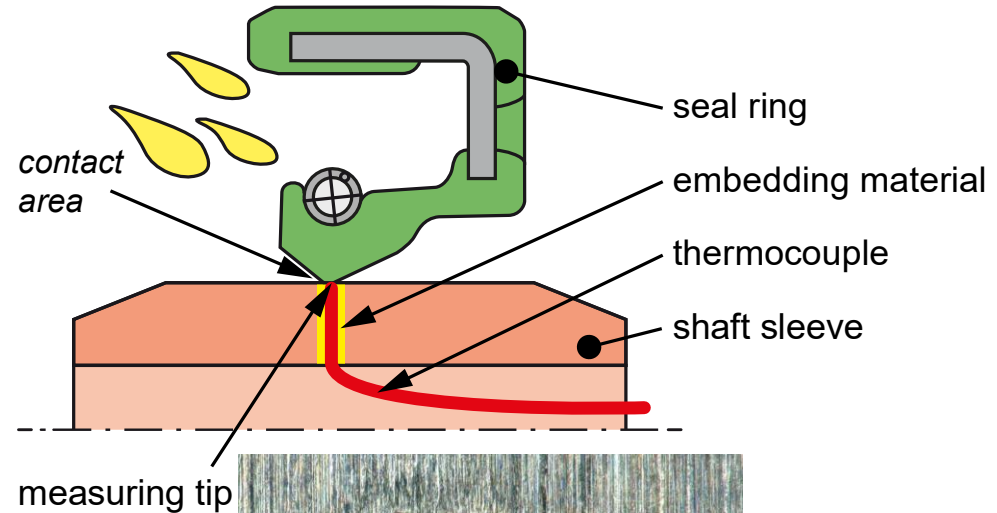
thermal imager measuring area



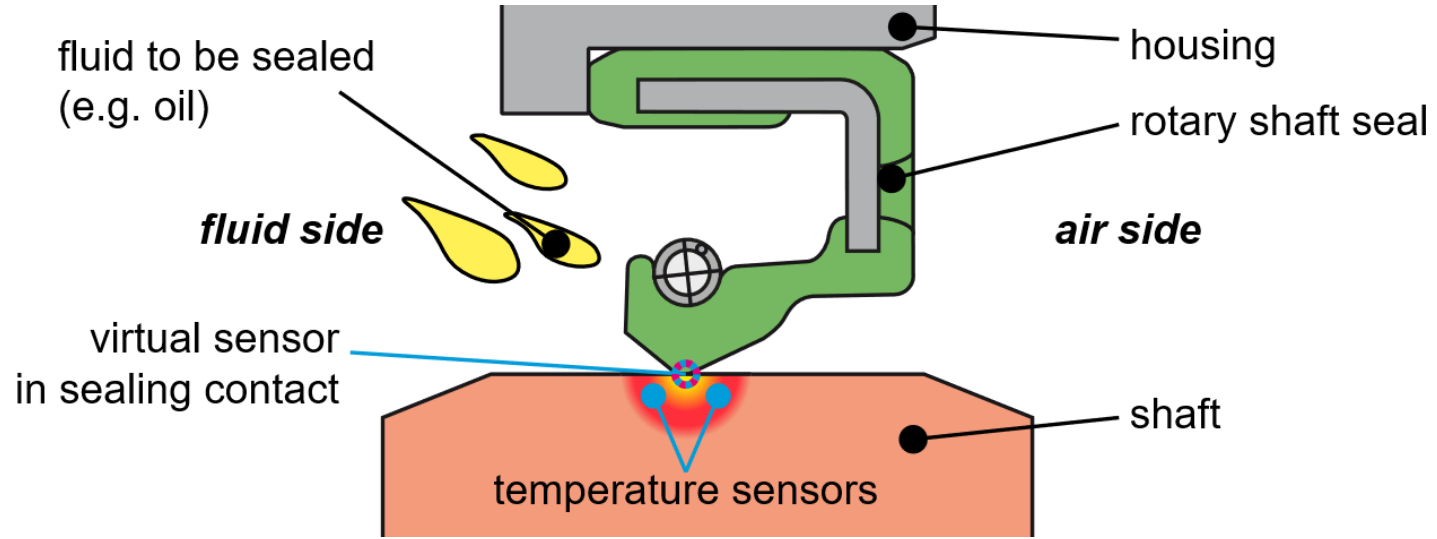
Options for temperature measurement

Sensor in shaft (common setup)

- technically demanding
- change of the tribo-contact
- Thermal insulation between sensor and shaft
→ different measurement

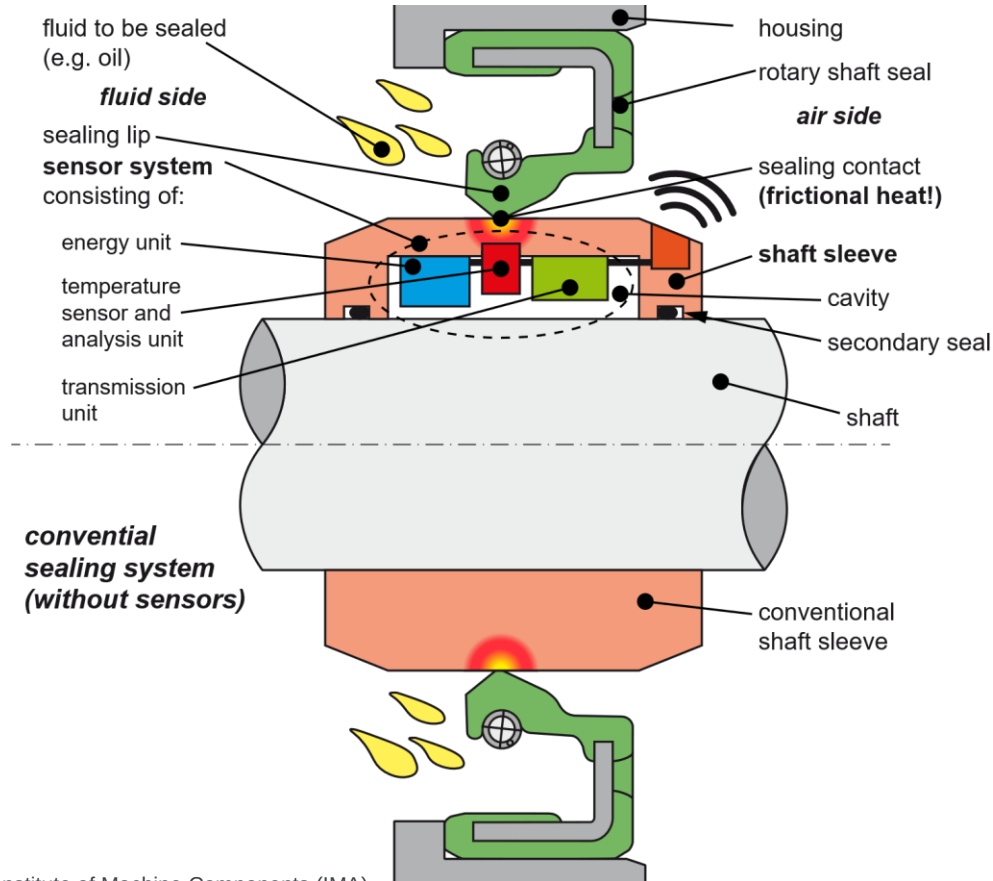


Idea for the temperature measurement (virtual sensor)

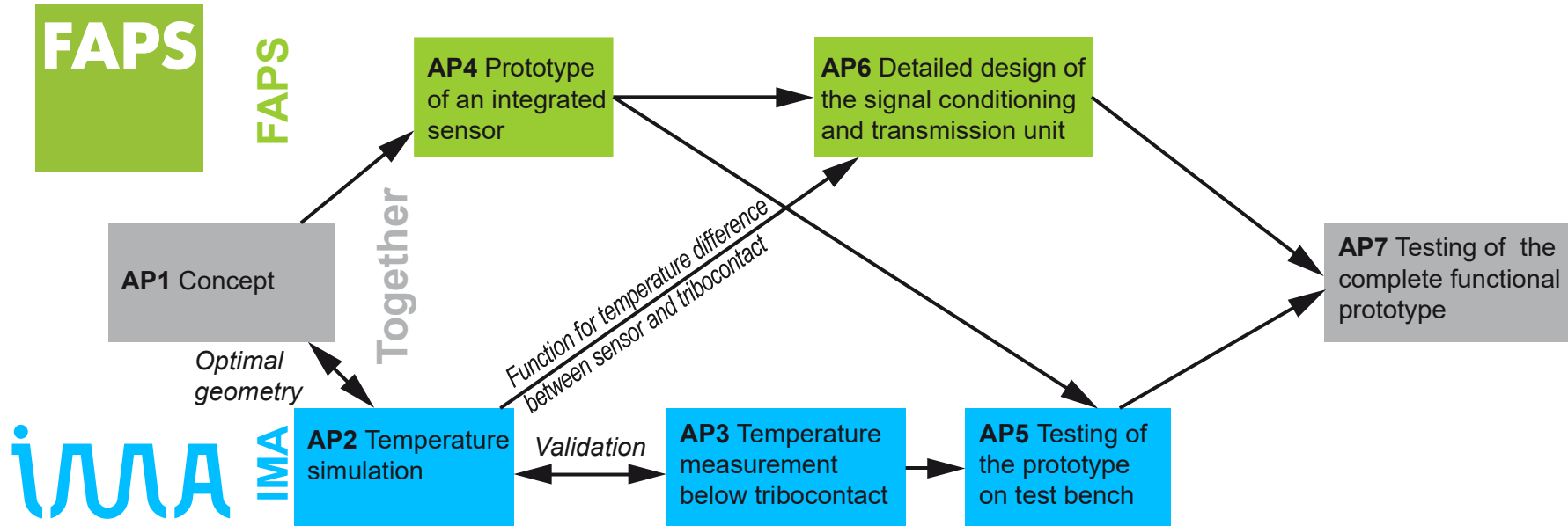


- Virtual Sensor estimates temperature using mathematical models and data from other physical sensors
- Virtual sensor does not affect the tribological system

SmartSeal Concept



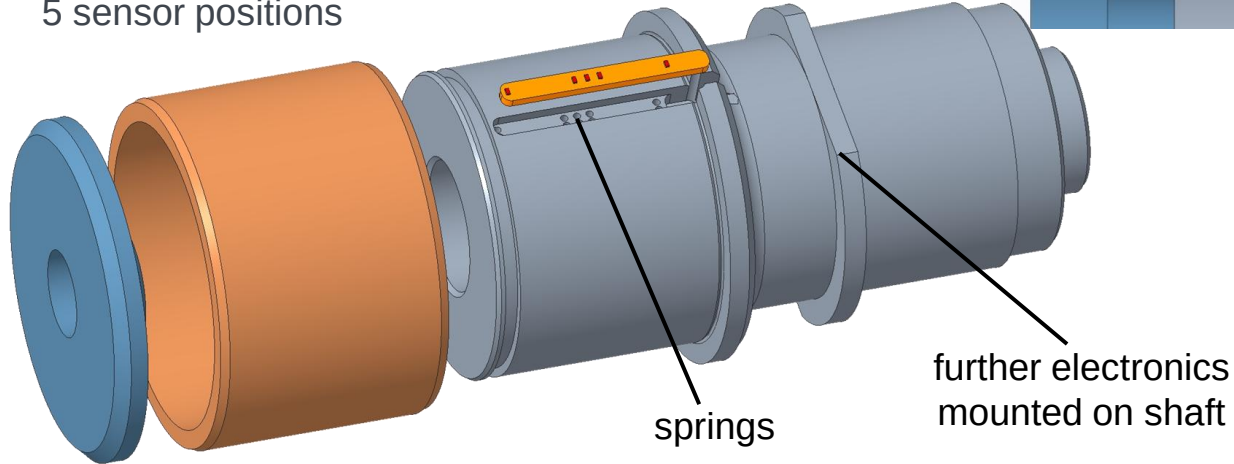
- Replacement part for conventional shaft sleeve
- does not affect the tribological system



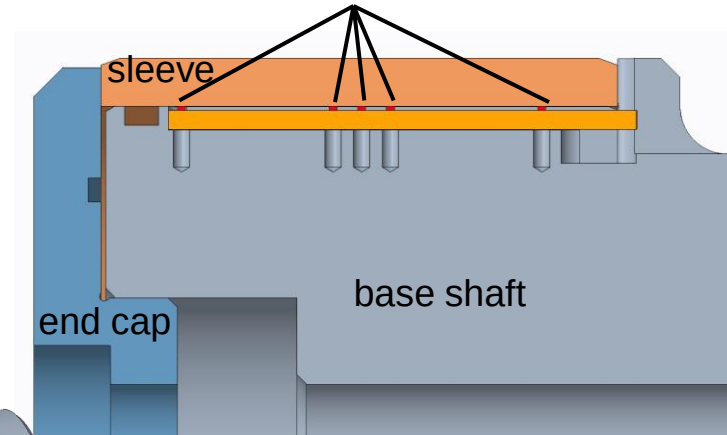
First prototype

→ Integration into the shaft

- Early component testing
- More space in/ on the shaft than in the sleeve
- Lower temperatures for electronics than in the sleeve
- Use of a standard shaft sleeve (without cavity)
- 5 sensor positions

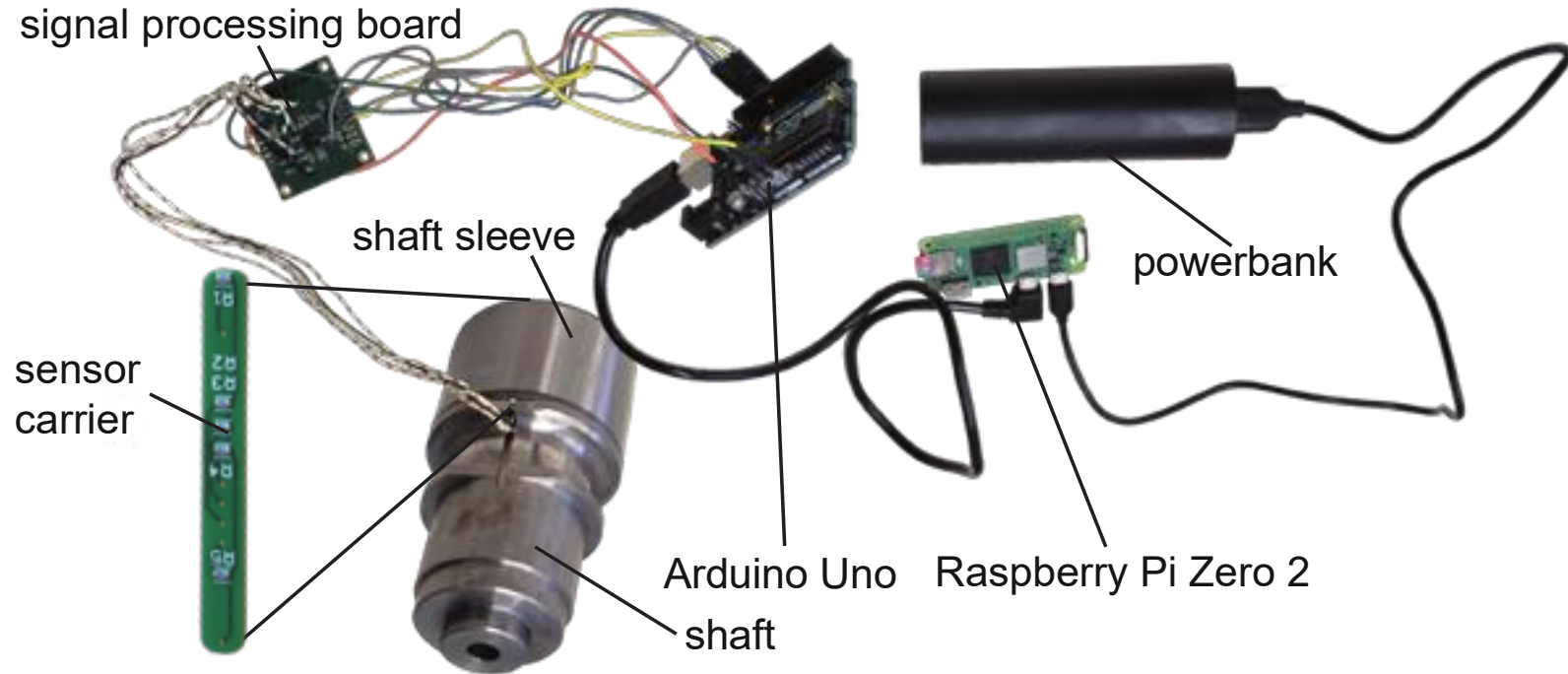


Temperature sensors on sensor carrier 5mm below surface

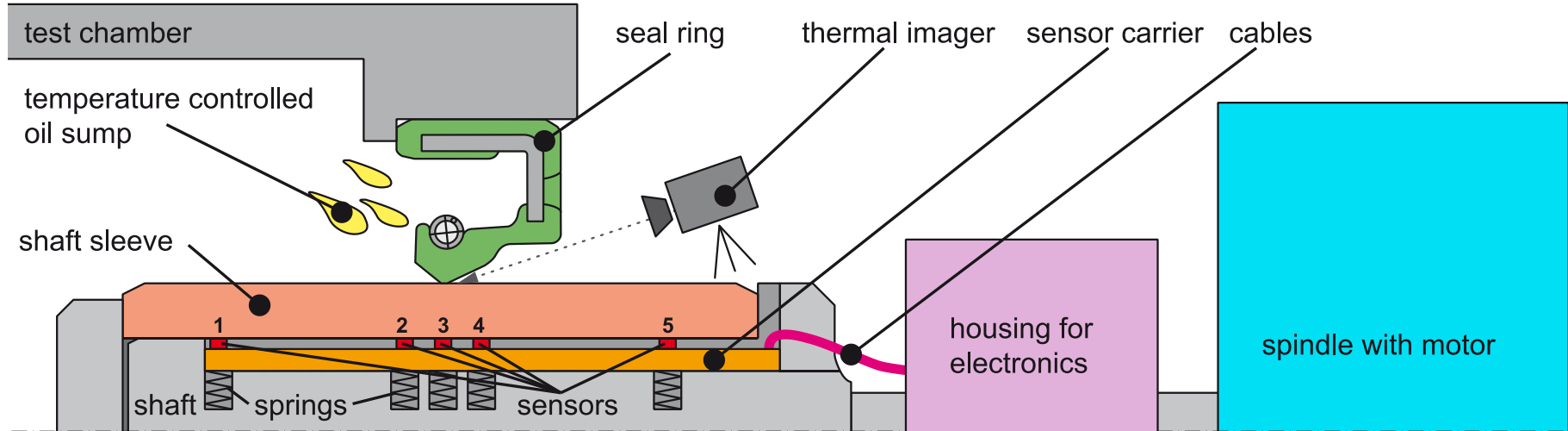


First prototype Electronics

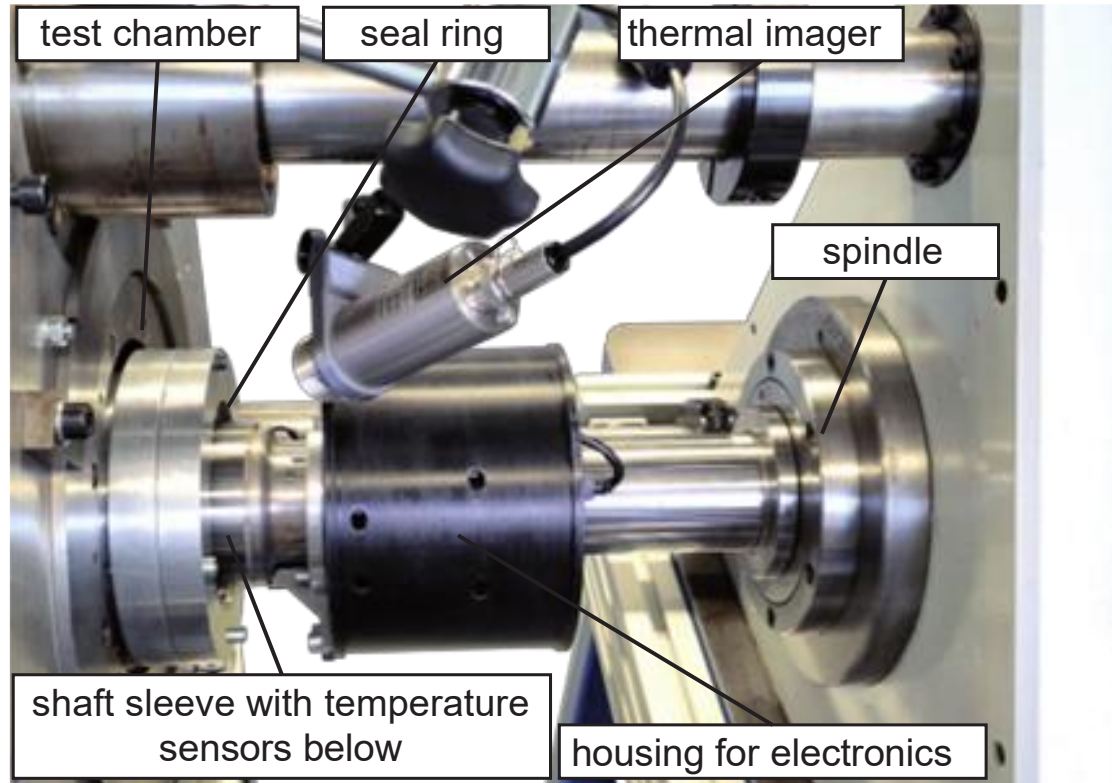
Everything is mounted on the rotating shaft



First prototype Test bench setup

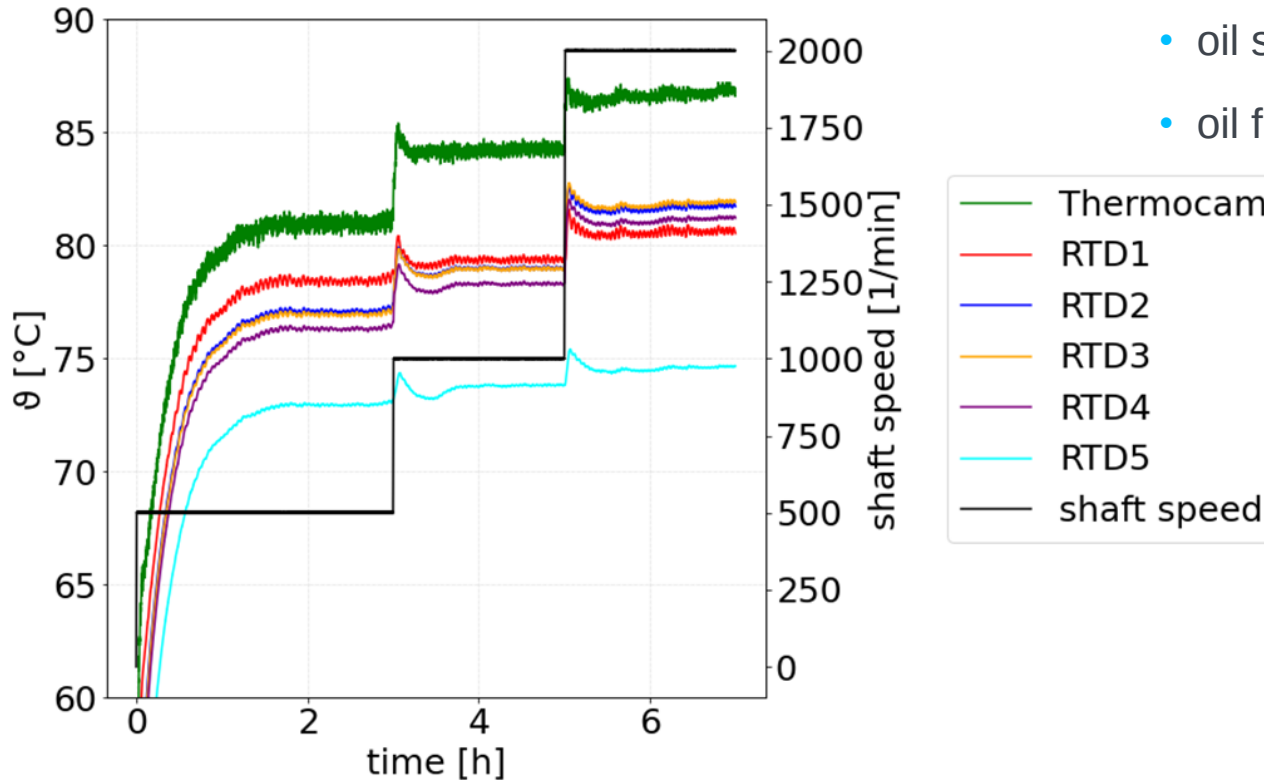


First prototype Test bench



First prototype

Measured temperatures and shaft speed over time

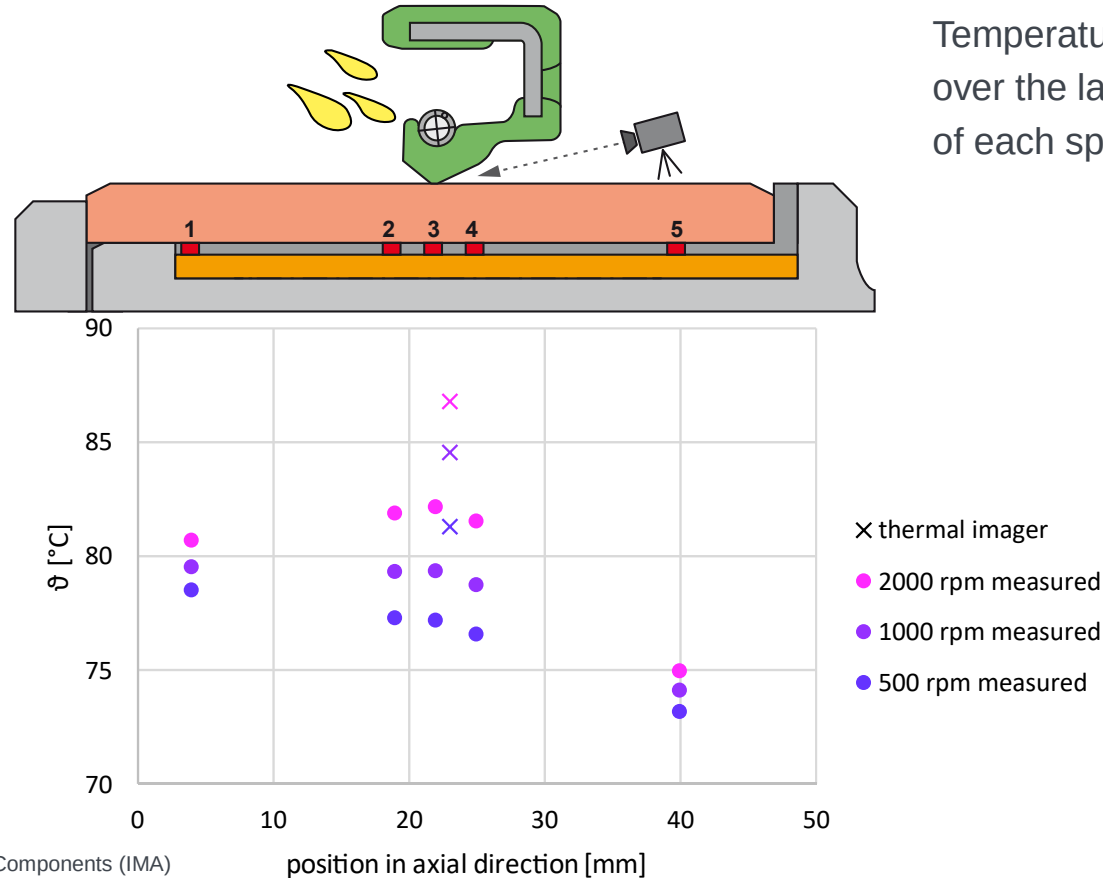


- oil sump temperature: 80°C
- oil fill level: centre of shaft

First prototype

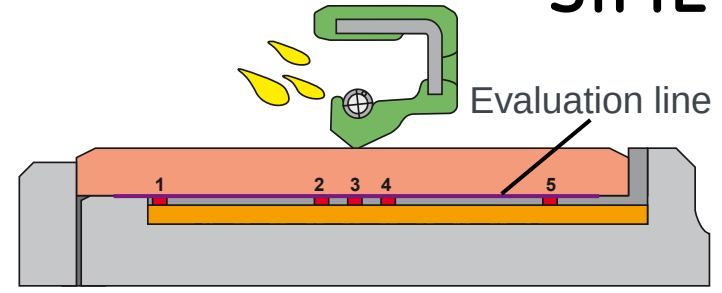
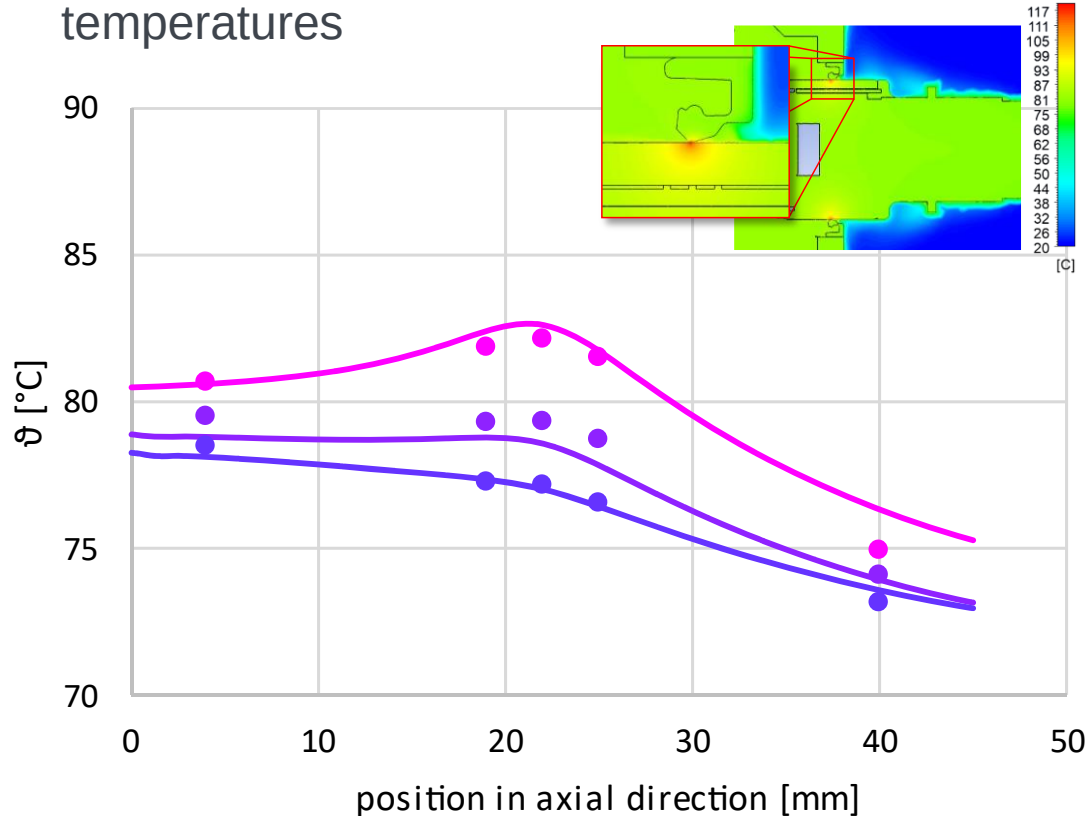
Measured temperatures over axial position for different shaft speeds

Temperatures averaged over the last 30 minutes of each speed step



Simulation

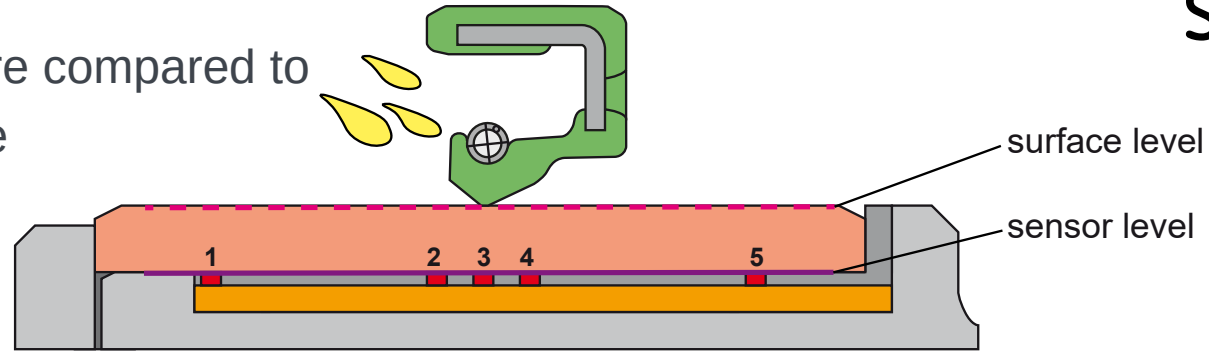
Measured temperatures compared to simulated temperatures



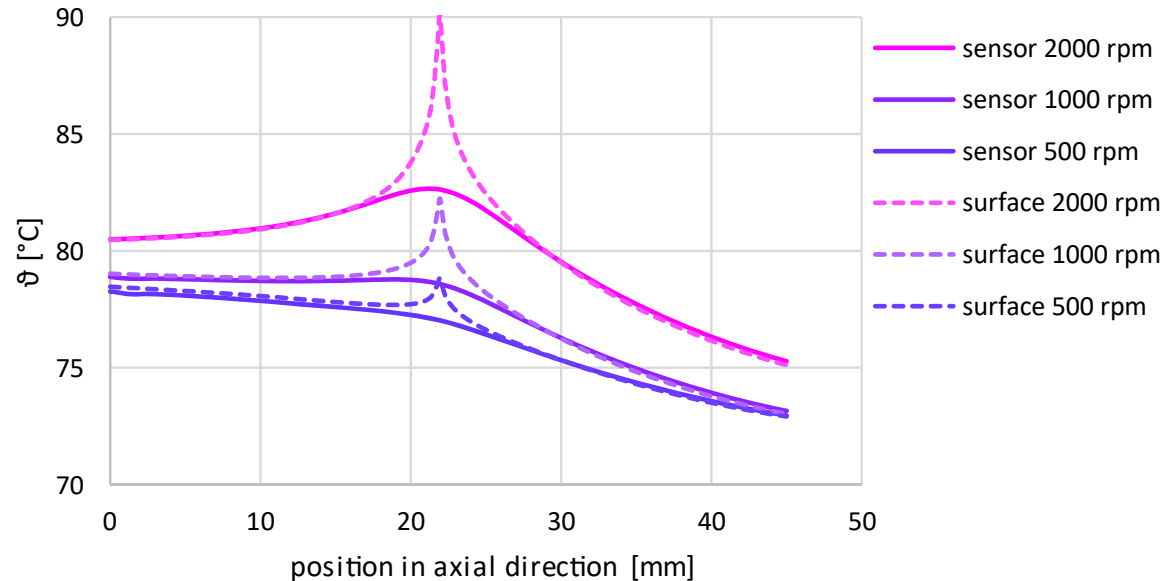
- 2000 rpm simulated
- 1000 rpm simulated
- 500 rpm simulated
- 2000 rpm measured
- 1000 rpm measured
- 500 rpm measured

Simulation

Surface temperature compared to sensor temperature

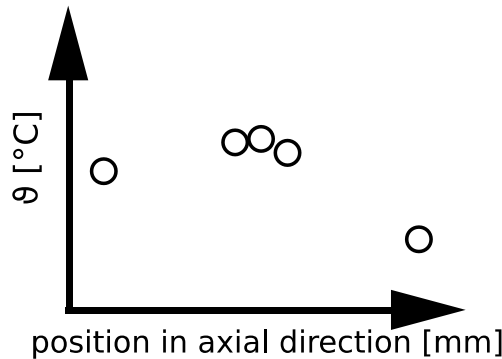


- Further away from the contact area the profiles are similar
- They strongly resembles a normal distribution.
- The surface temperature near the contact area is significantly higher.

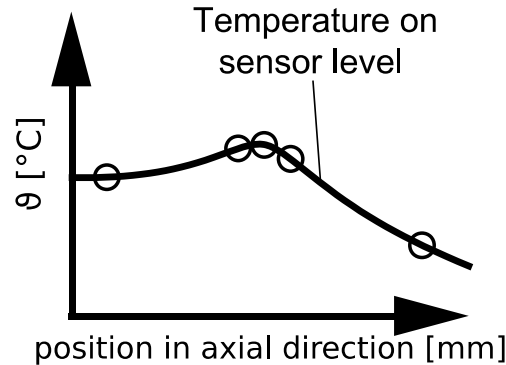


Procedure for predicting the contact temperature

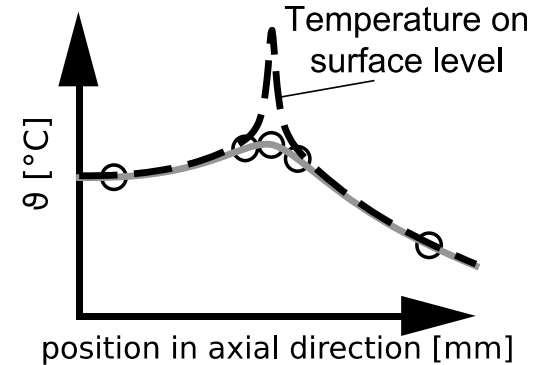
- Contact temperature derived from 5 RTD temperatures
- Idea:
 - Fit through RTD temperatures
 - New surface function based on fitted data



Step 1:
Temperature measurement
in 5 positions



Step 2:
Curve fit and determination
of fitting parameters



Step 3:
Prediction based on
fitting parameters

Functions for the prediction

- **Function on the level of the sensors :**

$$\vartheta_{sensor}(x) = a_1 \cdot e^{-\left(\frac{x-x_1}{b_1+|x-x_1|}\right)^2} - a_2 \cdot (x - x_1) + a_3$$

- **Function for surface temperature:**

$$\vartheta_{surface}(x) = \vartheta_{sensor}(x) + b_2 \cdot a_1 \cdot e^{-\left(\frac{x-x_2}{b_3+|x-x_2|}\right)^2} \cdot b_4$$

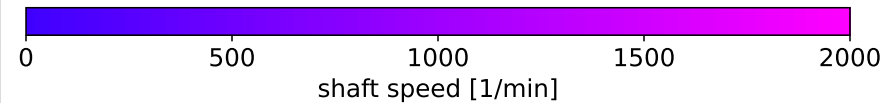
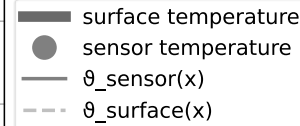
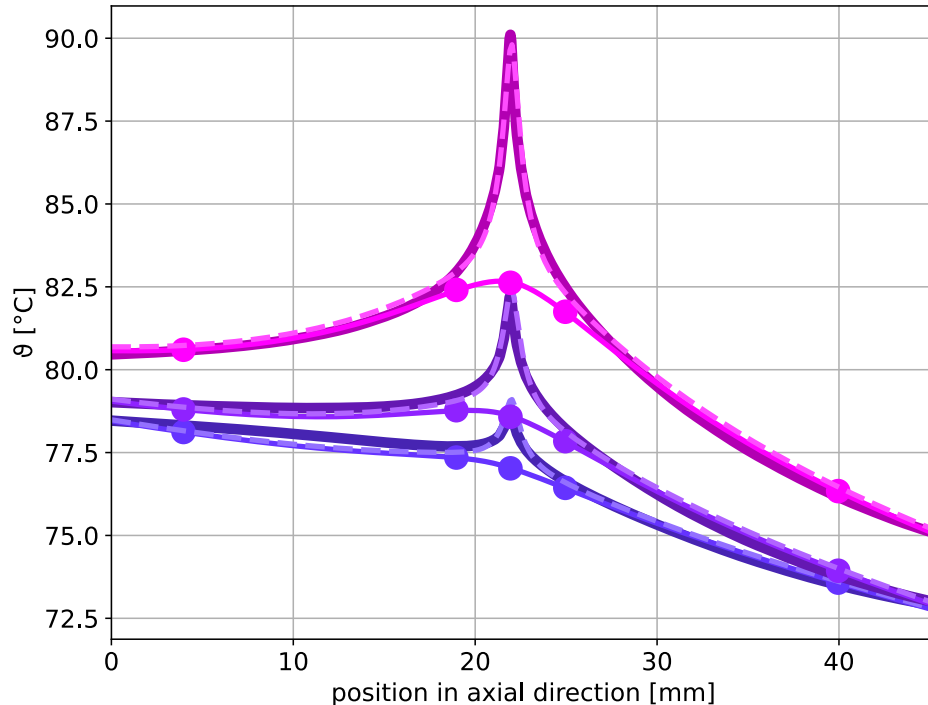
Fitted

Constants

Prediction of surface temperature based on sensor data

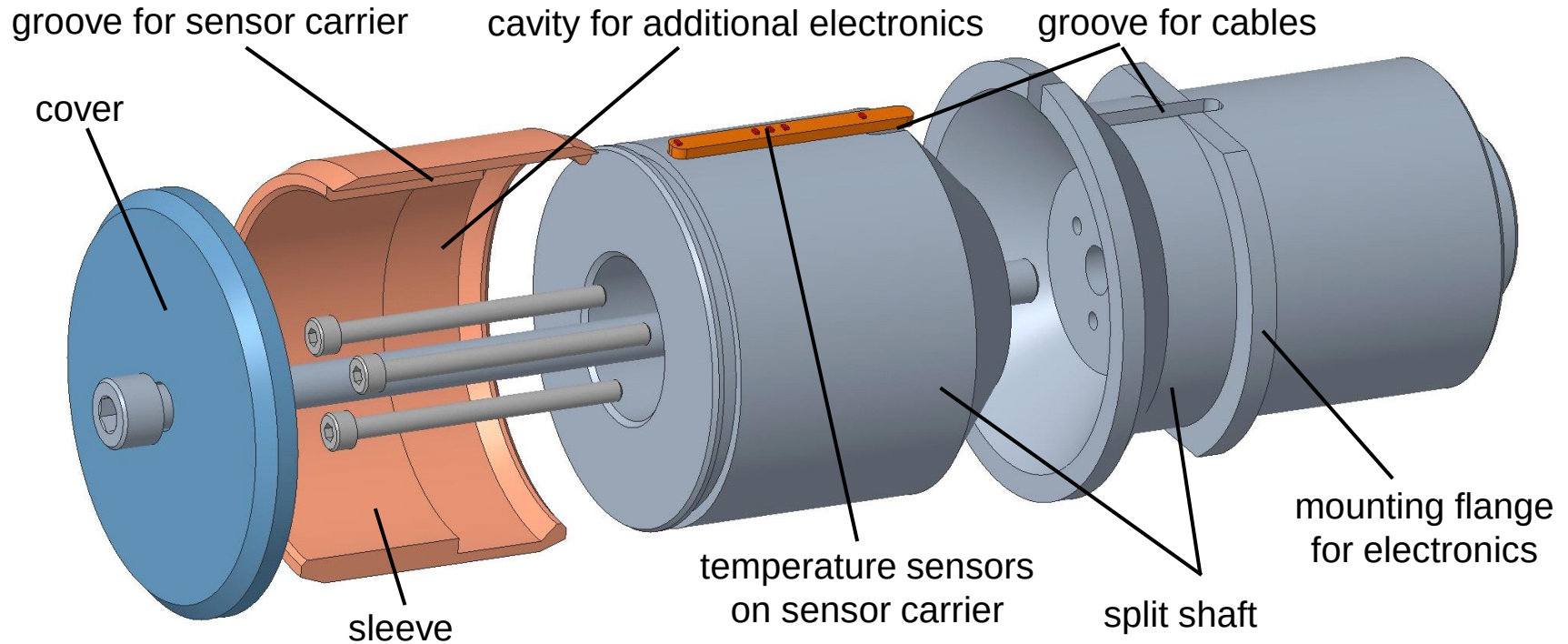
$$\vartheta_{\text{sensor}}(x) = a_1 \cdot e^{-\left(\frac{x-x_1}{b_1+|x-x_1|}\right)^2} - a_2 \cdot (x - x_1) + a_3$$

$$\vartheta_{\text{surface}}(x) = \vartheta_{\text{sensor}}(x) + b_2 \cdot a_1 \cdot e^{-\left(\frac{x-x_2}{b_3+|x-x_2|}\right)^2} \cdot b_4$$

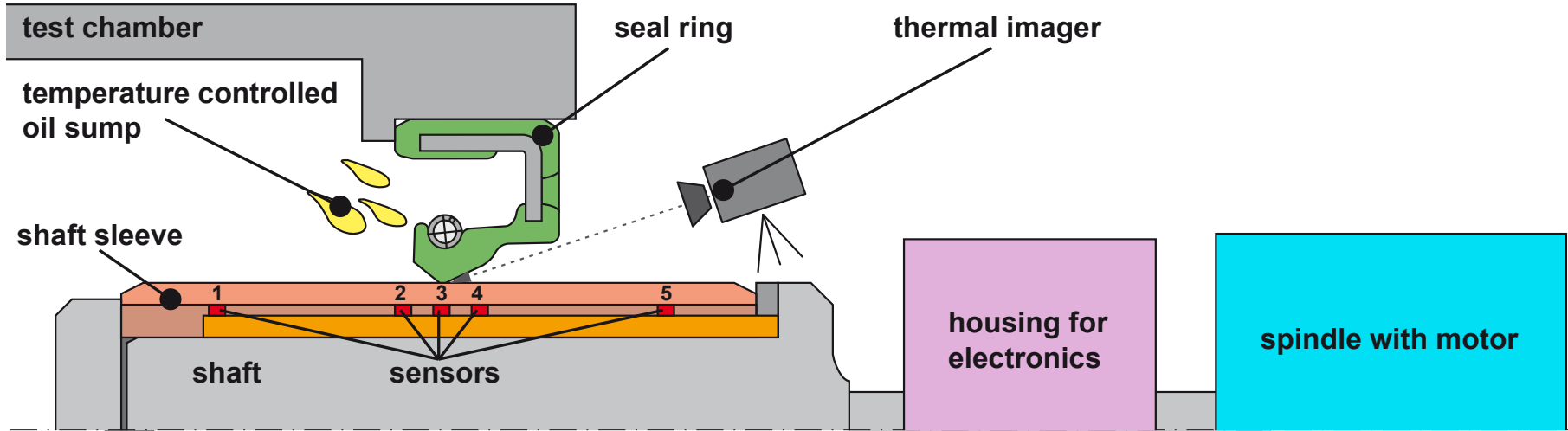


Surface and sensor temperatures based on simulations for better consistency

Second prototype

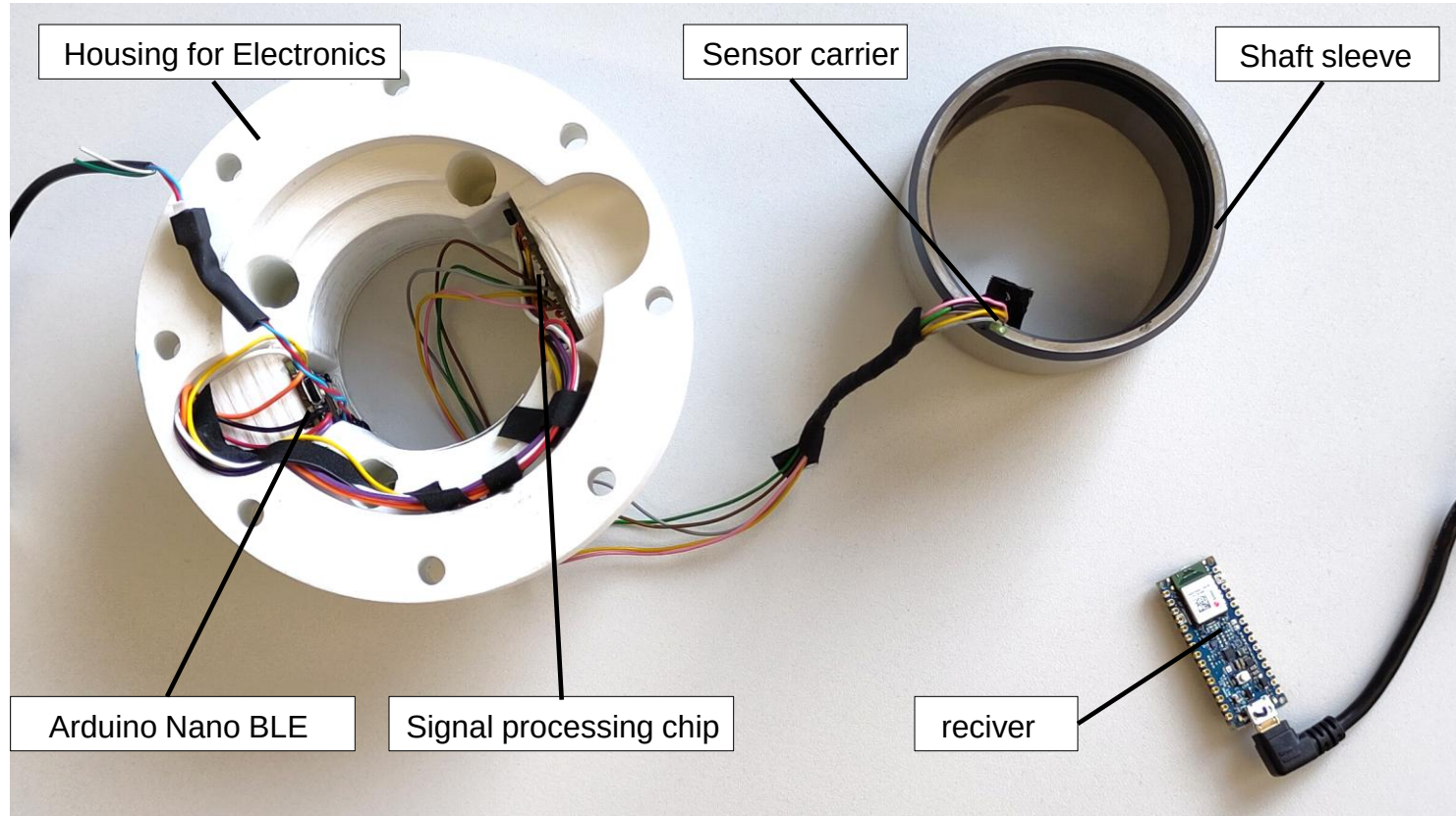


Second prototype Test bench setup



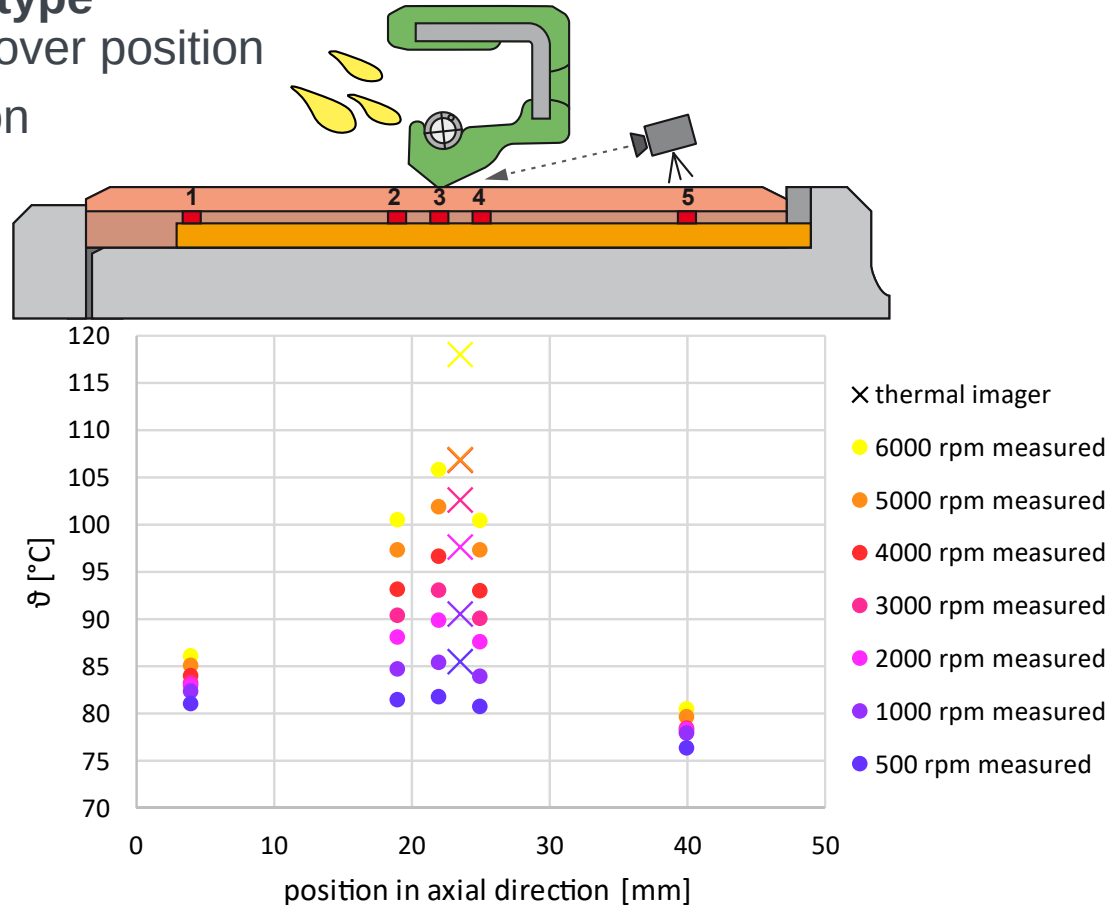
Second prototype Electronics

Everything is mounted on the rotating shaft



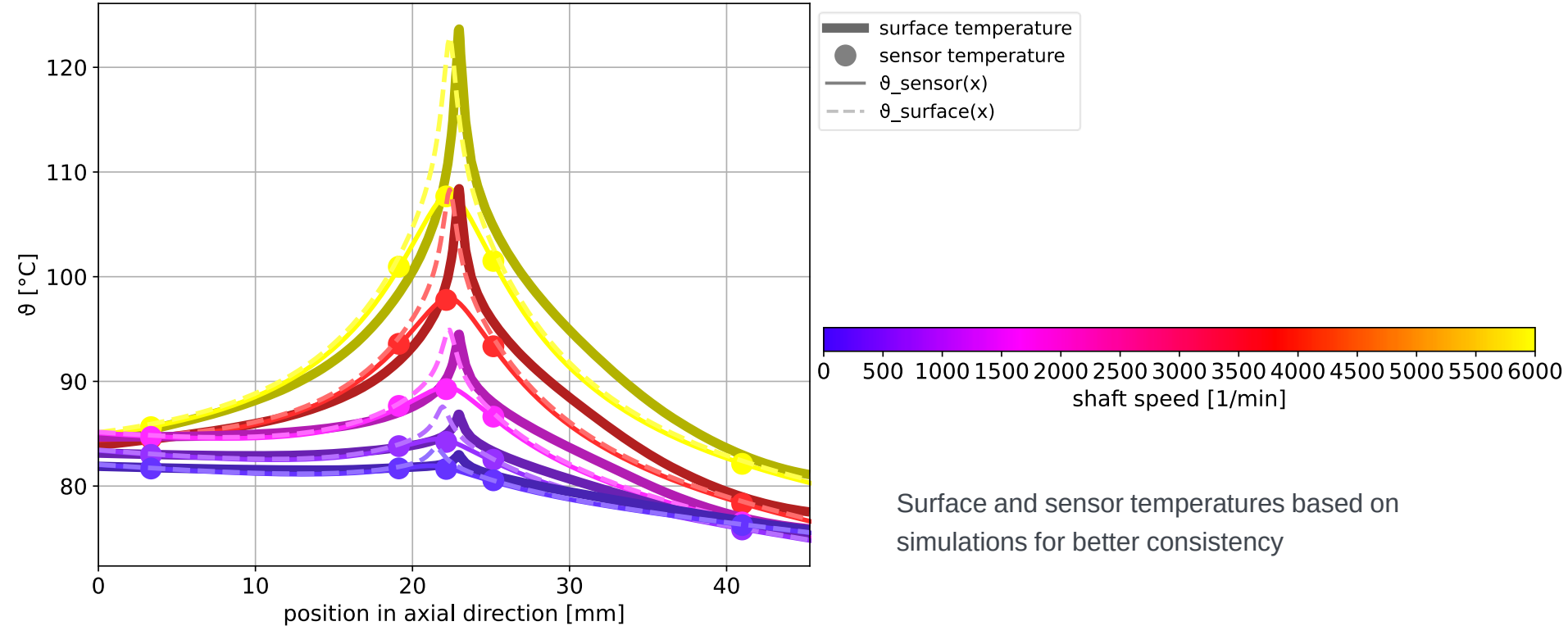
Second prototype

Temperatures over position in axial direction



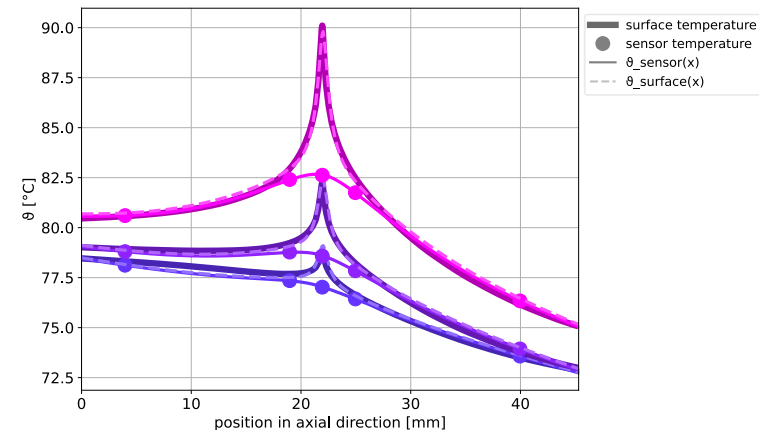
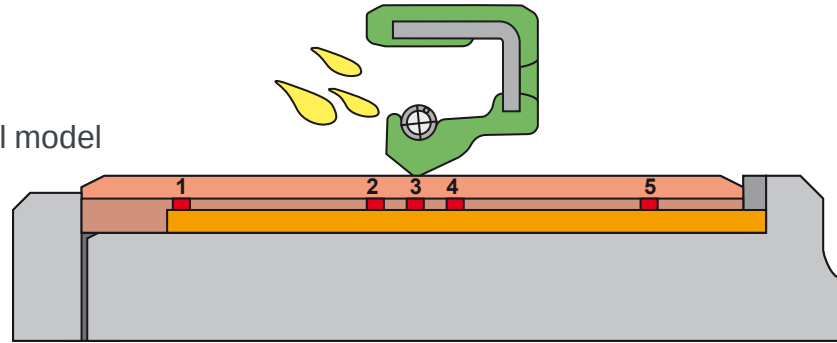
Second prototype

Prediction of surface temperature



Conclusion

- Virtual sensor for contact temperature
 - 5 sensor positions
- Prediction of surface temperature using a mathematical model
 - Based on simulations
- Advantages of the SmartSeal system
 - Comparatively low costs
 - Ease of use
 - Real-time evaluation
 - Suitable for long-term tests in real applications
 - No alteration of the tribocontact
- New possibilities
 - Adaptive operating strategies, predictive maintenance, lifetime prediction





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Thank you!



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