



Sensor Integrating Machine Elements Congress

15 – 16 September, 2026 in Darmstadt, Germany



Direct measurement of mechanical quantities via sensor-integrated machine elements —

for the design of drivetrain components and as a basis for HUMS and predictive maintenance

This presentation covers concepts and realized applications – from mechanical integration and energy supply to data transmission – and highlights their significance for HUMS and predictive maintenance.

Dr.-Ing. Stephanie Manner

CEO / Managing Director, MANNER Sensortelemetrie GmbH

Electrical Engineering and Information Technology (TU Munich) · Dr.-Ing. in aerospace engineering · formerly development engineer and project manager, Daimler AG

Co-authors: Dr.-Ing. Ernst Manner · Dr. Julia Manner

- Sensor-integrated machine elements have been a key research objective for decades – rising power density and compactness of modern drive systems continuously increase the demands on sensor integration, energy supply and data processing
- Enablers today: sensor miniaturization, energy-efficient integrated circuits and high-performance energy storage make economically feasible implementations possible and open new fields of application
- Development and prototype phase: experimental data validates numerical simulation and modern design methods – torque is the key quantity for efficiency and power flow, dynamic forces and moments reveal vibration and load behavior
- Industrialization and operation: continuous monitoring of mechanical quantities forms the basis for Health and Usage Monitoring Systems (HUMS) and predictive maintenance (PdM)
- Key challenge: minimally invasive integration – mechanical properties and function of the machine element must remain unaffected to obtain valid measurement data and enable later use for control, condition monitoring and predictive maintenance

Agenda

- 1 Motivation – why sensor-integrated machine elements?
- 2 Enabling technology: contactless telemetry
- 3 Realized:
 - Wheel Bolt
 - Torque-Sensing Sprocket
 - Chain Wheel
 - Gear Wheel
- 4 Concepts: per-revolution inductive charging and real-time wireless data
- 5 From measurement to HUMS and predictive maintenance
- 6 Summary and outlook

Motivation – Why Sensor-Integrated Machine Elements?

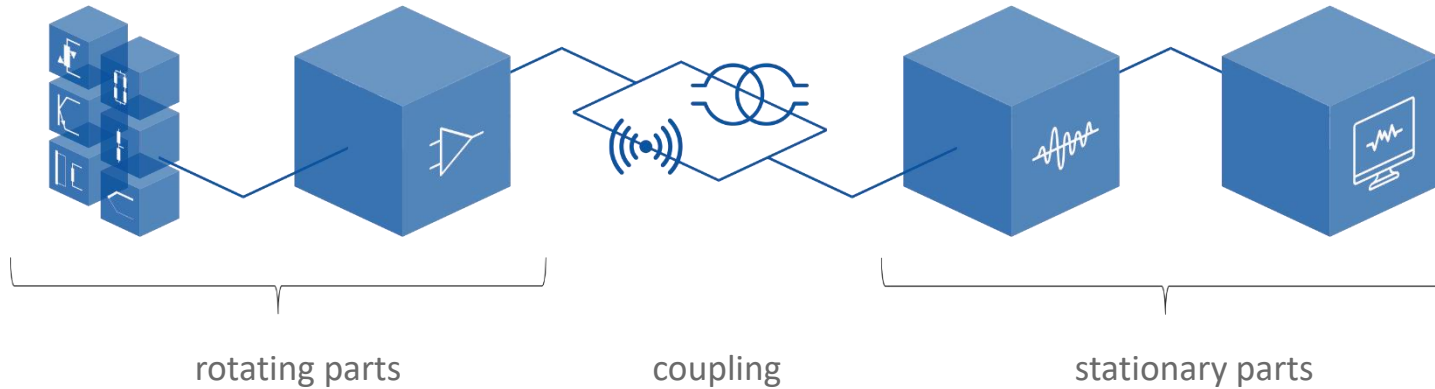
- Development phase: experimental validation of simulation and design methods
- Prototype phase: torque as the key quantity for efficiency and power flow
- Dynamic forces and moments reveal vibration and load behavior
- Operation: continuous monitoring as the basis for HUMS and predictive maintenance
- Requirement: minimally invasive integration – measure without changing the machine element

Enabling Technology

Telemetry – Contactless Energy Supply and Data Transfer

- Working principle: inductive energy transfer to the rotating part – no batteries, no slip rings
- Sensor signal conditioning on the rotor, digital contactless data transmission to the stator
- Minimally invasive integration: mechanical properties of the machine element remain unaffected
- Basis for all applications and concepts shown in this presentation

Known and Proven Principle of Telemetry



MANNER Software
incl. Data recording

Can Bus (digital)

Ethernet (digital)

EtherCAT (digital)

USB (digital)

Spannung

Electricity

Frequenz

remote control

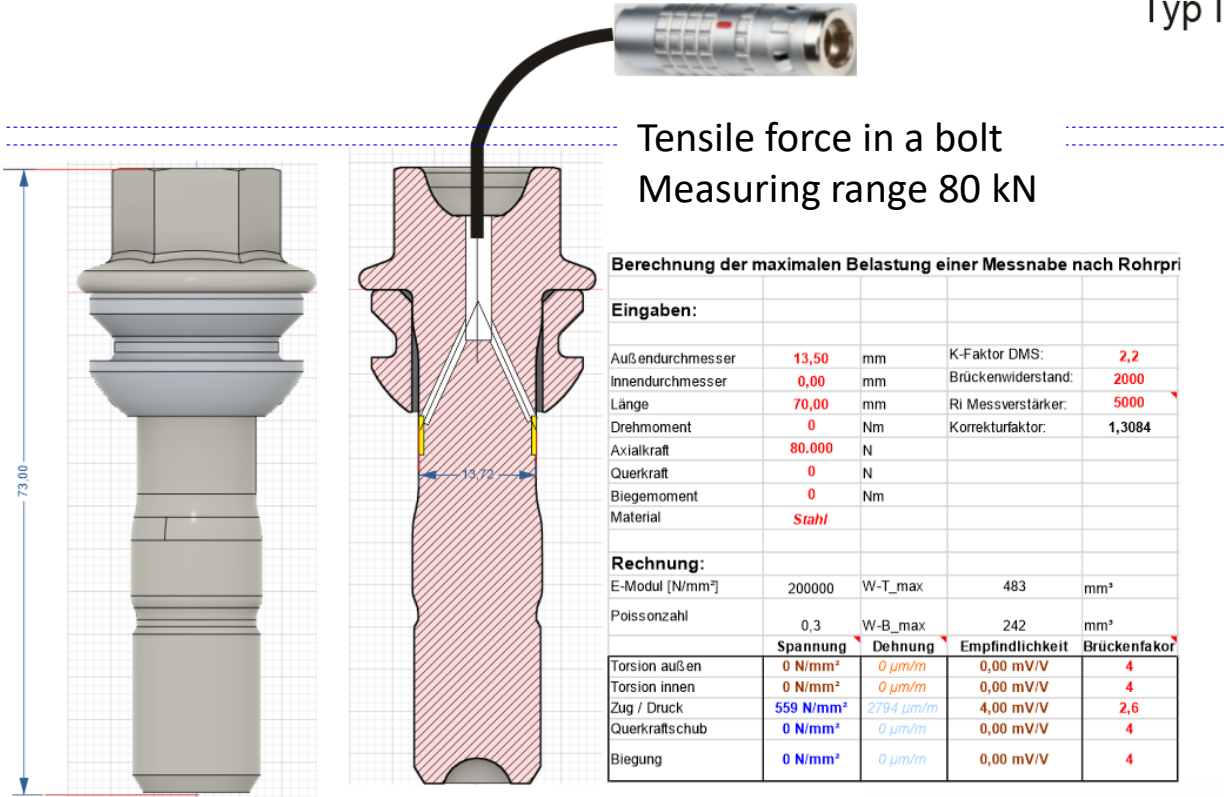
Realized: Torque-Sensing Wheel Bolt

- Task: direct measurement of the tightening torque of a passenger car wheel bolt
- Standard wheel bolt geometry and function retained – minimally invasive sensor integration
- Measurement chain: strain measurement in the bolt, radio telemetry for data transmission, energy supply by batteries
- Ensures a correctly preloaded wheel joint – safety-relevant fastening made measurable

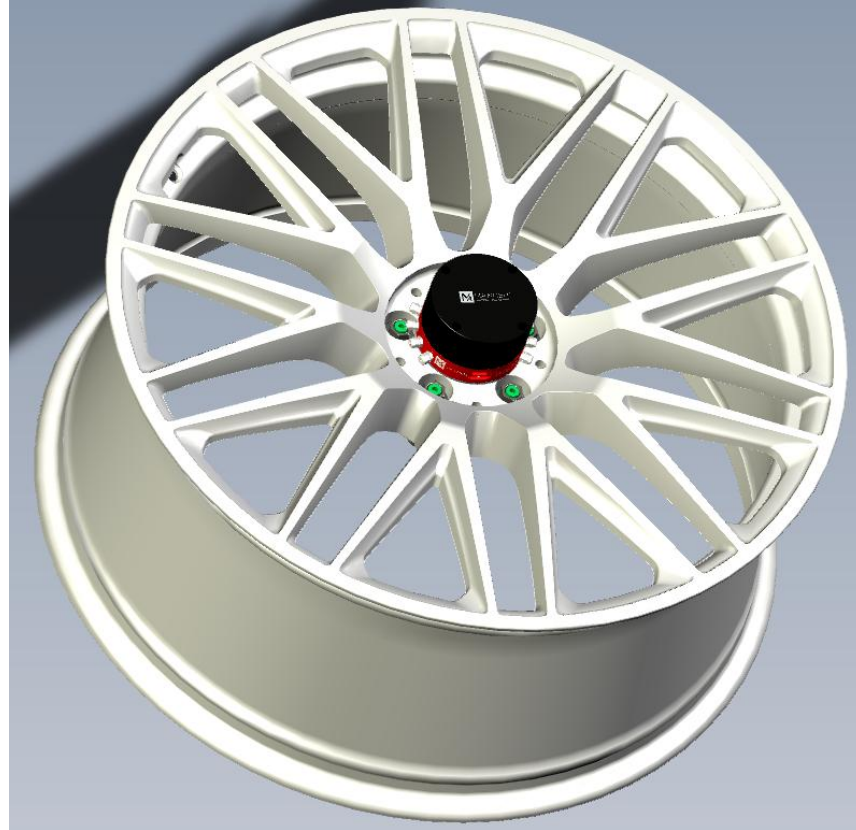


Realized: Torque-Sensing Wheel Bolt

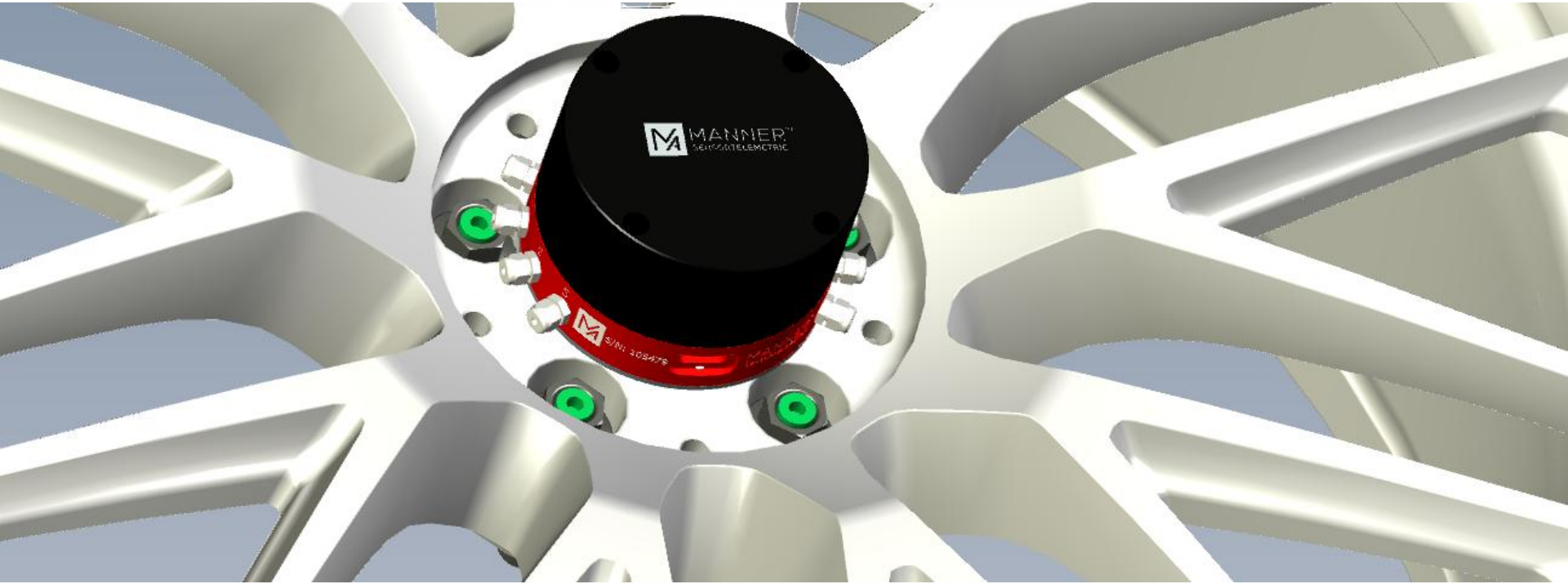
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Realized: Torque-Sensing Wheel Bolt

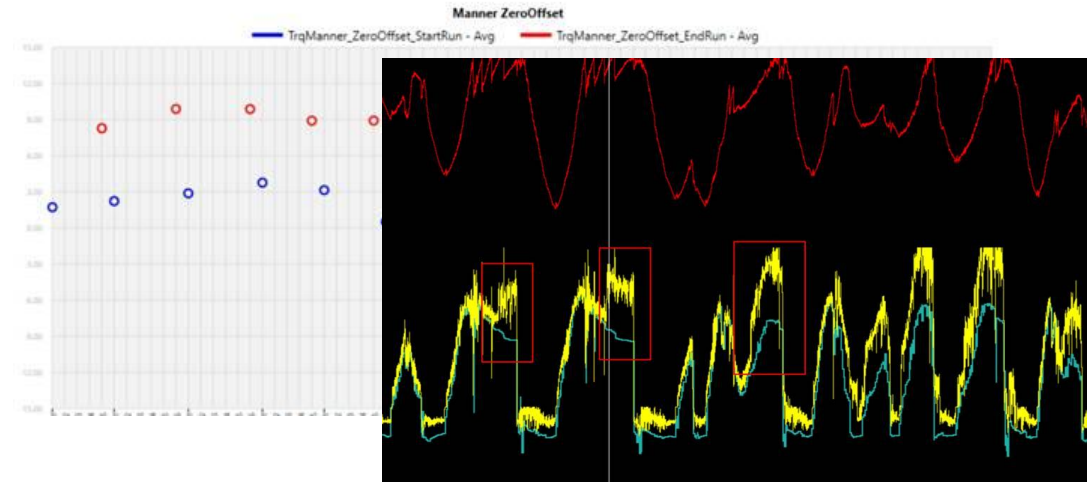


Realized: Torque-Sensing Wheel Bolt

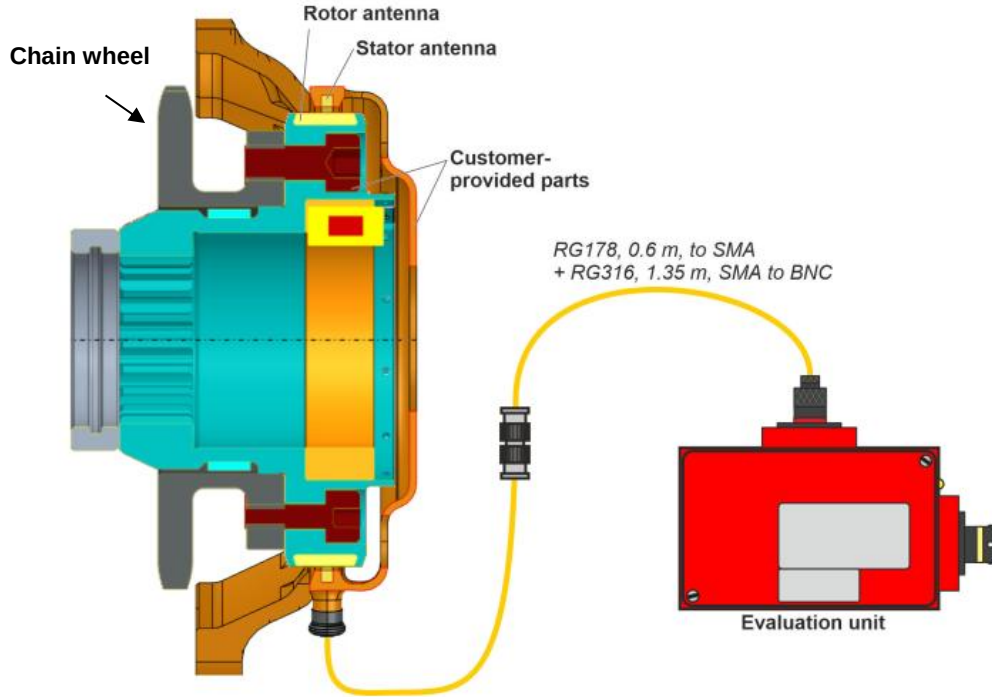


Realized: Torque-Sensing Motorcycle Sprocket

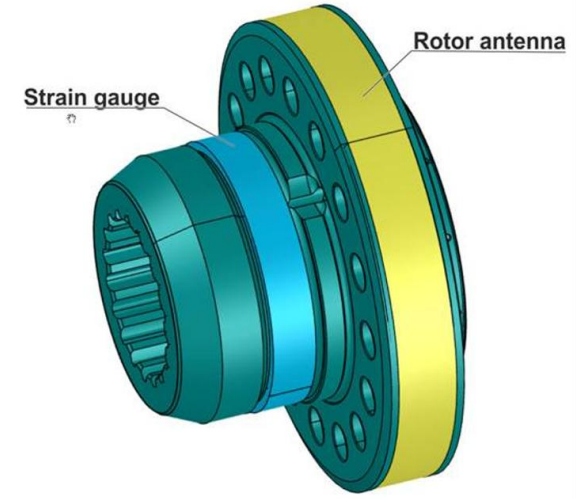
- Task: direct torque measurement at the rear sprocket under real riding conditions
- Sensor integration into the sprocket without changing its mechanical function
- Constraints:
 - limited installation space
 - shock/vibration
 - dirt
 - temperature



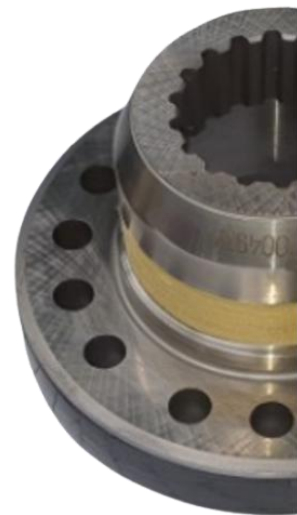
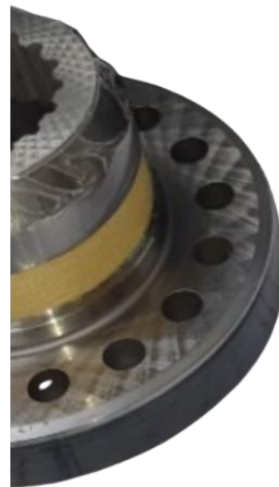
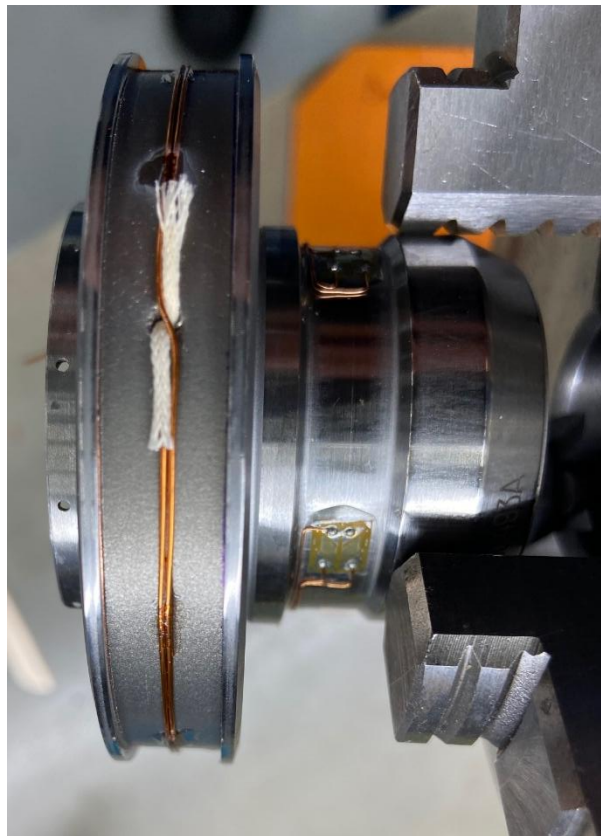
Realized: Torque-Sensing Motorcycle Sprocket



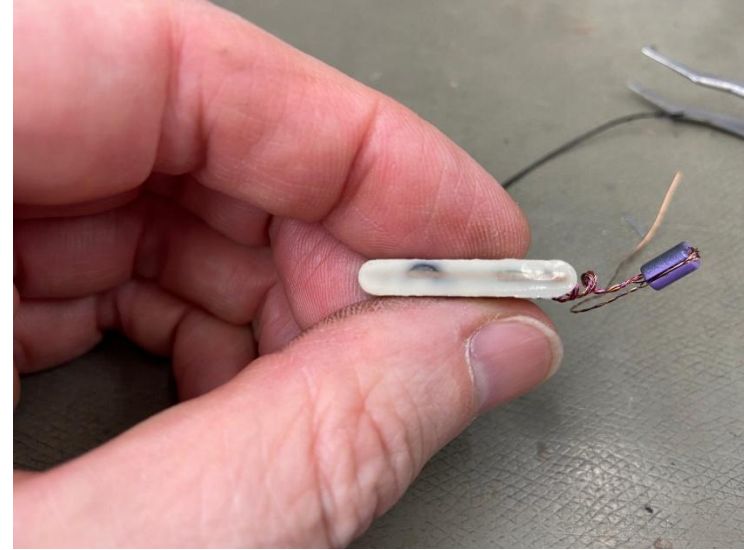
ig. 14: Coupling



Rear Sprocket Integrated Torque Sensor



Rear Sprocket - Power Supply and Brain



Rear Sprocket - Final



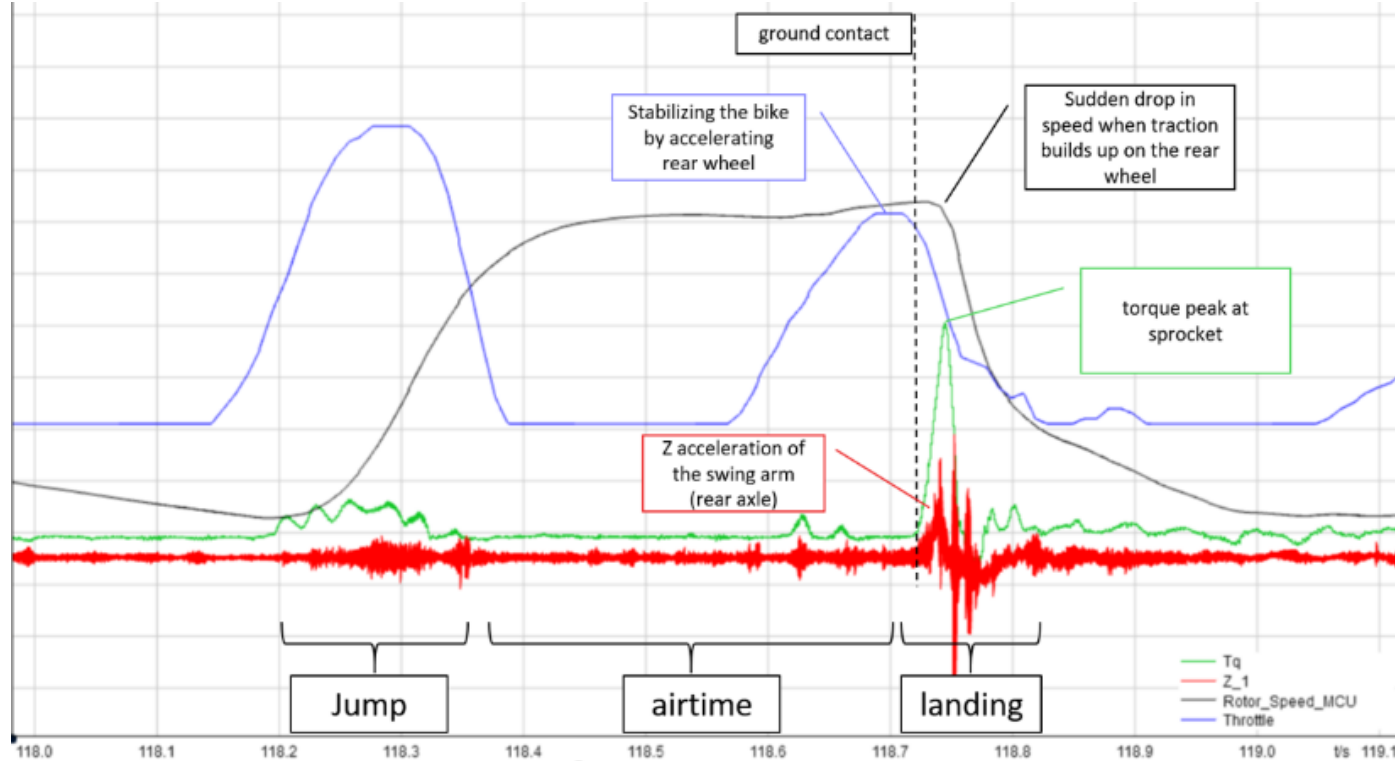
Torque-Sensing Sprocket – Lessons Learned

- Sensor integration into a highly loaded, exposed machine element is feasible in practice
- Robustness proven under real riding conditions – shock, vibration, dirt, temperature
- Limitation: space is a constraint – very time and skill consuming sensor integration

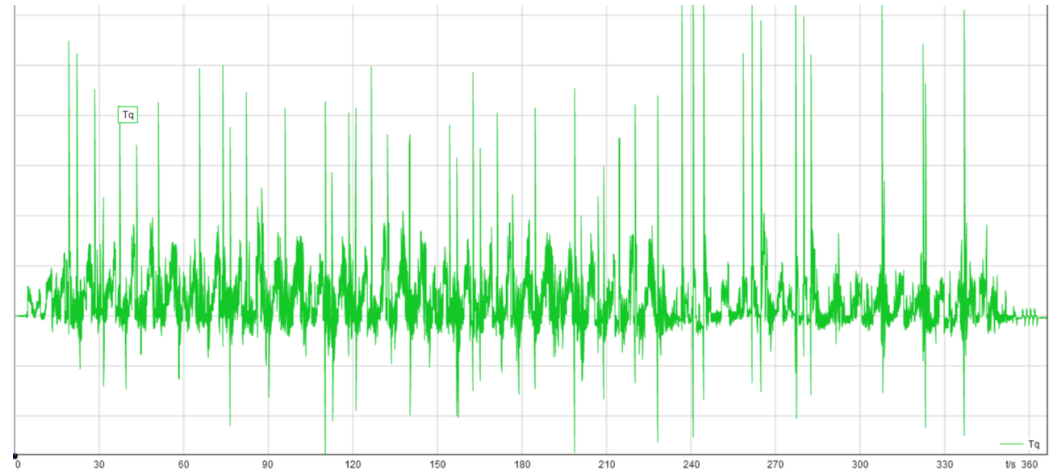
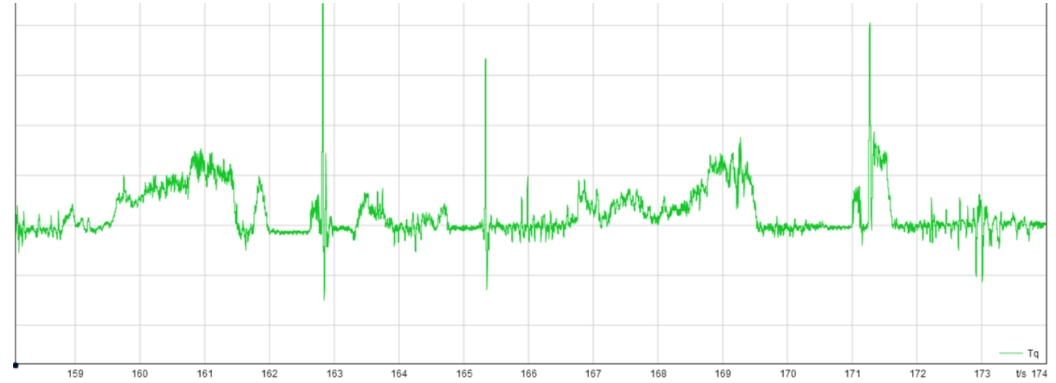
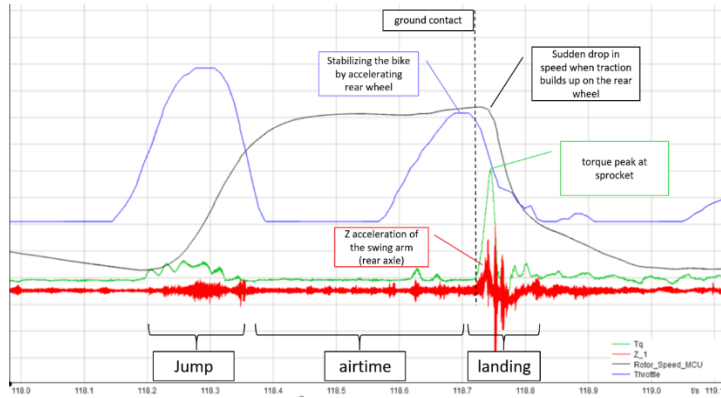
Realized: Chain Wheel



Realized: Torque-Sensing Chain Wheel



Realized: Torque-Sensing Chain Wheel

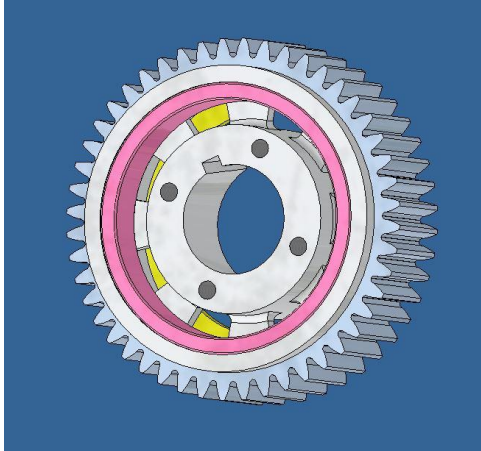
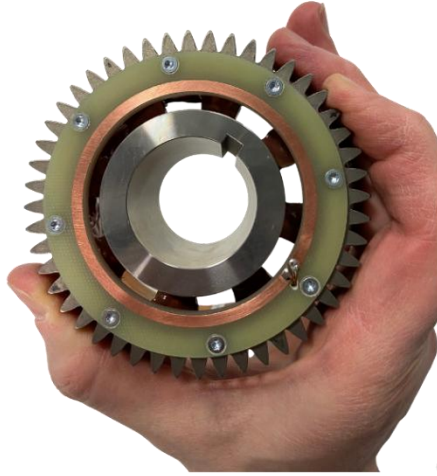
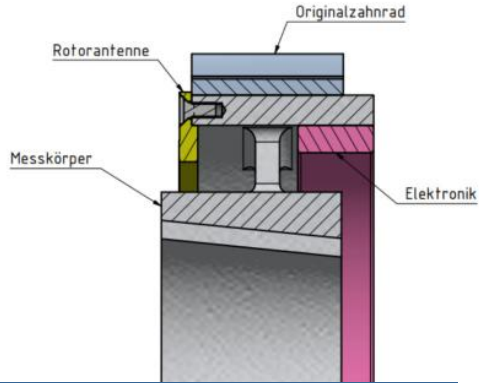


Torque-Sensing Chain Wheel – Lessons Learned

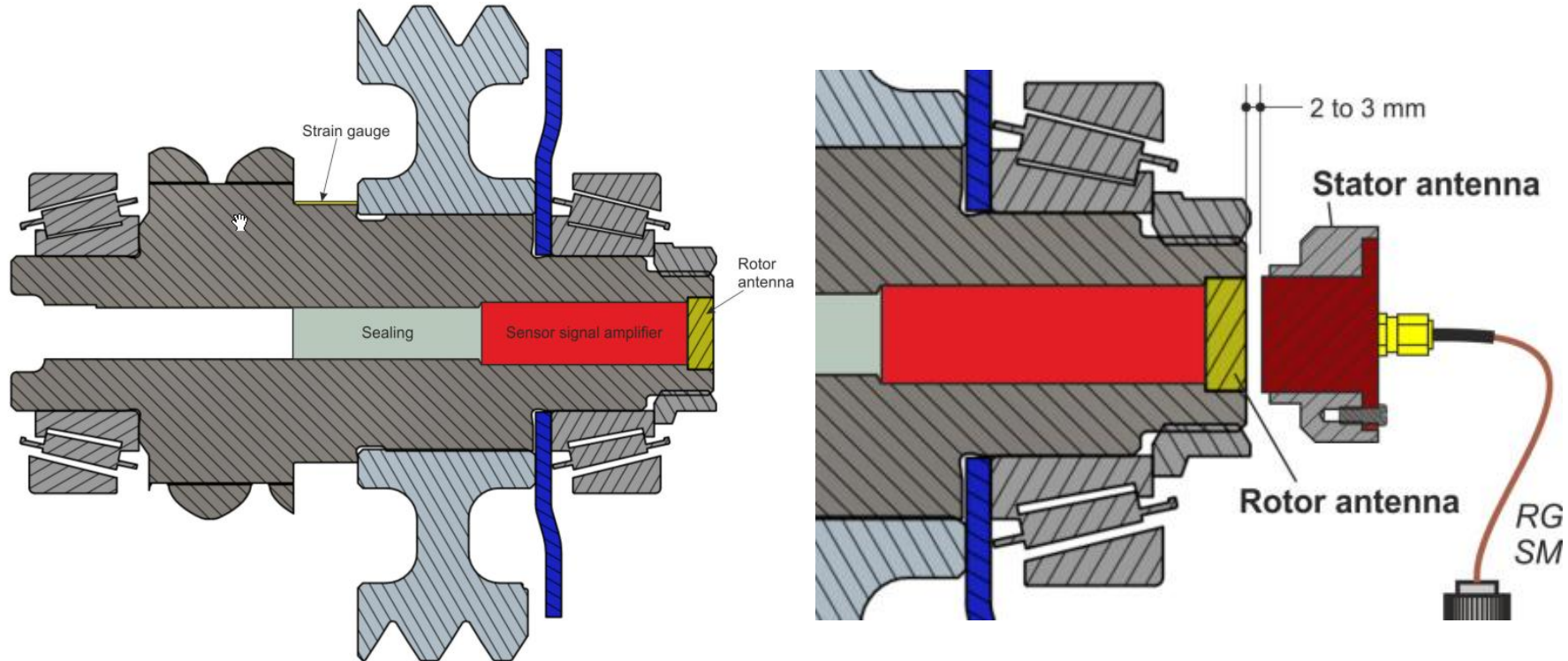
- Sensor integration into a highly loaded, exposed machine element is feasible in practice
- Robustness proven under real riding conditions – shock, vibration, dirt
- Limitation: miniaturization only to a certain degree

Realized: Gear Wheel – Torque and Axial Load

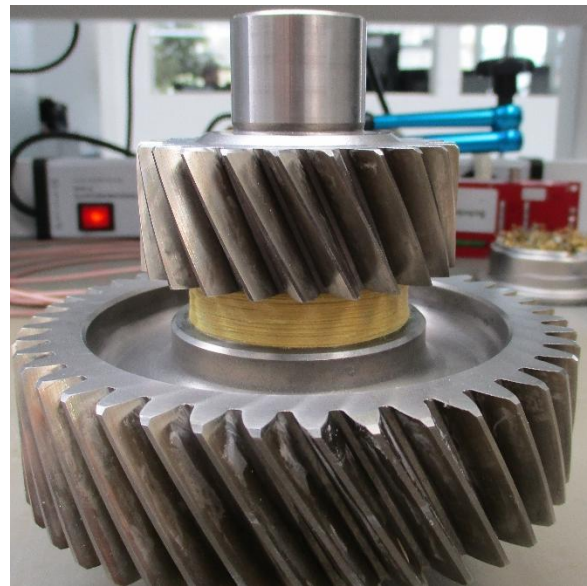
Zusammenbau Messzahnrad



Realized: Gear Wheel – Torque and Axial Load



Realized: Gear Wheel – Torque

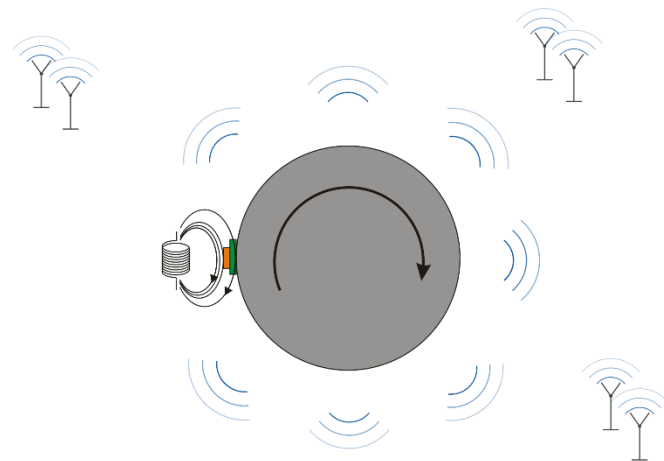


Challenges for Integrated Sensors

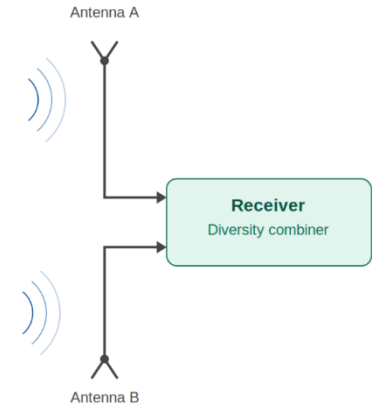
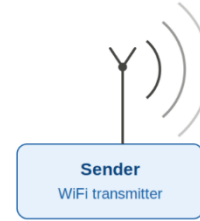
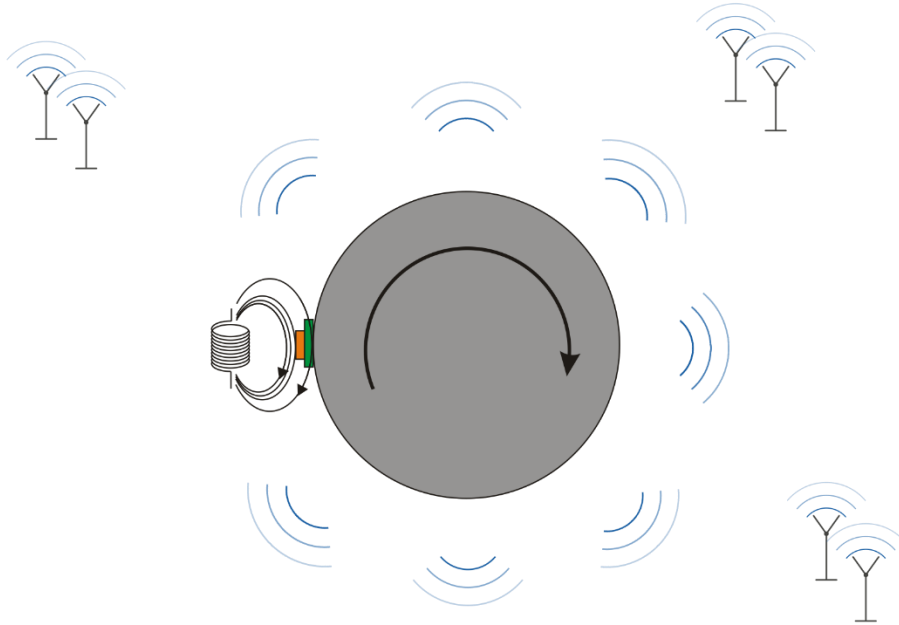
- From development testing towards continuous operation – what has to change?
- Challenge 1: energy – continuous measurement needs a continuous energy budget
- Challenge 2: data – real-time availability of measurement data during operation
- Challenge 3: miniaturization
- Challenge 4: cost and robustness – sensor-integrated machine elements as products

Concept: Once-per-Revolution Inductive Charging

- Idea: a stationary charging segment transfers energy inductively once per revolution
- Energy is buffered on the rotating part – sufficient budget for continuous measurement
- No wear, no slip rings, independent of speed range after start-up
- Enables permanently installed, self-sufficient sensing in machine elements



Concept: Once-per-Revolution Inductive Charging

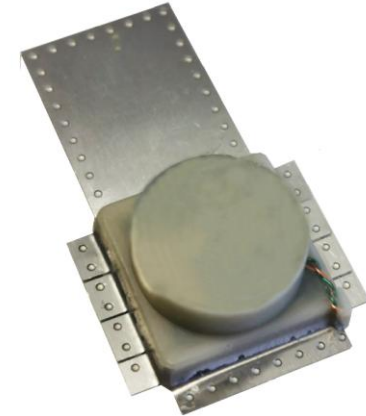
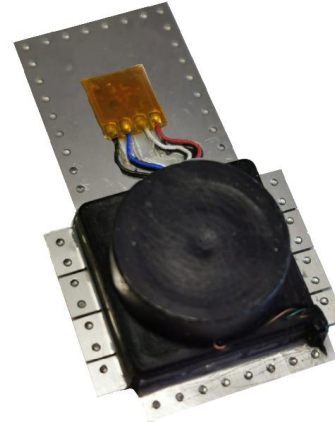


Concept: Real-Time Wireless Data Transmission

- Measurement data is transmitted from the rotating part via radio in real time
- Continuous data stream during operation – no on-board logging, no downtime for read-out
- Synchronized, low-latency data as input for control, monitoring and analytics
- Combination with per-revolution charging: fully autonomous measuring machine element

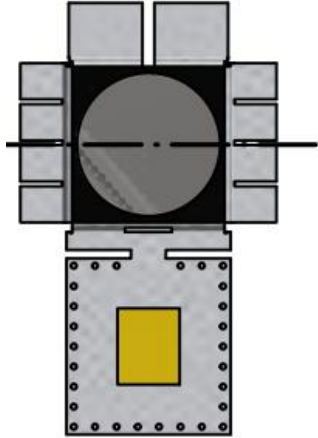
Concept: MANNER TelMA Sensor

- TelMA: compact torque measurement integrated directly into the drivetrain
- Sensor, signal conditioning and telemetry combined in one machine element
- Designed for series use: robust, calibrated, minimally invasive
- Bridges the gap between test-bench measurement and permanent in-service monitoring

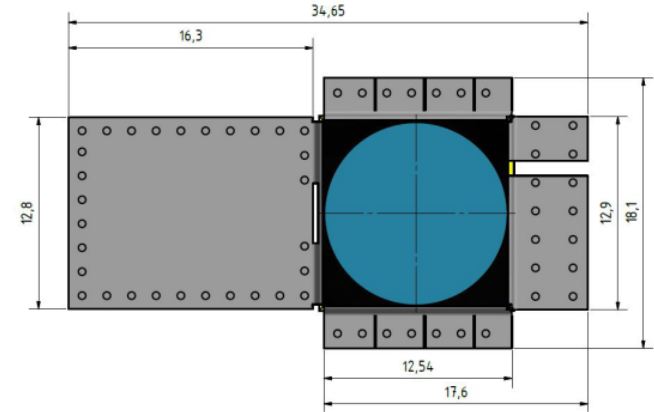
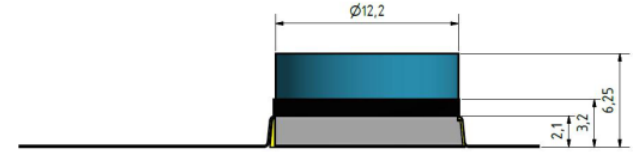
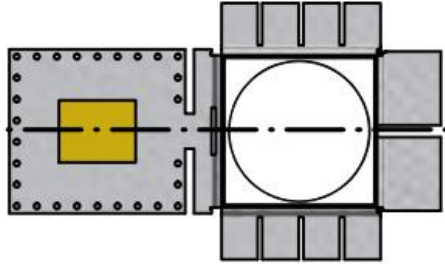


Concept: MANNER TelMA Sensor

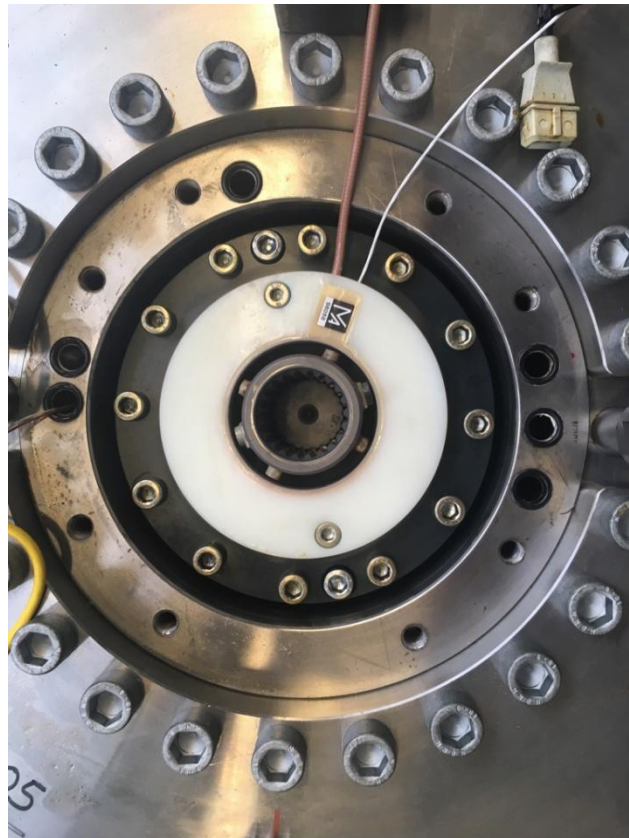
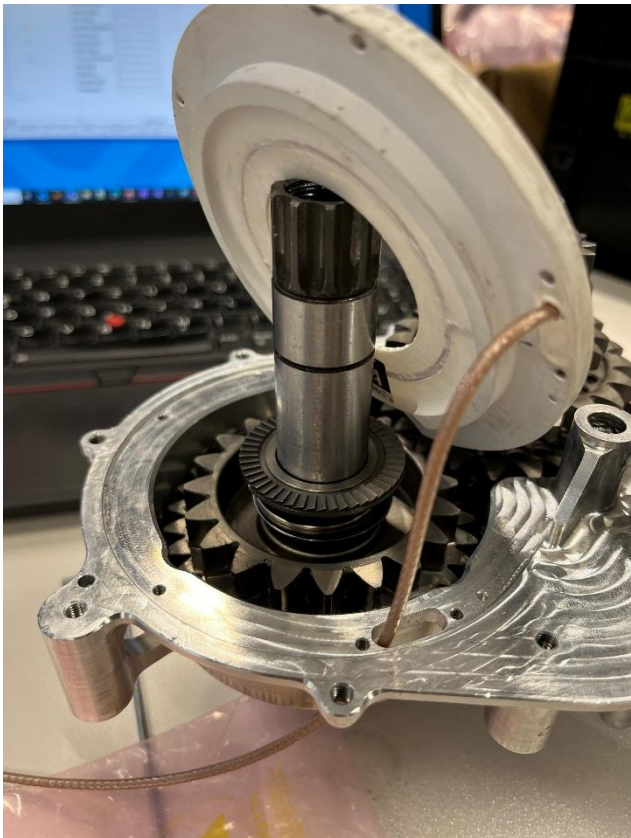
Tangentiale Montage
Vergussfarbe schwarz
Serien-Nr. SV_Q_...



Axiale Montage
Vergussfarbe weiß
Serien-Nr. SV_Qq_...



Concept: MANNER TelMA Sensor



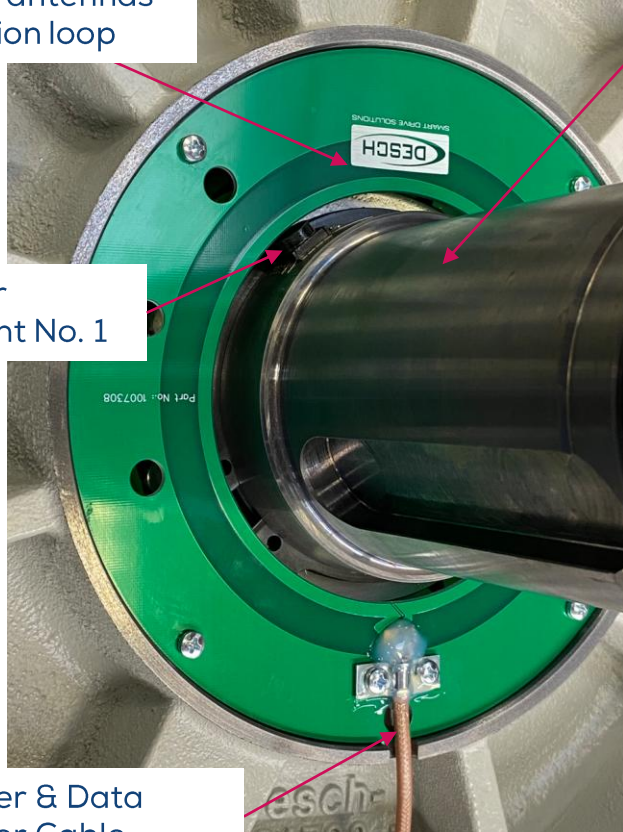
Concept: MANNER TelMA Sensor

Stator antennas
Induction loop

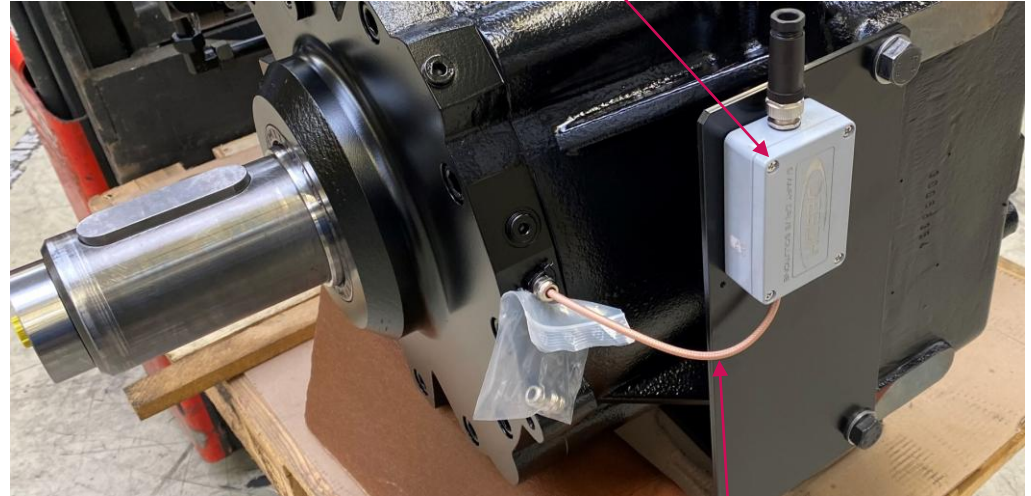
Shaft body

Sensor
Element No. 1

Power & Data
Stator Cable



Evaluation unit
IP67



Power & Data
Stator Cable

From Measurement to HUMS and Predictive Maintenance

- Continuous mechanical quantities enable Health and Usage Monitoring Systems (HUMS)
- Load spectra from real operation feed back into design and lifetime models
- Predictive maintenance: detect anomalies before failure, plan service on condition
- Sensor-integrated machine elements as data source for the digital twin

Summary and Outlook

- Realized: torque-sensing sprocket, chain wheels, bolts, gears – minimally invasive integration proven in practice
- Concepts: per-revolution inductive charging, real-time wireless data, TelMA sensor as a first ready to use sensor
- Path forward: new micronized sensors, ultra low energy budget circuits, robust low energy data transmission or logging
- Foundation for HUMS, predictive maintenance and data-driven design
- Thank you for your attention – questions welcome

Our production and Knowhow is in Germany
- providing worldwide solutions is our aim!



Dr. Julia Manner, Dr. Stephanie Manner, Dr. Ernst Manner

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