

Functional Validation of a Sensor-Integrating Jaw Coupling for Torque Estimation

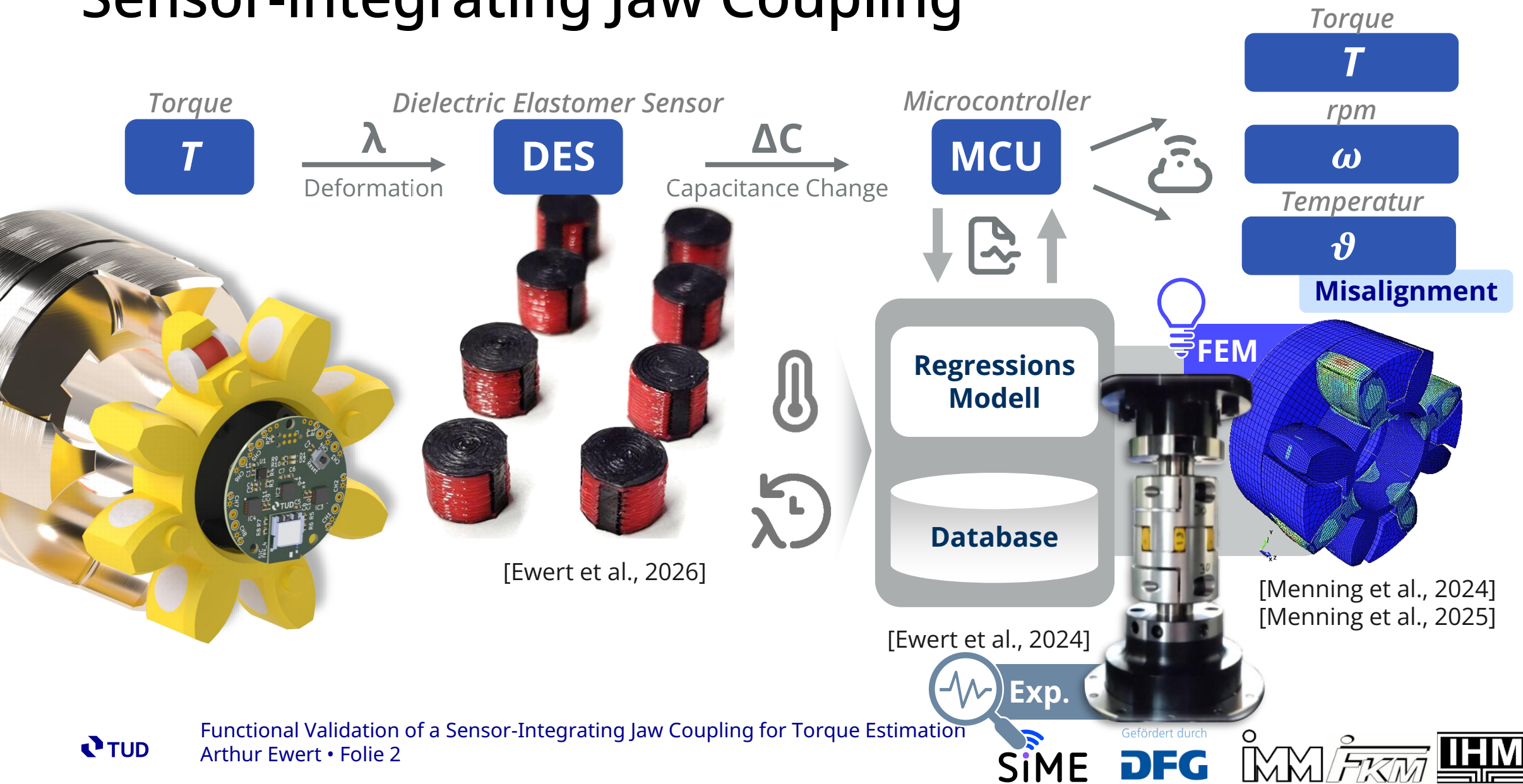
A. Ewert¹, J. Menning², A. Prokopchuk³, T. Rosenlöcher¹,
M. E.-F. Vorrath³, T. Wallmersperger², B. Schlecht¹

¹ Institute of Machine Elements and Machine Design, IMM

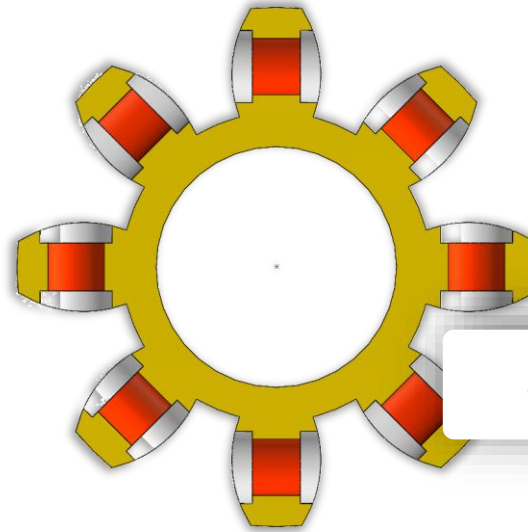
² Institute of Solid Mechanics, IFKM

³ Institute of Semiconductors and Microsystems, IHM

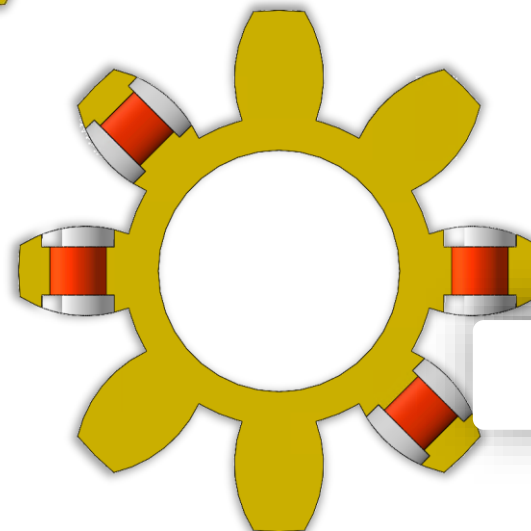
Sensor-integrating Jaw Coupling



Components – Gear Rim



8 x Sensor Tooth

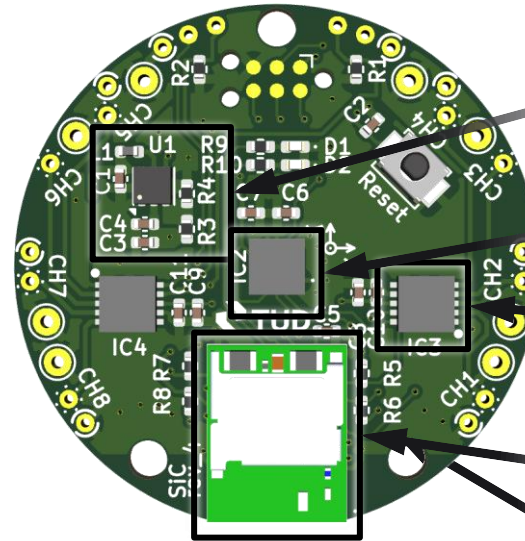
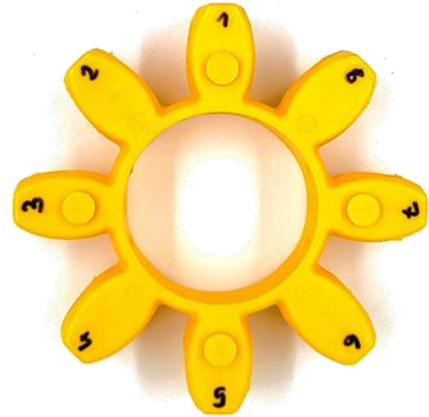


4 x Sensor Tooth

Modifications

- Counterbore
- Removing the Bridge

Components – Electronics



Power Management

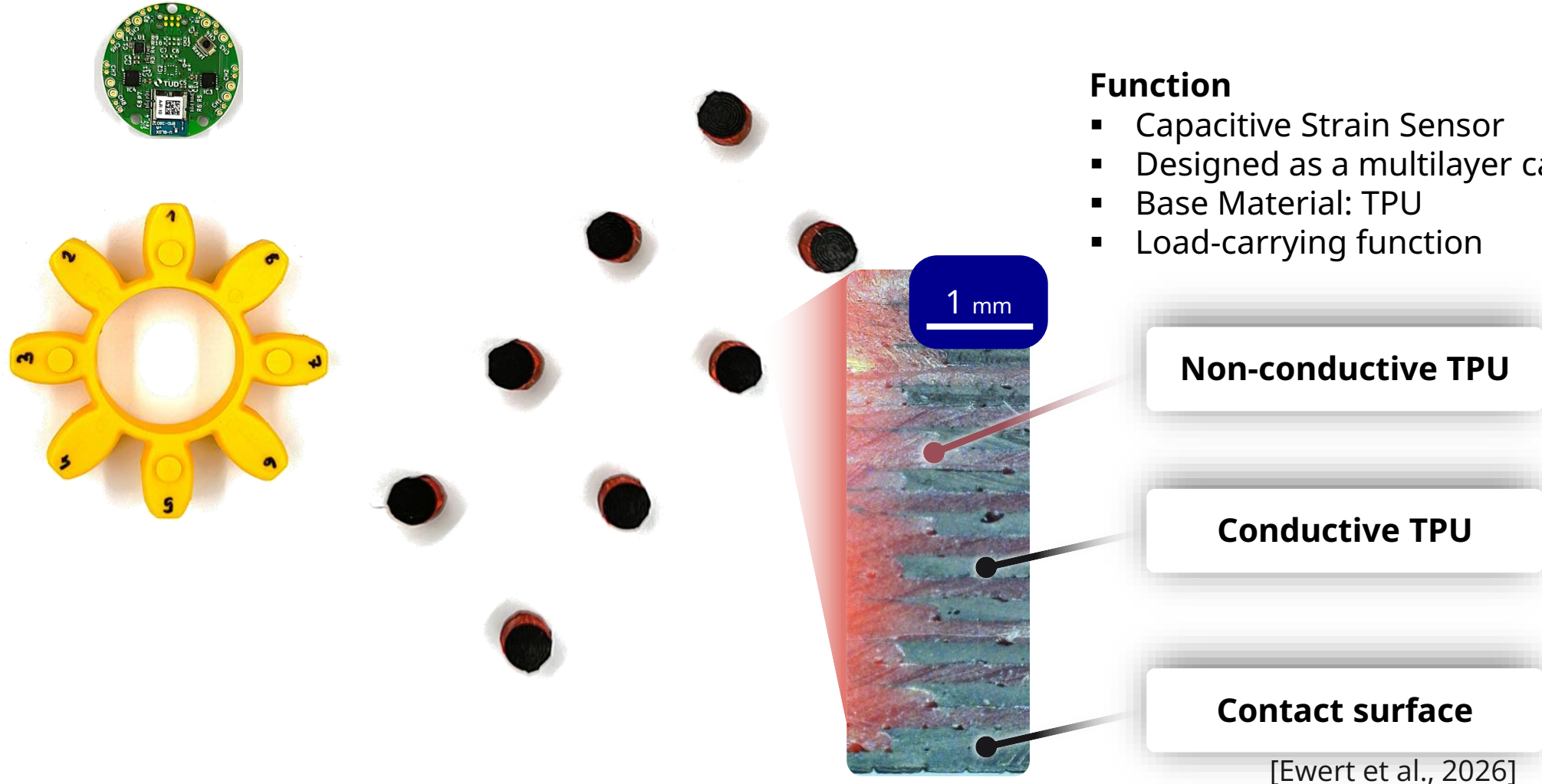
IMU

**2 x Capacitance to
digital converter**

Mikrocontroller

Battery

Components – Sensor

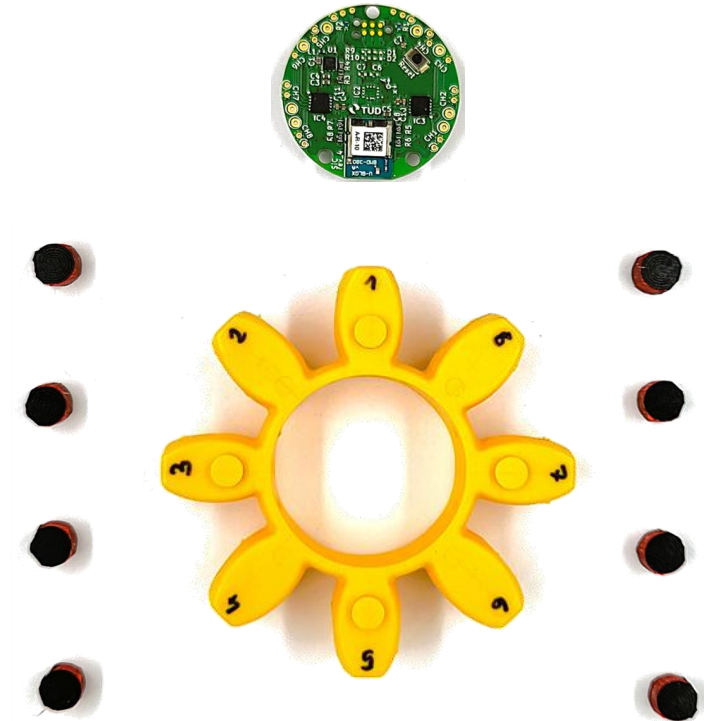


Function

- Capacitive Strain Sensor
- Designed as a multilayer capacitor
- Base Material: TPU
- Load-carrying function

[Ewert et al., 2026]

Components – Contact Caps



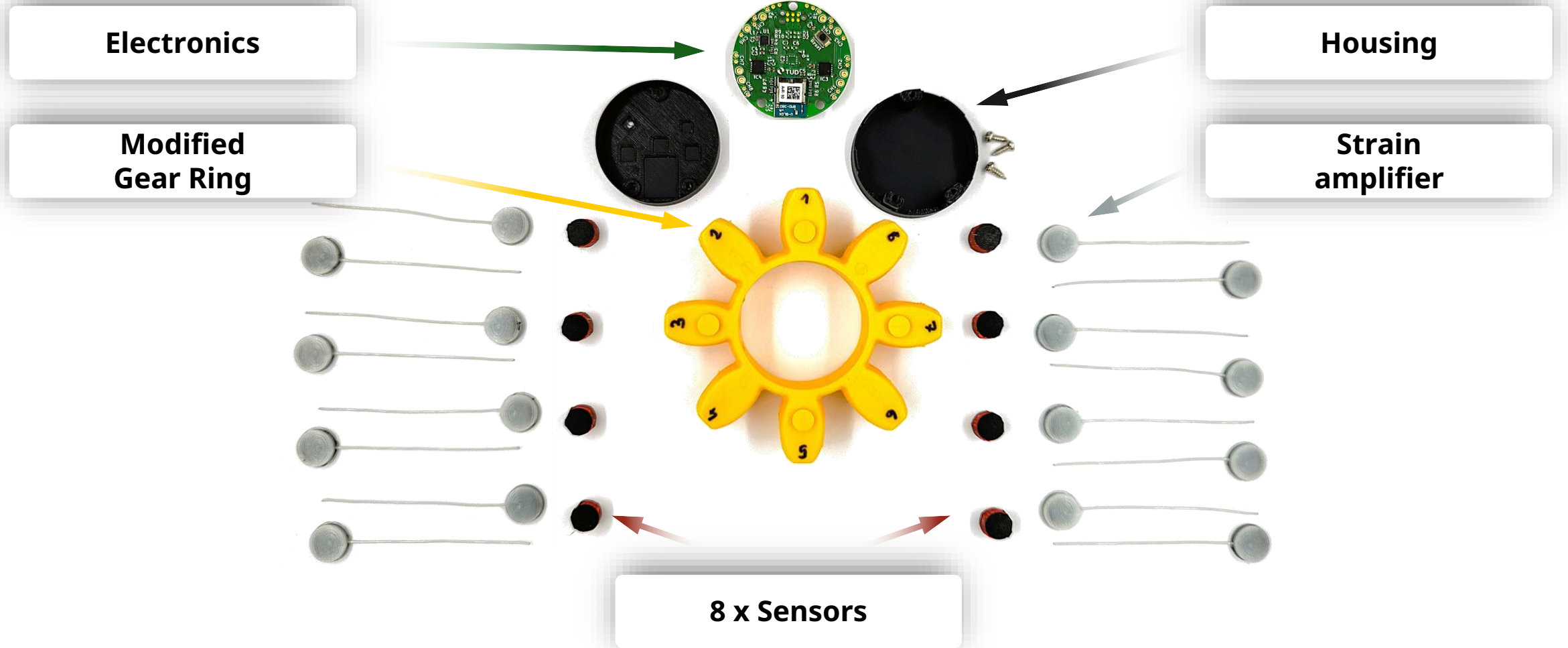
Function

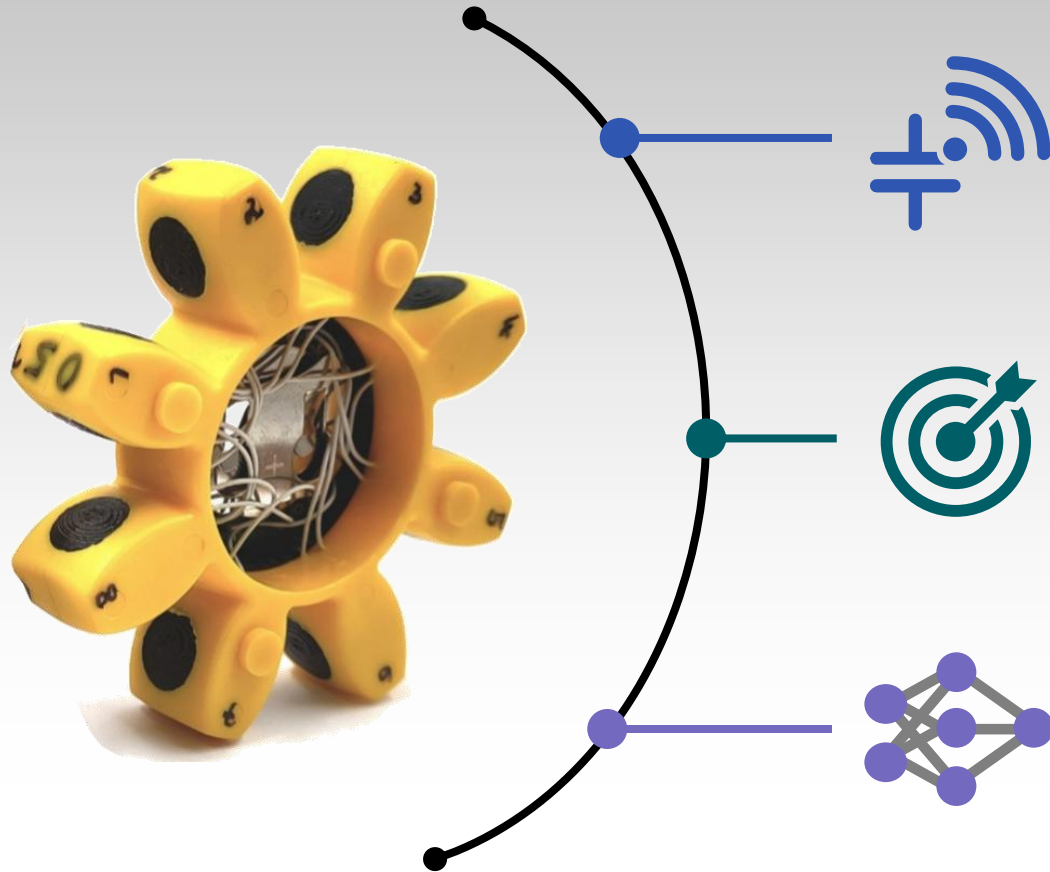
- Connection points to the DES
- Insulation

Strain Amplifier

**Coaxial Cable
With AWG 36 wire**

Components





Sensors

Can the sensors withstand the stresses in the load path?

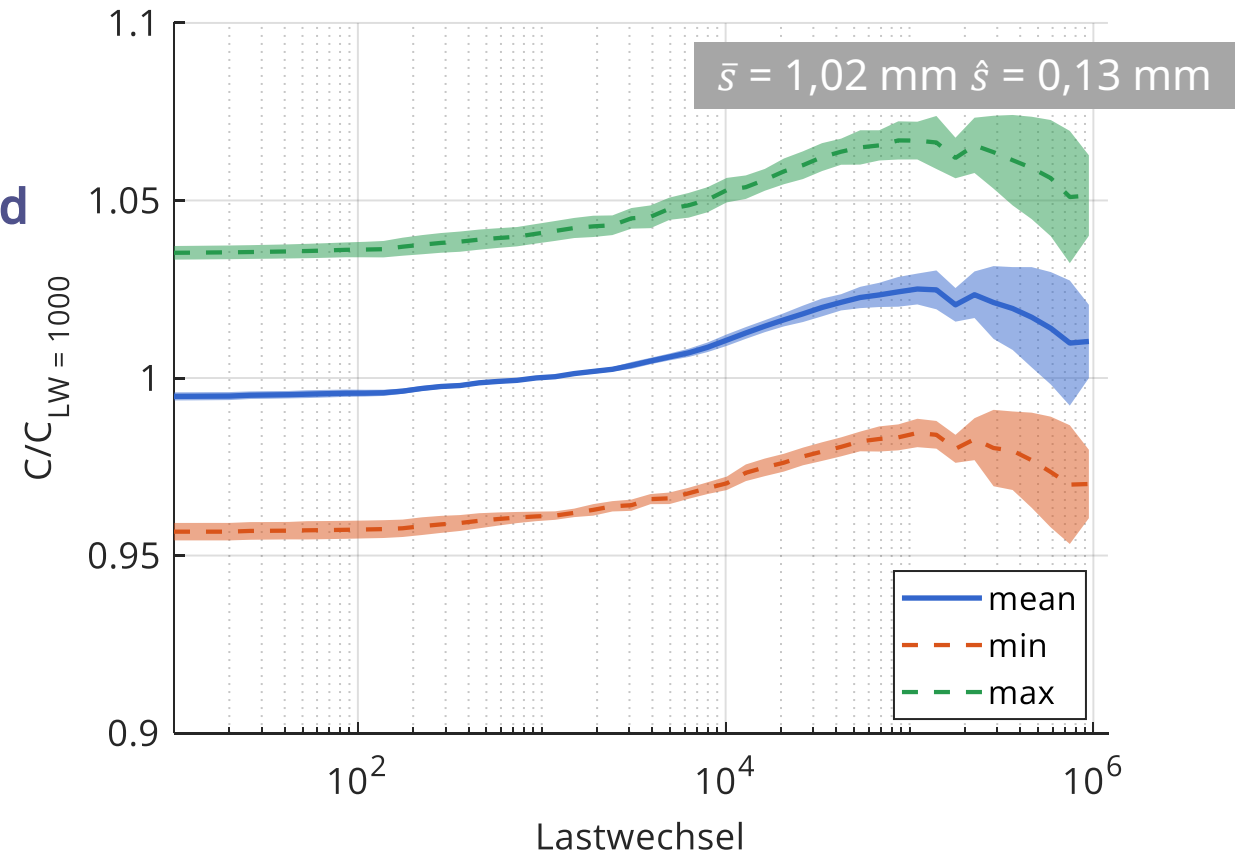
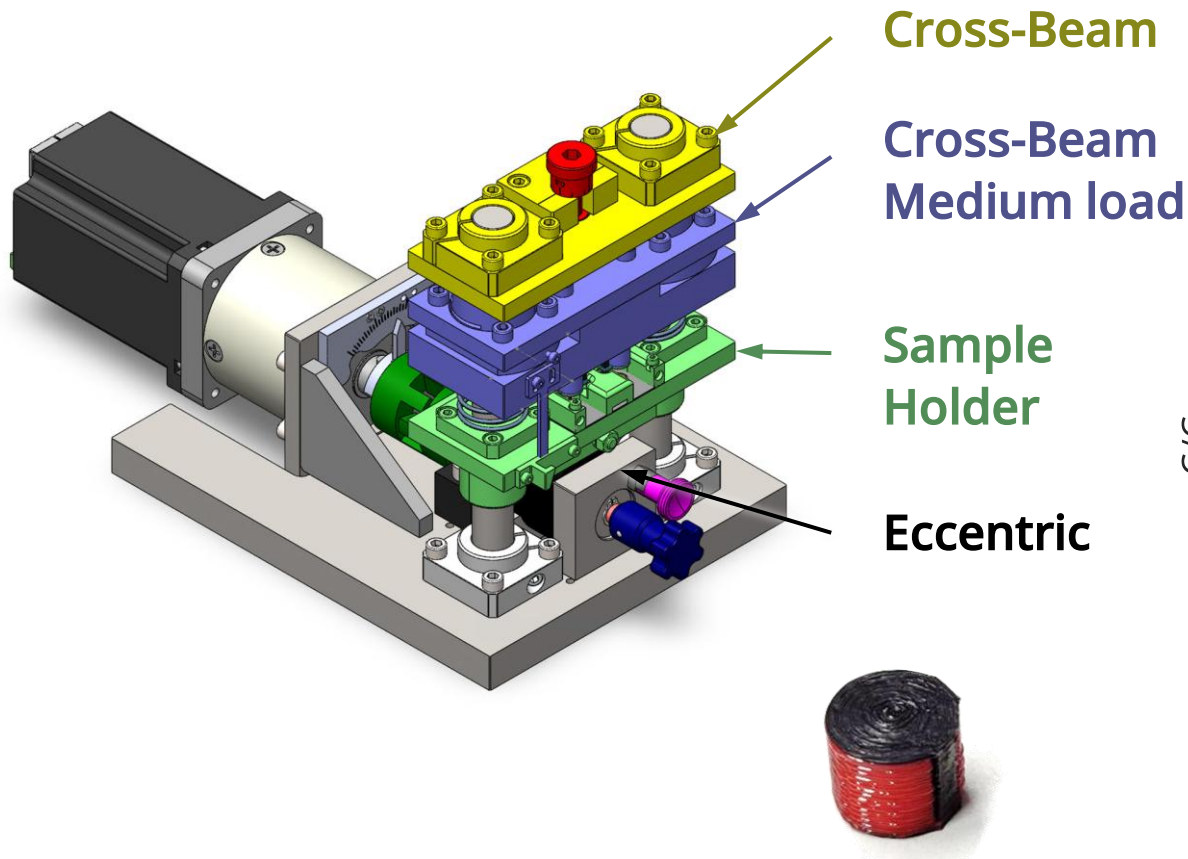
Mechanics

How does sensor integration affect load-bearing capacity?

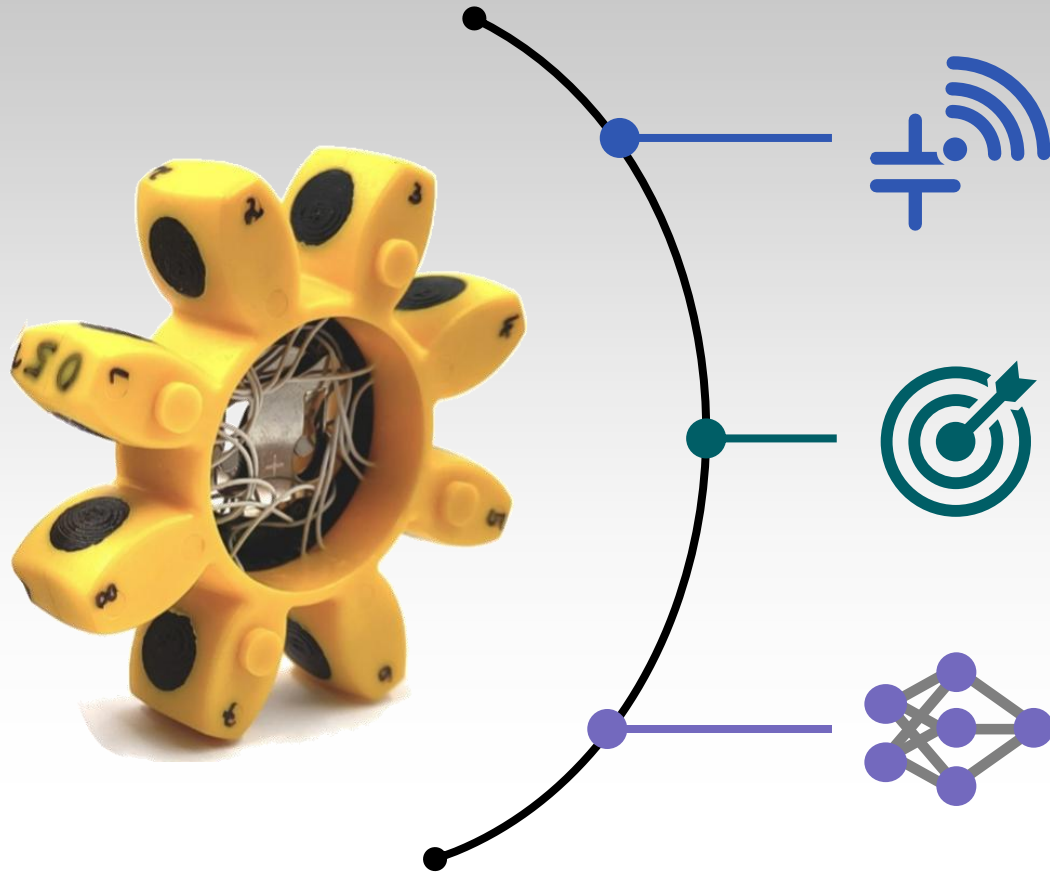
Regression Model

How accurate is the transfer function?

Sensors – Long-Term Tests



Sensors are suitable for continuous use



Sensors

Can the sensors withstand the stresses in the load path?

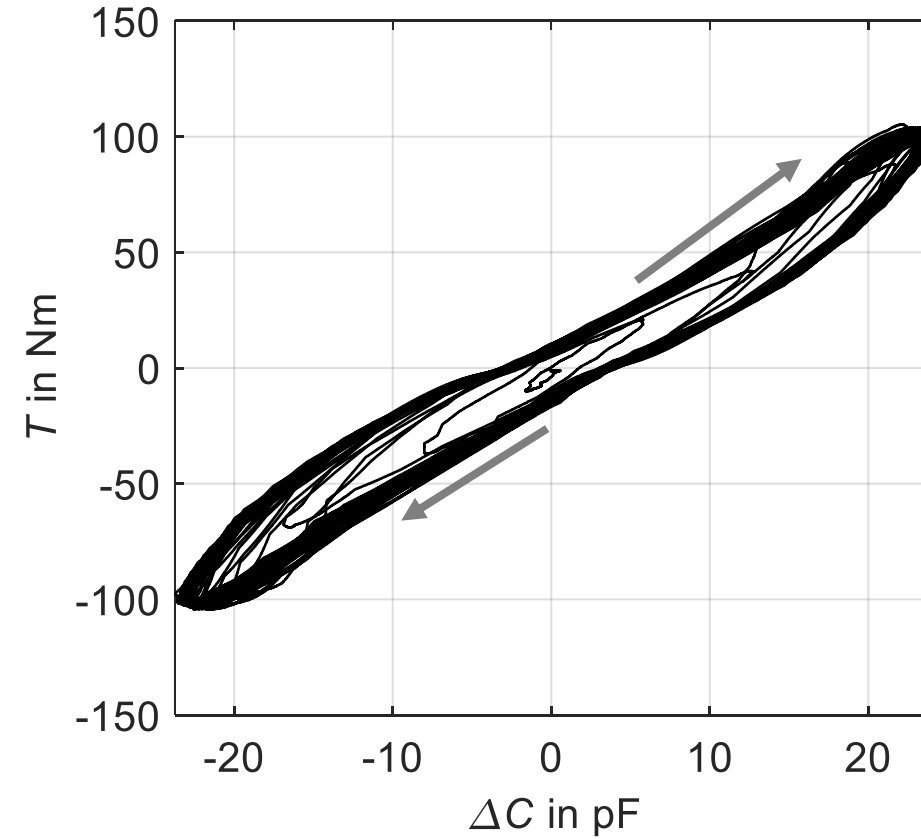
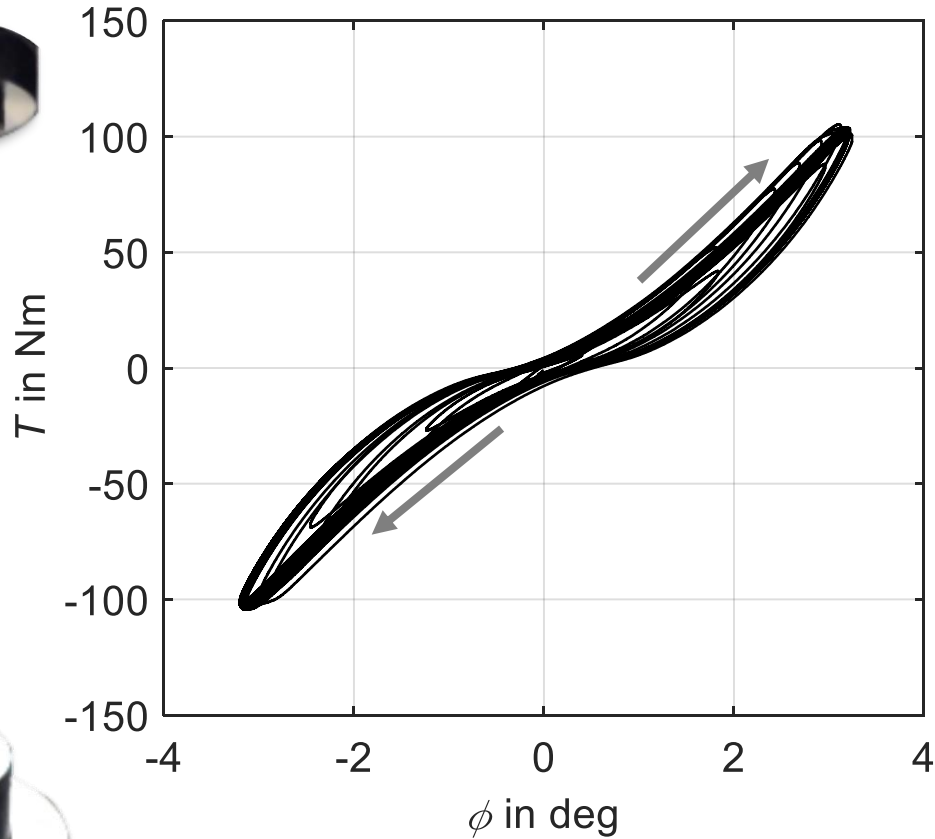
Mechanics

How does sensor integration affect load-bearing capacity?

Regression Model

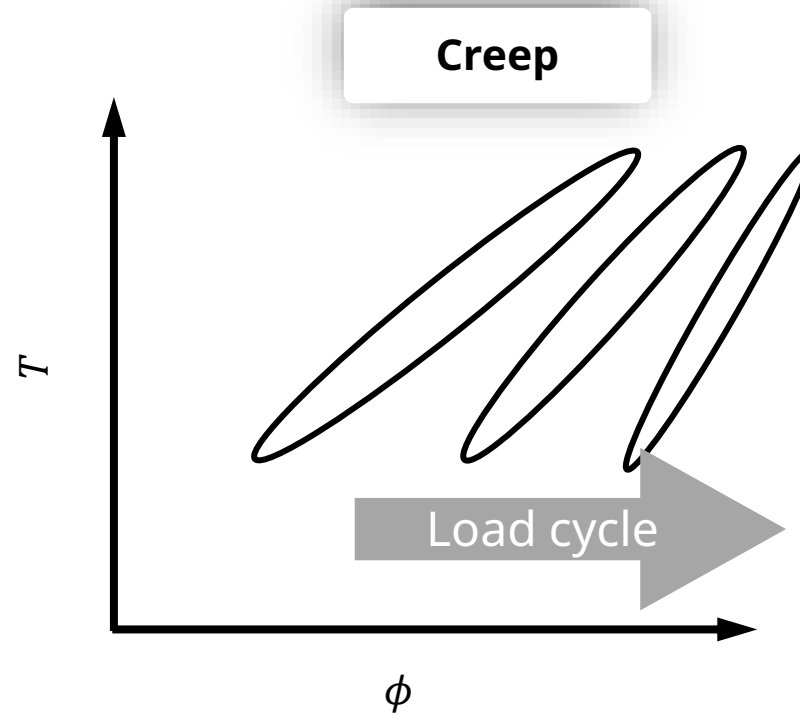
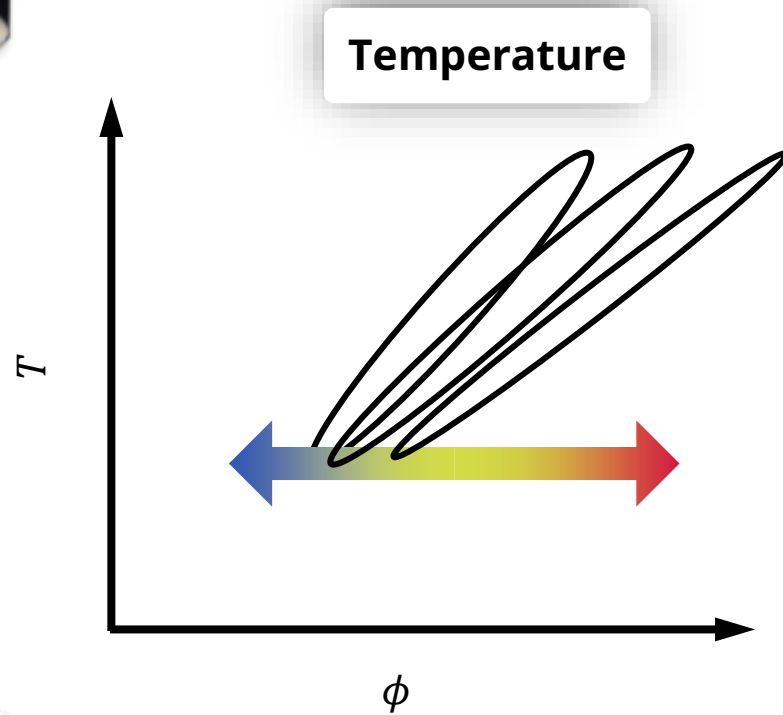
How accurate is the transfer function?

Mechanics – Quasi-static Loading



Good correlation between angle of rotation and capacitance

Mechanics – Influencing Factors

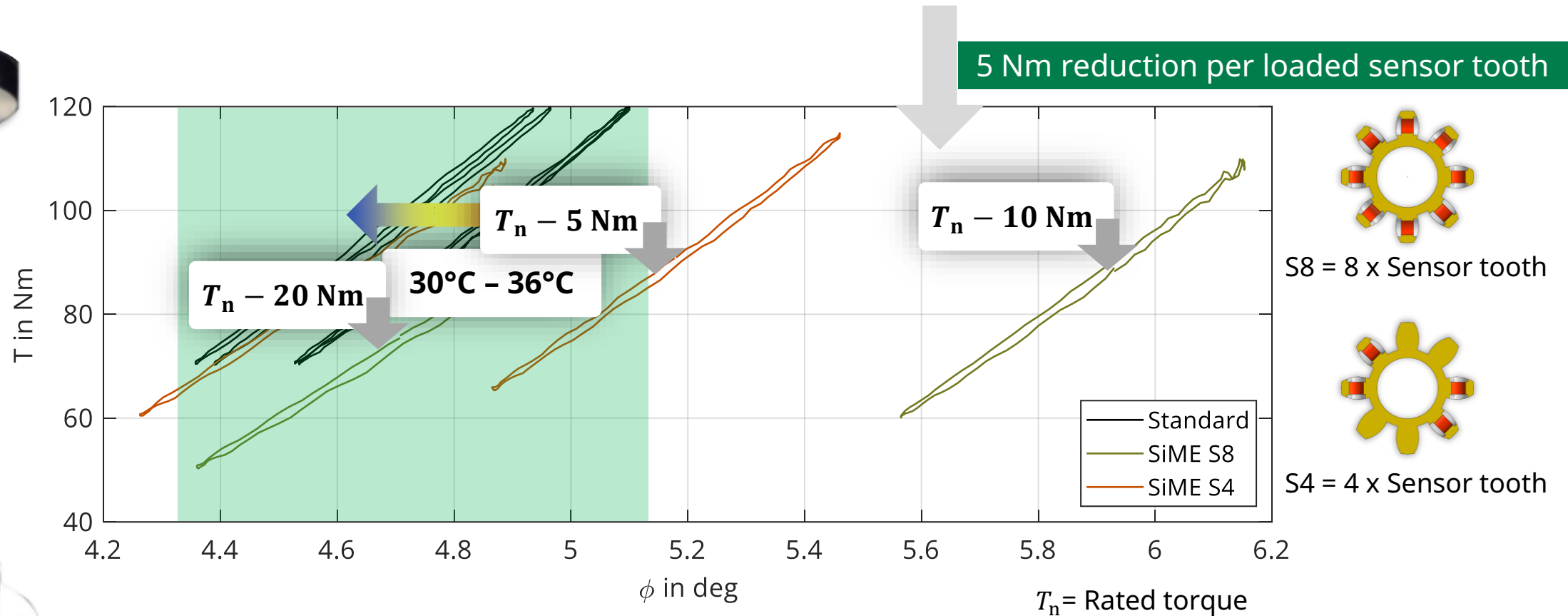


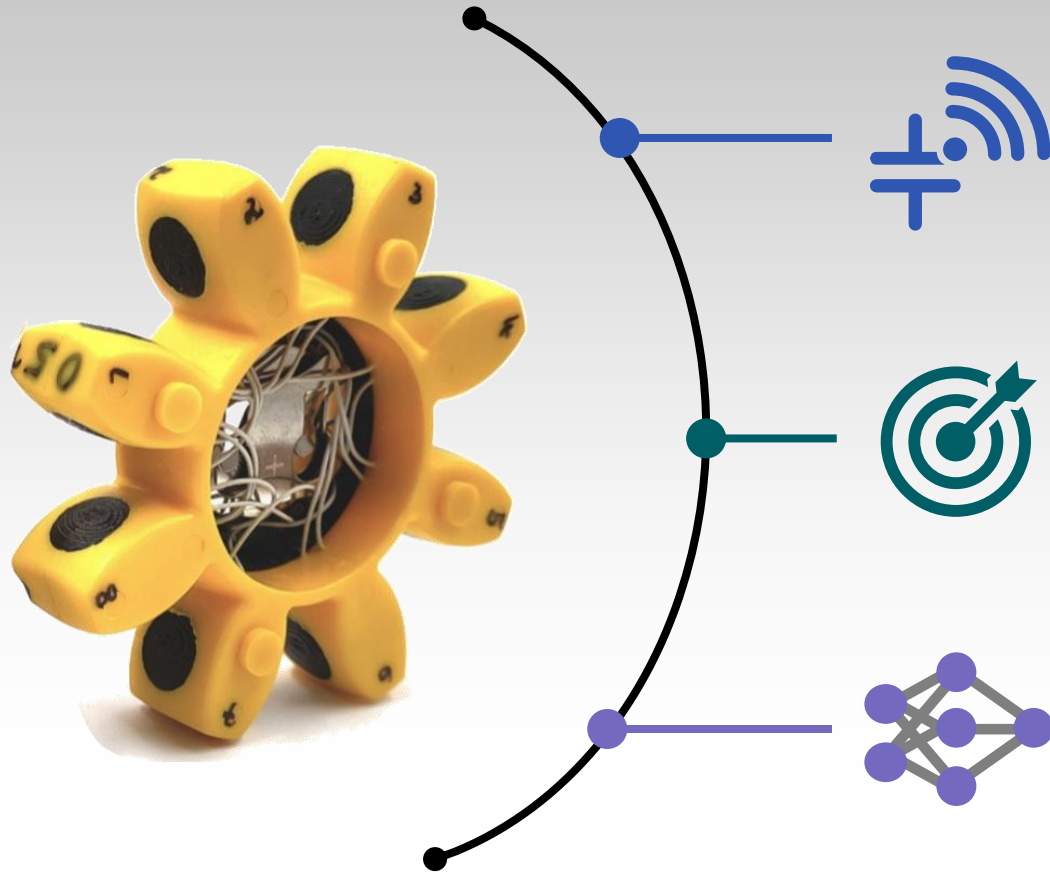
Amplitude

Wear

...

Mechanics – Endurance Test According to FVA 189 II





Sensors

Can the sensors withstand the stresses in the load path?

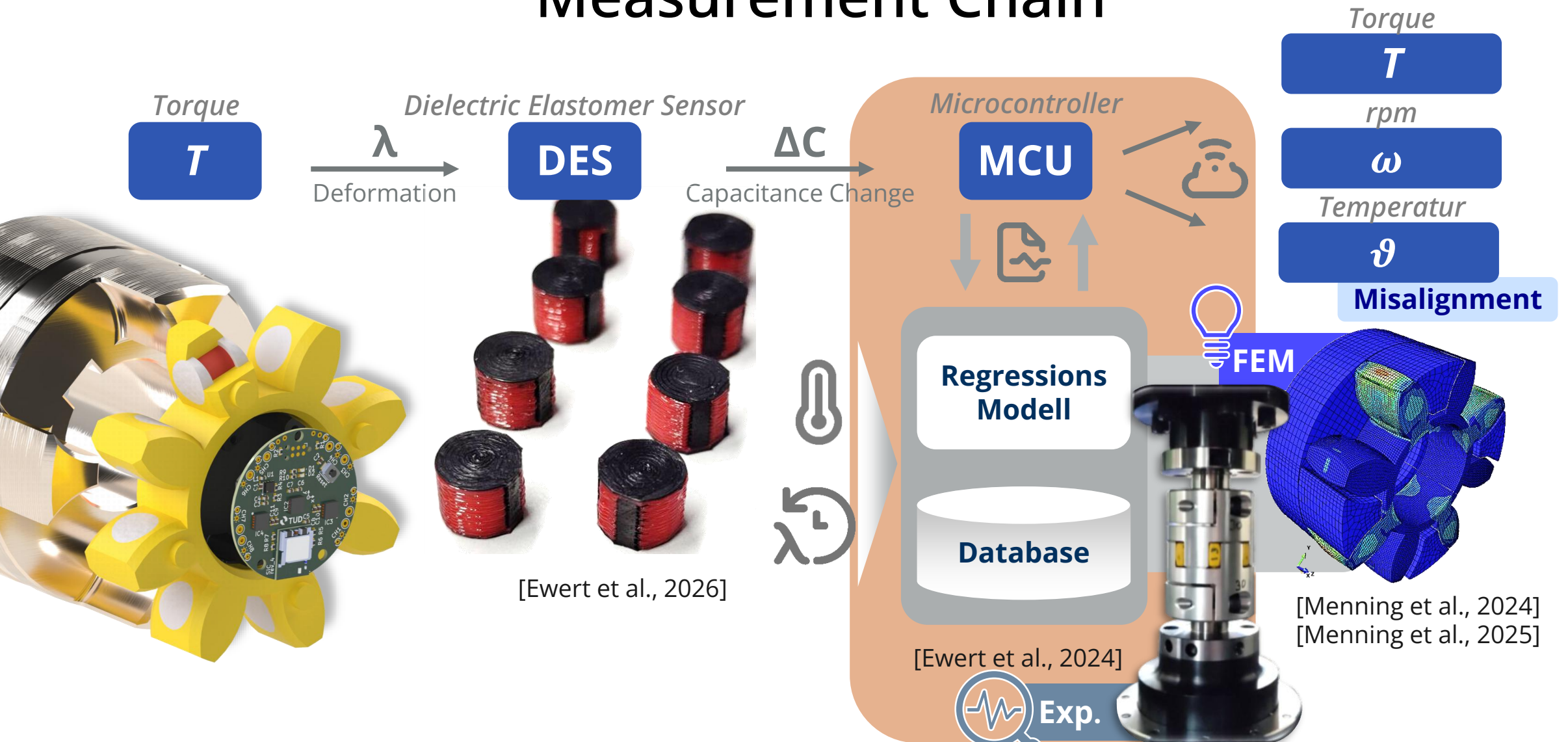
Mechanics

How does sensor integration affect load-bearing capacity?

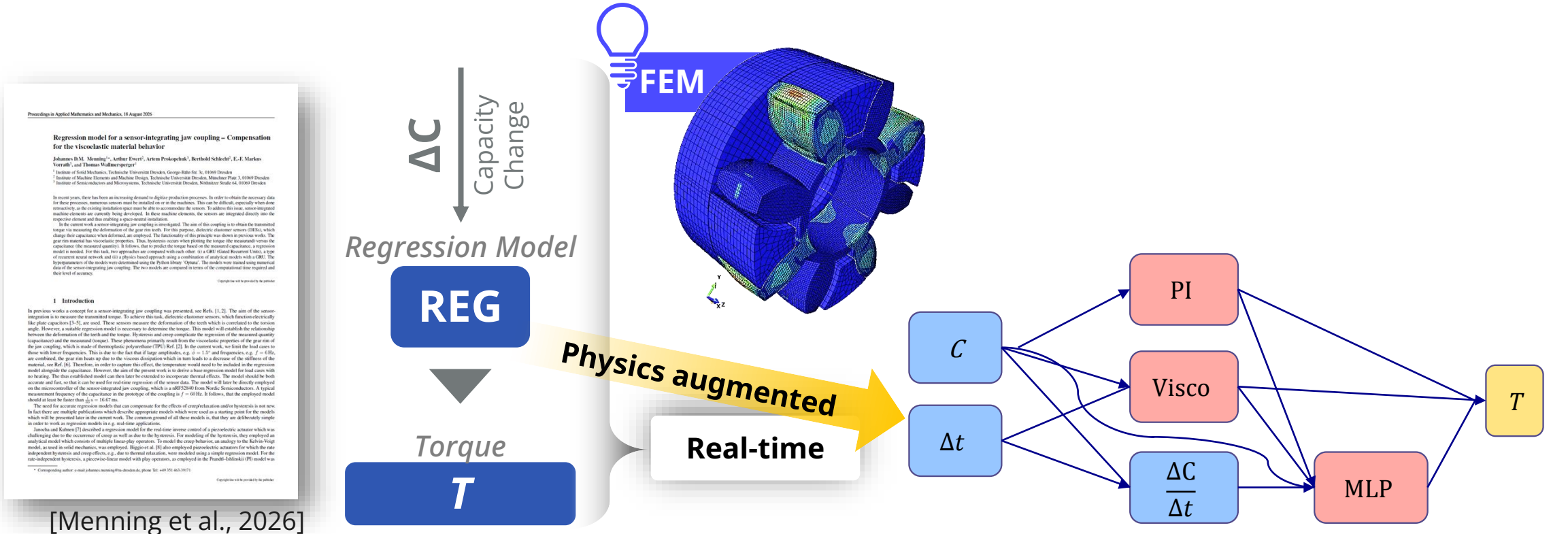
Regression Model

How accurate is the transfer function?

Measurement Chain

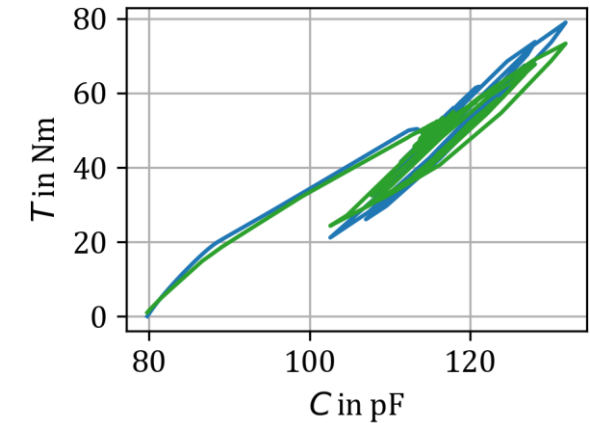
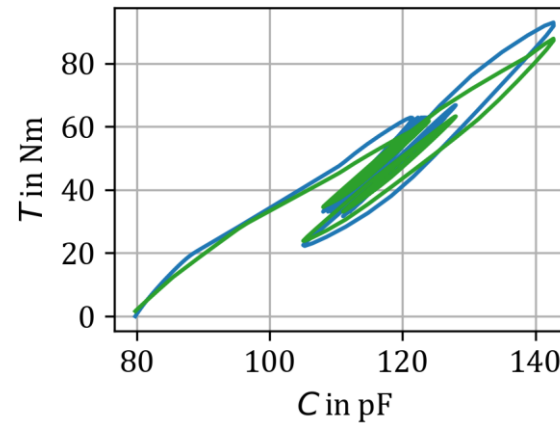
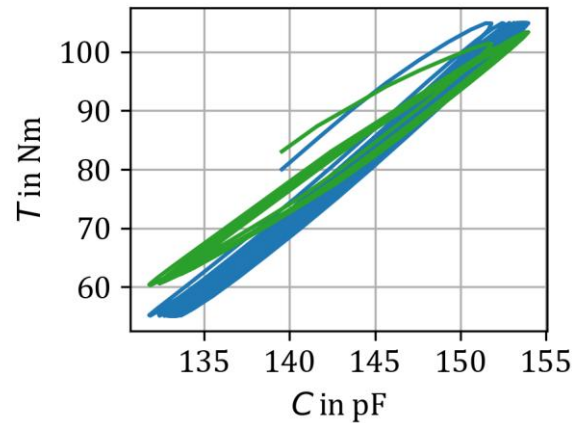
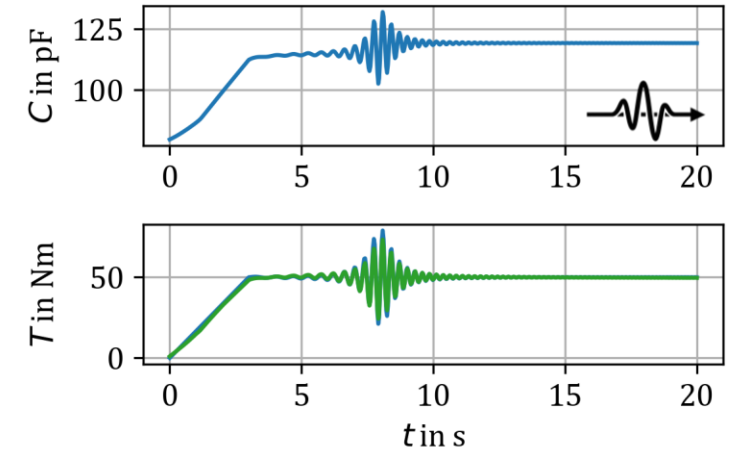
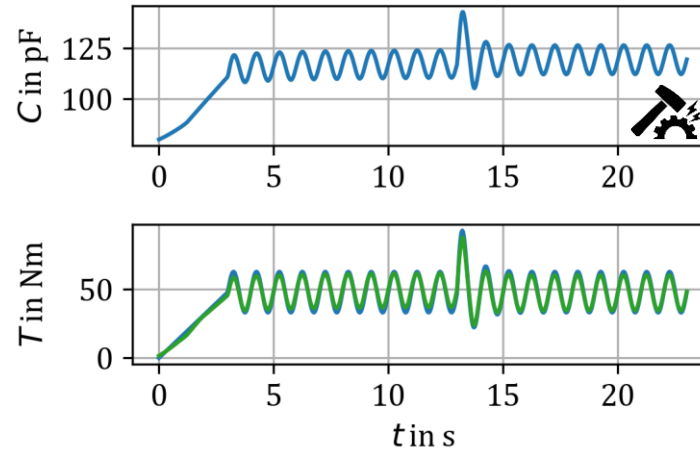
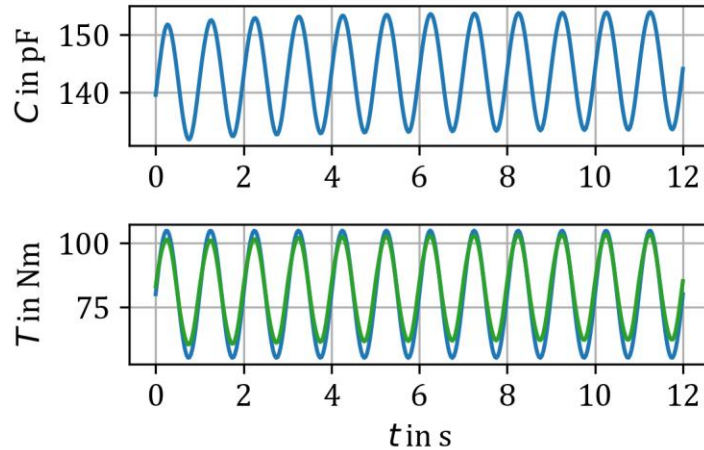


Regression Model – Approach



PI – Prandtl-Ishlinskii element
Visco – Zener element
MLP – Multilayer Perceptron

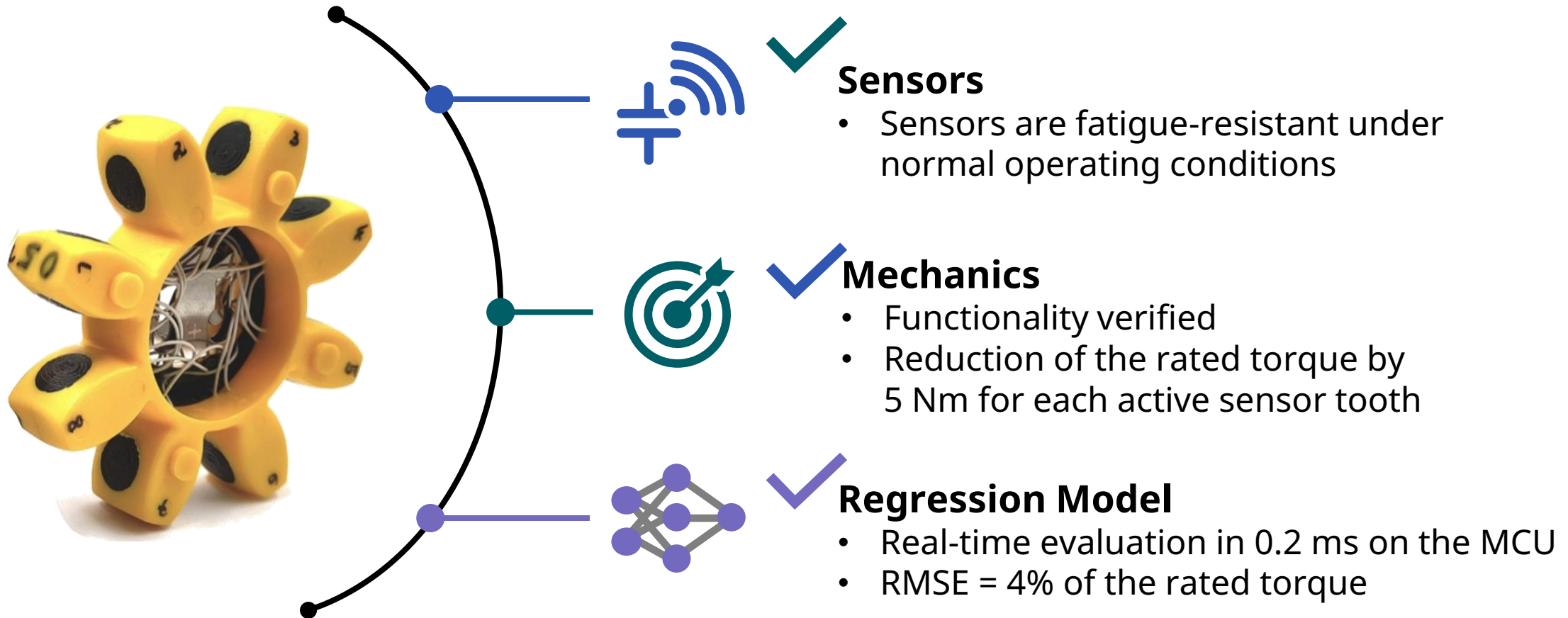
Regression Model – Results



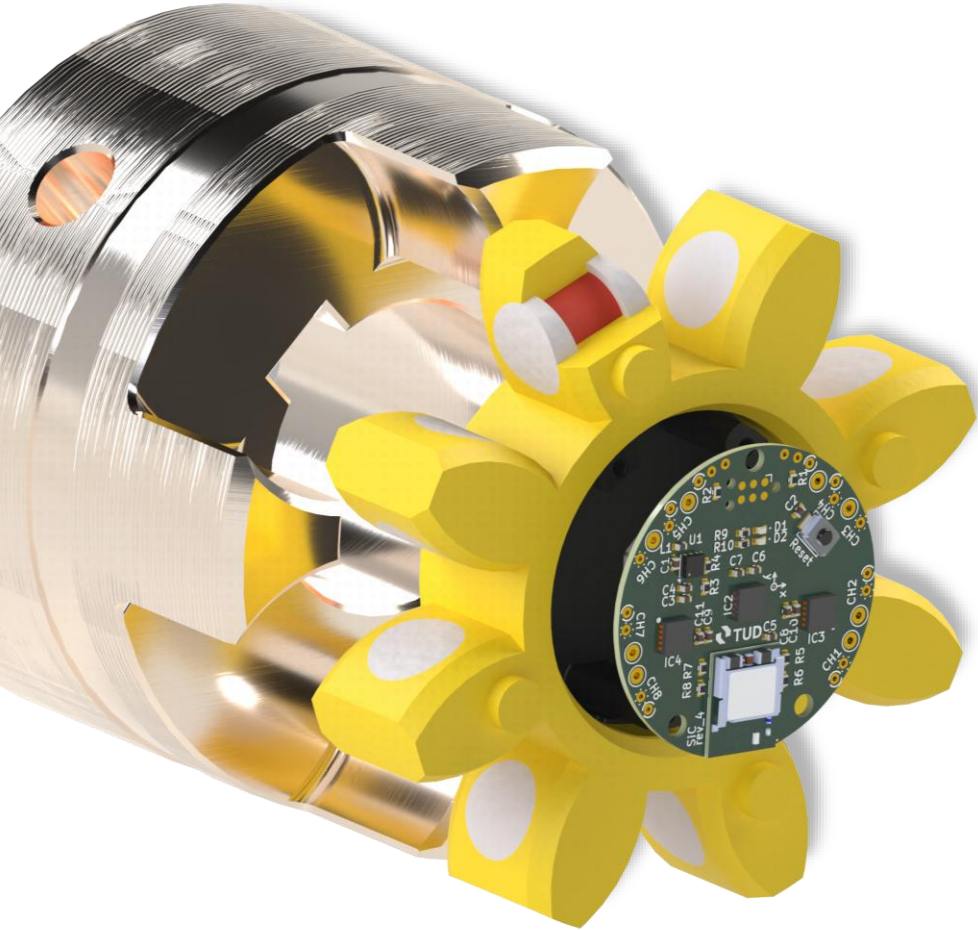
Test data from [finite element simulations](#) and predictions from the [regression model](#)
Root mean squared error = $1.30 \text{ Nm} \pm 0.55$, **Runtime on the MCU: 0.2 ms per datapoint**
[Menning et al., 2026]

Model runs on an MCU

Summary



Outlook



Energy Harvesting

Testing the
Harvesting Module



Quantity

Increase in the
prototype count



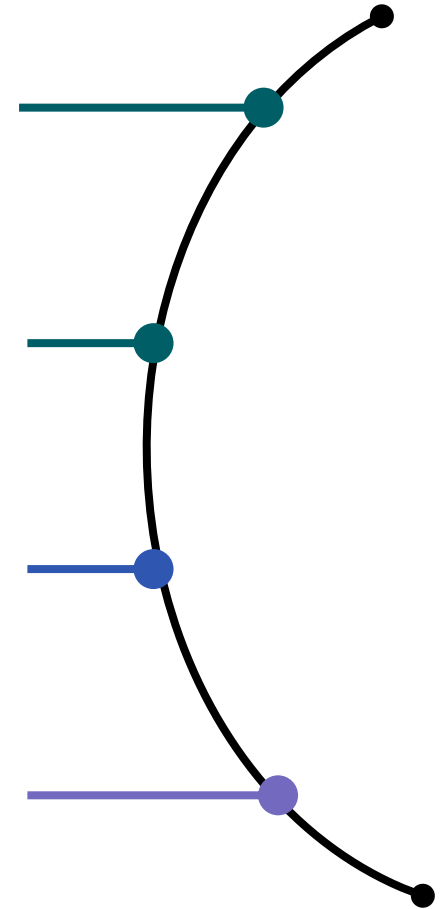
Training Data

Creating Training Data
and Extending Regression Models



Drift

Research on the influence of
time, and temperature drift



Acknowledgment

- The support of the German Science Foundation (DFG) (project numbers: **466661922** and **441853410**) is gratefully acknowledged.
- The authors gratefully acknowledge the computing time made available to them on the high-performance computer at the NHR Center of TU Dresden. This center is jointly supported by the Federal Ministry of Research, Technology and Space of Germany and the state governments participating in the NHR (www.nhr-verein.de/unsere-partner).

References

- [Menning et al., 2025] Menning, J.D.M., Ewert, A., Prokopchuk, A., Henke, E. F. M., Schlecht, B & Wallmersperger, T, Numerical and experimental investigations of conventional and sensor-integrating jaw couplings. Forsch Ingenieurwes 89, 139 (2025). <https://doi.org/10.1007/s10010-025-00897-w>
- [Menning et al., 2024] Menning, J. D. M., Prokopchuk, A., Ewert, A., Schlecht, B., Markus Henke, E. F., & Wallmersperger, T. (2023). Dielectric elastomer sensor integrated in a jaw coupling: Modeling and simulation of mechanical and electrical behavior. Journal of Intelligent Material Systems and Structures, 1045389X241274816.
- [Ewert et al., 2024] Ewert, A., Menning, J. D., Prokopchuk, A., Rosenlöcher, T., Henke, E. F. M., Wallmersperger, T., & Schlecht, B. (2024). Concept of a sensor-integrating jaw coupling for measuring operating data. Forschung im Ingenieurwesen, 88(1), 28.
- [Ewert et al., 2025] Ewert, A., Menning, J. D. M., Prokopchuk, A., Rosenlöcher, T., Henke, E. F. M., Wallmersperger, T., & Schlecht, B. (2025). Experimental investigation of a novel sensor-integrating jaw coupling for data acquisition, XI ECCOMAS Thematic Conference on Smart Structures and Materials
- [Ewert et al., 2026] Ewert, A., Menning, J. D. M., Prokopchuk, A., Rosenlöcher, T., Henke, E. F. M., Wallmersperger, T., & Schlecht, B. (2026). Auslegung, Herstellung und Erprobung von additiv gefertigten skalierbaren dielektrischen Elastomersensoren für sensorintegrierende Zahnkranzkupplungen, DMK 2026
- [Menning et al., 2026] Menning, J. D. M., Ewert, A., Prokopchuk, A., Henke, E. F. M., Schlecht, B & Wallmersperger, T (2026). Regression model for a sensor-integrating jaw coupling – Compensation for the viscoelastic material behavior, Proceedings in Applied Mathematics and Mechanics, under Review

Thank you very much for your attention

Arthur Ewert

arthur.ewert@tu-dresden.de

Technische University of Dresden

Institute for Machine Elements
and Machine Design

Chair of Machine Elements
Münchner Platz 3
D-01062 Dresden

www.tu-dresden.de/me

