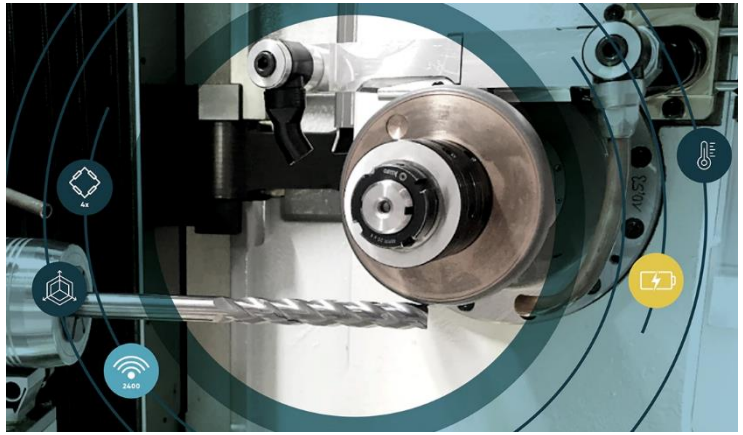
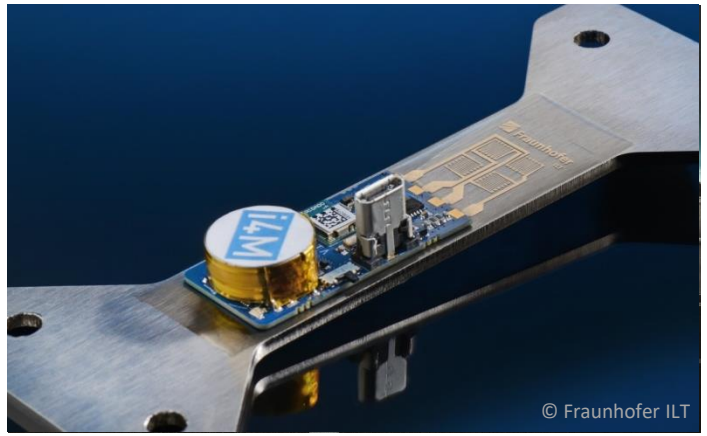
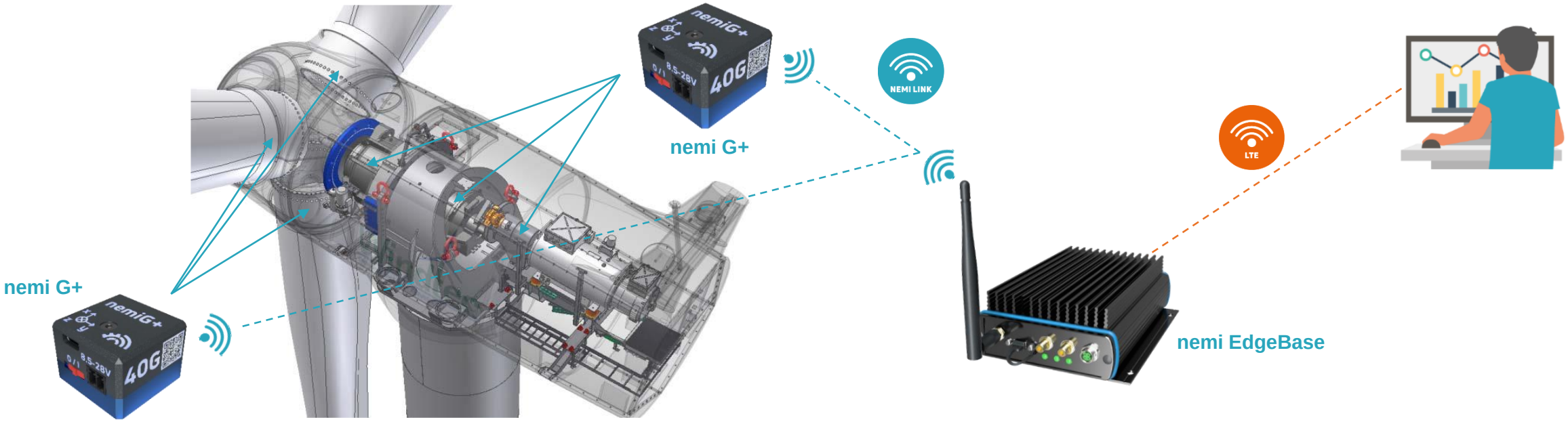
# Intelligent, wireless and highly adapted. The potential of Integrated Sensing technology demonstrated on a tooling machine spindle

DSEC 23



# Lowest level: Of the shelf standard products



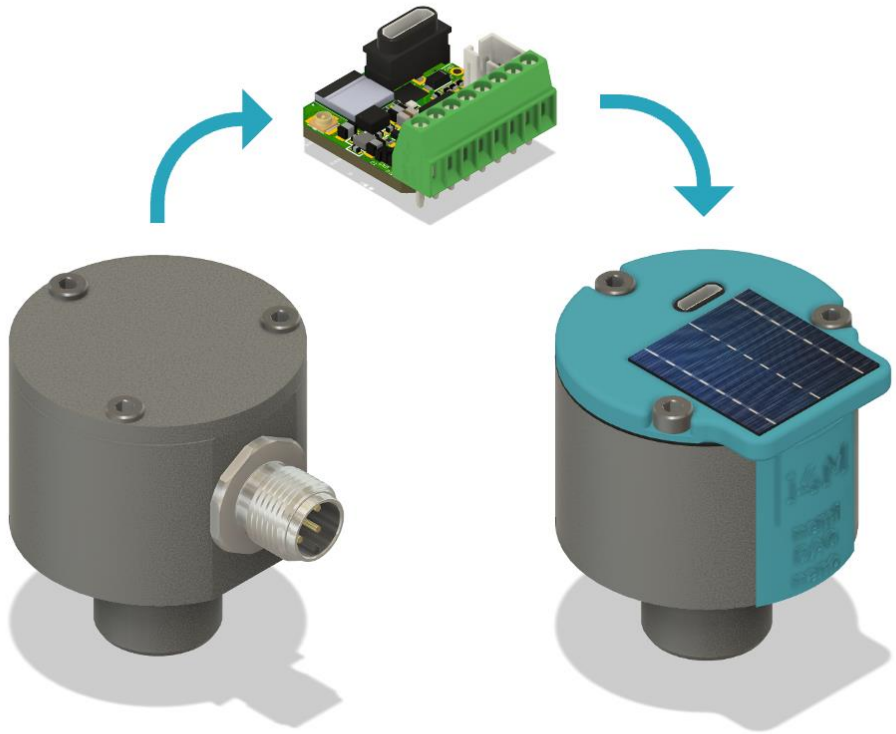

## nemi G+

- Vibration & rotation angle sensor in one system
- Ideal for low speed drives / bearings
- Wireless data transmission
- Internal battery for mid-term monitoring
- Battery pack or 24 V input for long-term monitoring

## nemi EdgeBase

- Sensor gateway
- 4G and Ethernet links → data transmission without connection to safety cricital WT networks
- Robust IP 65 rated housing
- Python scripting for Online-Edge-Analytics

# Mid level: Integrated sensing products (e.g. nemi DAQ nano)



- Intelligent and wireless **D**ata **A**c**Q**uisition (DAQ) module for …
  - Strain gauges
  - Pt 100 / Pt 1000
  - 0 – 10 V analog sensors
  - Digital sensors up to 24 V
  - …
- Integrated 9-DoF IMU
- Edge computing
- Internal or external antenna
- Energy harvesting

⇒ **PCB size equivalent to a 1 € coin**

⇒ **Cuts development costs in half**

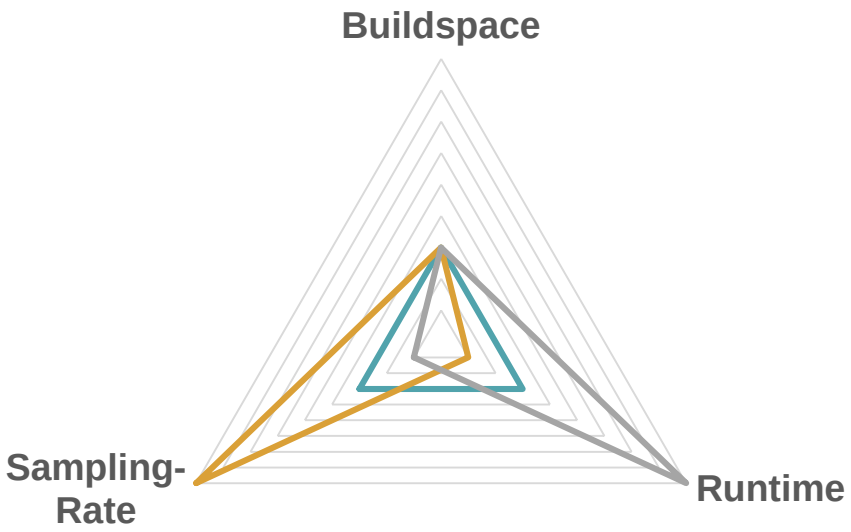
# Highest level: Challenges

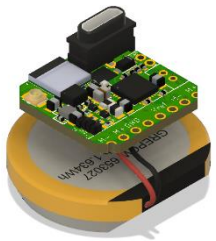
**Challenge: High sampling-rates & long runtimes despite limited buildspace**

⇒ Limited buildspace

⇒ Limited energy storage

⇒ **Optimizing all power modes**



1.63 Wh
**without** Solar Power

| Conditions | Power | Important Power-Modes | Runtime @ 100 % duty cycle | Runtime @ 4 % duty cycle (≈ 1 hour a day) |
|---|---|---|---|---|
| Sleep | 0.3 mW | Sleep | 5433 h or 226.4 days | - |
| 25 Hz strain gauge | 7.9 mW | Sensing | 206 h or 8.6 days | 2699 h or 112.4 days |
| 4.8 kHz strain gauge<br>10.56 kHz 9-DoF IMU<br>2 kHz Digital Inputs<br><br>**→ 17.36 kSPS** | 61.4 mW | Radio | 26.5 h or 1.1 days | 594 h or 24.8 days |

# Highest level: Advantages of nemi Link 2400

NEMI LINK

- Tailor made
- Flexible parameters for perfect results in each application

⇒ Small overhead

⇒ Low power / High data rate

⇒ Low latency

⇒ Microsecond level synchronization

⇒ **Perfect fit for measurement tasks**

VS.

Bluetooth Low Energy (BLE)

- Made to serve various applications mainly in consumer electronics
- Maximum compatibility with various devices (smartphones etc.)

⇒ Protocol overhead

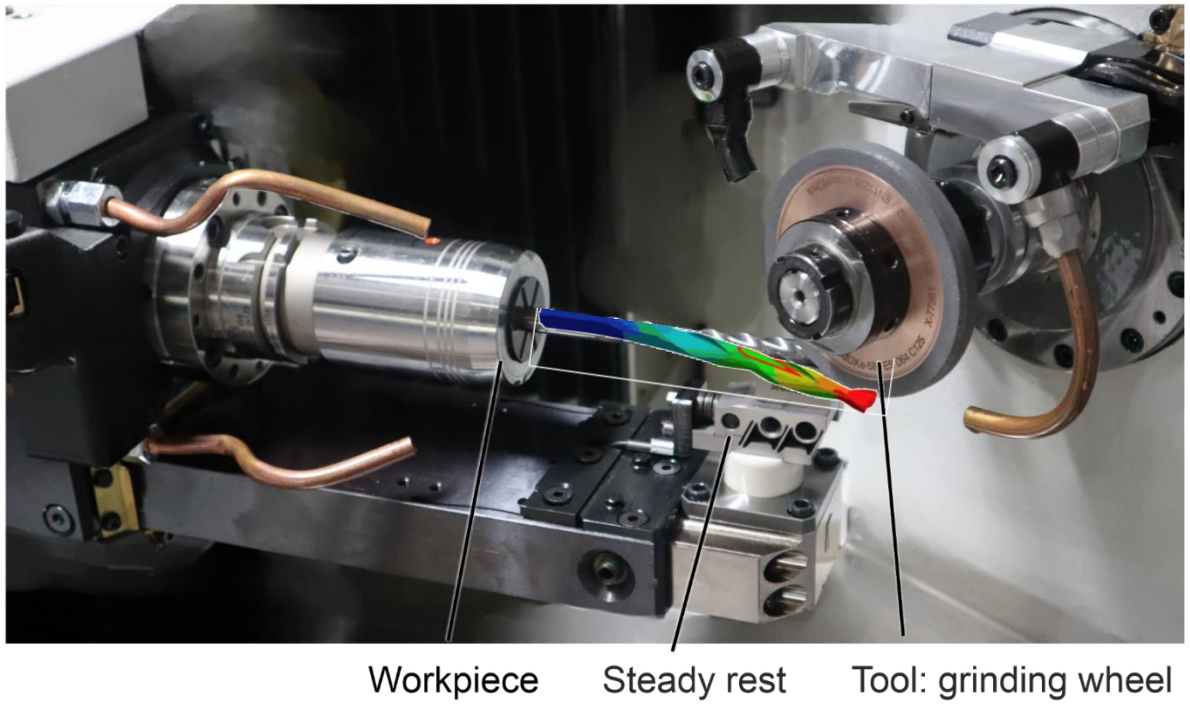
⇒ Medium data rate

⇒ Higher latency

⇒ **Limited fit for measurement tasks**

# Highest level usecase: Feeling spindle


## Tool grinding process




### Challenges in tool grinding

- Workpiece deflection caused by process forces
- High manual set-up effort for steady rest
- Risk of scrap manufacturing

# Highest level usecase:
# Adaptive compensation of displacement during tool grinding

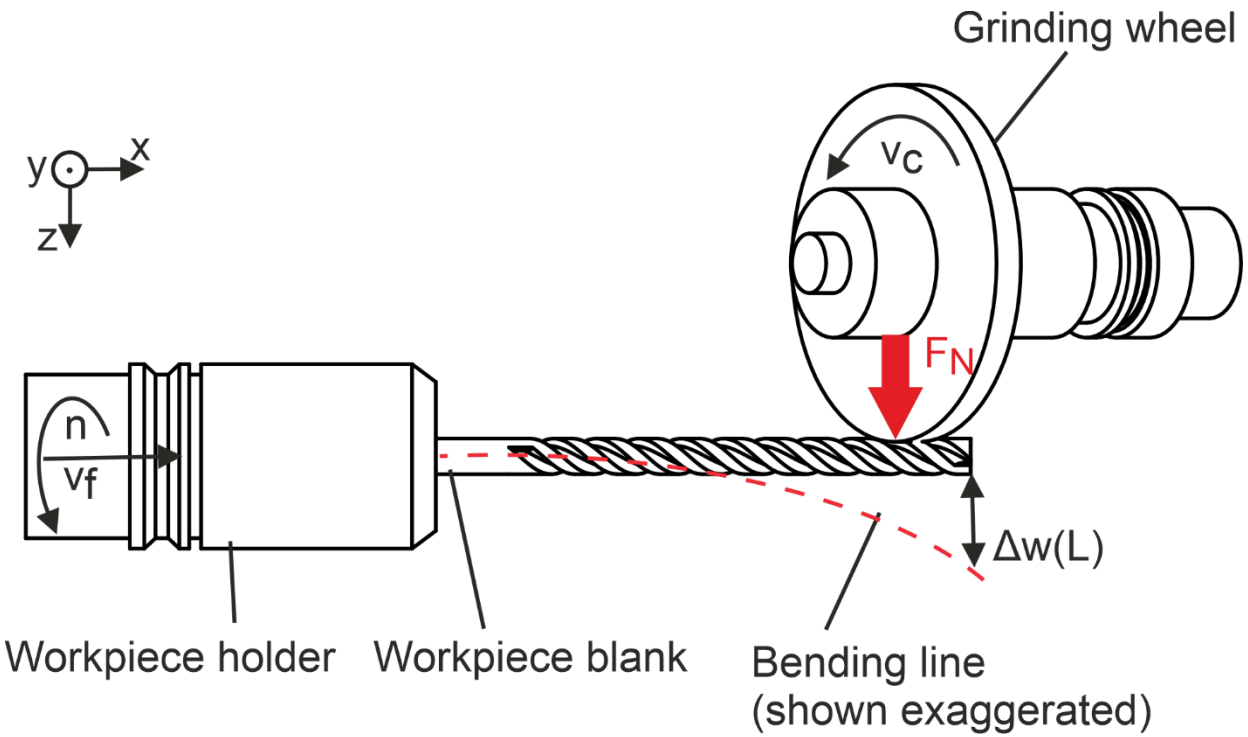
**Challenges in tool grinding**

- Workpiece deflection caused by process forces
- High manual set-up effort for steady rest
- Risk of scrap manufacturing

**Adaptive compensation of displacement during tool grinding**

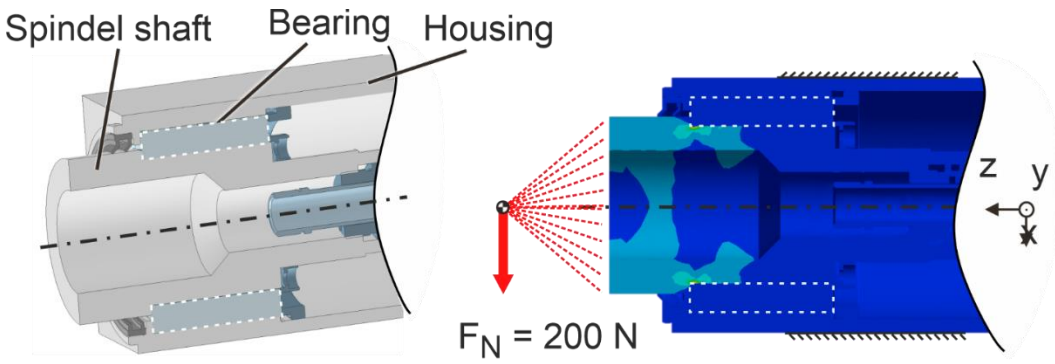
- Modelling of the workpiece stiffness
- Measurement of the process forces
- Calculation of displacement and adaption of path control

→ Manufacturing without steady rest

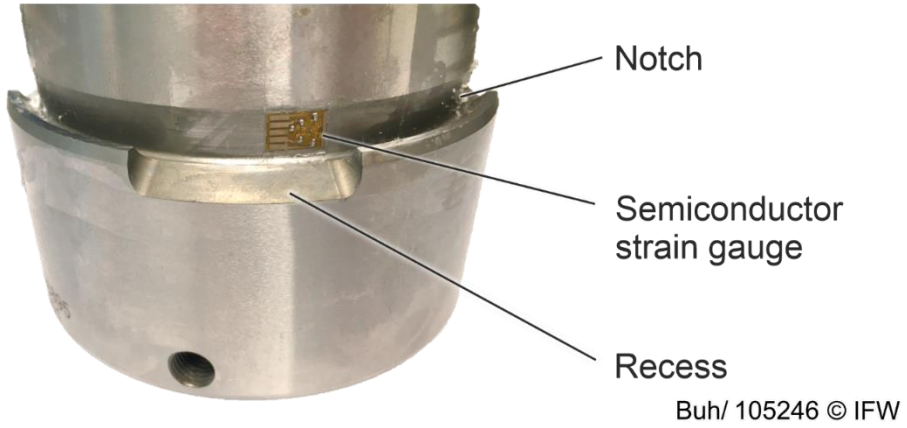


# Highest level usecase: Requirements

## Sensor positioning on spindle shaft by FE - Analyse

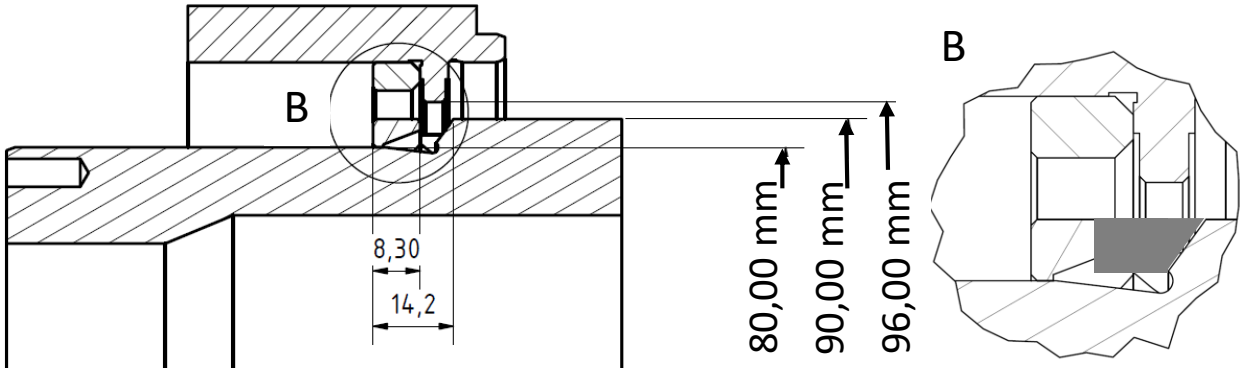



## Initial situation for sensor development

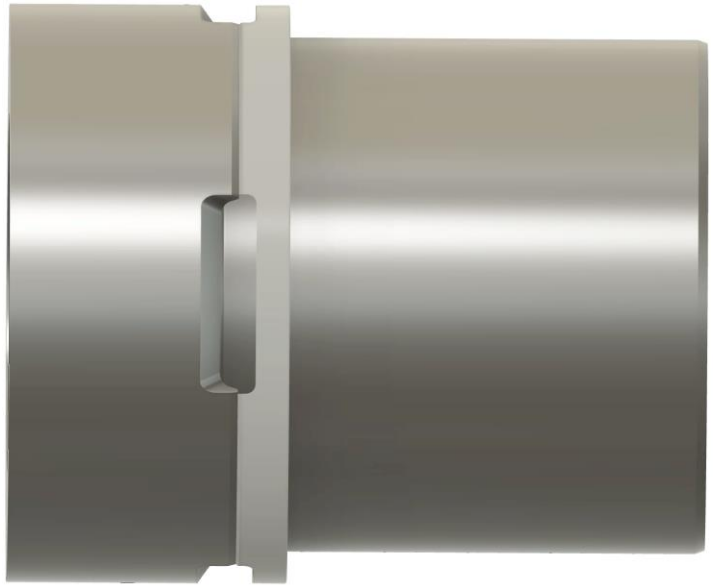



## Requirements

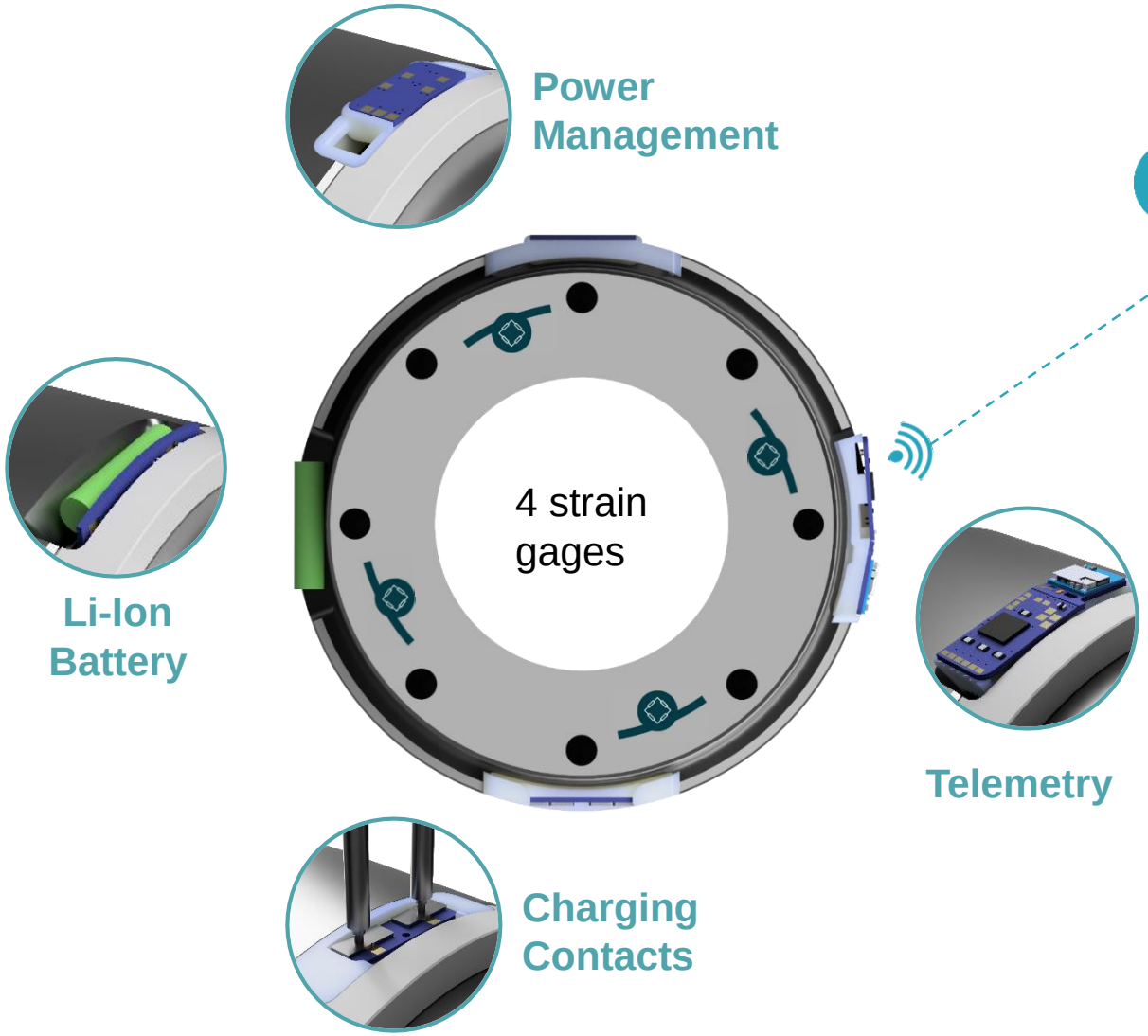
| 1. | Design | |
|---|---|---|
| 1.1 | Geometrical size | 30/ 7,3 / 3,5 mm |
| 1.2 | Sensors | 4 strain gauges |
| 1.3 | Supply voltage | 3 V |
| **2.** | **Data and energy transmitter** | |
| 2.1 | Data transmitter | Contactless |
| 2.2 | Energy supply | Rechargeable battery |
| 2.3 | Data rate | > 500 Hz |
| 2.4 | Data resolution | 24 Bit |



# Highest level usecase: Engineering the sensor system



# Highest level usecase: Engineering the sensor system

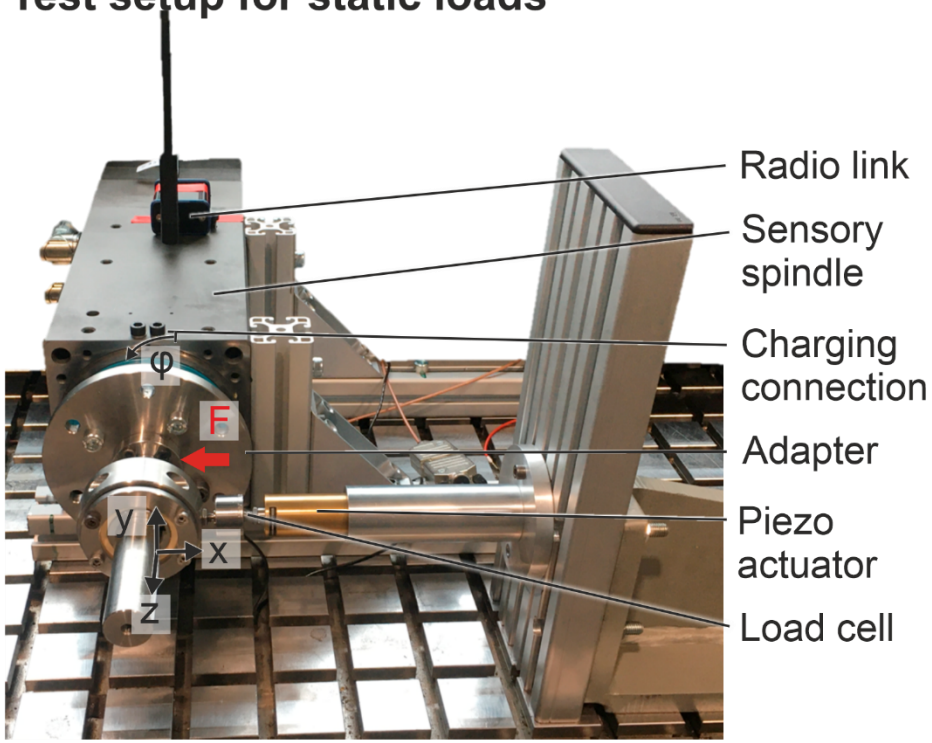




- 4x semiconductor strain gauge full bridges
  - 24 Bit
  - up to 1.5 kHz
- 6-DoF IMU
  - 3 axis accelerometer and gyroscope
  - up to 6.5 kHz
- Edge computing capabilities
- Quick charging
  - 2 minutes charging for 10 minutes runtime
  - max. 80 minutes runtime
- Up to 85 °C

# Highest level usecase: Measurement with sensory grinding spindle

## Test setup for static loads




**Strain gauge**
Semiconductor strain gauge
SSGF-060-033-500PB-M4

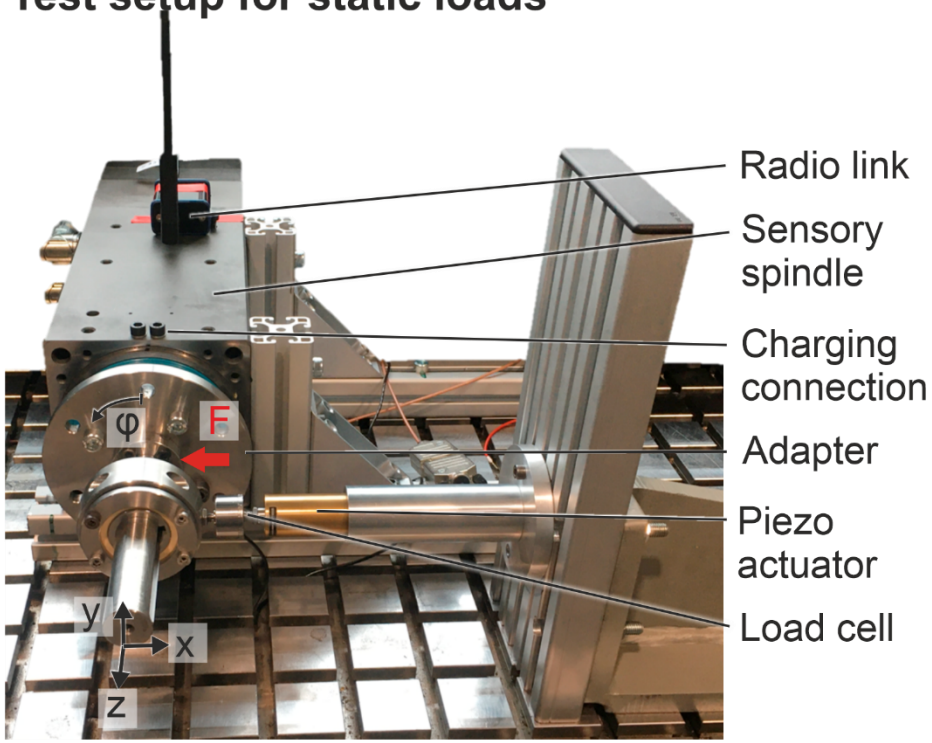
**Radio link**
nemi Link 2400

**Load cell**
KM26z-2kN

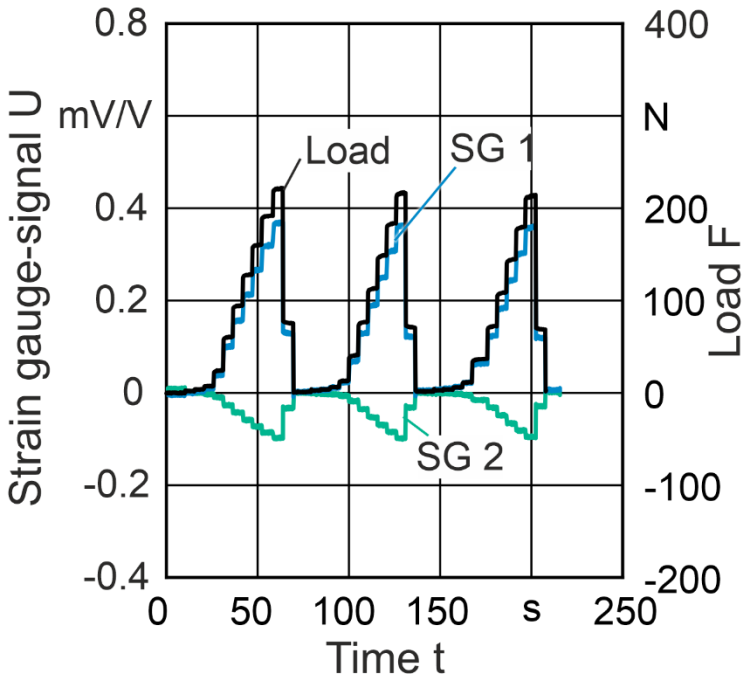
**Piezo actuator**
PSt 1000/16/150/ VS25

# Highest level usecase: Measurement with sensory grinding spindle

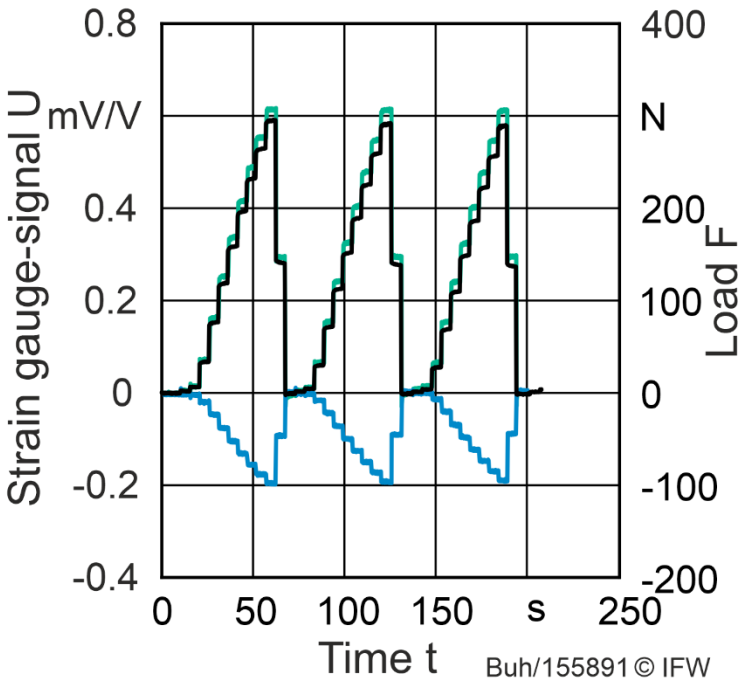
## Test setup for static loads




## x-direction




## y-direction




Buh/155891 © IFW

**Strain gauge**
Semiconductor strain gauge
SSGF-060-033-500PB-M4

**Radio link**
nemi Link 2400

**Load cell**
KM26z-2kN

**Piezo actuator**
PSt 1000/16/150/ VS25

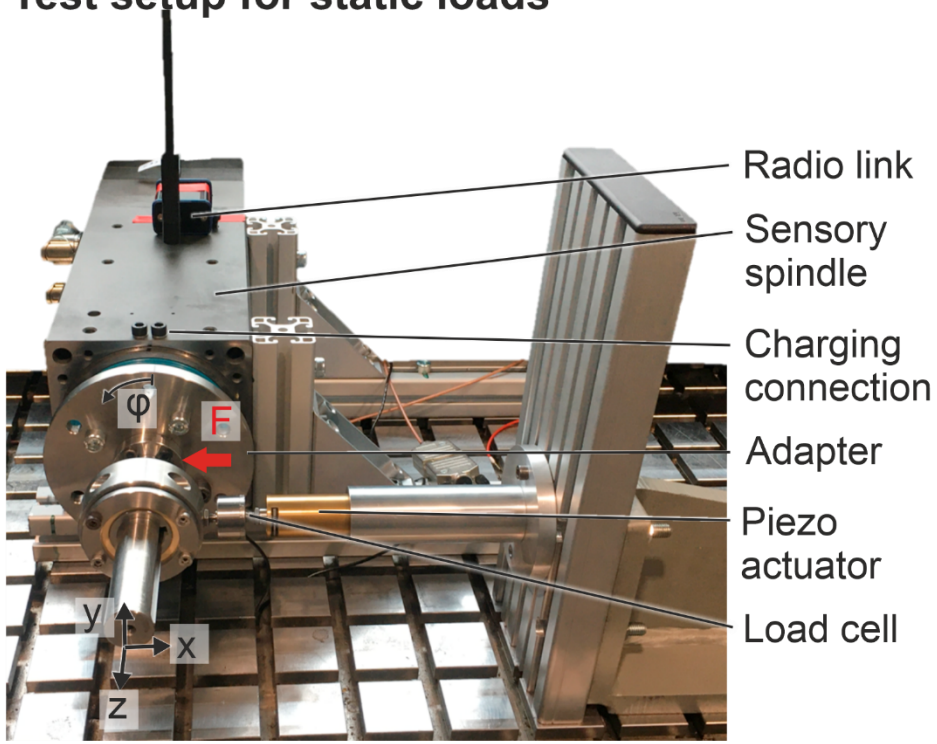
**Linear correlation between the sensor signals and the external load with only low noise.**



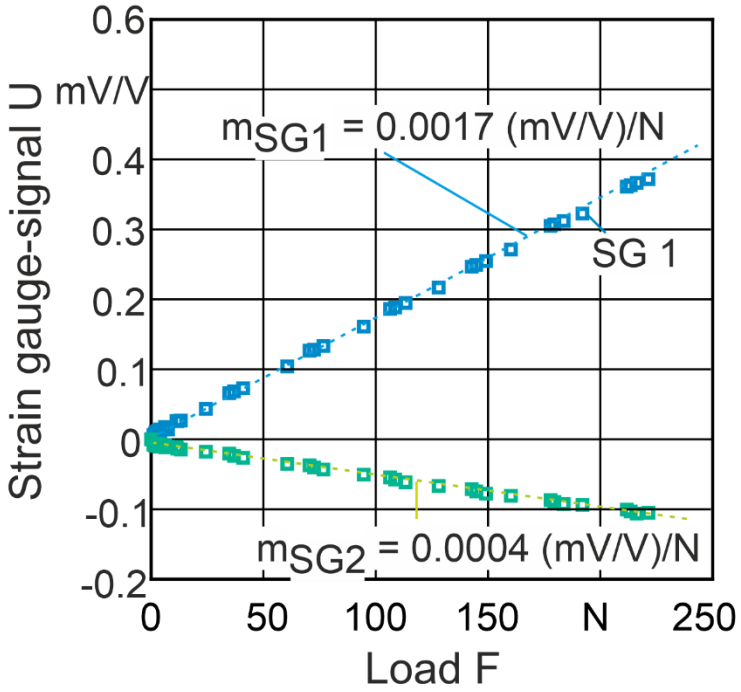
nemione
i4M technologies GmbH intelligence for mechanical systems
IFW Institut für Fertigungstechnik und Werkzeugmaschinen

# Highest level usecase: Directional force sensitivity

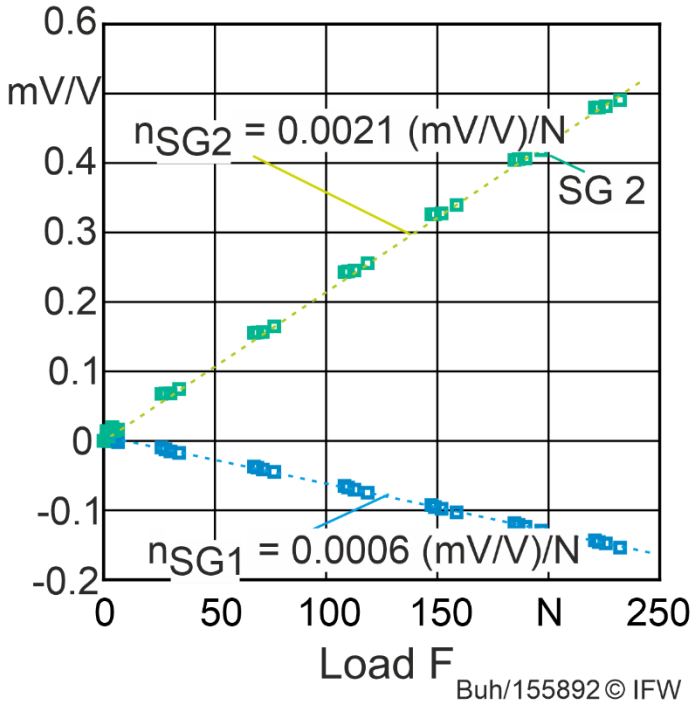
## Test setup for static loads




## x-direction




## y-direction




Buh/155892 © IFW

**Strain gauge**
Semiconductor strain gauge
SSGF-060-033-500PB-M4

**Radio link**
nemi Link 2400

**Load cell**
KM26z-2kN

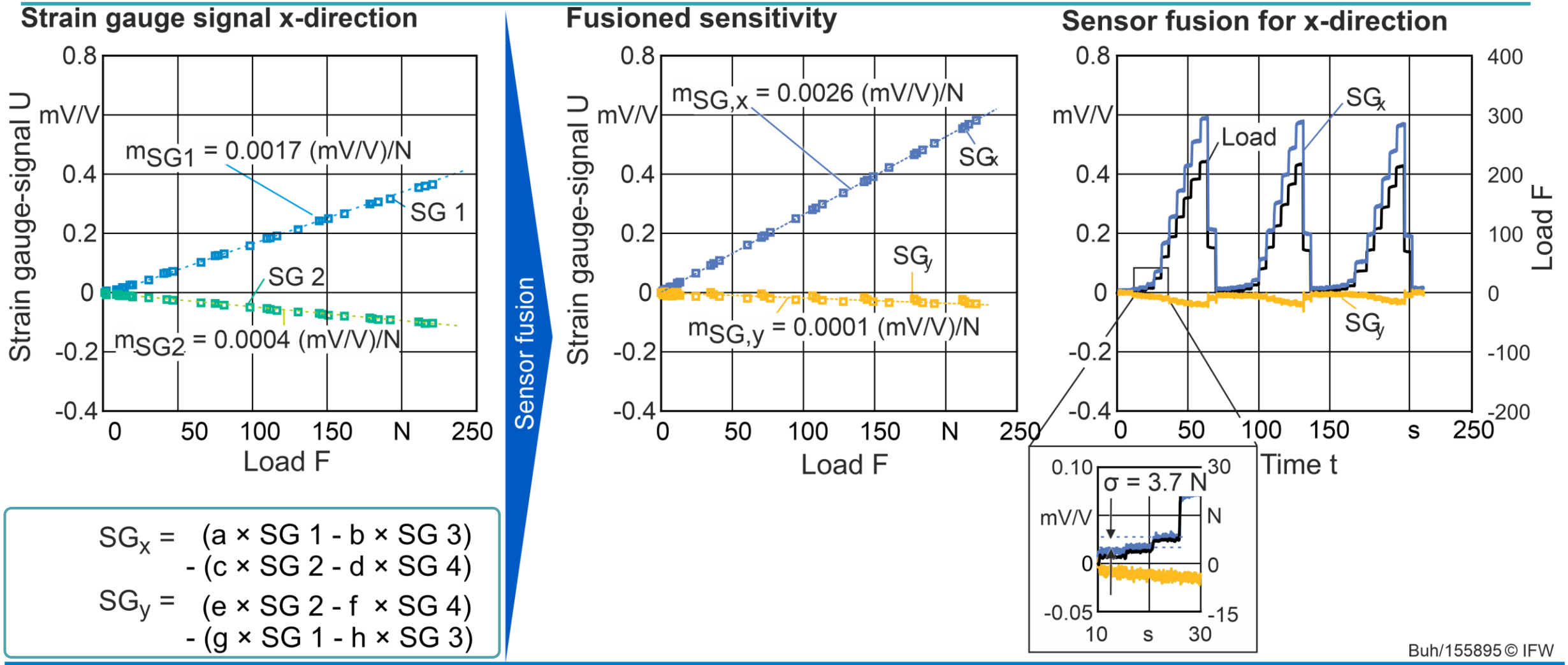
**Piezo actuator**
PSt 1000/16/150/ VS25

**Linear and direction dependent correlation enables constant sensitivity.**



nemione
i4M technologies GmbH intelligence for mechanical systems
IFW Institut für Fertigungstechnik und Werkzeugmaschinen

# Highest level usecase: Sensitivity enhancement using sensor fusion




$$SG_x = (a \times SG\,1 - b \times SG\,3) - (c \times SG\,2 - d \times SG\,4)$$

$$SG_y = (e \times SG\,2 - f \times SG\,4) - (g \times SG\,1 - h \times SG\,3)$$

Buh/155895 © IFW

**Increase of the fusioned sensitivity up tp 53% - which is additionally a direction-independent sensitivity.**



nemione

i4M technologies GmbH intelligence for mechanical systems

IFW Institut für Fertigungstechnik und Werkzeugmaschinen

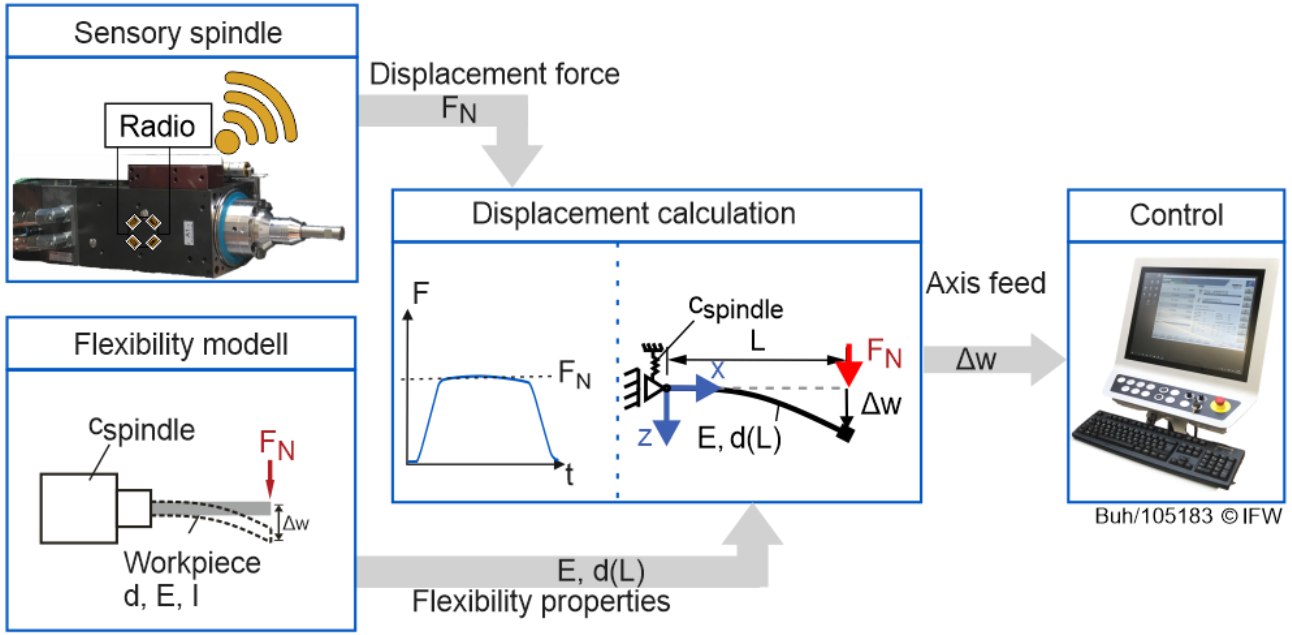
# Usecase: sensoric grinding spindle – Outlook for use in machining process

**Goal:**

**Adaptive compensation of displacement during tool grinding**

## Requirements

| | | |
|---|---|---|
| **1.** | **Design** | |
| 1.1 | Geometrical size | 30/ 7,3 / 3,5 mm ✓ |
| 1.2 | Sensors | 4 strain gauges ✓ |
| 1.3 | Supply voltage | 3 V ✓ |
| **2.** | **Data and energy transmitter** | |
| 2.1 | Data transmitter | Contactless ✓ |
| 2.2 | Energy supply | Rechargeable batte ✓ |
| 2.3 | Data rate | > 500 Hz ✓ |
| 2.4 | Data resolution | 24 Bit ✓ |




- Process forces measurement by means of a sensory grinding spindle
- Modelling of the workpiece stiffness

→ **Calculation of the displacement and adaptiv compensation**

# Contact

**Henning Buhl**
Machine Components Department Manager

**IFW - Institute of Production Engineering and Machine Tools, Leibniz Universität Hannover**
An der Universität 2
30823 Garbsen

Tel.: +49 (0) 511 - 762 - 5210
Buhl@ifw.uni-hannover.de

www.ifw.uni-hannover.de

**Lois Jacobs**
COO & Partner

**i4M technologies GmbH**
Försterstr. 5
52072 Aachen

Tel.: +49 (0) 157 34 10 59 28
lois.jacobs@i4m-tech.de

www.i4m-tech.de
www.nemi.one