INTEGRATION AND APPLICATION OF PROCESS SENSORS IN COMPLEX ADAPTIVE MANUFACTURING SYSTEMS

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Shaping the Future of Production.

Fraunhofer IWU
Institute for Machine Tools and Forming Technology

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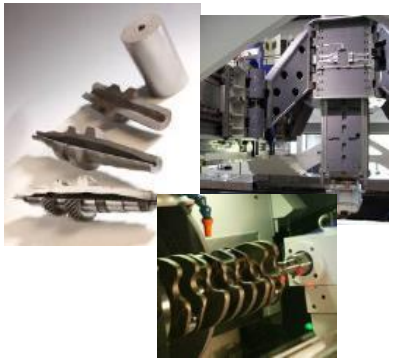
Fraunhofer IWU

Introduction of Fraunhofer IWU

- Founded: July 1st 1991
- Approximately 620 employees
- Budget: 41,5 Mio. €
- Guiding theme:
  Resource-efficient Production
- 5 locations in Germany:

Headquarter in Chemnitz

Chemnitz (Headquarter)
- Machine Tools
- Forming Technologies
- Machining Technologies
- Smart Factory



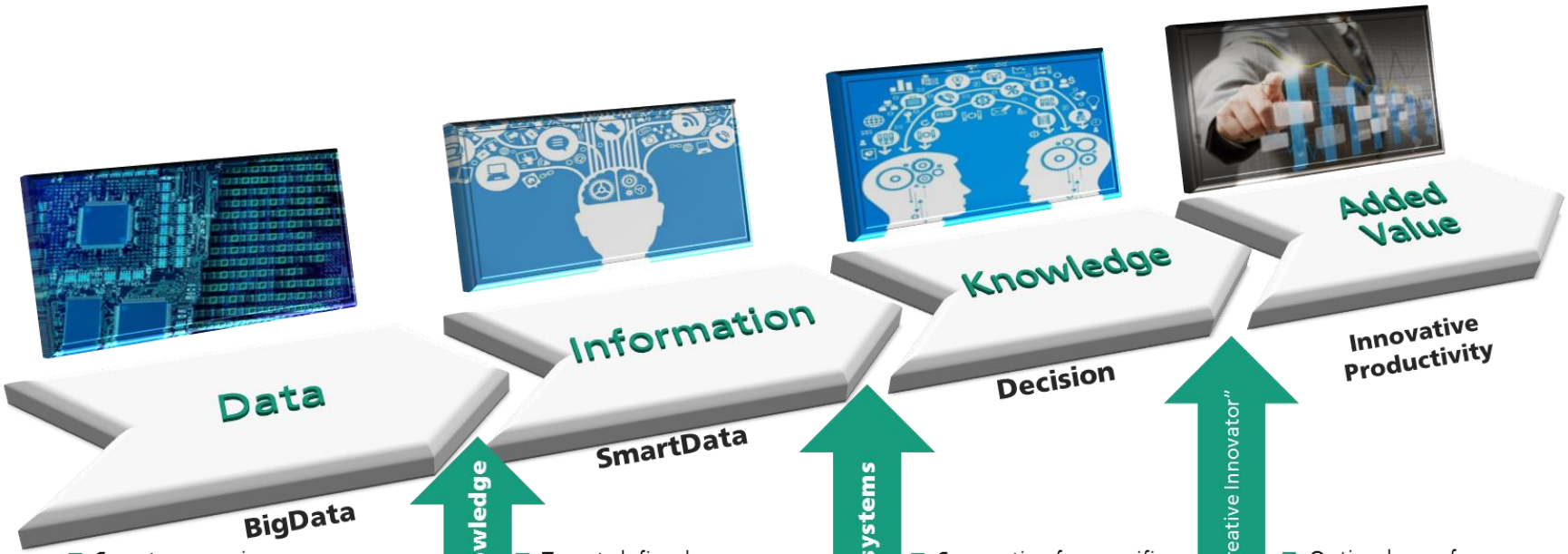
Dresden (since 2001)
- Mechatronics
- Technical Acoustics
- Additive Manufacturing
- Joining Technologies
- Medical Engineering

Zittau (since 2011)
- Plastic Center

Wolfsburg (since 2012)
- Electro-Mobility and Lightweight Design
- Open Hybrid LabFactory e.V.

Leipzig (since 2011)
- Technology Transfer for Regional Engineering Industry

Next Generation Manufacturing
Production Technology in the new World of Data



- Smart sensors in production systems
- IT solutions manage large data volumes

- Target-defined user assistance
- Supply of information related to location / role

Prerequisite:
Suitable data base
Specialized software tools

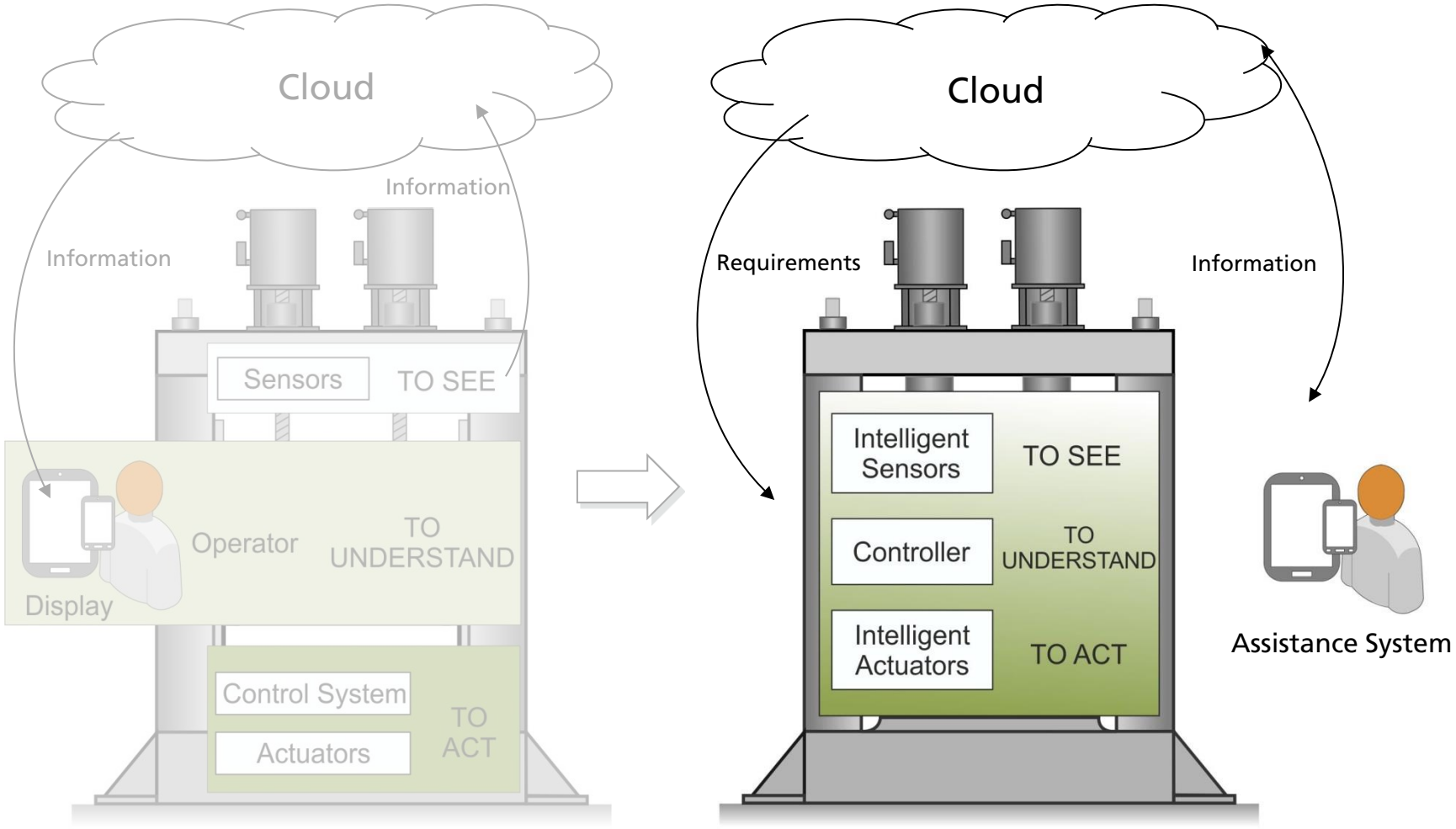
- Suggestion for specific instructions
- Securing knowledge

Prerequisite:
Filtering/ providing information

- Optimal use of resources
- Cost reduction, optimization of production

Prerequisite:
Possibilities of intervention

Complex Adaptive Manufacturing System – An Overview



Technologies

Wireless Data Transmission

Sensor Technologies

Wireless Power Transfer

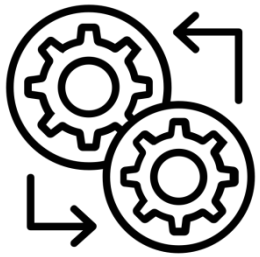
Actuator Technologies

Energy Harvesting

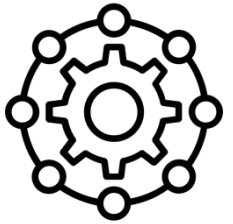
Applications

Condition Monitoring

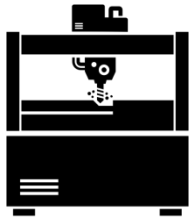
Process Monitoring



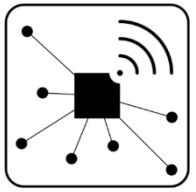
Process Control



System Integration



Manufacturing Processes



Cyber-Physical Production Systems

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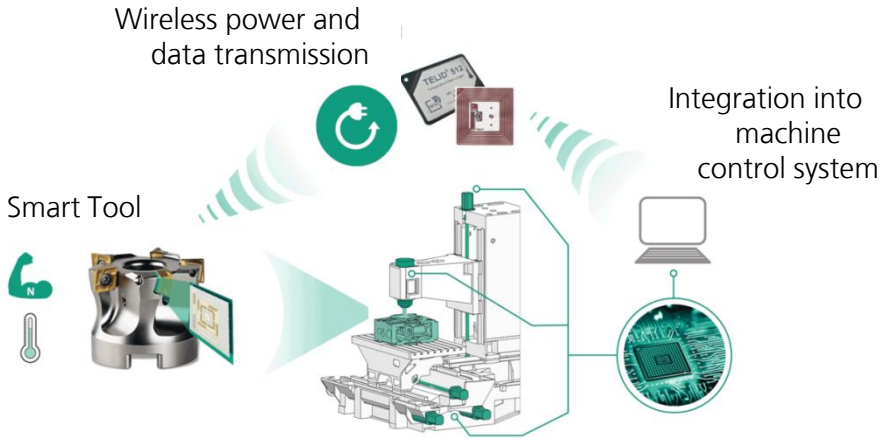
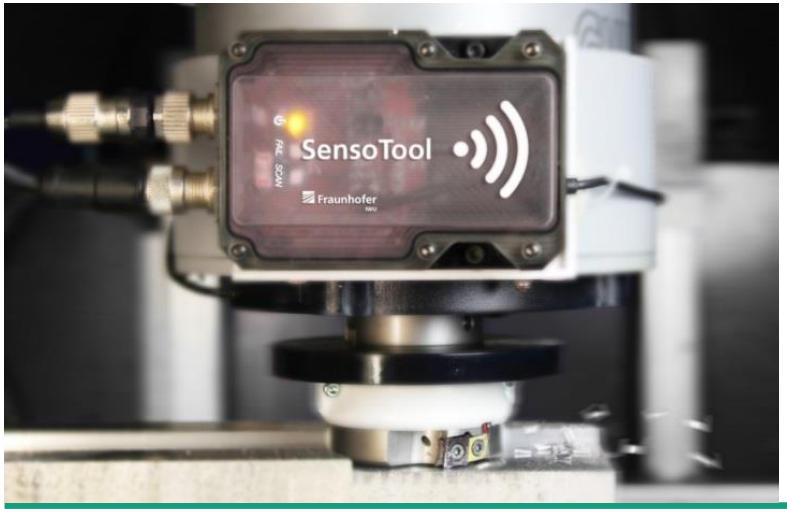
Sensor Technologies and Systems for

- Development of force- and temperature-measurement systems directly at the cutting edge
- Detection of wear and process instabilities
- Wireless data and power transfer

Monitoring and Control of Machining Processes





- Integration in overall control system
- Realization of a situationally-optimal machining process
- Cost and resource efficient manufacturing

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Project Example - SensoTool

Motivation

- Increasing complexity requires an increasing adjustment of process parameters
- Small deviation leads to a leave of the process window

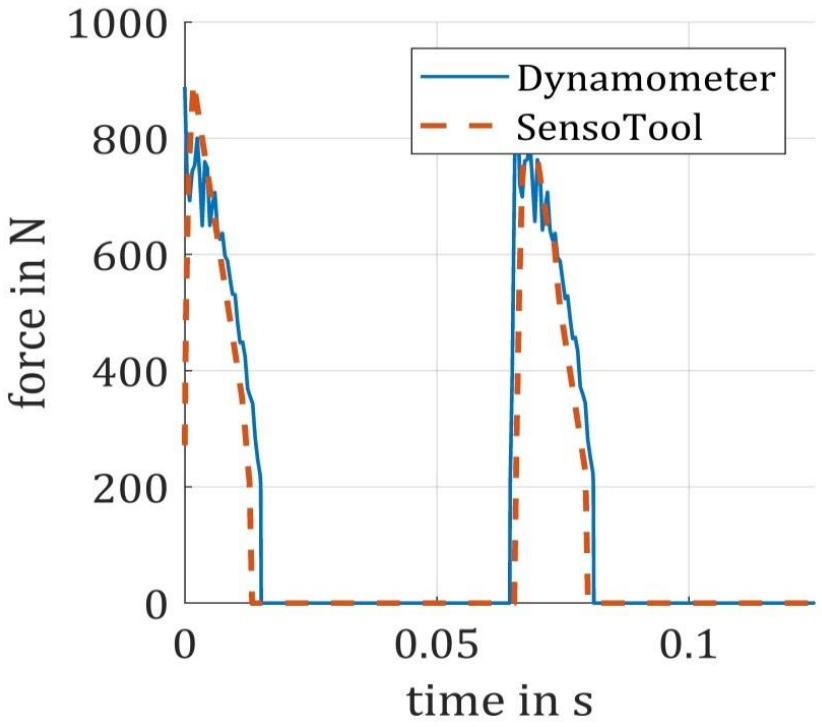
Objective / Approach

- Measuring of cutting forces and temperatures at the cutting edge by means of piezoelectric sensor layers
- Wireless transmission to the machine control
- Evaluation and reaction by autonomous adjusting of the process parameters

Project Example - SensoTool

Comparison between Kistler plate Dynamometer and new sensorsystem

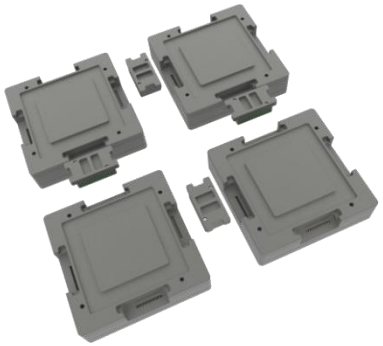
- Dynamometer bandwidth < 1.8 kHz
- SensoTool Bandwidth:
  - Piezo sensor bandwidth > 10 kHz
  - Mechanical bandwidth <10 kHz

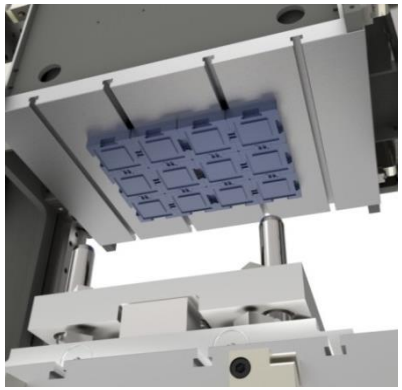


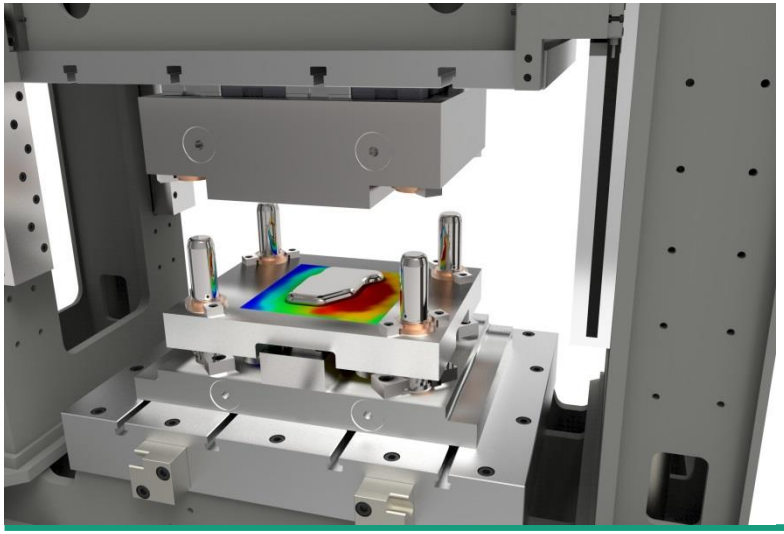
Sensor Technologies and Systems for

- Force distribution as one of the most important factors for high quality manufacturing
- Detection of process instabilities and optimal process setup
- Maintenance on demand

Monitoring and Control of Forming Processes







- Tool and machine independent and modular approach allows the application on all tool geometries
- Integration in overall process control
- Visualization via Augmented Reality

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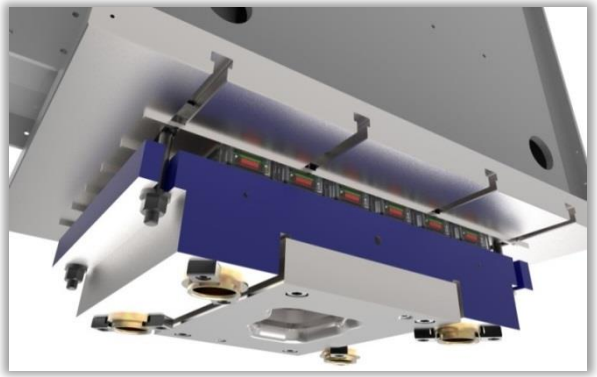
Project Example – Modular Measuring System

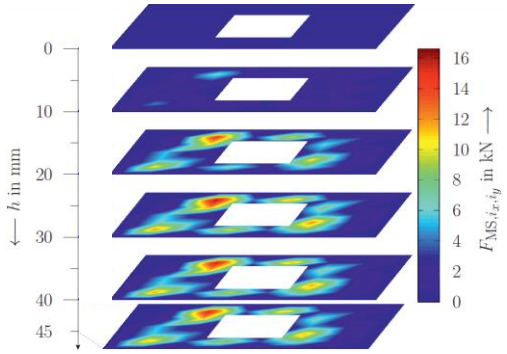
Current State of Development at Fraunhofer IWU

- Built-up System in Application
- Module size: 52 x 52mm, Smaller dimensions and combination of several modules to one bigger module possible
- Force Range of each module: 20kN
- Measuring dynamics: <10ms



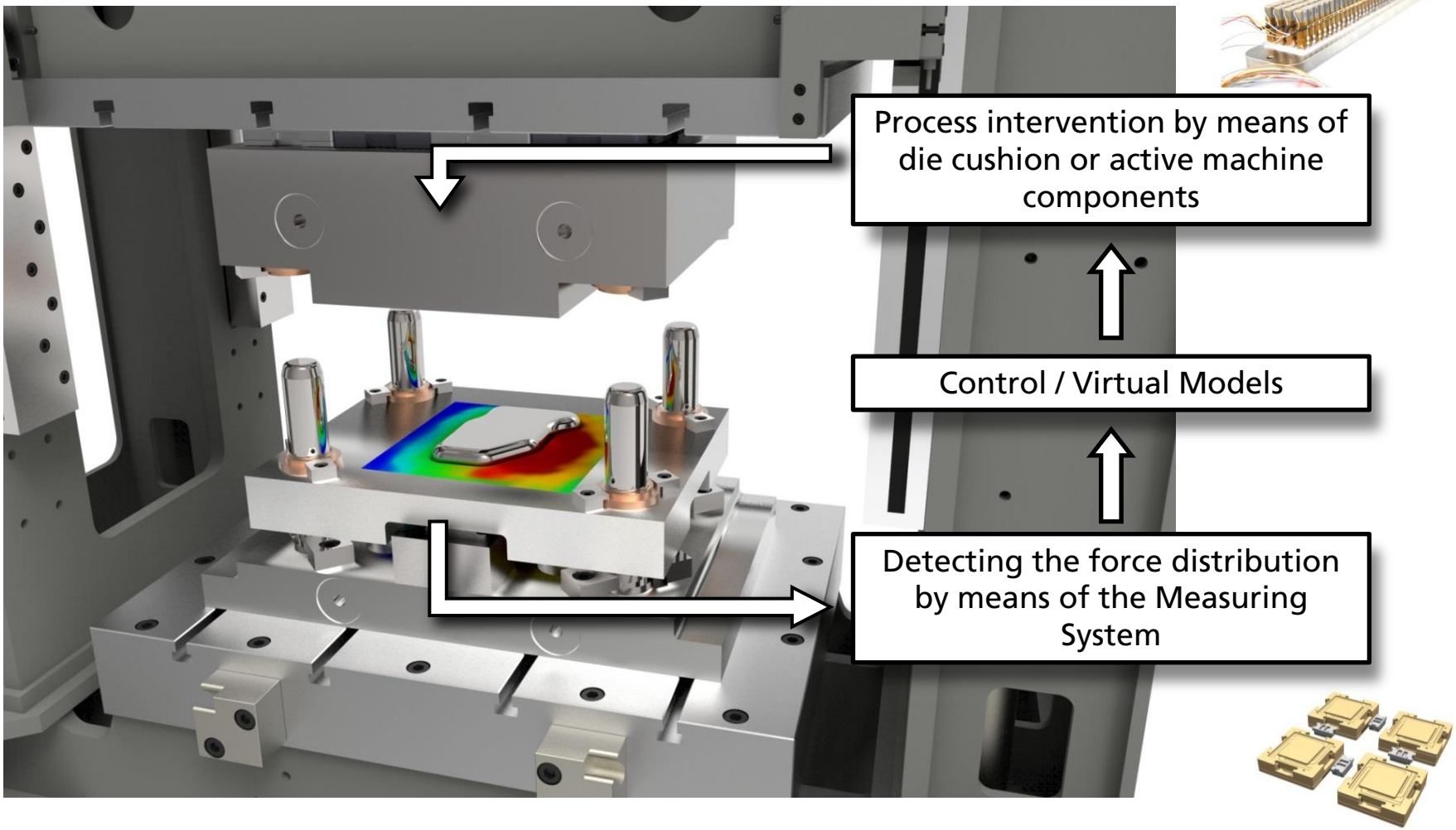
Benefits

- Temporal and areal visualization of the force distribution in forming
- Detection of changes in process
- In-process Crack detection and localization
- Every tool-size and geometry coverable
- Maintenance on demand



Project Example – Modular Measuring System

Use-Case: Situationally-optimal Forming Process



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Sensor Technologies and Systems for

- Pretension in bearings and ball screw drives allow high accuracy in machining processes
- Process heat and wear leads to a loss of pretension and accuracy

Condition Monitoring of Machine Components

- Retrofittable sensor for measuring axial forces and temperatures
- Component-side data preprocessing and wireless data transmission
- Predictive Maintenance and model based adjustment of control parameters (system integration)

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Project Example – Smart Sensor Ring for Ball Screw Drives

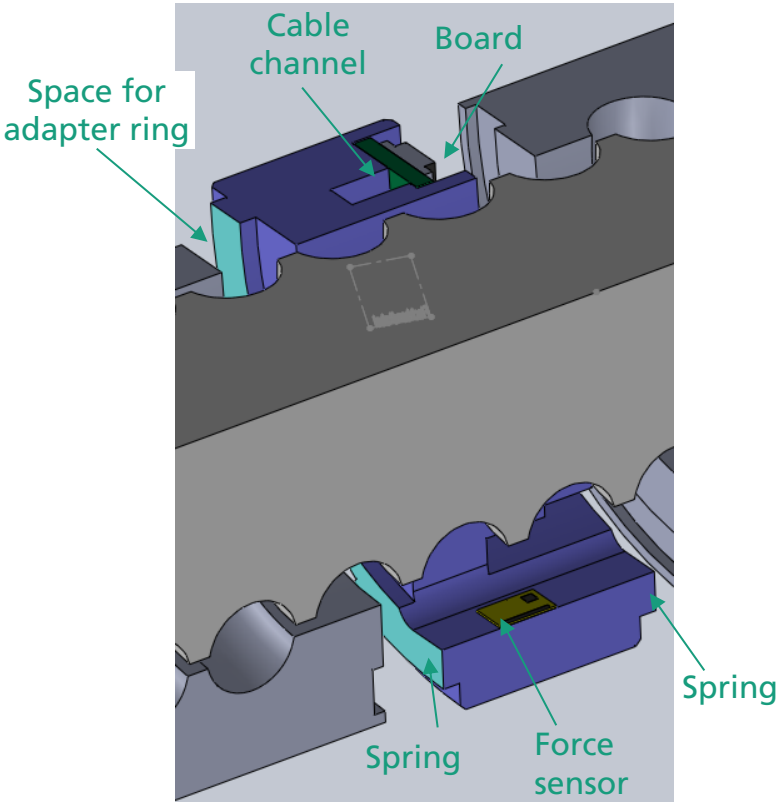
Motivation

- Ball Screw Drives as one of the most important components in Machine Tools
- Applied preload realize high-precise motion
- Heating up of the components within high-performance applications leads to a loss of preload, and thus a loss of precision in worst case
- Idea: On-line-monitoring of preload during the process guarantees an operation close-to-the-edge to performance limits

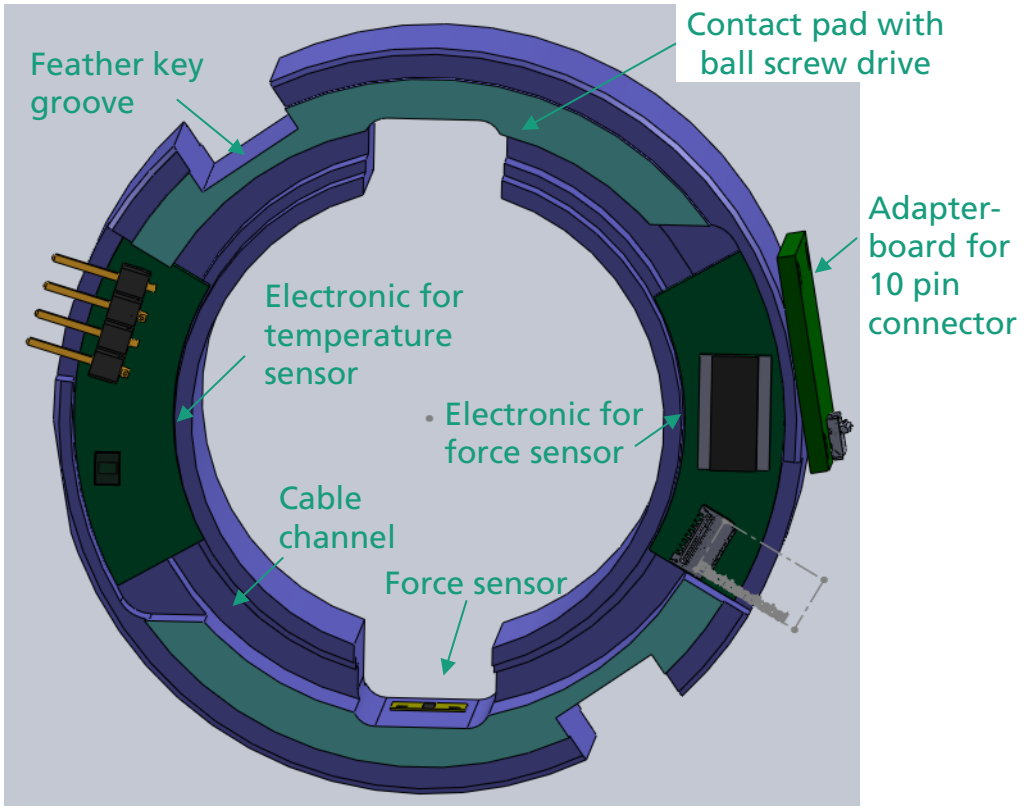
Approach

- Arrangement of a measuring ring between the two nuts of the ball screw drive
  - Integration of force and temperature sensors
  - Integration of electronics inside the ring

Project Example – Smart Sensor Ring for Ball Screw Drives

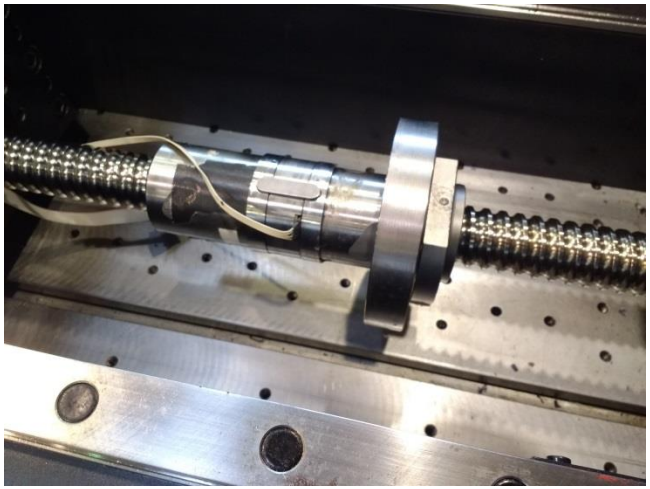


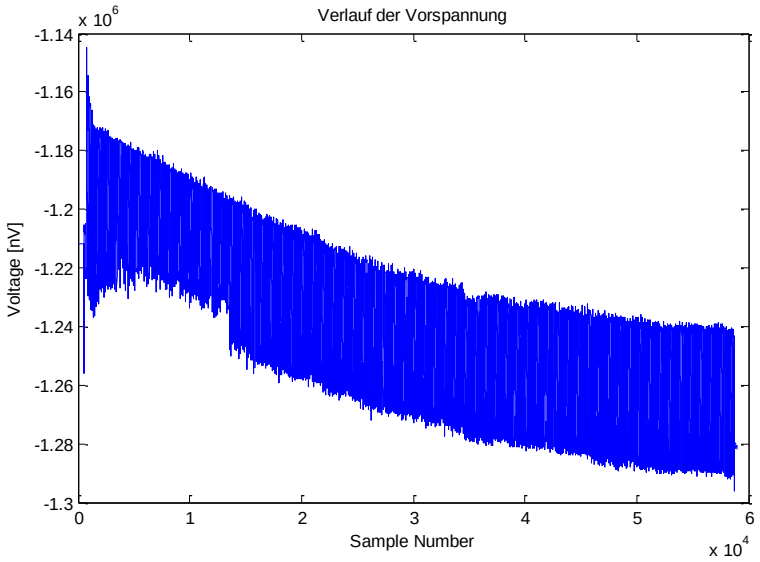
Integrated into ball screw drive



Model sensor system with force sensor and electronic

Project Example – Smart Sensor Ring for Ball Screw Drives





Benefits

- Retrofittable sensor for measuring axial forces and temperatures
- Component-side data preprocessing and wireless data transmission
- Predictive Maintenance and model based adjustment of control parameters (system integration)

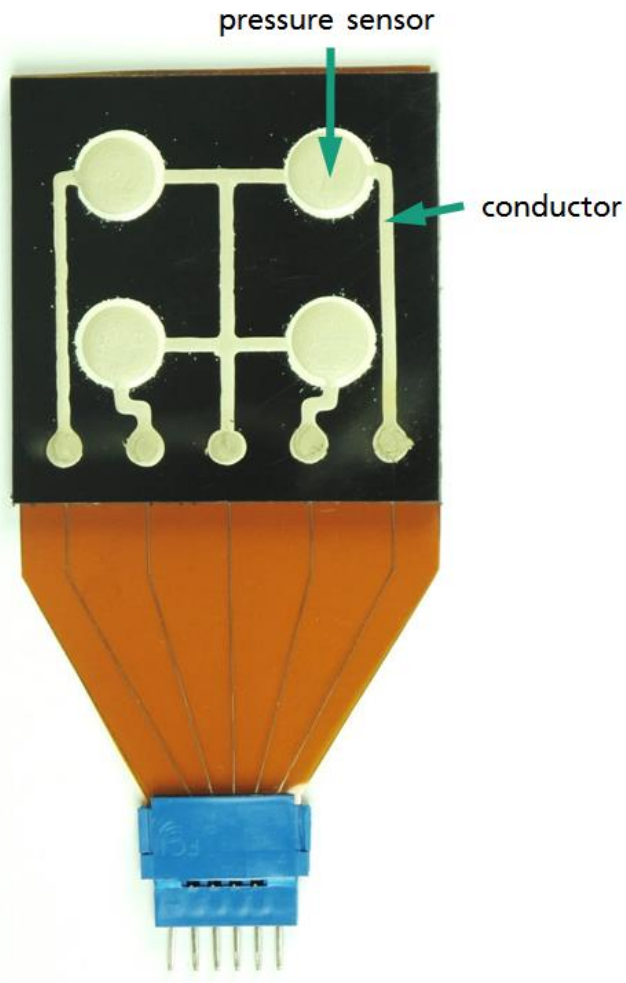
Outlook: Project Example – Go Beyond 4.0

Motivation

- Increasing integration density of sensors
- Sensors can't be easily mounted on hard-to-reach spots
- Electrical contacts for the sensors need either connectors or solder joints
- Idea: Integrate sensors and wiring directly onto the machine part

Approach

- Highly integrated functional structures without assembly
  - Integration of temperature, humidity, strain, and force sensors via functional printing
  - Simplifying wiring and electrical contacts with printed conductors



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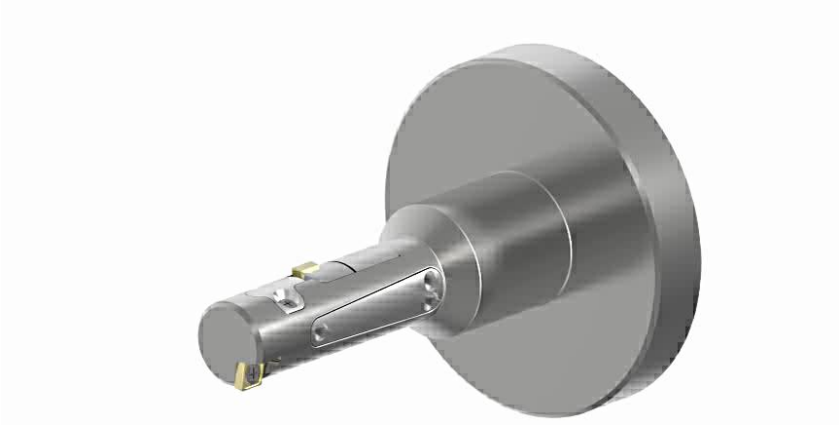
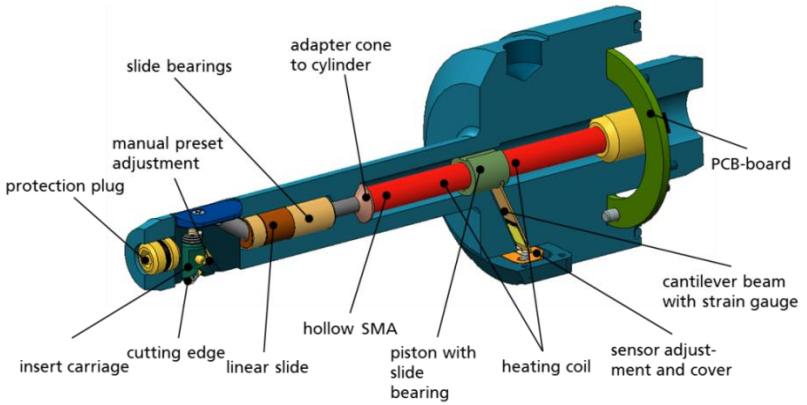
Active Tools and Machine Components for

- Development of active tools and machine components for tool fine adjustment and wear compensation based on shape memory alloy heavy-duty actuators

Tool Fine Adjustment and Wear Compensation





- Different ways of integrating the actuators into the tool holder
- Incremental readjustment for fine position and wear compensation
- Multiple activations

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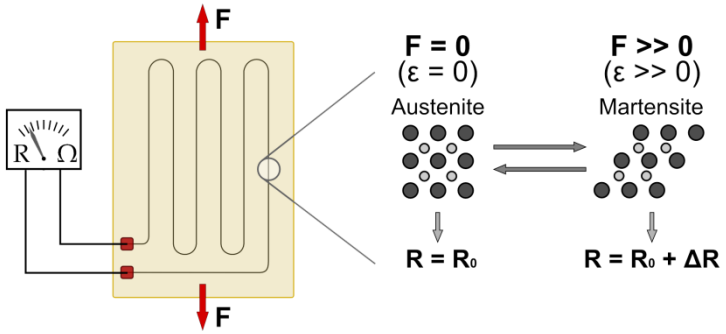
Sensor Technologies and Systems for

- Development of strain sensors based on shape memory alloys
- Structural integration into polymers and composites through injection molding, laminating and infiltration

Strain Measurement in Fiber Composite Structures



- High sensitivity (gauge factor k > 5)
- High elasticity: reversible strain <8%
- Low-fatigue (multiple million cycles)
- Simple data acquisition by means of electric resistance changes

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Sensor Technologies and Systems for

- Structural health monitoring of fiber composite components / structures through SMA strain sensors
- Substitution of conventional strain gauges with insufficient properties

Monitoring (SHM) of Fiber Composite Components

Fields of application

- Rotor blades of wind power plants
- Structural components of vehicles
- Pipelines, tubes, pressure vessels
- mechanical characterization / testing

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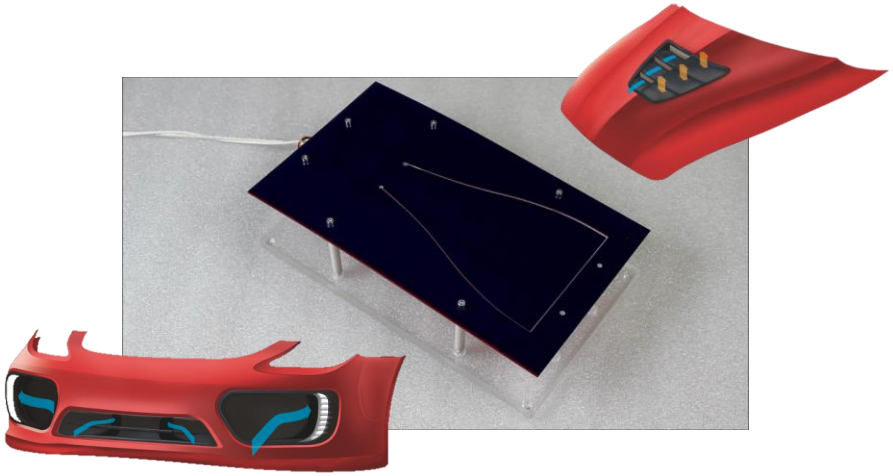
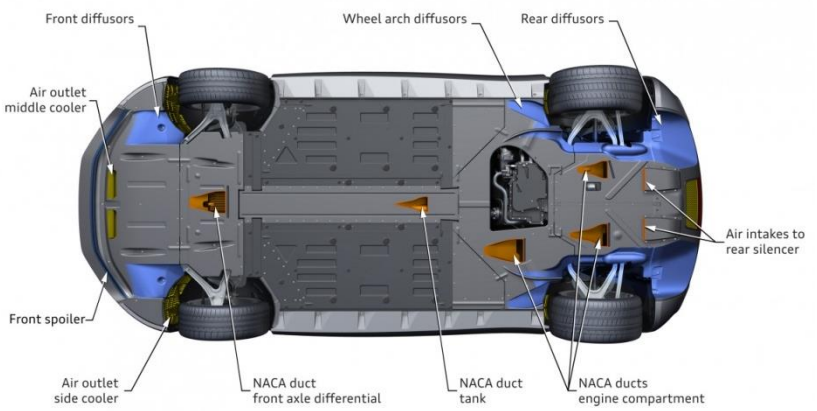
Structure Integrated Actuators for

- Embedment of actuators based on shape memory alloy wires
- Activation by environmental heat
- Reduction of weight by substitution of conventional actuators

Functionalization of Fiber Composite Components





Fields of application

- Self-sustaining actuators
- Adoption of housing shape or stiffness to improve thermal or acoustic properties
- Opening / closing of cooling flaps

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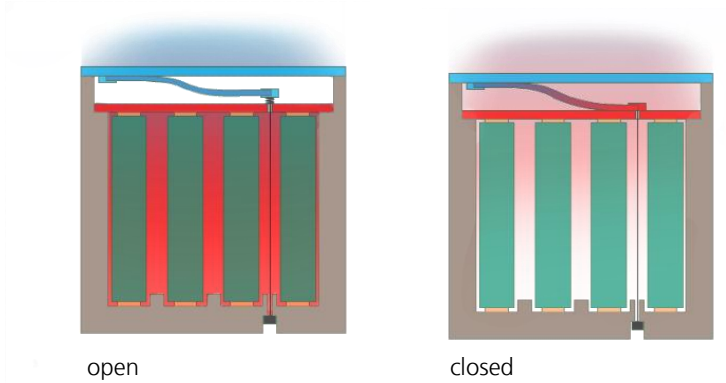
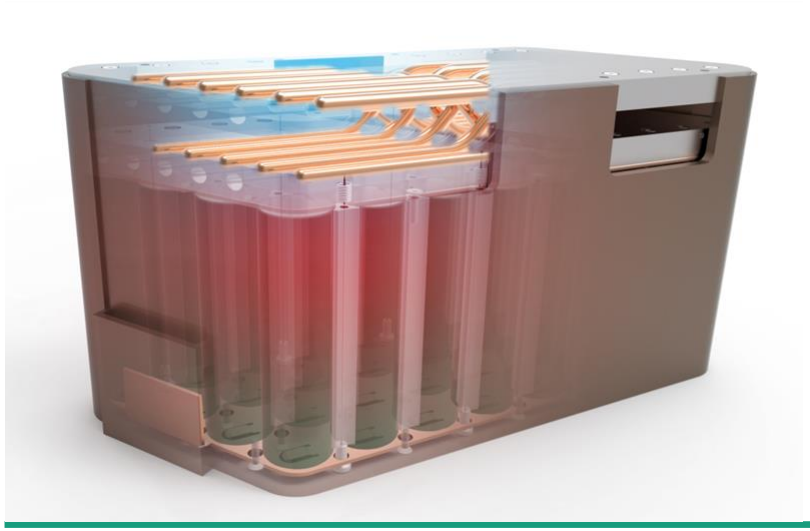
Smart Solutions for

Thermal Management and Heat Transfer

- Switchable thermal conduction through self-switching thermosensitive shape memory material
- Removal of battery heat through the use of heat pipes





Other solutions for EV batteries

- Crash-resistant energy storage with thermal management through aluminum foam, organo sheet cover layers and phase change materials (PCM)

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