Enabling the factories of the future:
The role of smart systems in manufacturing and robotics

Tracht, K., Kuhfuss, B., Brinksmeier, E., Busse, M., Kroll, L., Hogreve, S., Garbrecht, M., Lehmhus, D., Heinrich, M., Bosse, S.

Zurich, 21.03.2012

Universität Bremen

Roles of Smart Systems

… in Manufacturing & Robotics

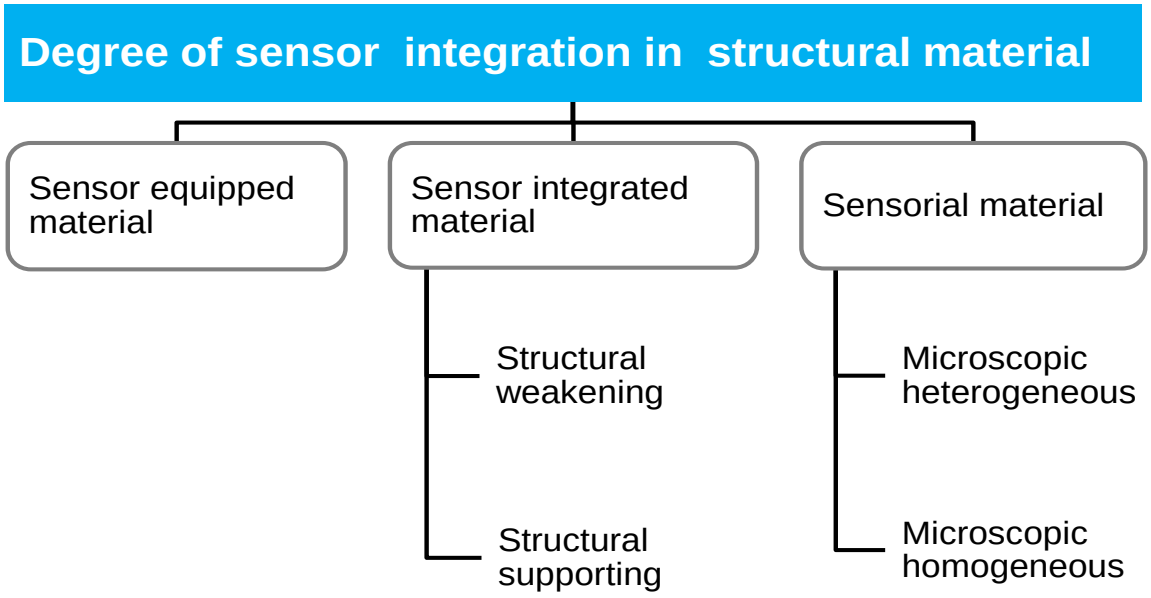
Smart Systems for Manufacturing	Manufacturing of Smart Systems	Smart Systems for Use
• Factory automation • Production planning	• Manufacturing technology • Process control	• Condition monitoring • Adaptivity

Evolution of Smart Systems

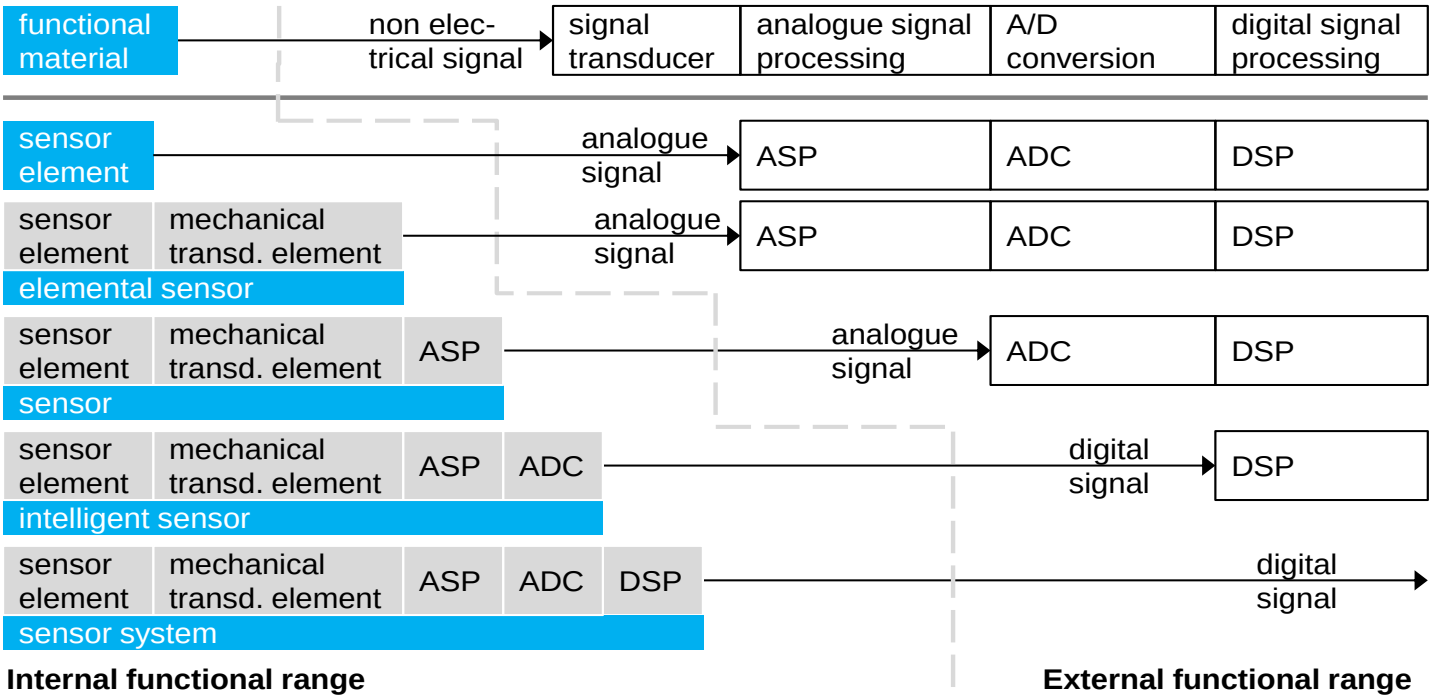
1st Generation **Integrated & Miniaturized**	• Advanced functionality • Compact design	• Intelligent tooling • Fibre Bragg grating for fibre-reinforced plastic
2nd Generation **Predictive & Reactive**	• Environment matching • Energy harvesting	• Adaptive gripper • Self-calibrating robot sensing
3rd Generation **Autonomous**	• Autonomous systems • Cognitive abilities	• (Autonomous robot) • (Internet of things)

Source: according to EPoSS WG Manufacturing and Robotics

Structural Integration in Sensorial Materials

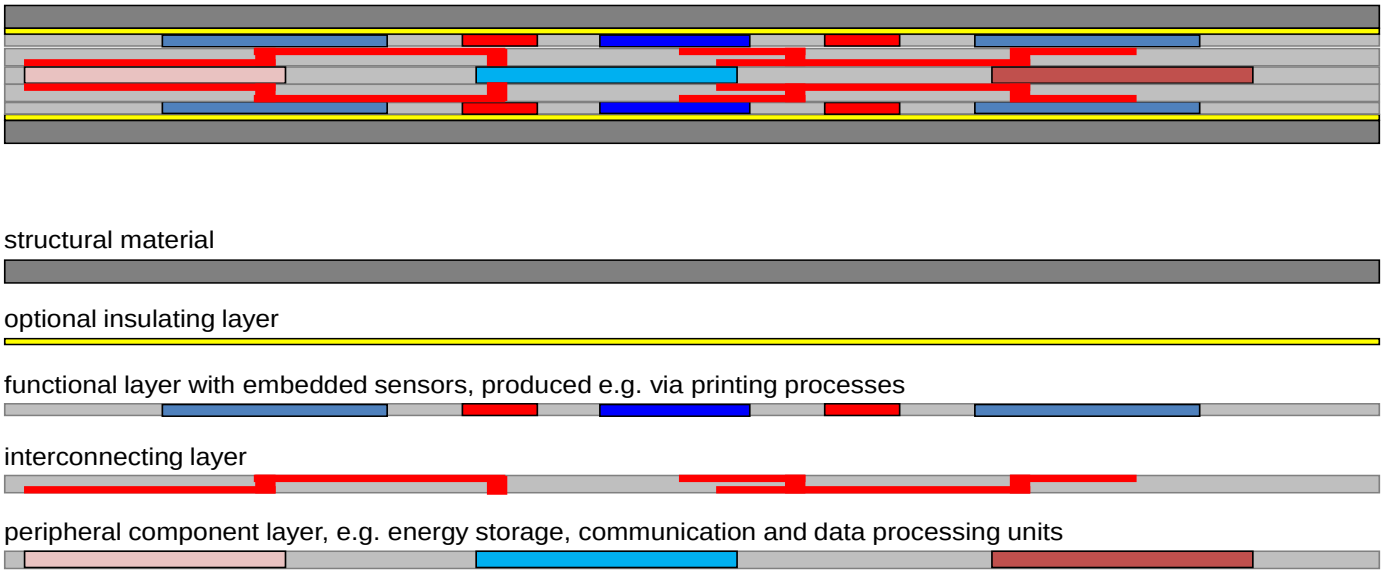


Functional Integration in Sensorial Materials



Realization of Sensorial Materials

Layer by Layer



Sensorial Materials

Layer by Layer

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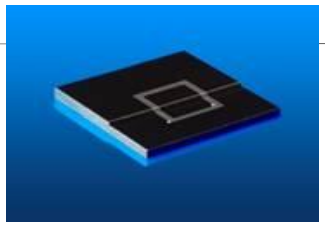
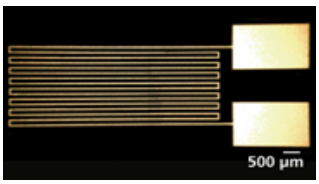
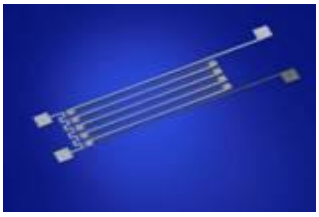
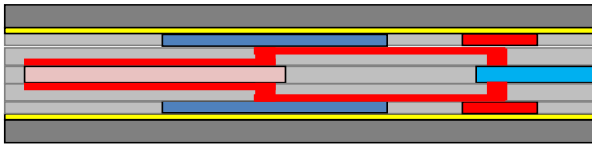
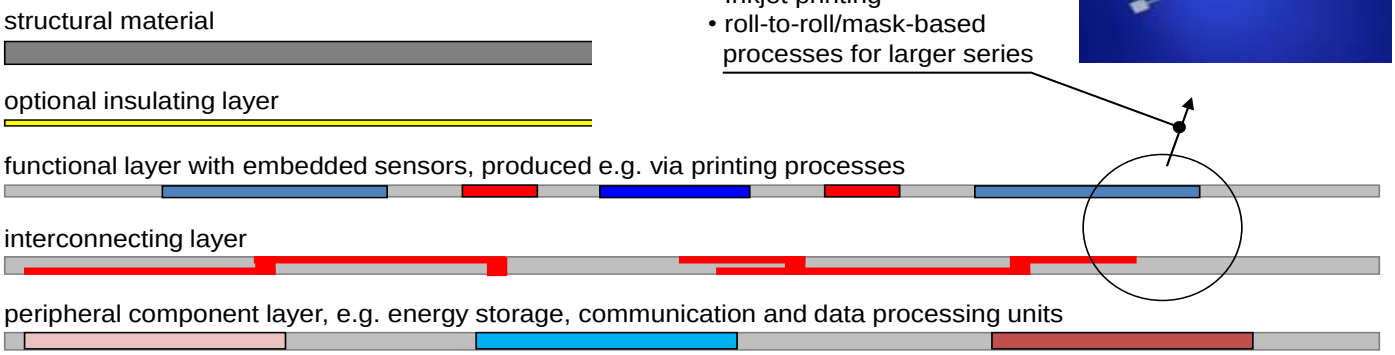






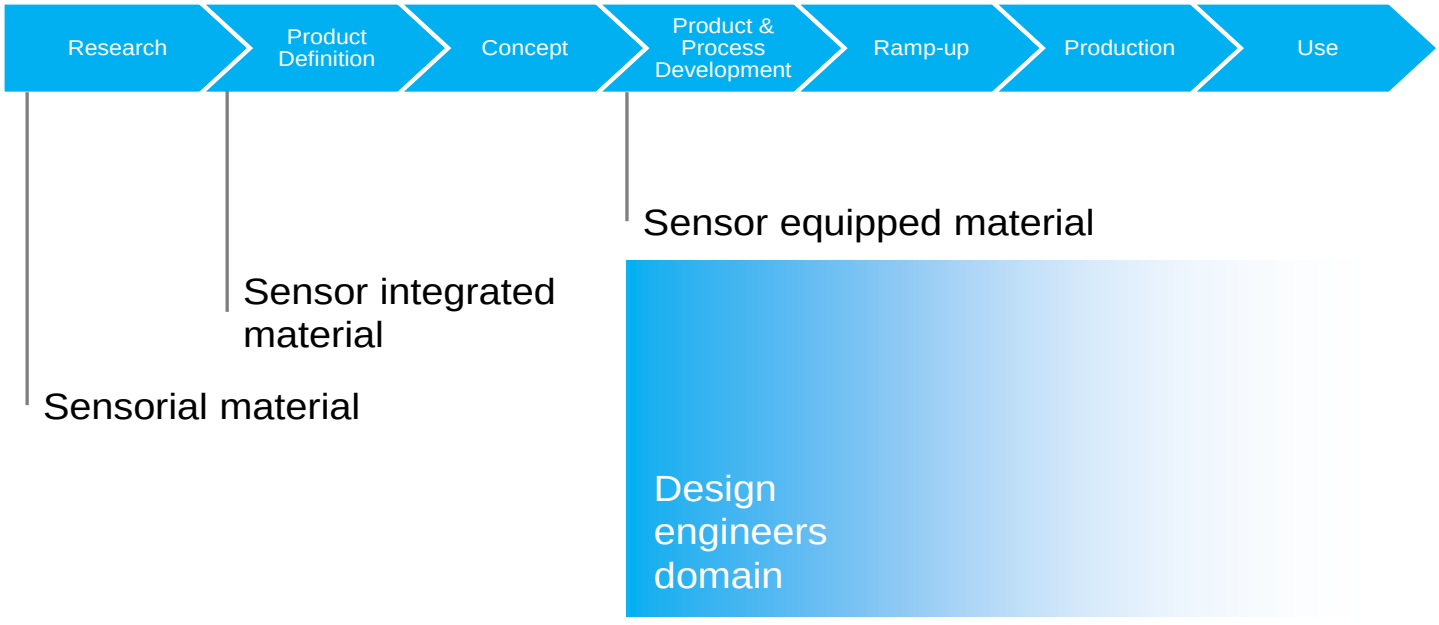


Potential techniques for sensor application:
- Aerosol Jet® printing
- Inkjet printing
- roll-to-roll/mask-based processes for larger series

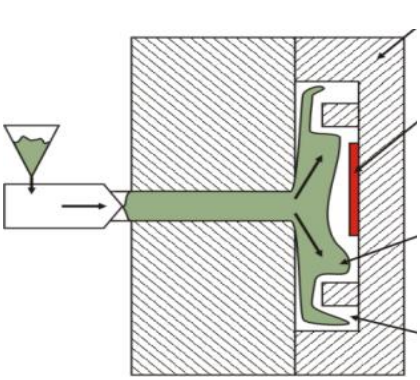


Product Development & Production

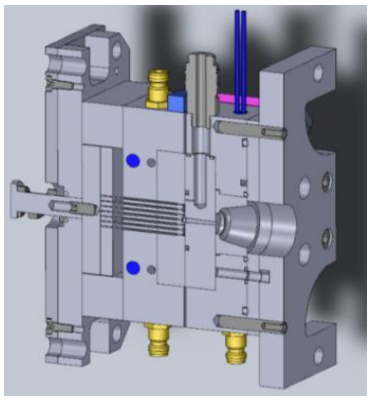
Integration level vs. place in prod. Developm.



Concept of a Polymer Based MEMS



Process of back injection of a PVDF-sensor film



µ-injection moulding tool

Battenfeld/Wittmann: Microsystem 50; µ-injection moulding machine

Purely micro injection moulded MEMS

- Absolutely mass production
- Use of available established materials
- Low cost production
- One step process

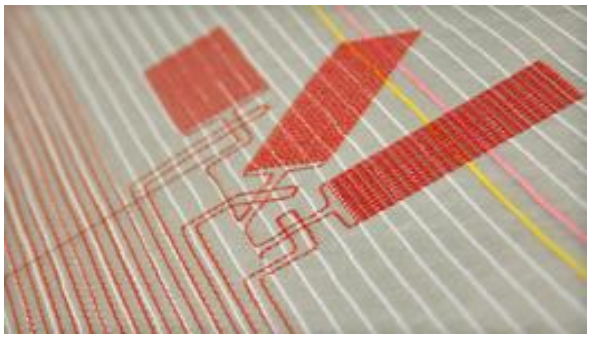
Department of Lightweight Structures and Polymer Technology
Univ.-Prof. Dr.-Ing. habil. L. Kroll

Sensors for Structural Health Monitoring

Bridging Smart Systems Roles

- Control of process while manufacturing of rotorblades
- Extension of service interval by detection of failure
- Early reaction in case of failures
- Detection of loads thereby optimal pitch setup possible
- Ice detection

„FiberCheck“



Stitched strain gauge on a semi finished glass fibre textile.

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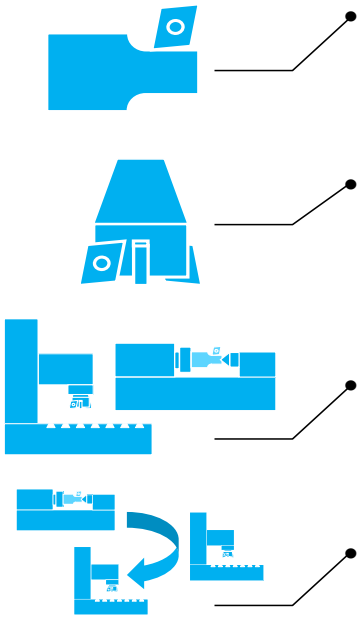
Smart Systems for Manufacturing

Where to get, where to use the data ?



Workpiece

Smart/sensorial materials to monitor not only life cycle loads, but also the manufacturing process (online process monitoring, OPM). Exchange of data with machine tool control an option/aim.

Tool

Smart tooling to collect data „closer to the process“, to better understand the process itself, supply new/alternative/additional data, to provide information to process control, to increase accuracy by allowing compensation of tool-related deterioration.

Machine Tool & Robotics

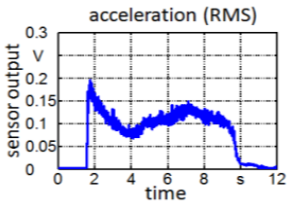
Machine tool sensorization to detect/compensate system-related sources of inaccuracy, provide new /alternative/additional data to the machine control system, enabling among others predictive maintenance solutions.

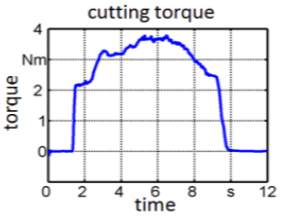
Production Cell/Line/Site

Integrate sensor data over all levels to support production planning/control.

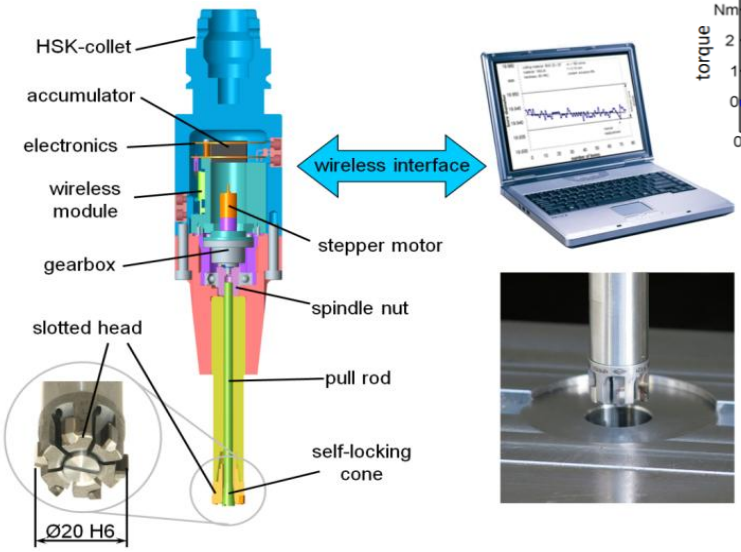
Smart Syst. for Manufacturing

Smart Tooling: Reaming Tool (I)





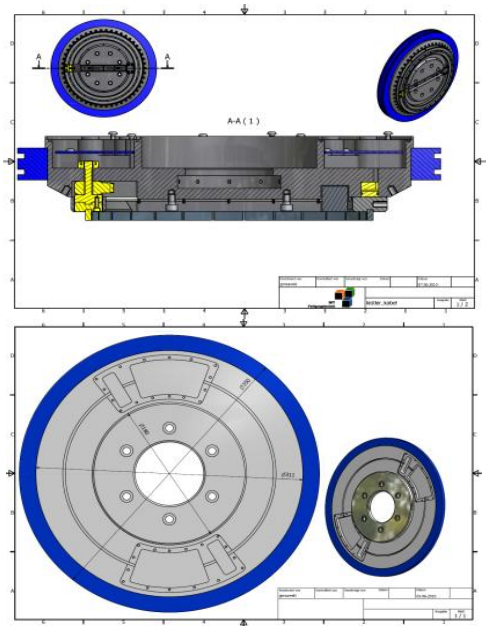
Adaptive reaming tool with integrated strain gauges and stepper motor based system for compensation of cutting edge wear to achieve increased accuracy and extended tool life.



bime

Smart Syst. for Manufactur.

Smart Tooling: IntelliTool (I)



3rd/4th generation IntelliTool smart grinding wheel using wheel-integrated signal transmission via optical fibre, photodiode-based infrared temperature sensing and telemetric data transmission to external signal evaluation unit.

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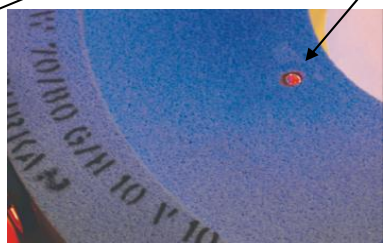
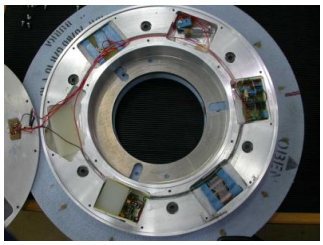
wheel-integrated optical fibre, measuring site and photodiode

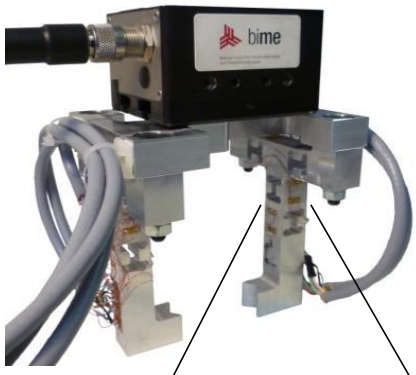




Smart Systems for Manufacturing

Smart Tooling: 3D force sensitive Gripper (I)

- Grasping of pressure sensitive objects
- Grasping of objects with uncertain geometry
- Force adaptive path corrections
- Force measuring with strain gauges
- Weak areas to concentrate deformation
- Separation between x-, y- and z- direction forces



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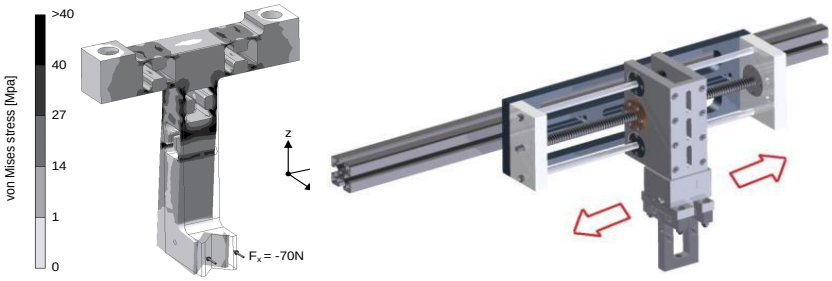
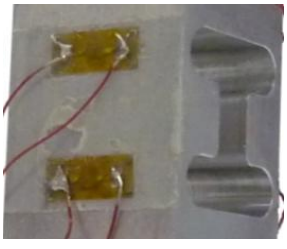
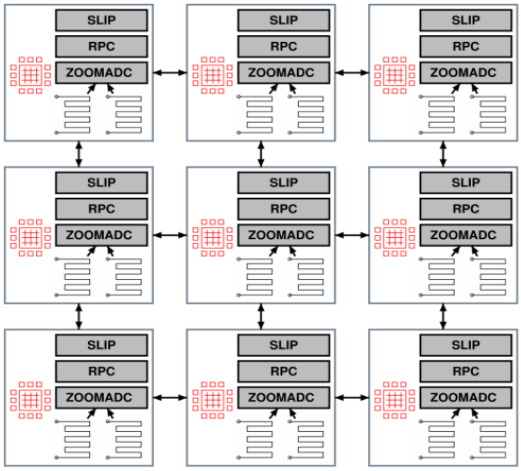


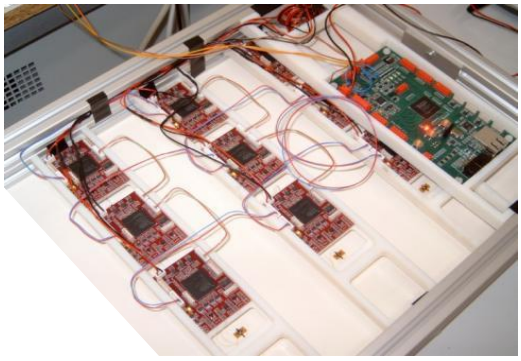


Smart Syst. for Manufact.

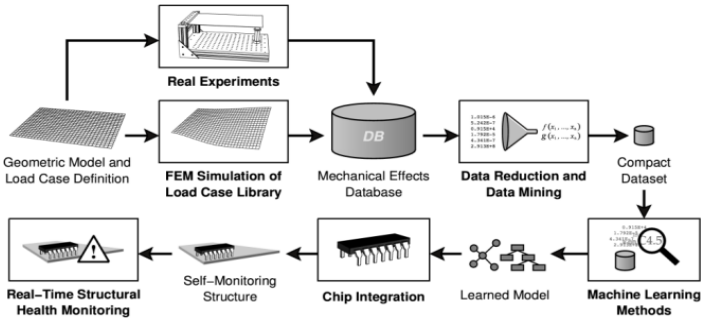
Sensor Networks



Machine learning and networks of active sensor nodes with decentralized data processing and advanced methods from Artificial Intelligence are used to sense both environmental and embodied information and aids structural health monitoring.



Lehrstuhl Kirchner



Smart Systems for Manufacturing

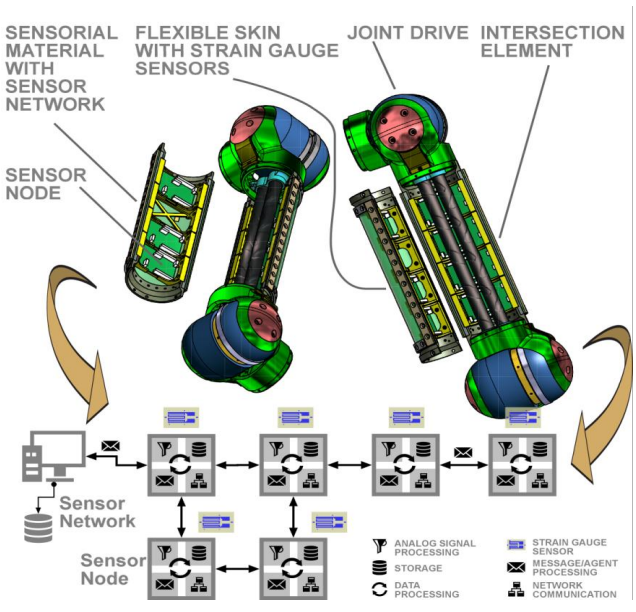
Sensor Network in Robotics

Lehrstuhl Kirchner

Integration of sensorial materials in robotics using active sensor networks embedded in a robot arm manipulator to provide perception of the environment (e.g. collision detection and interpretation).

Tight coupling and integration of sensors, actors, and data and information processing.

Multi-agent systems are used to implement distributed data processing and information derivation.



Smart Systems for Manufacturing

Smart Products | Smart Production

- Intelligent tools and processes

  Sensor integration, embedded systems, real-time data evaluation, improved process understanding and modeling to allow for immediate reaction to processing deviations, data evaluation and knowledge accumulation to allow derivation of reaction strategies, predictive maintenance etc.

- Guidance through production assistants

  Reduction of external control complexity by provision of multiple sensor/signal- and knowledge-based, simplified views on production status to operators.

- Intelligent production design process

  Use of sensorial materials as product models for physical simulation/evaluation of production designs in experimental machine setups.

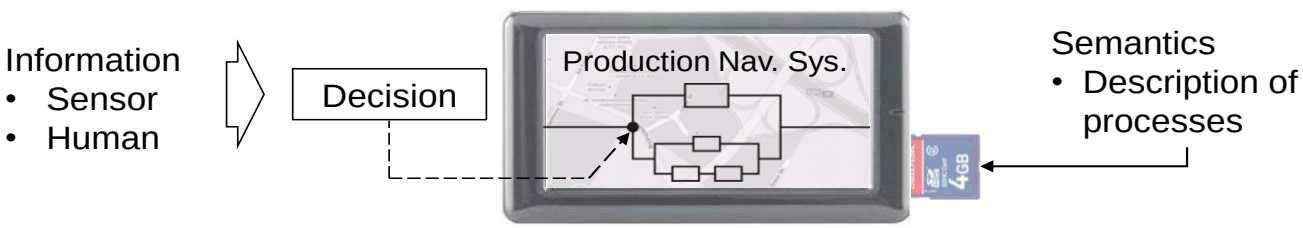
- User-friendly human-machine-interfaces (HMI)

  New ways to communicate status information and justify decisions in part or fully autonomous production systems.

Smart Products for smart production

Production Navigation System

Production Information Systems	• Tolerances • Production parameters • Evaluation of scheduling alternatives
Production Assistance Systems	• Process control • Fault compensation • Process adjustment
Production Navigation System	• Avoidance of bottlenecks • Route optimization • Proposition of alternative routes



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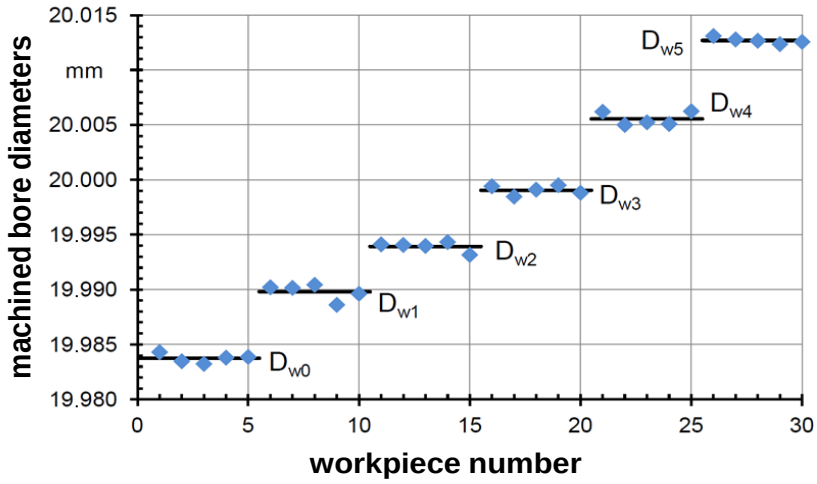
Smart Systems for Manufacturing

Smart Tooling: Reaming Tool (II)

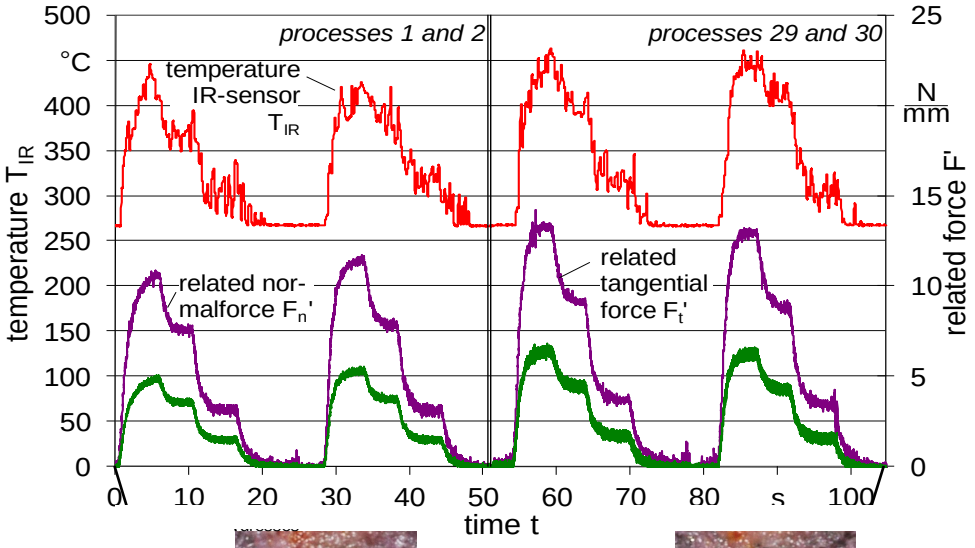
The correct and accurate function of the adjustment mechanism is proven

Adjustment has no influence on the quality of the bores



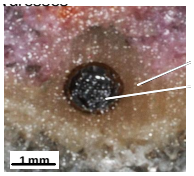
Sensing in Production

Smart Tooling: IntelliTool (II)

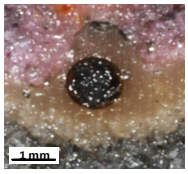


workpiece:
18 CrNiMo 7-6
dw = 99 - 95,4 mm
b = 12 mm
grinding wheel:
A 80 K 8 V 10
process:
Außenrund
v_s = 30 m/s
n_w = 80 min^{-1}
rough grinding:
v_{fr} = 1,2 mm/min
$a_{e.rg}$ = 0,09 mm
fine grinding:
v_{fr} = 0,8 mm/min
$a_{e.fg}$ = 0,08 mm
finish grinding:
v_{fr} = 0,3 mm/min
$a_{e.fhg}$ = 0,03 mm
sparking out:
t = 8 s
coolant:
6,6 l/min
mineral oil

dressed



after 30 grinding cycles



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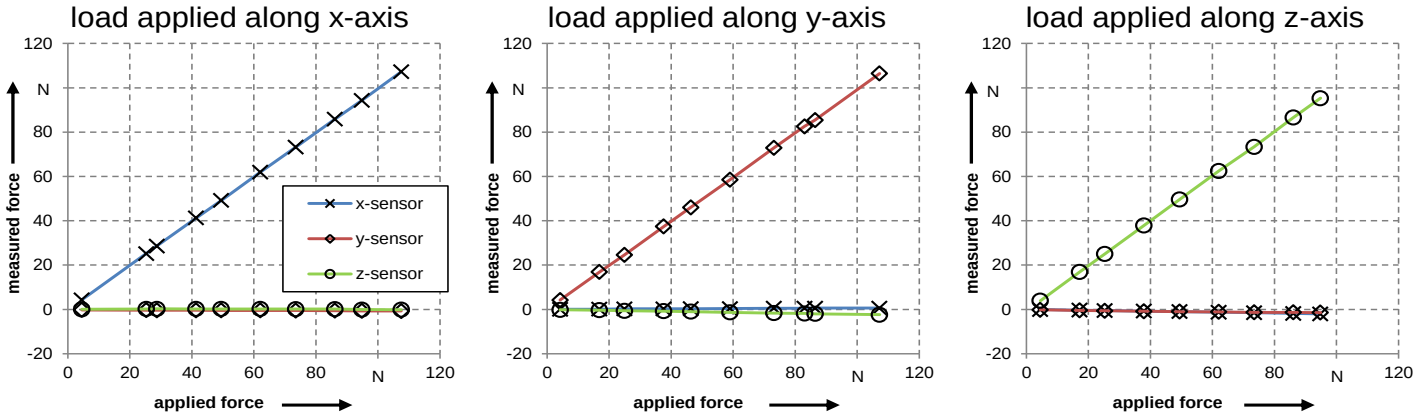
Sensing in Production

Smart Tooling: 3D force sensitive Gripper (II)



bime

- Sufficient physical separation, interferences < 3 %
- Maximum measuring error 1.43 %
- Proof-of concept successful
- Design evolution towards embedded systems