

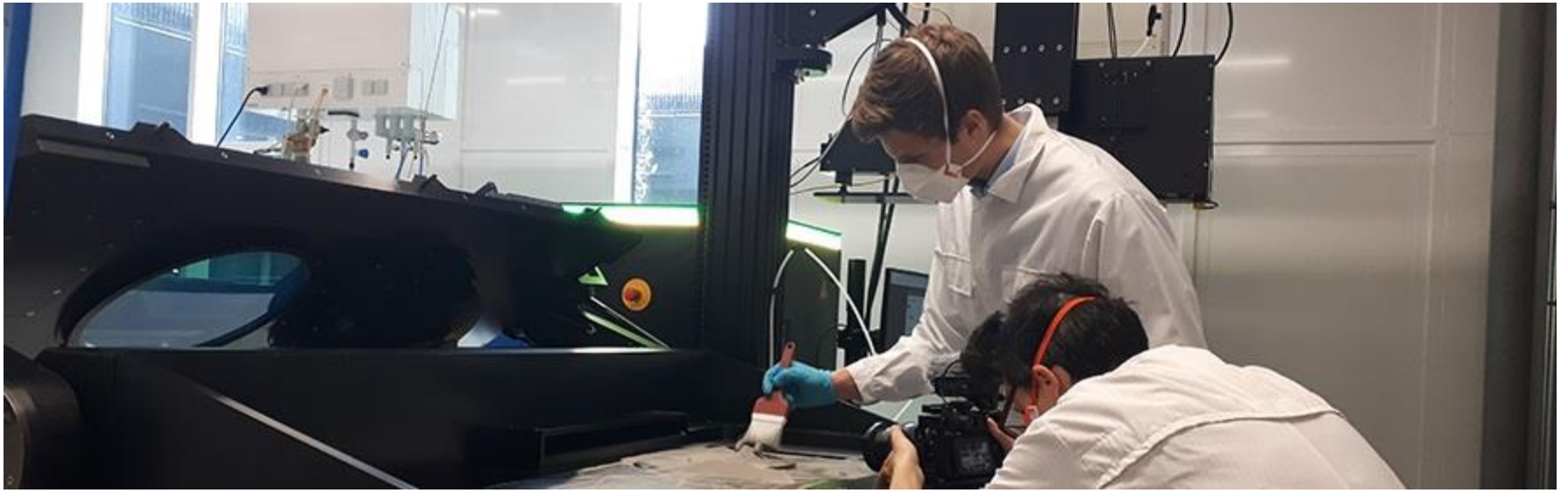
# FUTURE POTENTIAL OF AM – METAL AM

## „SMART PARTS AND MULTI-MATERIAL PARTS“

AMTC – Session “AM 2030: AN INSPIRING LOOK INTO THE FUTURE”, October, 13<sup>th</sup> 2021

**Prof. Dr.-Ing. Christian Seidel**

contributors: M. Binder, M. Horn, M. Schneck, M. Schmitt, C. Singer, V. Stapff, M. Zaepfel



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# AGENDA

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Additive Manufacturing@Fraunhofer IGCV



“Quick Start Guide” Metal-3D-Printing



“Quick Start Guide” Smart Parts and Multi-material Parts



Case Studies



Conclusion

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# AGENDA

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## Additive Manufacturing@Fraunhofer IGCV



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Case Studies



Conclusion

# Fraunhofer Institute for Casting, Composites and Processing Technology IGCV is the Bavarian Fraunhofer Institute for Production.

## Augsburg Innovation Park

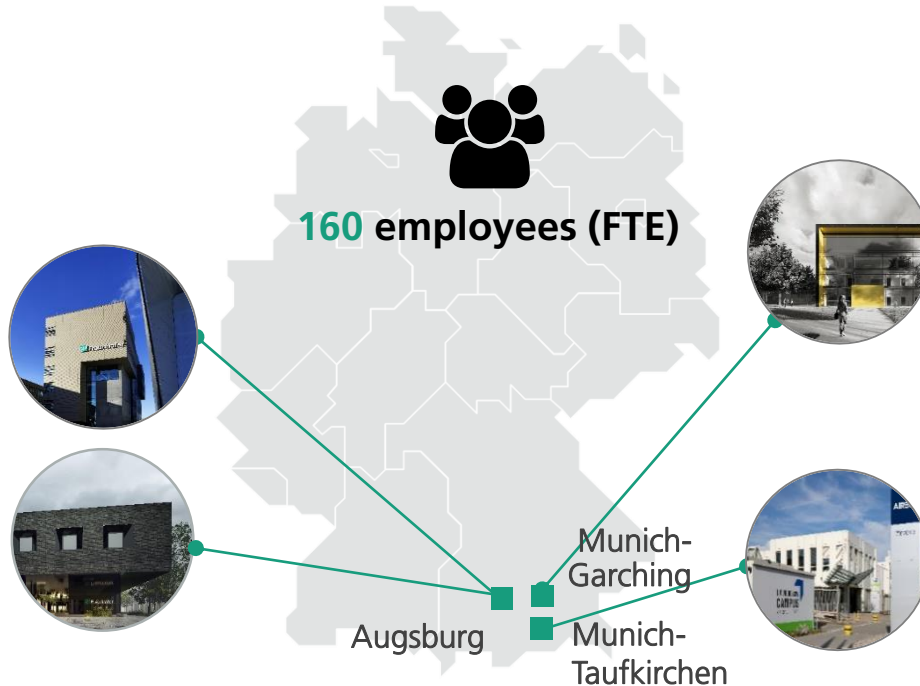
2 buildings with over 6,000 m<sup>2</sup> of office and lab space:

## Composite

Am Technologiezentrum 2  
86159 Augsburg

## Processing

Am Technologiezentrum 10  
86159 Augsburg



## Casting@Research Campus of Technical University of Munich

Office: 300 m<sup>2</sup>  
Lab: 1.500 m<sup>2</sup>

## Casting

Zeppelinstr. 15  
85748 Garching / Munich

## Ludwig Boelkow Campus

Willy-Messerschmitt-Str. 1  
82024 Taufkirchen

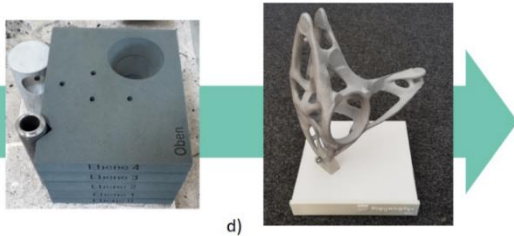
# As a cross-department competence, 30 scientists are working on Additive Manufacturing.



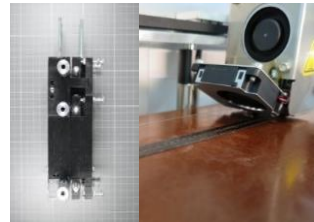
30 Scientists, 60 Students



Head of Additive Manufacturing  
Prof. Dr. Christian Seidel



AM@Sand/Tooling  
Dr. Daniel Guenther



AM@Polymer/Composites  
Prof. Dr. Iman Taha



AM@Metal  
Dr. Georg Schlick / Dr. Peter Barth /  
Prof. Dr. Johannes Schilp

## Focus:

Additive Manufacturing of sand moulds and tools via **Binder Jetting** for casting application

## Focus:

**Extrusion-based** technologies and **Liquid Deposition Modeling** (LDM) for processing of (fibre-reinforced) **Polymers**

## Focus:

**Laser-based Powder Bed Fusion** and **Directed Energy Deposition** (High-Pressure Cold Gas Spraying) for **Metals** and **Multi-materials**

# Together with the *iwb* of the Technical University of Munich, 16 industrial AM machines are operated in the joint laboratory "AMLab"!

## Sand

### Binder Jetting



**Voxeljet**  
VX1000<sup>1</sup> | VXC800<sup>1</sup>  
| VX500<sup>1</sup> | Test rig<sup>1</sup>



**Laser:** Trumpf TruDisk 4001  
**Optic:** Precitec CoaxPrinter  
**Robot:** KUKA KR60  
**Wire unit:** Dinse DIX FDE-PN 100L<sup>2</sup>



**CMT-Advanced 4000**  
6-Axis-Kuka-Robot  
KR15/6<sup>2</sup>



**High-Pressure Cold Gas Spraying<sup>1</sup>**



**Fronius**  
TPS 400i; 6-Axis-Yaskawa-Robot  
2-Axis-Positioner<sup>2</sup>



To be announced

## Metal

### PBF-LB/M Multi-material / Standard



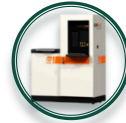
**Aconity**  
ONE<sup>1</sup>



**SLM Solutions**  
SLM@280 2.0<sup>1</sup>



**SLM Solutions**  
250 HL<sup>1</sup>



**Concept Laser**  
M1 Cusing<sup>2</sup>



**EOS**  
M280<sup>2</sup> | M400-1<sup>2</sup> |  
M290<sup>1</sup>



**SLM Solutions**  
125 HL<sup>1</sup>



**Trumpf**  
TruePrint 1000 Green<sup>1</sup> |  
TruePrint 2000 Dual<sup>2</sup>



**Test rig**  
In-house development<sup>2</sup>

## Polymer

### MEX / PBF-LB/P / VAT



**3D Systems**  
ProJet HD3000<sup>2</sup>



**Cresality3D**  
Ender 3<sup>2</sup> | 3



**Ender**  
3 Pro<sup>1</sup>



**Makerbot**  
5th Generation<sup>2</sup> | 2



**Voxeljet**  
AG VTS 128<sup>2</sup>



**Atum 3D<sup>2</sup>**



**Markforged**  
Marc Two<sup>1</sup>



**RepRap**  
X400 Pro V3<sup>1</sup>



**Stratasys**  
F270<sup>1</sup> | µPrint SE plus<sup>1</sup>



**Ultimaker**  
Original+<sup>2</sup> | 2  
Extended + 3<sup>1</sup> | 3  
Extended<sup>1</sup>



**Zortrax**  
M200<sup>1</sup> | M300<sup>1</sup>



**EOS**  
Formiga P100<sup>2</sup>



**Sintratec Kit**  
(Laser sintering)<sup>1</sup>



**Elegoo**  
Mars 2 Pro<sup>1</sup>

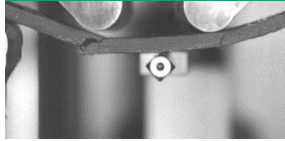


**Formlabs**  
Form 3<sup>2</sup>

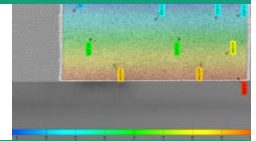
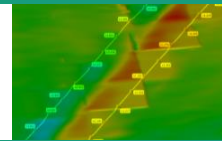
## Material Jetting

We offer a wide range of analytical equipment with special focus on powder characterization.

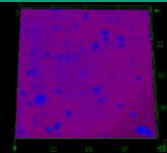
MECHANICAL



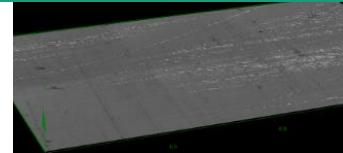
OPTICAL



THERMAL



PHYSICAL



POWDER LAB



Elemental Analysis (ONH)  
*Bruker*



Sieving  
*Haver, Fritsch*



Moistness  
*Sartorius*



Particle size distribution  
*MALVERN Panalytical*



Climate cabinet  
*Binder*



Dynamic Rheometry  
*Freeman Technology*

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“Quick Start Guide” Metal-3D-Printing



“Quick Start Guide” Smart Parts and Multi-material Parts



Case Studies



Conclusion



# Suitability for series production demonstrated across various industries and metal-3D-printing processes.



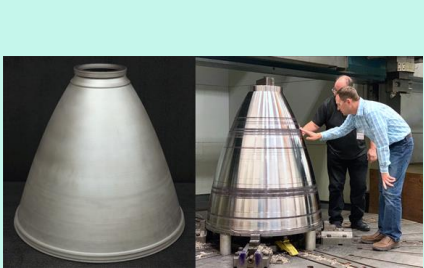
*Rolls-Royce body component produced by Laser-based Powder Bed Fusion<sup>1</sup> (aluminium)*



*Hip implant produced by Electron-based Powder Bed Fusion<sup>2</sup> (titanium)*



*(Large) components produced by (laser) Directed Energy Deposition<sup>3,4</sup> (nickel)*



*Milling head holder manufactured by means of "Metal-FDM" hybrid<sup>5</sup> (steel)*

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Case Studies



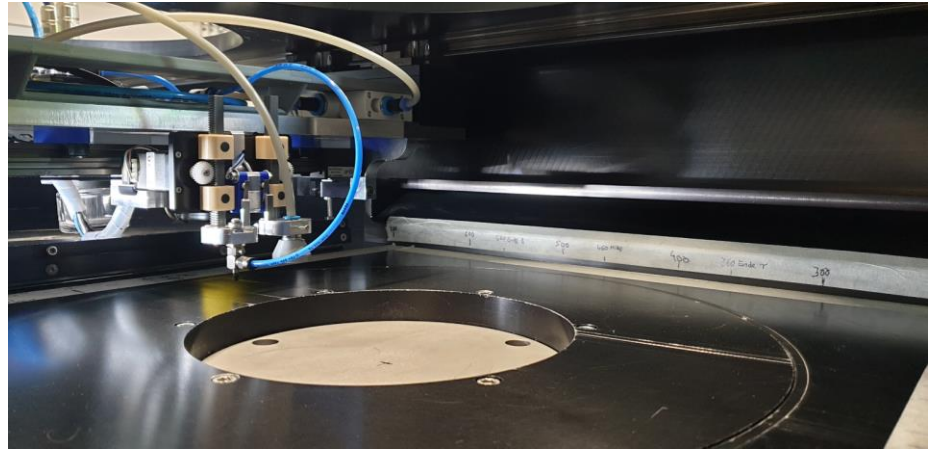
Conclusion

# Automated integration of sensors and actuators during 3D build-up demonstrated.

## Definition

- Sensors are implemented automatically during the 3D printing process.
- There is no need to open the process chamber for the implementation of the sensors.
- The sensors are inserted via a gantry robot on the coater axis and, if necessary, welded to the workpiece with the working laser.
- It is also possible to insert actuators.

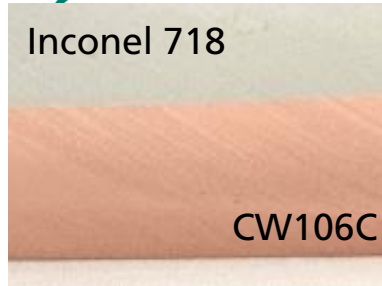
## Fraunhofer IGCV's sensor implementation



# Extension of Metal-3D-Printing (Laser-based Powder Bed Fusion) for the production of multi-material components is possible.

## Definition

2-D multi-material processing



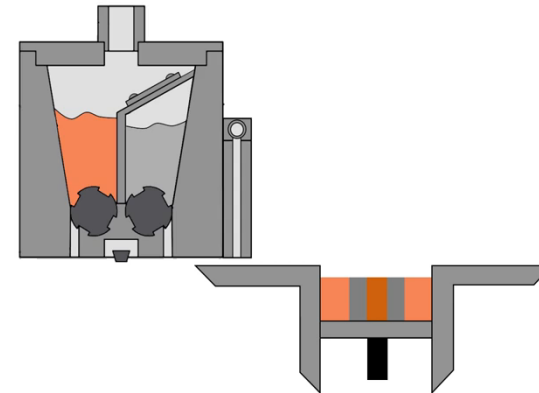
3-D multi-material processing



Technology demonstrator as of 2019, Tool steel 1.2709, Copper alloy CW106C built on SLM250 HL modified by Fraunhofer IGCV

## Fraunhofer IGCV's Multi-material module

### Multimaterialprozess



© Fraunhofer-Einrichtung für Gießerei-, Composite- und Verarbeitungstechnik IGCV

Fraunhofer  
IGCV

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Case Studies



Conclusion

# Multi-material injection nozzle for increased performance of large bore engines.

## Benefit

Increased heat conduction in the highly stressed area

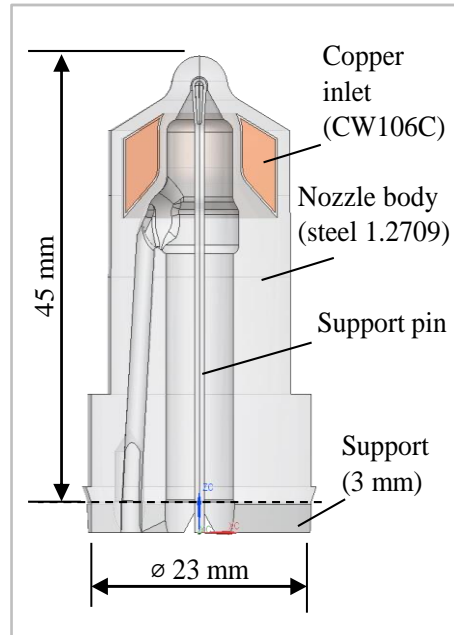


Improved temperature control in the injection nozzle



Enhanced engine performance

## Case Study in cooperation with MAN Energy Solutions SE



CAD model

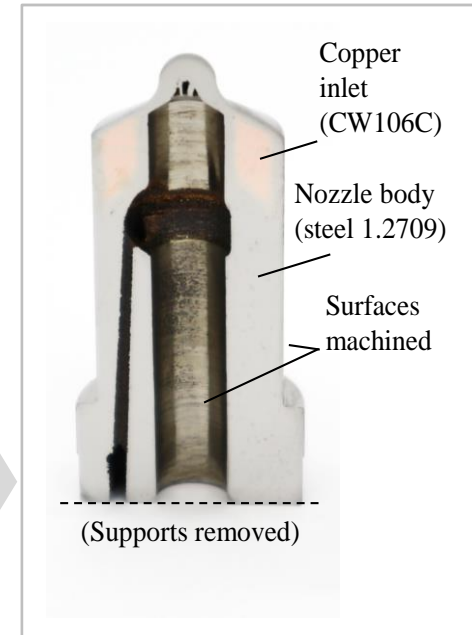
Data preparation for MM PBF-LB

Manufacturing by MM PBF-LB

Post-processing (machining)

Final part

Analysis



# Multi-material processing as enabler for in-situ alloying to „print“ high-performance gear wheels.

## Benefit

Extension of “freedom of design” by tailored material properties



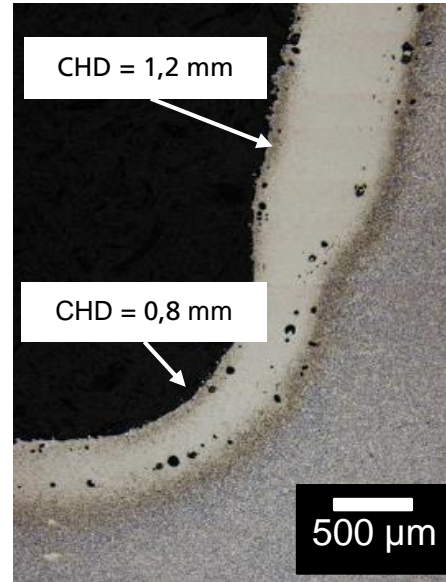
Improved wear resistance and mechanical performance



Enhanced performance

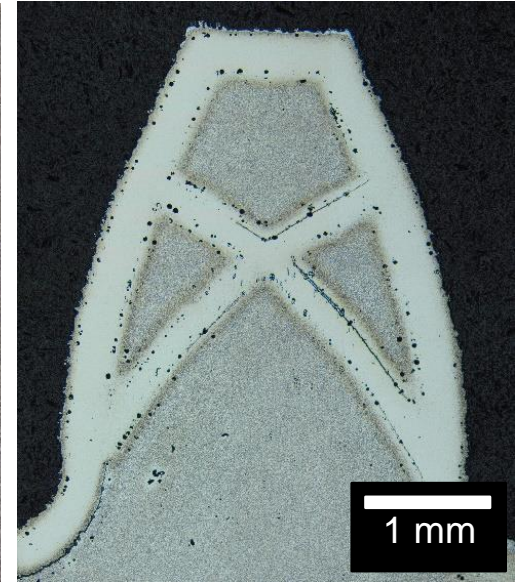
## Case Study funded by DFG – German Research Foundation

- a) Varied case-hardening depth (CHD) at tooth flank and at tooth root for optimal load carrying capacities



a)

- b) Tooth with intrinsic structure for reinforcement



b)



# Printed electronics in structural parts – technology demonstrator achieved in September 2021.

## Benefit

Processing of 3 materials by means of laser-based powder bed fusion

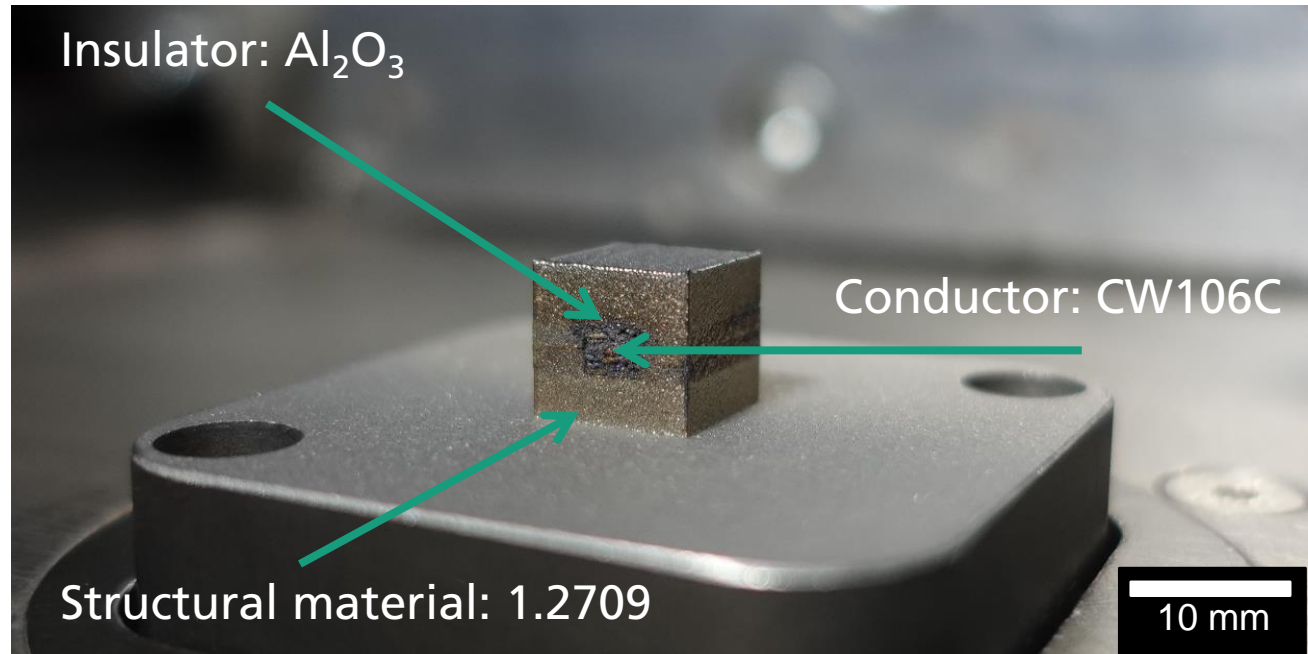


Enables printed conductor paths in structural components



Printed sensors

## Printed 3-material-Demonstrator





# Sensor-integrated gear wheel with 3D-printed antenna for advanced condition monitoring.

## Benefit

Simulation-based design of a 3D-printable Ultra-High-Frequency (UHF-) antenna



Implementation of RFID-temperature and -vibration sensor



Improvement of high-performance gears

## Case Study funded by Free State of Bavaria



# Sensor-integrated (strain gauges) rake for Aero Engine Application

## Benefit

Integration of strain gauges

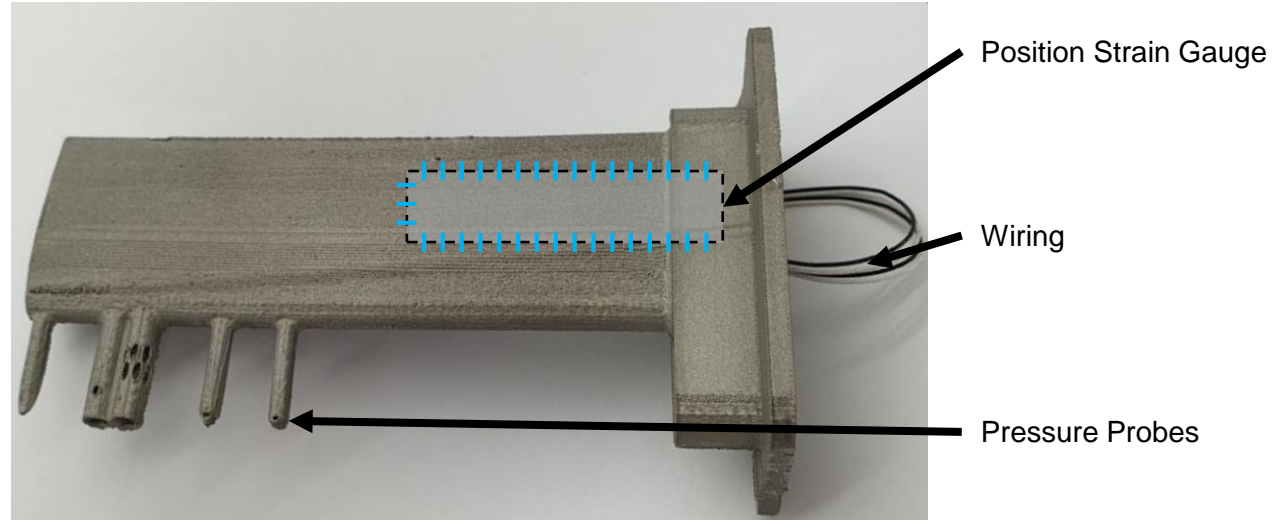


Validated performance of strain gauges after the print



New possibilities for condition monitoring

## Case Study in cooperation with Vectoflow GmbH



# Sensor-integrated (strain gauges) gripper jaws enable robots to perform joining processes.

## Benefit

Sensor-integrated gripper jaws

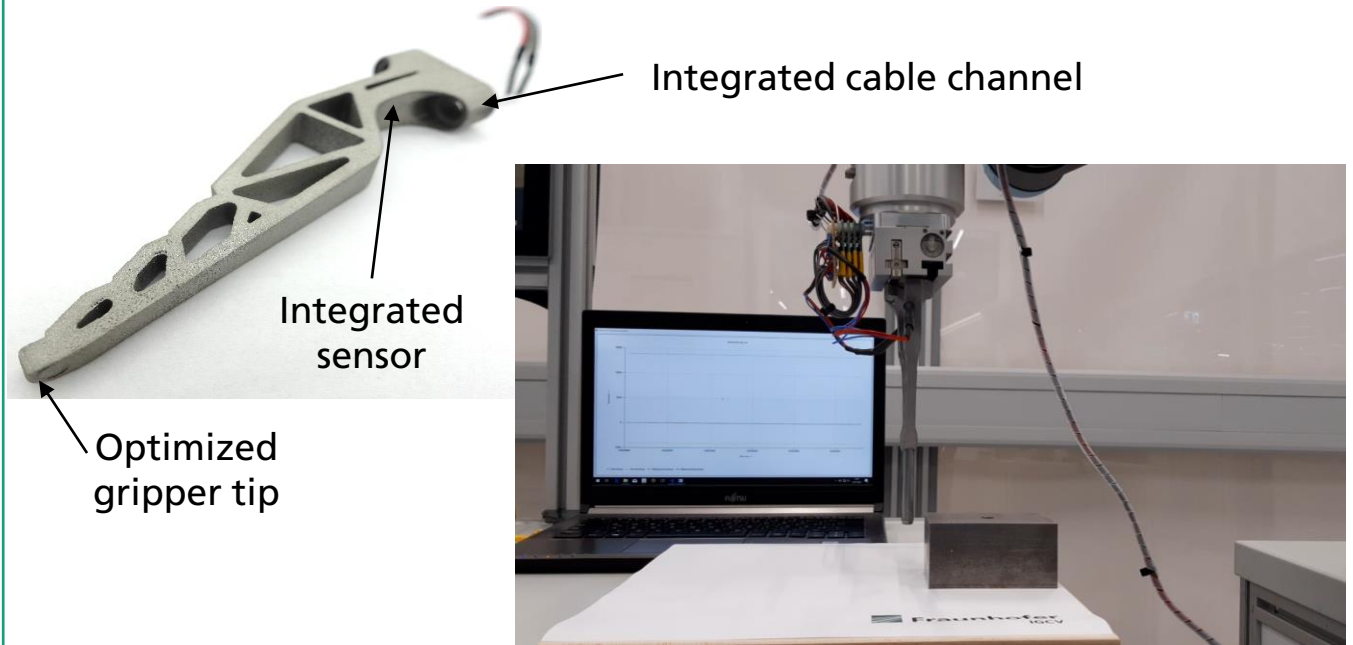


Enabling the robot to “feel the part”



Self-optimization of the robot

## Case Study in cooperation with FESTO SE & Co. KG



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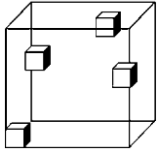


Case Studies



Conclusion

# "AM2030" – The best is yet to come!



Advanced part properties enabled by multi-material 3D-printing

+

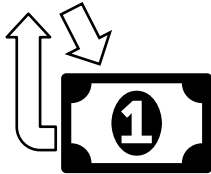


3D-printed Smart Parts through automated (cost-effective) sensor/actuator integration

=



More applications, more inspiration, more ideas and ultimately more technology users



Decrease of cost per printed cubic centimeter through Economies-of-scale and new 3D-technologies

Thank you for your attention → Q&A.

### Acknowledgement

The results shown are from the project „MULTIMATERIAL-Zentrum Augsburg“ funded by Free State of Bavaria.



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