LASER BEAM MELTING DRIVES EFFICIENCY OF TOOLING APPLICATIONS

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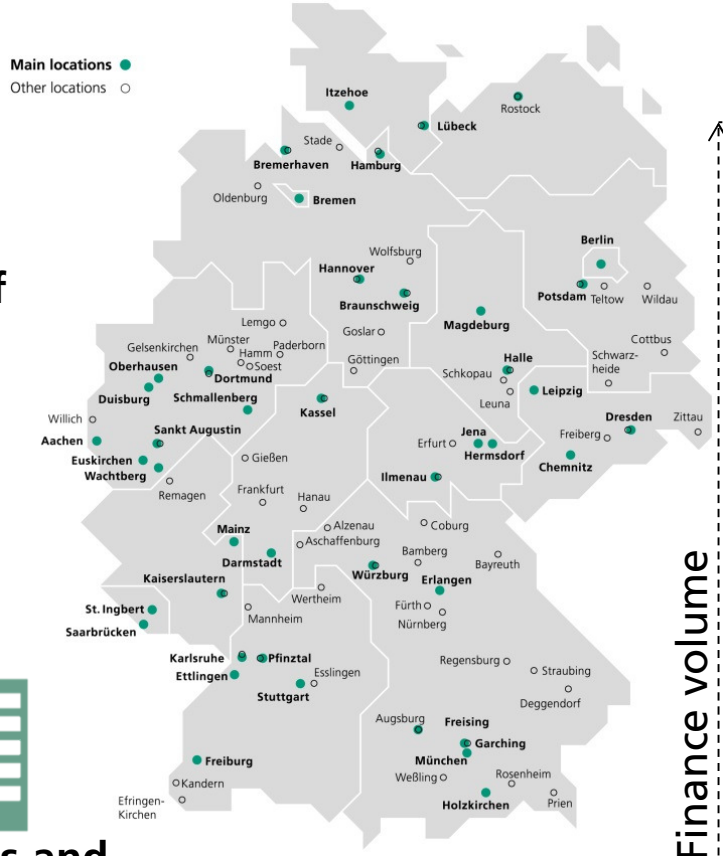
CONTENT

- The Fraunhofer-Gesellschaft at a Glance
- Status quo of industrial application in automotive
- Added value for tooling applications by LBM
- Project examples by manufacturing process
- Outlook / further research activities

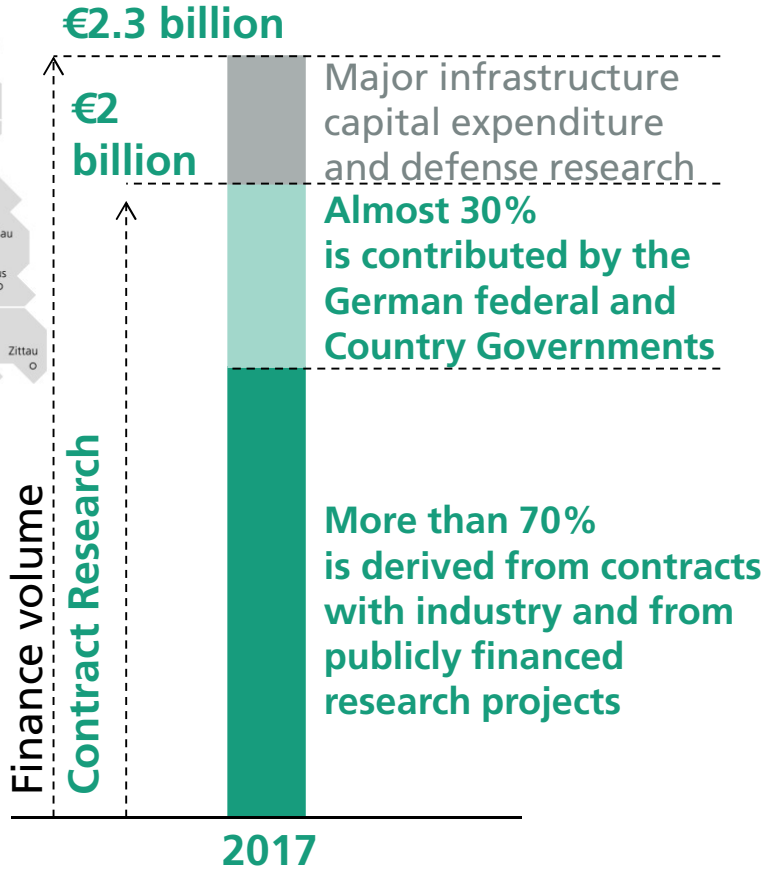
The Fraunhofer-Gesellschaft at a Glance

The Fraunhofer-Gesellschaft undertakes applied research of direct utility to private and public enterprise and of wide benefit to society.

25,527 staff



72 institutes and research units



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The Fraunhofer IWU

Research under the heading “Resource-Efficient Production“

- Founded July 1st 1991
- Currently approx. 530 employees
- Approx. € 40 million annual budget
- Locations: Chemnitz (headquarters)
  Dresden, Zittau, Wolfsburg, Leipzig
- 3 scientific fields:

Mechatronics and Lightweight Structures	Forming Technology	Machine Tools, Production Systems and Machining

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Status quo of industrial application in Automotive

BMW Group – Substitution of conventional prototyping

Substitution of conventional technologies for prototypes by SLM:

● master forming ● metal forming ● joining ○ cutting

Source: BMW AG

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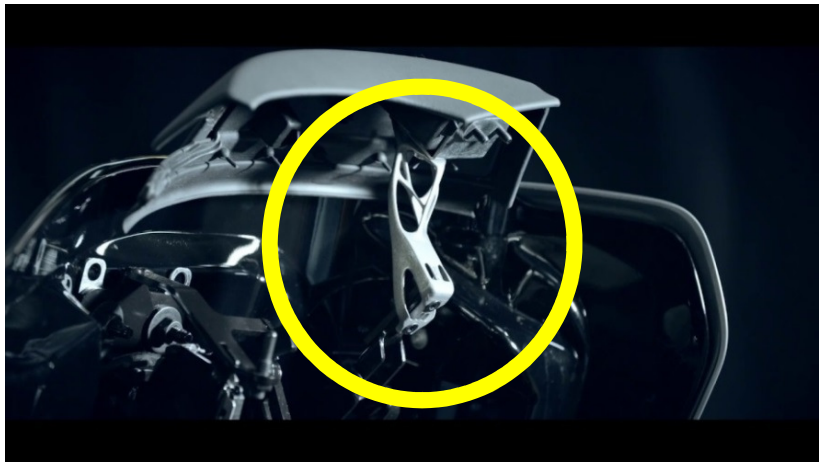
Status quo of industrial application in Automotive
BMW Group – Starts additive mass production in metal

- **BMW i8 Roadster**: first metal 3D printed production part (17,000 pcs/a) *https://www.press.bmwgroup.com/global/video/detail/PF0005744/the-new-bmw-i8-roadster-with-metal-3d-printed-parts*
- BMW Group invests €10 million in **Additive Manufacturing Campus** *http://www.metal-am.com/bmw-group-to-invest-e10-million-in-additive-manufacturing-campus/*



Source: BMW AG

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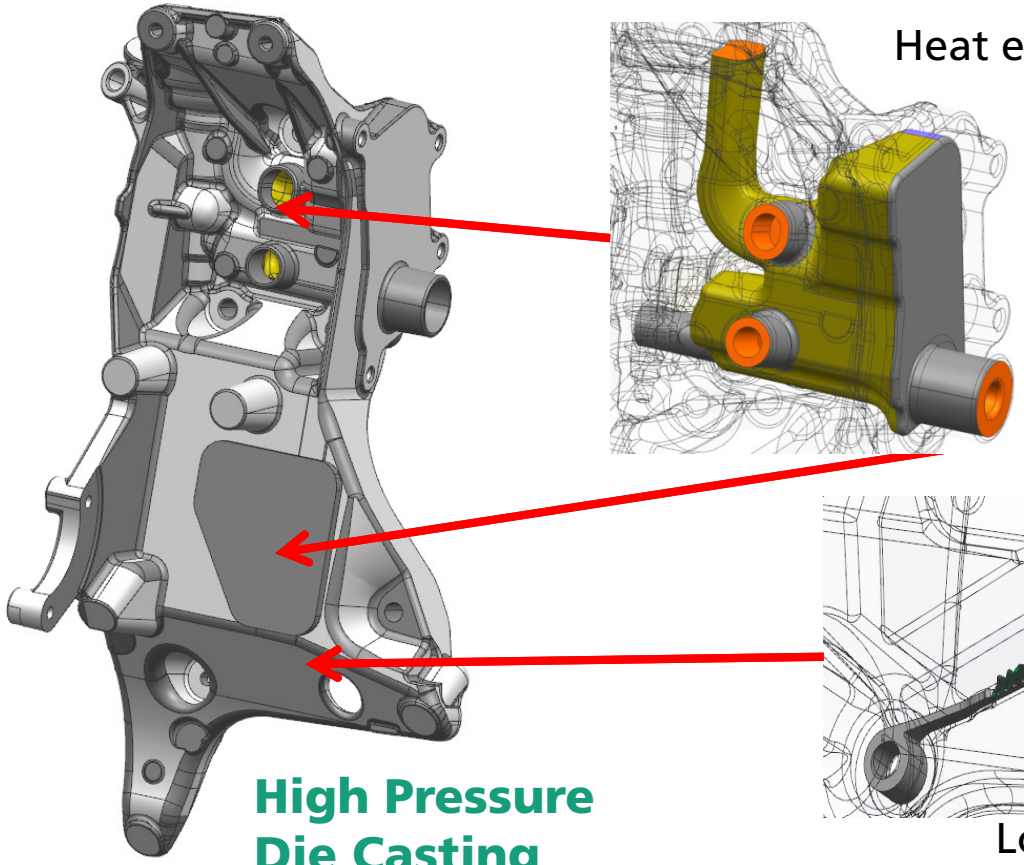
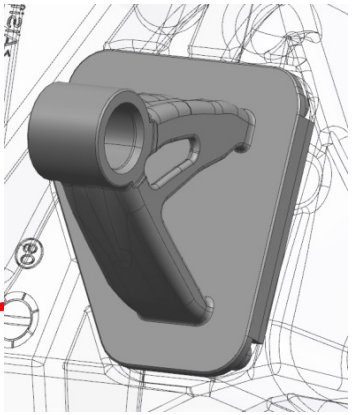
Status quo of industrial application in Automotive

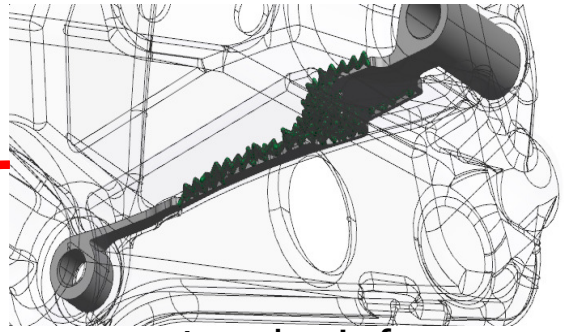
CastAutoGen – Hybrid process chain



Heat exchanger

Power steering mount





3D Printed Inserts (Laser Beam Melting)

High Pressure Die Casting

Local reinforcement

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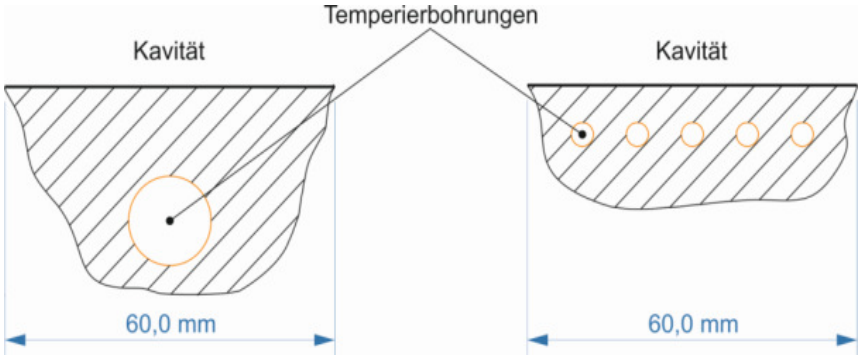
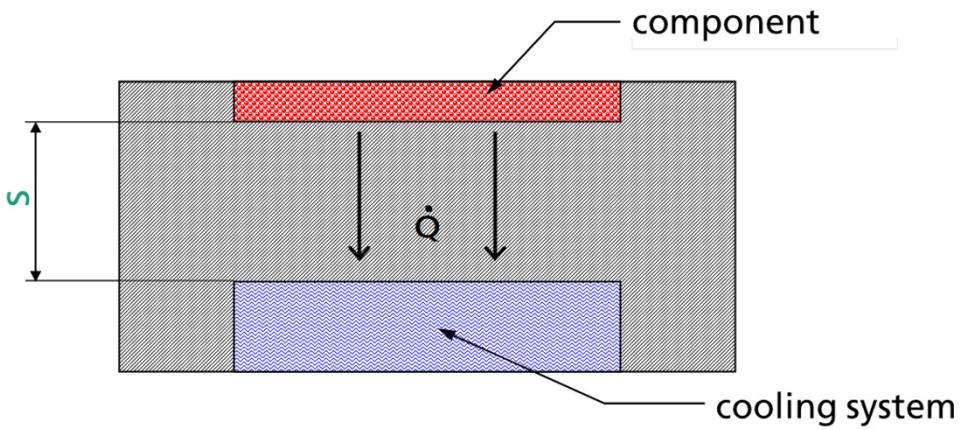
Added value for tooling applications by LBM
Thermal management – conformal cooling

- Major factors of influence are distance to the cavity **s** and the channel surface area **A**

$$\dot{Q} \uparrow = \frac{\Delta T \cdot \lambda \cdot A}{s}$$





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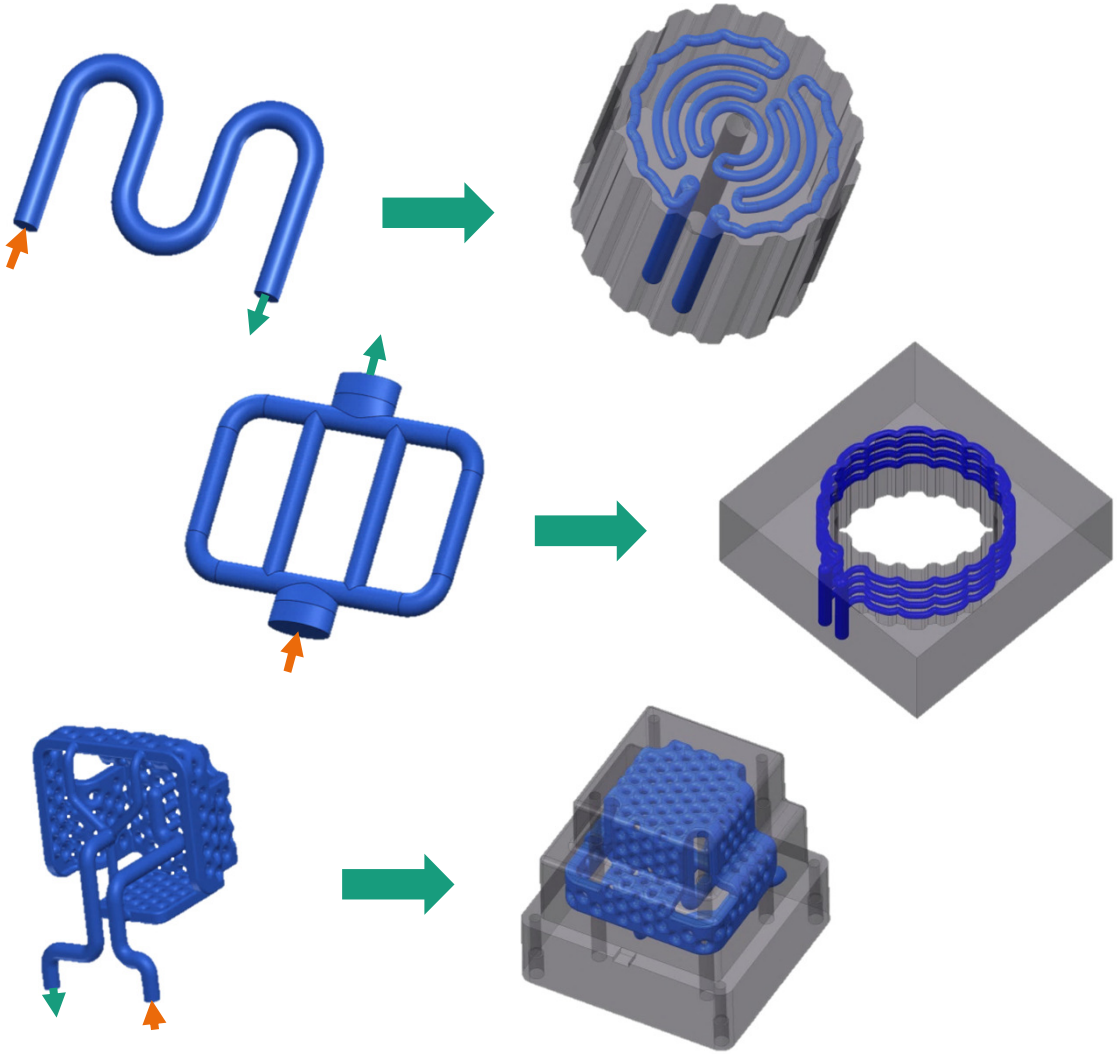
Added value for tooling applications by LBM

Thermal management – types of cooling circuits

- Serial cooling circuit
- Parallel cooling circuit
- Panel cooling



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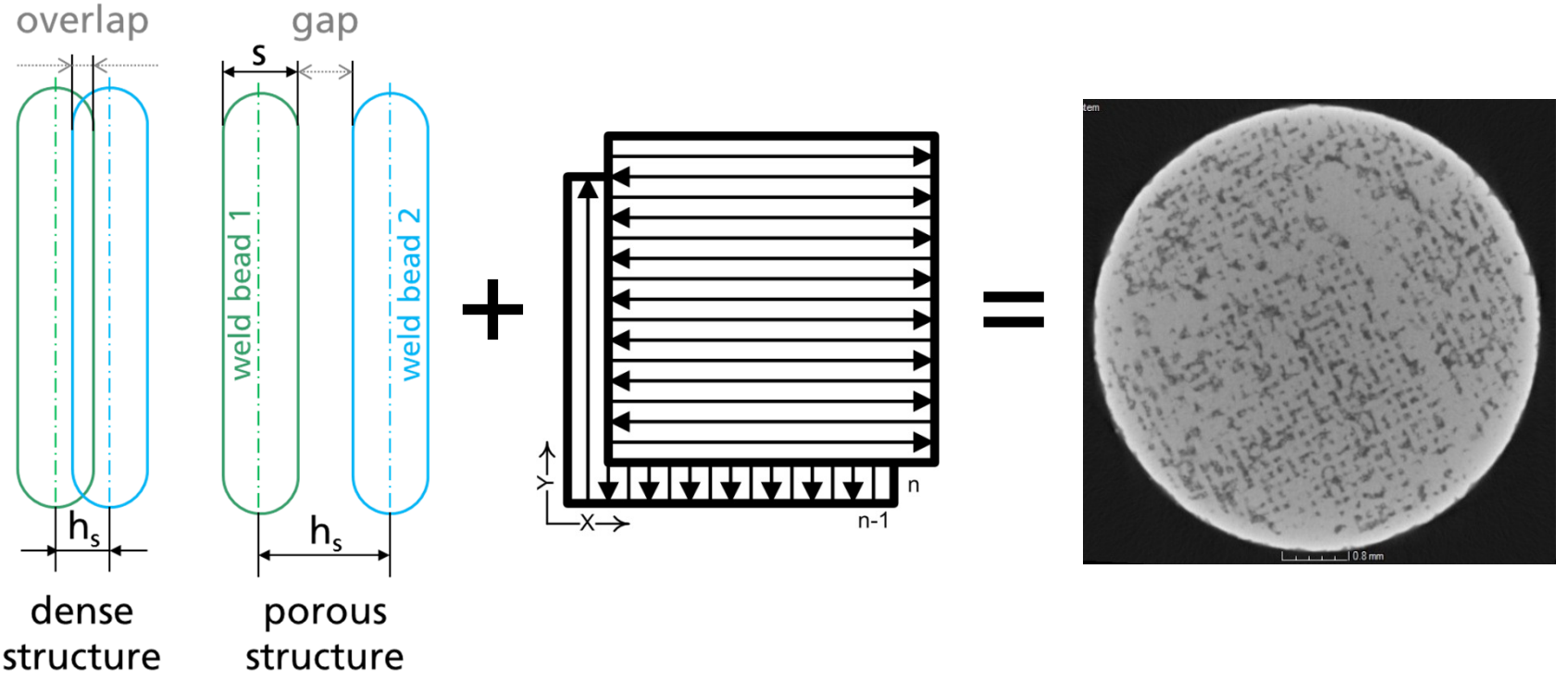
Added value for tooling applications by LBM
Venting

- Use of cellular/porous structures for tool venting



s … weld bead width
h_s … scan line / weld bead spacing

Added value for tooling applications by LBM
Lubrication / tribology

- Use of cellular/porous structures for lubrication

(source: Stoll, Philipp: Gute Poren - Erwünschte Porosität in SLM-Werkstücken. Rapid.Tech 2015, Erfurt, 10. - 11.06.2015)

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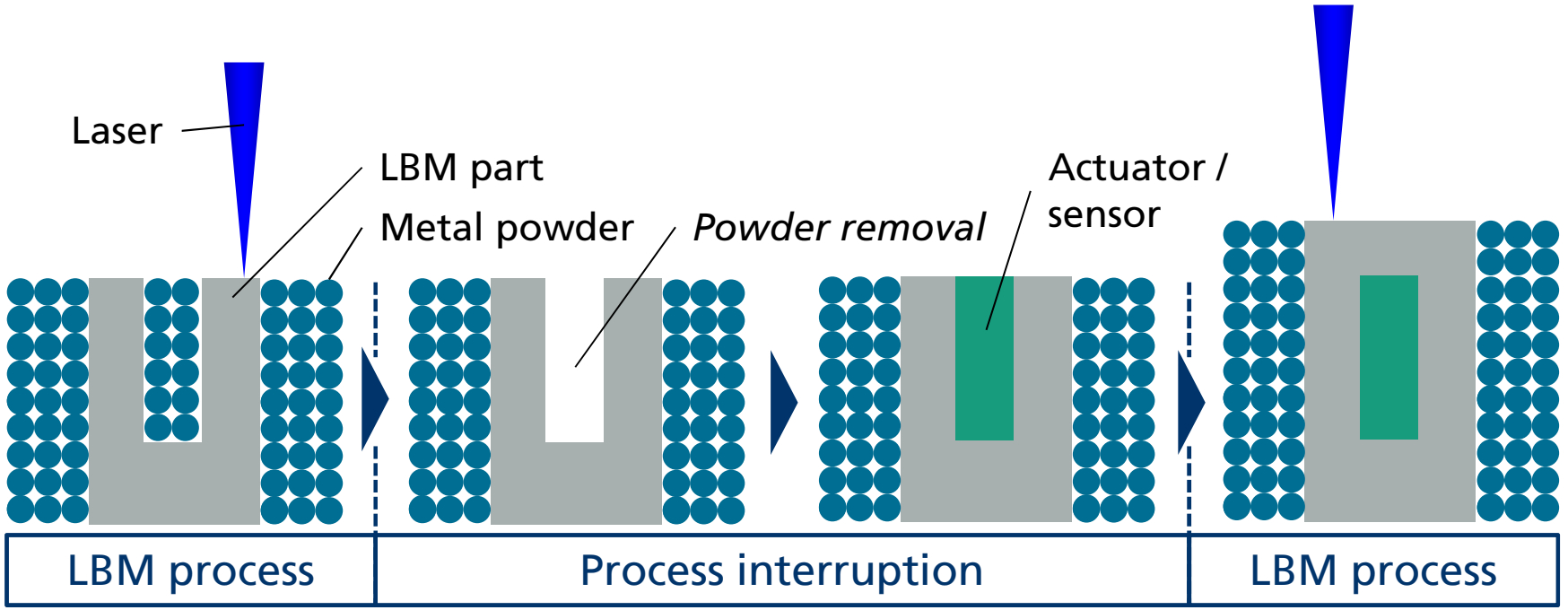
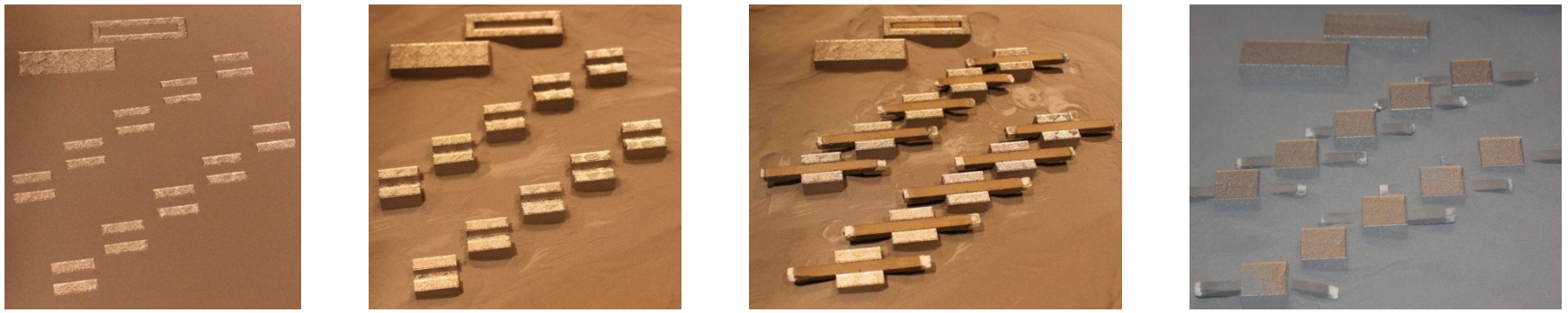
Added value for tooling applications by LBM

Sensor integration





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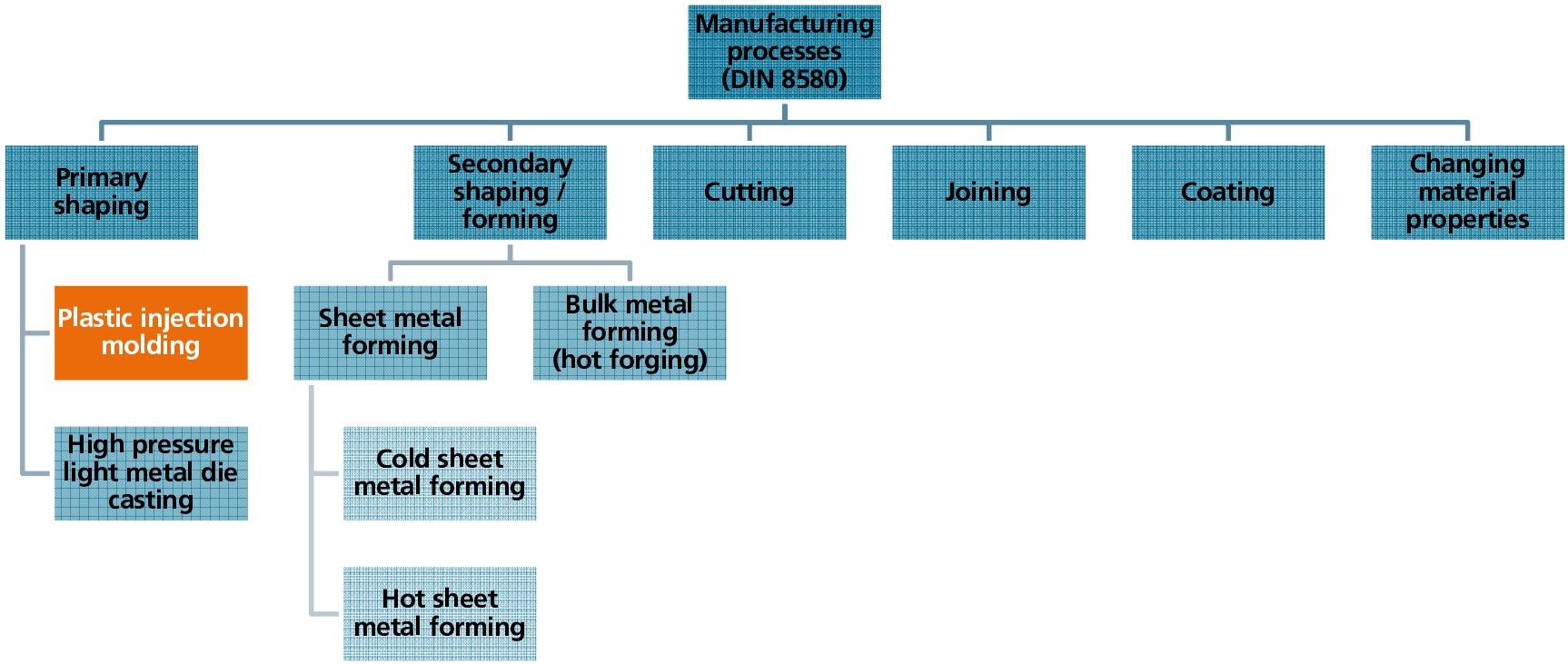
Project examples by manufacturing processes



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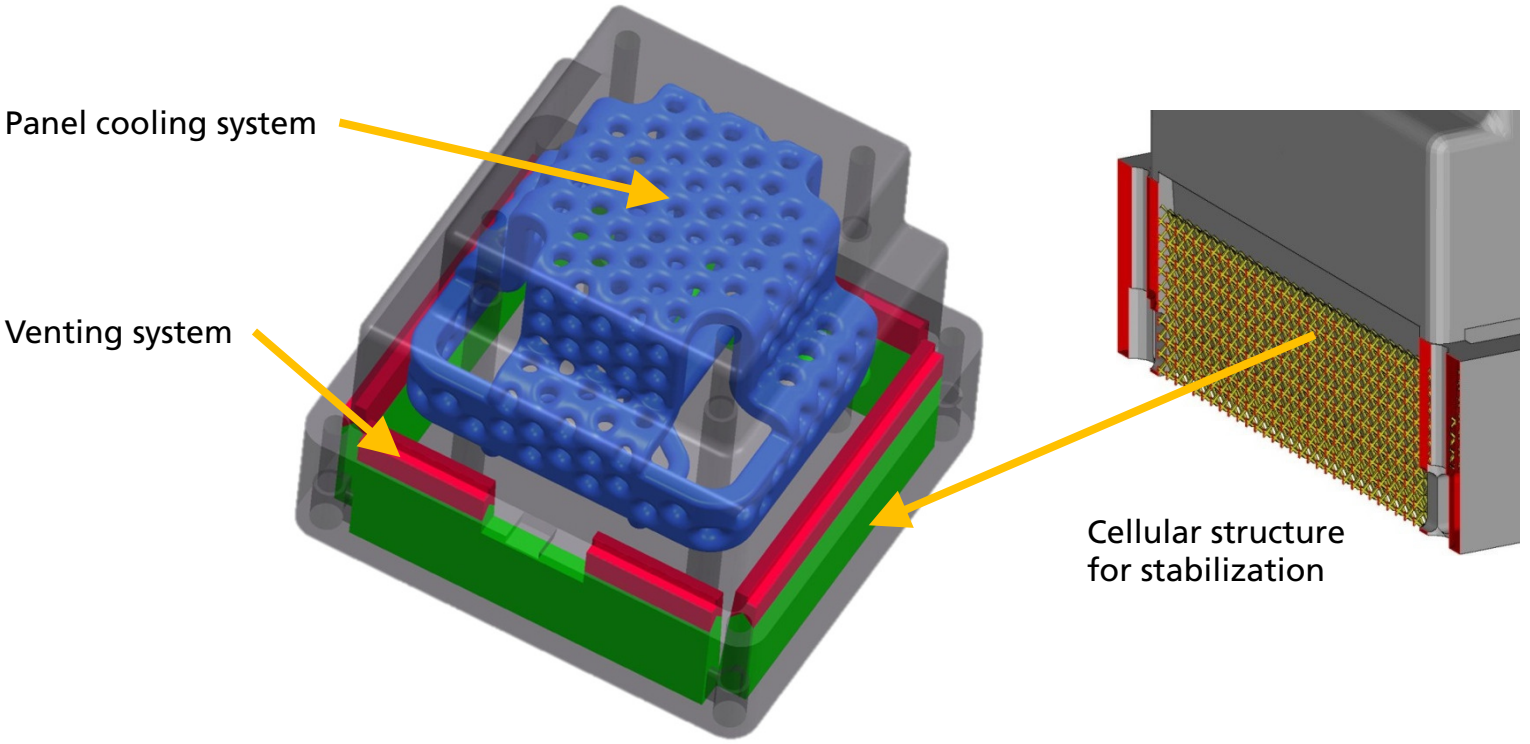
Project examples by manufacturing processes
Plastic injection molding – cover for electric device

- Tool insert with panel cooling and venting structures in integral design



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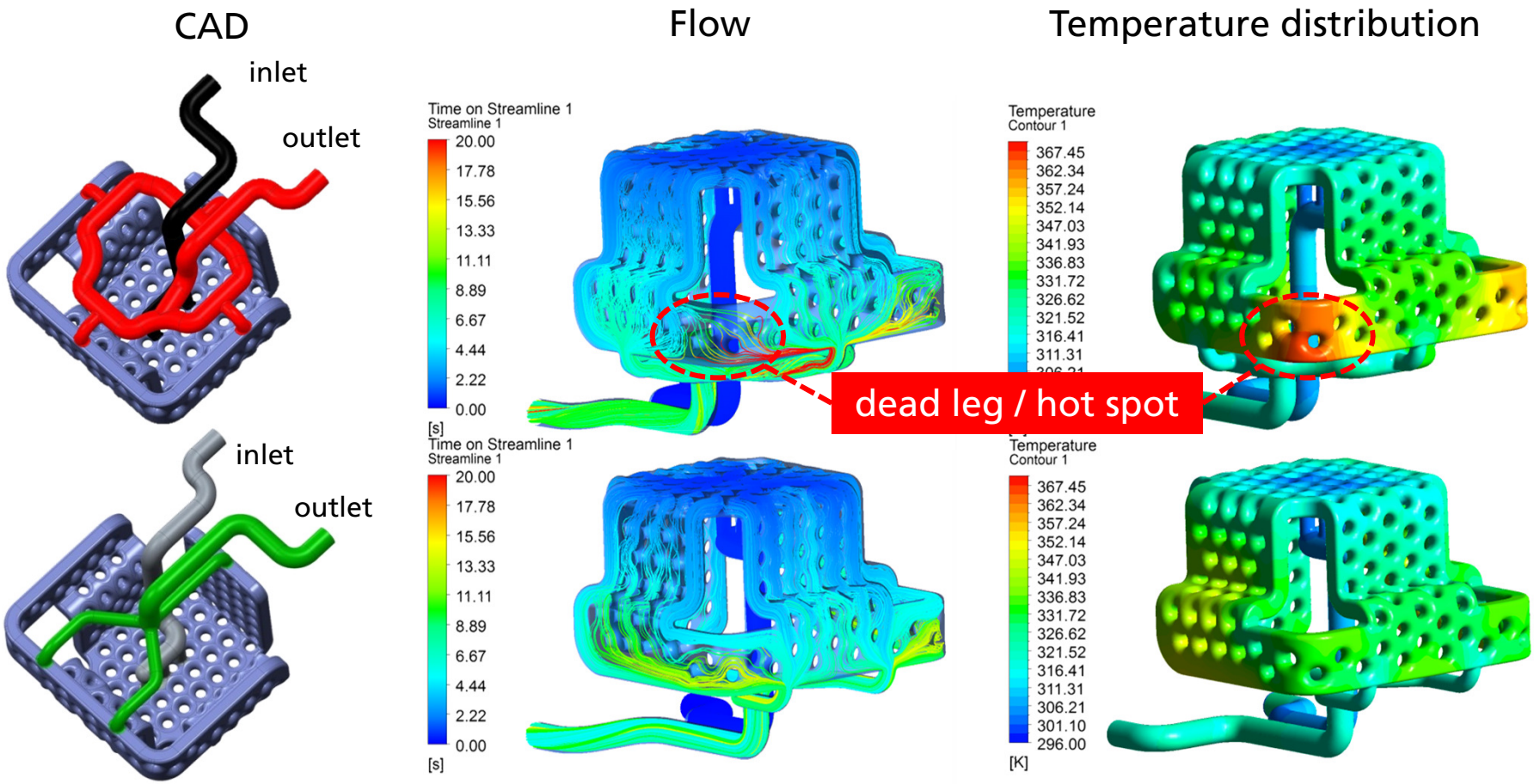
Project examples by manufacturing processes

Plastic injection molding – cover for electric device



- CFD simulation for panel cooling mandatory

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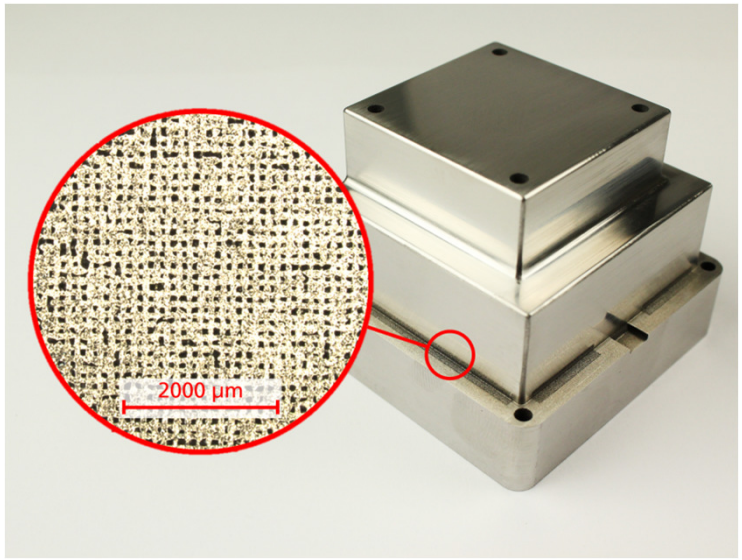
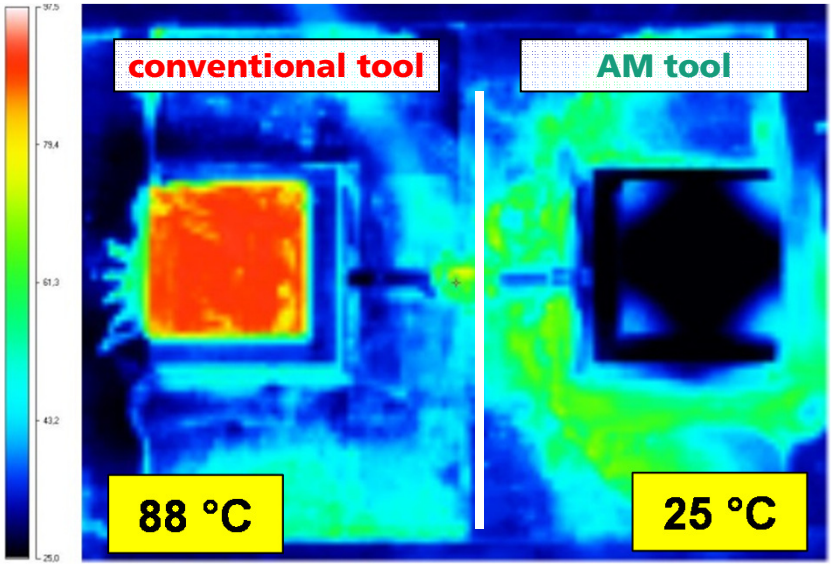
Project examples by manufacturing processes

Plastic injection molding – cover for electric device

Results





- Reduction of cooling time (hold time) by **33 %** (from 18 to 12 s)
- Reduction of cycle time by **19 %** (from 31,4 to 25,3 s)
- Reduction of injection time and pressure by **5 %** each
- Better dimensional accuracy

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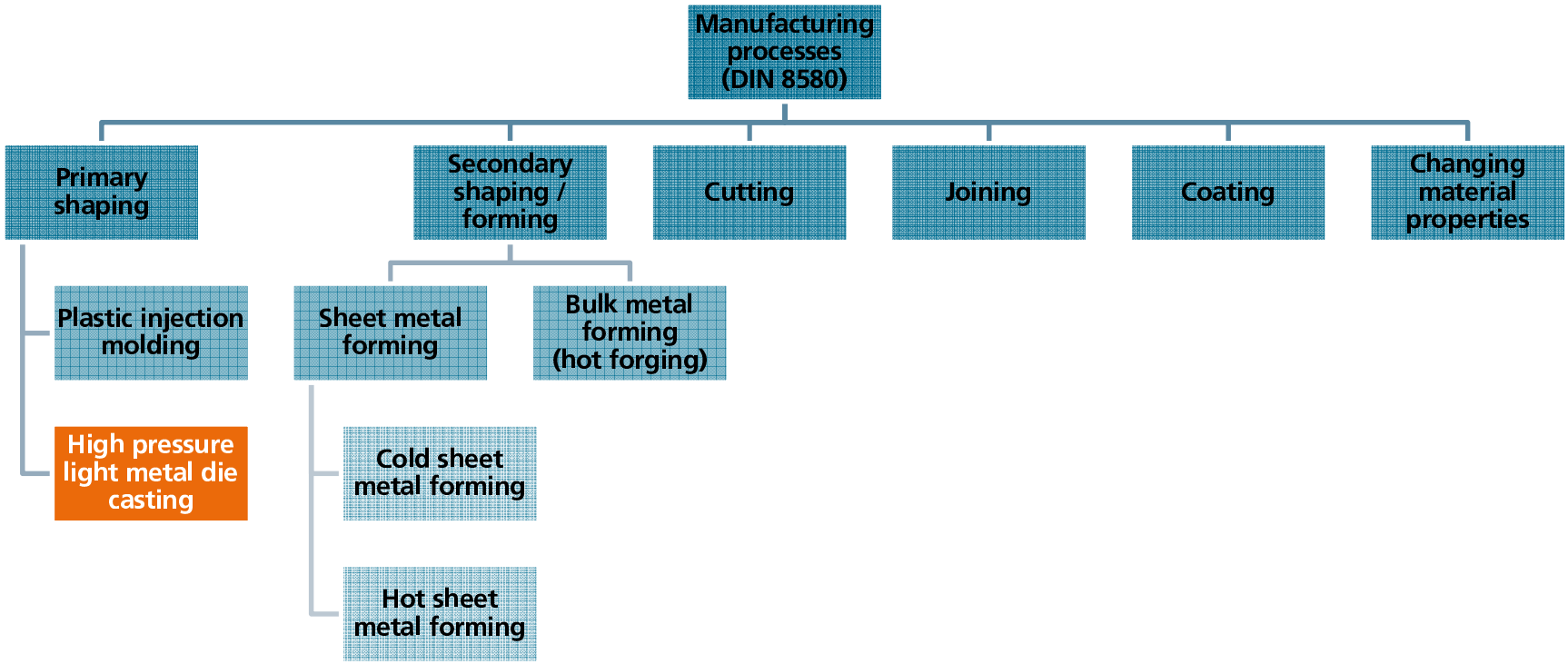
Project examples by manufacturing processes



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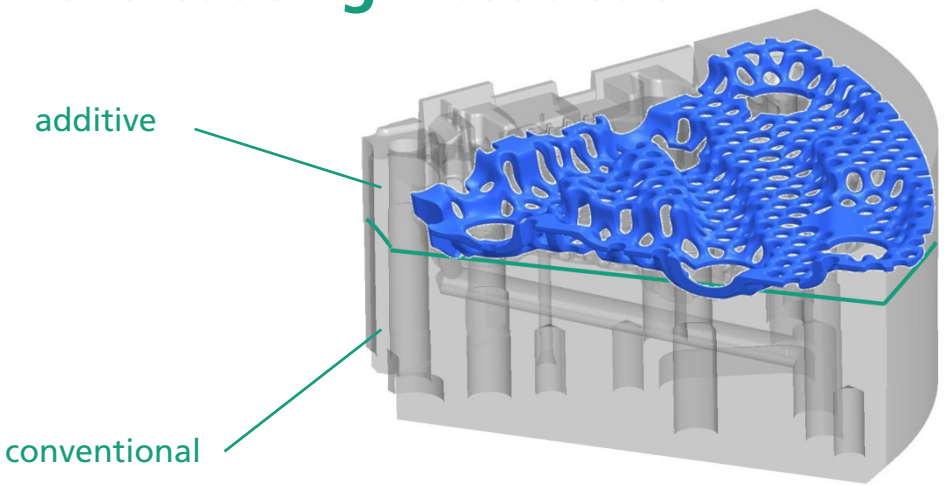
Project examples by manufacturing processes
High pressure light metal die casting – test tool

Motivation

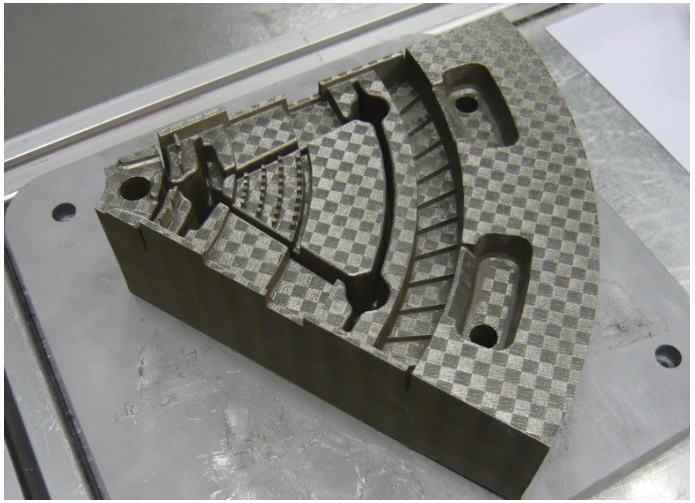
- Evaluation of the possible uses of AM in die casting

Objective

- Hybrid tool insert (conventionally machined base body + additively manufactured upper part including cooling channels and cavity)
- Laser-beam-melted tool insert with surface conformal cooling



CAD model tool insert with conformal cooling



Additively manufactured tool

Audi

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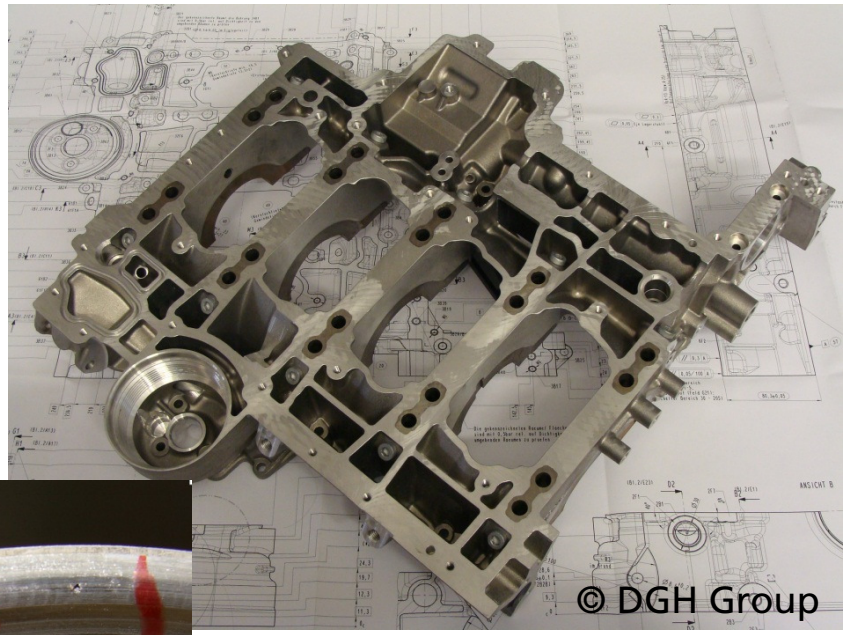
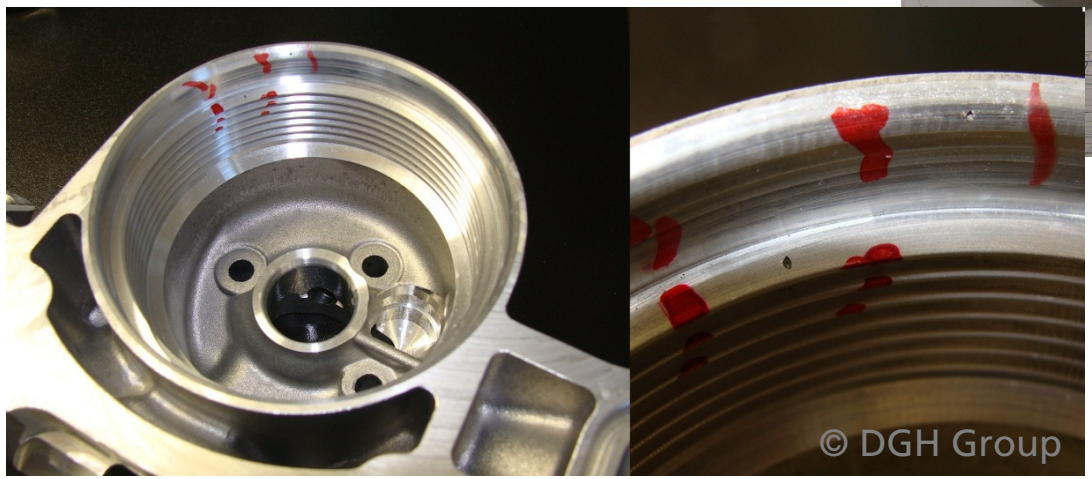
Project examples by manufacturing processes
High pressure light metal die casting – engine bed plate

Objective

- Reducing local porosity at oil filter housing within bed plate of a V8 engine





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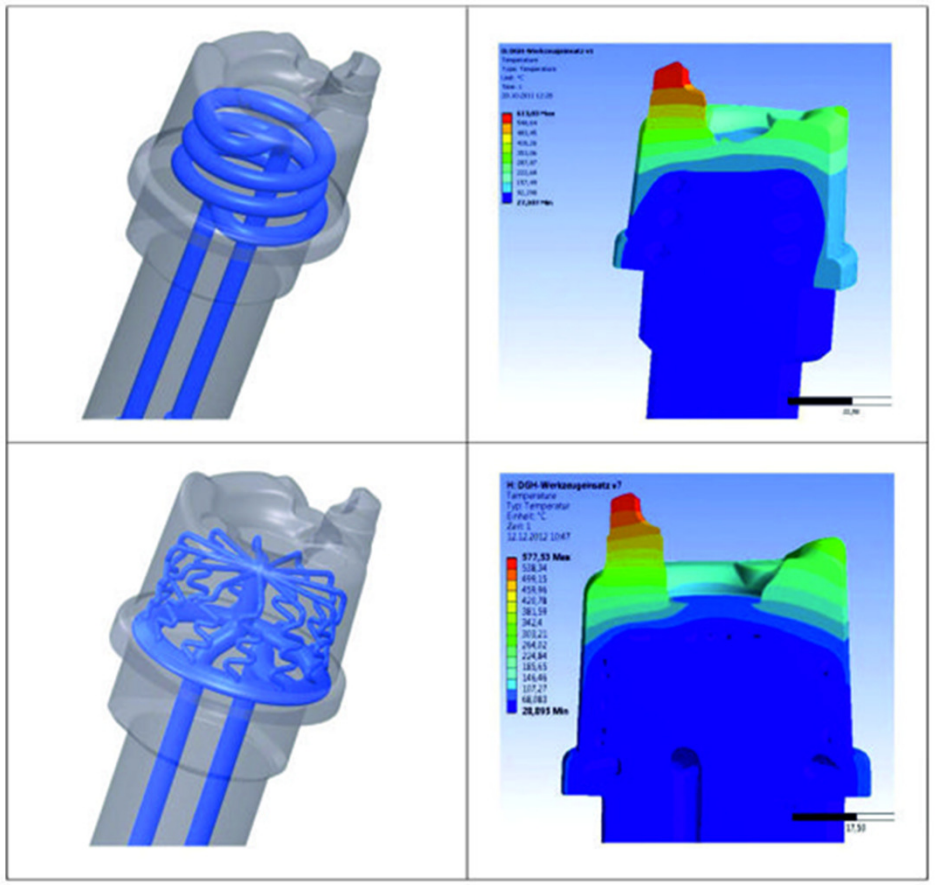
Project examples by manufacturing processes

High pressure light metal die casting – engine bed plate

- Design of an die insert with conformal cooling system
- Thermal and mechanical simulation for
  - Minimum distance to the die surface
  - Evaluation of different concepts of cooling systems (serial and parallel cooling)



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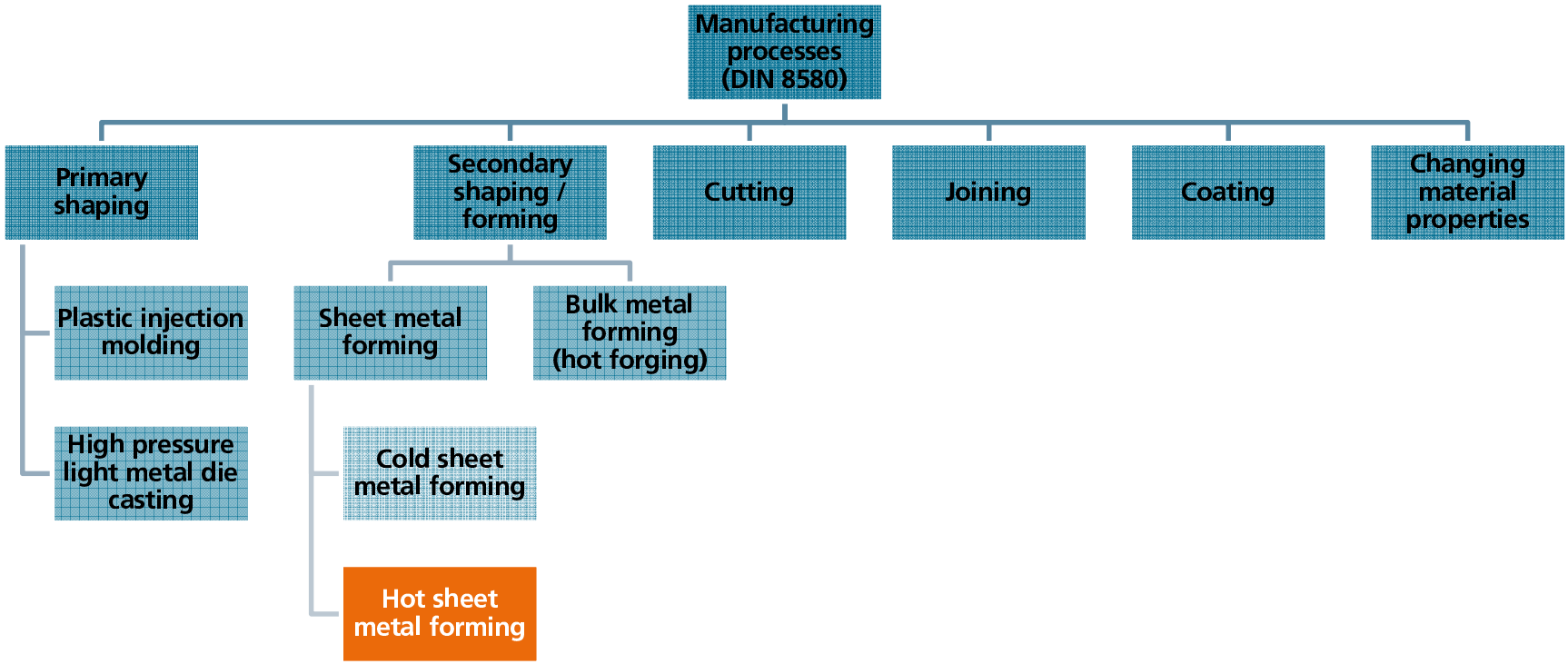
Project examples by manufacturing processes
High pressure light metal die casting – engine bed plate

Results

- Die insert with conformal cooling system
- Reduction of scrap rate by more than **50 %**
- Cycle time reduction by **3 %**

Project examples by manufacturing processes



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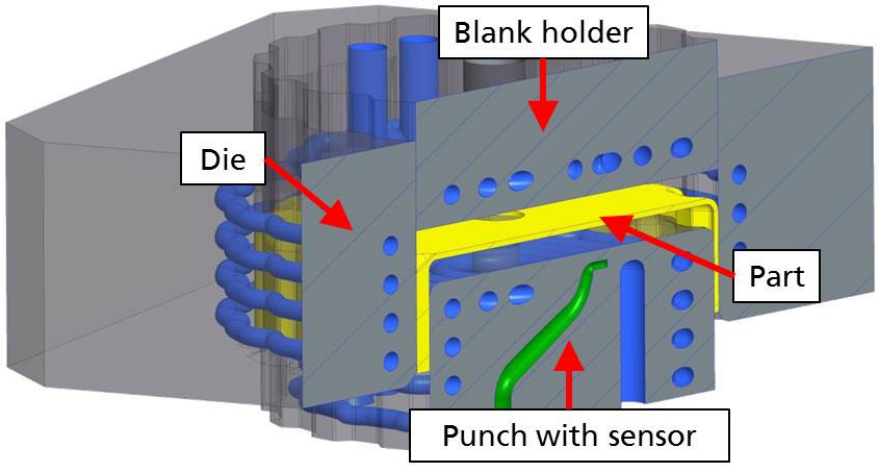
Project examples by manufacturing processes

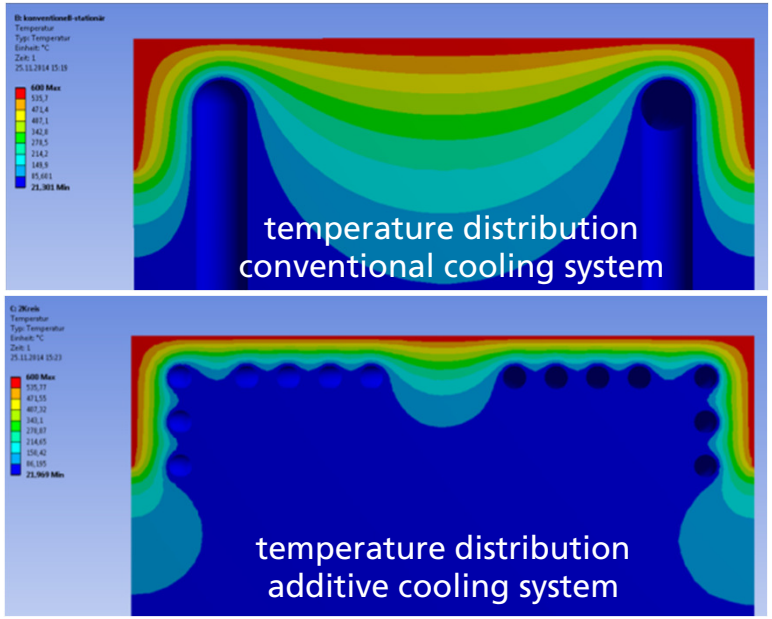
Hot sheet metal forming – project HiperFormTool

Objective

- Added value and integration of additional functionalities
- Reduction of cycle time
- Improving process stability



Assembly with innovative cooling system (CAD model)



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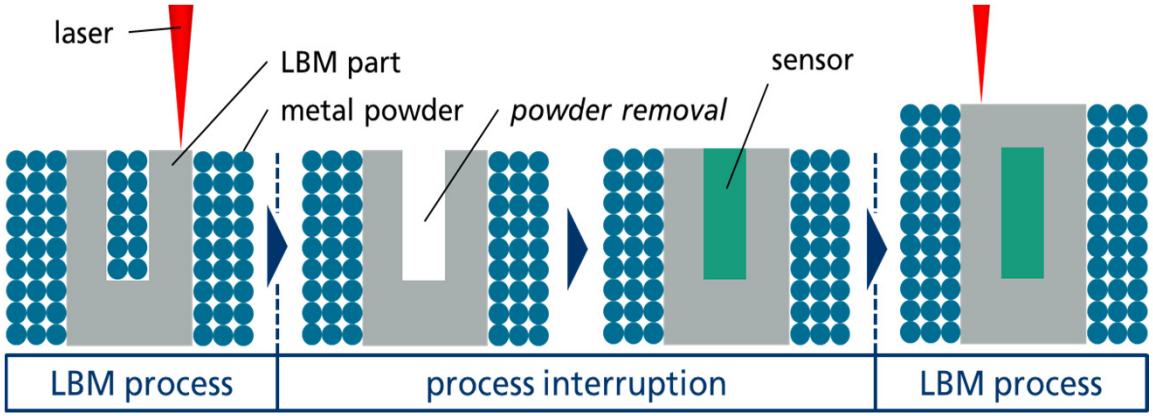
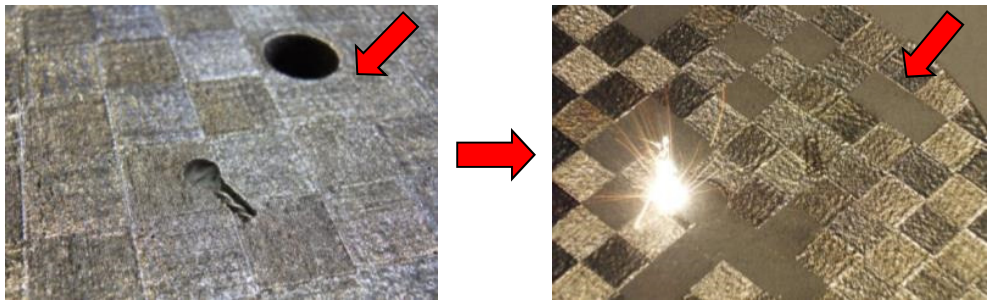
Project examples by manufacturing processes
Hot sheet metal forming – project HiperFormTool

- Process monitoring through thermocouples
  - Integration during additive manufacturing process → metallurgically-bonded connection for exact measurements (only 3 mm distance to the cavity)





Tool insert with integrated thermocouple (type K)

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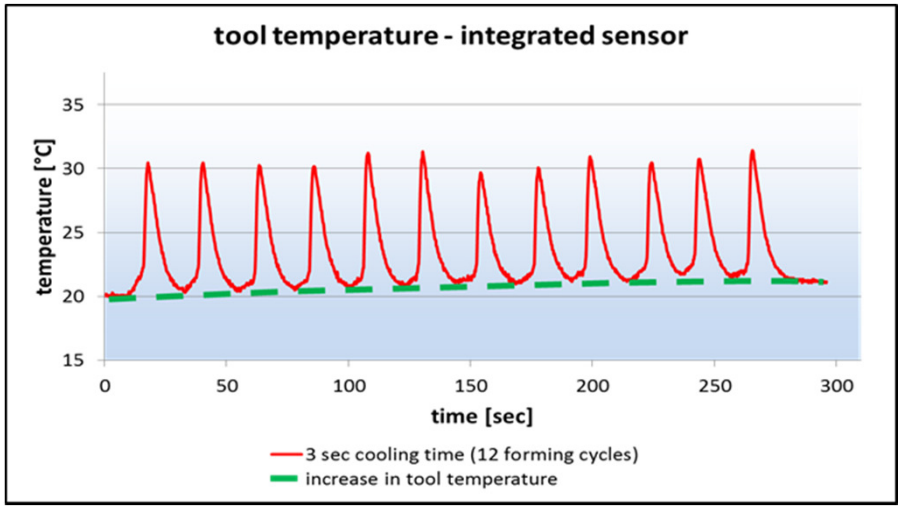
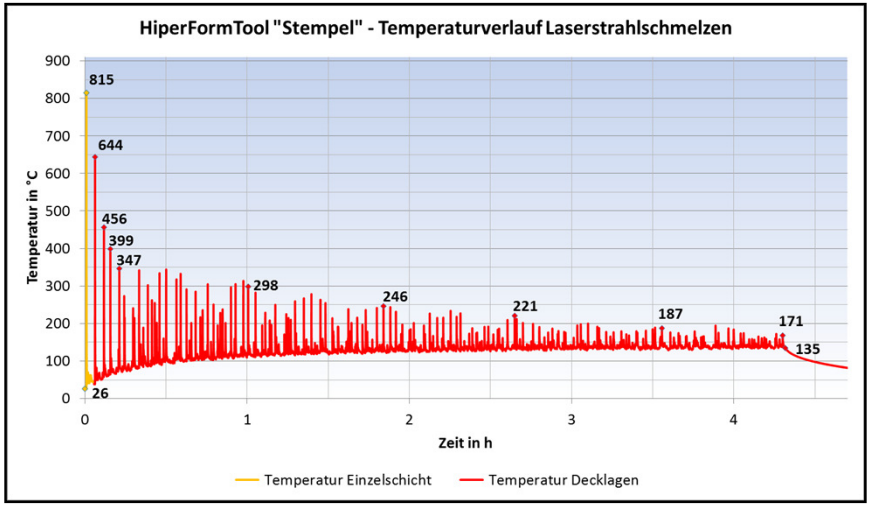
Project examples by manufacturing processes

Hot sheet metal forming – project HiperFormTool

- Temperature measurement during Additive Manufacturing
  - Sampling rate 500 / s for first layer → 2 / s for remaining layers
  - Part heats up to more than 135 °C





- Temperature measurement during tooling use in hot metal forming process
  - Measured with thermocouple AM embedded in the punch
  - 12 forming cycles per holding time in multiple test series

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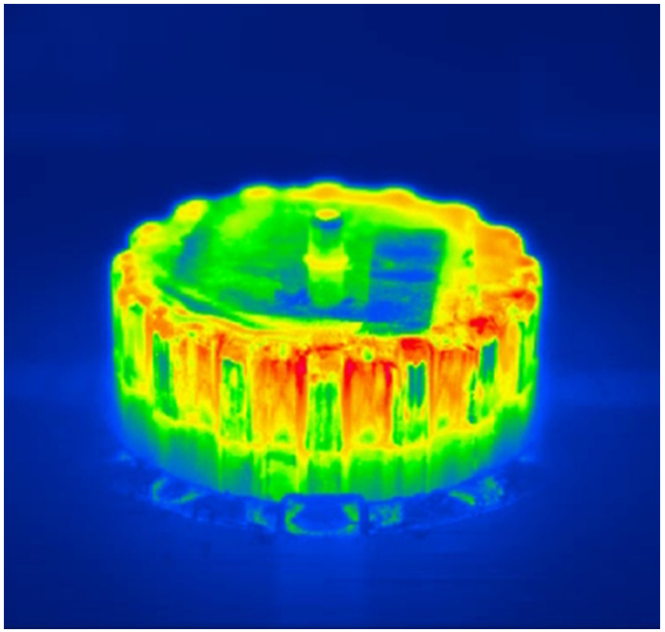
Project examples by manufacturing processes

Hot sheet metal forming – project HiperFormTool

Results

- Successful integration of thermocouple during additive manufacturing
  - ➢ Proof of concept by measurements during the additive process, heat treatment and forming trails
- Innovative additively manufactured tooling allows significantly reduced holding/cooling time
  - ➢ From 10 to 3 seconds for this component
- Formed parts show the same dimensional accuracy
- LBM of tooling components facilitates large savings in time & money



Re-cooling additively manufactured tool punch

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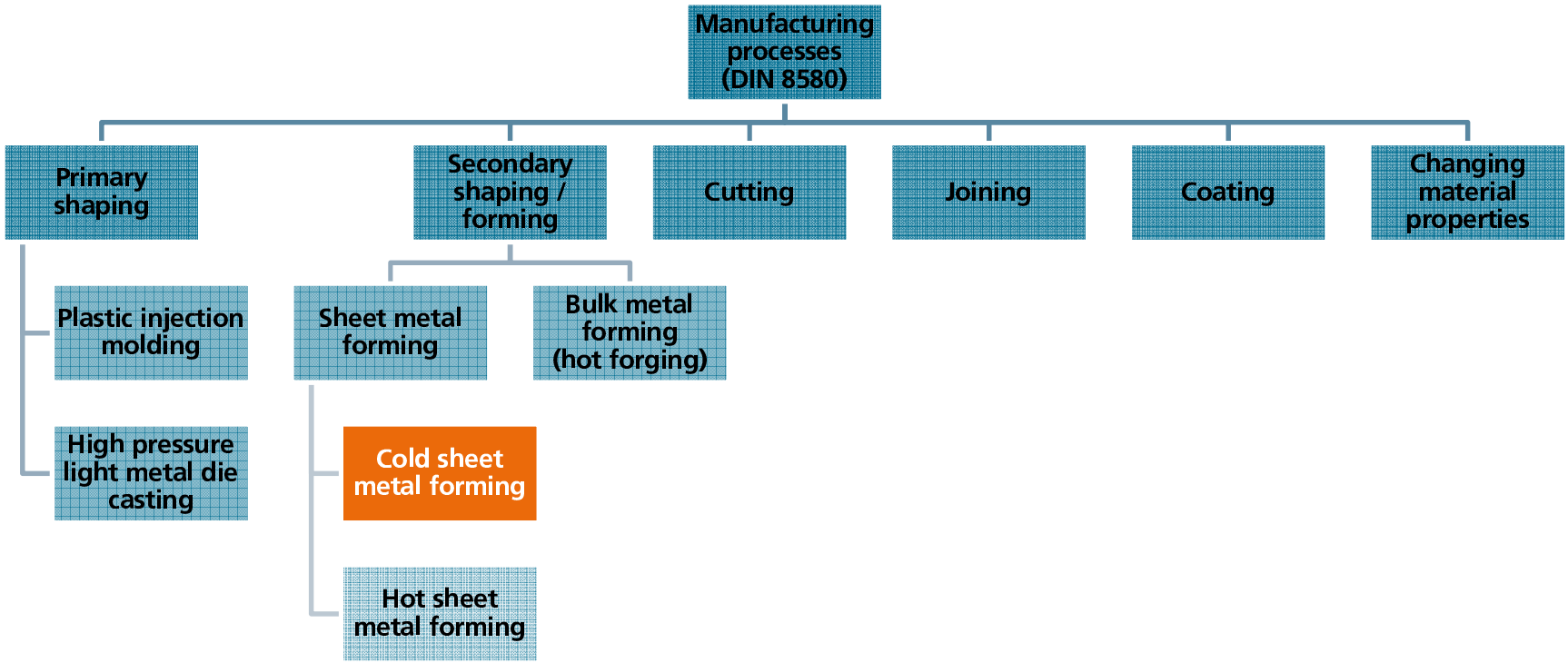
Project examples by manufacturing processes



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Project examples by manufacturing processes

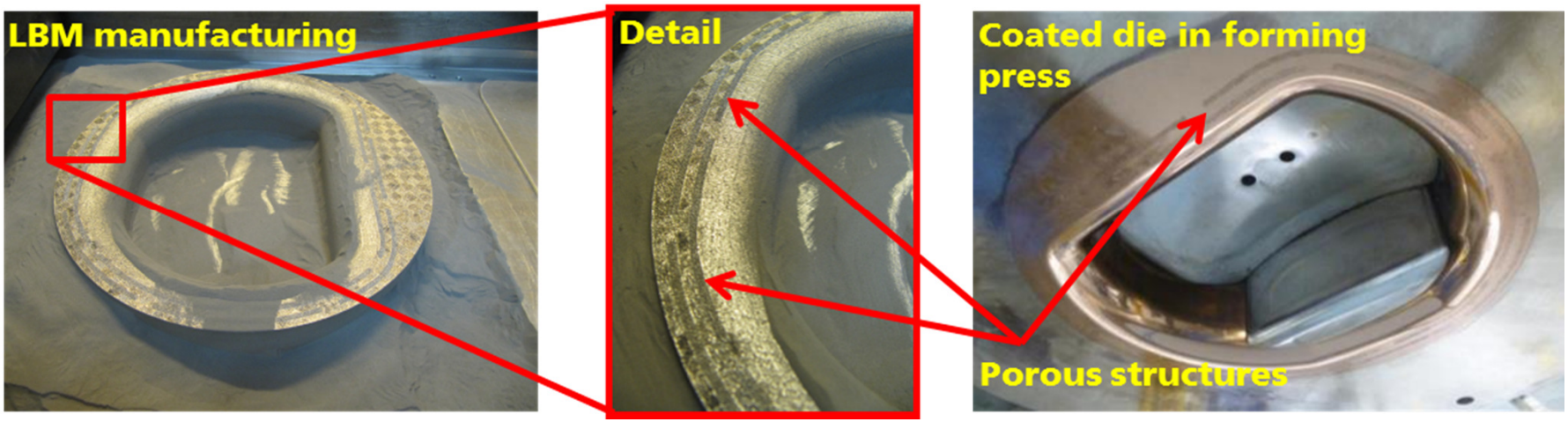
Cold sheet metal forming – project HiperFormTool

Objective

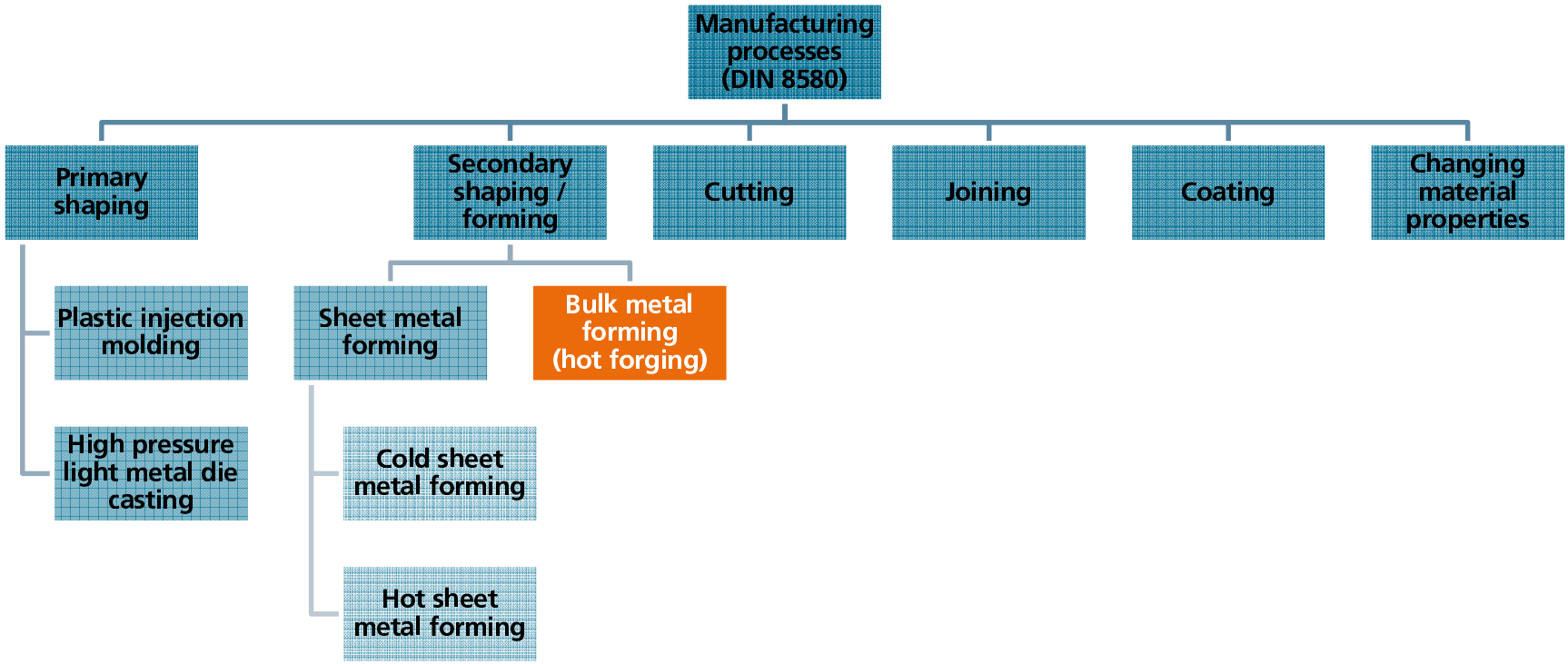
- Improving the deep drawing process by in-situ lubrication supply through the tool

Results

- Lubrication supply through porous structures is feasible



Project examples by manufacturing processes



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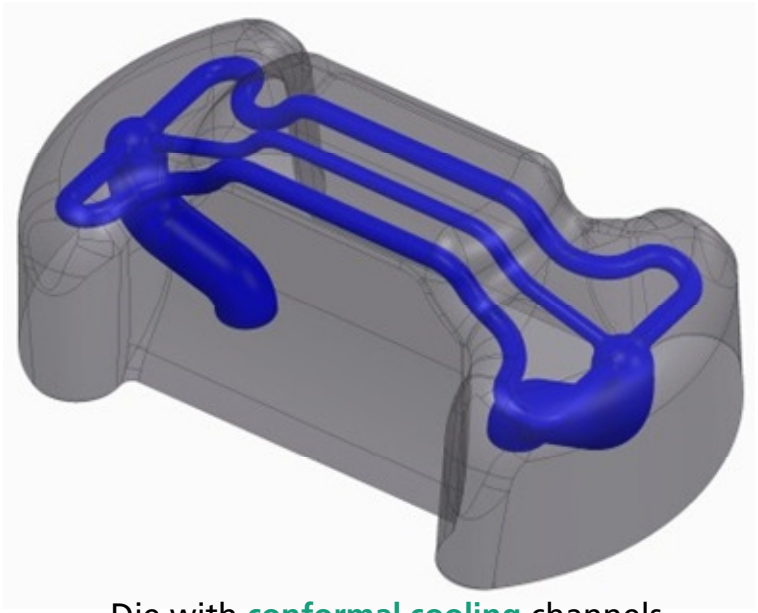
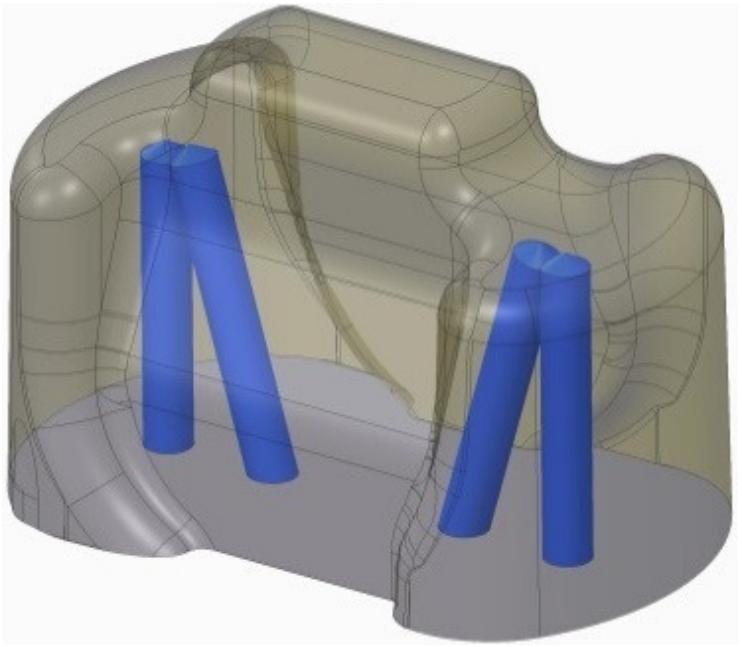
Project examples by manufacturing processes
Bulk metal forming (hot forging) – piston

Motivation

- High thermal-mechanical friction → low tool life
- Reduction of thermal wear through improved thermal management



Die with **conformal cooling** channels



Die with **conventionally** deep drilled cooling channels

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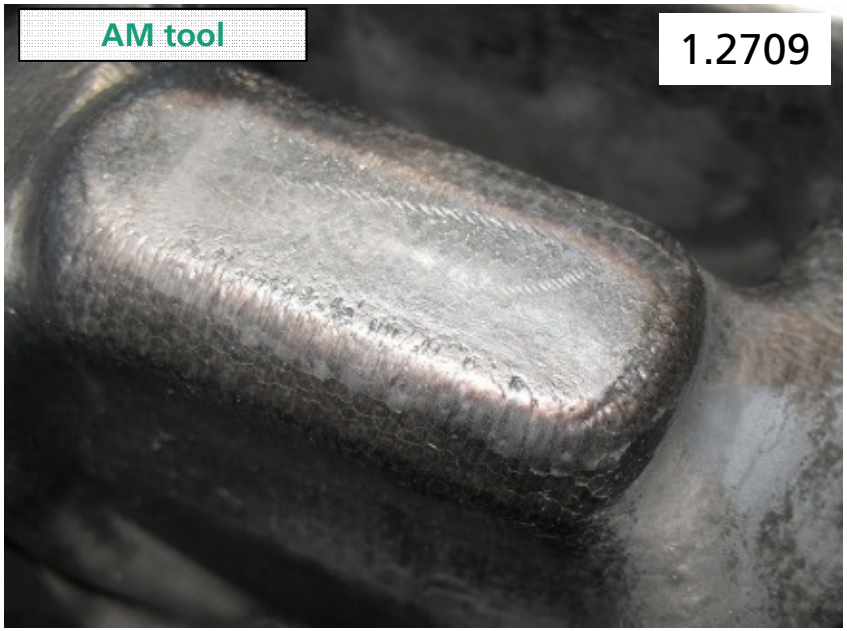
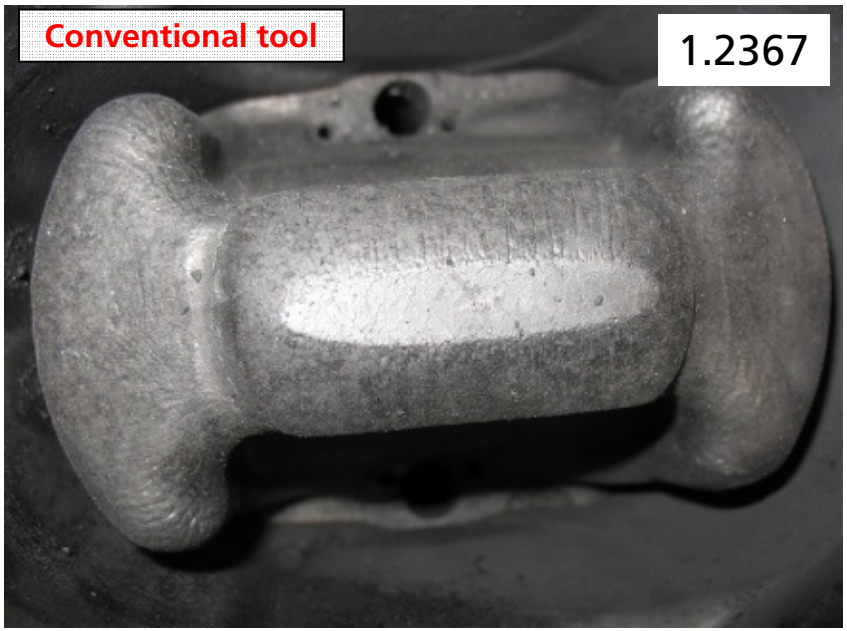
Project examples by manufacturing processes
Bulk metal forming (hot forging) – piston

Results



Wear after **6855** forgings



Wear after **5836** forgings

- Significantly less wear
- Increased part output

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Outlook / further research activities

Improving thermal management further

- Integrated **heat pipe** structures for temperature control of complex and thermally highly loaded tool areas or small geometries
  - Direct structural integration of heat pipes into the tool, instead of retrofitting (no thermal contact resistance, maximizing effective surfaces)
  - Superior cooling performance and targeted temperature control in the smallest possible space
- Integrated heating elements for eg aluminum forming
  - Integration of tubular cartridge heaters type RP

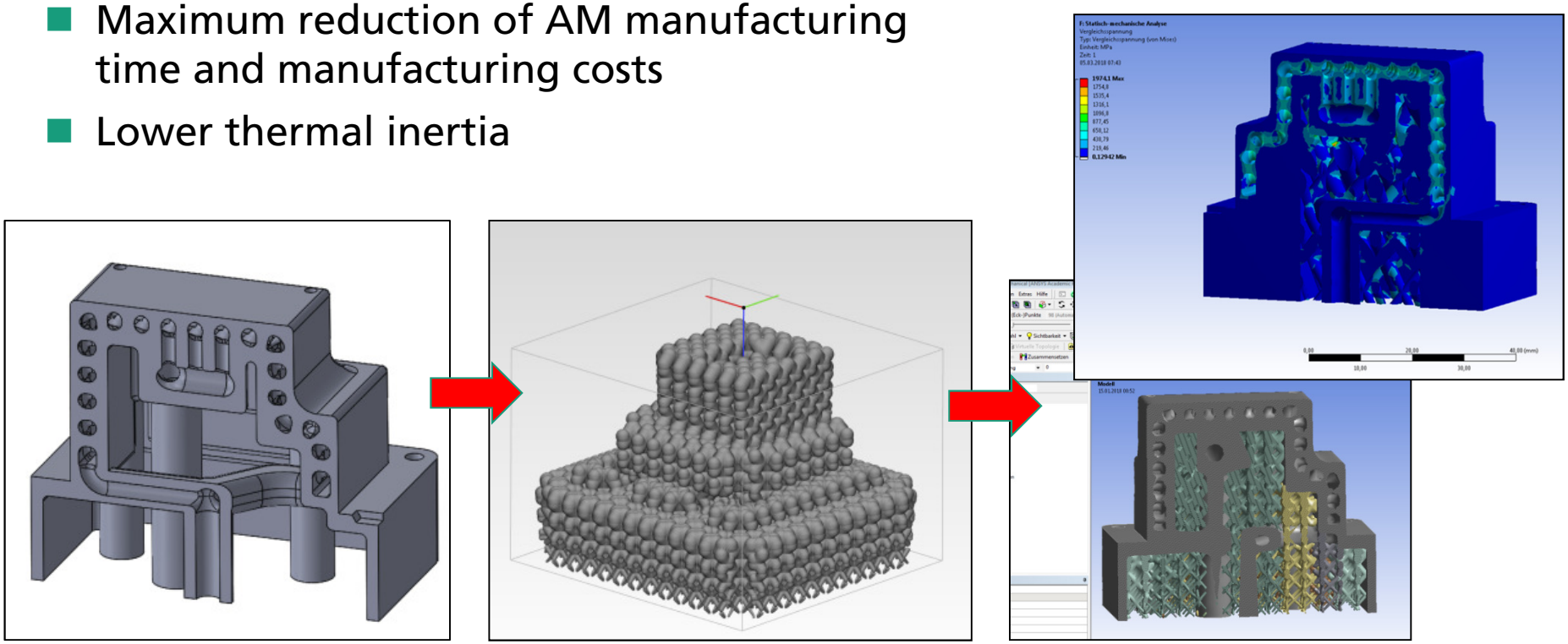
Pushing sensor integration

- Goal is an intelligent tool with sensors for temperature, pressure or to determine tool wear

Outlook / further research activities

Tool design according to actual tool load

- Maximum reduction of AM manufacturing time and manufacturing costs
- Lower thermal inertia



3D CAD design | Inner graded lattice structures | FEM Simulation

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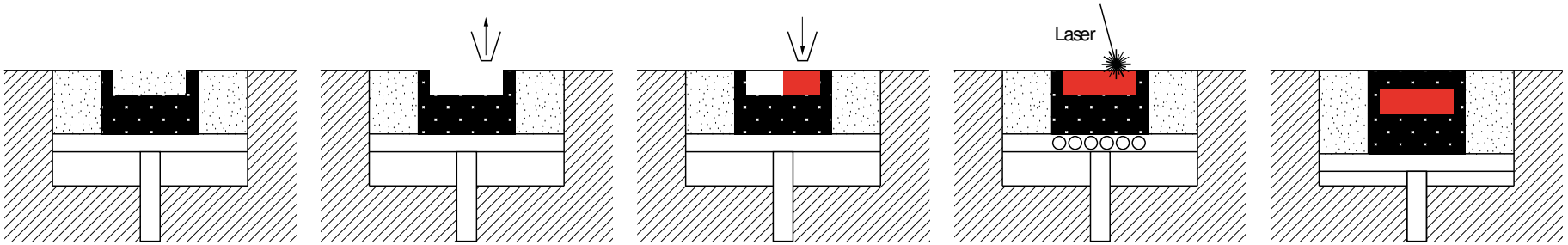
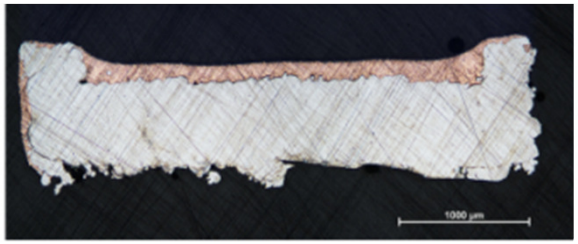
Outlook / further research activities

Multi-material

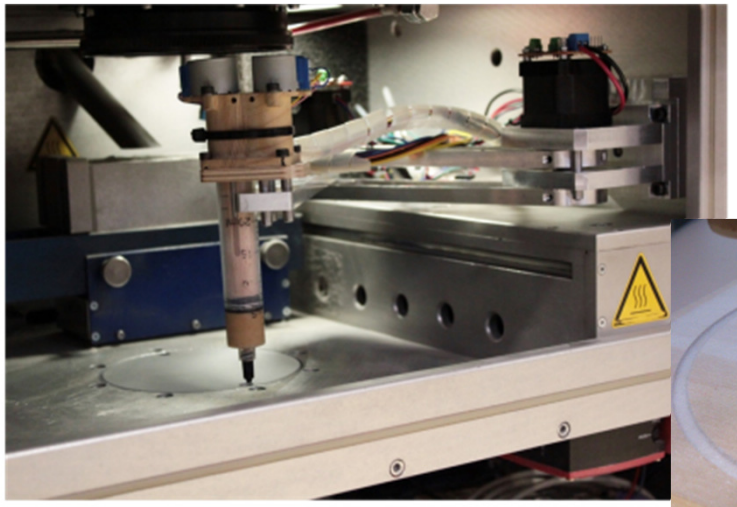
- Dispensing copper paste for higher heat dissipation in critical areas



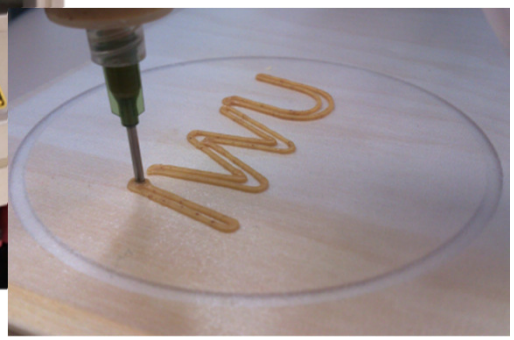
Creating a cavity (LBM) | Extracting powder (automatically) | Dispensing copper paste | Curing by platform heating and Laser | Continuing the LBM process



Multi-material sample Steel (LBM) with copper inlay (dispensing)



Scara robot arm for powder extraction and dispensing (IWU development)

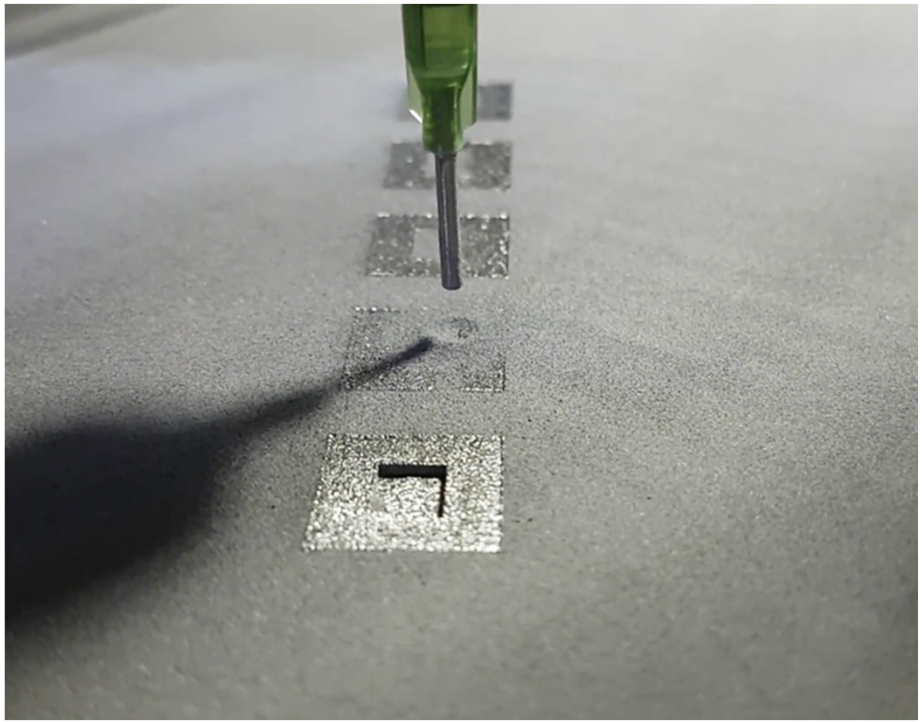


Fraunhofer IWU

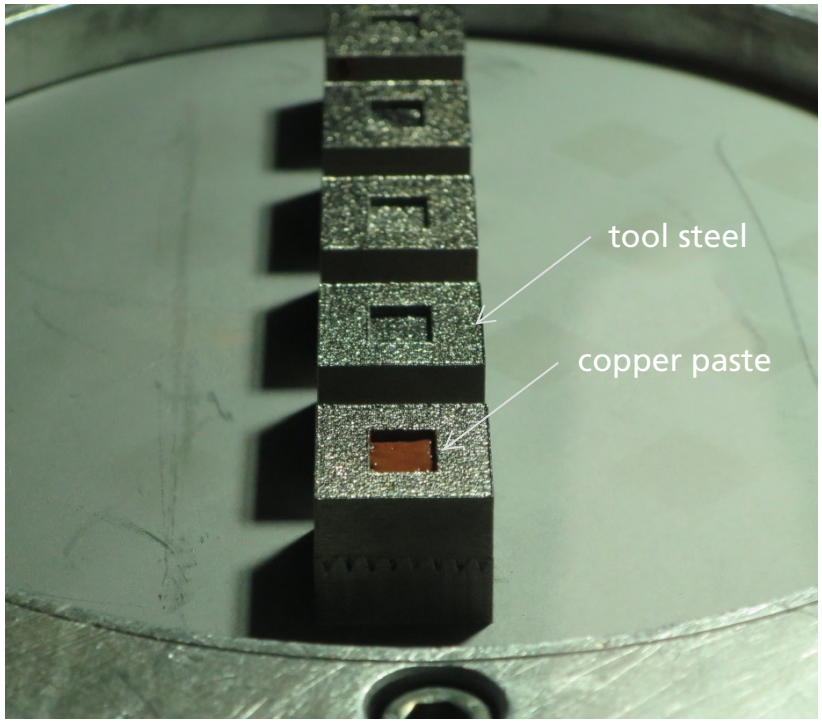
Outlook / further research activities

Multi-material

- Dispensing copper paste for higher heat dissipation in critical areas



Successful powder removal



Uniform paste extrusion is achieved – 100 µm

➔ Next step: investigation of suitable process parameters, e.g. Laser output, bed pre-heating temperature

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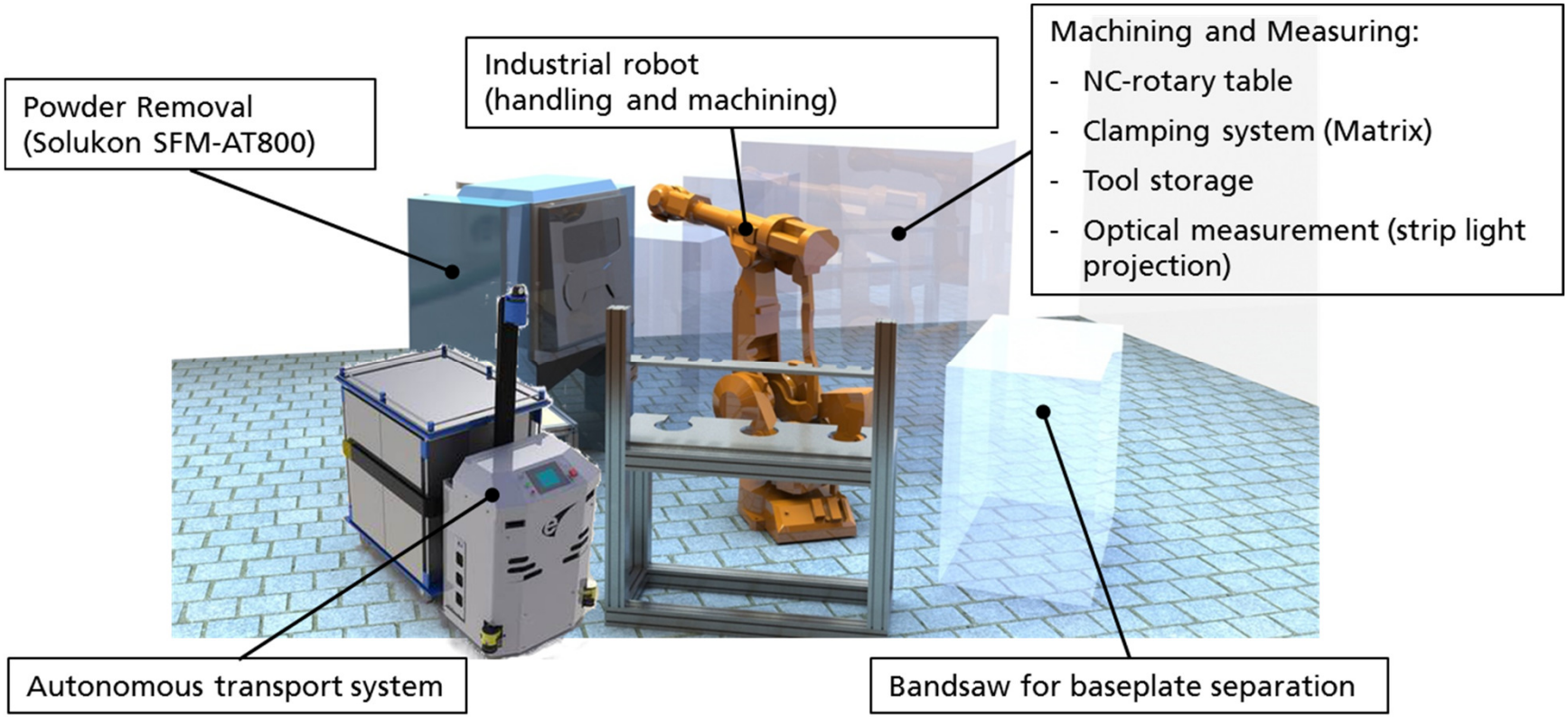
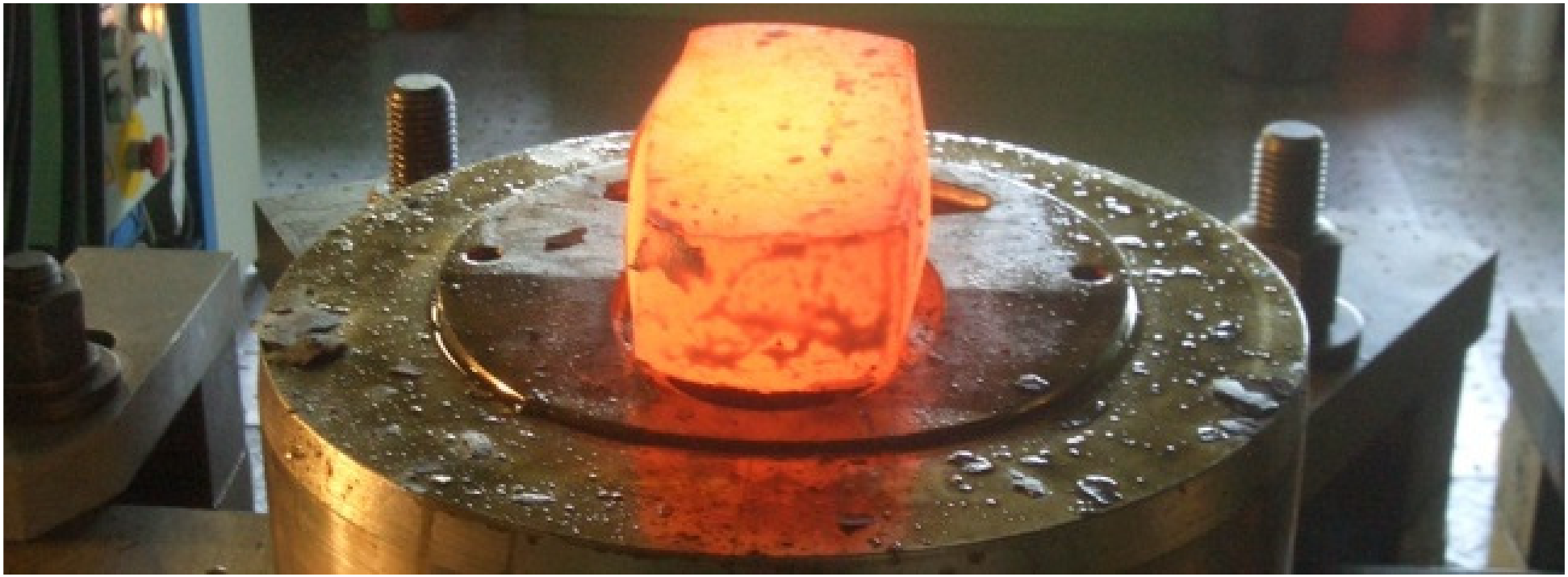
Outlook / further research activities

Concept of fully automated AM (post-)process chain



Thank you for your attention!!!



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