AM im Spannungsfeld: Materialien und AM-Qualität?

”Materials – The name of the game”

20. Juni 2024, Park Innovaare, 5234 Villigen

Veranstalter: cross-ING Pure Cross Development, anaxam analytics for advanced manufacturing, SWISSMEM Swiss Additive Manufacturing Group

Partner: Sika BUILDING TRUST, Lincotek Additive, +GF+, Empa Materials Science and Technology

Additive manufacturing of Ni-base superalloys for Industrial Gas Turbine (IGT) applications

Thomas Etter

20. Juni 2024, Park Innovaare, 5234 Villigen

Lincotek Additive

Agenda

- Lincotek group introduction and additive site Spreitenbach
- Additive manufacturing for industrial gas turbine applications:

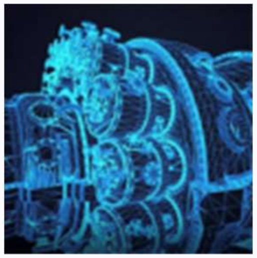
  - Laser Powder Bed Fusion (L-PBF)

  - Lincotek Ni-base alloy portfolio
- Material-related considerations in L-PBF

Lincotek Group Divisions

Lincotek

Lincotek Surface Solutions



- Commercial and helicopter aircrafts parts processing.
- Hot gas and compressor section coatings.
- Small to large Gas Turbine (4 to 567MW).
- Hot gas section coatings (Airfoils, HS, Combustion parts).

Lincotek Medical

- Product development
- Machining
- Casting
- AM
- Vacuum and air plasma spray coating of implants.
- Finishing and final packaging of products.

Lincotek Equipment

- Custom design & mfg with high degree of automation.
- Superior quality and productivity targets.

Lincotek Additive

- Ti implants, machining and packaging.
- Super alloy development, and production for GT and Aerospace.

Fully-integrated Supply Chain Solution

Machining

- Turning
- Milling
- Grinding

Coating

- LPPS / VPS
- HVOF
- Diffusive Coat
- APS
- SPS
- Stripping

Surface Finishing

- Shot Peening
- Tumbling
- Drag Finishing
- Electrochemical smoothening
- Holes Protection

Heat Treatment

- Vacuum HT
- Air HT

Holes Drilling

- Laser Drilling
- Laser Shaping
- EDM Drilling
- Combined Drilling Solutions
- Holes Reopening

Metal Joining

- Vacuum Brazing
- Welding (TIG, LASER)

Testing

- Metallography
- Tensile Testing
- 3D Scan
- CMM
- Airflow
- FPI
- TCF

Lincotek Additive Site Spreitenbach

Lincotek Additive

SETUP & INDUSTRIALIZATION ROADMAP

SCALE UP

CAPACITY INCREASE

- **March 2019** – Plant Selection
- **July 2019** – 1st EOSM290
- **Jan 2020** – 1st EOSM400-4
- **Sept 2020** – VHT Furnace
- **Jan 2021** – 2nd EOSM400-4
- **Feb 2021** – 3rd EOSM400-4

INDUSTRIALIZATION ROADMAP

- Definition of areas: AM, Post-AM, Lab
- Shopfloor preparation
- Lean Manufacturing

SCALE UP CONCEPT & EQUIPMENT:

- W-EDM cutting
- Gom 3d scan robot.
- Metallurgical lab

PROCESS & MATERIAL QUALIFICATION:

- HastX [M290 & M400-4] 2020
- IN939 [M290 & M400-4] 2021
- IN738 [M290] 2021

PILOT AM PRODUCTION (1 SET, 20 pcs, HastX 350 Kg)

DEV PRODUCTS for **COMBUSTOR** and **TURBINE** sections with HX, IN939 & IN738.

CERTIFICATION SWISS SITE
AS9100D/EN9100:2018 and ISO 9001:2015

AM Production Capacity

March 2019

Jan 2020

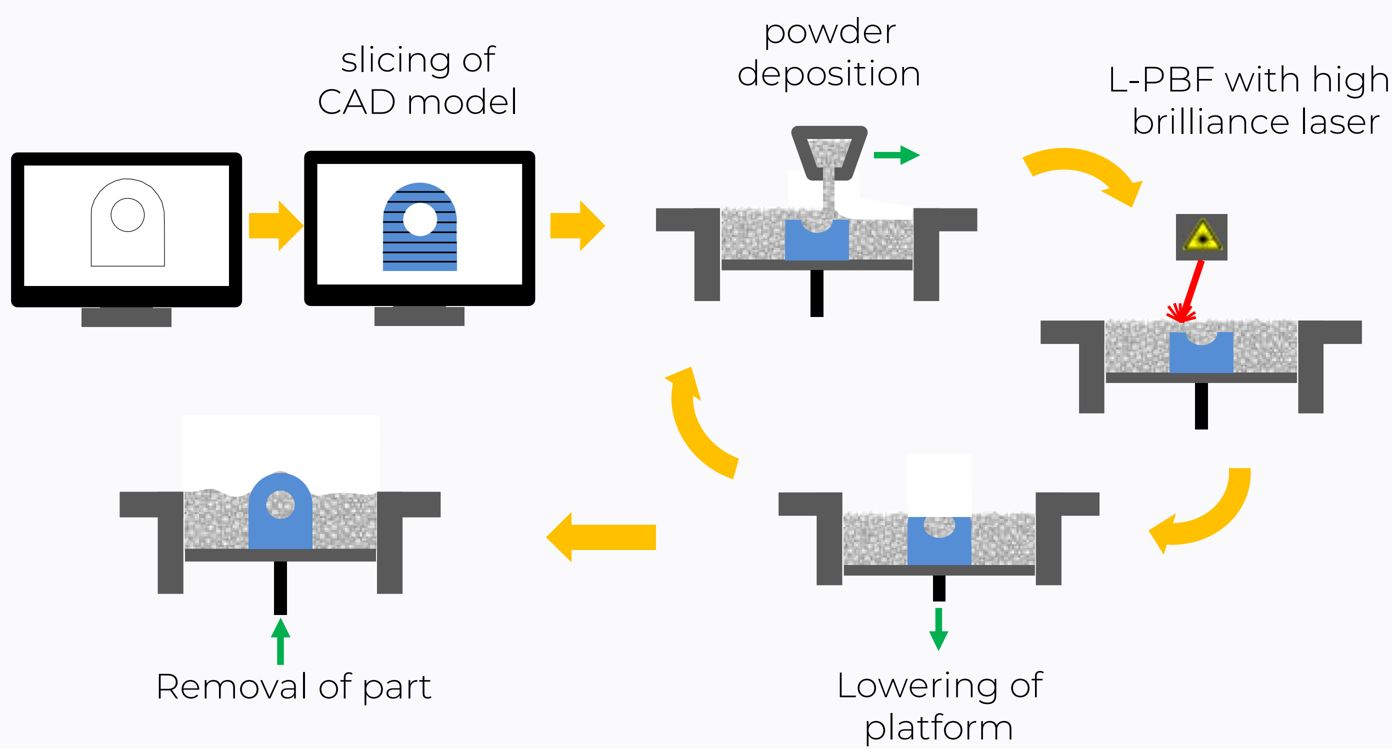
May 2021

Laser Powder Bed Fusion (L-PBF) / Selective Laser Melting (SLM)

- Laser Powder Bed Fusion (L-PBF) generates parts directly from a powder bed
  - high design flexibility, capable of producing thin-walled, complex structures
  - no casting moulds required
  - processing of fully dense components made from Ni-base alloys has become possible

<u>Input:</u>
3D CAD model

<u>Output:</u>
Parts with density
>99.7%



*public available information

Alloys in Industrial Gas Turbine (IGT) applications

Targeted parts:
high-tech components with complex design and high customer value

Combustor parts (e.g. Burners, fuel nozzles,...)	Turbine parts (e.g. Heat shields, vanes,...)
Hastelloy X, **Haynes 282**, Haynes 230, IN625, IN718,... Co-base superalloys	**IN939**, **IN738LC**, CM247LC,... **ABD-900AM**

Solid-solution strengthened alloys

γ'-containing Ni-base superalloys

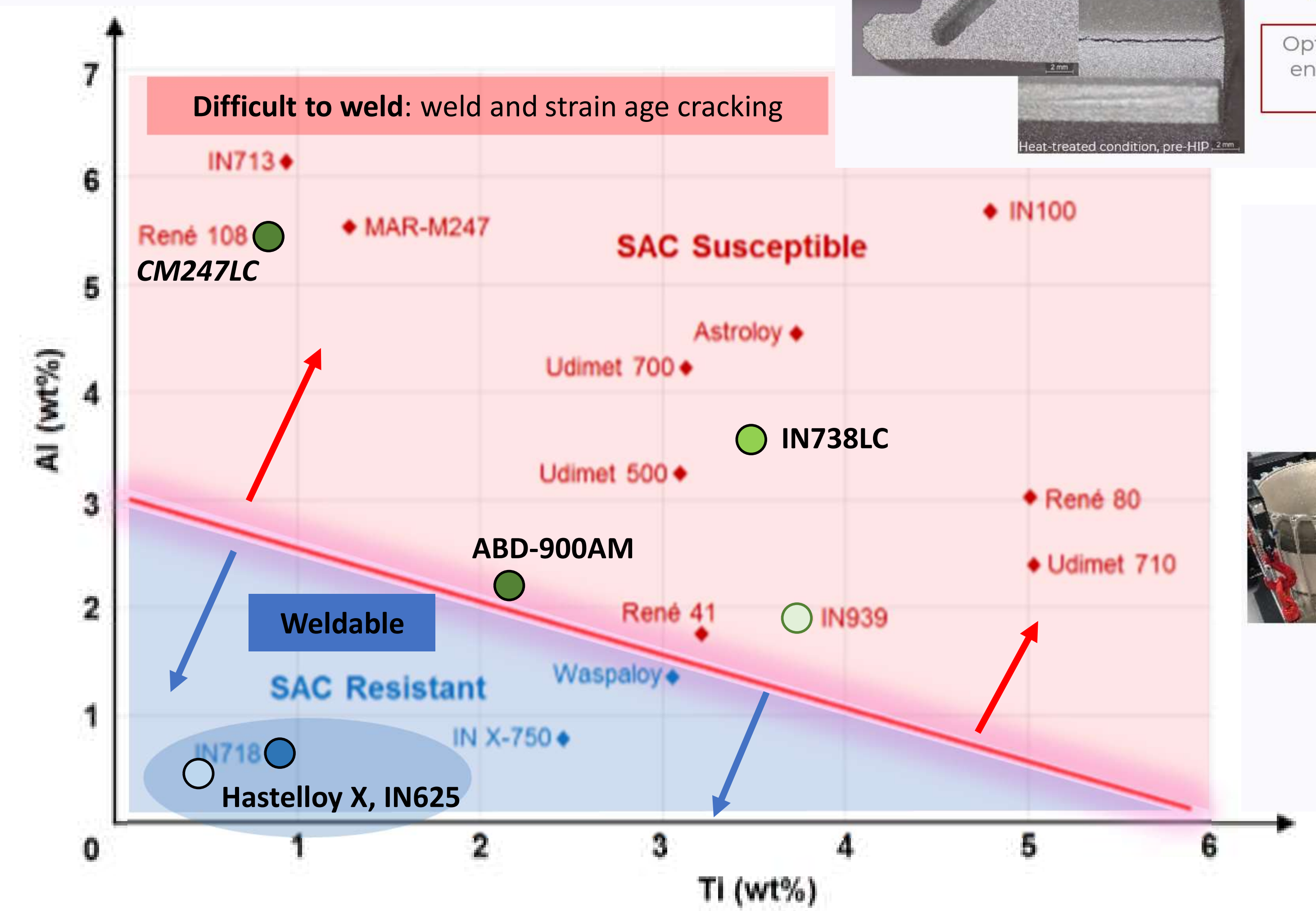
Combustor parts (Hast X,...)

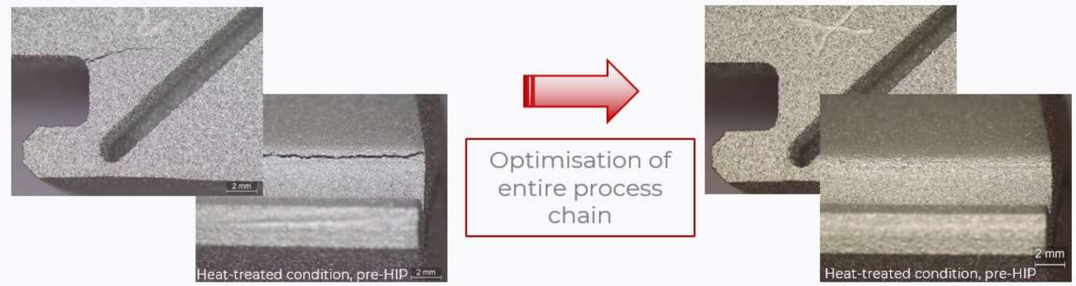
Stationary turbine parts (IN939, IN738LC)

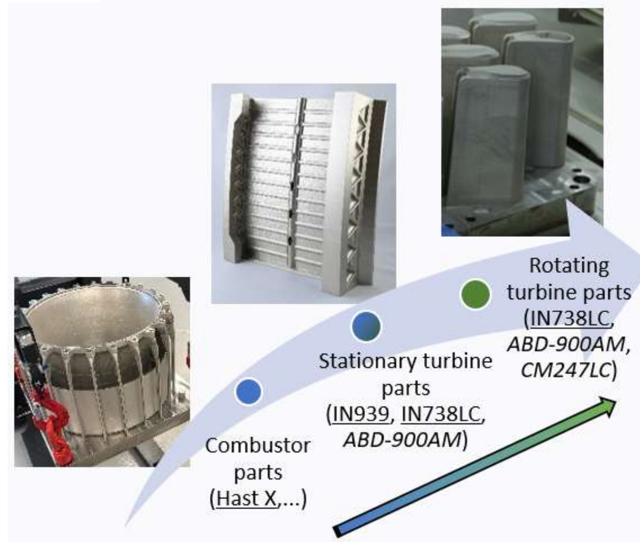
Rotating turbine parts (IN738LC, *CM247LC*)

Increase in alloy complexity
(-> impact on SLM process and post-SLM steps)

Alloys in IGT applications







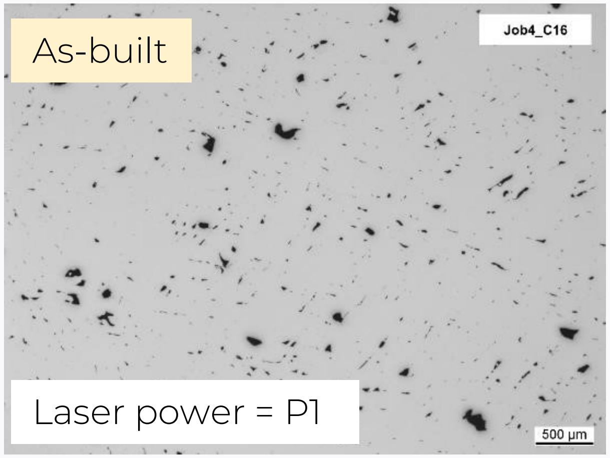
Increase in alloy complexity
(-> impact on SLM process and post-SLM steps)

Figure adapted from: A. S. Shaikh, *Development of a y' Precipitation Hardening Ni-base Superalloy for Additive Manufacturing*, 2018.

SLM process: Impact of processing parameters on metallurgical quality

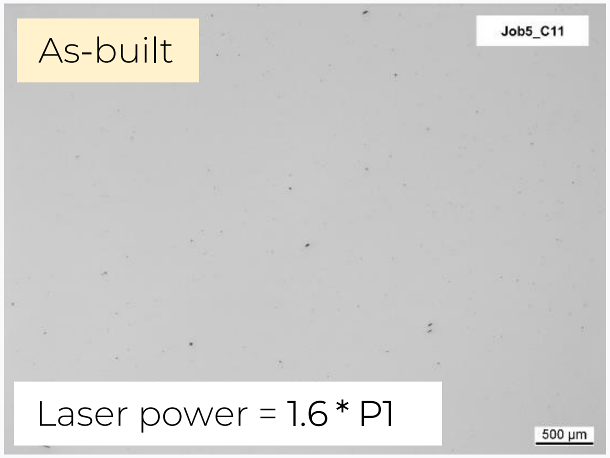
IN939: Same chemistry / different SLM parameters

- Metallurgical investigations to identify optimum SLM-process window by analysis of defect densities (e.g. pores / cracks)



SLM process optimisation

- Increase in laser power
- Scanning speed constant

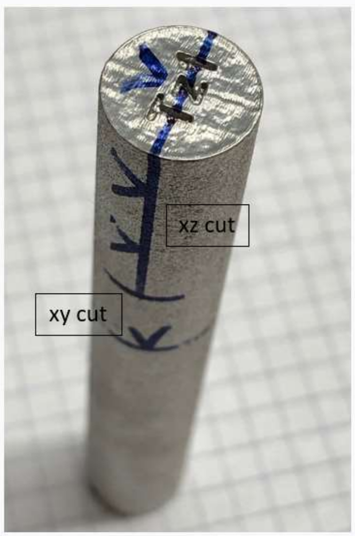


Z

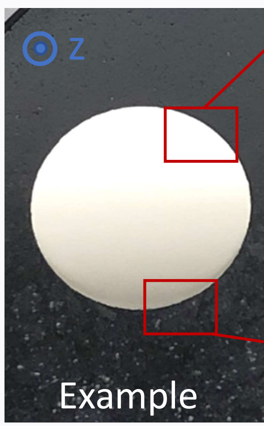
- Down selection of SLM processing parameter based on metallurgical quality, productivity and transferability to component

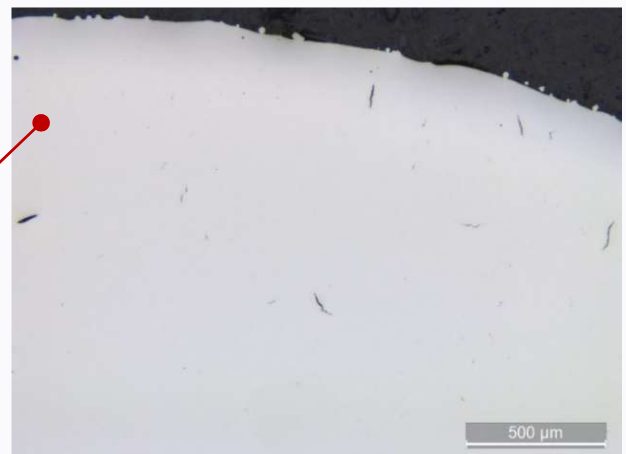
Post-SLM operations: Impact of hot isostatic pressing (HIP)

- It is very challenging to produce safety-critical components made of Ni-base superalloys by SLM without micro-cracking
- For components, manufactured by selective laser melting (SLM), HIP is used to eliminate defects such as pores, voids and internal micro-cracks
- HIP plays a vital role in assuring and increasing the quality of critical components produced by SLM



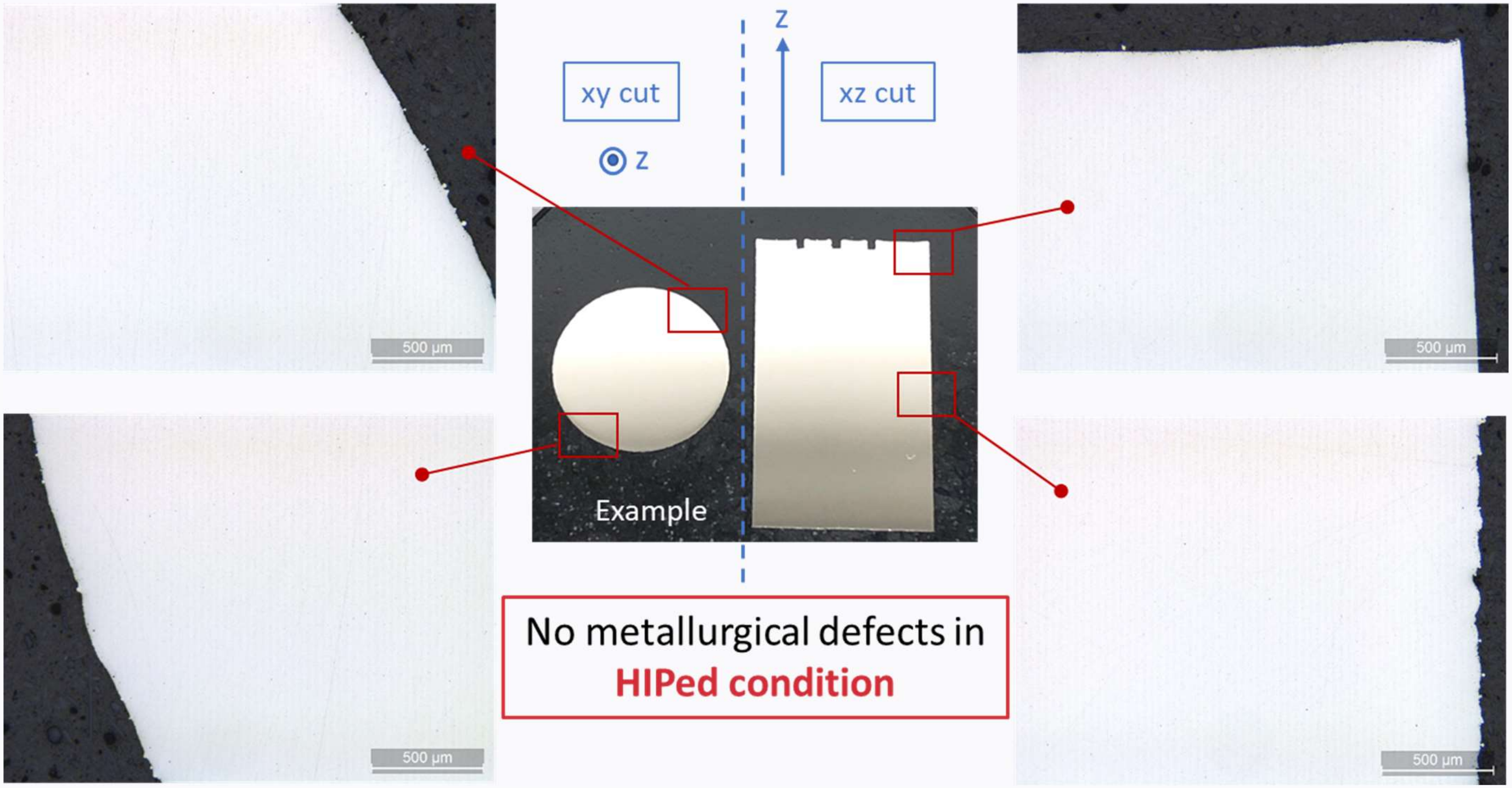
xy cut



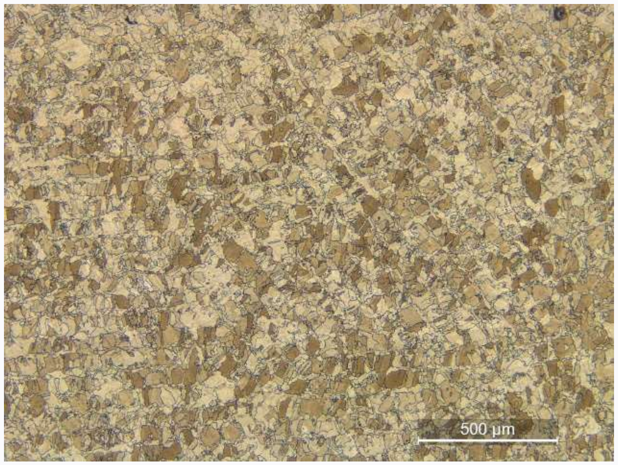
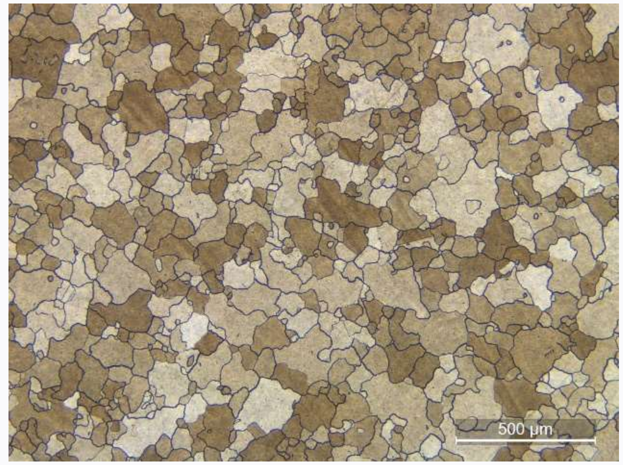
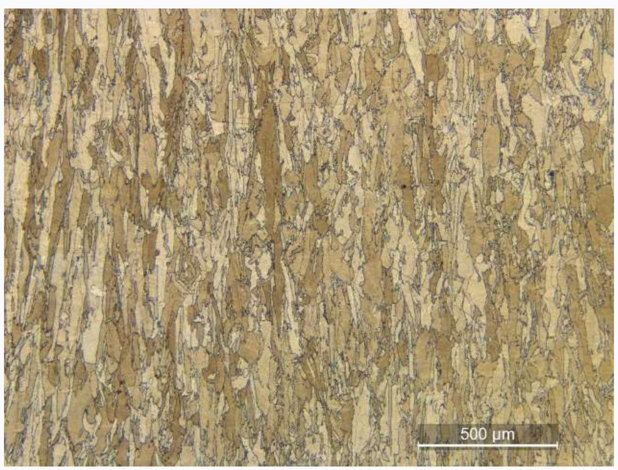
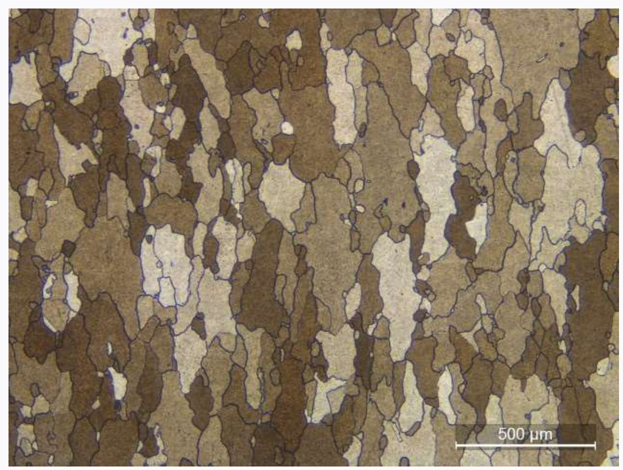


Metallurgical defects in
As-built condition

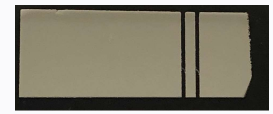
Post-SLM operations: Impact of hot isostatic pressing (HIP)



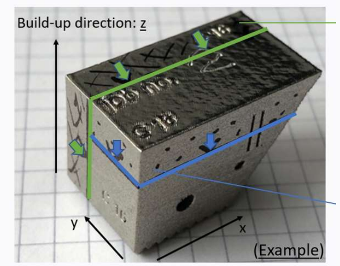
Post-SLM operations: dedicated heat treatment for AM materials

	"Standard HT for cast IN738LC"	Lincotek HT for IN738
z — XY cut		
z — XZ cut		

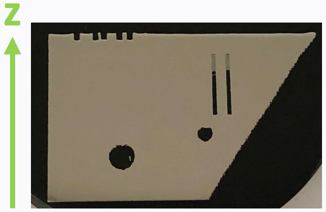
z



xy cut



z

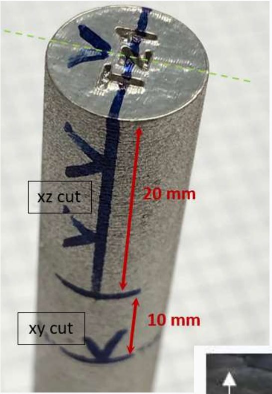


xz cut

(Example)

Material data for SLM parts: Hastelloy X

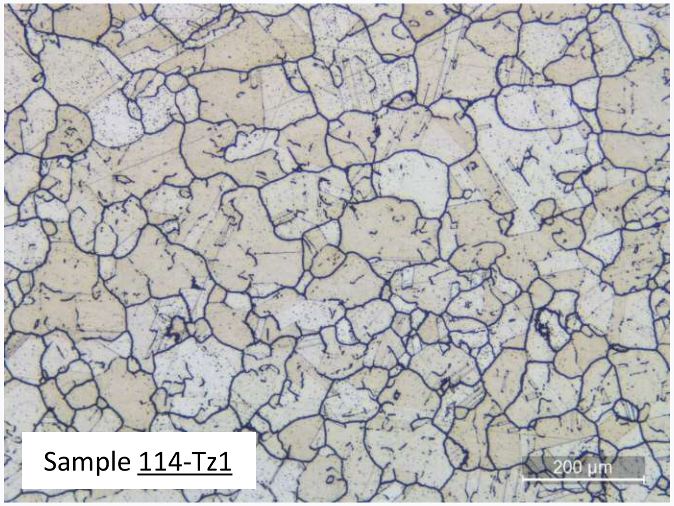
Alloy	Orientation	Temp. [°C]	Yield strength [MPa]	Tensile strength [MPa]	Elongation after fracture [%]
Lincotek Hastelloy X Fully HTed (incl. HIP)	xy (horizontal)	RT	~318	~732	~51
	Z (vertical)	RT	~320	~724	~50
	Z (vertical)	850°C	~195	~346	~49



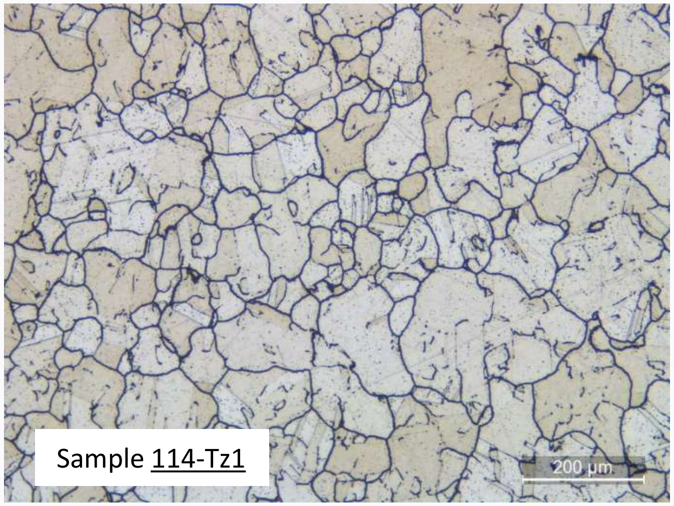
Build-up Direction (z)

Z

Fully HTed, xy cut



Fully HTed, xz cut



Z

Summary

- Lincotek can offer a complete AM supply chain solution, from support in the design for AM and the AM process itself all the way to post processing and coating of parts
- Lincotek is perfectly positioned to provide engine ready AM parts in the IGT and Aviation field
- IGT components are a good example for a combination where complexity brings performance gains and lot sizes are small leading to highly successful implementation of AM
- Different parameters along the process chain influencing final material properties and AM part behaviour:
  -> control of complete manufacturing chain
- Understanding of the material behaviour is essential for successful implementation of AM in highly loaded components

Lincotek Additive

Thank you

thomas.etter@lincotek.com