Vision and challenges on setting up a global manufacturing network at Siemens Energy

Cynthia Wirth & Sebastian Piegert

DDMC 2025 - Fraunhofer Direct Digital Manufacturing Conference
Berlin | 2025-03-12

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Agenda

1. The energy transition needs innovation: Additive manufacturing as game-changer!

2. From R&D to serial manufacturing: How to overcome the challenges of running a global AM production?

3. Vision of a global digital AM network: The Siemens Energy approach.

4. Final remarks

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A successful energy transition requires balancing

affordability, reliability, and sustainability.

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As an integrated energy technology company

we support our customers along the energy value chain

Low- or zero-emission power generation

- Gas Services
- Siemens Gamesa

Transport and storage of energy

- Grid Technologies

Reducing GHG emissions and energy consumption in industrial processes

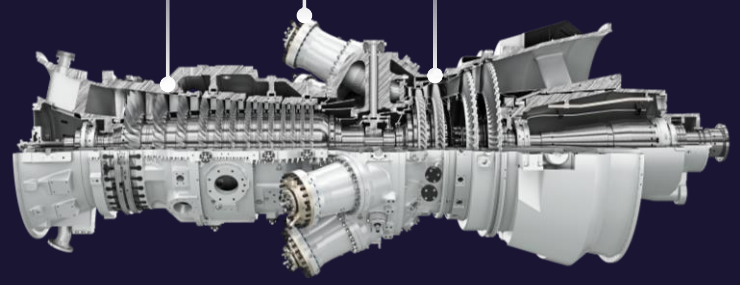
- Transformation of Industry

Additive Manufacturing as a key growth area within Gas Services

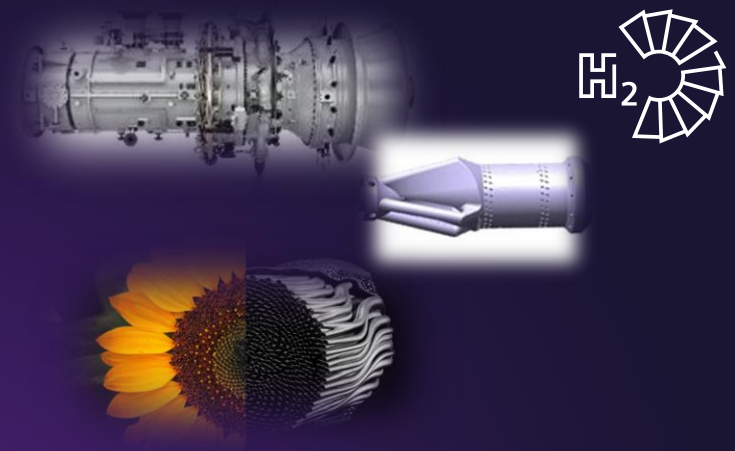
Compressor
- Seals

Combustion
- Burner / Swirler / Nozzle / Ducts / Heat Shields

Turbine
- Vanes / Blade Tips



H2 fuel flexibility and sustainable energy solutions enabled by AM



Grow

the fleet through unique AM designed components to enable:

- increased mass flow and pressure ratio in the compressor
- fuel flexibility and higher combustion temperature with improved efficiency and CO_2 reduction
- higher turbine inlet temperature with improved cooling and sealing

Protect

the fleet through modifications and upgrades to existing gas turbines with new AM enabled component designs.

We have accumulated over > 5,000,000 EOH on DLE burners and 59,000 EOH on AM vane upgrades across our lead customers engines, improving efficiency, power and emissions of the customer operations.

Decarbonize

the fleet through the design flexibility of AM:

- enabling fuel flexibility through advance combustion design to transition to green fuels and 100% H_2 firing capability
- To support development of sustainable energy solutions of the future e.g. complex heat exchange designs for solid oxide fuel cells

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Our Additive Manufacturing Footprint

Printing capacity is scalable to meet supply chain demand

21 x EOS M400-4

2 x Renishaw 500Q

2 x NXG

18 x EOS M290

Finspång (SWE)
17 x printers

Berlin (GER)
4 x printers

Worcester (UK)
28 x printers

Charlotte (US)
2 x printers

Orlando (US)
3 x printers

Today – more than
250 components
qualified (SE GS)

more than
200 people
dedicated to AM

currently
50+ printers
with factory space for up to 100 printers

Our production output amounts to more than 30,000 complex components per year.

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Standardised Materials & Process Development Cycle

A highly standardized approach ensures globally high and consistent quality

Input

- MRL & TRL procedure
- Engineering manuals
- Standard technical delivery terms & powder specification

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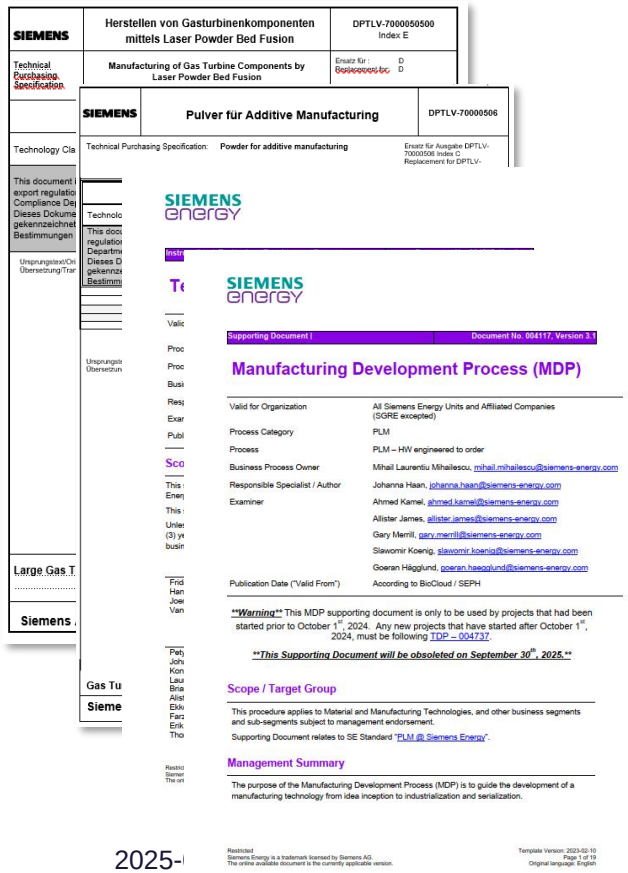

SIEMENS | Herstellen von Gasturbinenkomponenten mittels Laser Powder Bed Fusion | DPTLV-7000050500 Index E

Manufacturing of Gas Turbine Components by Laser Powder Bed Fusion

SIEMENS | Pulver für Additive Manufacturing | DPTLV-70000506

Technical Purchasing Specification: Powder for additive manufacturing

SIEMENS energy

Supporting Document | Document No. 004117, Version 3.1

Manufacturing Development Process (MDP)

Valid for Organization	All Siemens Energy Units and Affiliated Companies (SGRE excepted)
Process Category	PLM
Process	PLM – HW engineered to order
Business Process Owner	Mihail Laurentiu Mihailescu, mihail.mihailescu@siemens-energy.com
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Warning This MDP supporting document is only to be used by projects that had been started prior to October 1st, 2024. Any new projects that have started after October 1st, 2024, must be following TDP – 004737.

This Supporting Document will be obsoleted on September 30th, 2025.

Scope / Target Group

This procedure applies to Material and Manufacturing Technologies, and other business segments and sub-segments subject to management endorsement.

Supporting Document relates to SE Standard "PLM @ Siemens Energy".

Management Summary

The purpose of the Manufacturing Development Process (MDP) is to guide the development of a manufacturing technology from idea inception to industrialization and serialization.

Materials & process development cycle

MRL2
Development plan
Technical targets
Component pull

MRL3
Parameters and chemistry
Geometrical capability

MRL4
Heat Treatment and Mechanical Property Capabilities
Component capability

MRL6
Surface and support Parameters, Repeatability of mechanical properties

TRL3
Estimated curves for intended component family

TRL4
Component focused limited level mechanical data

TRL6
Component focused validated level mechanical data

MRL6+
Process capability and achievable tolerances

Product PPQ

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A highly standardized approach ensures globally high and consistent quality

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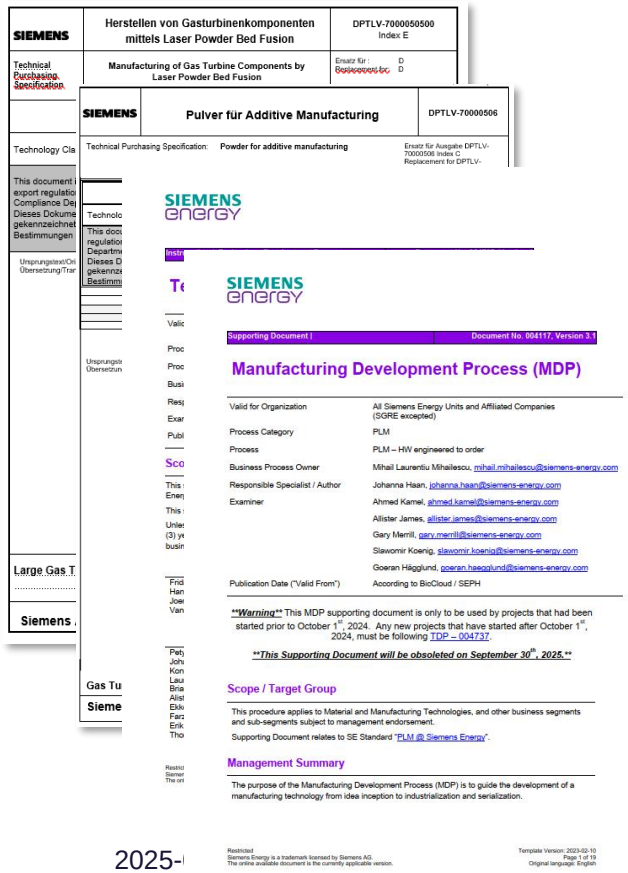

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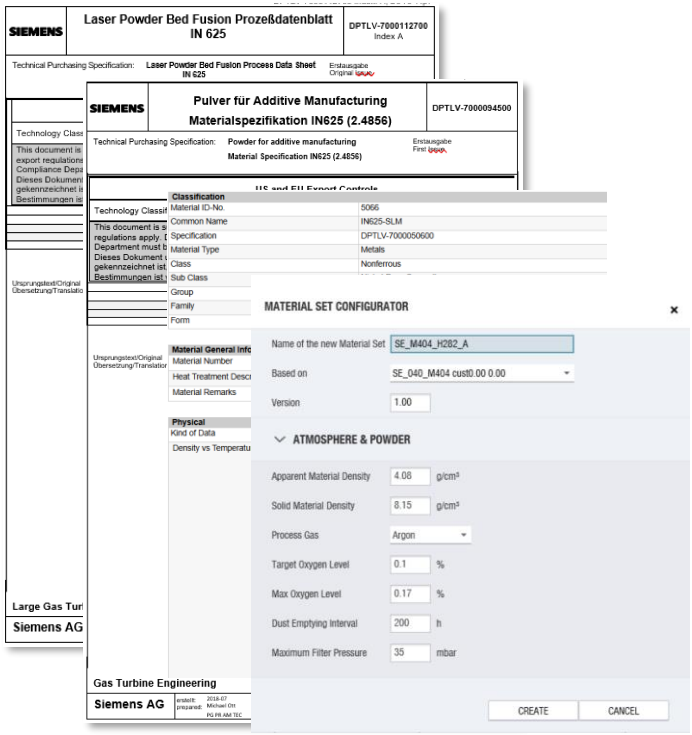
Product PPQ

Output



- Specific powder & printed material specification
- Material design curves
- **Set of fixed and validated/non-validated process parameters**

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Printer Fleet Industrialisation

We target a fully connected global printer fleet where we can manufacture “Any part on any machine!”

Flexibility

- Enable intra and inter site build job cross qualification

Build Job Cross-Qualification Procedure

Efficiency

- Improve L-PBF machine performance & availability

Global PBF Machine Event Capture, Resolution and Sharing Procedure

Quality

- Reduce L-PBF machine related non-conformance costs (NCC)

Standardised PBF Machine Maintenance, Calibration & Qualification Procedure

Global PBF Machine Configuration Control Procedure

Standardised Build Job Programming Procedure

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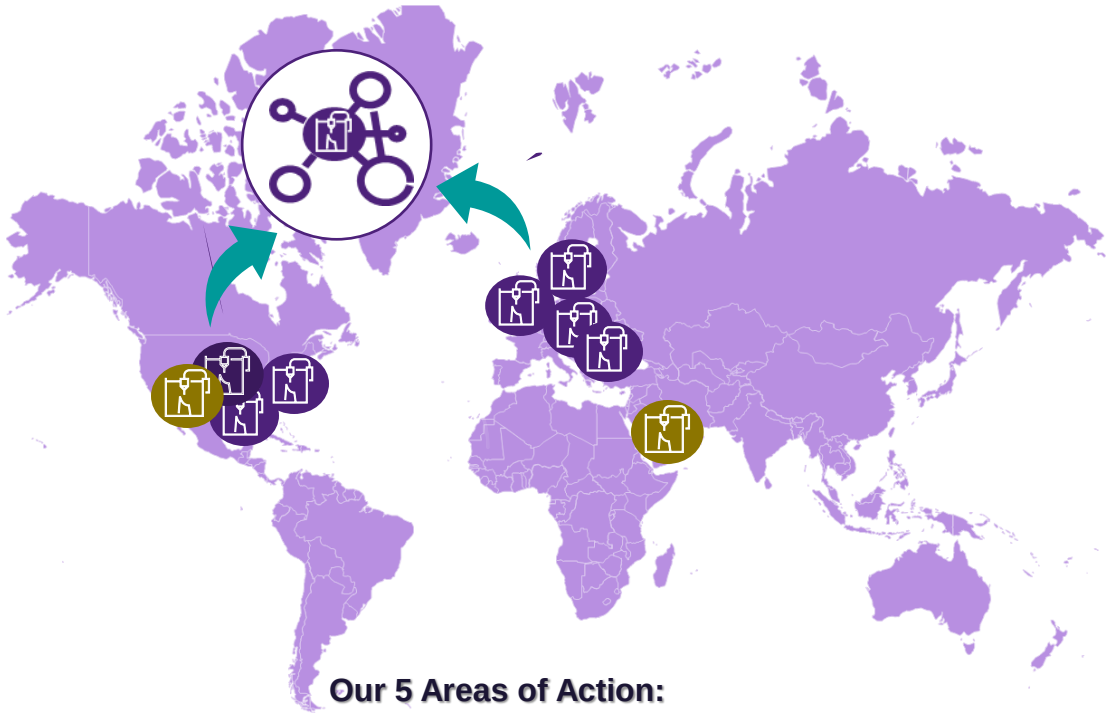
Global Digital AM Network – our Vision

Creating the digital thread for Siemens Energy's AM production



Our 5 Areas of Action:

Remote monitoring

Global AM printer fleet monitoring

Real time diagnostics

Real time fleet diagnostics & Remote machine qualification

Real time visualization

Real time AM Production

Fingerprint

Digital Fingerprint for AM Component & Processes

Robotics / digital factory

Automated post-processing: > 15% post-processing chain

internal fleet ext. partner

by 2030

SE AM sites digitally connected allowing:

1) ONE TEAM: Expertise in engineering and manufacturing streamlined and globally harmonized from design to inspection. Reference Center for SE AM external organizations.

2) ONE FLEET: digitally connected, globally monitored. Automated RCAs, Real time fleet diagnostics. Remote machine qualification. Process and component fingerprint. Remote process assurance for ext. AM suppliers.

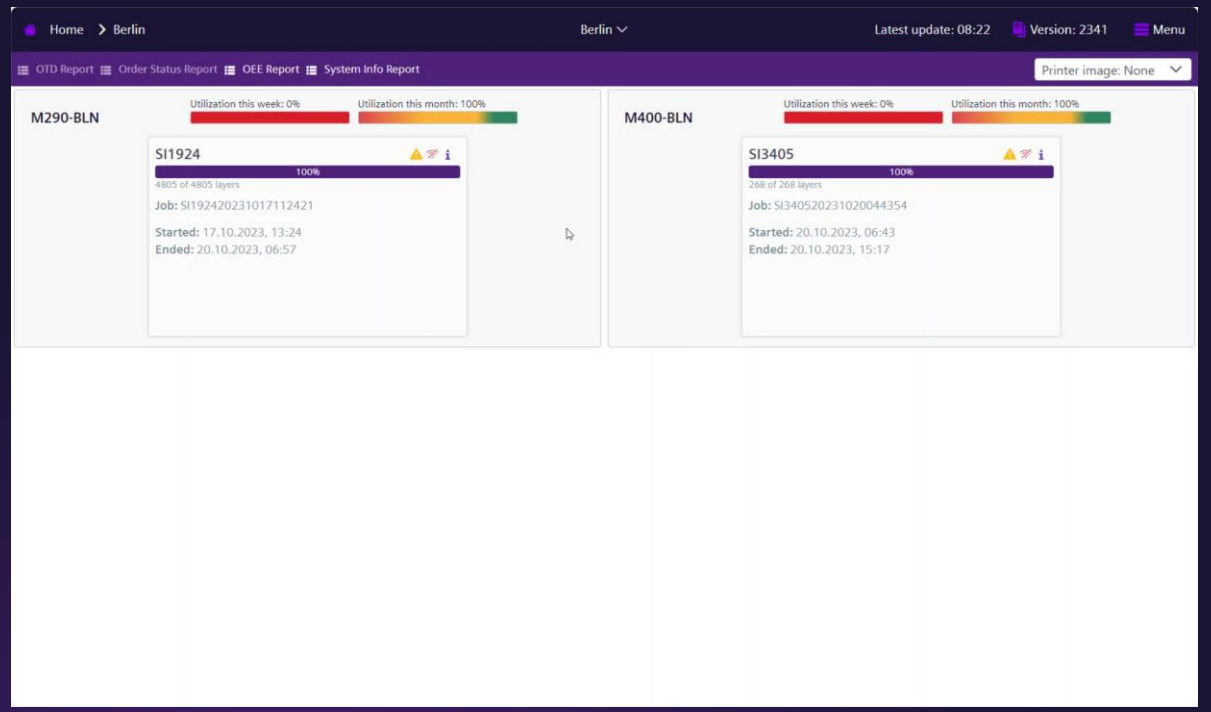
Global AM Printer Fleet Monitoring

In-situ monitoring and data quality checks for RnD and serial production

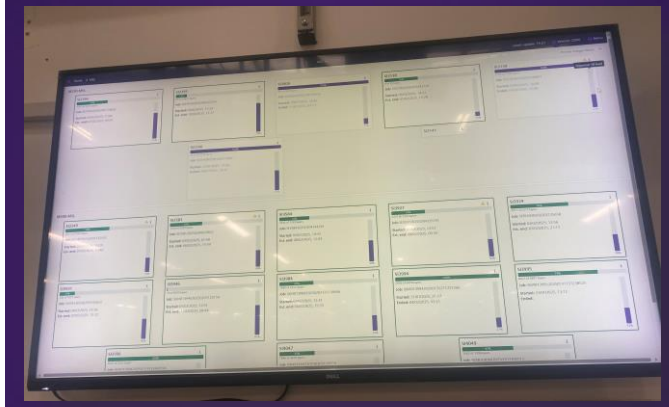
- ✓ 90% RnD & serial production printers connected to SE in-house software “AM Cockpit”:
  - *95% EOS M-290 and M-400/4 fleet connected;*
  - *Data retrieval for 2x Renishaw 500Q and 1x SLM500; connection to dashboard planed ‘til end 2025;*
  - *Current evaluation of NXG XII connection.*

13x EOS M400/4 07x EOS M290	02x EOS M400/4 01x EOS M290	0x EOS M400/4 0x EOS M290	09x EOS M400/4 02x EOS M290

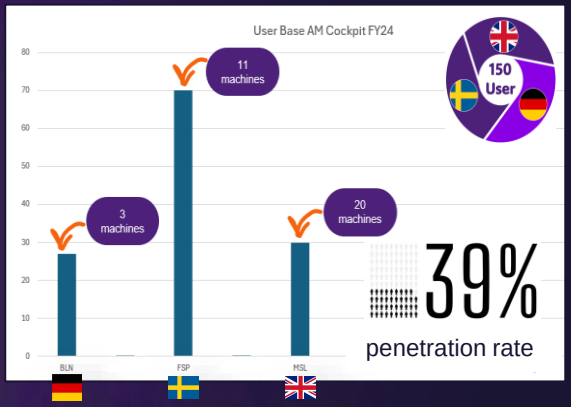
- ✓ AM Cockpit capabilities include:
  - *Analytics for in-situ and post-print data*
  - *“Semi live” view for Powder Bed Deviation score*
  - *Root Cause Analysis (Serial job comparison)*
  - *Multi-sensor approach (machine, image, etc)*
  - *Layer Images*
  - *Machine sensors*
  - *CAD/file content*
  - *Powder data*
  - *Maintenance information*



Siemens Energy AM Cockpit – In-situ process monitoring software



AM Cockpit dashboard is use on UK factory floor



Increasing user group within global ENG and OPS teams

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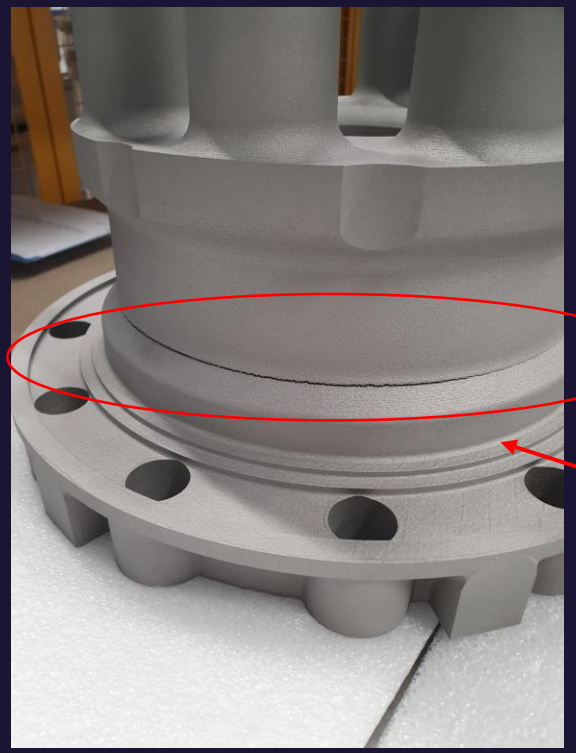
Use-Case “ULN Manifold”

Potential to reduce up to 35% of non-conformance costs (NCC) in serial AM production via an automated failure detection w/ warnings



Defect in ULN Manifold AFTER inspection.

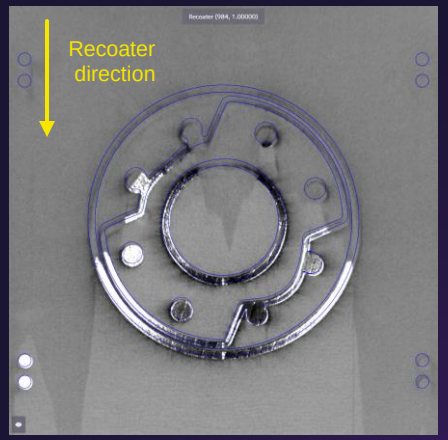


Image after recoater @ layer 984

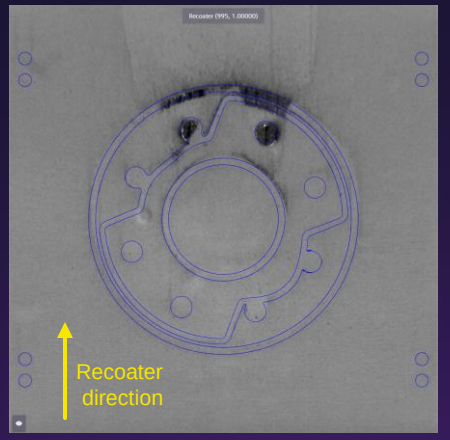
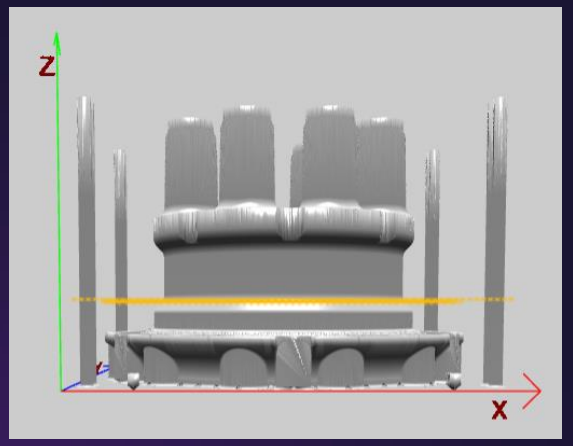


Image after recoater @ layer 995



The current algorithm overlaps in yellow the occurrence of unusual areas with the openJZ file.

A “powder-bed deviation score” of 1 means an *unusual event (based on the layer reflectivity) has occurred*, but does not assign a category to it.

- The current algorithm was capable to detect anomalies but not to categorize them; therefore, the software was not sending any specific alert to the user to react;
- Implementing “alerts” into a serial production environment requires higher levels of confidence and validation: e.g. defining “user groups” for each category; defining and fixing a “decision matrix” to take action (WHO does WHAT, WHEN…).

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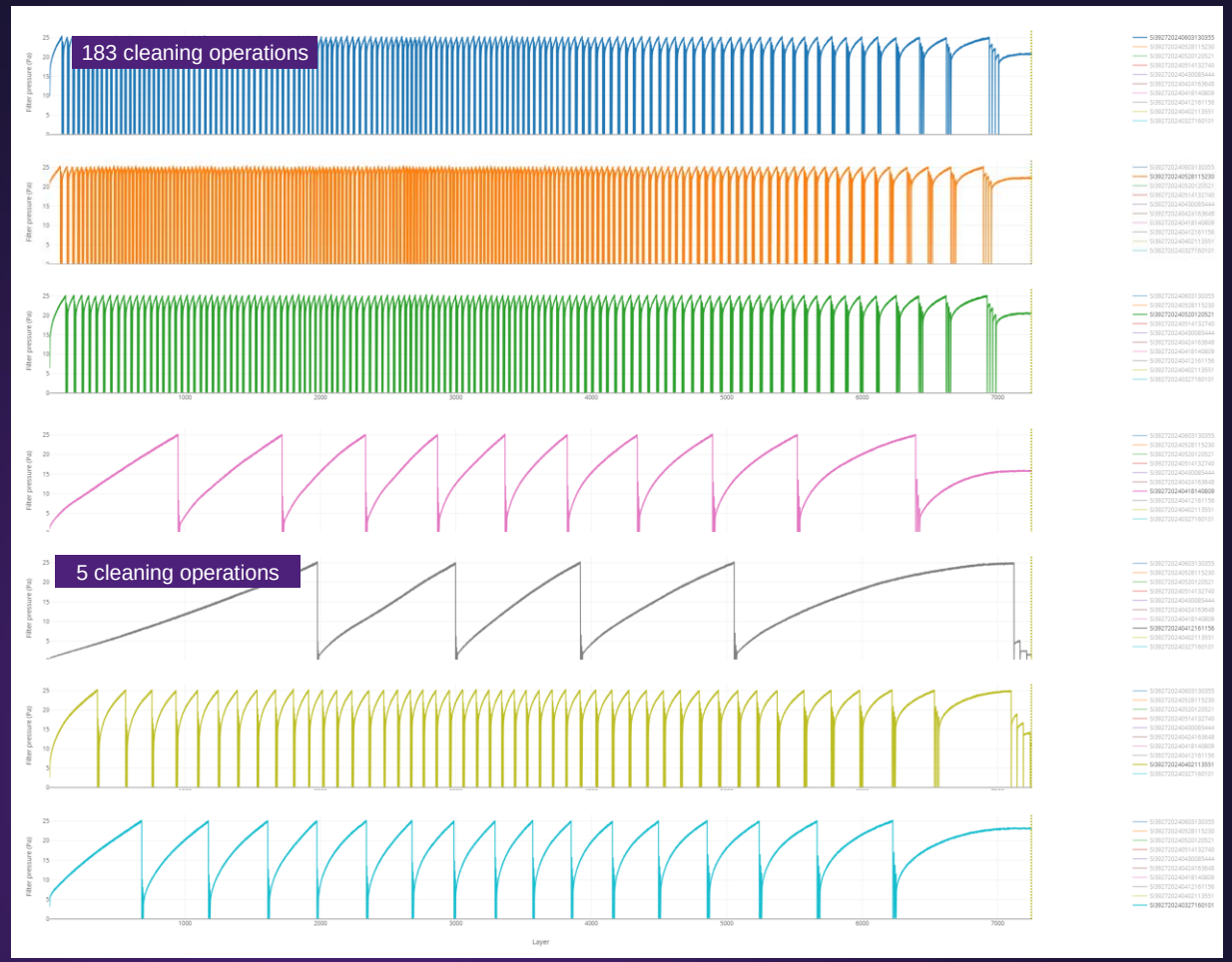
Real Time Fleet Diagnostics

Irregular filter cleaning behaviour during serial production causing up to 6h unplanned production time PER build.

* Observation is a mixture of RFS 1.3, Nano filter and Particle separator

- Serial production running on 7 different machines/ ca. 2000 layers per build;
- Sensor data analysis detecting irregular cleaning cycles, w/ up to 2min/cleaning cycle/ machine;
- Current fleet runs on different filter system variants, which has resulted in different machine behaviours;
- Monitoring & Data Analysis supporting decision making for improving process efficiency & reducing production costs.



May ..... July

Info from Digi to Industrialization about observations

Received a Patch to mitigate issue

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Final remarks

Materials & Processes

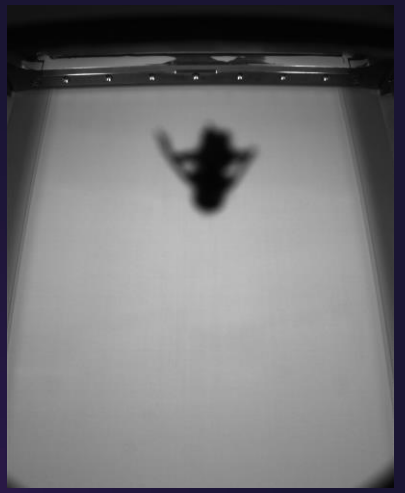
- A standardized and controlled approach for the development of processes ensures high quality processes throughout the network
- Manufacturing feedback is crucial to improve the established processes
- The fixed and validated process parameters need to be controlled by a respective digital solution – zero failure tolerance!

Printer Fleet Industrialization

- True flexibility follows efficiency and quality
- Quality is the result of tight control of
  - Machine maintenance and calibration,
  - Machine configuration control, and
  - Standard build job programming.
- As a result, AM production achieves > 96 % machine availability & >> 72 % OEE

Global Digital Network

- AM offers a unique opportunity to democratize manufacturing and build up resilient supply chains, *“you can print anywhere”;* Digitalization enables it!
- Processes need to be harmonized and standardized, prior to deployment of digital solutions;
- Data quality and availability are crucial for the success of the digital transformation.



Never stop BUG FIXING!

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