Quality assurance concept of additive manufacturing in engine construction

2019 EASA - FAA Workshop on Additive Manufacturing

EASA Headquarter Cologne

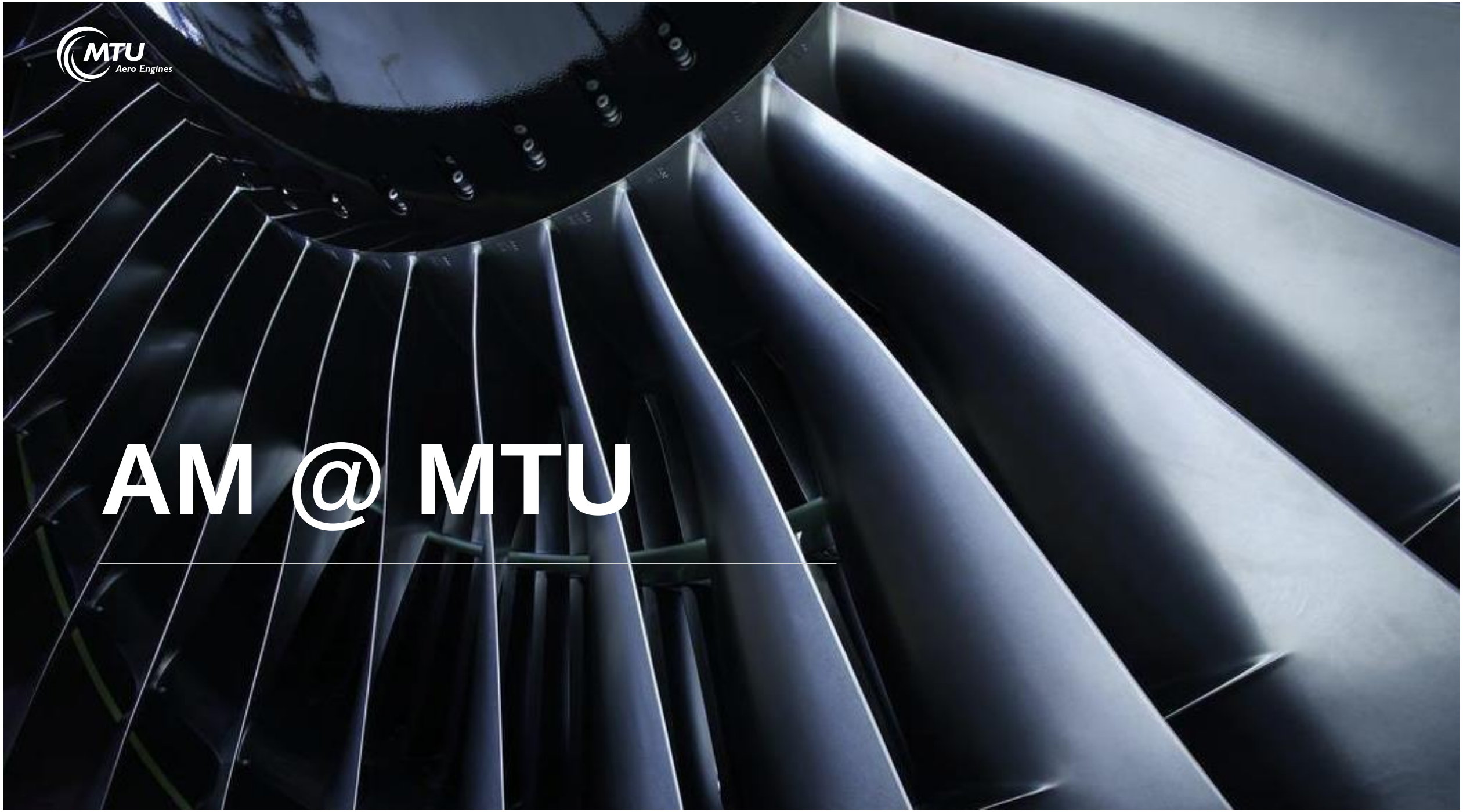
11/06/2019 – Dr. Jürgen Kraus

Agenda

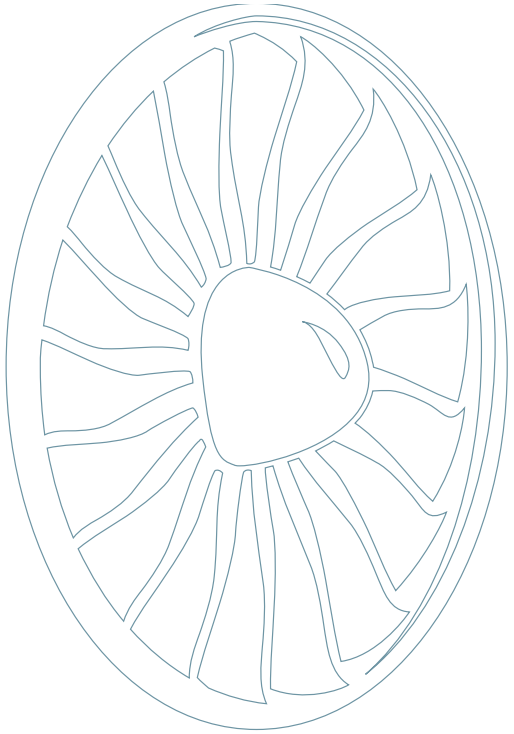
AM @ MTU

QA concepts

Issues in powder recycling


MTU
Aero Engines
AM @ MTU

MTU Aero Engines at a glance



Leading German engine manufacturer
and key partner to OEMs for military and commercial engines

A leading provider of engine services
for various military and commercial engines

€ 4.6 billion revenue in 2018
with ~ 10.000 employees

Worldwide network
with 15 major facilities and representative offices

AM technology is established with more than 10 years of experience

First serial production part: Borescope eye

In service since January 2012 at PW1100G-JM (A320neo)

Production ramp-up since 2017

More than 4.000 parts produced

Very positive field experience

Learning

Lower cost benefits with a only-substitution-approach

Post-process essential to achieve target costs

High scrap rates due to machine imperfections

Center-of-excellence established


Borescope eye


PW1100G-JM


Airbus A320neo

Parts portfolio will consistently increase in volume and complexity

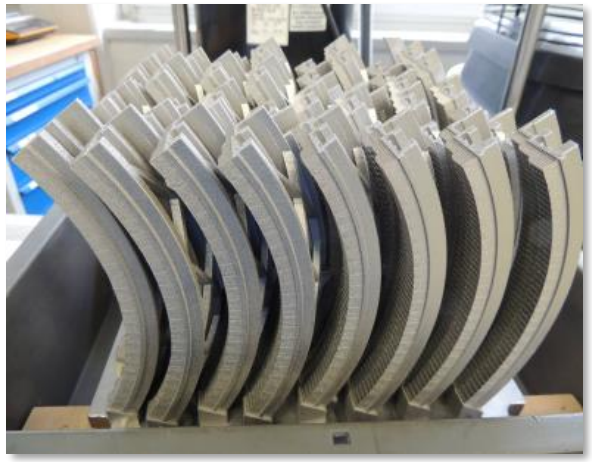
Compressor sealing carrier

Approach of substitution and new design

Less effort due to integral honeycomb design

Increase of compressor stability and efficiency

30 to 40% cost benefit



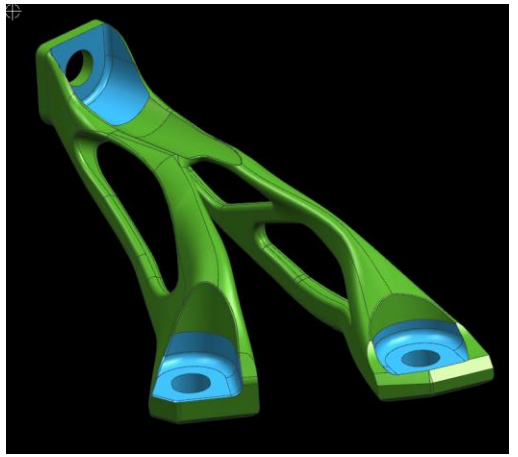
Oil tube bracket

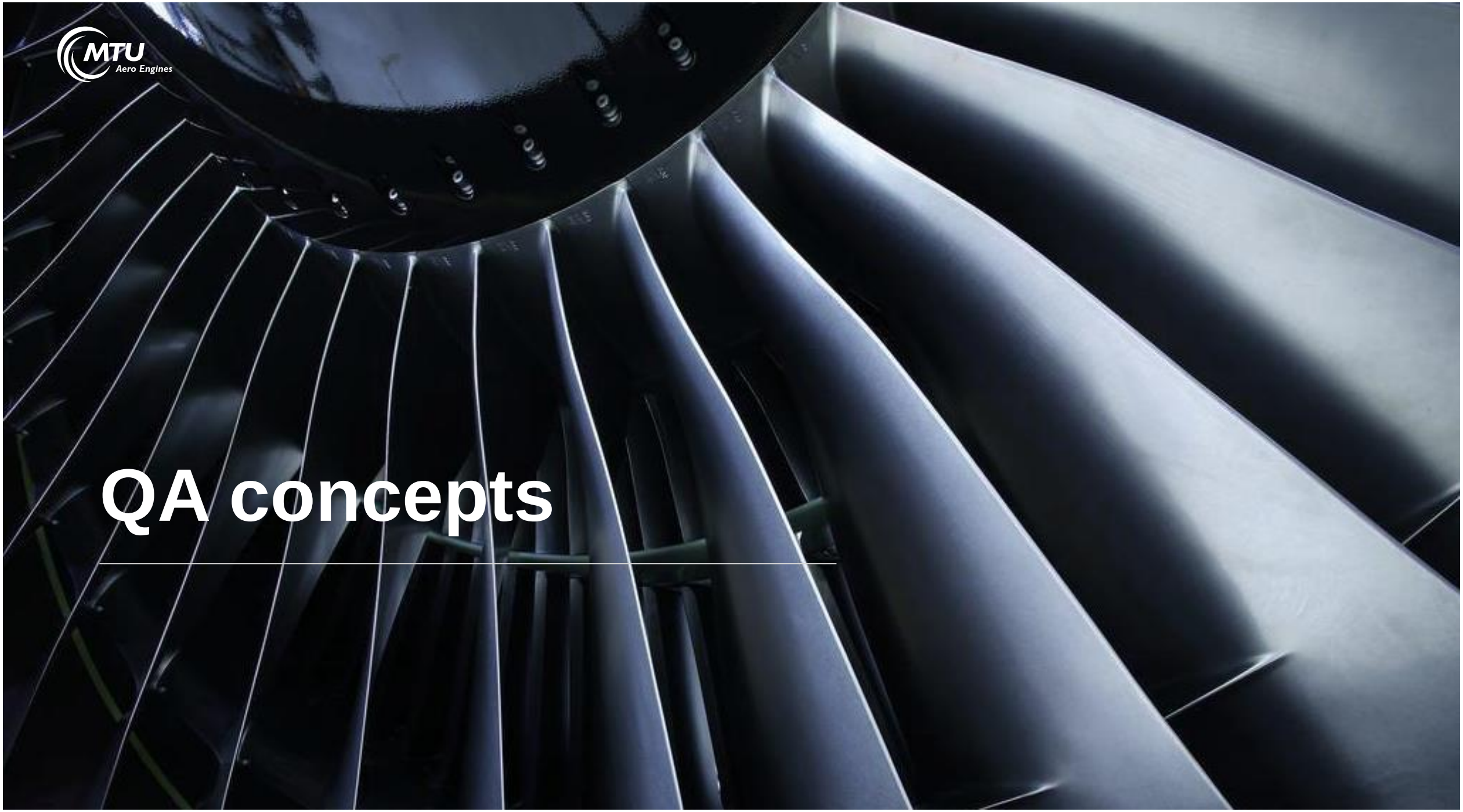
Full bionic design

Less effort due to drastically reduced machining

50% weight reduction

80% cost benefit

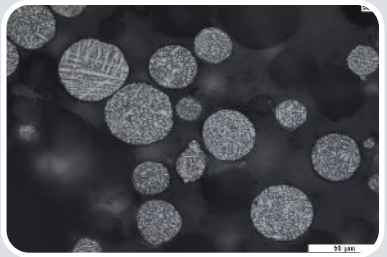




QA concepts

AM@MTU

Quality Control for Aero Engine Components



Raw Material / Powder

Supplier

- Certificates

MTU

- Incoming goods inspection
- Requalification of used powder

Production Line

Machine Qualification

- Machine calibration
- Total productive maintenance
- Machine approval

Process

Process Monitoring

- Optical Tomography
- Machine Parameters
- Process Parameters

Part

Component Testing / NDT

- Optical Tomography
- NDT
- Geometr. measurement
- Test bars
- Cut-ups

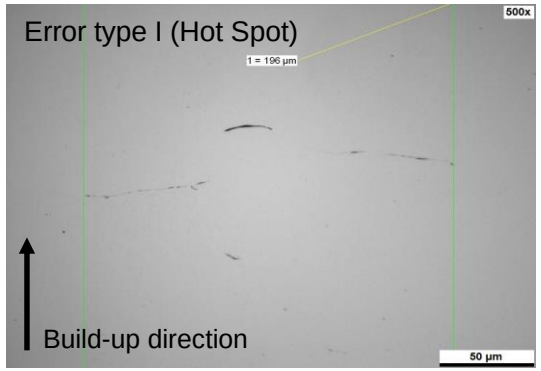
Quality control system has to cover full range of the process chain

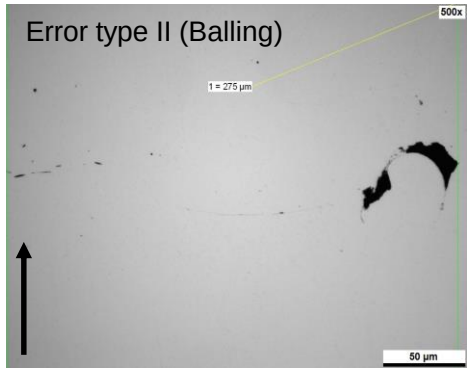
AM typical volume defects and test methods

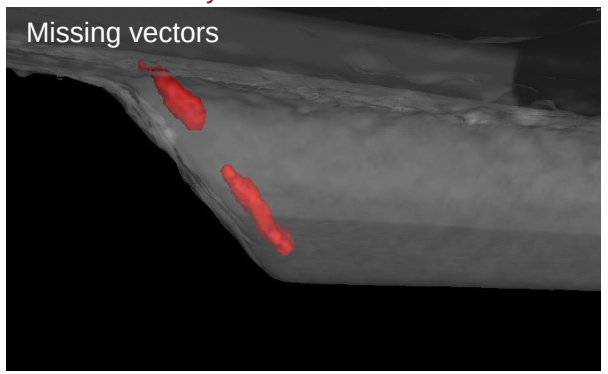
Error types	OT	X-Ray	CT	Metallography (systematic errors)
Lack of fusion Type I (Hot Spot)	✓	–	–	(✓)
Lack of fusion Typ II (Balling)	✓ POD in work	✓ Depends on geometry	✓ Depends on geometry	(✓)
Missing vectors	–	✓	✓	–
Pores	–	(✓) >100 µm	(✓) >100 µm	(✓)
Micro-cracks	–	–	–	(✓)
Inclusions	(✓)	(✓) Huge inclusions with sign. differences in density	(✓) Sign. differences in density	(✓)

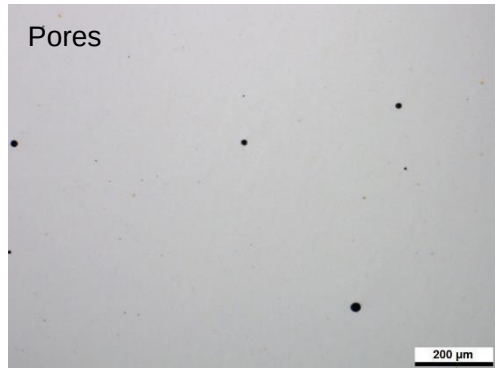
Accepted in process specific size

software check



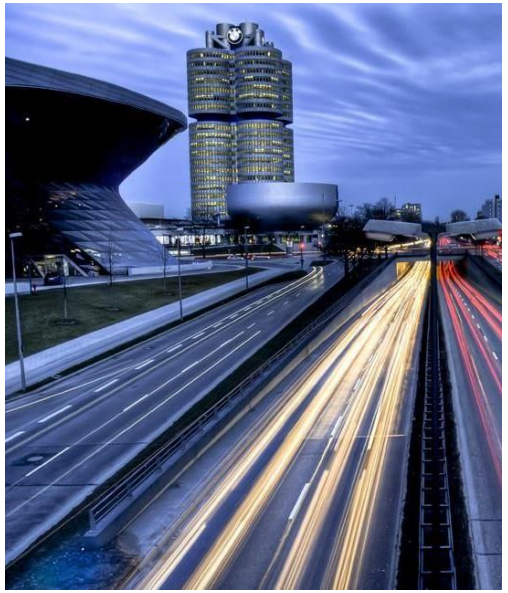






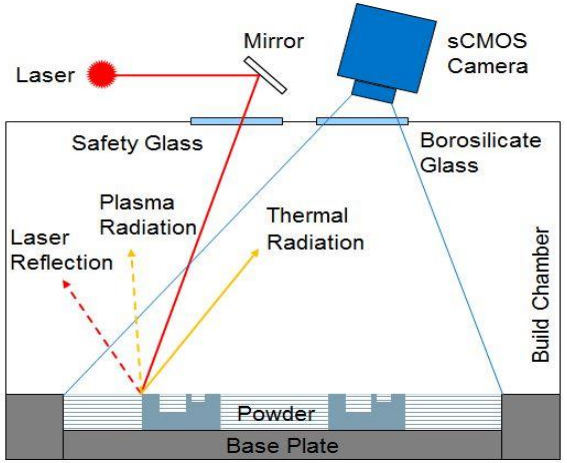
Optical Tomography (OT)

System Principle



Long time exposure of urban traffic

→ traffic volume



Brightness in the picture equals radiation integrated over time

→ Measurement of energy per length

Long time exposure in additive manufacturing

→ radiation density

Optical Tomography is an inseparable part of MTU's SLM process

Optical Tomography

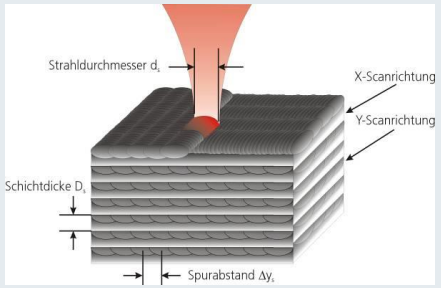
Types of deviation

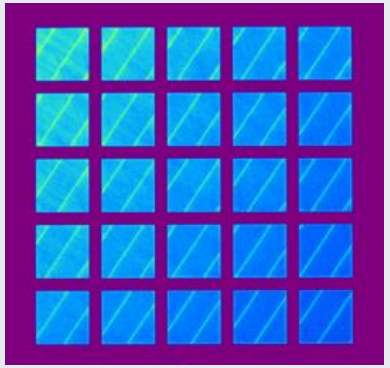
Systematical deviations

Monitoring of energy input, e.g.:

- Laser power
- Scan speed
- Hatch distance

Average gray values (GLM) allows the monitoring of all positions and layers in a build job.





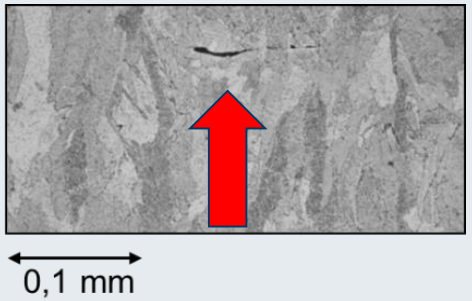
Alternative methods:

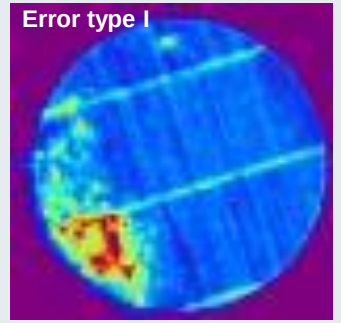
- Inspection of accompanying samples
- Destructive inspections of components
- X-ray (depends on geometry)

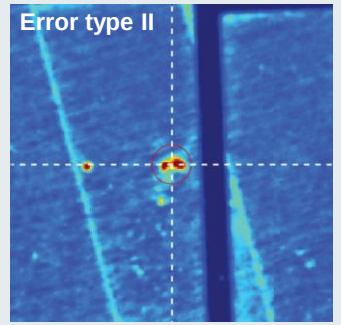
Local deviations

Random process disruptions causing the emergence of lacks of fusion:

- Disruption of guided gas flow (defect type I)
  → de-focusing of laser beam
- Powder agglomeration (defect type II)







Series introduction of OT and suggestion of assurance through CT testing

- <u>Requirements for replacement of CT serial testing:</u>
  - OT qualification as NDT method for error types I and II
  - Approval of the powder bed monitoring system

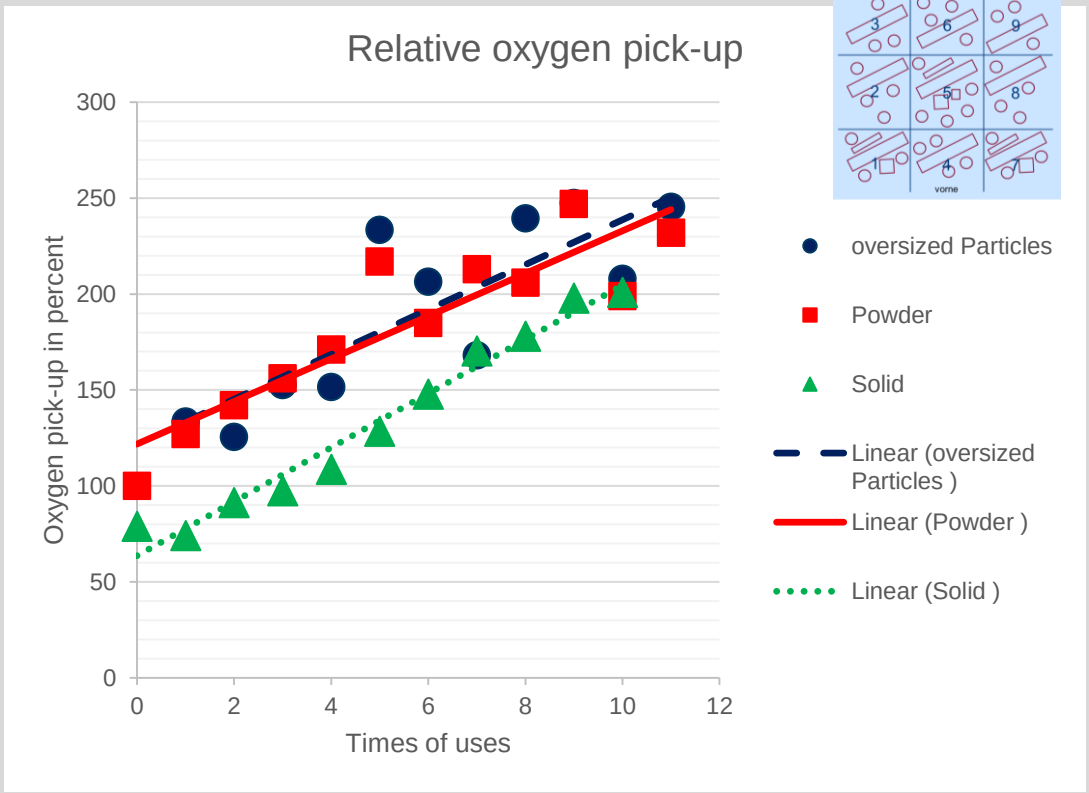
Testing method	FAI	LRIP (series introduction)	Series
OT defect type I and II	100 %	100 %	100 %
X-Ray / CT	100 %	Part specific share.	-
Metallography	5 components, 1 process sample	1 process sample per build job	1 process sample per build job
FPI	100 %	100 %	100 %

OT and X-Ray/CT to be performed in parallel for FAI and LRIP

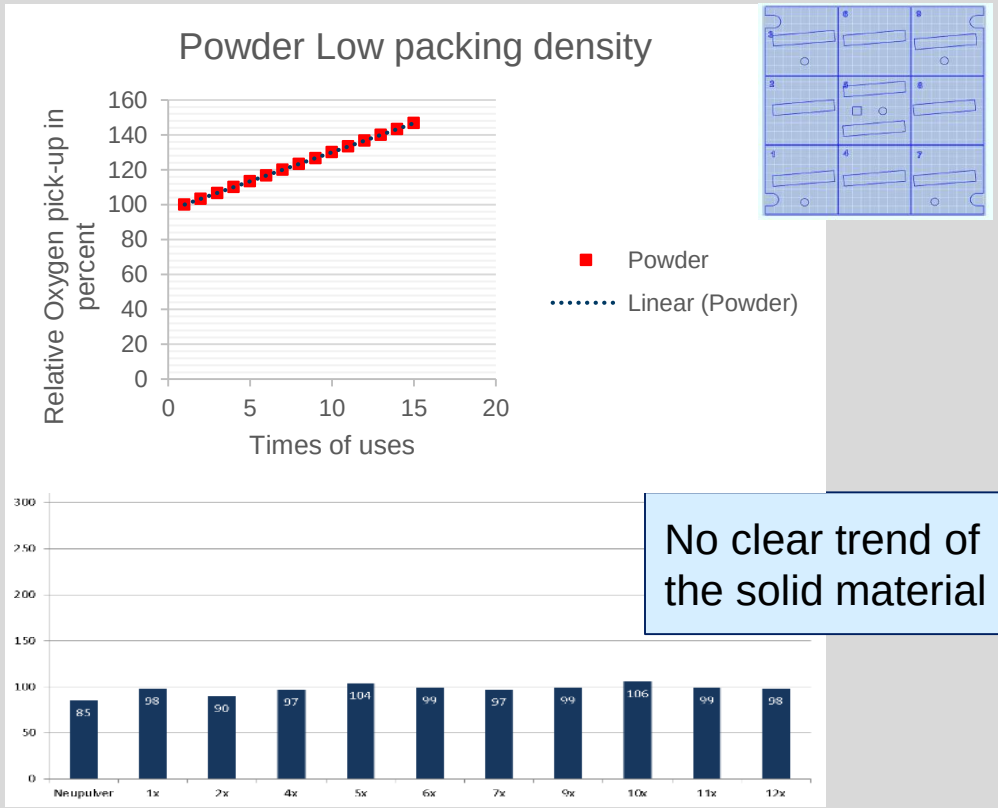
Issues in powder recycling

Oxygen pick-up for reference jobs

High packing density-job



Low packing density-job

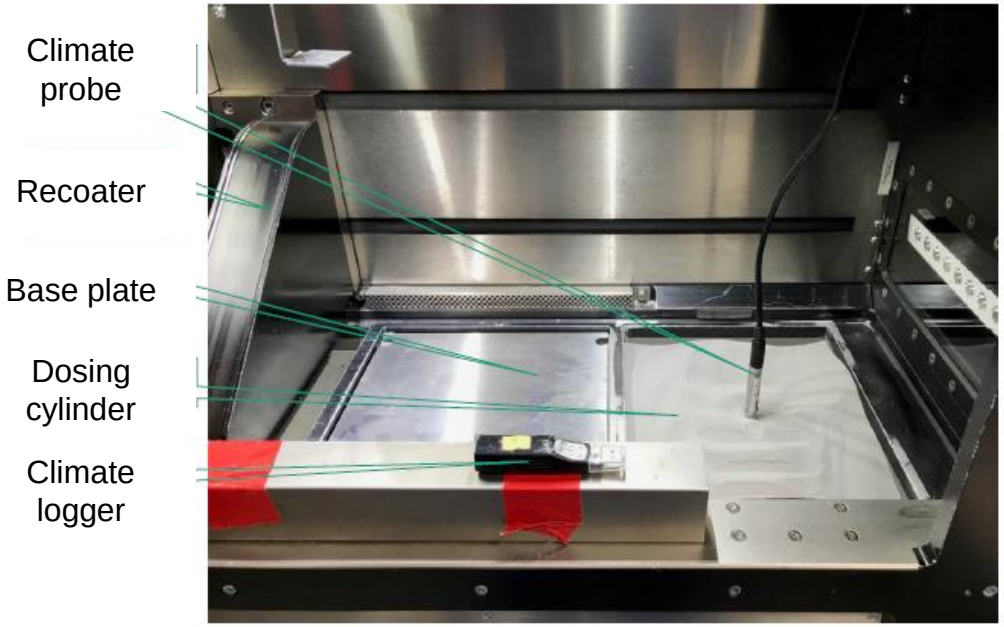


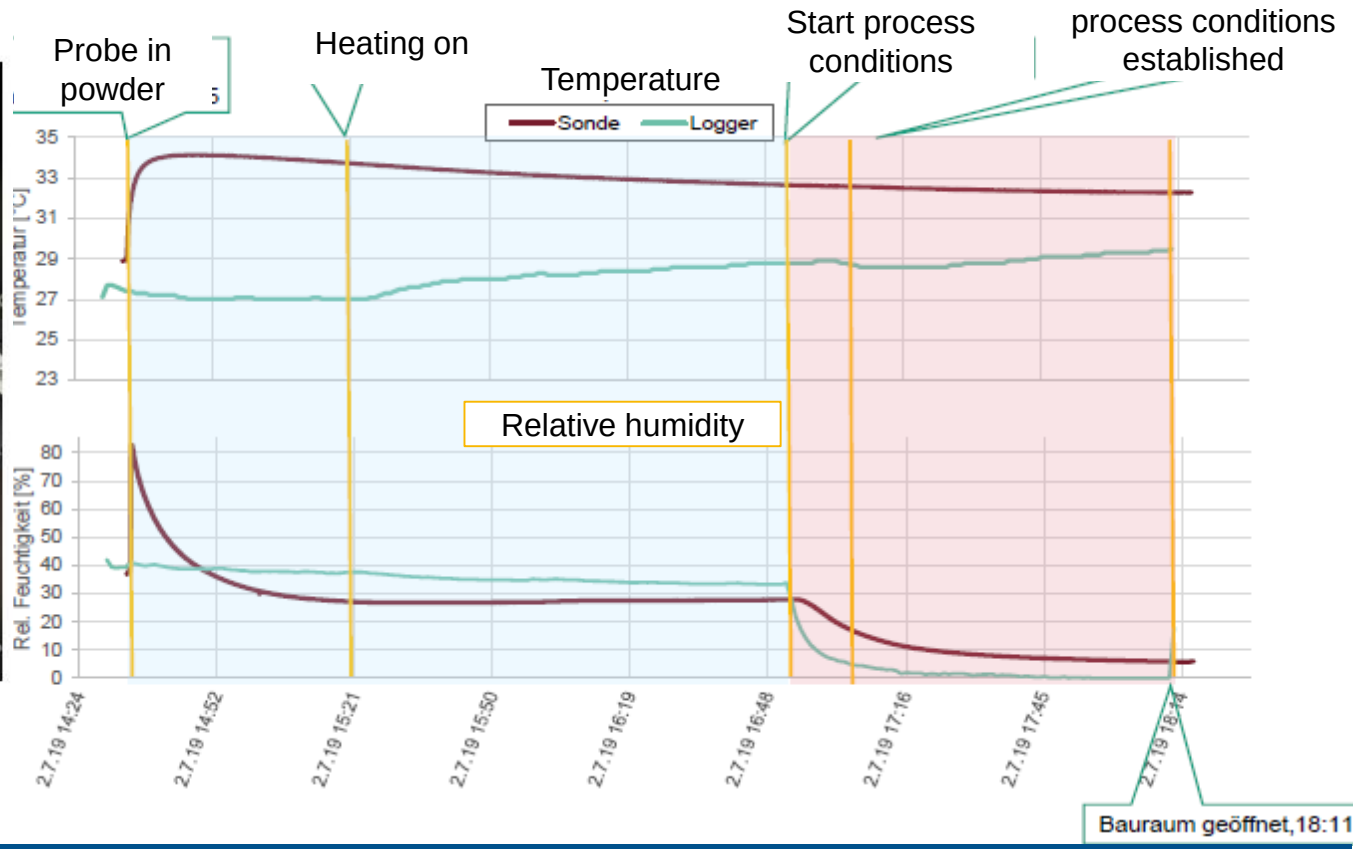
No clear trend of the solid material

Degree of oxygen up-take is job-dependent
Accepted „times of uses“ vary in a wide range

Environmental exposure – powder humidity II

Scenario: Preparing a LPBF machine





Humidity in LPBF process is widely independent from original powder condition

Boundary conditions & basic strategies

Standard requirements

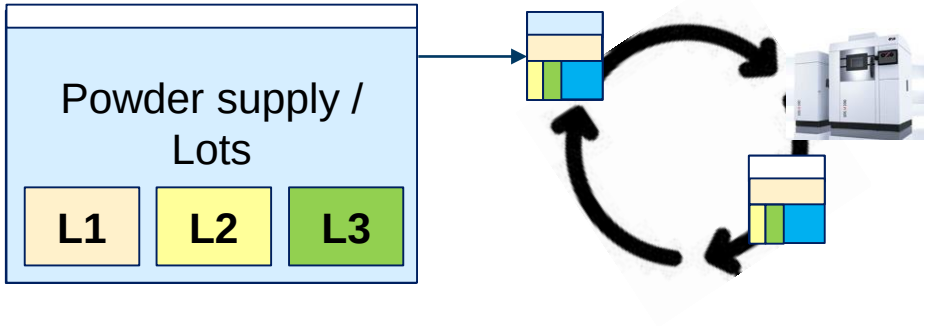
e.g.

ASTM F3055 (AM with IN718, section 7.3)

- *Powder blends are allowed unless otherwise specified*
- *Powder used to create the powder blend meets the requirements…*
- *Lot. numbers are documented and maintained*
- *Used Powder is allowed*
- *Proportion of virgin powder to used powder shall be recorded for each production run*
- *Maximum number of times used powder can be used*
- *Maximum number of times any portion of a powder lot can be processed*

Collective ageing

Continuosly adding new powder

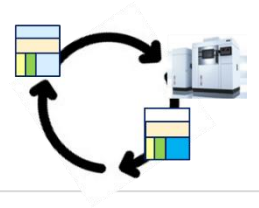


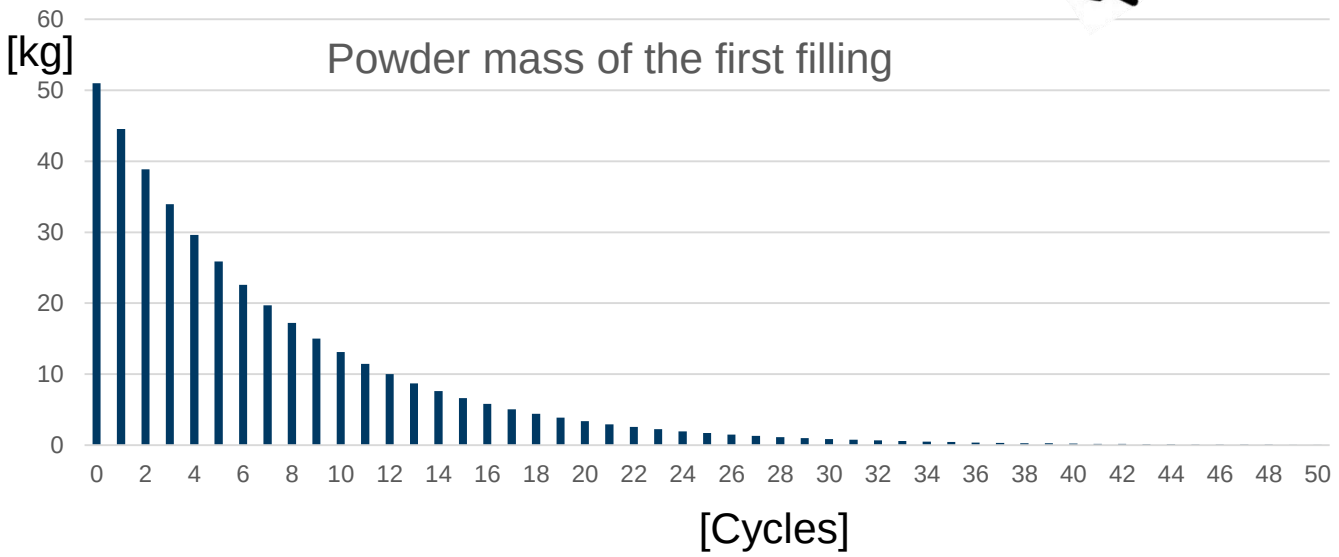
„Collective ageing“ might cause systematic scrap of powder
and creates a large stock next to production with a great variety of powder condition.

Traceability in a refreshing powder cycle

Experiment of thought
Scenario: Boroscope boss Lot Size of powder: 1500 kg Machine filling: 51 kg Material usage: 5 kg (part incl. Losses) *=> 300 Refills from one Lot (max)*

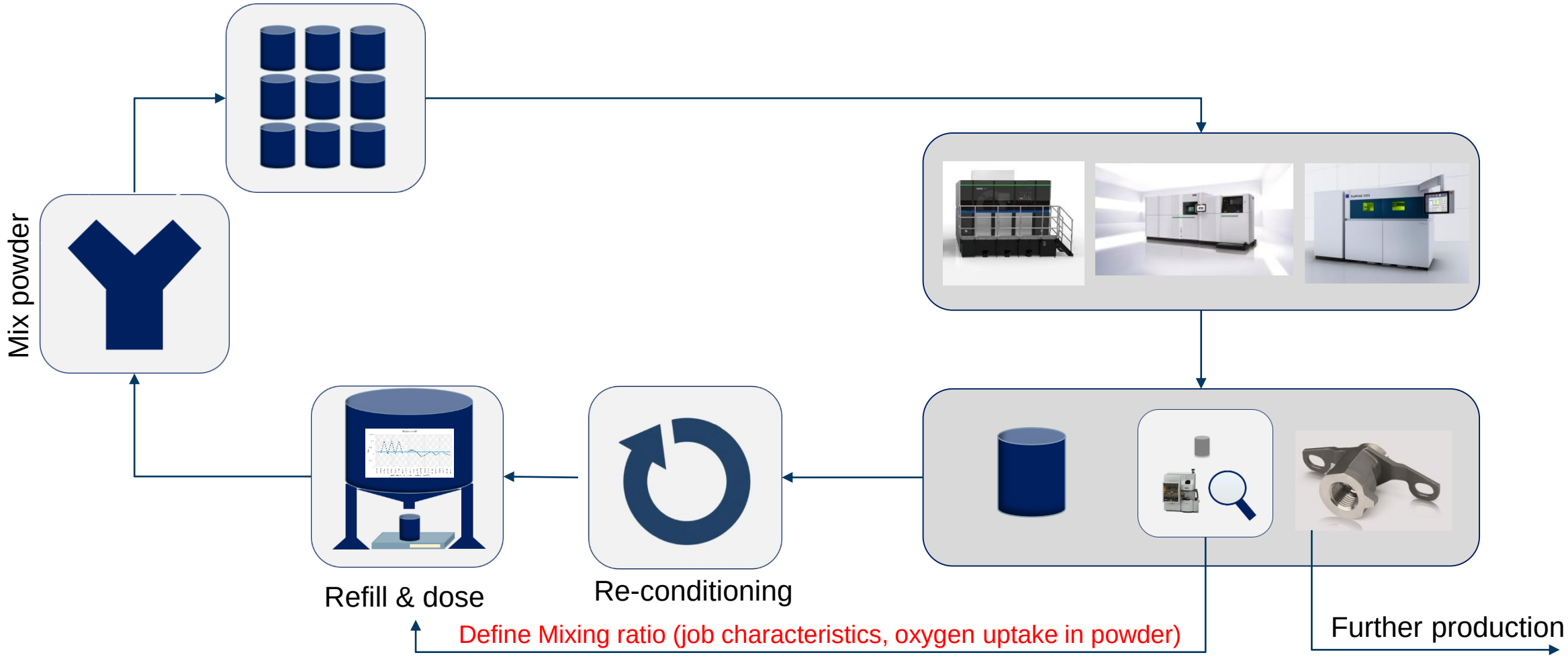
Refill-Strategy





Number of refills	50	75	100	150
Machines with same Lot	6	4	3	2
Residual amount	57 g	1,9 g	0,064 g	7 x $_{10}$-8 g

Outlook: future recycling scheme




MTU
Aero Engines
Thank you