



Dedicated to innovation in aerospace

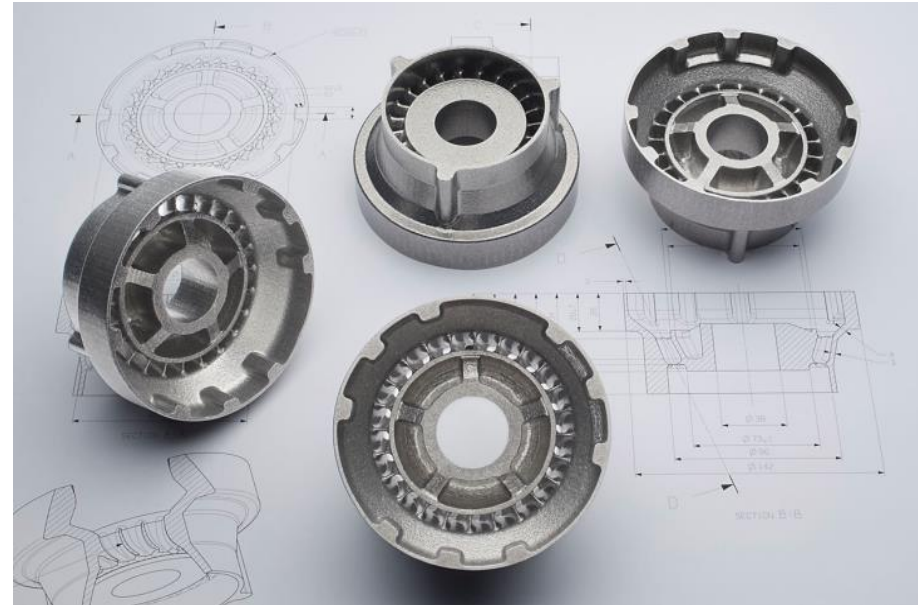
Quality Assurance in Additive Manufacturing

Some notes from our AM-logbook

NLR MAMTeC , 2016 **Marc de Smit**

Content

- Short introduction NLR & MAMTeC
- Some notes from our AM-log related to:
 - Powder QA
 - AM Process
 - Materials & parts





NLR in brief



One-stop-shop



Global player with
Dutch roots

>95

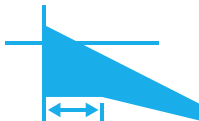
95 years young



Amsterdam,
Marknesse, Schiphol



Innovative, engaged
and practical



For industry and
government



For civil and
defence



Extremely high
client satisfaction



639 employees



€ 73 M revenue



74% Dutch, 23% EU
and 3% international

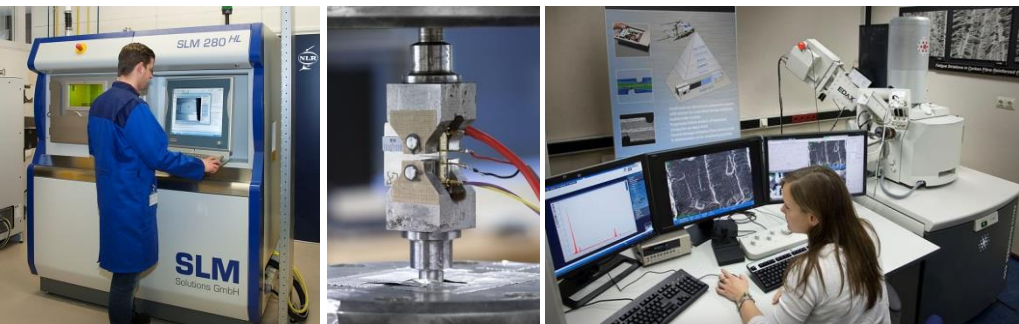
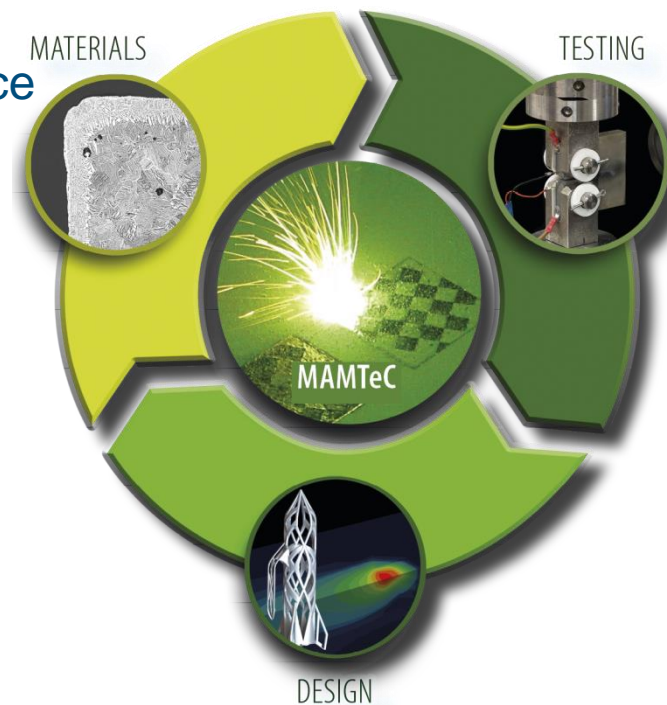


Active in 33 countries

Manufacturing Technology Centre (MAMTeC)

Thé Metal AM Technology Centre in NL

- Unique combination of knowledge, experience and facilities
- Independent & Non profit
- Qualification/Certification track record



Examples of MAMTeC projects

- Research for Dutch Defence
- Parts for wind tunnel models
- Space applications
- Prototyping for various applications
- Process development new materials
- Process development Multimaterial AM



Brackets for NH90 on tail section

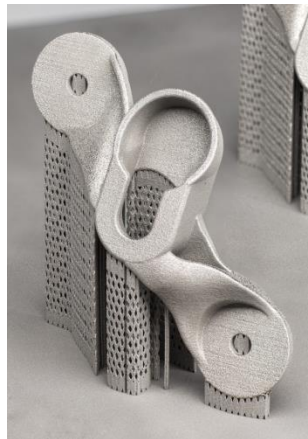
- Defence Technology Project
- Design optimisation
- Certification & qualification
- Supply chain & Logistics
- weight reduction 42 %



Ministerie van Defensie

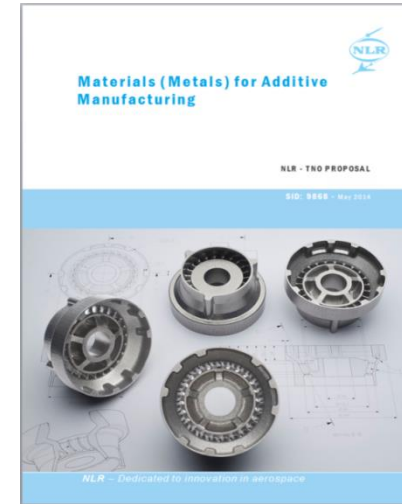
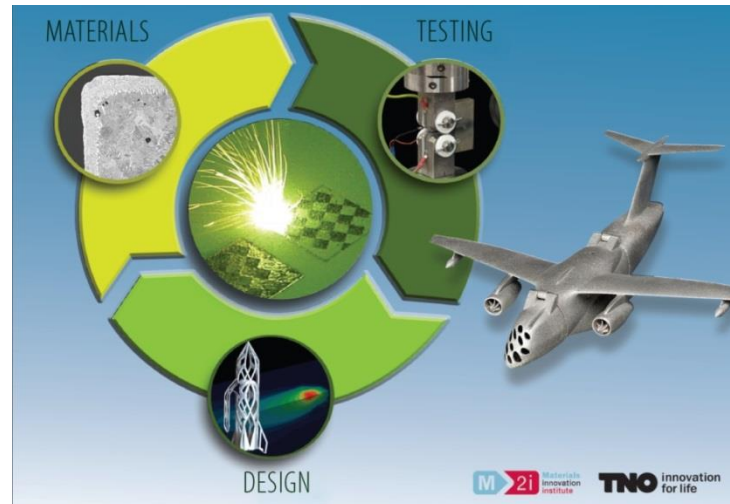


FOKKER
AEROSTRUCTURES



Metals for Additive Manufacturing Programme

- Four years programme on Metal-AM for high tech applications
- Public-Private Partnership with international participants
- One of the objectives: Material qualification and process certification methodologies for AM





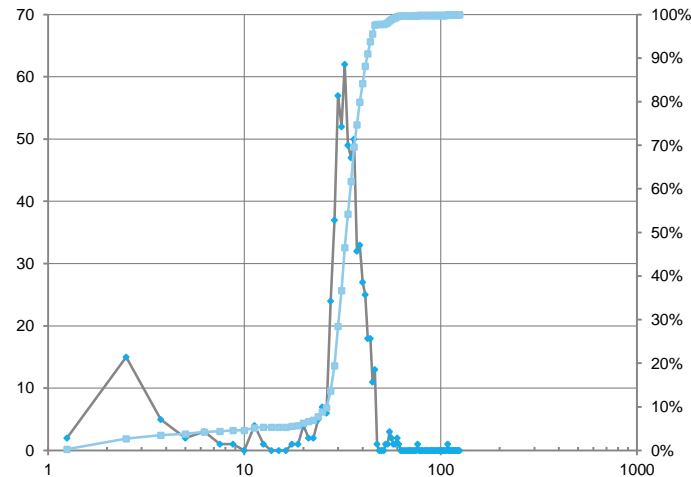
Powder Quality assurance

- Quality control of new powder and buffer
- Common specification= sieve fraction
- Relevant for flow: Particle size distribution



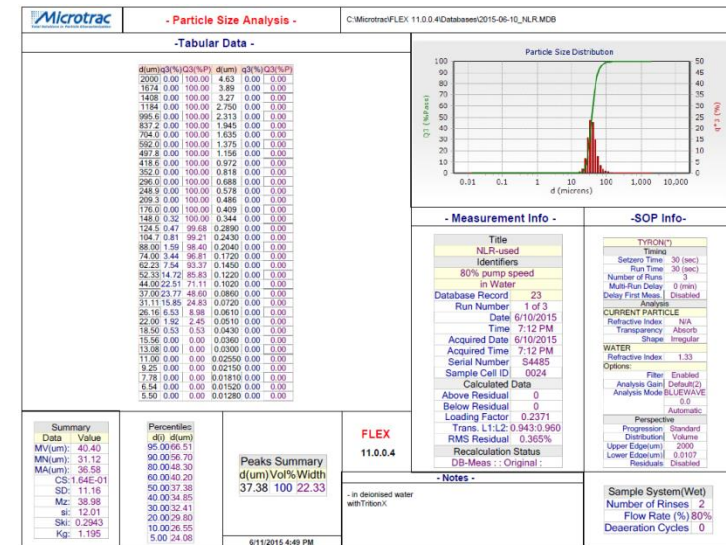
Powder: particle size distribution & Flow

- How to measure?
 - Sieve analysis
 - Laser diffraction
 - SEM Image analysis
 - Microscope image analysis



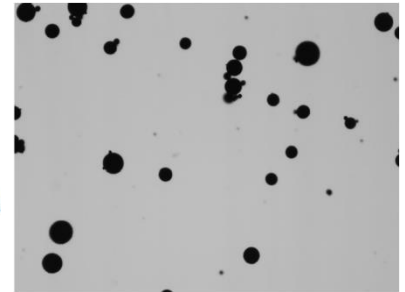
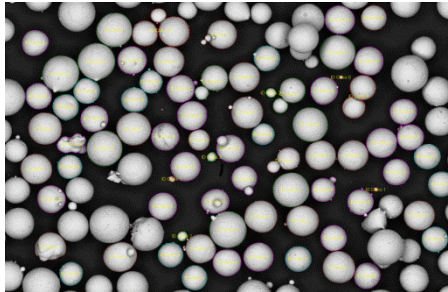
Powder: particle size distribution & Flow

- Laser diffraction
 - Well established
 - Described in ASTM B822-10
 - Fast and repeatable
 - Assumes spherical particles
 - %Vol => small particles invisible
 - Use result only in a relative sense



Powder: particle size distribution & Flow

- Image analysis
 - Measurement of geometrical parameters
 - Num%
 - SEM: Sharp image, EDX, Also cross sections, Small sample, Time consuming
 - Microscope: Fast, Large sample, Focal depth
 - Image analysis settings have effect on measurement result



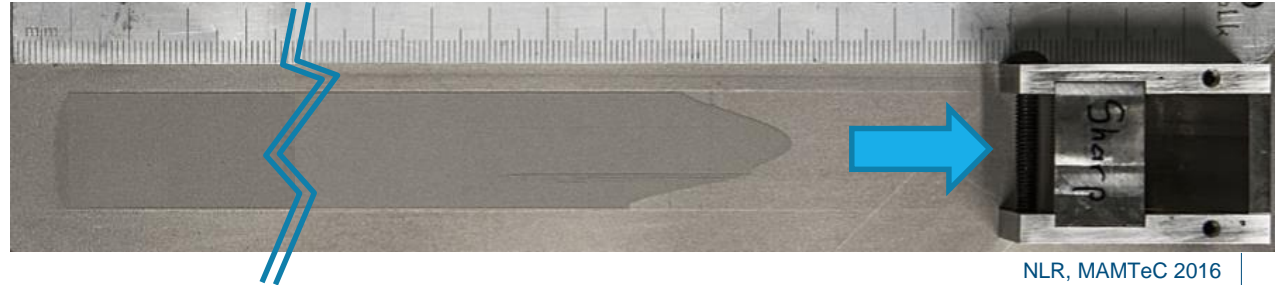
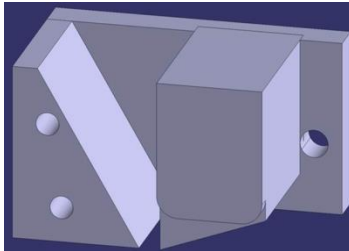
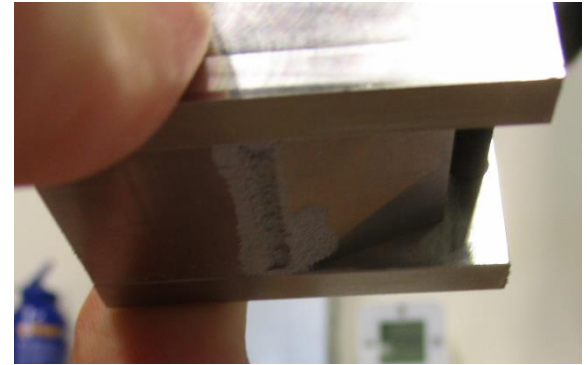
Powder Quality assurance

- But what is relevant?
- Key properties in powder layer deposition:
 - Behaviour in application of thin layers
 - Density of thin powder layer
 - Chemical composition
 - Contamination
 - Moisture content



Powder Quality assurance

- NLR developed easy method to check:
 - Behaviour in application of thin layers
 - Density of thin powder layer
- Accurately weigh powder
- Apply track of known width & thickness
- Measure length
- Calculate density & evaluate powder layer
- Easy & effective



Powder QA: Influence of chemical composition

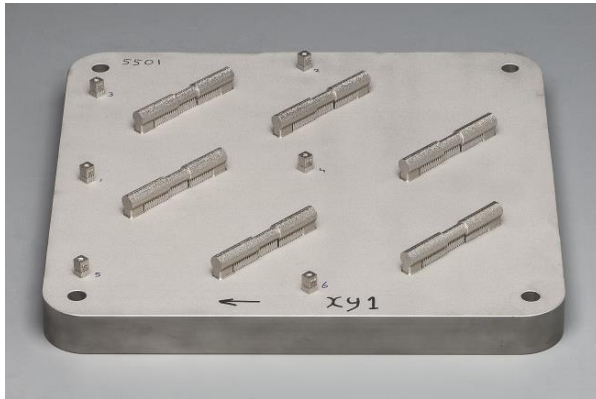
Inc718 Static tensile test programme was carried out

- Variation in chemical composition:

Mn and Si modified

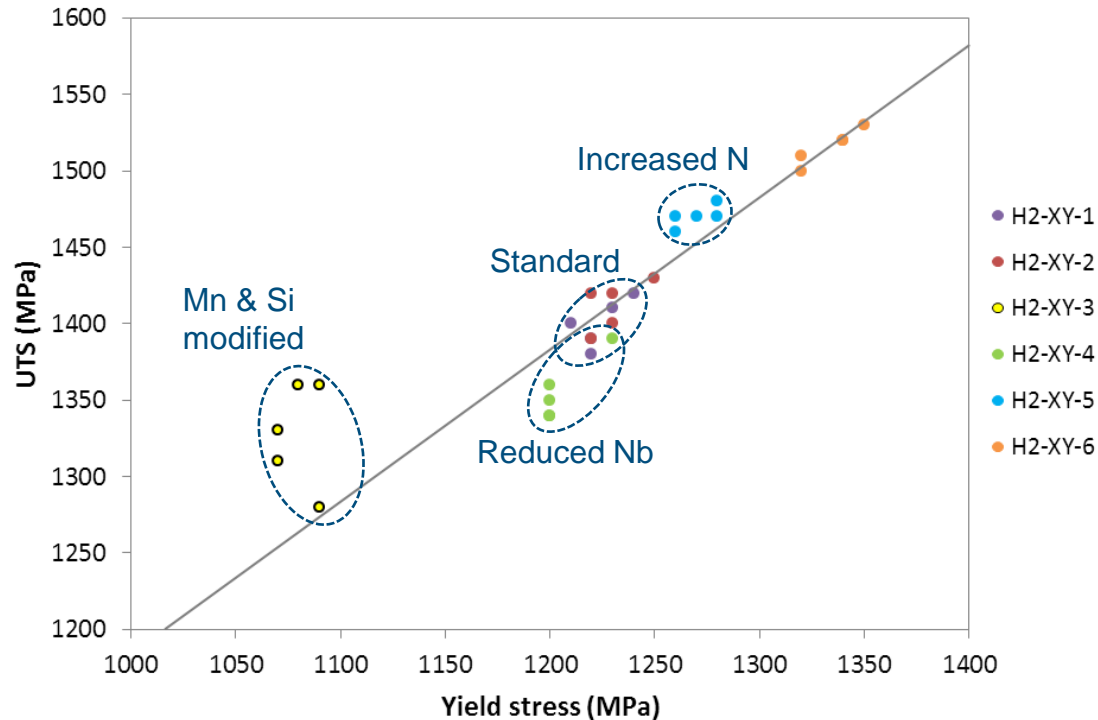
Reduced Nb content

Increased N content



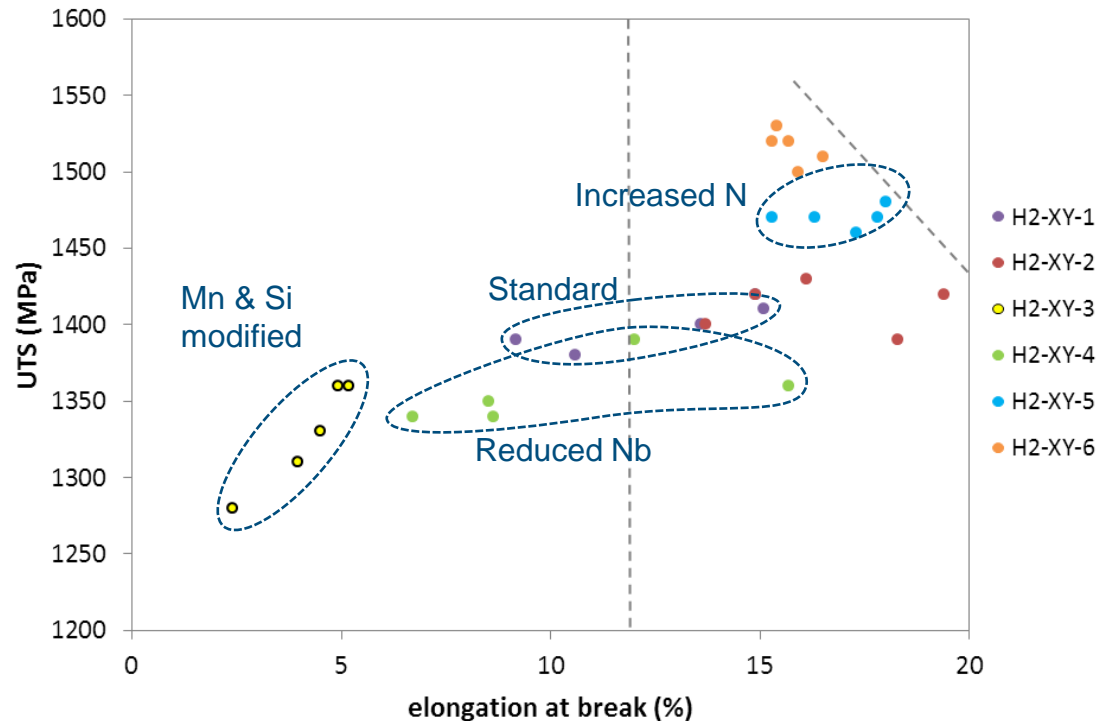
Powder QA: Influence of chemical composition

- Increased N: good strength in XY dir
- Reduced Nb: lower strength
- Mn & Si modified: lowest strength



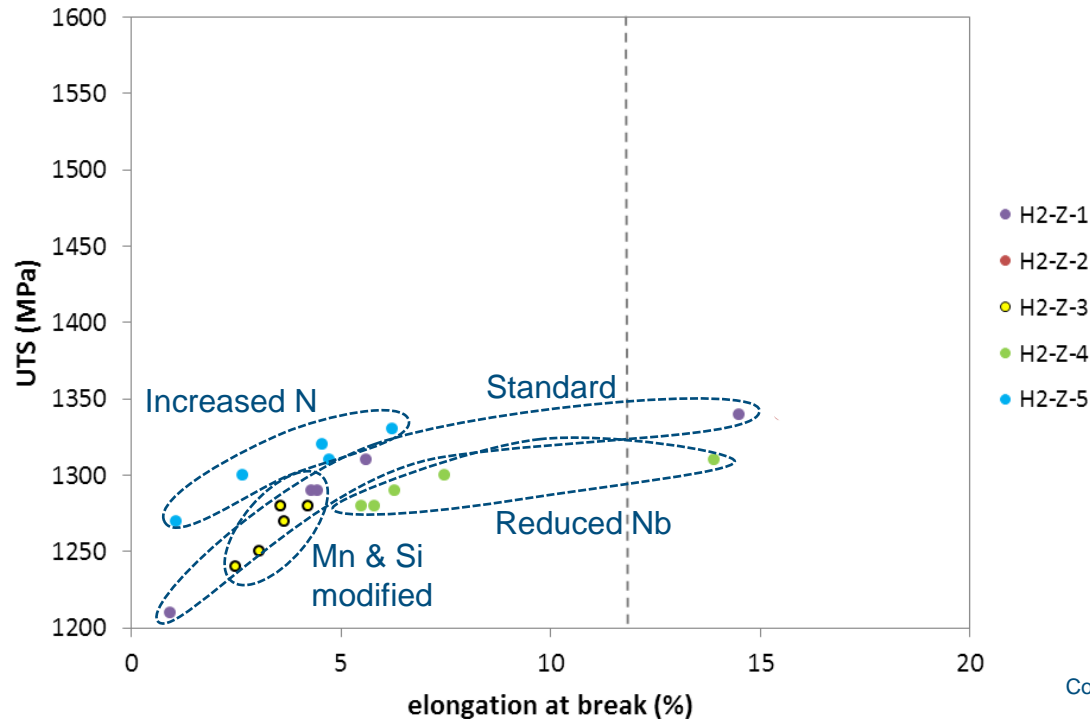
Powder QA: Influence of chemical composition

- Increased N: good strength & elongation
- Reduced Nb: lower strength & elongation
- Mn & Si modified: lowest strength & elongation



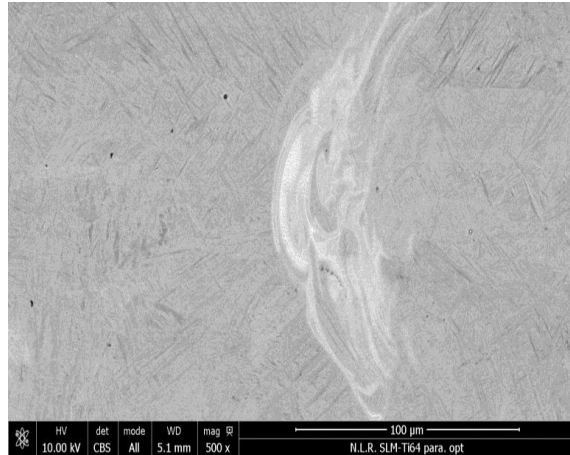
Powder QA: Influence of chemical composition

- Increased N: large difference between the elongation at break between the XY- and Z- direction observed for coarse PSD

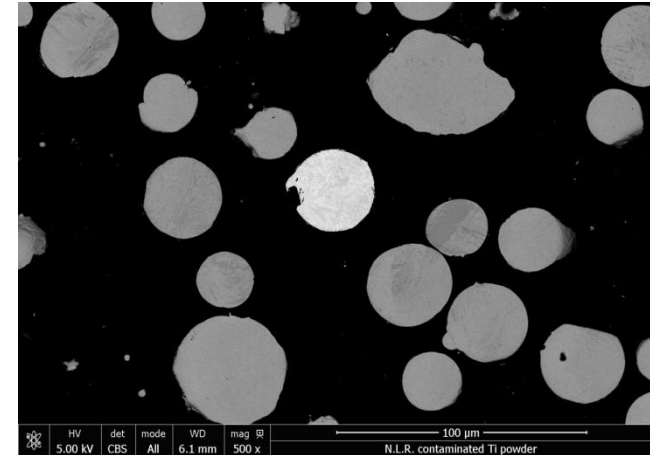


Powder QA: Contamination

- Powder contamination observed in cross sections
- Chemical analysis did not indicate pollution
- Pollution can be found in SEM analysis
- Percentage of contamination 0.32%, what is the influence?



Component	ASTM F2924 – 14	Chemical analysis	
		Lot I	Lot II
Al [%]	5.5-6.75	6.62	6.68
V [%]	3.5-4.5	3.98	4.05
Fe [%]	0.3	0.2	0.2
C [%]	0.08		
H [ppm]	150		
N [%]	0.05		
O [%]	0.2		
Y [%]	0.005		
Other element each	0.1		
Other element total	0.4		
Ti [%]	Balance	88.91	88.79



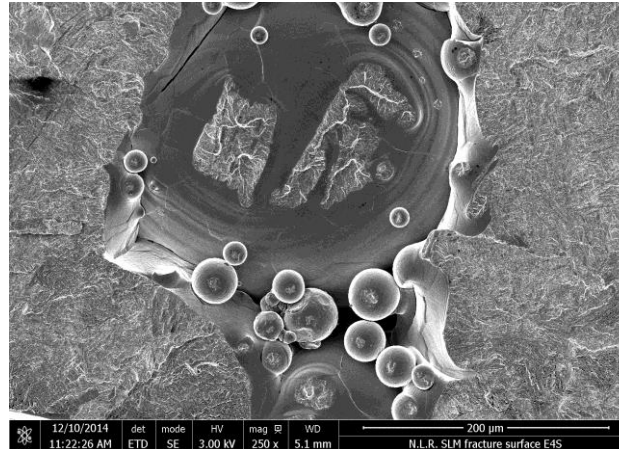
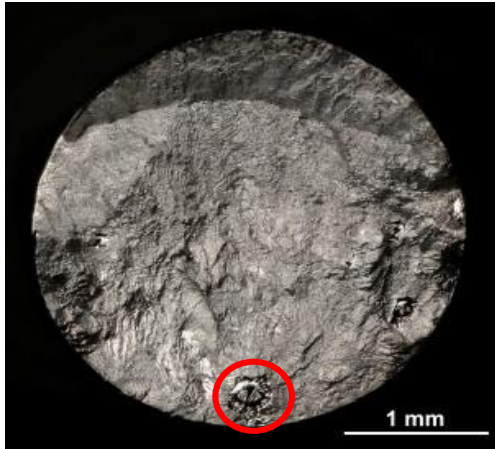
Powder QA

- Moisture in powder:
 - Bad flow behaviour
 - Porosity
 - Colouration (oxidation)
 - Lower mechanical performance
 - Bad surfaces
- Missing: standard procedures for drying & QA
- (Work in progress)



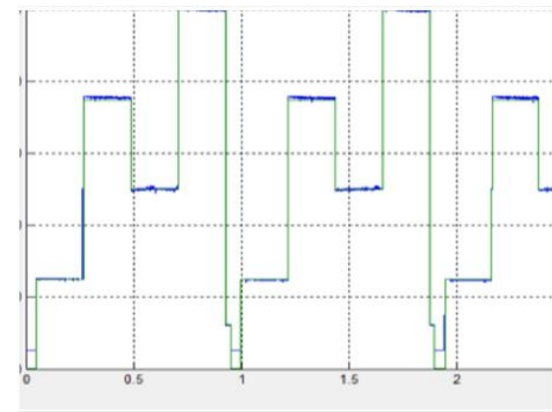
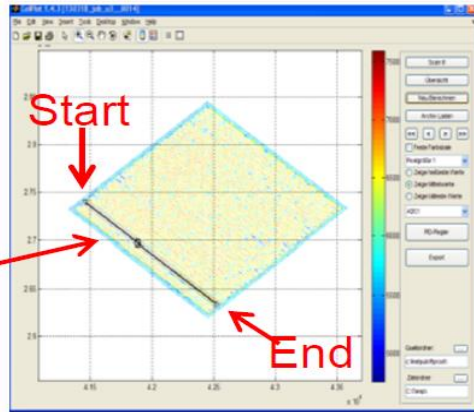
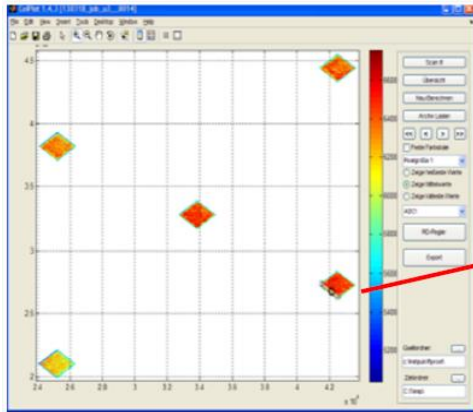
Process Certification

- Fatigue is the predominant failure mode
- Good understanding is essential for production of structural parts
- Blind folded production is no option



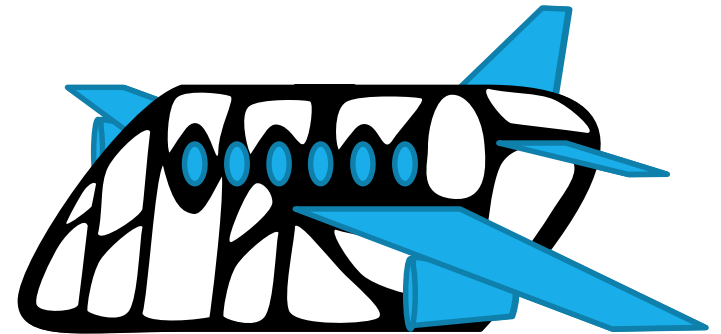
Process certification: Melt pool monitoring

- Melt Pool Control module is installed in Q4 2015
 - IR emission measurements at two wavelengths @ ~ 100kHz
 - Current work: find relation between system output and defects
 - Future= Dynamic adjustment of laser output power to achieve closed-loop power control



Materials & parts

- Metal AM : Freedom of design & Complex internal structures enable weight reduction & better product performance
- Small variation in Mech properties essential for design allowables



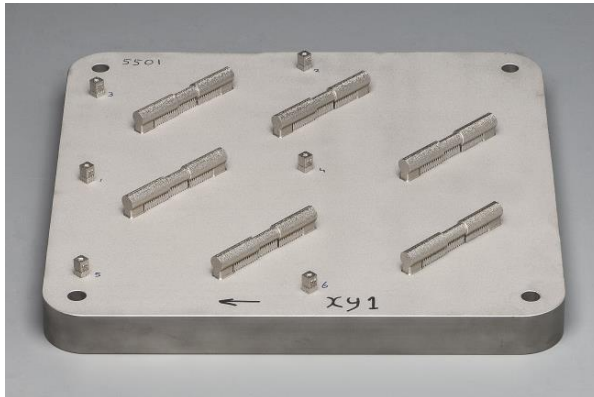
Inc718 Static tensile test programme

- Coarse and fine PSD / layer thickness

-53 + 20 μm	-45 + 15 μm
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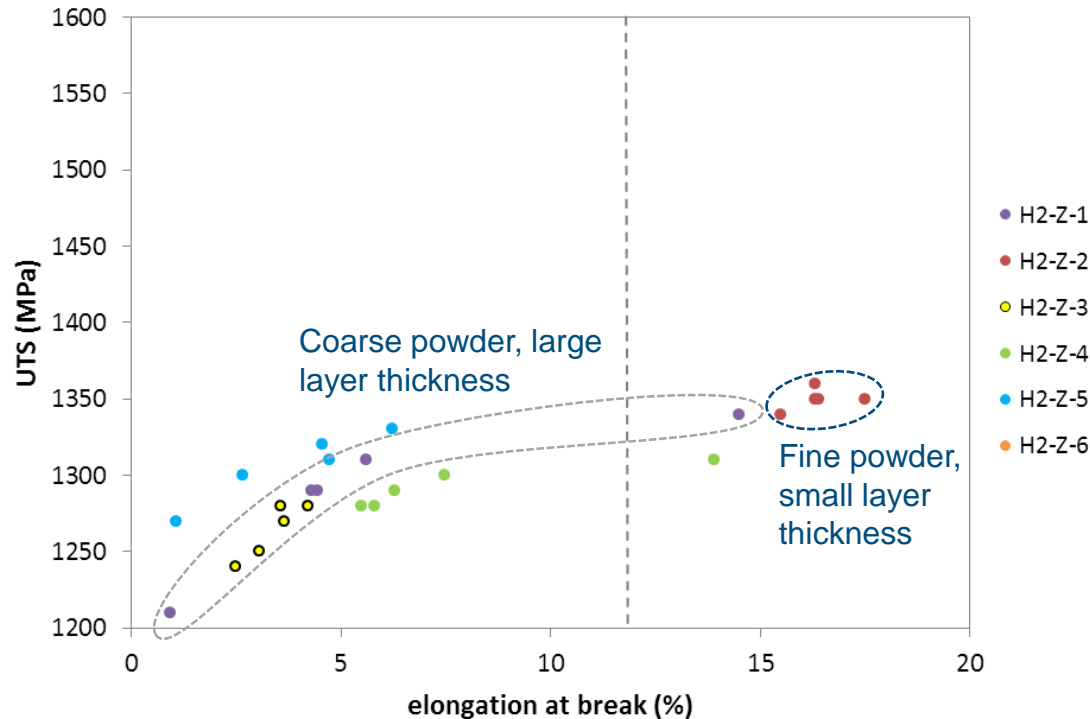
- 2 machine configurations

Standard machine	Improved config
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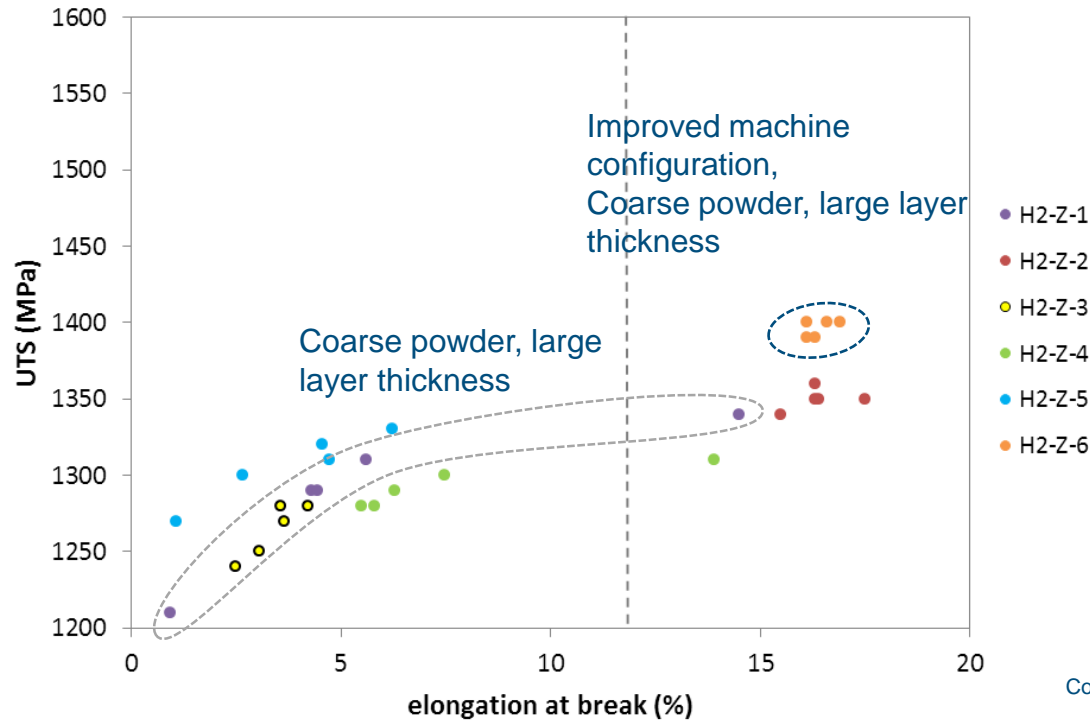
Observations: Influence of PSD/Layer thickness

- Improved performance especially in Z-dir after SR+Solution+Ageing
- Smaller variation for fine PSD
- Small layer thickness = $\pm 80\%$ higher machine cost



Observations: Influence of machine configuration

- Substantial improvement can be obtained by optimisation of machine configuration!



Conclusions

- Great opportunities to reduce weight and boost performance
- Metal AM continues to mature
- Conclusions from our logbook:
 - Powder QA: Clear handling & inspection procedures required
 - Process Certification: Melt Pool Monitoring as part of NDI
 - Materials/parts: Reduce variation & improve confidence in AM Technology





Dedicated to innovation in aerospace

Fully engaged

Netherlands Aerospace Centre

A high-angle, perspective view of a futuristic, grey, four-engine aircraft flying over a vast, snow-covered mountain range. The aircraft is positioned in the upper right quadrant, angled towards the lower left. The landscape below is a complex, rugged terrain of snow-capped peaks and valleys, stretching towards the horizon under a clear blue sky. The word 'Questions?' is overlaid in a large, dark blue font on the lower left side of the image.

Questions?

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