MAMTeC

Metal-AM for Aerospace and high-end applications

Developments in Metal Additive Manufacturing for successful production of critical parts

NLR MAMTeC , 2018 **Marc de Smit**

Content

- Short introduction NLR & MAMTeC
- Examples of MAMTeC projects
- MAMTeC Activities
- Can Spare Parts be printed?

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

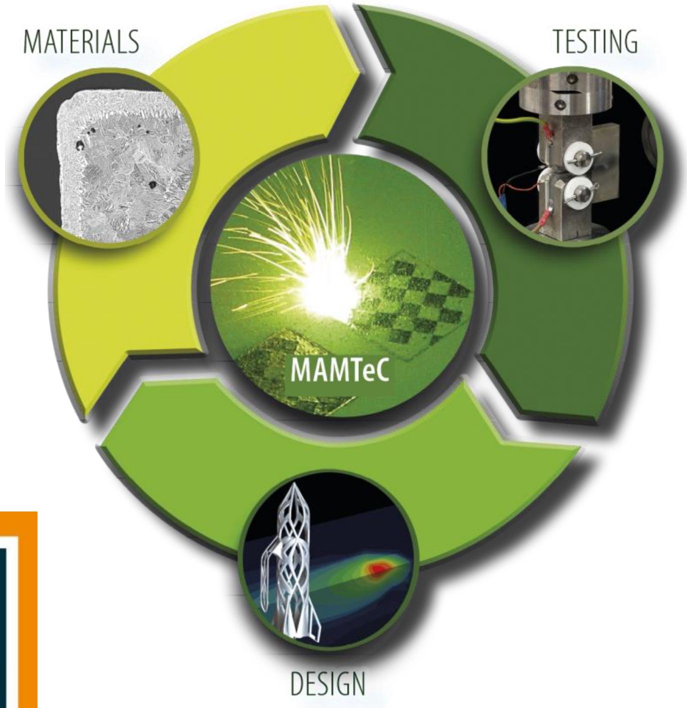
74% Dutch, 23% EU and 3% international

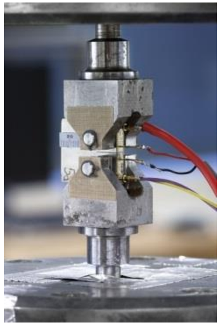
Active in 33 countries

Manufacturing Technology Centre (MAMTeC)

Thé Metal AM Technology Centre in NL

- Unique combination of knowledge, experience and facilities
- Qualification/Certification track record
- Focus on High tech High spec applications
- Part of Smart Industry Fieldlab ACM^3

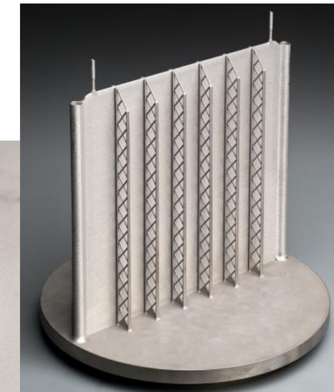
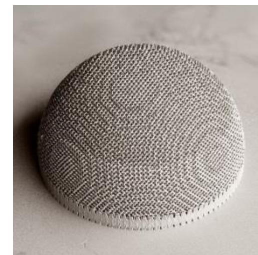


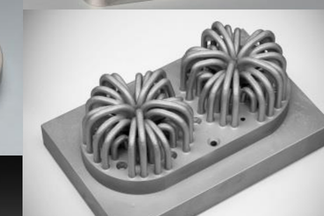


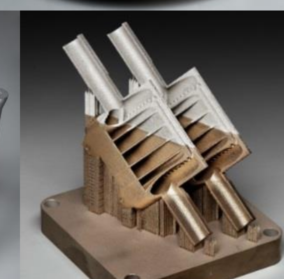
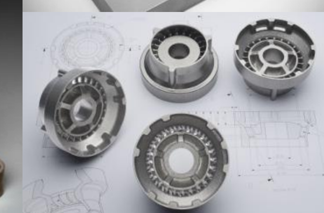
smart
industry
DUTCH INDUSTRY FIT FOR THE FUTURE

Examples of MAMTeC projects

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

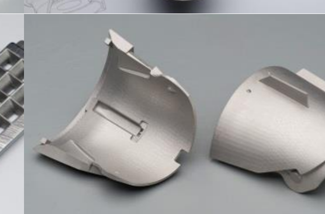






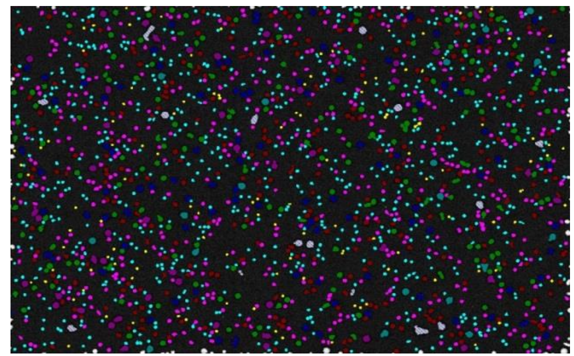


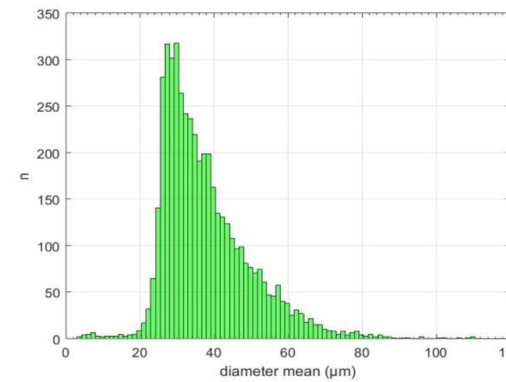


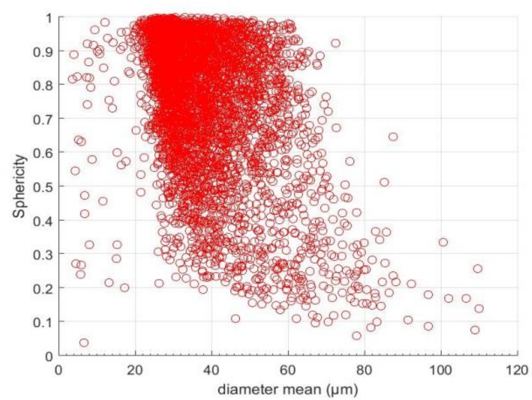


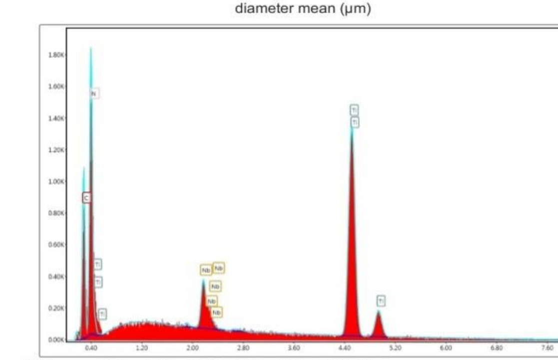
Developments in Metal Additive manufacturing for successful production of critical parts

- Improved powder quality control
- Process optimisation
- Process monitoring



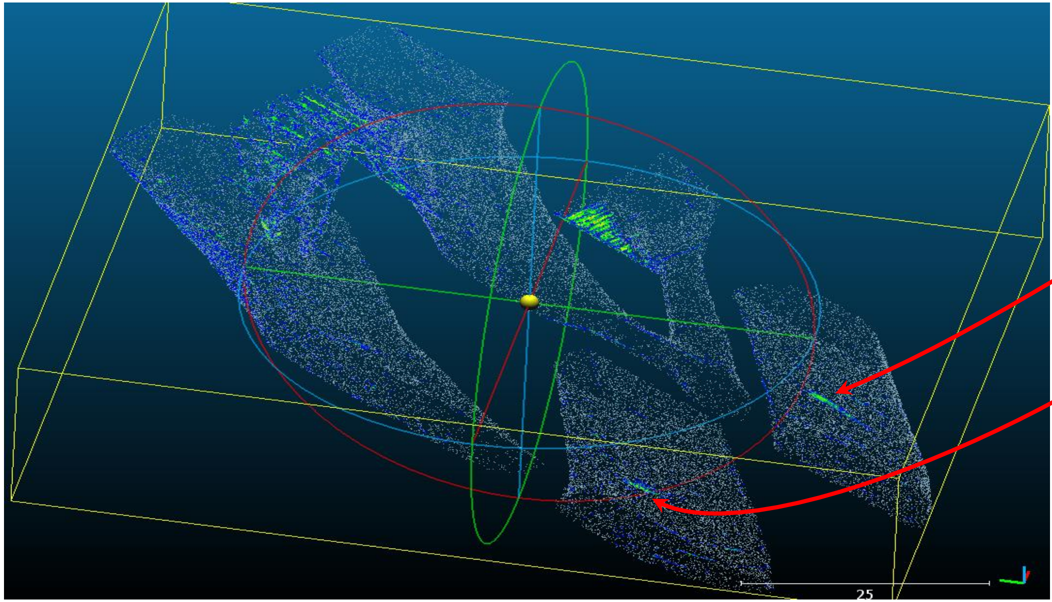






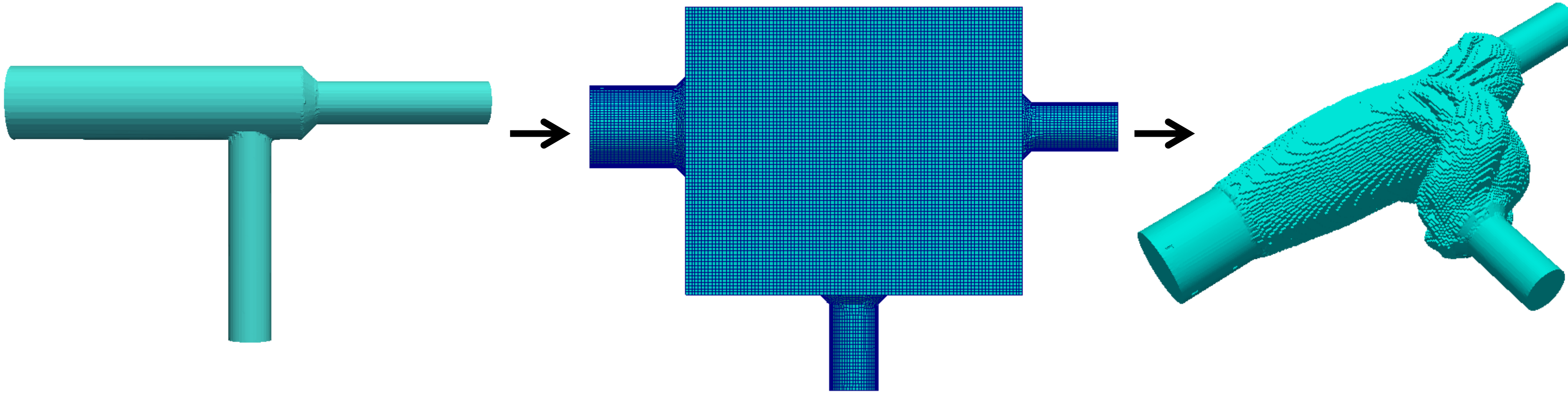
Developments in Metal Additive manufacturing for successful production of critical parts

- Improved powder quality control
- Process optimisation
- Process monitoring



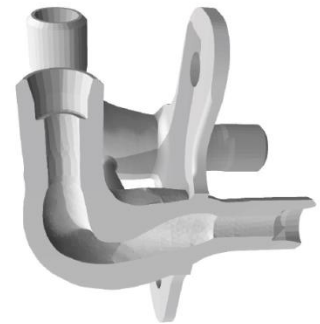
Additive Manufacturing of Hydraulic applications

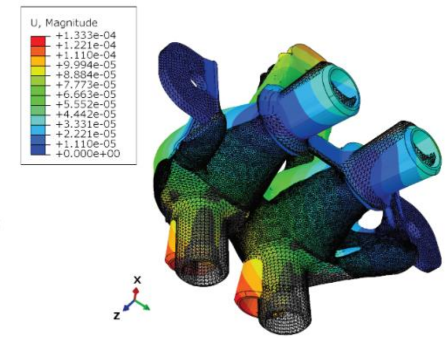
- Fluid topology optimization
- Increase performance, Reduce pressure drop
- Also lighter hydraulic pump
- Minimize weight of channels
- Take design rules into account

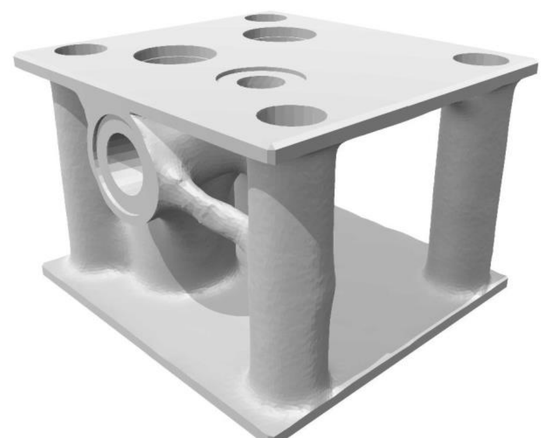


Additive Manufacturing of Hydraulic applications

- Big advantage where weight and efficiency is an issue

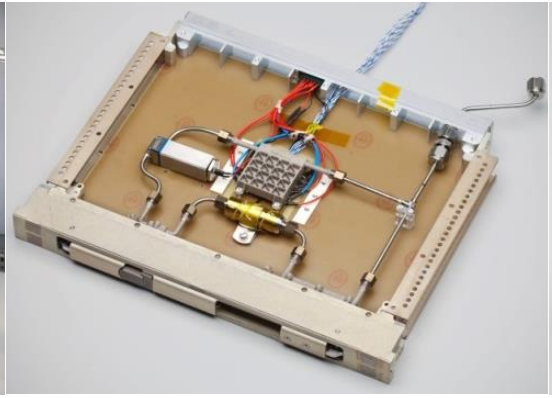


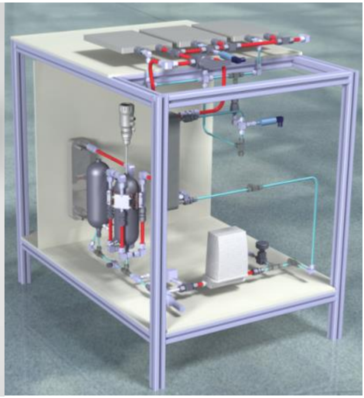




Additive manufacturing for Thermal control

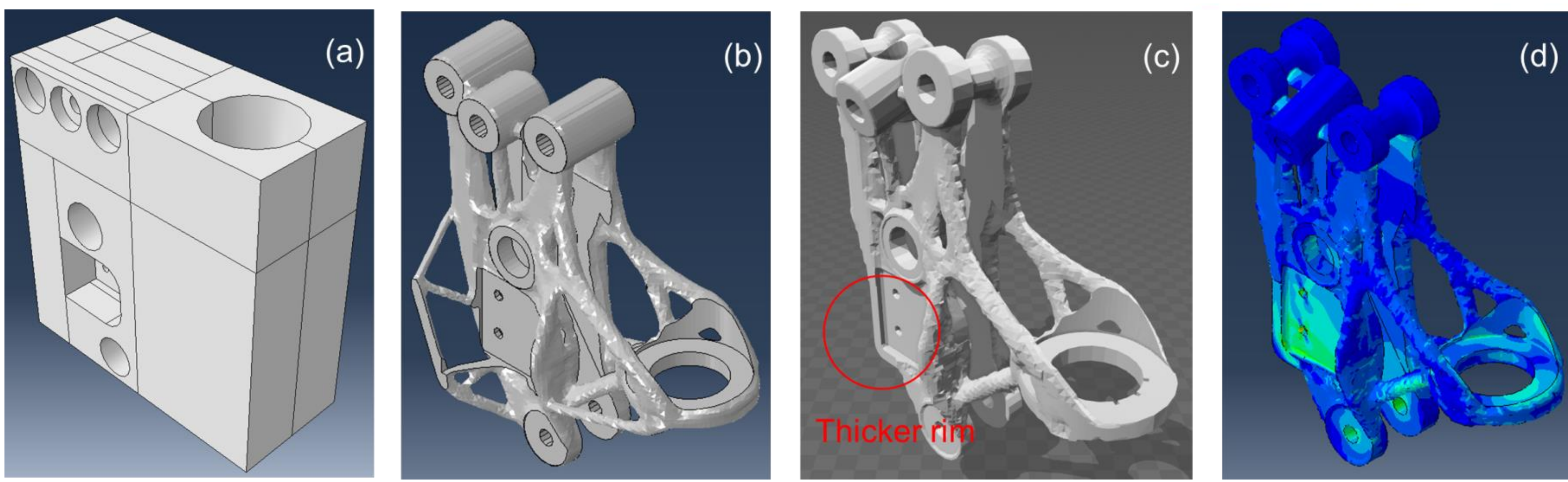
- Additive manufacturing of heat exchangers and other components
- When very stable temperatures and/or low mass are crucial
- Active thermal control (pump) or passive thermal control (heat pipes)





Additive Manufacturing of structural applications

- Redesign obsolete part
- Forging requires forging mould
- High cost and long lead time
- Design for AM: 34% weight reduction



Limitations and opportunities of Metal-AM…

- Laura Cordova

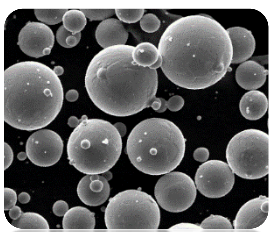
UNIVERSITY OF TWENTE.

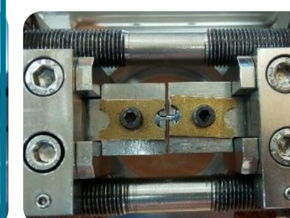
TOWARDS TECHNICAL LIMITATIONS AND OPPORTUNITIES OF METAL-AM

Laura Cordova, Tiedo Tinga

LIFE CYCLE OF METAL POWDERS FOR ADDITIVE MANUFACTURING
PROCESS

Powder Production → Storage/ Handling → Additive Manufacturing → Post-processing → Material characterization





LIFE CYCLE OF METAL POWDERS FOR ADDITIVE MANUFACTURING
PARAMETERS

Powder Production

- *Morphology*
- *Size distribution*
- *Chemical composition*
- *Flowability*
- *Apparent/tap density*

Storage/ Handling

- *Moisture content*
- *Oxygen & nitrogen pick-up*
- Homogeneity
- *Powder reuse / sieving*

Additive Manufacturing

- Thermal and radiation properties
- Scan pattern and speed
- *Layer thickness*
- Laser Power
- Melting temperature distribution
- Surface tension
- Melt viscosity
- Hatch distance
- …

Post-processing

- Supports and powder removal
- *Surface roughness*
- Residual stresses
- *Porosity*

Material characterization

- *Mechanical properties*
- *Microstructure*
- *Density*
- *Non-destructive testing*

IMPACT ON POWDERS HANDLING
ON LOCATION CASE

- Environment (moisture, contamination)
  - Storage conditions (time, containers, ambient)
  - Supply (frequency, supplier, transportation, quality)

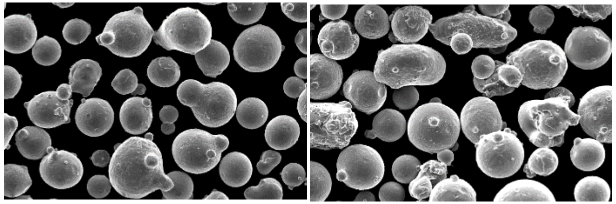
Problem: Highest impact of moisture on Al alloys

Solution: Drying policy for Al alloys.

- Operation (powder reuse)
  - Cost (quality vs. price)
  - Sustainability (energy & resources consumption)
  - Supply (frequency, quality)
  - Storage facilities (size, conditions)

Problem: Potential impact on powder reuse for > 40 build jobs

Solution: *"Rejuvenation"* for prolonged reuse.



LIFE CYCLE OF METAL POWDERS FOR ADDITIVE MANUFACTURING
PARAMETERS

Powder Production

- *Morphology*
- *Size distribution*
- *Chemical composition*
- *Flowability*
- *Apparent/tap density*

Post-processing

- Supports and powder removal
- *Surface roughness*
- Residual stresses
- *Porosity*

Storage/ Handling

- *Moisture content*
- *Oxygen & nitrogen pick-up*
- Homogeneity
- *Powder reuse / sieving*

Material characterization

- *Mechanical properties*
- *Microstructure*
- *Density*
- *Non-destructive testing*

Additive Manufacturing

- Thermal and radiation properties
- Scan pattern and speed
- *Layer thickness*
- Laser Power
- Melting temperature distribution
- Surface tension
- Melt viscosity
- Hatch distance
- …

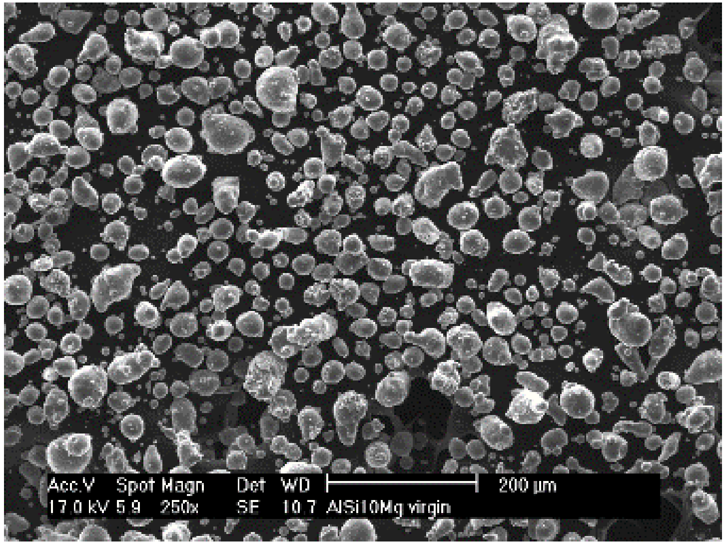
UNIVERSITY OF TWENTE.

ADDITIVE VS CONVENTIONAL MANUFACTURING

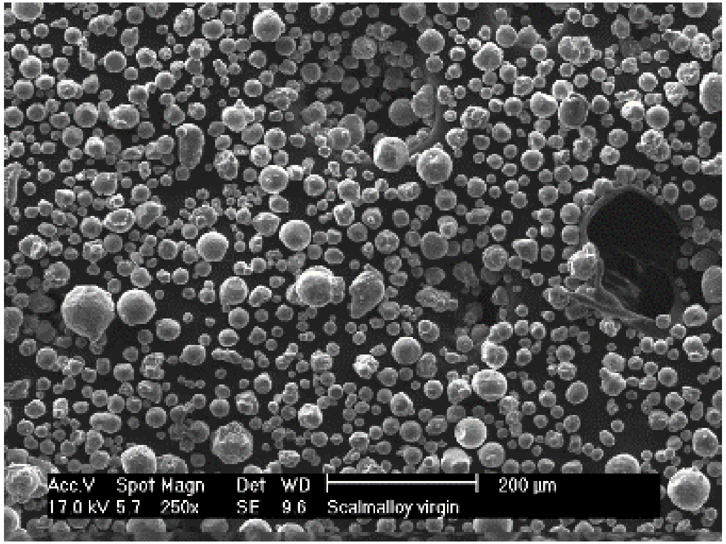
MECHANICAL PROPERTIES AND MICROSTRUCTURE

POWDER MATERIALS
ALSI10MG AND SCALMALLOY

AlSi10Mg



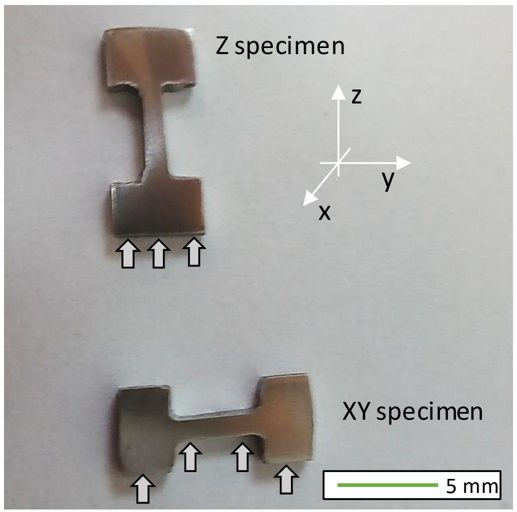
Scalmalloy



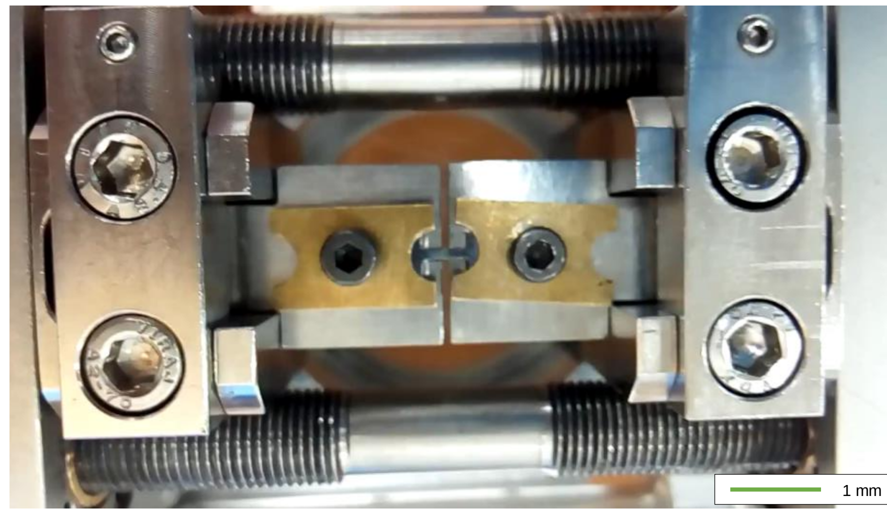
Composition

Material	Al	Fe	Mg	Mn	Ni	Sc	Si	Ti	V	Zr
AlSi10Mg	~bal	0.11	0.38	<0.01	<0.01	-	10.10	<0.01	-	-
Scalmalloy	~bal	0.13	4.39	0.49	-	0.66	<0.01	0.021	0.013	0.31

MICRO-TENSILE TEST

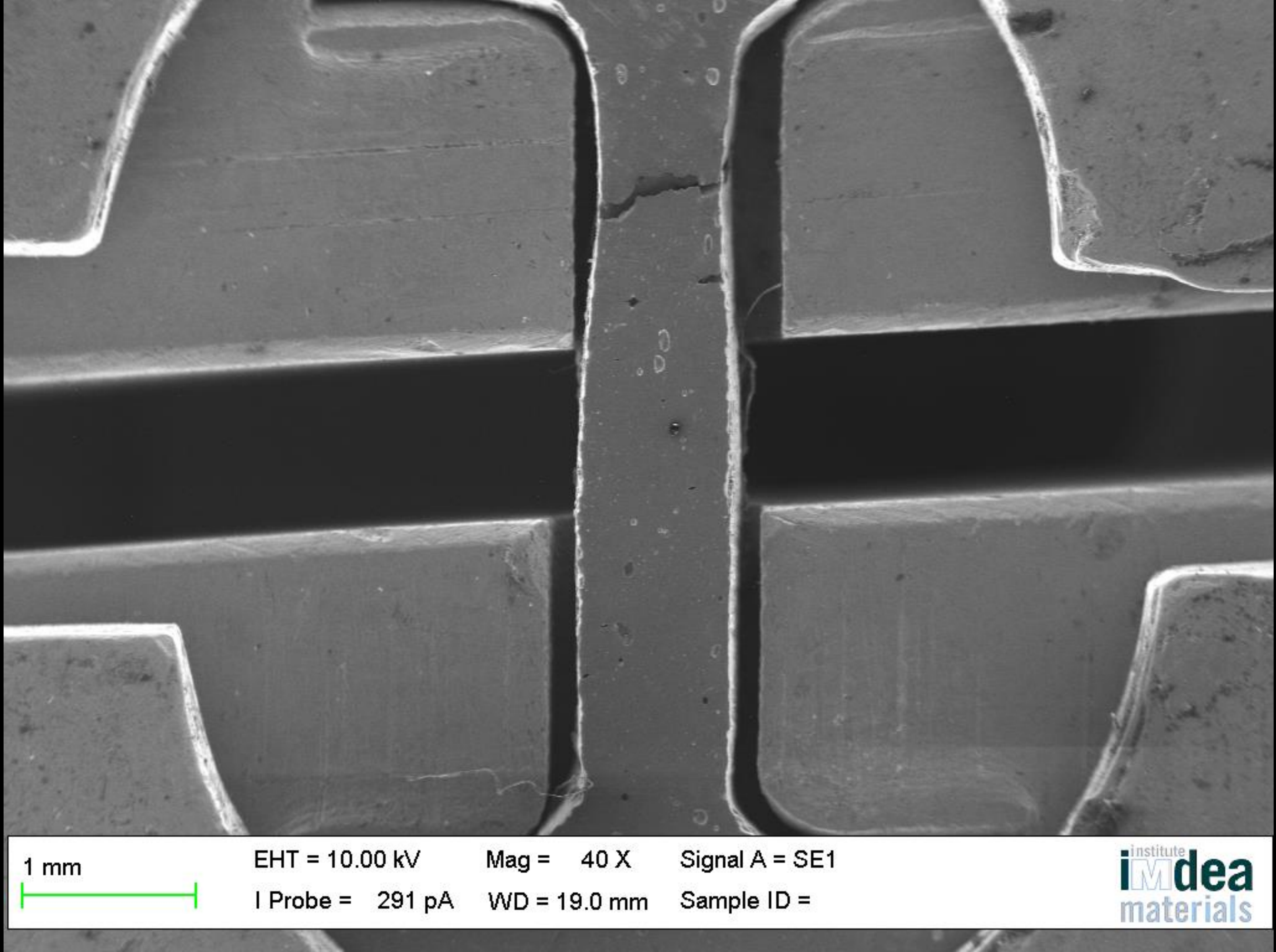


specimens

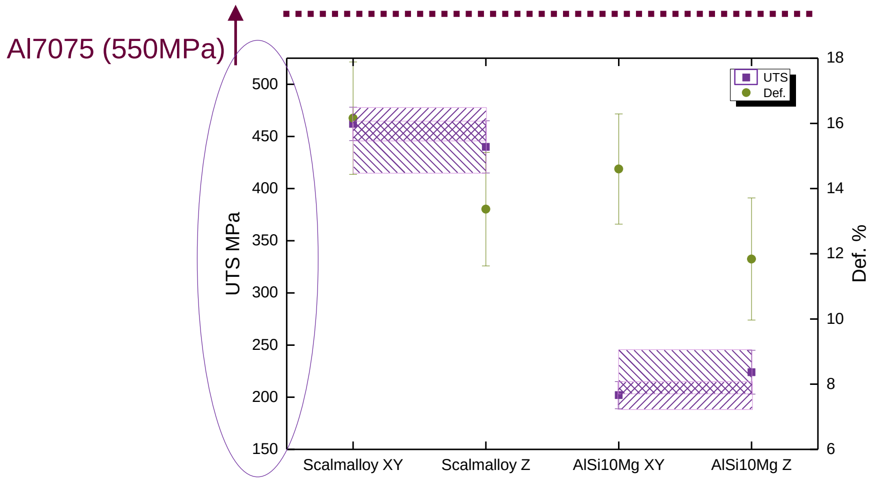


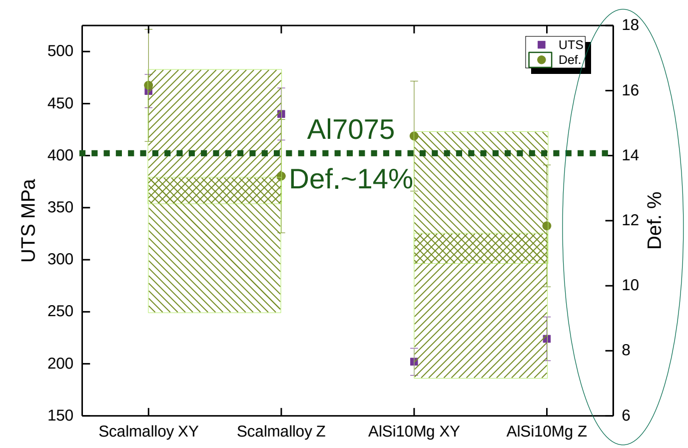
Micro-tensile test set-up

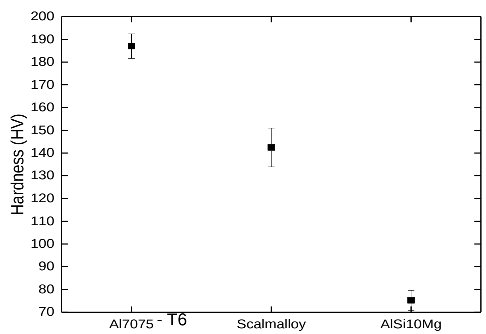
1KN load
10x smaller than standards


1 mm
EHT = 10.00 kV
Mag = 40 X
Signal A = SE1
I Probe = 291 pA
WD = 19.0 mm
Sample ID =
institute
imdea
materials

MECHANICAL PROPERTIES
MICRO-TENSILE TEST, HARDNESS







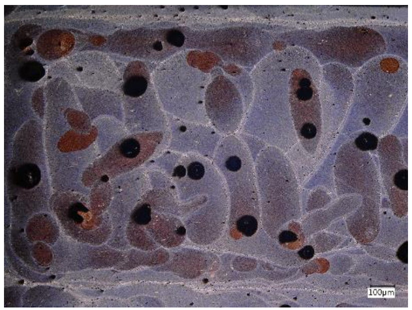
Hardness measured on the cross-sections.

The values are heat treatment dependent.

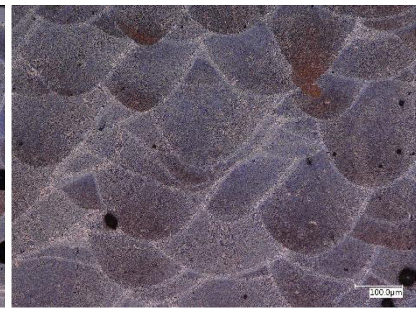
l.cordovagonzalez@utwente.nl

MICROSTRUCTURAL FEATURES
MELT POOLS - GRAINS

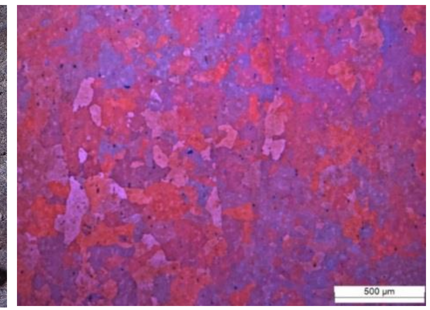
AlSi10Mg XY



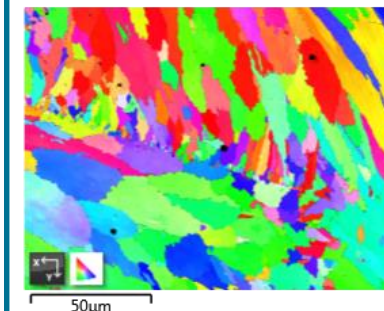
AlSi10Mg Z



Al7075-T6



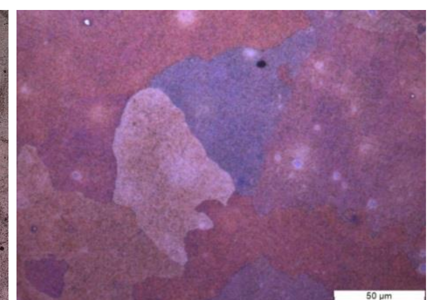
AlSi10Mg



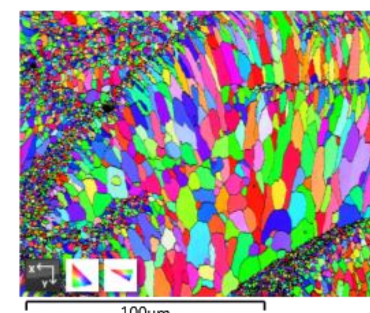
Scalmalloy XY

Scalmalloy Z

Al7075-T6



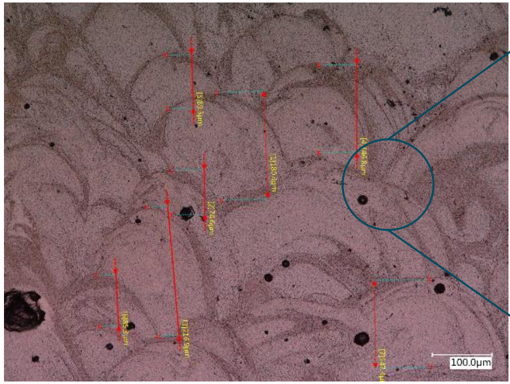
Scalmalloy

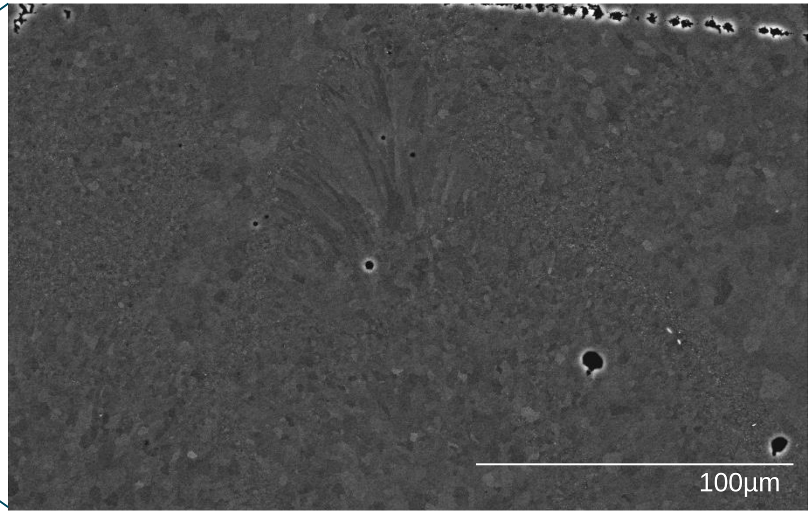


l.cordovagonzalez@utwente.nl

MICROSTRUCTURAL FEATURES
EXAMPLE: SCALMALLOY Z

Scalmalloy Z





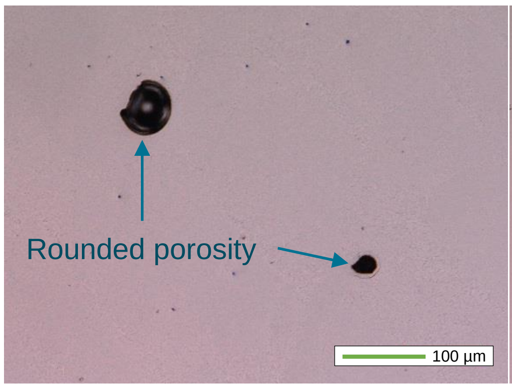
Meltpool size ~100µm

Grain size ~1µm

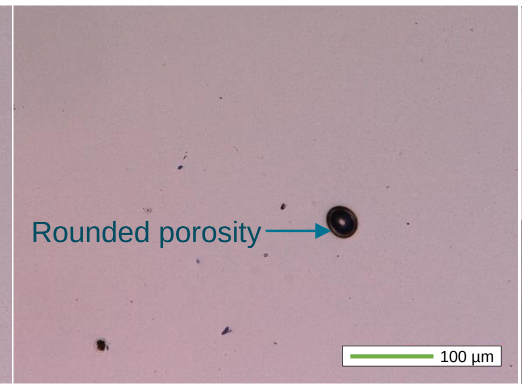
l.cordovagonzalez@utwente.nl

POROSITY
POROSITY TYPE AND LEVEL

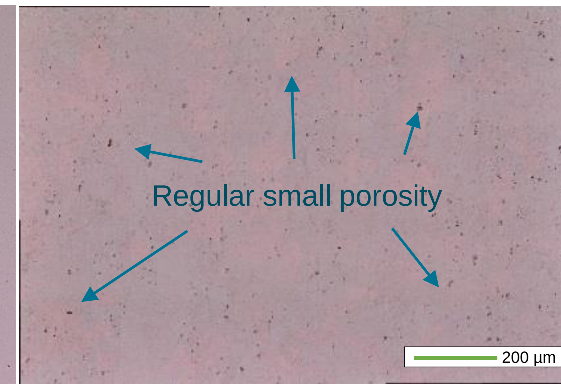
AlSi10Mg



Scalmalloy



Al7075-T6



Porosity level	AlSi10Mg	Scalmalloy	Al7075-T6
max	159µm	110µm	~30µm
min	33µm	30µm	~15µm

l.cordovagonzalez@utwente.nl

SUMMARIZE MECHANICAL PROPERTIES
ADDITIVE VS. CONVENTIONAL MANUFACTURING

Materials	**UTS (MPa)**	**ε_{break} (%)**	**HV**
AlSi10Mg XY	202±13	15±2	72±5
AlSi10Mg Z	224±20	12±2	76±3
Scalmalloy® XY	462±17	16±2	147±3
Scalmalloy® Z	440±25	13±2	139±10
AlSi10Mg AM [1]	*335*	*3*	*127*
Scalmalloy® AM [2]	*490*	*8*	*177*
AlSi10Mg casted [3]	*300-317*	*2,5-3,5*	*86*

1. *Material Data Sheet - AlSi10Mg.* AIRBUS APWORKS GmbH, Taufkirchen, Germany.
2. *Material Data Sheet - Scalmalloy®.* AIRBUS APWORKS GmbH, Taufkirchen, Germany.
3. *Matweb materials data*. Web-Based Data, http://www.matweb.com/ ,Matweb, UK, as on 12.05.2018.

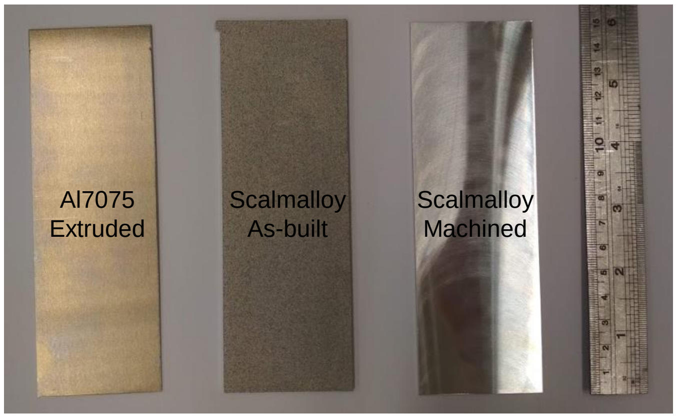
l.cordovagonzalez@utwente.nl

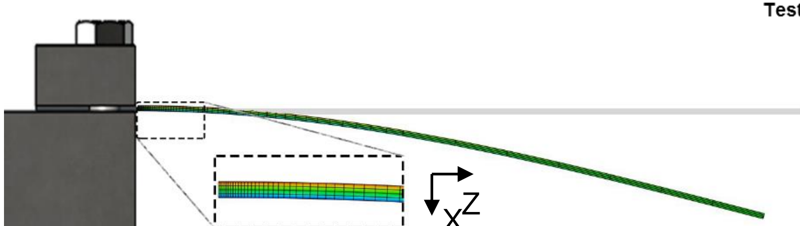
UNIVERSITY OF TWENTE.

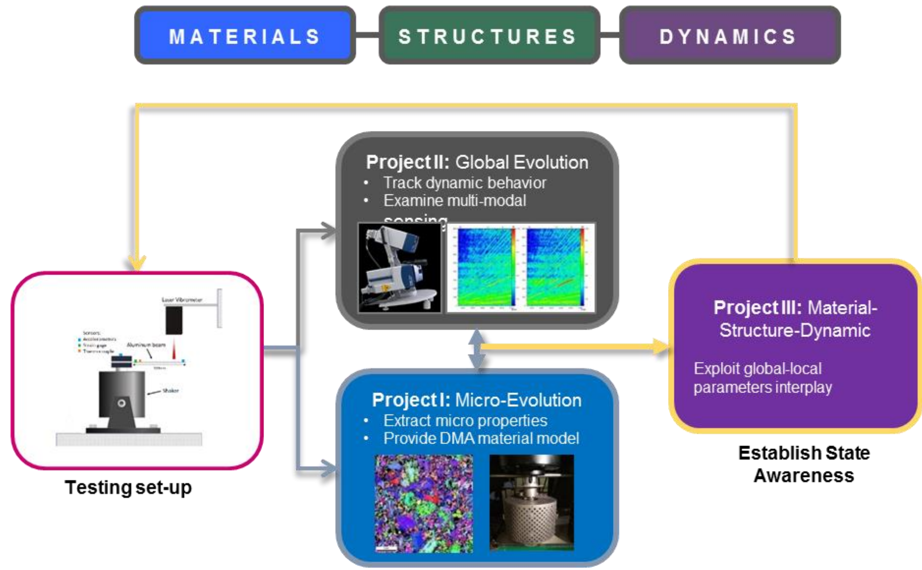
DYNAMIC ANALYSIS

ONGOING RESEARCH

DYNAMIC ANALYSIS
ADDITIVE VS. CONVENTIONAL MANUFACTURING







SUMMARY
AM VS. CM

- ❖ AM offers an alternative to conventional manufacturing
- ❖ Storage and handling have an impact in the process planning
- ❖ AM means design freedom, weight and waste reduction, no need for tooling, and opens material forming possibilities
- ❖ AM alloy systems can be tailored for specific applications
- ❖ Process parameters of AM techniques are specific for a group of materials and mechanical properties (tailored)

CM is still necessary for certain applications, AM covers potentially interesting niche markets

UNIVERSITY OF TWENTE.

Laura Cordova

l.cordovagonzalez@utwente.nl