Metal Additive Manufacturing Research Progress via GKN-University Collaboration: Recent Updates

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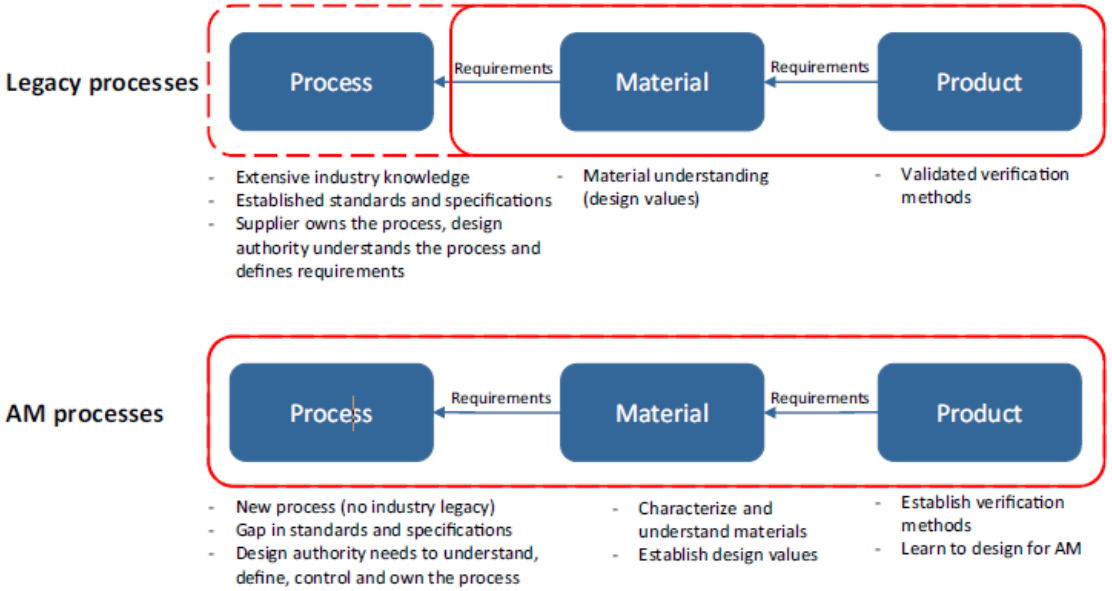
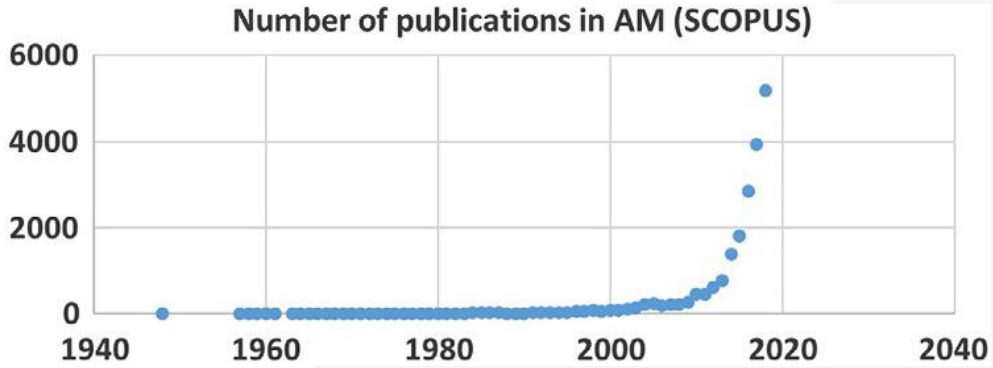
- **Repair**

Projects: CeSRA

- **Challenges & Future Opportunities**
- **Dissemination**

Background





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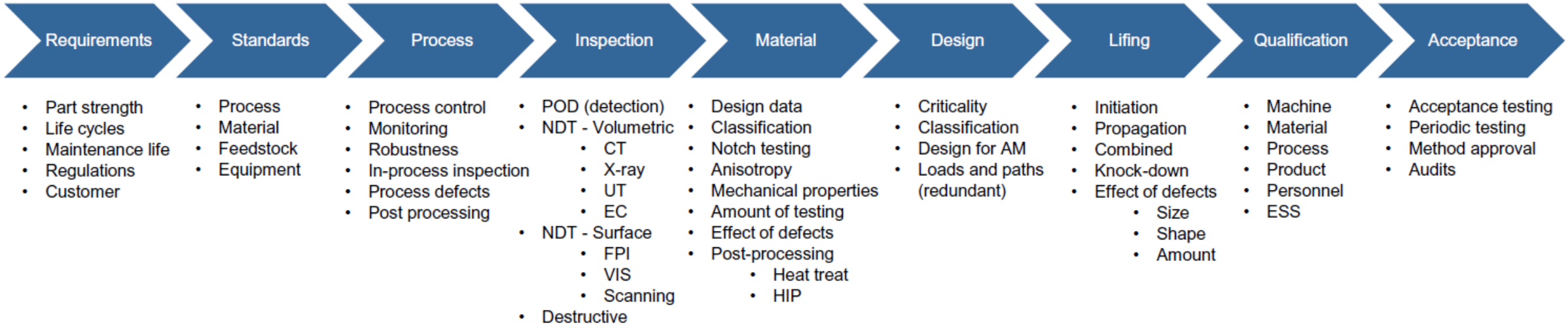
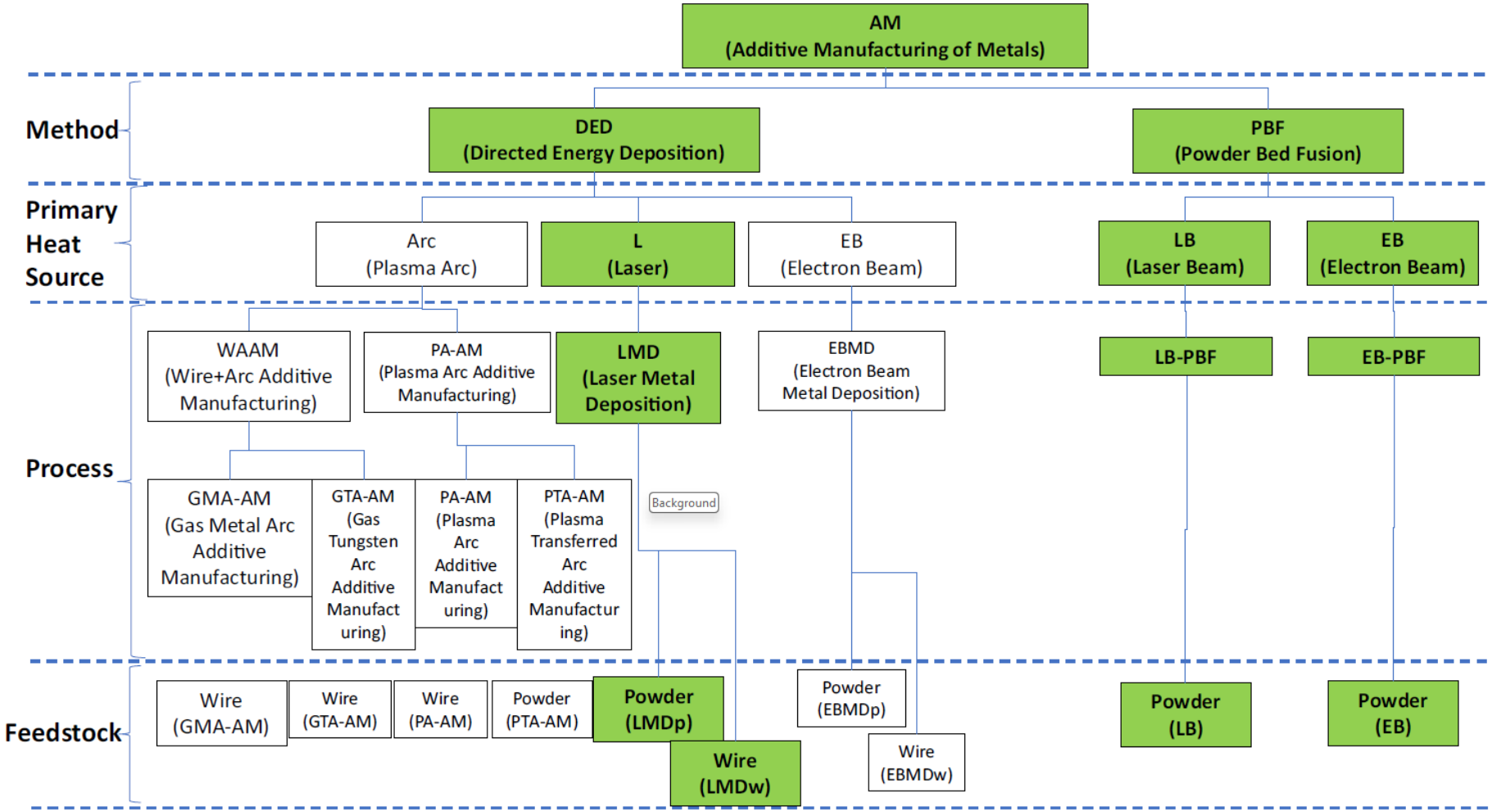


Topics to be covered for certification of AM parts. Figures and photos are GKN Aerospace Sweden AB copyright

Background


AM
(Additive Manufacturing of Metals)
Method
DED
(Directed Energy Deposition)
PBF
(Powder Bed Fusion)
Primary Heat Source
Arc
(Plasma Arc)
L
(Laser)
EB
(Electron Beam)
LB
(Laser Beam)
EB
(Electron Beam)
Process
WAAM
(Wire+Arc Additive Manufacturing)
PA-AM
(Plasma Arc Additive Manufacturing)
LMD
(Laser Metal Deposition)
EBMD
(Electron Beam Metal Deposition)
LB-PBF
EB-PBF
GMA-AM
(Gas Metal Arc Additive Manufacturing)
GTA-AM
(Gas Tungsten Arc Additive Manufacturing)
PA-AM
(Plasma Arc Additive Manufacturing)
PTA-AM
(Plasma Transferred Arc Additive Manufacturing)
Background
Feedstock
Wire
(GMA-AM)
Wire
(GTA-AM)
Wire
(PA-AM)
Powder
(PTA-AM)
Powder
(LMDp)
Wire
(LMDw)
Powder
(EBMDp)
Wire
(EBMDw)
Powder
(LB)
Powder
(EB)

Background

AM Processing techniques at GKN Aerospace Sweden Site:

- Laser Directed Energy Deposition with Wire (LDED-w)
- Laser Directed Energy Deposition with Powder (LDED-p)
- Powder Bed Fusion (PBF) – Laser/Electron Beam as energy source

Choice of Materials:

Titanium-based (Ti-6Al-4V, Ti-6Al-2Sn-4Zr-2Mo [Ti6242], etc.)

Nickel-based Superalloys (IN 718, IN 625, Haynes 282, Haynes 233, Waspaloy, MAR-M-247)

High Entropy Alloys (exploratory track)

Approach:

- Experimental
- Modelling & Simulation
- Experimental-Modelling-Machine Learning

Recent updates (Overview of ongoing GKN-University Research Projects)

Call: HORIZON-CL4-2023-TWIN-TRANSITION-01
(TWIN GREEN AND DIGITAL TRANSITION 2023)

Topic: HORIZON-CL4-2023-TWIN-TRANSITION-01-02

Type of Action: HORIZON-IA

Proposal number: 101138718

Proposal acronym: WISE

Type of Model Grant Agreement: HORIZON Lump Sum Grant

Project title: *WISE – Multi-scale multi-process machine for high value-added complex products with disruptive functionalities*

Laser DED blown powder processing of turbine baldes

Recent updates (Overview of ongoing Projects - WISE)

Project title: *WISE – Multi-scale multi-process machine for high value-added complex products with disruptive functionalities*

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Proposal number: 101138718

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Type of Model Grant Agreement: HORIZON Lump Sum Grant

No	Name of Beneficiary	Country	Role
1	Prima Additive Srl	IT	Coordinator
2	Iris Srl	IT	Partner
3	Atlant 3d Nanosystems Aps	DK	Partner
4	Amplitude	FR	Partner
5	Alite Srl	IT	Partner
6	Morphica Srl	IT	Partner
7	Idryma Technologias Kai Erevnas	EL	Partner
8	Foto-katalytika Nano Ylika I.k.e.	EL	Partner
9	Politecnico Di Torino	IT	Partner
10	Hogskolan Vast	SE	Partner
11	Gkn Aerospace Sweden Ab	SE	Partner
12	Neos Surgery Sl	ES	Partner
13	Hydro Alps	CH	Associated
14	Scuola Universitaria Professionale Della Svizzera Italiana	CH	Associated

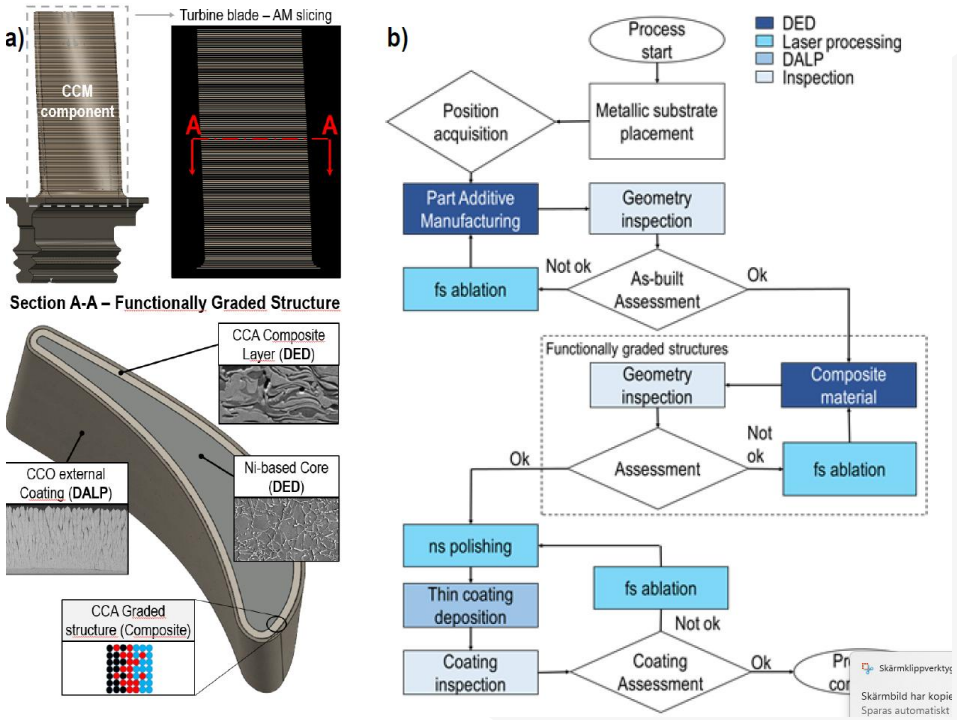
Horizon Europe ver 1.00 20230119

This proposal version was submitted by **Gianluca Pavesi** on **20/04/2023 16:31:13** Brussels Local Time. Issued by the Funding & Tenders Po

Administrative forms

Proposal ID **101138718**
Acronym **WISE**

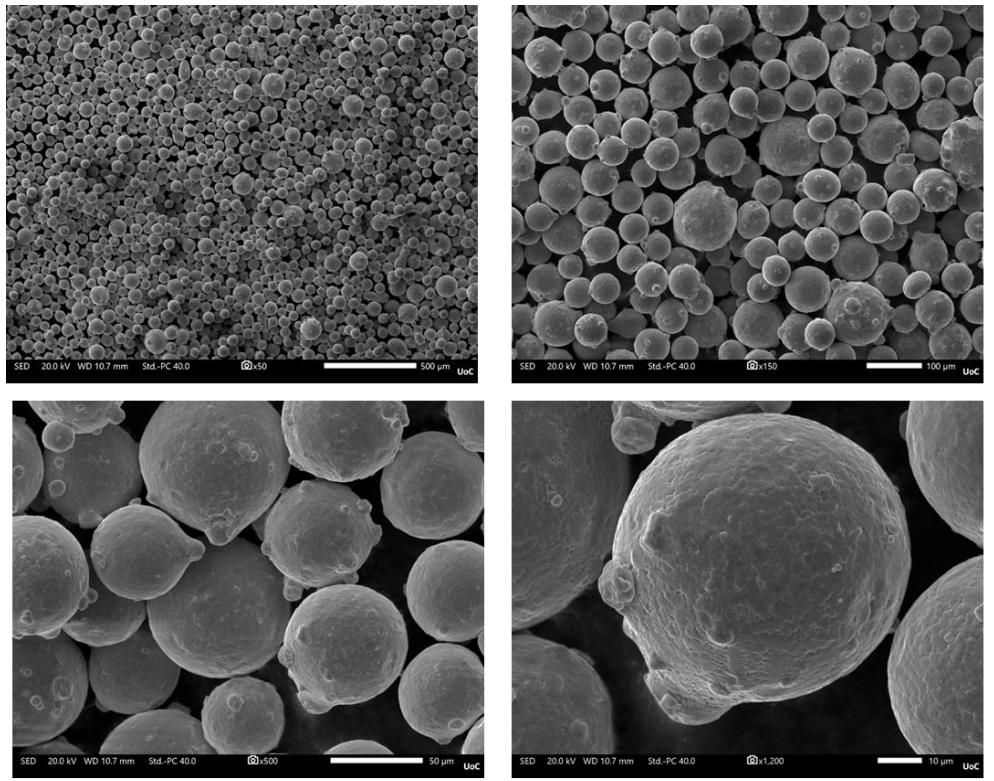
15	Femtoprint Sa	CH	Associated
16	Mch-tronics Sagl	CH	Associated

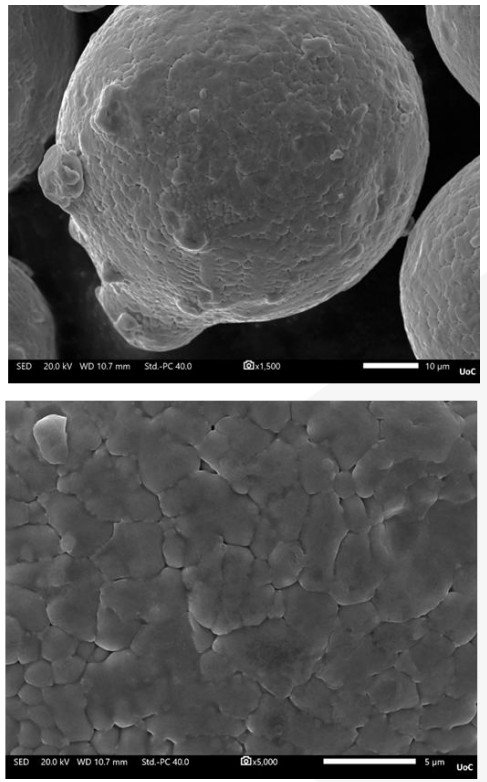


Laser DED-powder processing of MAR-M-247for turbine blade application

Recent updates (Overview of ongoing Projects - WISE)

MAR-M-247 LC





Particle	Diameter (µm)
1	80.9
2	58.7
3	57.5
4	78.7
5	45.7

Particle size analysis using ImageJ

Recent updates (Overview of ongoing Projects - WISE)

Experimental campaign - workflow

Single Tracks (STs)

Single Layers (SLs)

Cubes

ST assessment to:

- Define process conditions for continuous material depositions
- Measure ST width for computing ST hatching distance for SL manufacturing

SL assessment to:

- Define process conditions for homogeneous material depositions
- Measure SL height for computing layer thicknes for cube manufacturing

Cube characterization to:

- Assess internal integrity (i.e., cracks, pores)
- Assess microstructure
- Assess the influence of process conditions on the final cube quality

Recent updates (Overview of ongoing Projects - WISE)

Single Track

Dimension:

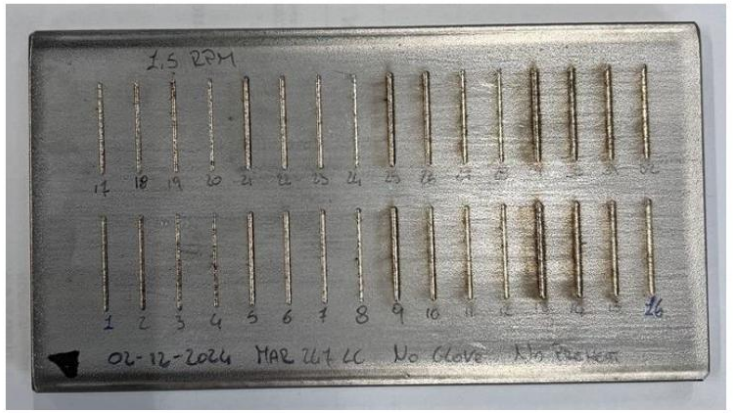
- 20 mm

Printing parameters:

- Power: 300 W – 600 W
- Axis speed: 450 mm/min – 900 mm/min
- ST hatching distance = 60% measured ST width
- 2 repetitions (16*2 combos)

Type of analysis:

- External quality assessment – through digital microscope
- ST width measurement – through digital microscope



Recent updates (Overview of ongoing Projects - WISE)

Single layer

Dimension:

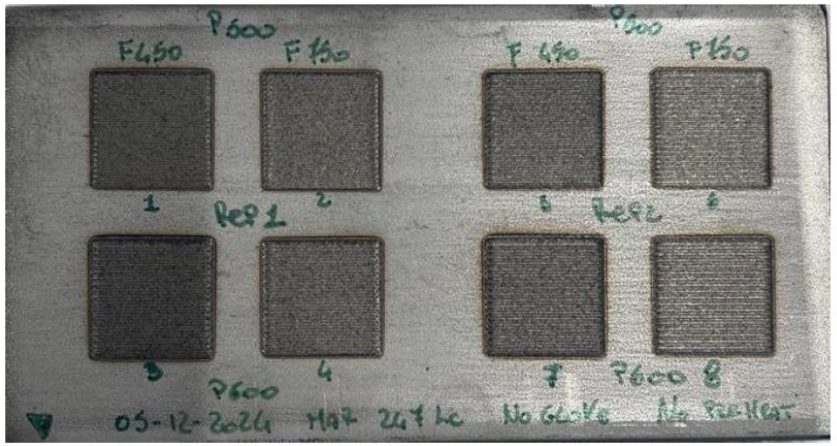
- 20x20 mm

Printing parameters:

- Power: 500 W, 600 W
- Axis speed: 450 mm/min, 750 mm/min
- 2 repetitions (4*2 combos)

Type of analysis :

- External quality assessment – through digital microscope
- SL height measurement – through digital microscope



Recent updates (Overview of ongoing Projects - WISE)

Cubes

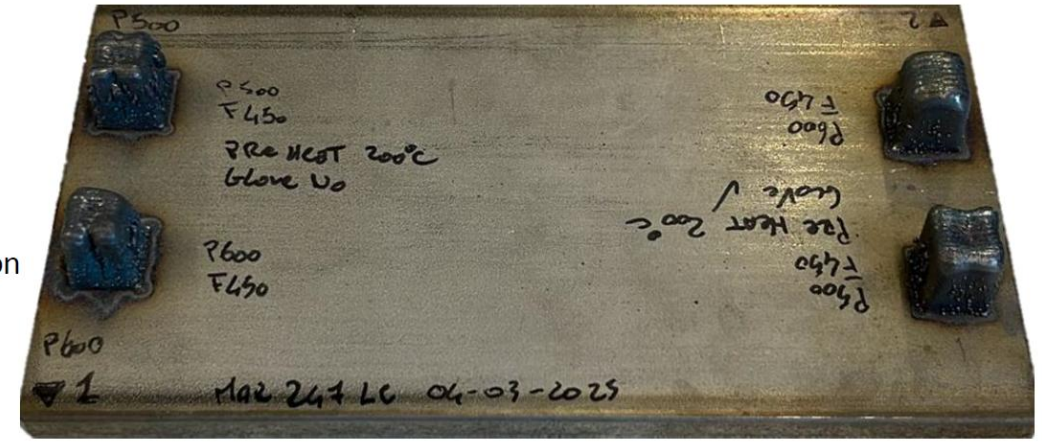
Recent updates (Overview of o...

Dimension:

- 10x10x10 mm

Printing parameter used:

- Power 500 W, 600 W
- Axis speed 450 mm/min
- 2 repetitions for every combo & printing condition



Process conditions

- Oxygen level 21%, 0.11%
- Substrate preheating 20°C, 200°C, 300°C

Analysis done

- Cross-section analysis (i.e., cracks, pores, microstructure) – through SEM & EDS

Recent updates (Overview of ongoing Projects - WISE)

Reasons behind chosen process conditions

From the literature crack are generally caused by oxide and high cooling rate.

- The use of a substrate preheating to reduce cooling rates.
- The use of an enclosed environment to lower oxygen level

Recent updates (Overview of o...

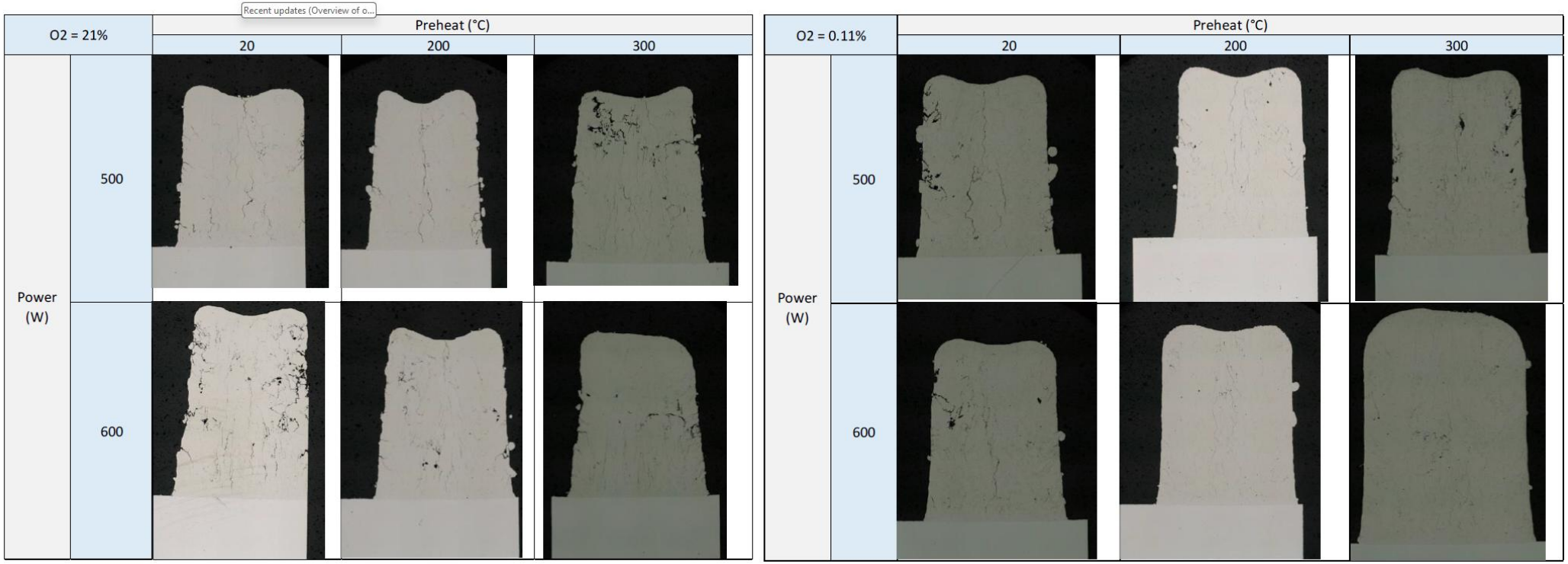
Tested printing conditions:

A. No preheating / no enclosed environment
B. No preheating / enclosed environment
C. 200°C preheating / enclosed environment
D. 200°C preheating / no enclosed environment
E. 300°C preheating / enclosed environment
F. 300°C preheating / no enclosed environment

Sample N°	Axis speed (mm/min)	Laser Power (W)	H.D. (mm)	Dz (mm)	Preheating (°C)	Oxygen level (%)	Printing condition
1	450	500	0.480	0.275	20	21	A
2	450	600	0.552	0.343	20	21	A
3	450	500	0.480	0.275	200	0.11	C
4	450	600	0.552	0.343	200	0.11	C
5	450	500	0.480	0.275	200	21	D
6	450	600	0.552	0.343	200	21	D
7	450	500	0.480	0.275	300	0.11	E
8	450	600	0.552	0.343	300	0.11	E
9	450	500	0.480	0.275	300	21	F
10	450	600	0.552	0.343	300	21	F
11	450	500	0.480	0.275	20	0.11	B
12	450	600	0.552	0.343	20	0.11	B

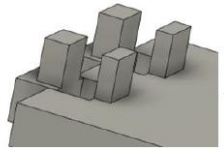
Recent updates (Overview of ongoing Projects - WISE)

Cubes – result overview



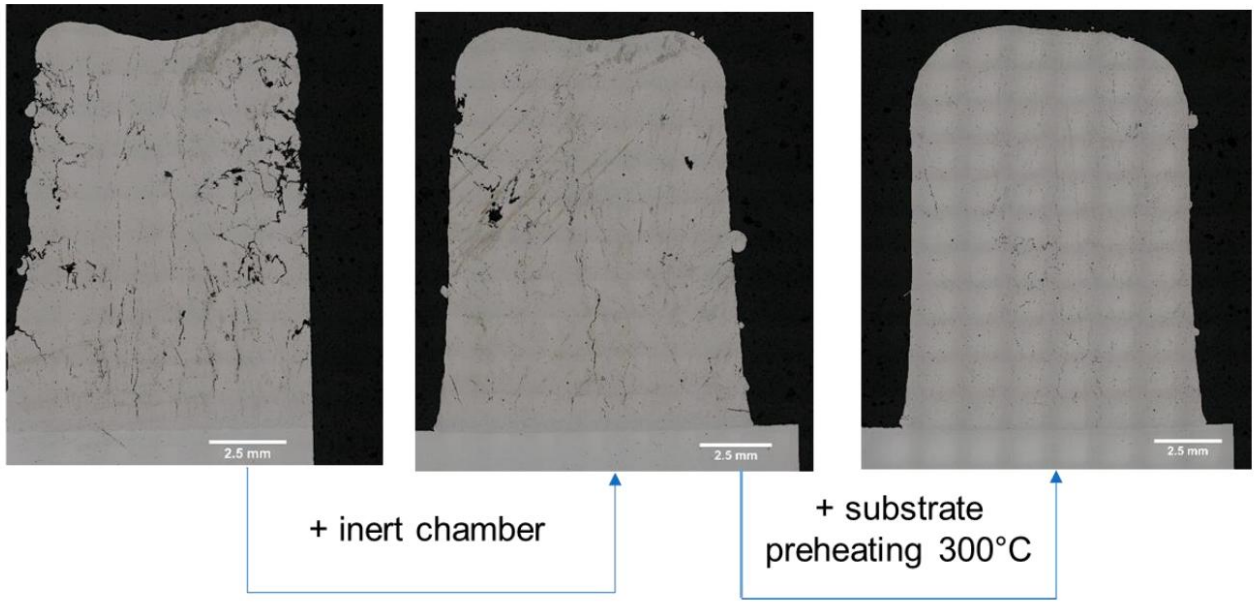
Recent updates (Overview of ongoing Projects - WISE)

Crack analysis



Cut representation

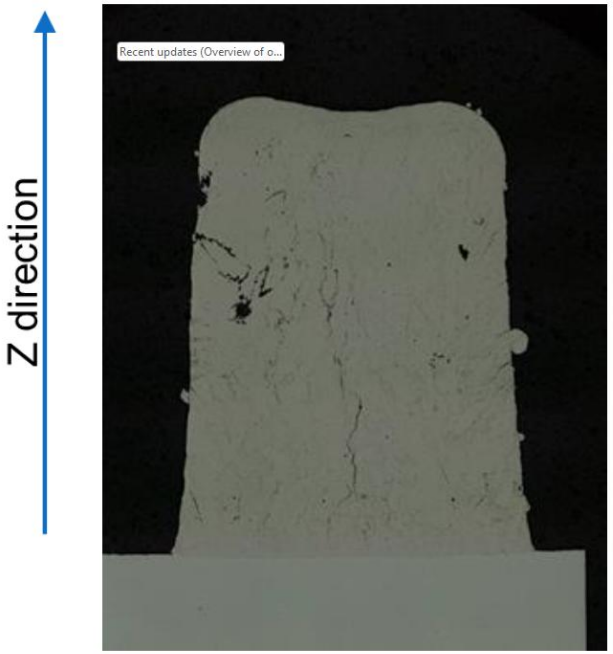
Cube: 600W, 450 mm/min



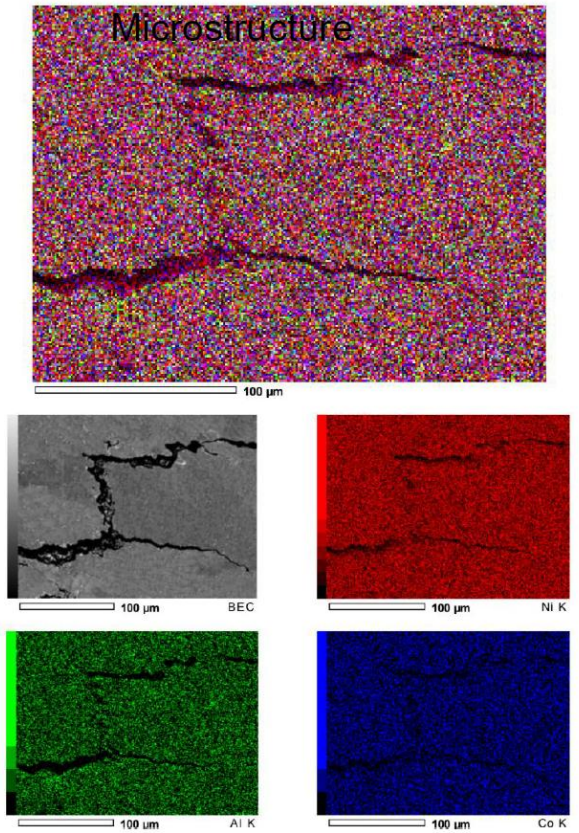
- No delamination observed
- Reduction of the crack along the boundaries reducing the oxygen level
- Reduction of internal crack with 300°C of preheating
- No lack of fusion observed with substrate preheating

Recent updates (Overview of ongoing Projects - WISE)

Crack analysis



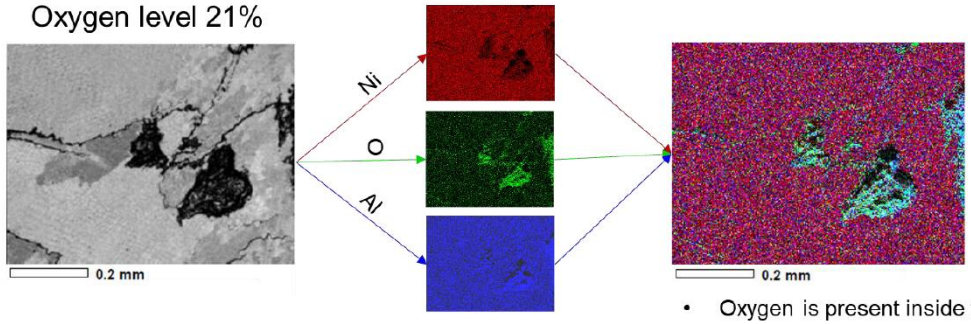
Cube: 600W, 450 mm/min, O2=0.11%, 20°C



Recent updates (Overview of ongoing Projects - WISE)

SEM/EDS analysis

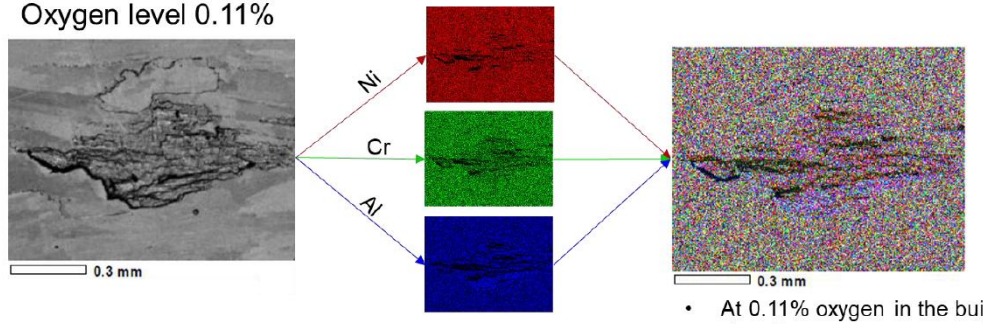
Oxygen level 21%



Element	Atom%
Al	13.48
Ti	1.01
Cr	9.59
Co	9.22
Ni	61.45
O	5.25

- Oxygen is present inside the defect

Oxygen level 0.11%



Element	Atom%
Al	11.79
Ti	1.26
Cr	9.59
Co	9.48
Ni	65.42
W	2.46

- At 0.11% oxygen in the build chamber, no oxygen was detected in the defect

Detailed invesitgation to identify cracking mechanisms is ongoing!!

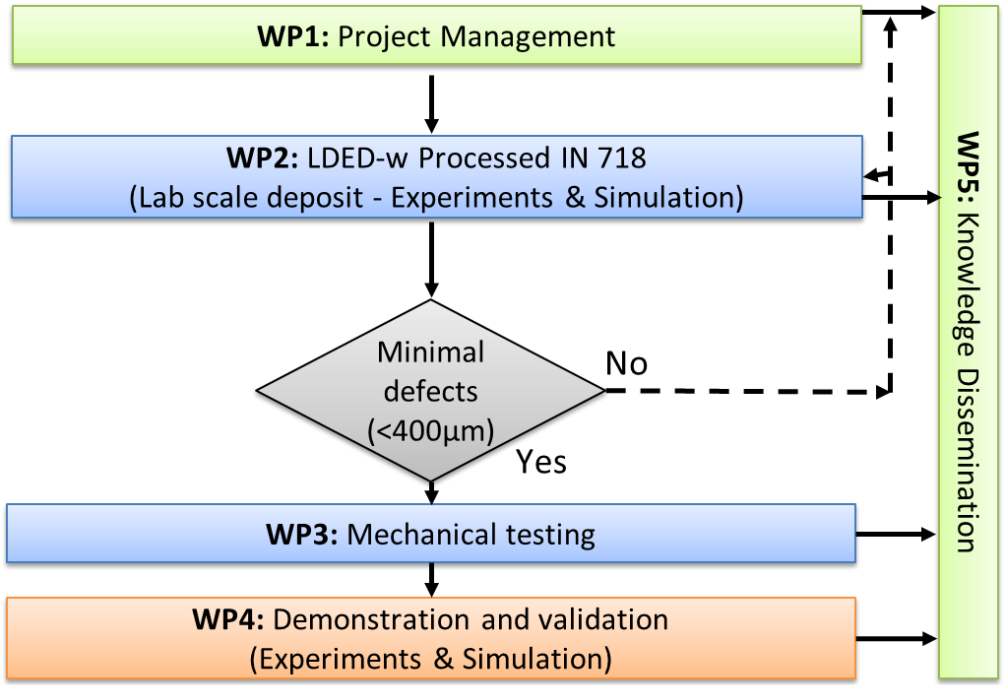
Recent updates (Overview of ongoing Projects-ANEMON)

Additive on Space Nozzles for Efficient Manufacturing and Material OptimizatioN (ANEMON) --
Rymdtillämpningsprogrammet 25-1

Figure 1 – Illustration of ETID[1] nozzle extension including selected features (left), and typical features on NE prototype of interest in this project for LDED-w deposition (right).

Material of choice: IN 718
Processing route: LDED-w
Budget: 6 Million SEK
Timeline: 2 Years (Sep 2025 start date)
TRL maturity: TRL3-TRL5
Project Participant: GKN Aerospace

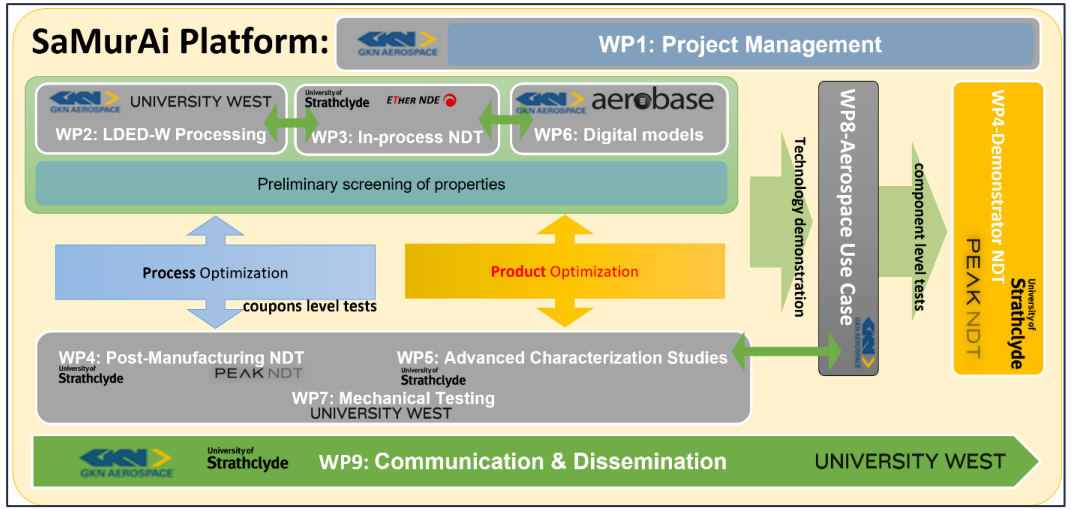
Planned Work Flow



Recent updates (Overview of ongoing Projects-SaMurAi)

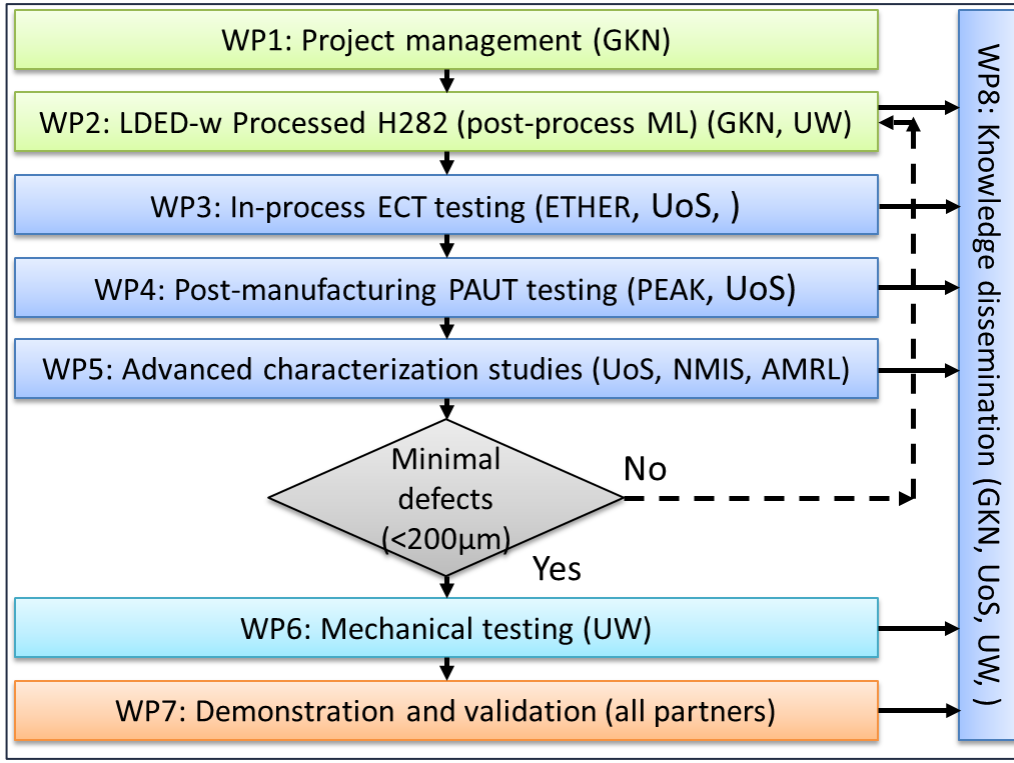
EUREKA SMART (Sweden-UK)

Sustainable Manufacturing of High-Integrity Aeroengine Components with Excellent Mechanical Properties (SaMurAi)



Consortium: GKN, Univ. West, Univ. Strathclyde, PEAK, ETHER
Material of choice: Haynes 282
Processing route: LDED-w
Budget: 1.68 Million EUROs
Timeline: 3 Years
TRL maturity: TRL3-TRL5
Processing at Univ. West and NDT development at Univ. Strathclyde, Scotland (UK)
Project Approved and start date is in June 2025

Planned Work Flow



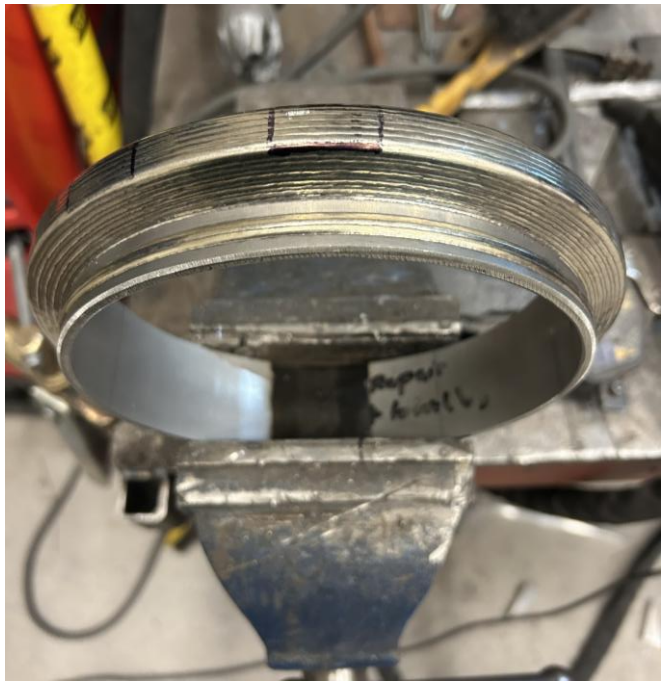
Recent updates (Overview of ongoing on repair – CeSRA)

National Center for Sustainable Remanufacturing and Repair in Aerospace (CeSRA)

- ✓ *GKN*
- ✓ *University West*
- ✓ *Innovatum AB*

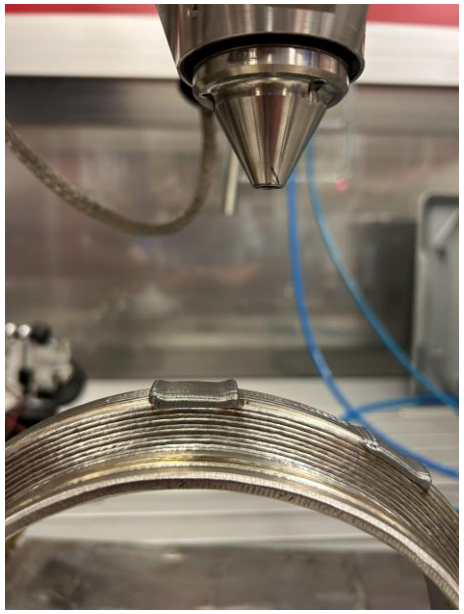
Fabrication

Engine casing-like geometry



Repair Methods

DED-LB/p

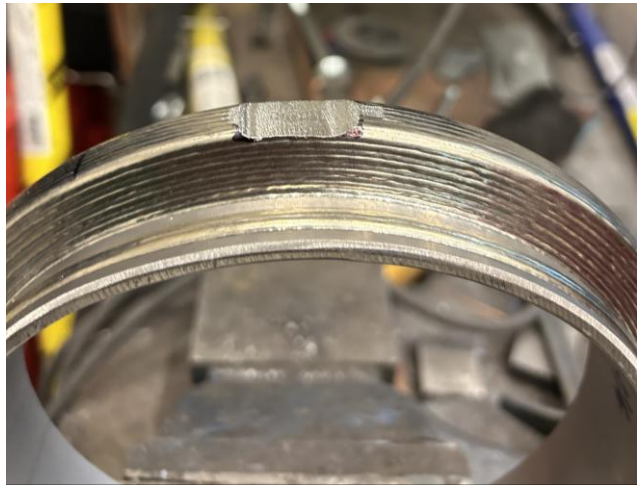


Manual TIG

Recent updates (Overview of ongoing on repair - CeSRA

National Center for Sustainable Remanufacturing and Repair in Aerospace (CeSRA)

Manual groove preparation



LDED-powder

Laser Source: TRUMPF Trudisc 12002 12 kW laser
Powder Nozzle: Co-axial HD HighNo 4.0
Alloy 718 powder 45-90µm
Laser power 800W
Laser spot diameter 1.6mm
Scanning speed 20mm/s
Powder feed rate 10g/min
4 deposition passes per groove

Manual TIG

Filler material: Alloy 7181 1.14mm dia

Welding parameters 70A 13V

Surface cleaning with acetone before and in between passes

2 weld layers per groove

Ongoing Work!

- Heat treatment
- Microscopy

Challenges and Opportunities in AM for Aerospace Apppication

Challenges

Lack of mature NDT inspection for Ni-based superalloys processed by AM

Repeatability of AM processed builds need to be improved

Modelling and simulation capabilities need to be validated with systematic experimental work

Opportunities

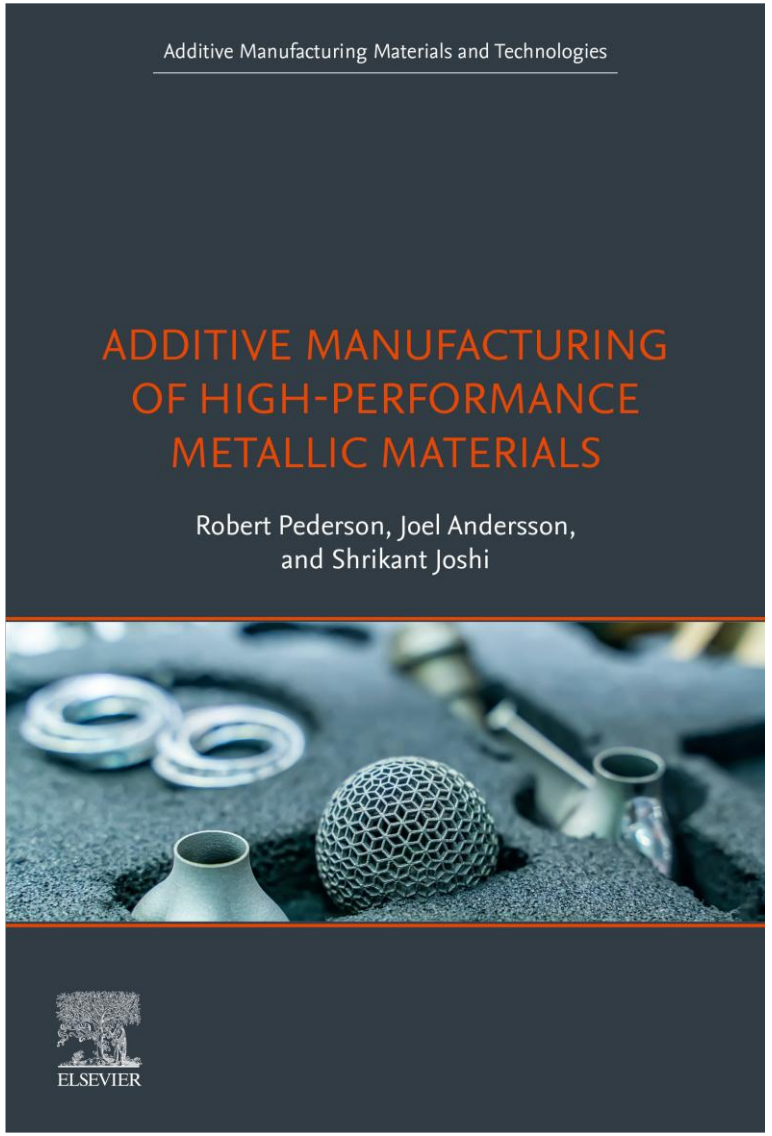
Develop advanced sensors (thermal cycles, electrical signals, meltpool size & shape) for monitoring of AM builds

Integrate AI with AM processing to address repeatability issues

Dissemination

Additive Manufacturing of High-Performance Metallic Materials
Elsevier, 2024,

https://doi.org/10.1016/C2021-0-00199-1



Dissemination

CHAPTER

6

Processing of high-performance materials by laser-directed energy deposition with powders

Andreas Segerstark[a] *and Magnus Neikter*[b]

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OUTLINE

Additive Manufacturing of High-Performance Metallic Materials
https://doi.org/10.1016/B978-0-323-91885-5.00011-1

CHAPTER

7

Processing of high-performance materials by laser directed energy deposition with wire

Satyapal Mahade[a], *Prajina Bhattacharya*[a], *Sakari Tolvanen*[a], *Robert Pederson*[b], *and Magnus Neikter*[b]

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OUTLINE

Additive Manufacturing of High-Performance Metallic Materials
https://doi.org/10.1016/B978-0-323-91885-5.00017-2

CHAPTER

15

Applications of additive manufacturing: Selected case studies and future prospects

Jerry Isoaho[a], *Christo Dordlofva*[a,b], *Andreas Segerstark*[a], *Peter Harlin*[c,d], *and Robert Pederson*[d]

[a]GKN Aerospace Engine Systems, Trollhättan, Sweden, [b]Luleå University of Technology, Luleå, Sweden, [c]Sandvik Additive Manufacturing, Sandviken, Sweden, [d]University West, Trollhättan, Sweden

OUTLINE