ADVANCES IN RESOURCE-EFFICIENT AND ACCELERATED AM BY EXPRESS WIRE COIL CLADDING (EW2C)

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Express Wire Coil Cladding (EW2C)

Aachen Manufacturing Technology – an Overview

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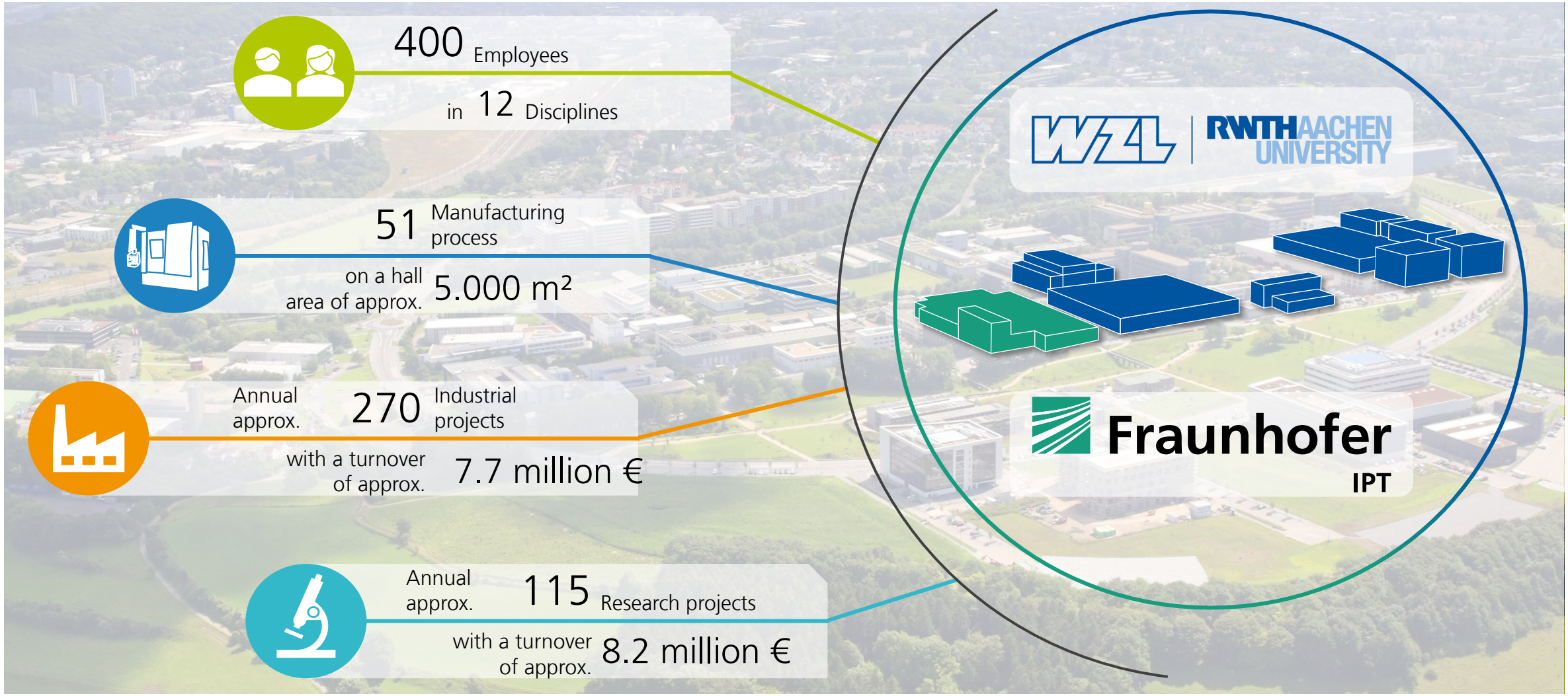
Express Wire Coil Cladding (EW2C)

Aachen Manufacturing Technology – an Overview



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EXPRESS WIRE COIL CLADDING

1 Process overview

2 Process investigations

3 Deep-dive: investigation of IN718 deposition

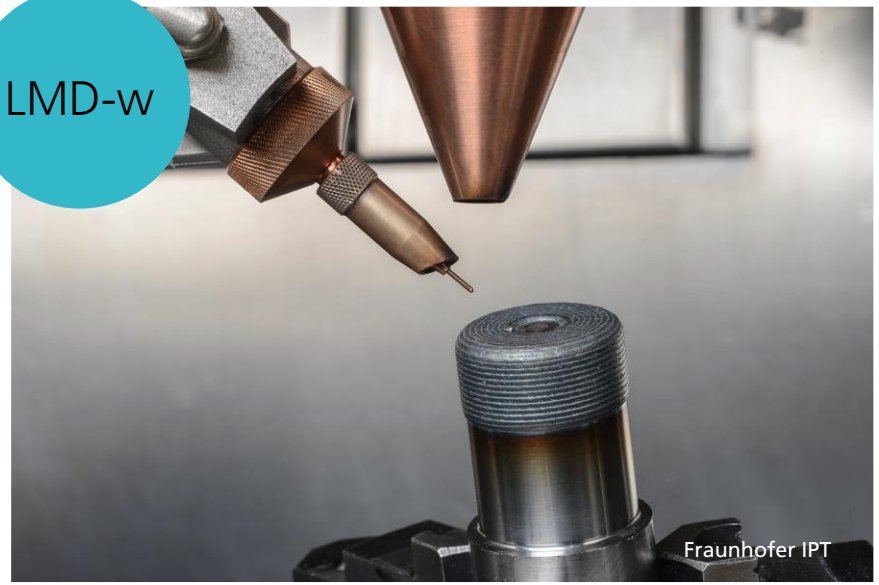
4 Summary and outlook

EXPRESS WIRE COIL CLADDING

Express Wire Coil Cladding (EW2C)

Process overview – LMD-w vs. WAAM

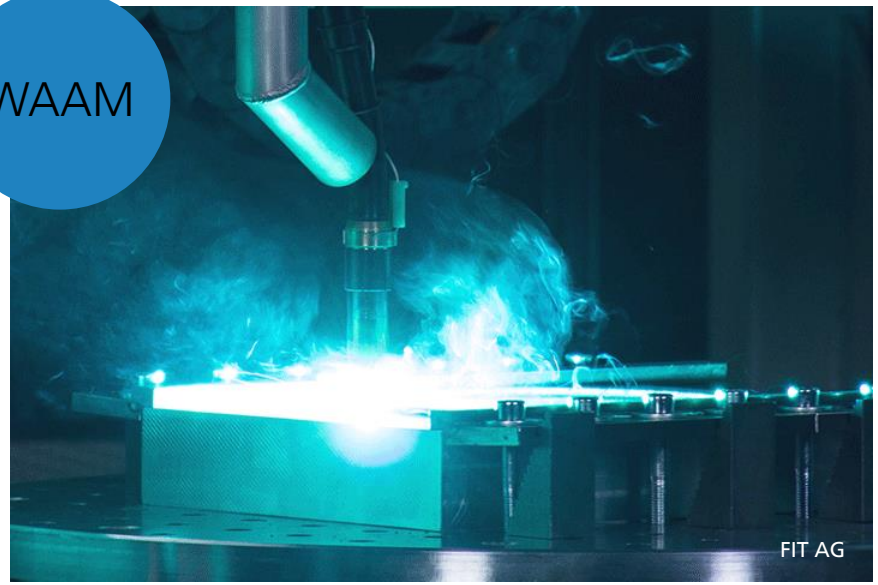
LMD-w



- High geometric accuracy
- Low and precisely controllable energy input

- High costs
- Low deposition rates (1-2 kg/h)

WAAM



- High deposition rates (up to 10 kg/h)
- Low process costs

- Geometric inaccuracy
- High heat input

LMD-w: wire-based Laser Metal Deposition
WAAM: Wire-Arc Additive Manufacturing

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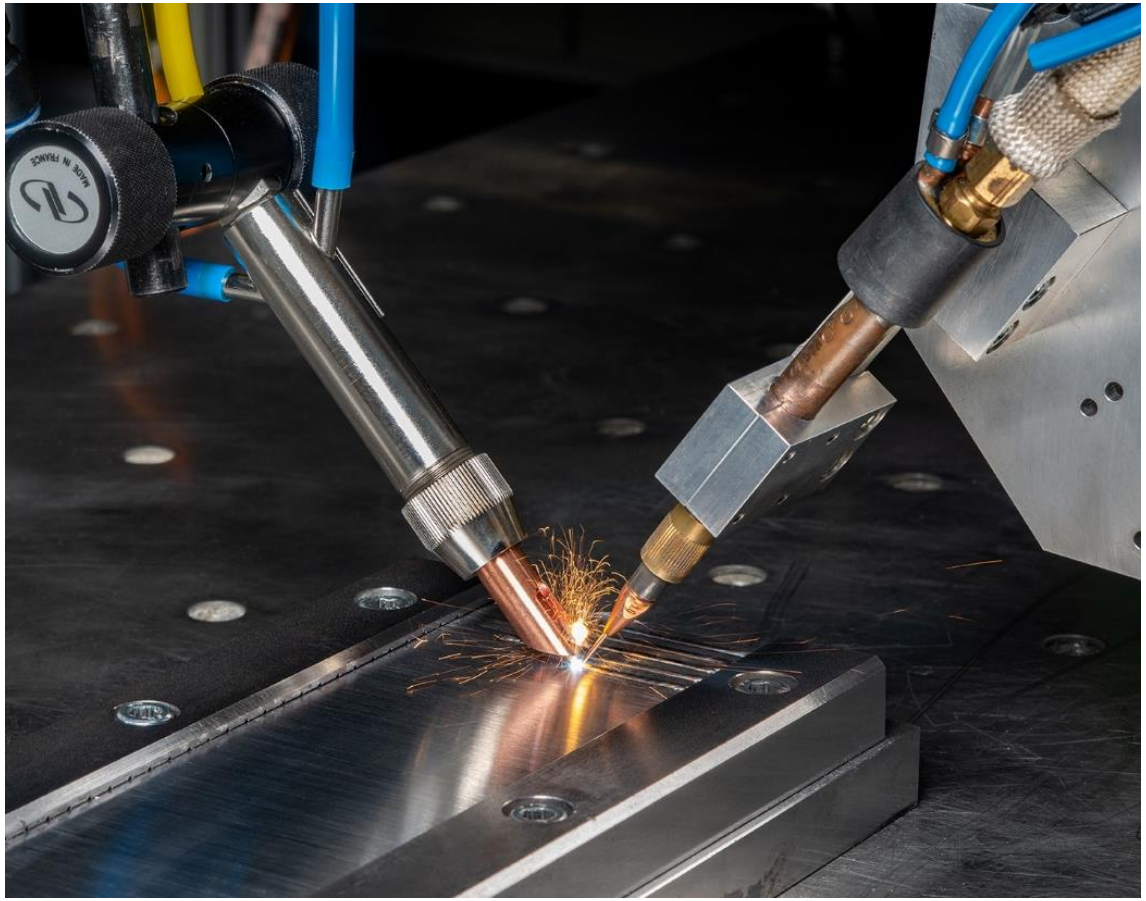
Process overview – Laser Metal Deposition with wire (LMD-w)



Limited deposition rate due to

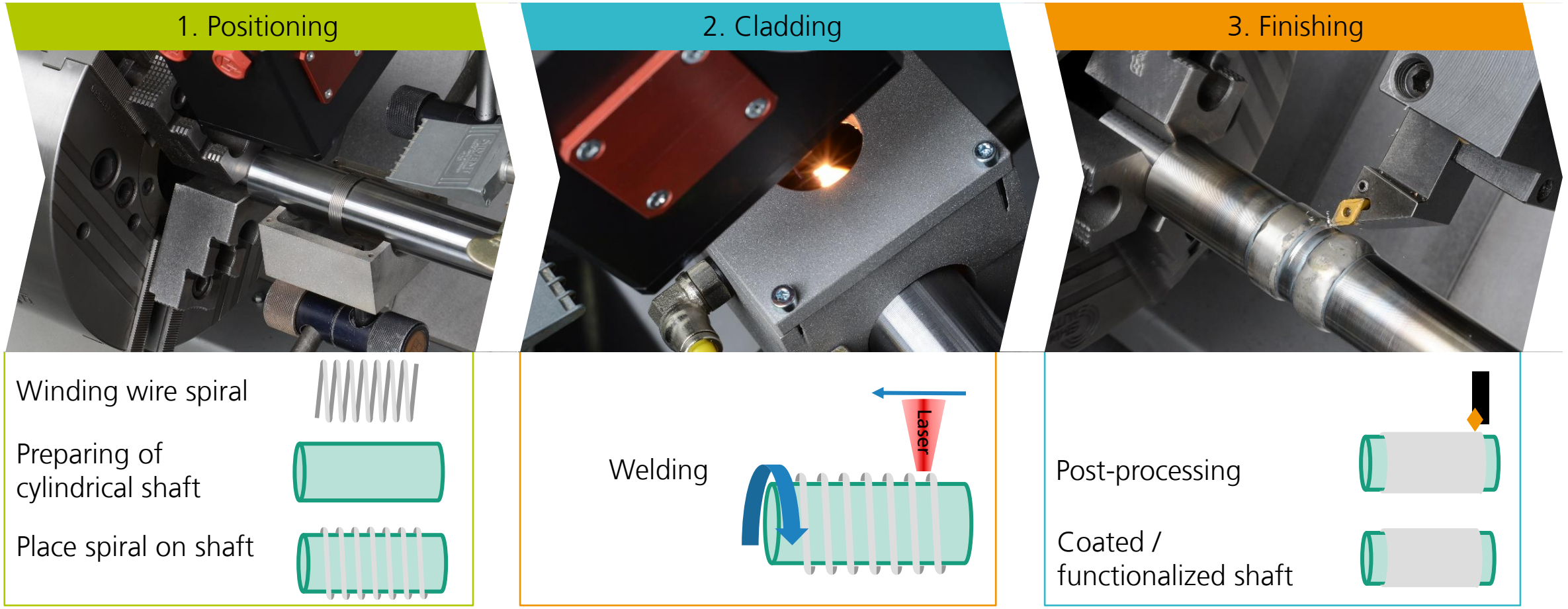
- Complex interaction of solid wire with liquid melt pool
- Comparatively small process window
- Limited scalability of wire feeding rate

Idea:

Increase deposition rate by decoupling wire feeding and cladding process

Express Wire Coil Cladding (EW2C)
Process chain

Video: https://www.youtube.com/watch?v=eL9i2D1rBy0



Express Wire Coil Cladding (EW2C)

Process overview – Potential

Environment

Saving resources due to a reduction of machined volume

Substitution of environmentally harmful anti-wear coatings (e.g. Chromium VI)

Costs

Increasing speed and stability by using pre-placed wire spirals

Increasing cost efficiency by using expensive high-performance materials locally and load-specific

Handling

Lowering safety requirements due to wire instead powder material usage

Reduction of logistic steps thanks to high automation potential

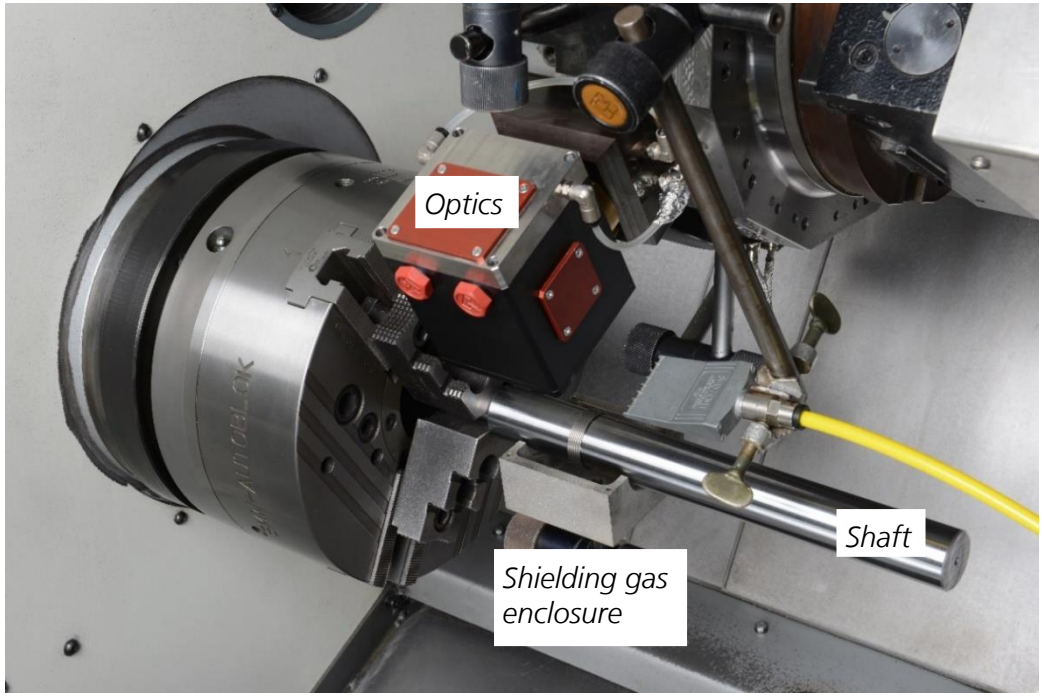
Manufacturing

Cladding and machining in one machine tool

Cladding in turning cycle times

Express Wire Coil Cladding (EW2C)
Process overview – System technology

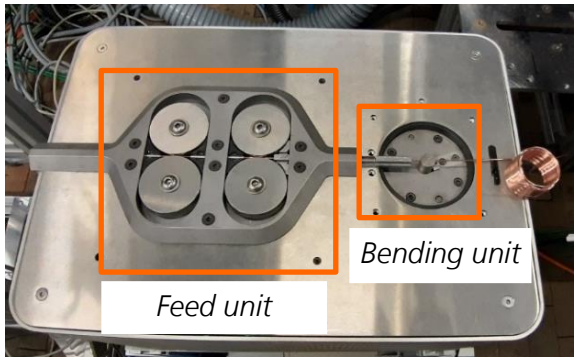
Monforts RNC400 "LaserTurn"

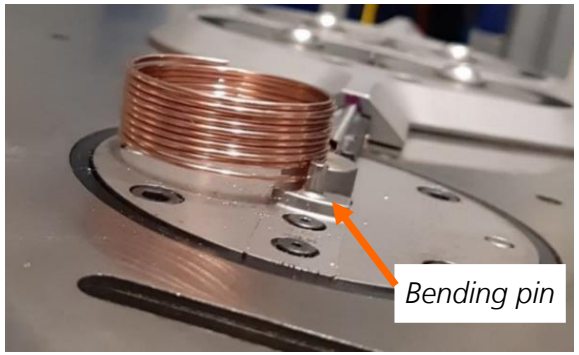


- Laser-integrated turning machine tool with different laser optics (round Ø 5 mm, rectangular 16 x 4 mm², ...)
- Suitable for laser-assisted turning, laser hardening and EW2C

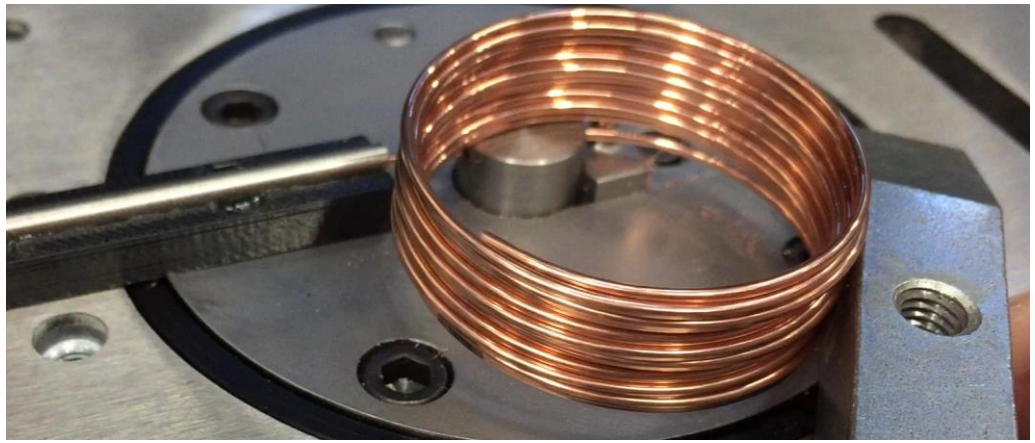
Express Wire Coil Cladding (EW2C)
Process overview – Wire winding

Wire coiling system D.I. Wire Pro (Pensalabs)





Coiling process



Stelloy 60-G | Robotool 58-G | Stelloy 6 BC-G | QuFe13 | IN718

- Solid wires show more homogeneous deformation behavior
- Filler wires interesting because of higher flexibility regarding alloying/composition

Express Wire Coil Cladding (EW2C)
Process overview – Applications

- Plating and corrosion/wear protection of rotationally symmetrical components (layer thickness > 0.5 mm)
- Material-efficient manufacturing of shaft shoulders (e.g. bearing seats) from high-performance materials on a low-cost base material
- Reduction of the machined volume in the production of complex shaft geometries
- Good scalability of the process
- High process stability
- Spiral supply uncritical (today's coiling machines can reach up to 200 m/min)

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Express Wire Coil Cladding (EW2C)

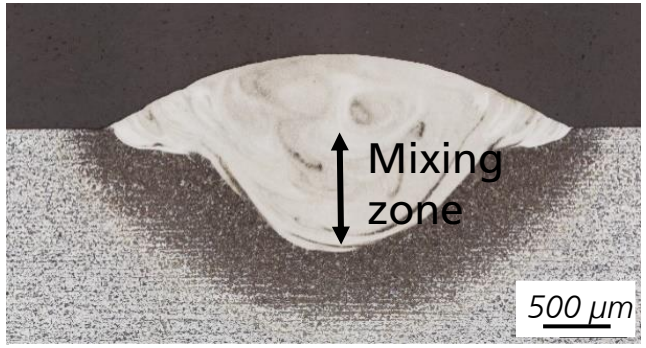
Process investigations – Single wires

Round spot, ø 2.5 mm

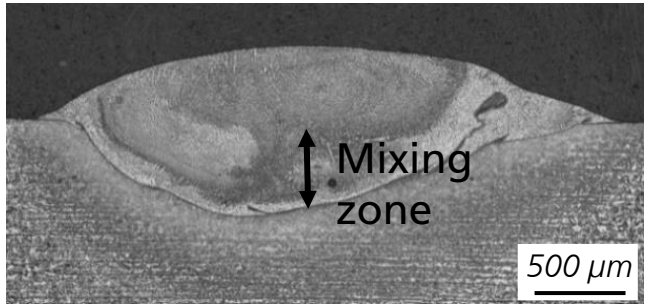
QuFe13. P_L = 2000 W, v_M = 1000 mm/min

IN718. P_L = 2500 W, v_M = 1900 mm/min

Stelloy 6 BC-G. P_L = 2600 W, v_M = 800 mm/min



Robotool 58-G. P_L = 2000 W, v_M = 1000 mm/min



Stelloy 60-G. P_L = 2400 W, v_M = 1000 mm/min

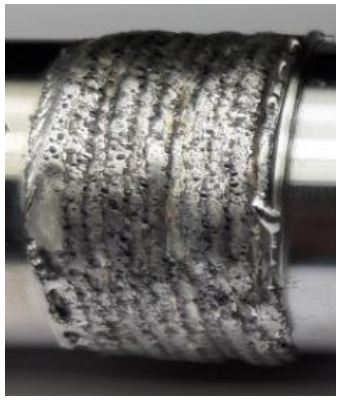
- In all cases, a metallurgical joint was established
- For filler wires, stronger mixing due to the lower material density

Express Wire Coil Cladding (EW2C)

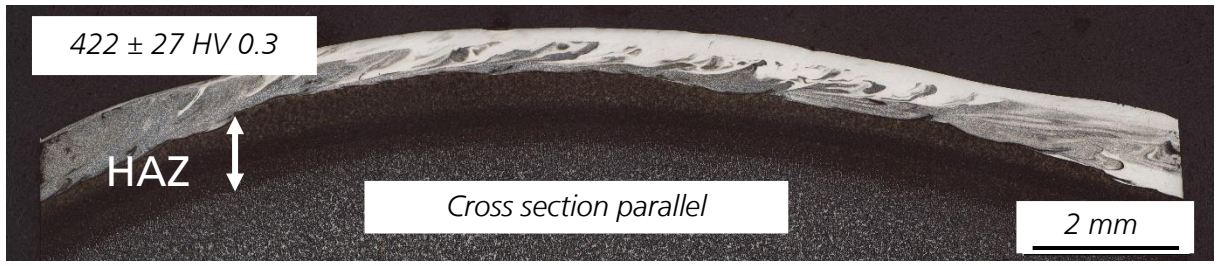
Process investigations – Pre-placed wire coils

Round spot, Ø 5 mm

Stelloy 6 BC-G, P_L = 3500 W, v_M = 1000 mm/min

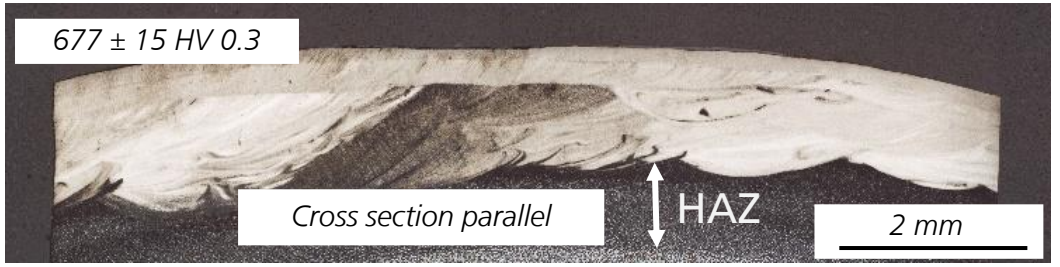


Cross section perpendicular



Robotool 58-G, P_L = 3500 W, v_M = 800 mm/min

Crosssection perpendicular



- Higher porosity, cracks, higher surface roughness
- Large heat affected zone (HAZ)

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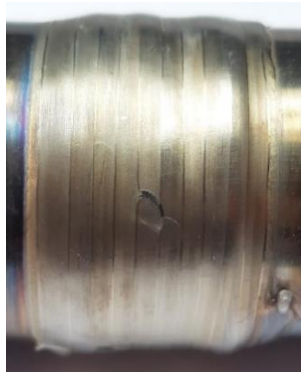
Express Wire Coil Cladding (EW2C)

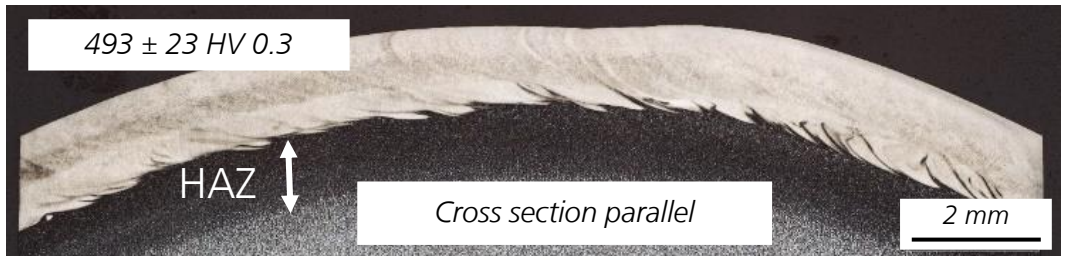
Process investigations – Pre-placed wire coils

Round spot, Ø 5 mm

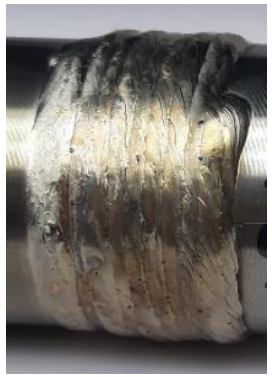
QuFe13, P_L = 4000 W, v_M = 550 mm/min, Remolten at 1000 W



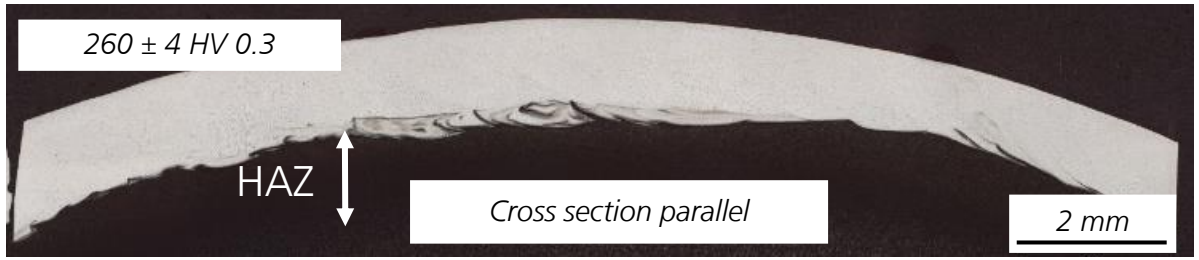
Cross section perpendicular



In718, P_L = 4000 W, v_M = 800 mm/min



Cross section perpendicular



- Low porosity, no bonding defects
- Large heat affected zone (HAZ)

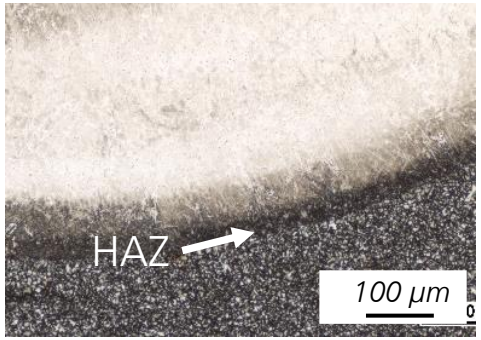
Express Wire Coil Cladding (EW2C)

Process investigations – Pre-placed wire coils

Rectangular spot, 16 x 4 mm²

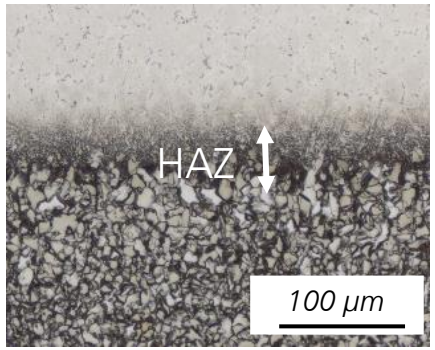
QuFe13

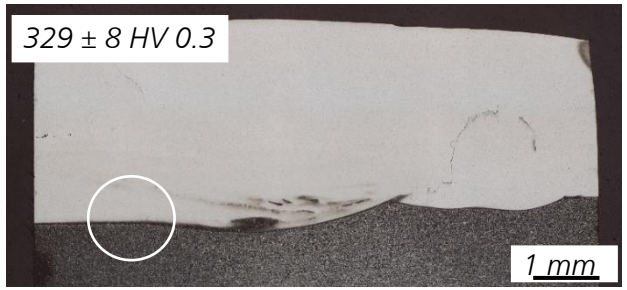
P_L = 3800 W, v_M = 160 mm/min



IN718

P_L = 3500 W, v_M = 150 mm/min, two layers





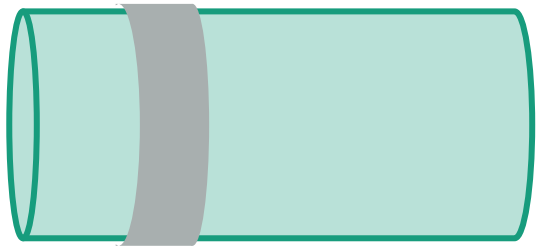
- Low surface roughness
- Good layer connection, very small heat affected zone (HAZ)

EXPRESS WIRE COIL CLADDING

Deep-dive: investigation of IN718 deposition
Geometries

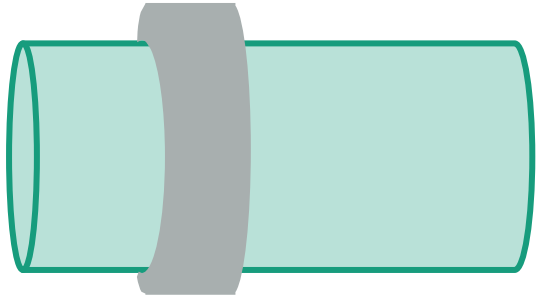
Single layer, short section

Deposition movement: 370° rotation



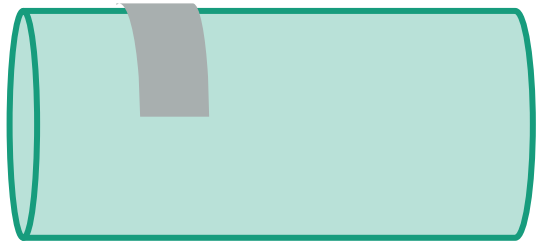
Multi-layer, short section

Deposition movement: 370° rotation



Single layer, half section

Deposition movement: <180° rotation



Single layer, long section

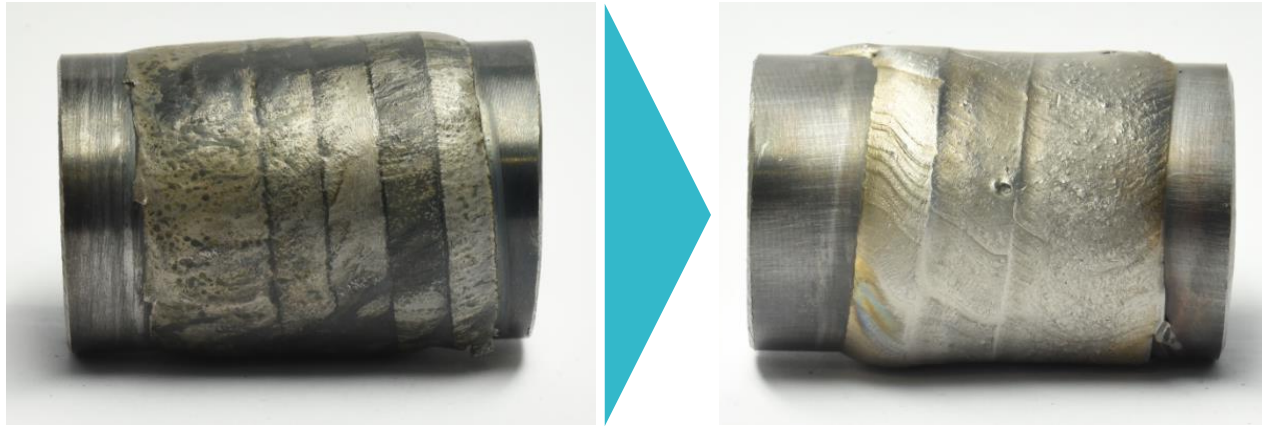
Deposition movement: rotation and axial displacement

Deep-dive: investigation of IN718 deposition

Step 1: Surface oxidation improvement

Multi-layer, short section

Single layer, long section

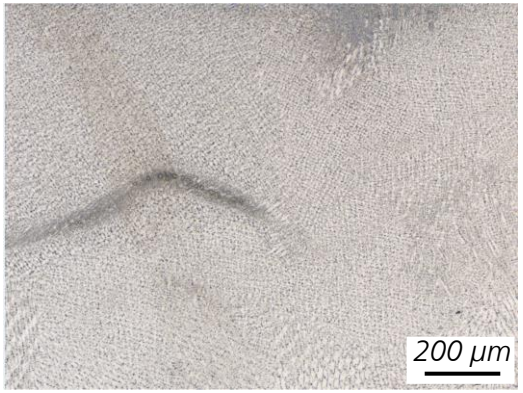


- Shielding gas flow improved (several inlets in chamber, higher flux)
- Surface oxidation was significantly reduced

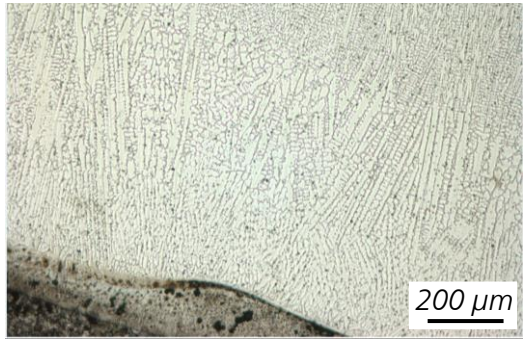
Deep-dive: investigation of IN718 deposition

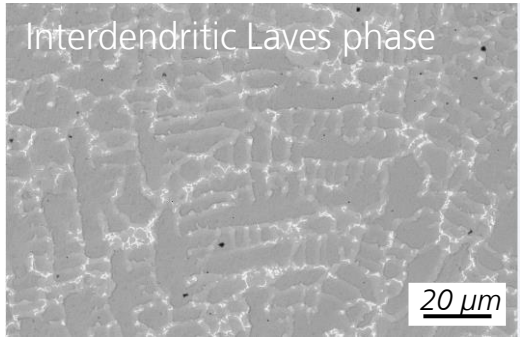
Step 2: Microstructure (as-deposited state)

Single layer deposition



Multi-layer deposition





- Single layer deposition leads to rather equiaxial grains, but microstructure is inhomogeneous
- In multi-layer depositions, grains close to the substrate have a columnar form; microstructure is homogeneous

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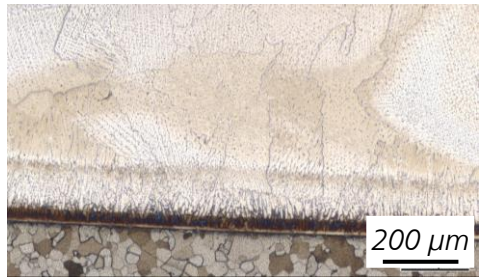
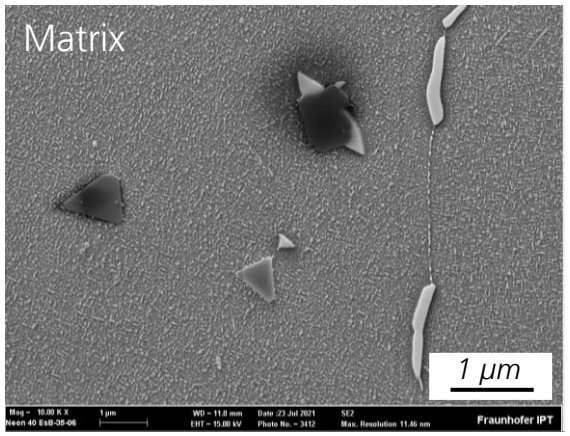
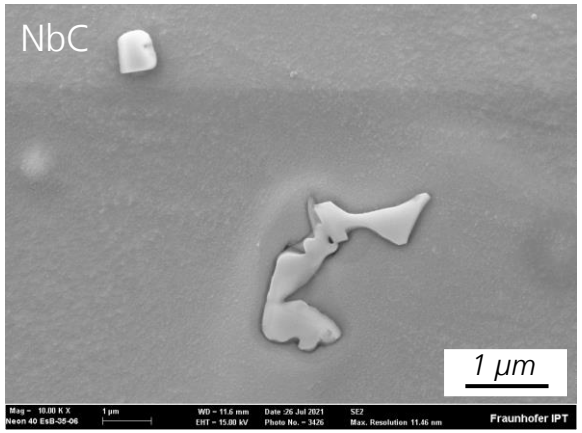
Deep-dive: investigation of IN718 deposition

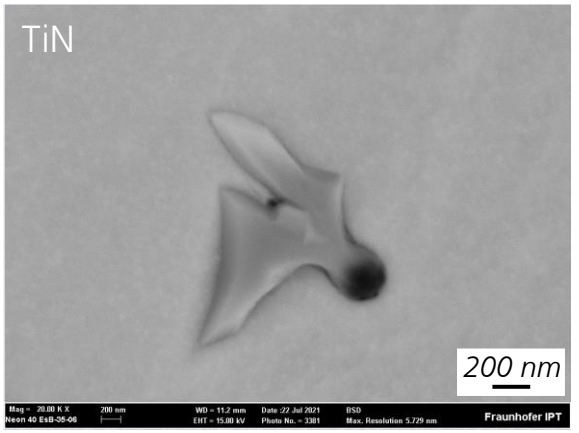
Step 2: Microstructure (after heat treatment)

Multi-layer deposition









- Formation of strongly columnar grains close in the mixing zone
- Characteristic IN718 precipitates are formed; undesired Laves phases disappear during heat treatment

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Deep-dive: investigation of IN718 deposition

Step 3: Deposition of non-circular geometries

Half section depositions (cam shaft)

EW2C

- By repeated deposition of half sections, non-circular geometries can be deposited
- AM cam shafts are a potential application

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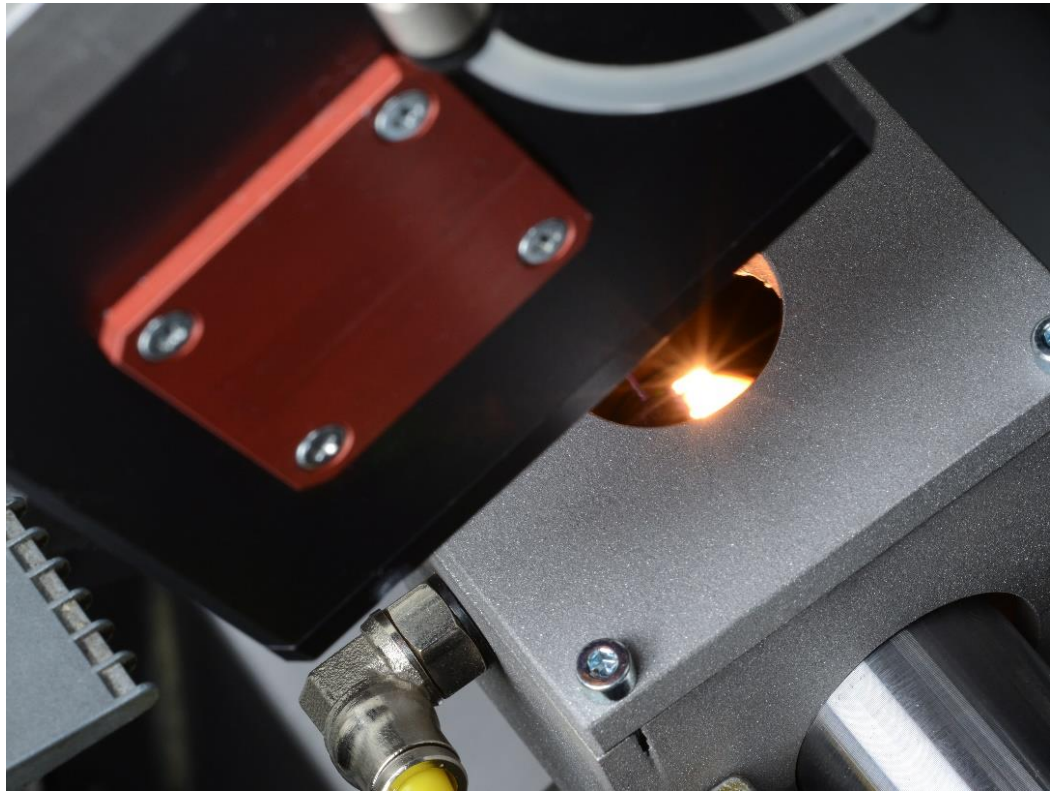
Express Wire Coil Cladding (EW2C)
Summary



- New, stable Additive Manufacturing process for shaft cladding and (rotationally) symmetrical build-up
- Current deposition rate ~ 2.5 kg/h
- Very good scalability of the process:
  up to 14 kg/h possible with 35 kW laser
- Various material combinations possible;
  according to current results, solid wires are better suited

Express Wire Coil Cladding (EW2C)
Outlook

- Increasing the degree of automation: tool development for automatic wire coil pre-placement
- Pushing process limits: Are there diameter-related process limits?
- Developing process variations: Tube coating
- Broadening material combinations (e.g. titanium-based spirals)

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