4èmes journées A3TS Traitements et parachèvements de pièces issues de fabrication additive

Une étude comparative de procédés disponibles pour le parachèvement de pièces réalisées par Fabrication Additive

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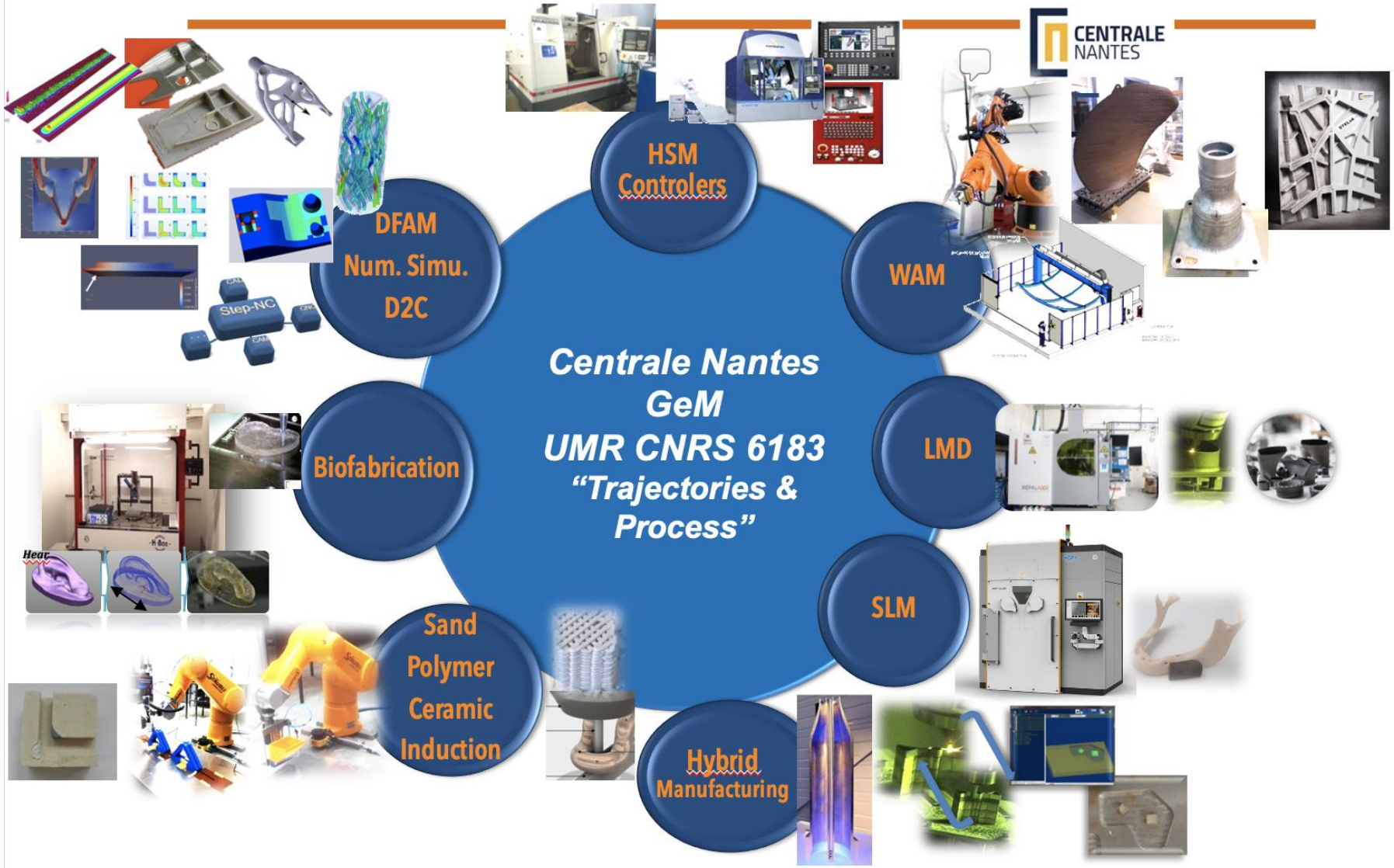
CENTRALE NANTES RAPID MANUFACTURING

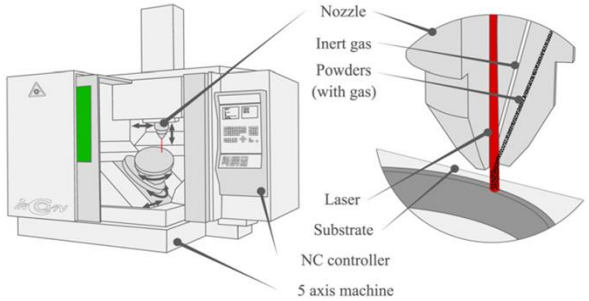
GeM Institut de Recherche en Génie Civil et Mécanique

Rapid Manufacturing Centrale Nantes

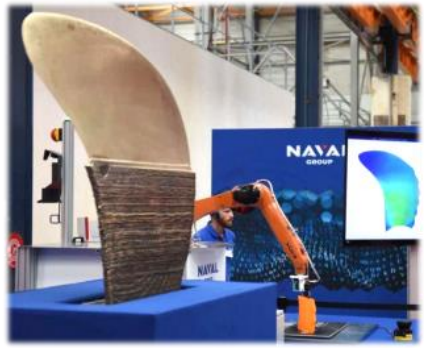


Additive Manufacturing

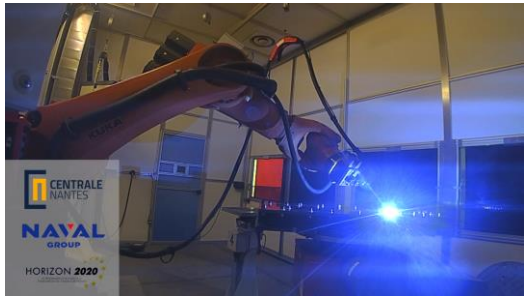
- **Additive Manufacturing Processes**
  - Laser Metal Deposition
  - Wire Additive Manufacturing
  - Laser Powder Bed Fusion
  - …



- **Promising capabilities**
  - Design freedom
  - Material Savings
  - …



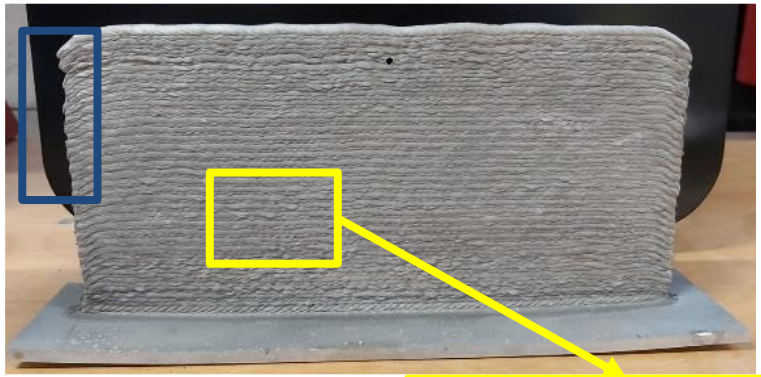
- **Building Principles**
  - Piling layers of material



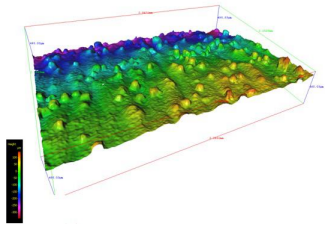
AM surfaces properties

- **As-built AM surfaces have a poor quality**
  - Not suitable for severe functional requirements
    - Tightness, friction coefficients, assemblies
  - Possible fracture initiation zones
  - Surface aspects…

WAAM surface

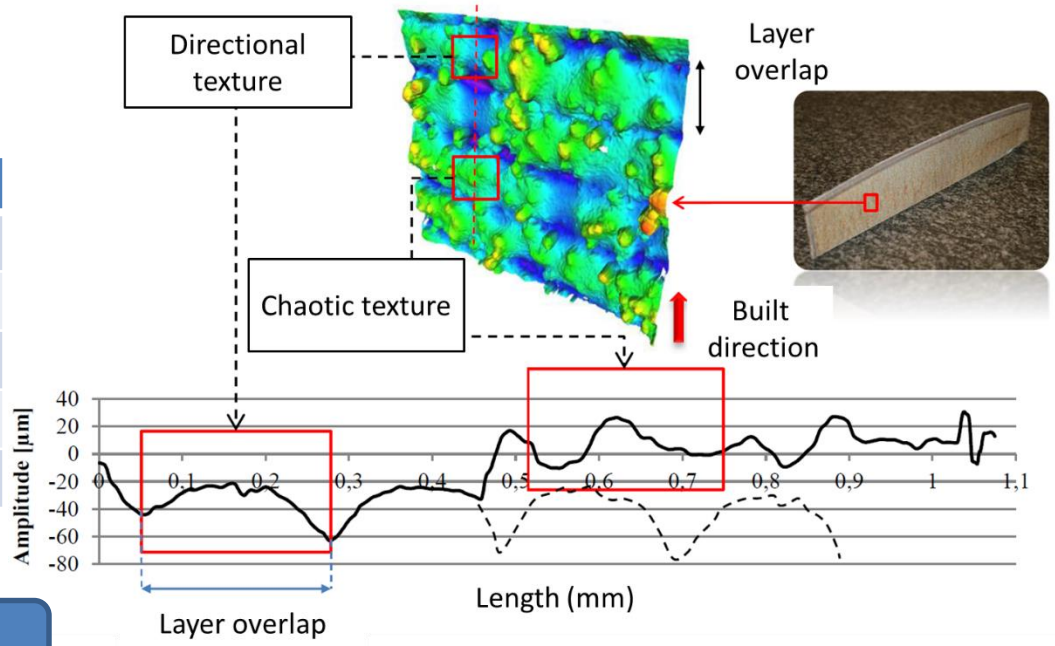


- **Example of a typical LMD surface**
  - Directional texture
  - Unmelted powder particles
  - Layer overlap



Indicator	As built
R_a	5.19
R_t	35.30
R_z	26.24
R_p	21.77
R_v	13.53

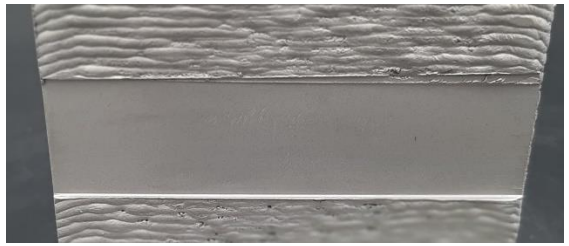
LMD surface



Post processing techniques may be necessary

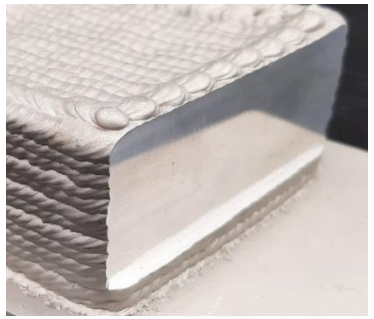
Material Removal Processes: High Speed Machining

- **Principles: a well-known finishing process**
  - Excellent surface properties
  - Already used to remove AM supports



LMD 316L

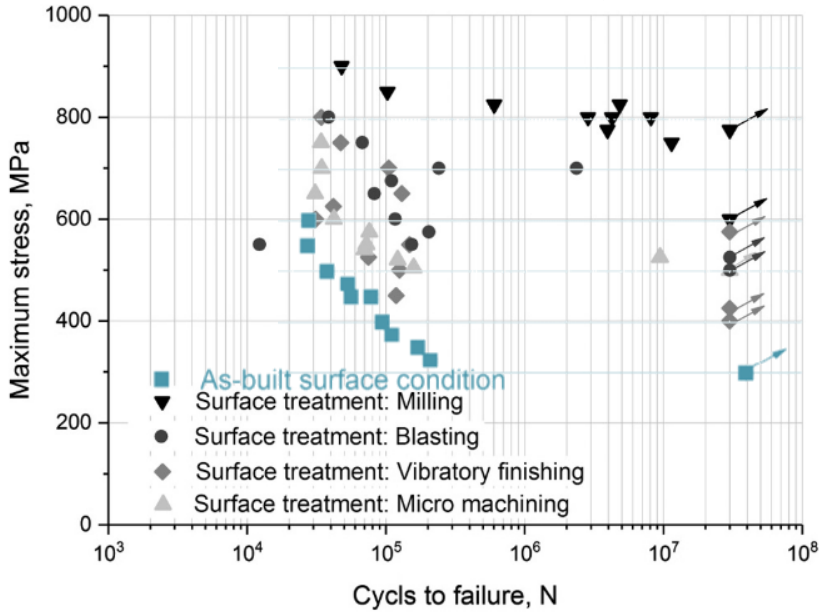
LMD Ti-6Al-4V



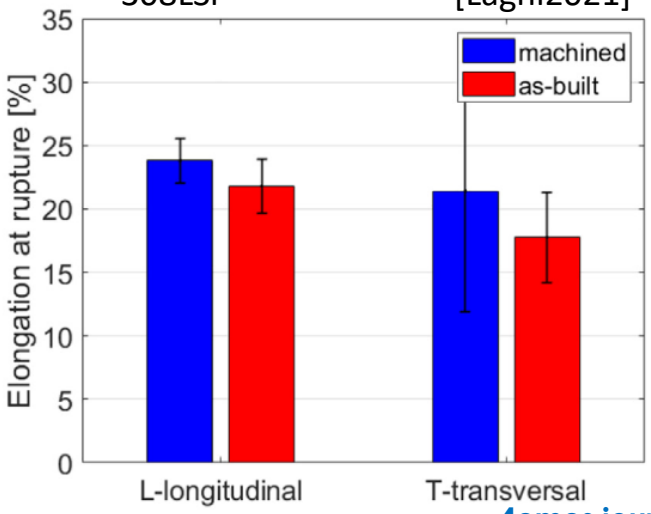
WAAM Al

- **Improved mechanical properties vs as-built**
  - Fatigue performance x2
  - Elongation: around 20% higher
  - Crack propagation AM+machining close to wrought properties

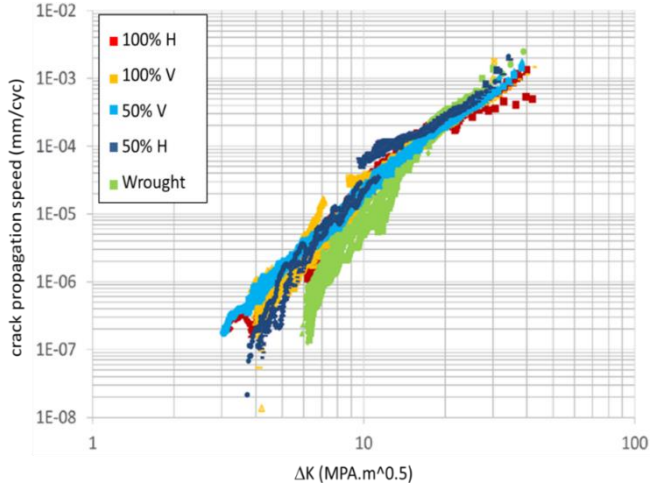
Ti-6Al-4V [Bagehorn 2017]

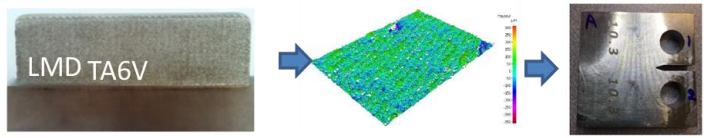


308LSi [Laghi2021]



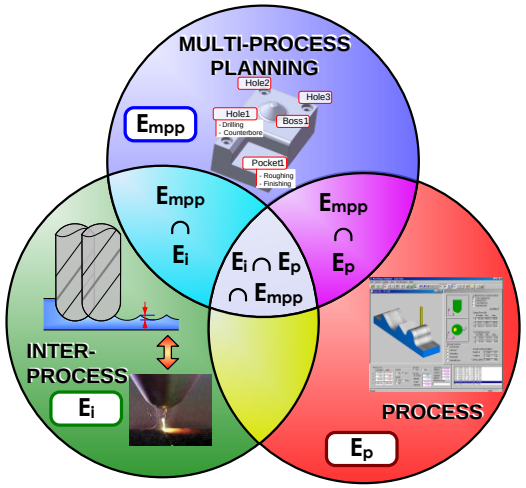
Ti-6Al-4V [Rauch, Hascoet, Manjaiah2019]

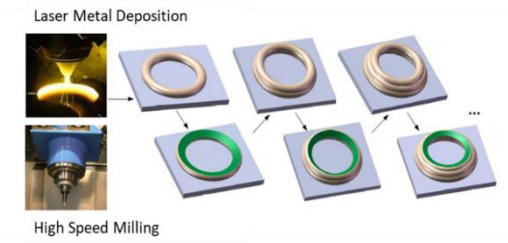




Material Removal Processes: High Speed Machining

- **Towards Hybrid approaches**
  - Process planning
    - Process selection and ordering
  - Surfaces accessibilities
  - Interprocess interactions
  - Numerical data chain for hybrid manufacturing

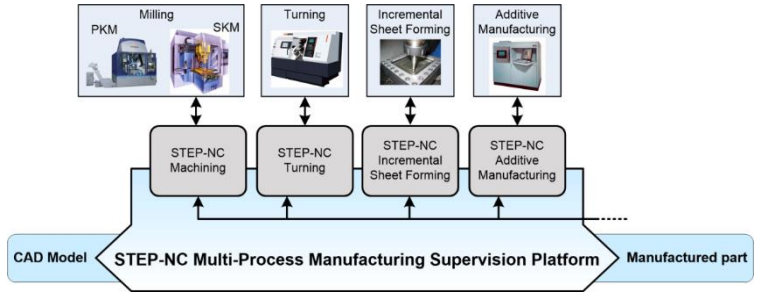




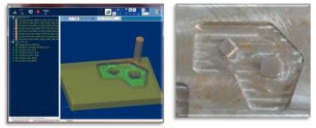
WAAM Al

WAAM CuAl

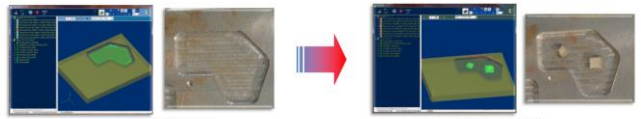
LMD 316L



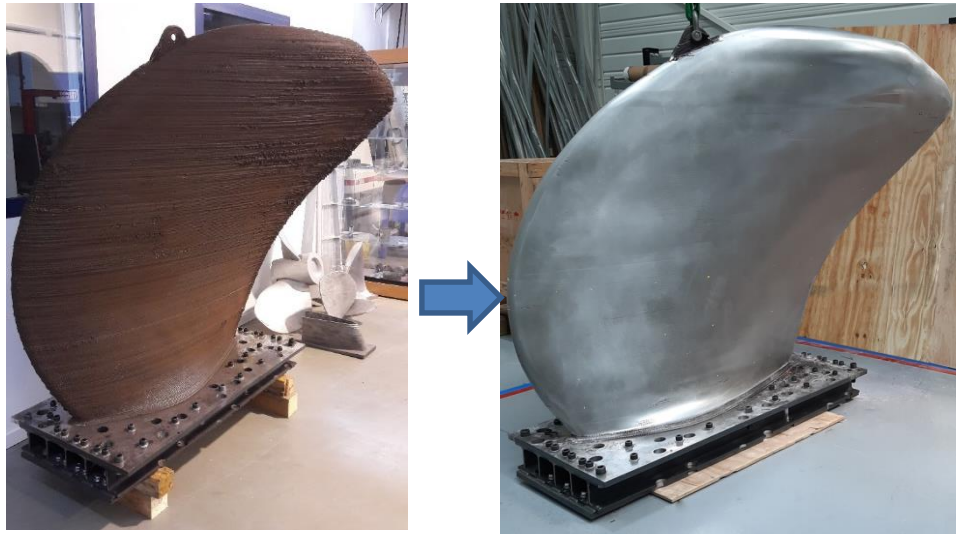
– **Usual Scenario**
  - **HSM**



– **Multi-process scenario**
  - **HSM and CLAD**



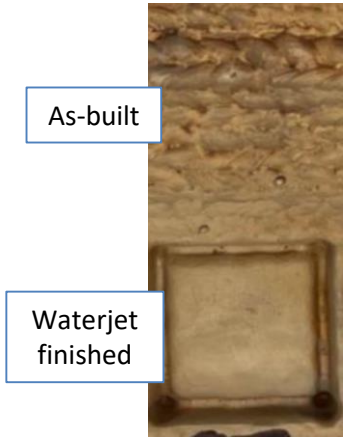
Pocket ***HSM*** Bosses ***LMD***



[Pechet, Hascoet, Rauch2020]

Material Removal Processes: Waterjet Machining

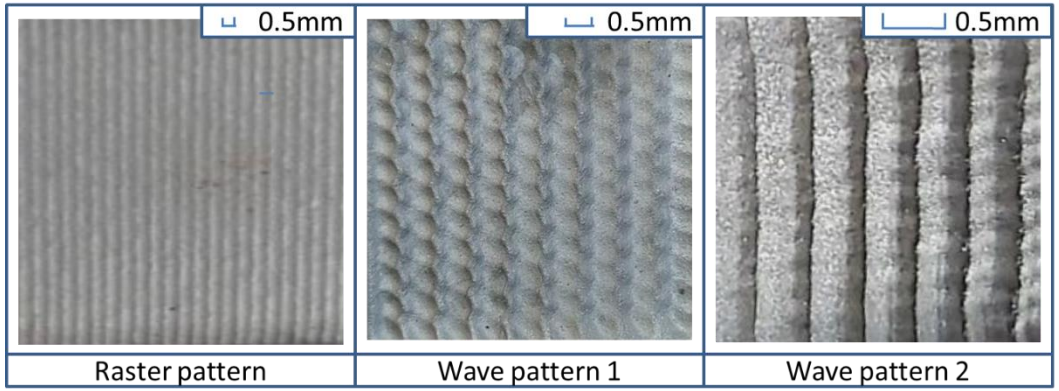
- **Principles**
  - Using the waterjet stream to polish AM surface
  - Very good performances
    - from R_a= 35µm to R_a= 6µm for Al alloys

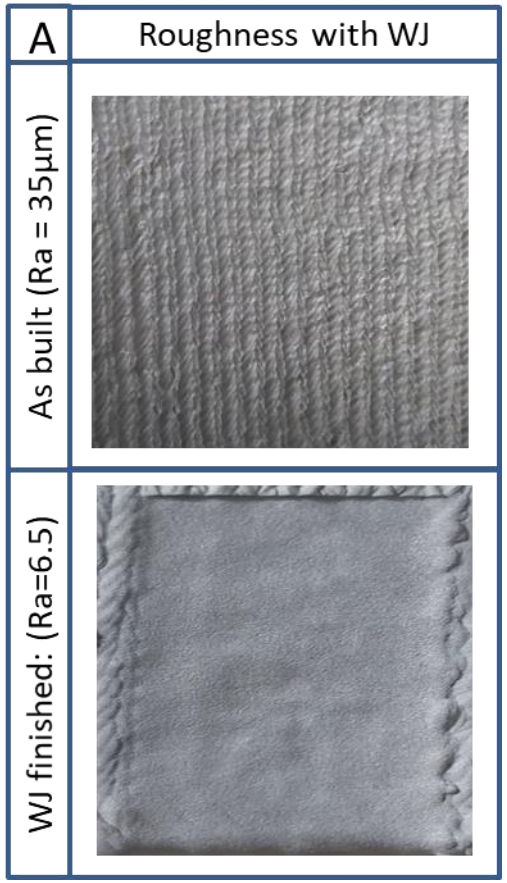


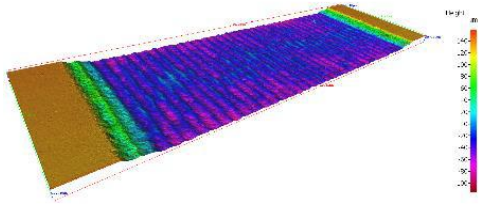
- **Interests**
  - No heat generated
  - Reduced cutting forces
  - Few constraints regarding material and as built surfaces
  - Addition of compressions residual stresses

- **Tool path control is the key to successful implementation**
  - Constant Feedrate
  - Patterns
  - Start & Stop control

- **Ability to textures surfaces**



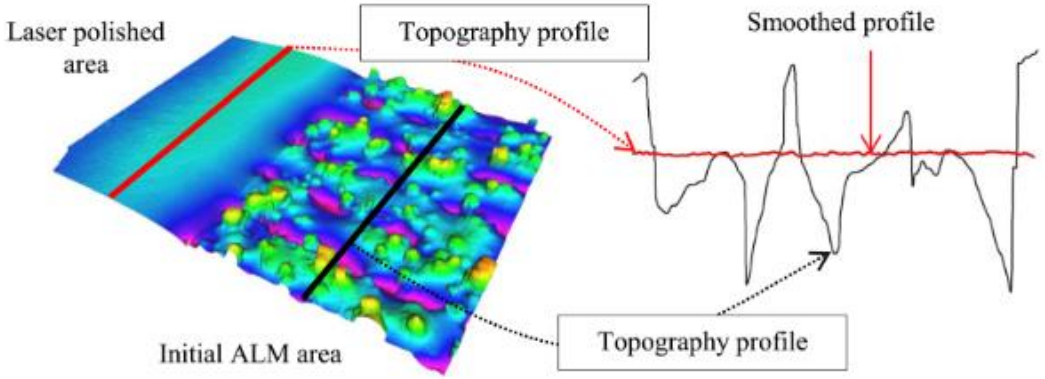




Surface properties modifications: Laser Polishing

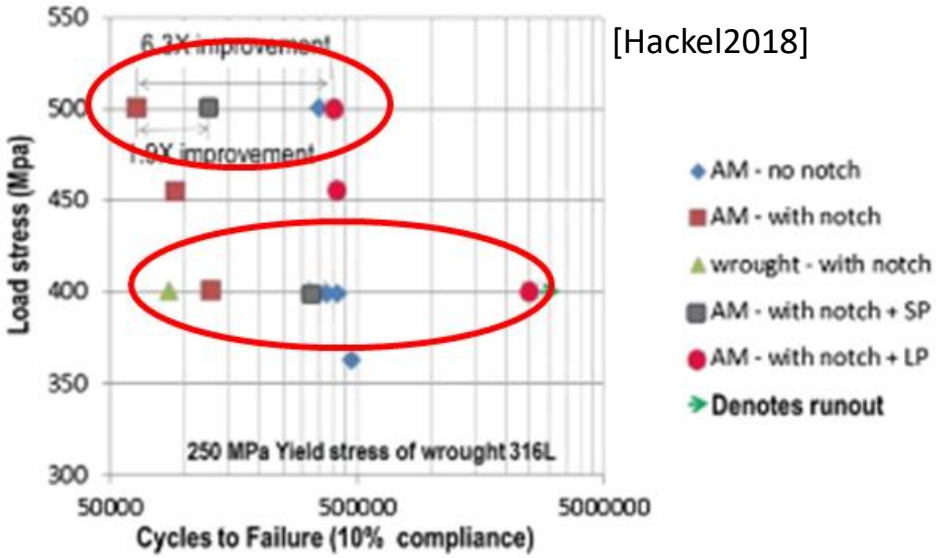
- **Principles**
  - Melting topography peaks with a laser
  - Surface tension of the melt pool reallocates molten material and smoothes the surface

[Rosa, Mognol, Hascoet2015]

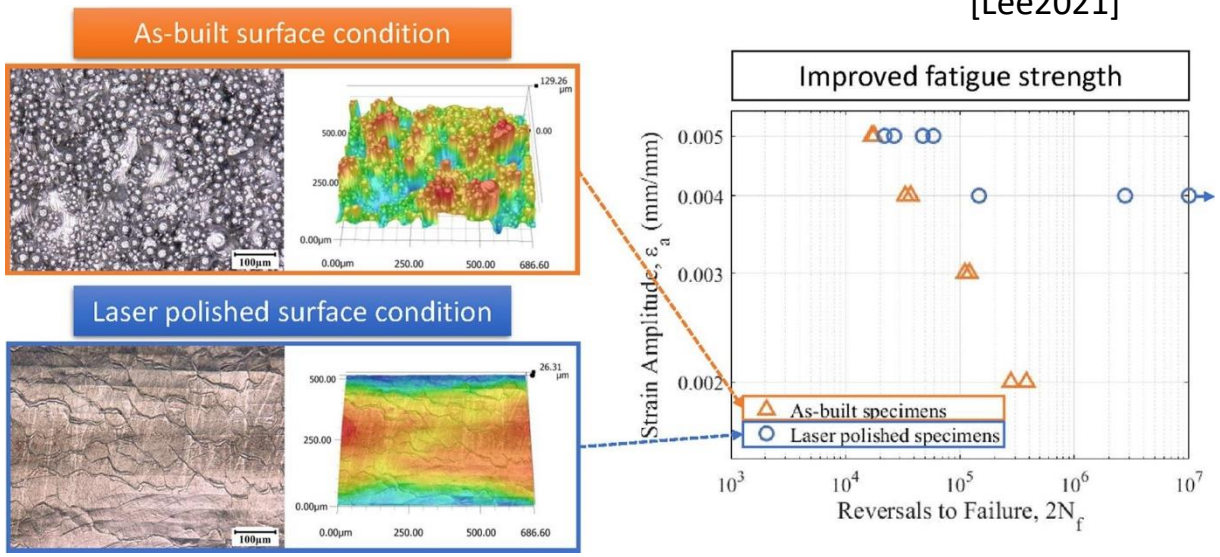


- **Improved surface properties vs as-built**
  - Fatigue Strength

[Hackel2018]



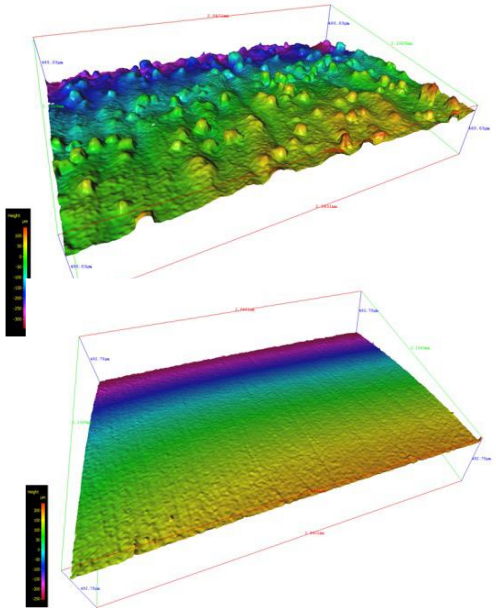
[Lee2021]



Surface properties modifications: Laser Polishing

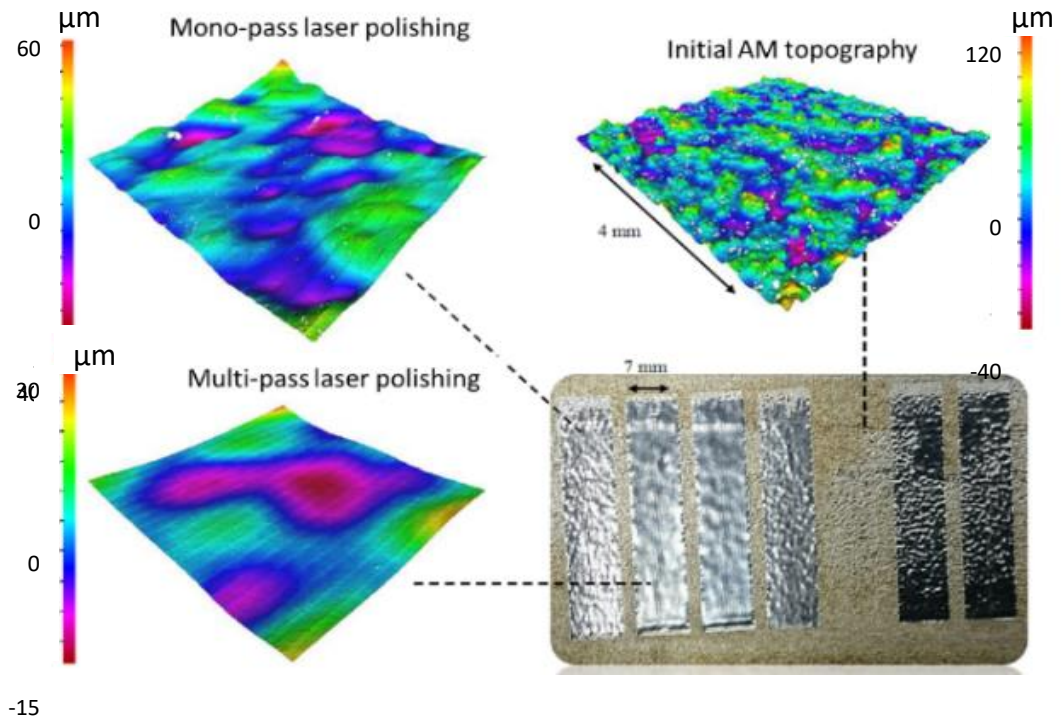
- **Interest for laser-based processes**
  - Defocusing the building laser
  - Hybrid approaches
  - Surface texturing available

- **Multiple passes to remove initial AM topology**



[Rosa, Mognol, Hascoet2015]

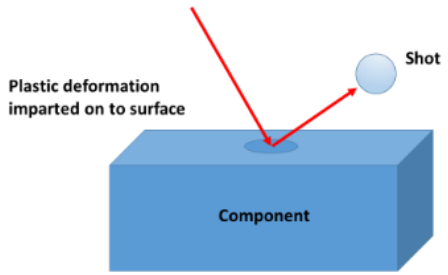
Indicator	As built	Laser polished
R_a	5.19	0.56
R_t	35.30	3.82
R_z	26.24	3.07
R_p	21.77	1.90
R_v	13.53	1.92



LMD TA6V

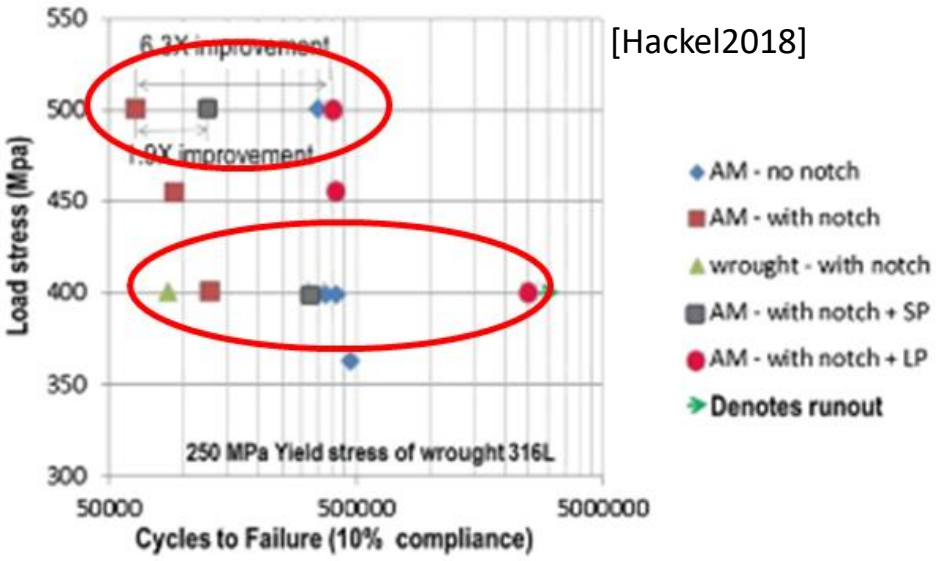
Surface properties modifications: Shot Peening

- **Principles**
  - Generate plastic deformation by bombarding small media on the surface

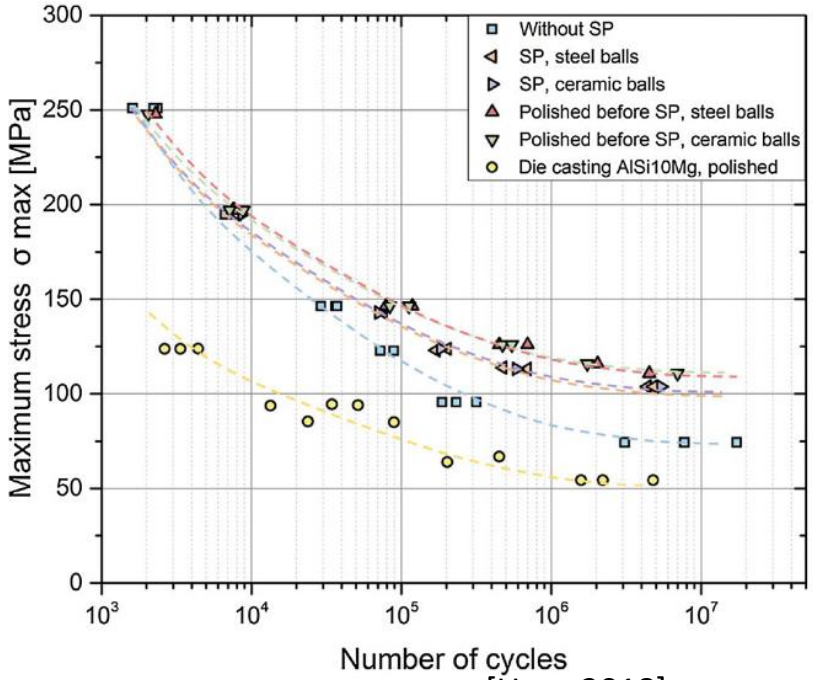


- **Objectives**
  - No phase transformation and no refinement of grain
  - Remove process dusts and unmelted patricles

- **Improved mechanichal properties vs as-built**



[Hackel2018]

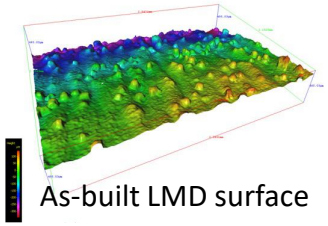


[Uzan 2018]

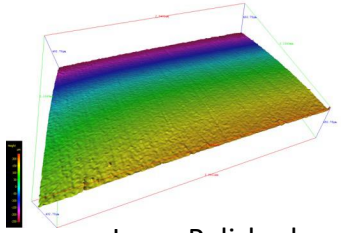
Surface properties modifications: Shot Peening

- **Challenges for AM parts**
  - Removing the initial surface aspects
  - Accessibility of surfaces

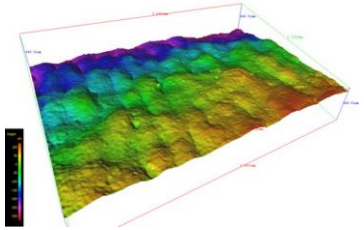
Indicator	As built	Shot peened	Laser polished
R_a	5.19	3.26	0.56
R_t	35.30	31.07	3.82
R_z	26.24	18.97	3.07
R_p	21.77	10.08	1.90
R_v	13.53	20.99	1.92



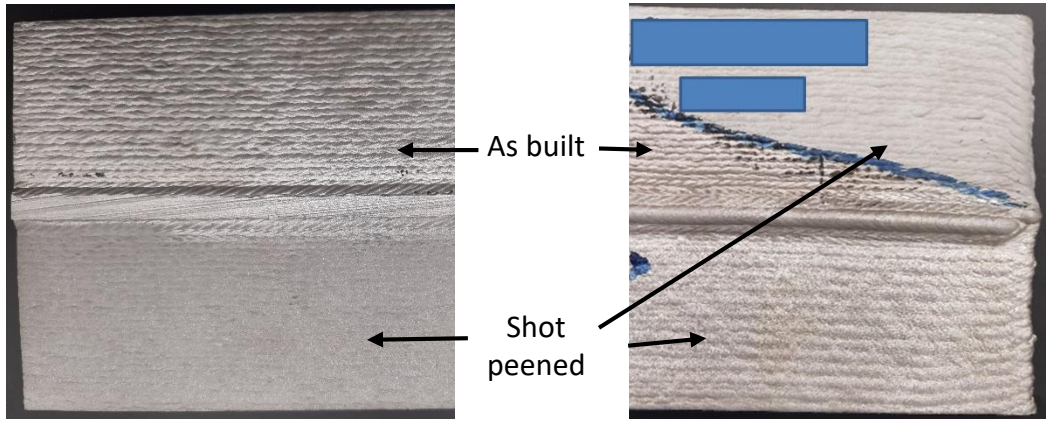
As-built LMD surface



Laser Polished

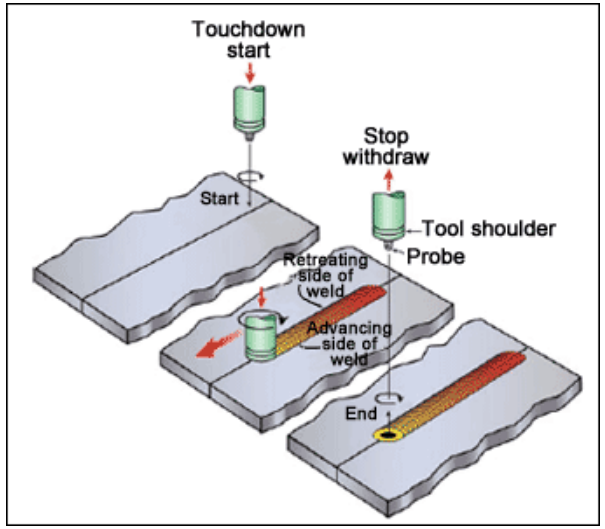


Shot peened



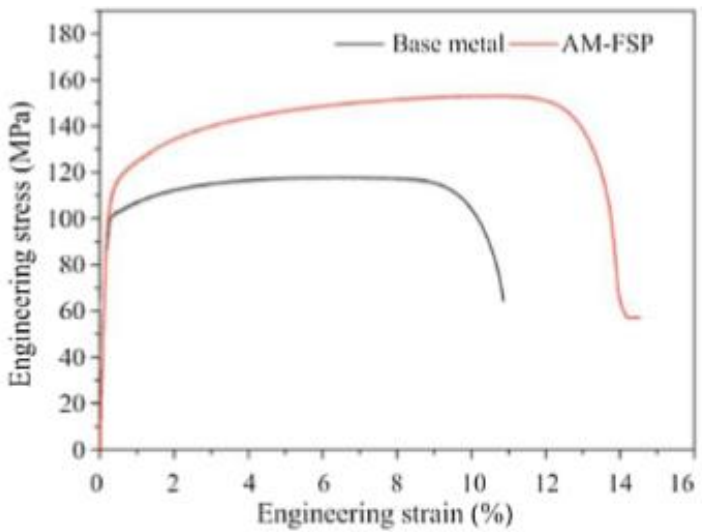
Surface properties modifications: Friction Stir Processing

- **Principles**
  - Plastic deformation,
  - Derived from Friction Stir Welding by making the tool rotate just below the surface



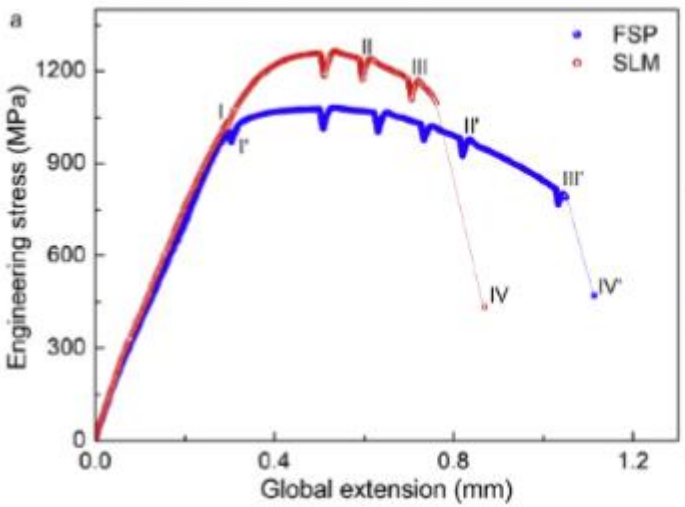
- **Improved mechanical properties**
  - Stress strain curves

Aluminium alloy [Mondal2019]



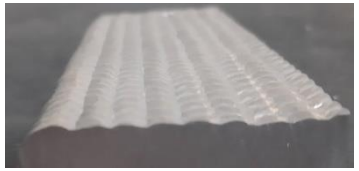
Ti-6Al-4V

[Huang 2019]

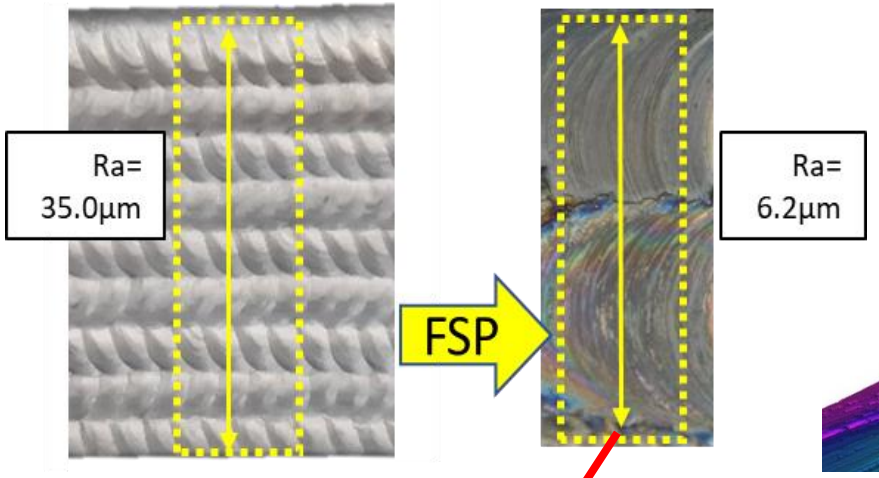


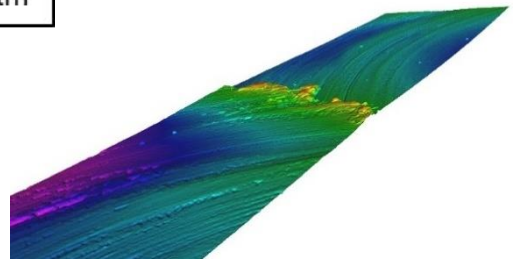
Surface properties modifications: Friction Stir Processing

- **Interest**
  - High productivity
  - Very good results (initial Ra = 35µm ; 6.2 µm after FSP)
  - Limited heat input impact compared to melting processes



- **Severe requirements on the equipment**
  - High process loads
  - High temperatures in the contact area
    - Geometry and material for the tool





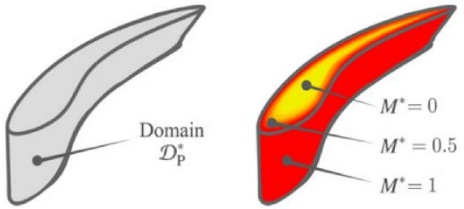
Other finishing Processes : Material Addition Processes

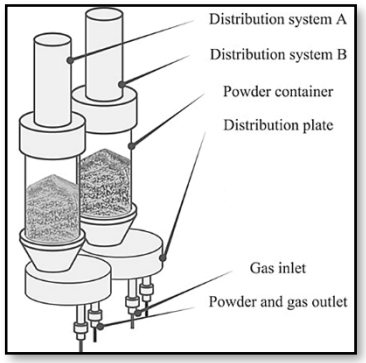
- **Principles**
  - Changing the initial surface properties by using another material bond on the AM surface

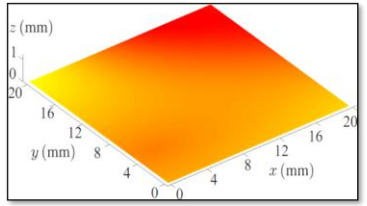
- **Objectives**
  - Enhance corrosion and wear resistance rather than surface roughness or mechanical properties

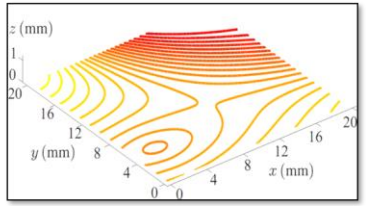
- **Interest of FGM approaches to meet the same goal**
  - Switching gradually from material A to material B during the AM process

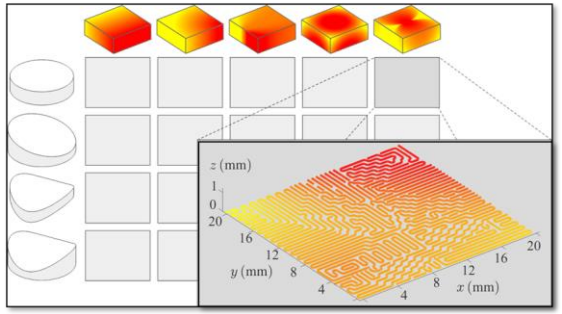
- **Challenge on tool paths generation to control the gradient**



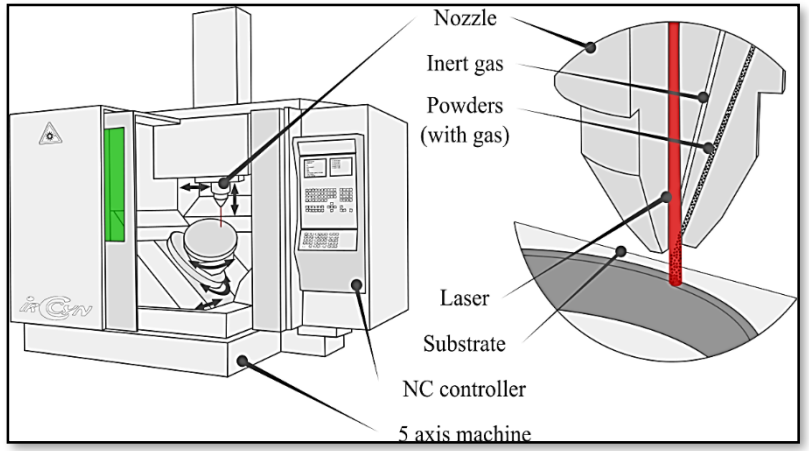








[Muller, Hascoet, Mognol2014]



Synthesis: performance comparison vs different criteria

Finishing Process	Surface roughness	Productivity	Low Heat input
High Speed Machining	+++	+	+++
Waterjet machining	+	+	+++
Mechanical Polishing	+++	+/-	+++
Laser Polishing	++	+/-	-
Shot Peening	+/-	++	+++
Friction Stir Processing	+++	+++	+/-
PAW/TIG remelting	+	+	--

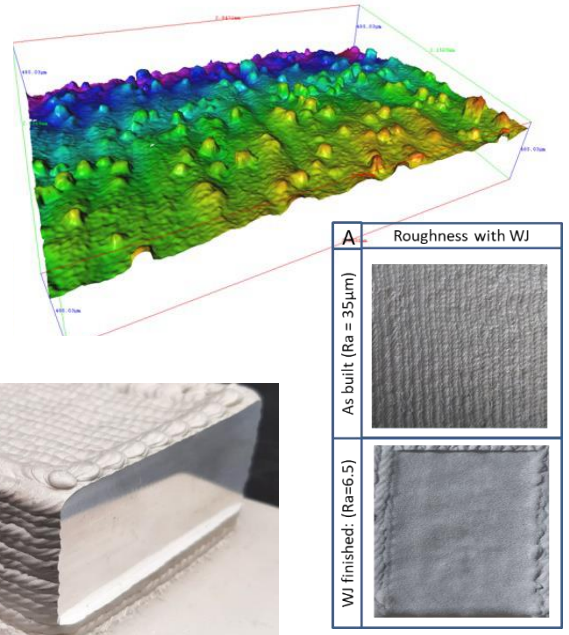
Conclusions

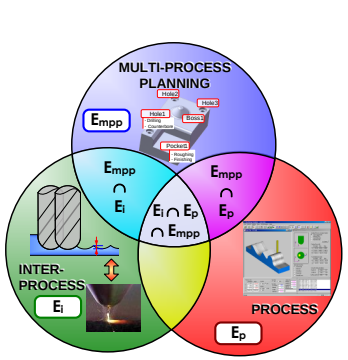
- **As-built AM surfaces have poor characteristics**
  - Peaks, unmelted particles, layer overlaps
  - Mechanical properties, especially fatigue strength can be affected

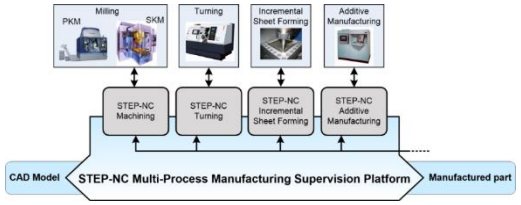
- **Most of the finishing processes are tool paths based**
  - Tool paths definition and control are critical
  - But local modifications are enabled to generate graded properties surfaces

- **Hybrid Approaches to enhance the performances**
  - Building AM and finishing operations scenarios
  - Towards Multiprocess manufacturing

- **Key challenges to investigate**
  - What are the functional requirements needed for AM surfaces?
  - Which surfaces are to be finished ?
  - What are the requirements to consider a surface as satisfactory?







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4èmes journées A3TS Traitements et parachèvements de pièces issues de fabrication additive

Une étude comparative de procédés disponibles pour le parachèvement de pièces réalisées par Fabrication Additive

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