PLASMA ELECTROLYTIC POLISHING: DEVELOPMENT OF THE PROCESS FOR METALLIC PARTS PRODUCED BY ADDITIVE MANUFACTURING

31/11/2022 - Colmar

CONFIDENTIAL CONTENT

Journées Traitements et parachèvements de pièces issues de fabrication additive (A3TS & Association française du titane)

Loic EXBRAYAT – Salomé PARRIAUX

IRT M2P
Institut de Recherche Technologique
Matériaux Métallurgie et Procédés

SAFRAN

Context

PLASMA ELECTROLYTIC POLISHING

NEMO PROJECT « NEXT ALM FINISHING PROCESSES »

Goals:

- Development and increase in maturity of different finishing processes for parts resulting from additive manufacturing.
- Treatment of technological samples (TRL4) and demonstrators (TRL6).
- Industrial transfer of finishing processes.

Duration & Budget

- 01/01/2022 – 31/12/2025 (4 years)
- 4 973 k€ (of which 55% are industrial)

Consortium

- 21 industrials & 3 academic laboratories

Donneurs d'ordres

AIRBUS, SAFRAN, LIEBHERR, Collins Aerospace, stryker, NAVAL GROUP, arianeGROUP

Fabricants de pièces ALM

lisi AEROSPACE, weare, VOLUM-e 3DComplexProduction, AddUp

Applicateurs TS

auchlin, chrome dur INDUSTRIEL, Satys surface treatment, GIT Galvanoplastie Industrielle Toulousaine, MINITUBES

Porteurs technologiques

ABC SwissTech, MicronX Fabricant d'Energie Positive, INEOSURF, Be2Sim, temisth

Laboratoires académiques

Institut UTINAM, CENTRALE LYON ENISE, CENTRALE NANTES

Work Packages

- Influence of the manufacturing conditions of ALM parts
- Finalization of the R&D work resulting from After ALM*
- Exploration of innovative technologies **
- Help in dimensioning
- Finishing for WAAM parts
- Recycling & ACV
- Transversal work

Link to A3TS presentations

*Maturation and industrialization of the chemical polishing process for base, Ti, Al, Ni or Fe alloys (J. Frayret; L. Exbrayat; J. Rolet).

*Electrolytic plasma polishing: developments for the finishing of metallic additive manufacturing parts (S. Parriaux; L. Exbrayat).

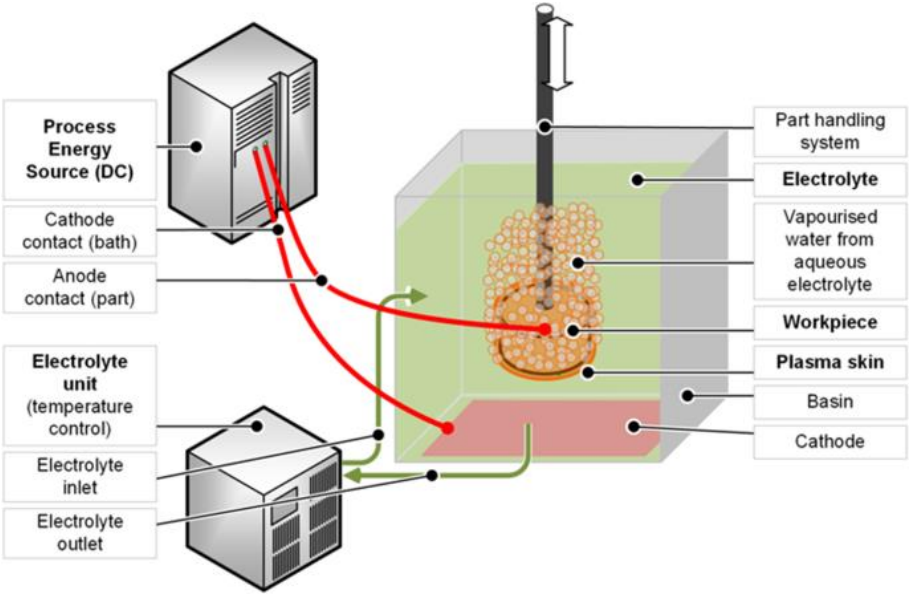
*Scale-up of an electro-polishing process for titanium alloy parts from additive manufacturing (S. Parriaux; M. Marcelet).

**New tribofinishing solutions applied to ALM parts (J. Rolet; S. Chagnard).

PLASMA ELECTROLYTIC POLISHING

PRINCIPLE OF THE PLASMA POLISHING PROCESS

Principle of the process*



- Anodic polarized part;
- Due to the process conditions, formation of a vapor skin which completely surrounds the workpiece → A plasma layer can be established inducing a significant temperature increase which lead to the dissolution and polishing of the metallic part;
- Combination of a plasma electrolysis and classic electrolysis
- Aqueous electrolyte (about 90%) ;
- No shaped cathode ;
- Treatment time can be adjusted according to the initial roughness.

GOAL: Develop and mature the plasma electrolytic polishing process for the four reference materials **TA6V, Inconel 718 and stainless steel 316**

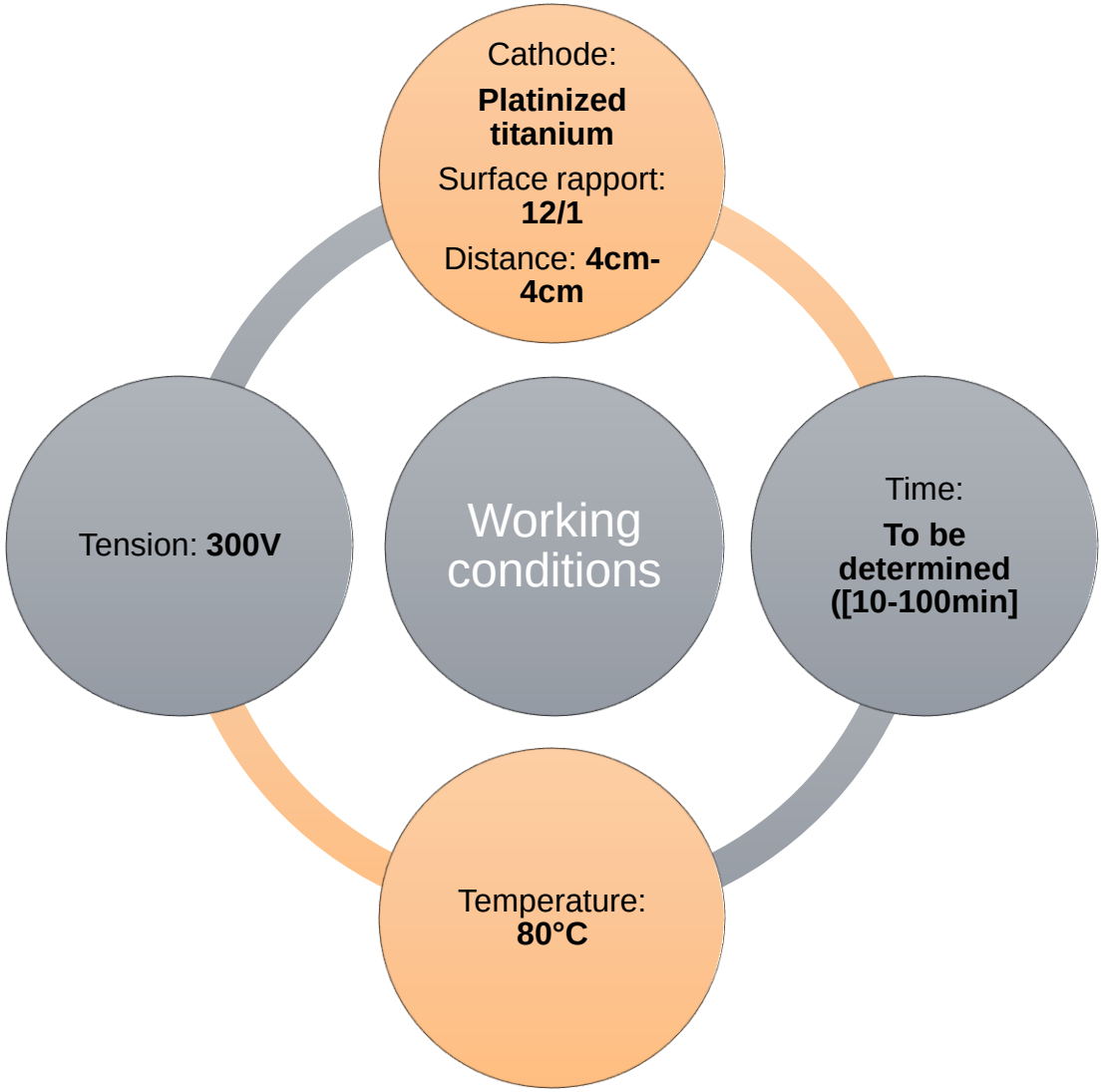
*K. Nestler, F. Böttger-Hiller, W. Adamitzki, G, Glowa, H. Zeidler, A, Schubert ; Plasma Electrolytic Polishing – an Overview of Applied Technologies and Current Challenges to Extend the Polishable Material Range ; Procedia CIRP 42 (2016)

PLASMA ELECTROLYTIC POLISHING

PROCESSING CONDITIONS FROM AFTER ALM

PeP first tests (IRTM2P Duppigheim) on 304L stainless steel

Parameters of PeP inco718 SLM



INCONEL 718 (%m)					
Ni +Co	**Cr**	**Mo**	**Ti**	**Al**	**Nb +Ta**
50-55	17-21	2.8-3.3	0.65-1.15	0.2-0.8	4.75-5.5

PLASMA ELECTROLYTIC POLISHING
PROCESSING EQUIPMENT

Treatment bath

Plasma rectifier

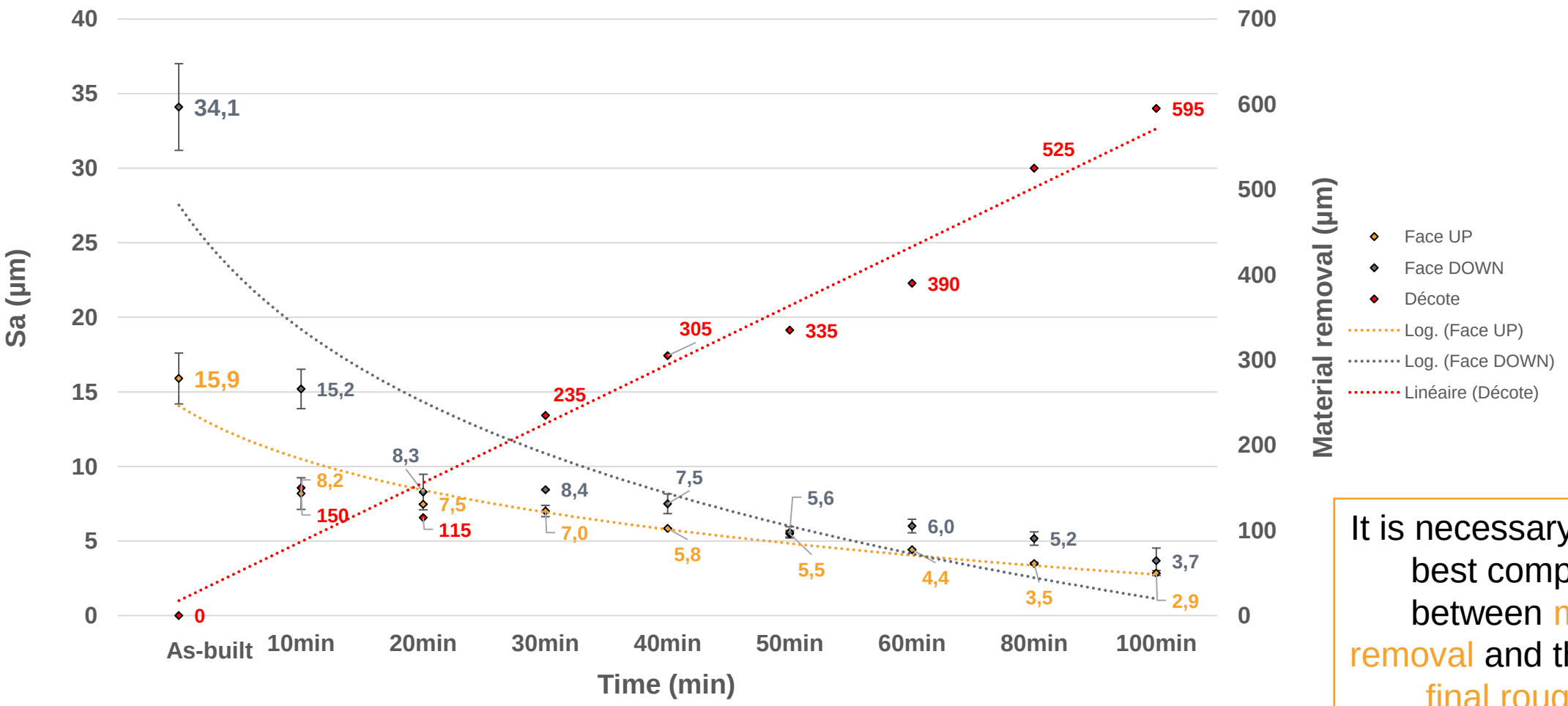
Plasma electrolytical polishing on Inconel alloy

IRT M2P
Institut de Recherche Technologique
Matériaux Métallurgie et Procédés

PLASMA ELECTROLYTIC POLISHING

ROUGHNESS/MATERIAL REMOVAL EVOLUTION ON 1 SAMPLE VS TIME

Inconel 718 SLM

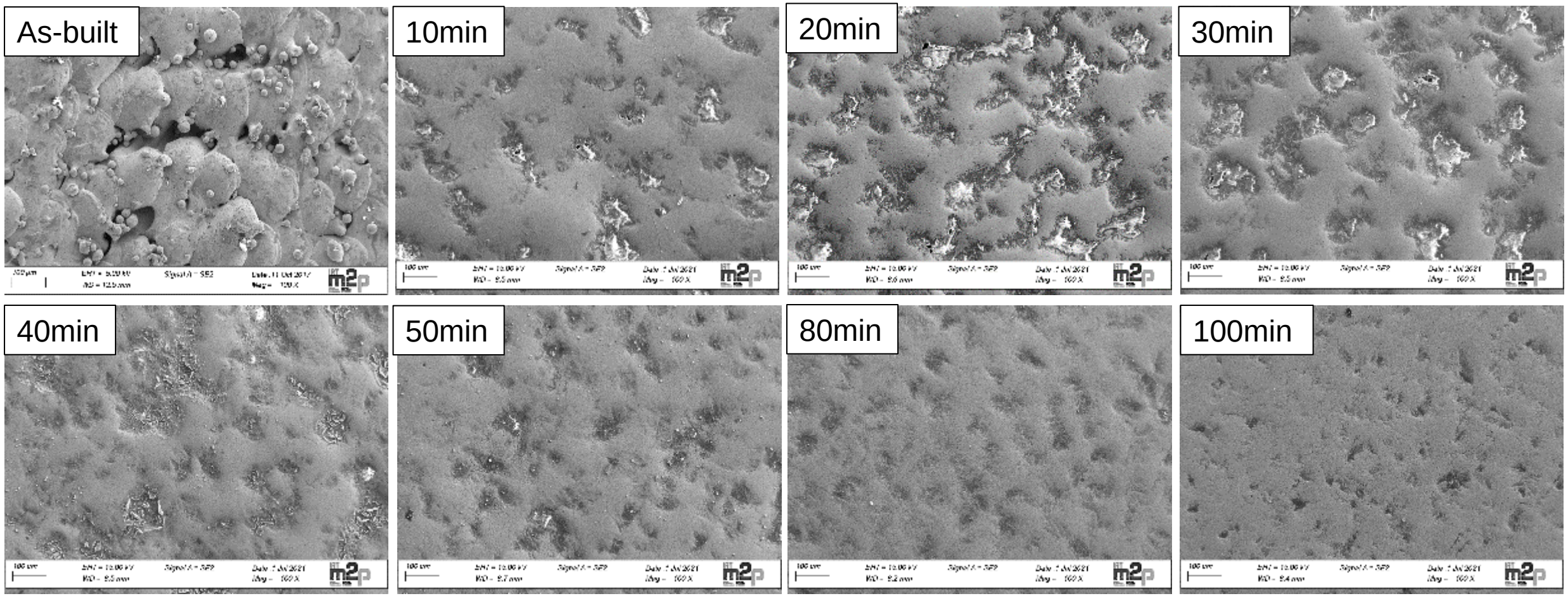


It is necessary to find the best compromise between material removal and the required final roughness

PLASMA ELECTROLYTIC POLISHING

ADDITIONAL RESULTS: SEM OBSERVATIONS (X100)

Inconel 718 SLM



Dissolution of unmelted particles on the surface of the samples

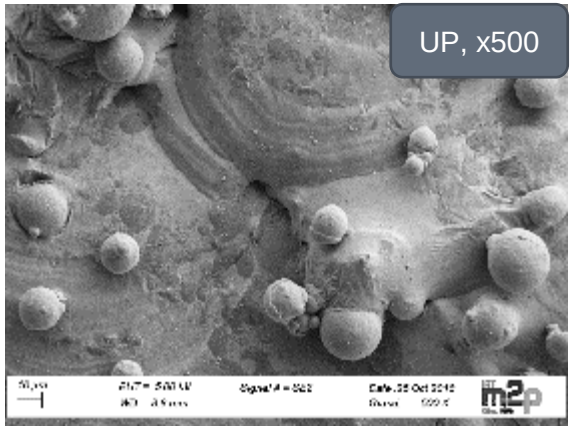
PLASMA ELECTROLYTIC POLISHING

RESULTS: ROUGHNESS MEASUREMENTS AND SEM OBSERVATIONS

Inconel 718 SLM

After 50 min of treatment

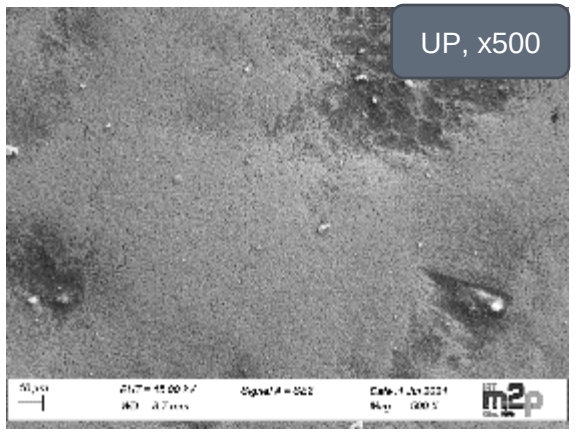
As-built



- Sa_{Upskin} : **15,9 ± 1,7 µm**
- $Sa_{Downskin}$: **34,1 ± 2,9 µm**

- Sz_{Upskin} : **220,3 ± 24,7 µm**
- $Sz_{Downskin}$: **272,6 ± 20,2 µm**

After PeP



- Sa_{Upskin} : **5,5 ± 0,2 µm**
- $Sa_{Downskin}$: **5,6 ± 0,4 µm**

- Sz_{Upskin} : **50,6 ± 6,1 µm**
- $Sz_{Downskin}$: **42,0 ± 3,3 µm**

- Material removal ≈ **280 µm/face**

PLASMA ELECTROLYTIC POLISHING

RESULTS: ROUGHNESS MEASUREMENTS AND SEM OBSERVATIONS

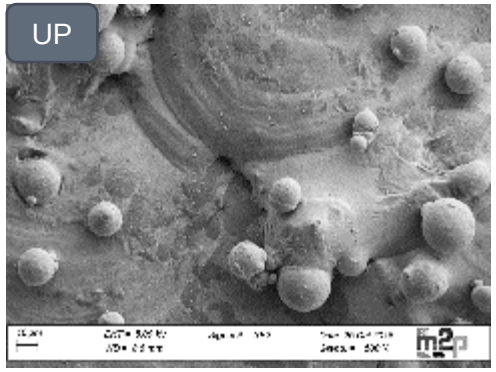
Evaluation on other grades of Ni based alloys (50 min of treatment)

Inconel 718 SLM

Initial roughness

- Sa_{Upskin} : **15,9 ± 1,7 µm**
- $Sa_{Downskin}$: **34,1 ± 2,9 µm**

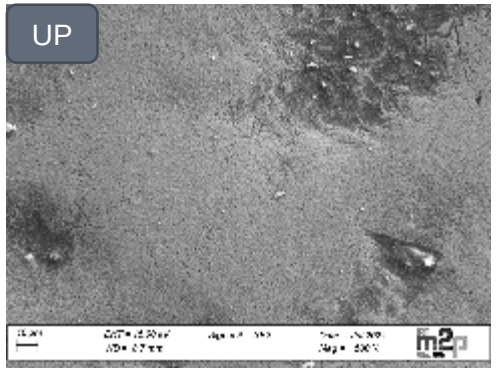
- Sz_{Upskin} : **220,3 ± 24,7 µm**
- $Sz_{Downskin}$: **272,6 ± 20,2 µm**



Final roughness

- Sa_{Upskin} : **5,5 ± 0,2 µm**
- $Sa_{Downskin}$: **5,6 ± 0,4 µm**

- Sz_{Upskin} : **50,6 ± 6,1 µm**
- $Sz_{Downskin}$: **42,0 ± 3,3 µm**

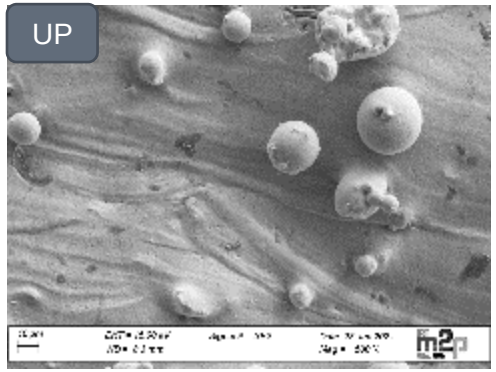


Inconel 625 SLM

Initial roughness

- Sa_{upskin} : **6,3 ± 0,4 µm**
- $Sa_{FDownskin}$: **6,6 ± 0,5 µm**

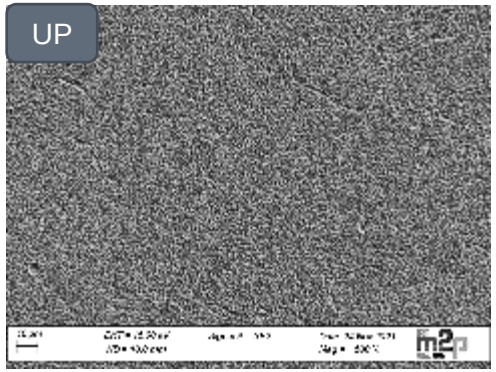
- Sz_{upskin} : **85,1 ± 12,8 µm**
- Sz_{down}: **81,1 ± 17,4 µm**



Final roughness

- Sa_{upskin} : **0,8 ± 0,0 µm**
- $Sa_{downskin}$: **1,0 ± 0,3 µm**

- Sz_{upskin} : **7,6 ± 1,8 µm**
- $Sz_{downskin}$: **9,6 ± 0,7 µm**



PLASMA ELECTROLYTIC POLISHING

RESULTS : ROUGHNESS MEASUREMENTS AND SEM OBSERVATIONS

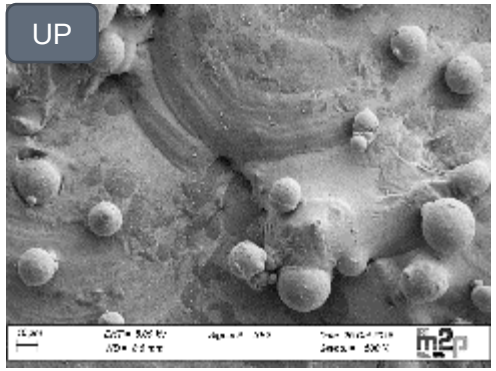
Evaluation on other grades of Ni based alloys (50 min of treatment)

Inconel 718 SLM

Initial roughness

- Sa_{Upskin} : **15,9 ± 1,7 µm**
- $Sa_{Downskin}$: **34,1 ± 2,9 µm**

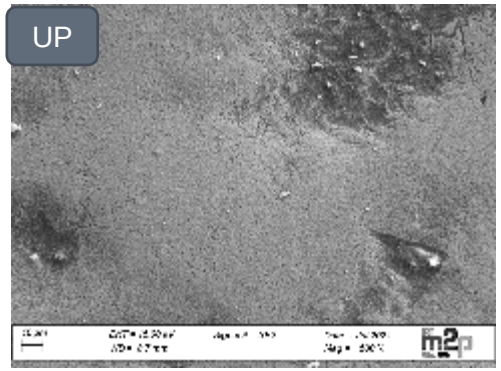
- Sz_{Upskin} : **220,3 ± 24,7 µm**
- $Sz_{Downskin}$: **272,6 ± 20,2 µm**



Final roughness

- Sa_{Upskin} : **5,5 ± 0,2 µm**
- $Sa_{Downskin}$: **5,6 ± 0,4 µm**

- Sz_{Upskin} : **50,6 ± 6,1 µm**
- $Sz_{Downskin}$: **42,0 ± 3,3 µm**

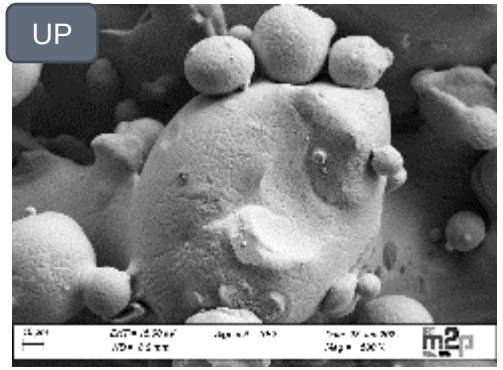


HASTELLOY X SLM

Initial roughness

- Sa_{Upskin} : **22,5 ± 4,8 µm**
- $Sa_{Downskin}$: **30,2 ± 5,5 µm**

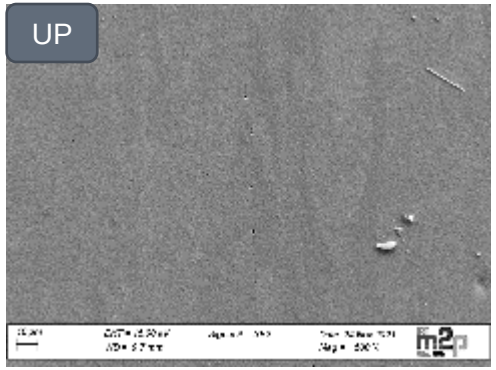
- Sz_{Upskin} : **199,7 ± 29,9 µm**
- $Sz_{Downskin}$: **232,3 ± 34,0 µm**



Final roughness

- Sa_{Upskin} : **2,3 ± 0,1 µm**
- $Sa_{Downskin}$: **2,7 ± 0,6 µm**

- Sz_{Upskin} : **21,3 ± 9,4 µm**
- $Sz_{Downskin}$: **18,9 ± 0,8 µm**



PLASMA ELECTROLYTIC POLISHING
RESULTS: ROUGHNESS MEASUREMENTS

Inconel 718 SLM

PeP on tubes

As-built

- Sa_{Ext} : **6,2 ± 0,8 µm**
- Sz_{Ext} : **81,4 ± 14,7 µm**

After PeP

- Sa_{Ext} : **1,9 ± 0,6 µm**
- Sz_{Ext} : **25,7 ± 6,3 µm**

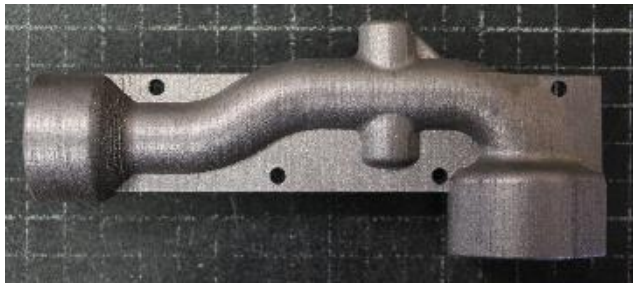
PLASMA ELECTROLYTIC POLISHING

RESULTS: MACROSCOPIC OBSERVATIONS AND ROUGHNESS MEASUREMENTS

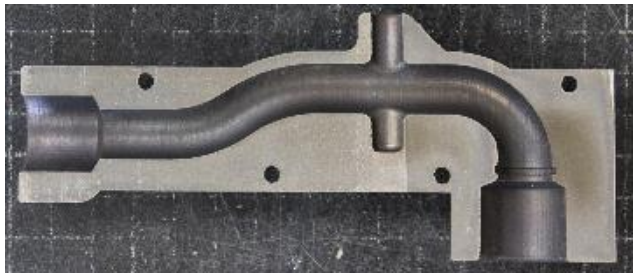
Inconel 718 SLM

PeP on complex shape part

As-built

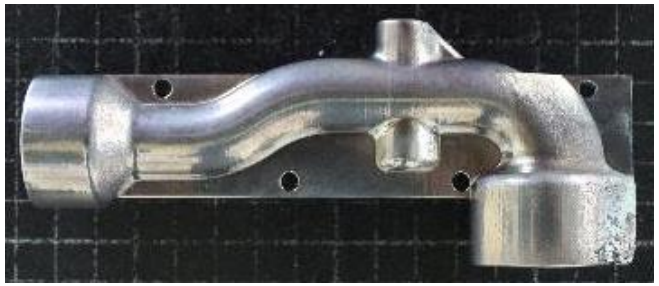


- Sa_{Ext} : **9,2 ± 1,1 µm**
- Sz_{Ext} : **122,8 ± 17,1 µm**



- Sa_{Int} : **4,9 ± 0,8 µm**
- Sz_{Int} : **89,0 ± 22,8 µm**

After PeP



- Sa_{Ext} : **2,4 ± 1,2 µm**
- Sz_{Ext} : **24,1 ± 9,2 µm**

- Sa_{Int} : **4,6 ± 1,7 µm**
- Sz_{Int} : **80,5 ± 27,1 µm**

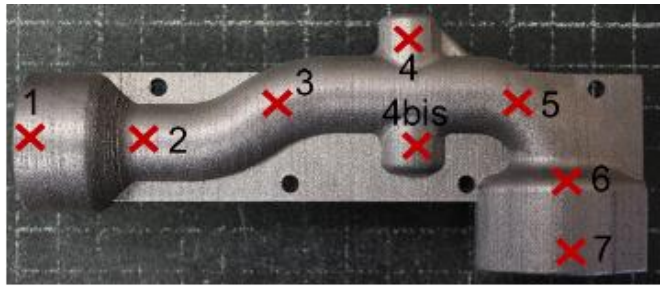
PLASMA ELECTROLYTIC POLISHING

RESULTS: EVOLUTION OF THE ROUGHNESS ACCORDING OF THE PART AREAS

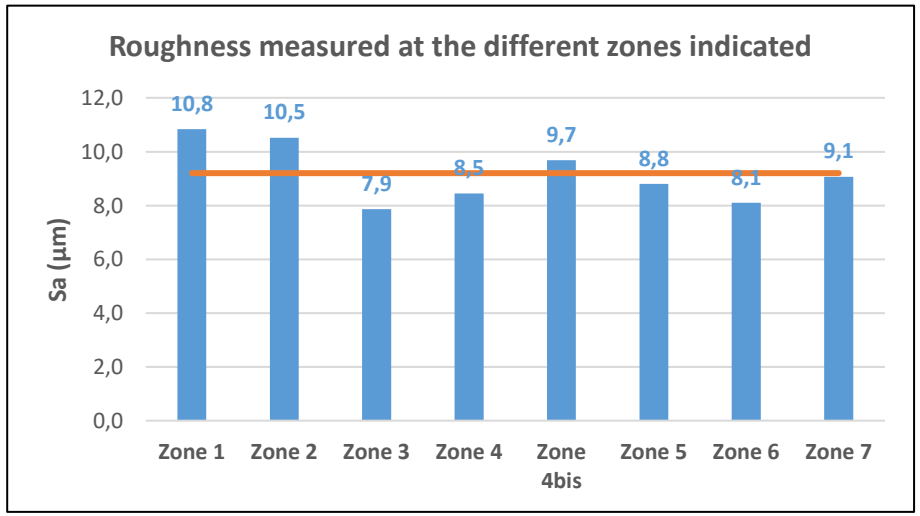
Inconel 718 SLM

PeP on complex shape part

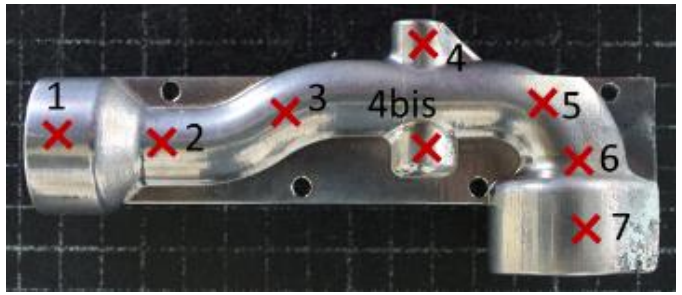
As-built



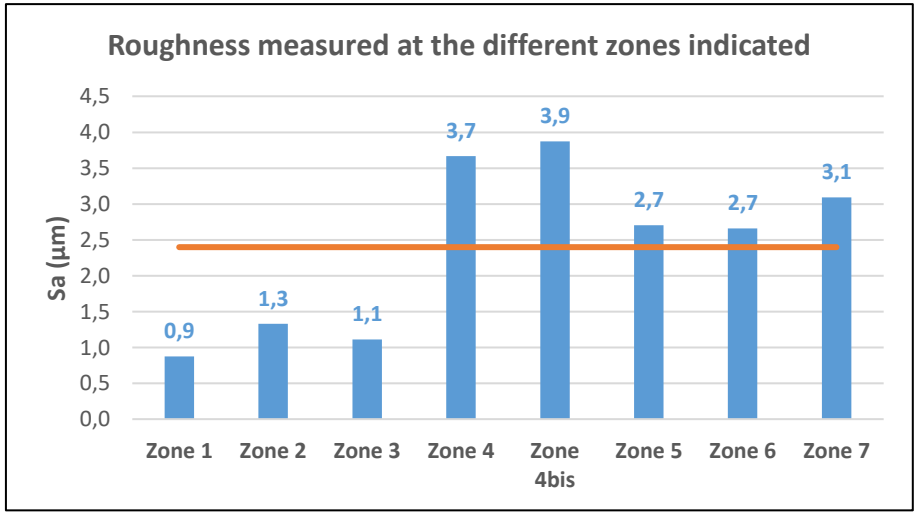
- Sa_{Ext} : **9,2 ± 1,1 µm**
- Sz_{Ext} : **122,8 ± 17,1 µm**



After PeP



- Sa_{Ext} : **2,4 ± 1,2 µm**
- Sz_{Ext} : **24,1 ± 9,2 µm**



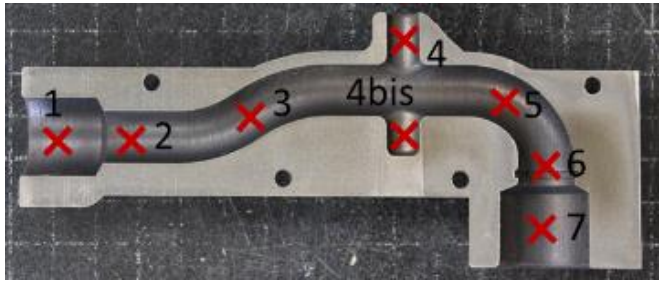
PLASMA ELECTROLYTIC POLISHING

RESULTS: ROUGHNESS MEASUREMENTS

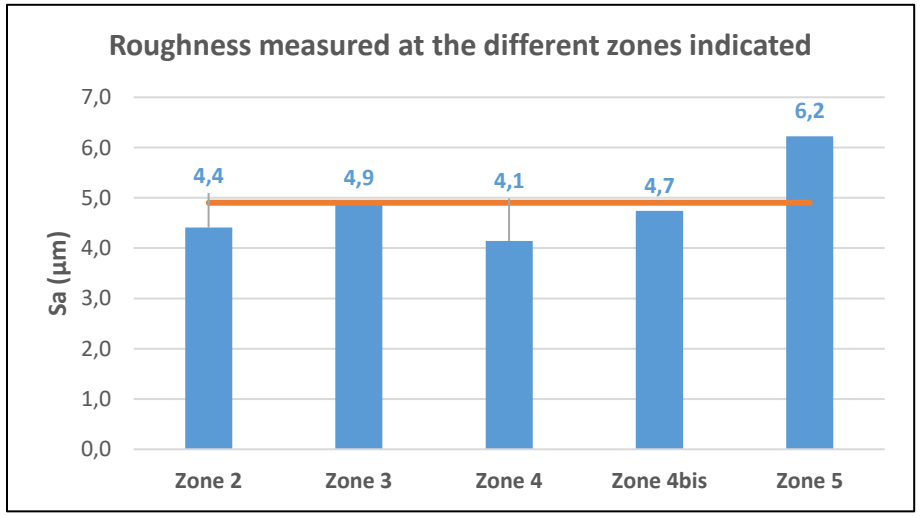
Inconel 718 SLM

PeP on complex shape part

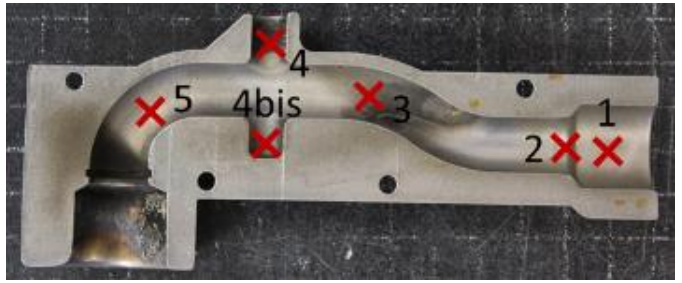
As-built



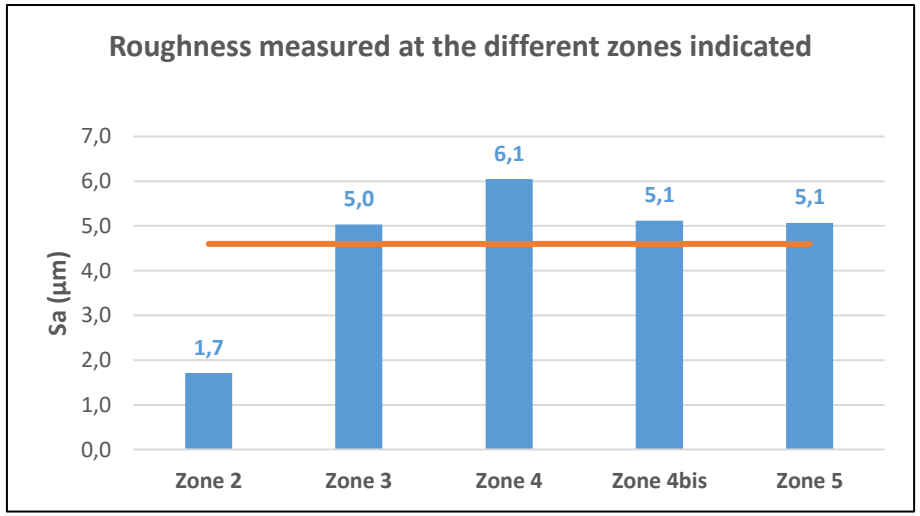
- Sa_{Int} : **4,9 ± 0,8 µm**
- Sz_{Int} : **89,0 ± 22,8 µm**



After PeP



- Sa_{Int} : **4,6 ± 1,7 µm**
- Sz_{Int} : **80,5 ± 27,1 µm**



PLASMA ELECTROLYTIC POLISHING

RESULTS: ROUGHNESS MESUREMENTS

PeP on fatigue test specimen

As-built

- Sa : **5,0 ± 1,0 µm**
- Sz : **67,7± 10,9 µm**

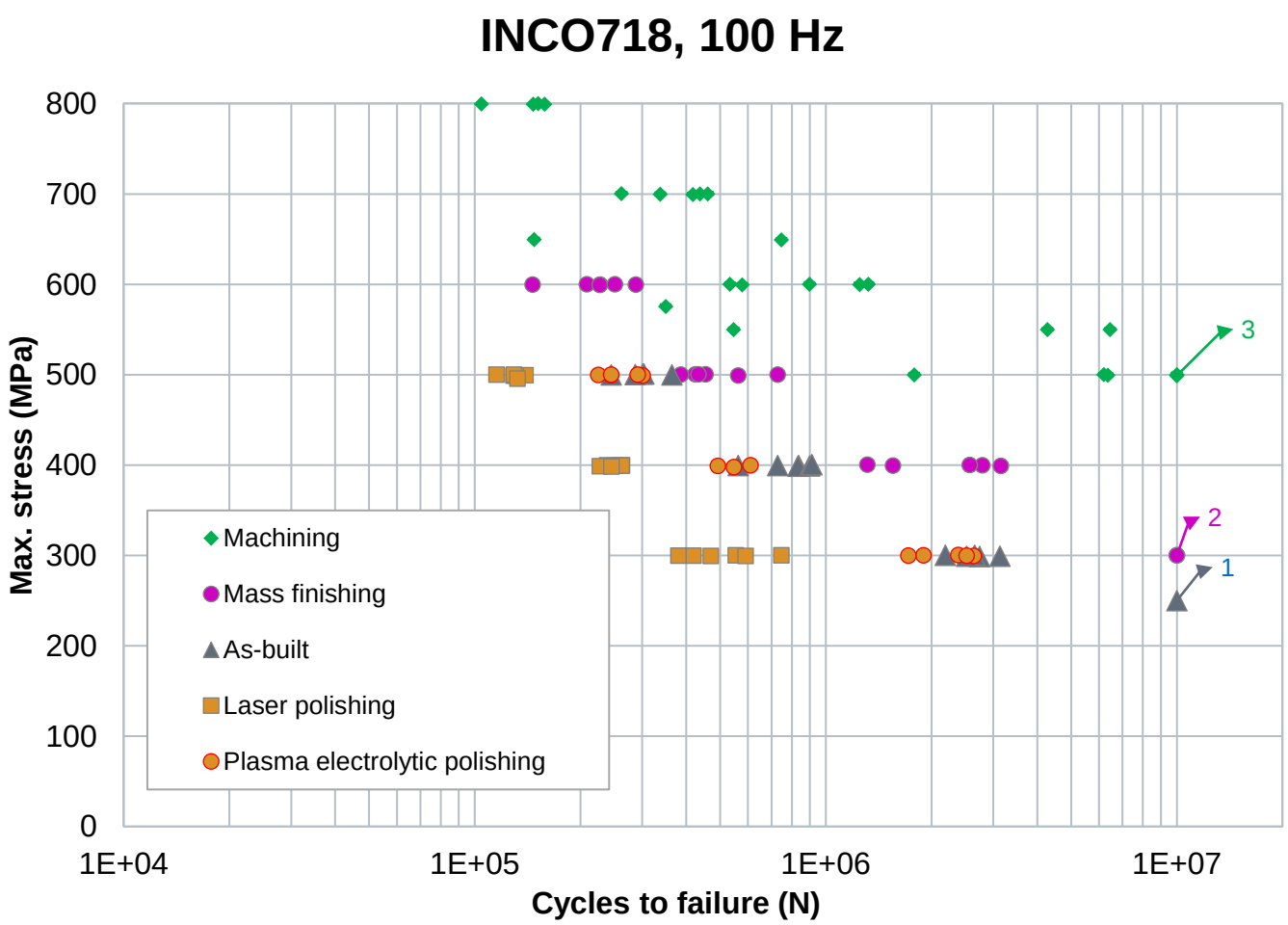
After PeP

- Sa : **0,9 ± 0,2 µm**
- Sz :**12,2 ± 3,5 µm**

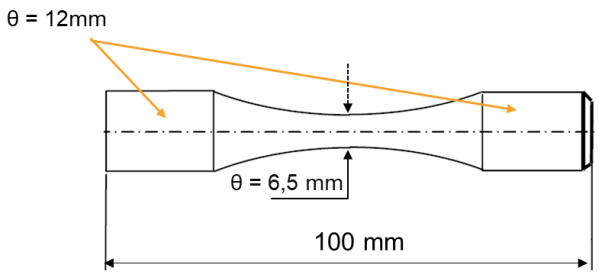
PLASMA ELECTROLYTIC POLISHING

RESULTS: FATIGUE TEST

Results of fatigue test (rotating bending test): comparison with other post-processing treatments



Specimen plan



Testing conditions:

- Kt 1,035
- Ambient temperature
- Censure to 10 M cycles
- F = 100 Hz
- R = -1

Application of PeP on Titanium alloys: first tests

PLASMA ELECTROLYTIC POLISHING

RESULTS: MACROSCOPIC OBSERVATIONS AND EVOLUTION OF ROUGHNESS

TA6V

After 40 min of treatment on TA6V SLM

As-built

- Sa_{Upskin} : **22,7 ± 4,7 µm**
- $Sa_{Downskin}$: **49,7 ± 6,8 µm**

- Sz_{Upskin} : **423,8 ± 81,7 µm**
- $Sz_{Downskin}$: **283,9 ± 70,1 µm**

After PeP

- Sa_{Upskin} : **3,5 ± 0,4 µm**
- $Sa_{Downskin}$: **4,2 ± 0,2 µm**

- Sz_{Upskin} : **28,5 ± 3,1 µm**
- $Sz_{Downskin}$: **37,0 ± 4,3 µm**

Conclusions & Perspectives

PLASMA ELECTROLYTIC POLISHING

CONCLUSIONS & PERSPECTIVES

- Easy to apply
- Aqueous based electrolyte
- Interesting surface roughness reduction on different alloys: Inconel 718, Inconel 625, Hastelloy X
- Relatively homogeneous treatment of simple parts (plates, tubes, fatigue test samples…)
- Difficulties to treat the inner parts of complex samples
- Promising results on TA6V