UNIVERSITA' DEGLI STUDI DI PADOVA

Dipartimento di Ingegneria Industriale DII

Corso di Laurea in Ingegneria Meccanica

Relazione per la prova finale

Optimization of AlSi7Mg printing parameters

Tutor Universitario: Prof Stefania Bruschi

Adriano Finetti 1219090

Anno Accademico 2023/2024

Measurements methods

The density measurements were performed on a scale using the Archimedes principle.

To measure the porosity of the samples we inglobated them in resin to better handle them, then we exposed one of the internal layers by removing material with a disc sander and a lapping machine.

The acquisition of a 3d scan of the sample’s surface was obtained with a profilometer and then converted to a 2d image with the program SensoScan. Then using the program ImageJ we identified all the pixels in the image that make up the porosity and calculated their area as a percentage of the image’s total area.

The roughness was calculated within SensoScan using the previously obtained 3d scan. The surfaces analysed are the top surface parallel to the layer lines (up) and any surface perpendicular to the layer lines (side).

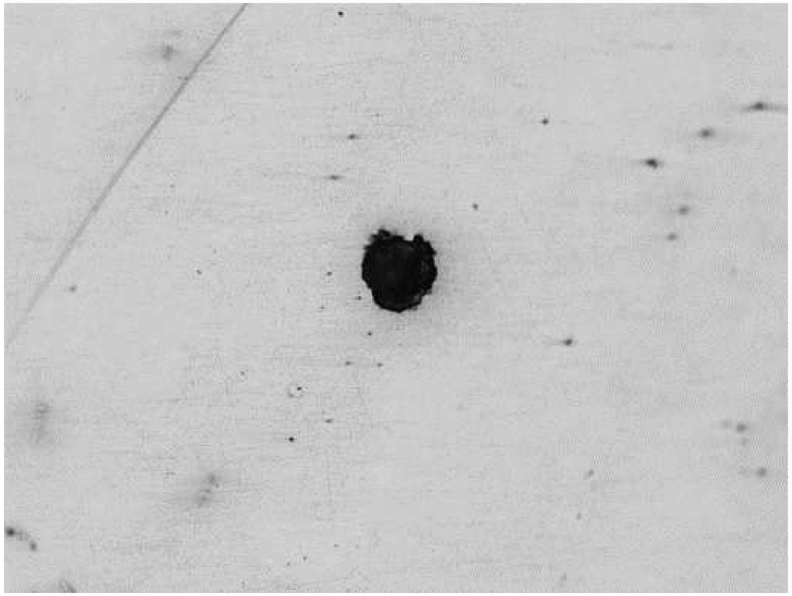
Samples

- The following samples were obtained by changing various key printing parameters one at a time to observe their effects on printing quality.
- Samples 1-3 were printed changing laser power and scanning speed to deliver a constant energy density to the powder.
- Samples 4-7 were printed changing laser power and scanning speed to deliver a different energy density to the powder.
- Samples 8-15 were printed changing hatch distance only.
- The layer height was set at a constant value for all samples produced.

Porosity types

The irregularly shaped porosity, also called spatter, happens when powder particles are ejected from the powder bed by the laser or don't get melted completely creating cavities when internal layers are exposed to the air.

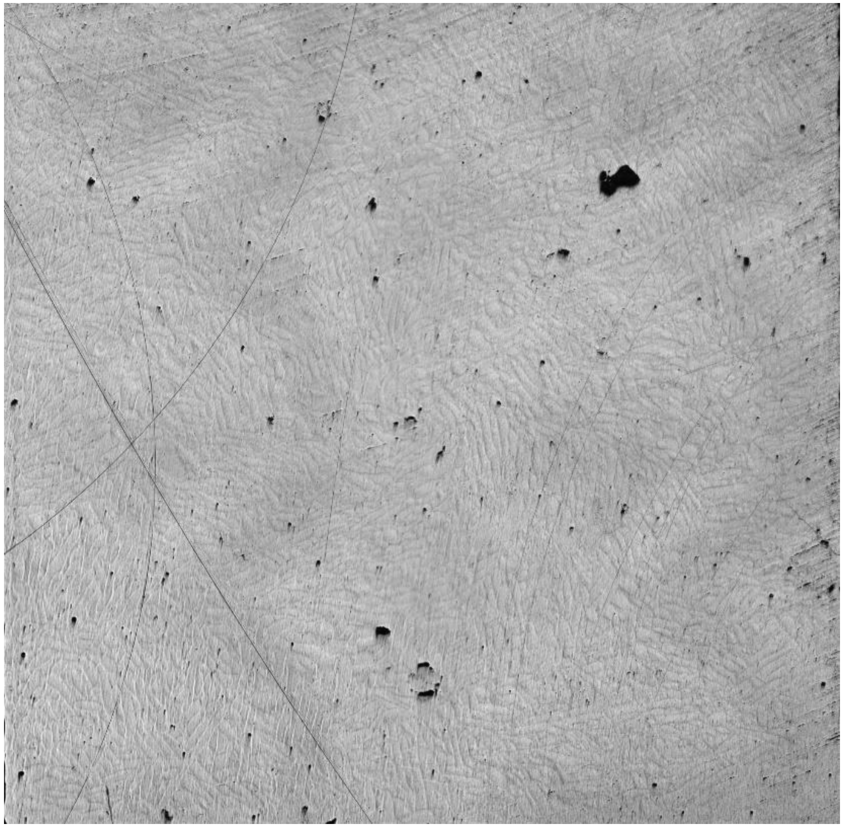
The spherical shaped porosity are created by entrapped gasses in the powder escaping the molten pool, often caused by eccessively high energy density input.



Defects at P140-V778-H0.100-L0.03 (1)

Defects found:

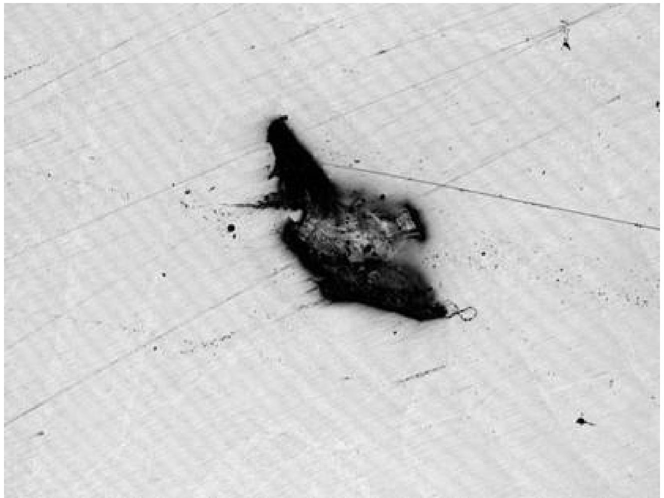
- Irregular shape;
- Spherical shape;

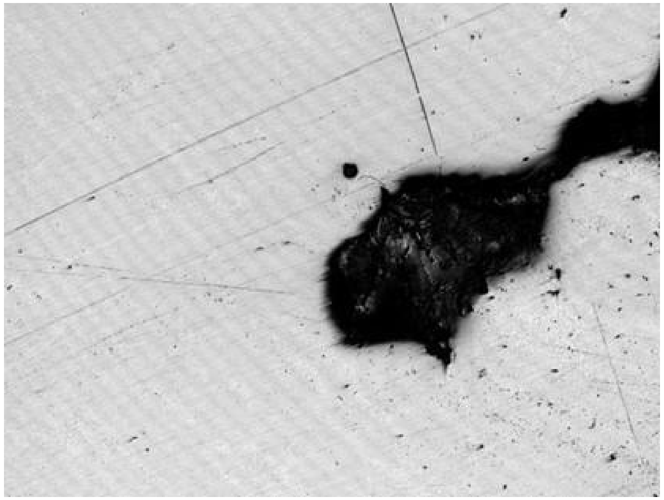


Defects at P160-V889-H0.100-L0.03 (2)

Defects found:

- Irregular shape;
- Spherical shape;

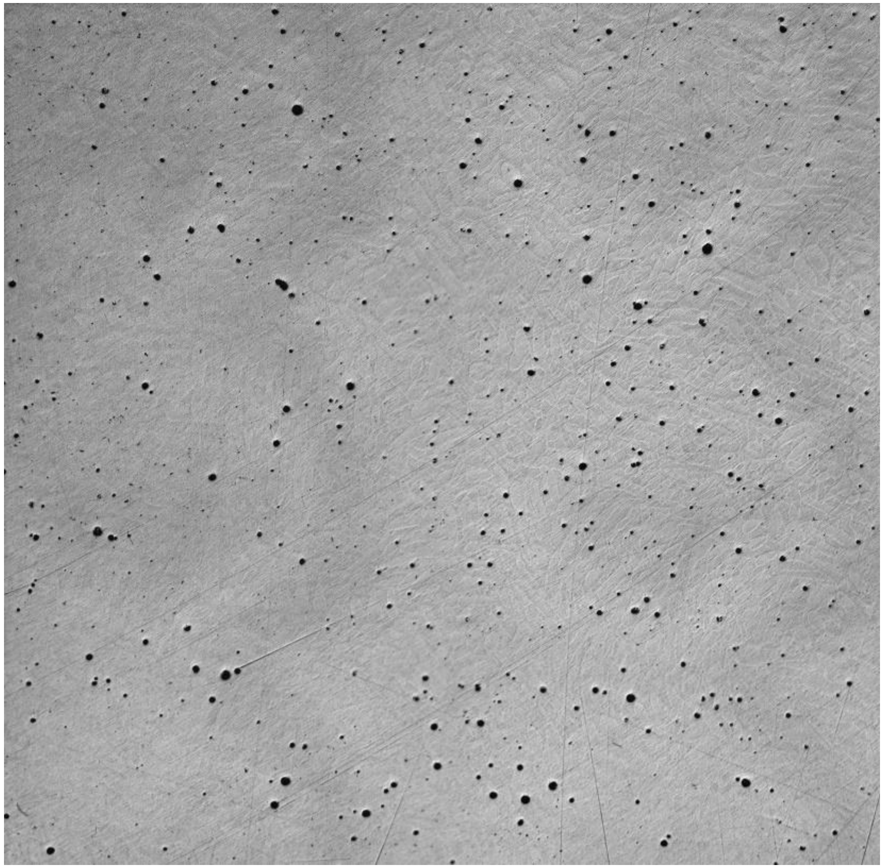


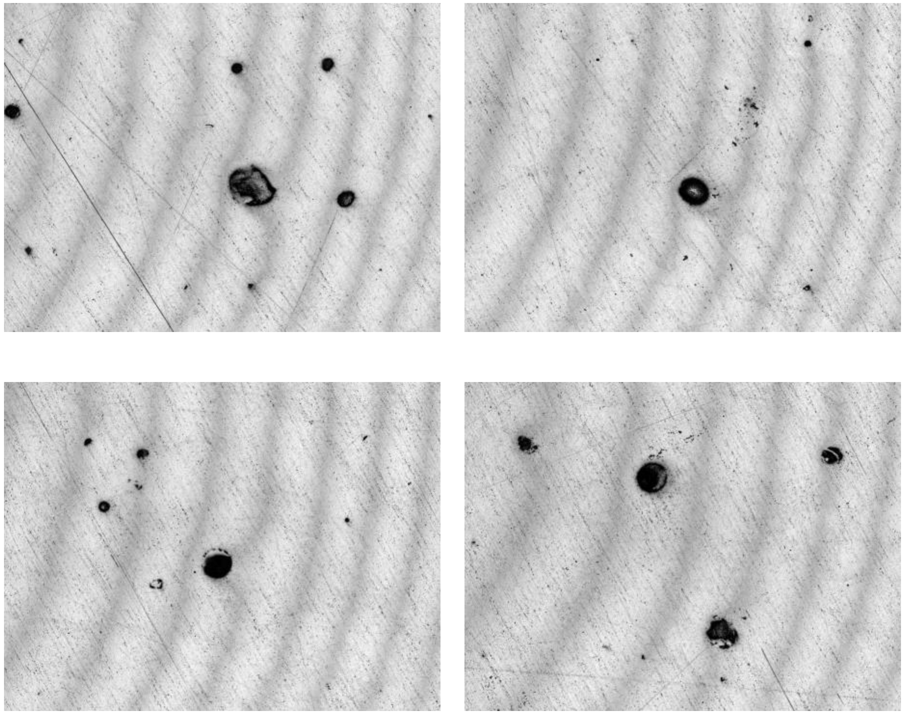


Defects at P180-V1000-H0.100-L0.03 (3)

Defects found:

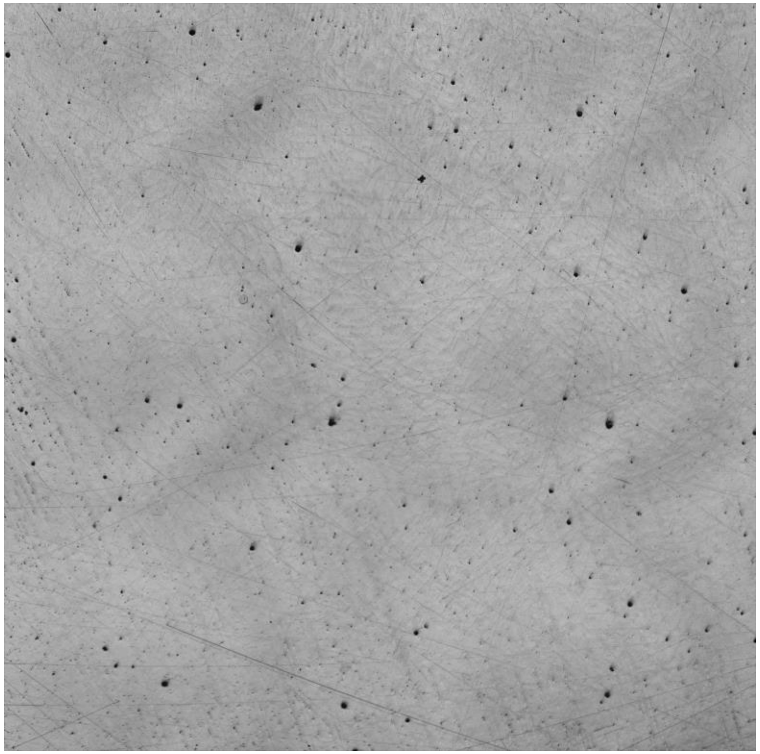
- Spherical shape;





Defects at P180-V1000-H0.100-L0.03 (3b)

- We decided to analyze a second surface of the last sample by removing more material and found results closer to the other samples, indicating that the first layer could have been an isolated case of poorly formed material.



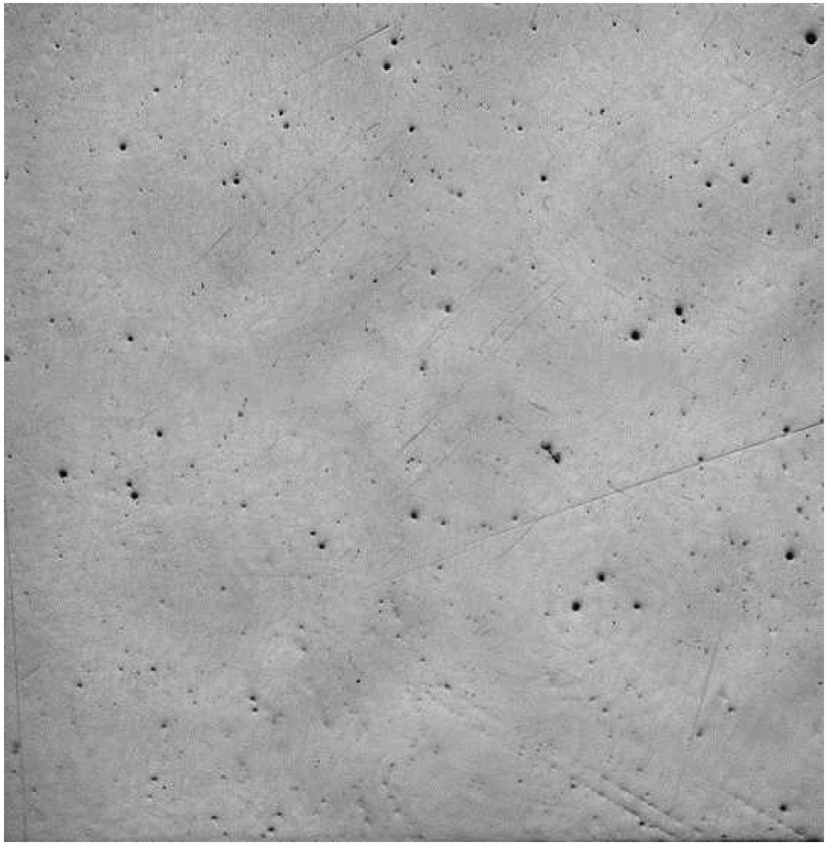
Defects found:

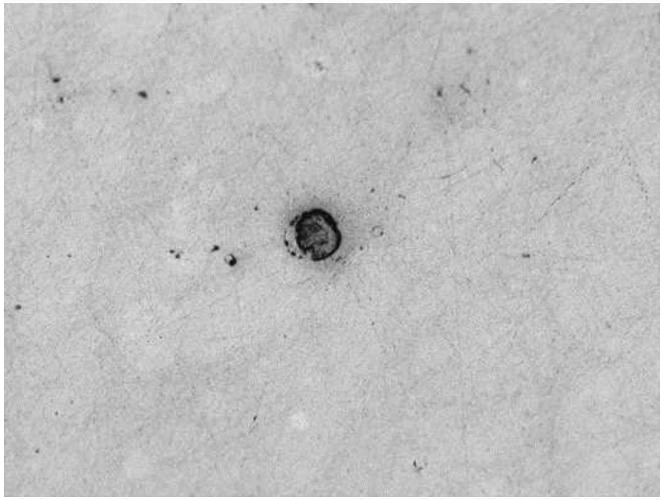
- Spherical shape;

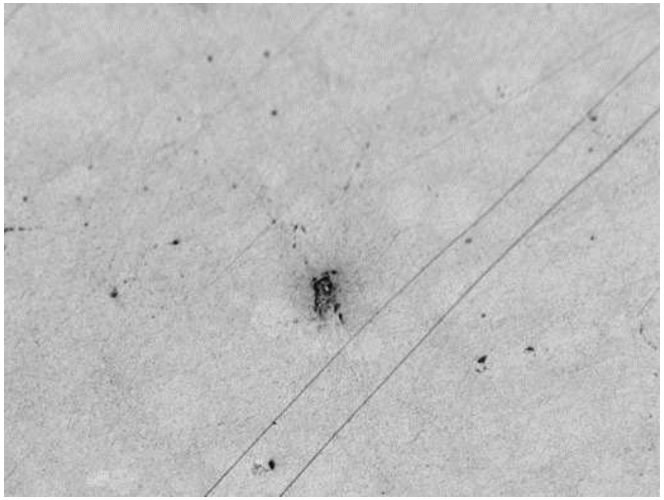
Defects at P170-V944-H0.100-L0.03 (4)

Defects found:

- Irregular shape;
- Spherical shape;

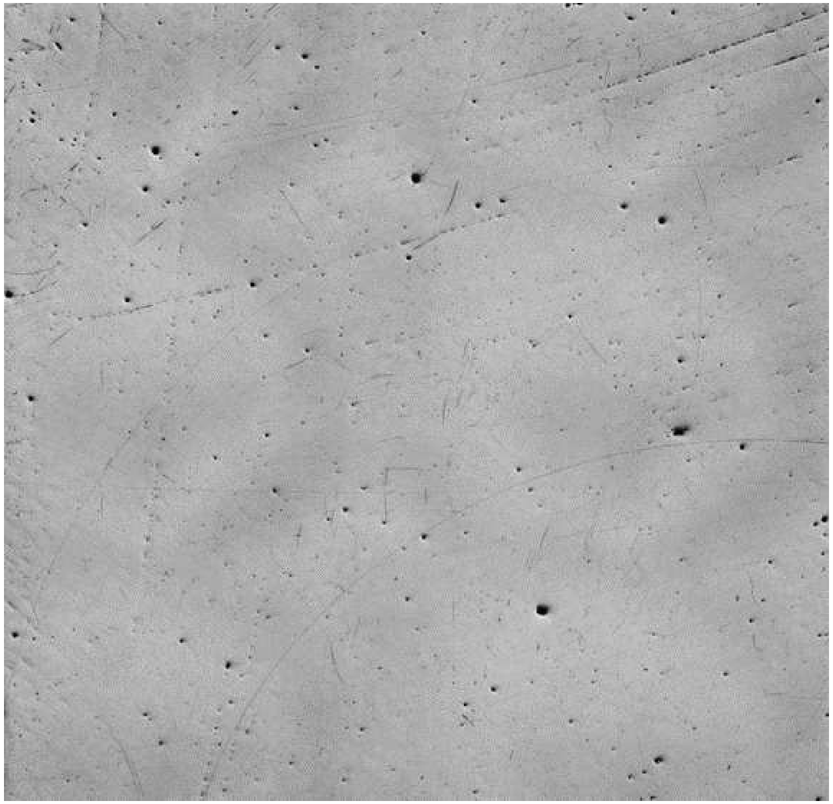


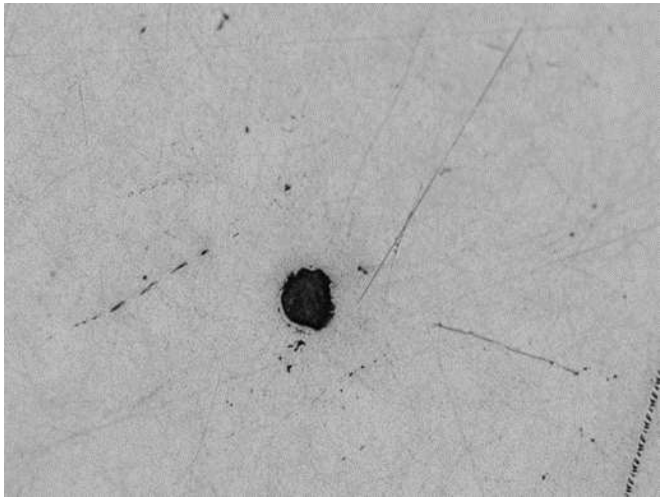


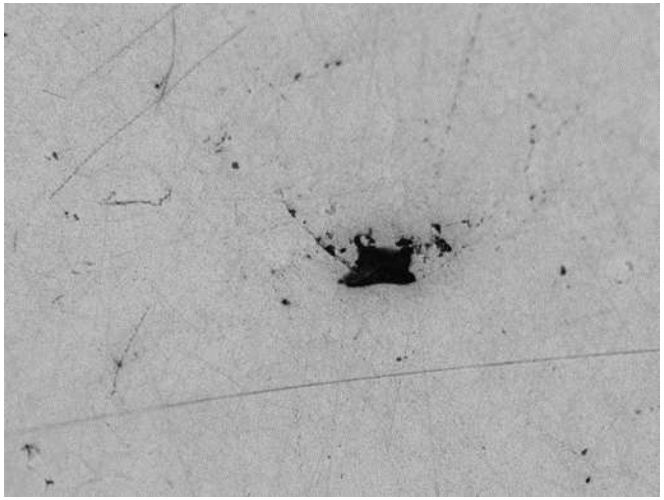


Defects at P170-V1036-H0.100-L0.03 (5)

Defects found:
- Irregular shape;
- Spherical shape;



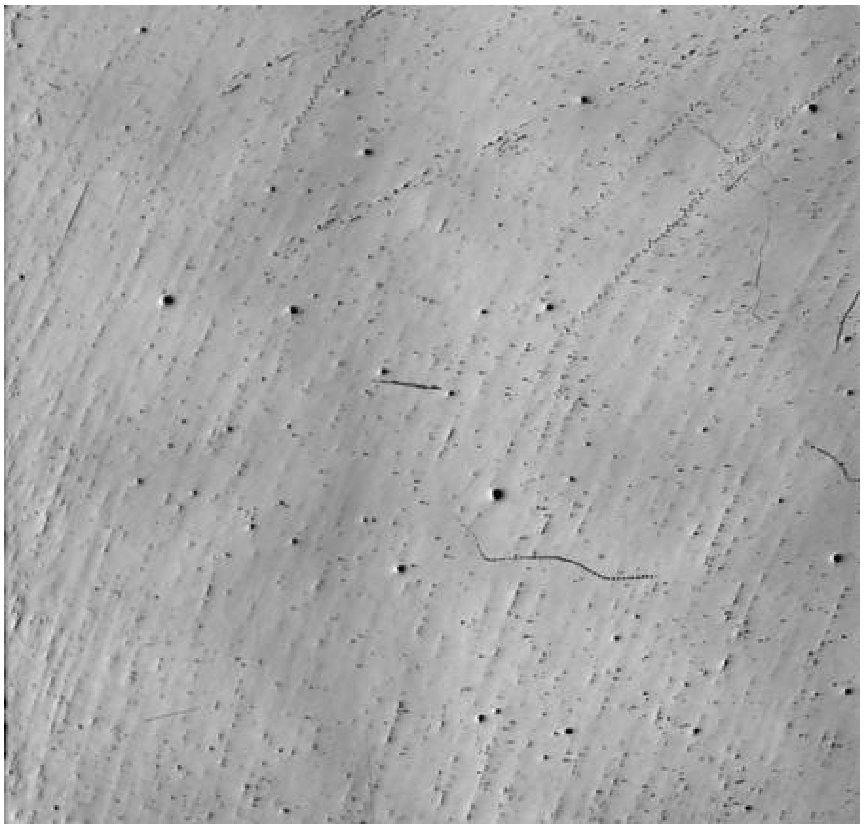


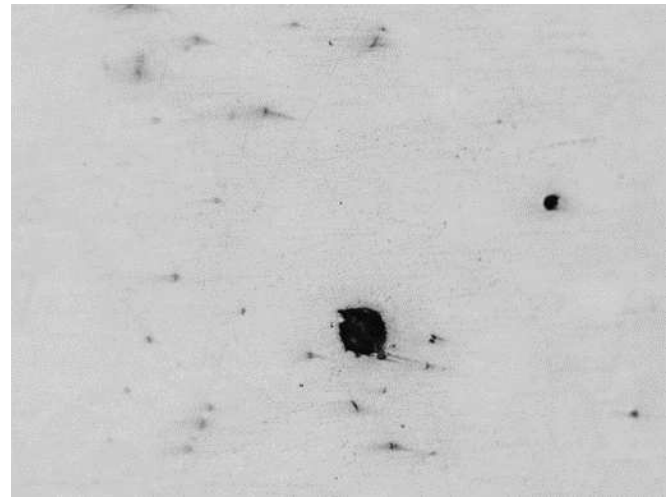


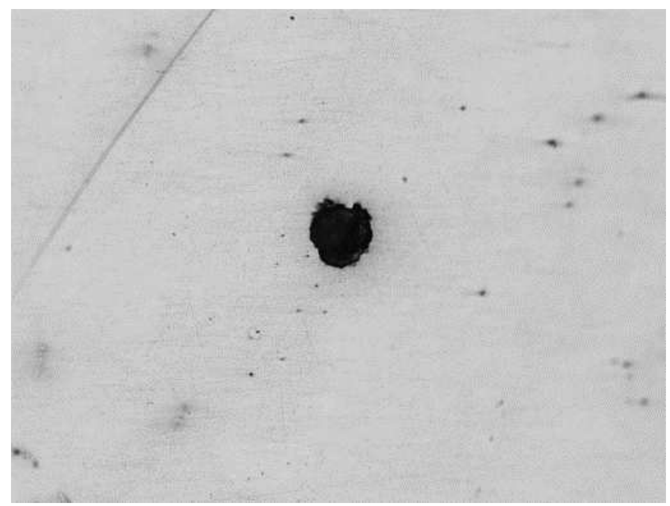
Defects at P190-V944-H0.100-L0.03 (6)

Defects found:

- Spherical shape;



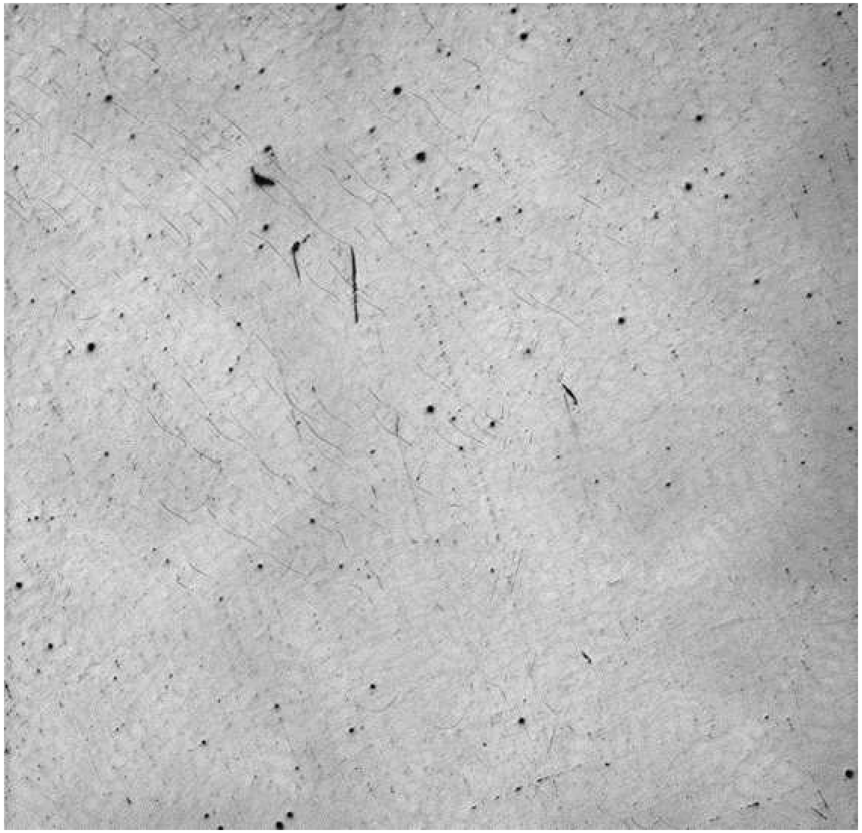


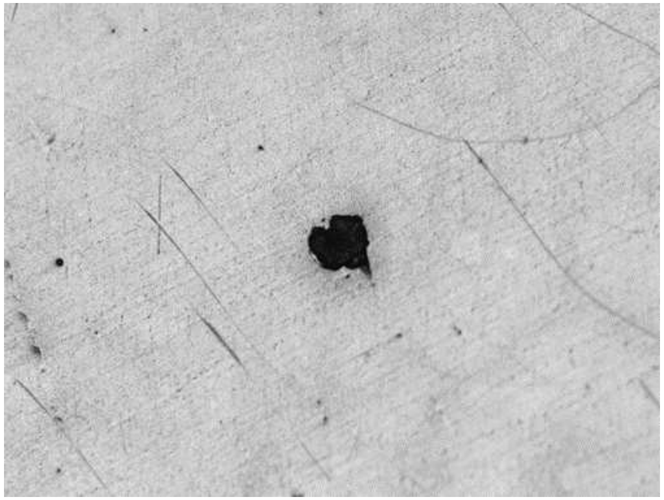


Defects at P190-V1050-H0.100-L0.03 (7)

Defects found:

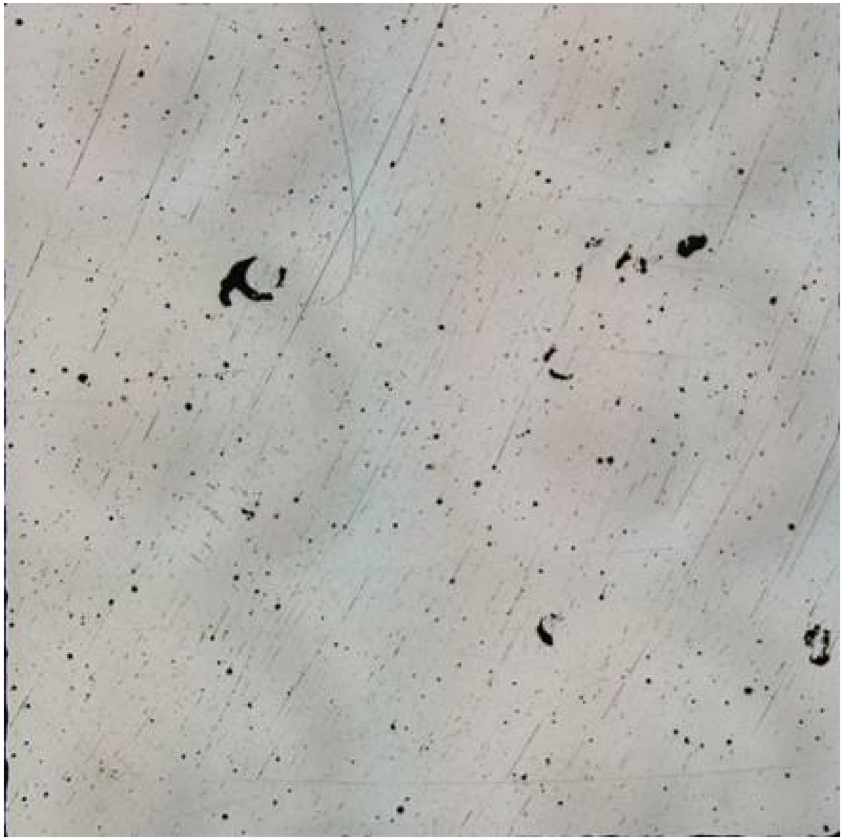
- Irregular shape;
- Spherical shape;

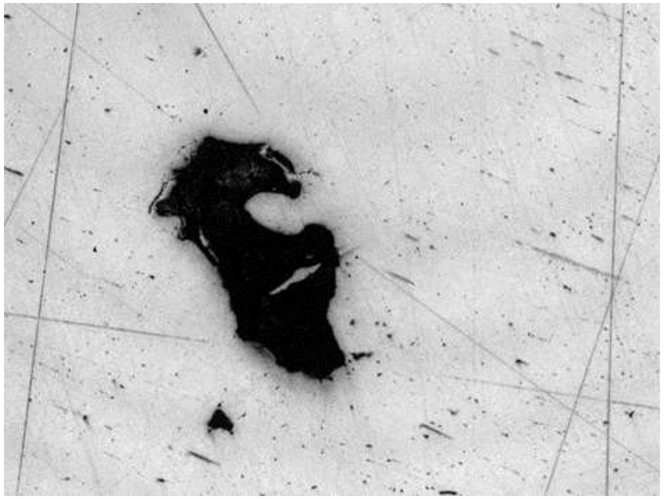




Defects at P180-V1000-H0.075-L0.03 (8)

Defects found:
- Irregular shape;
- Spherical shape;

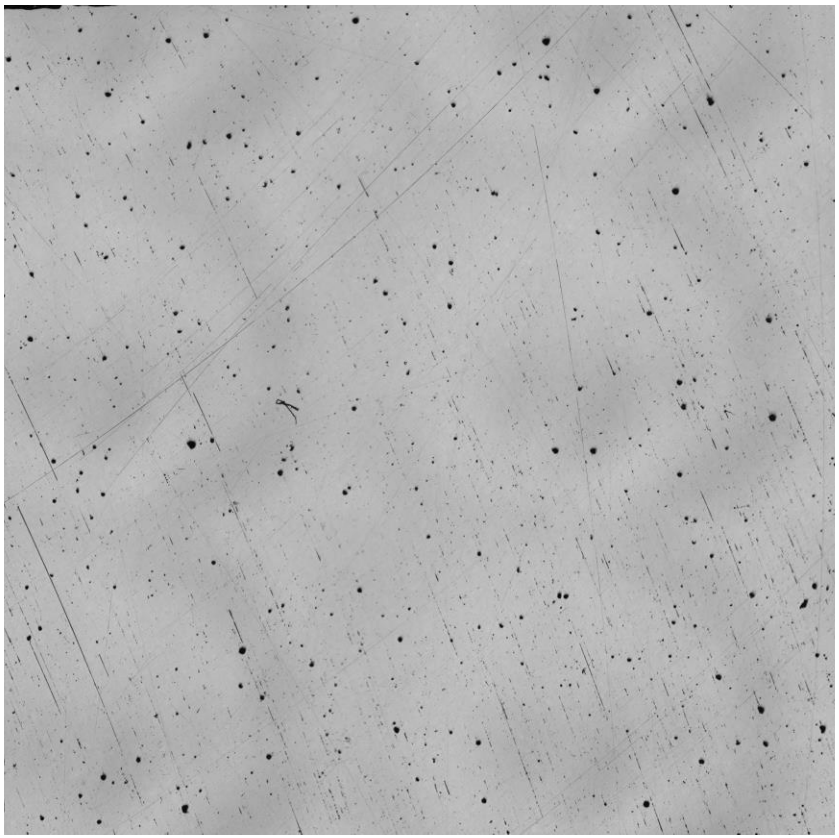


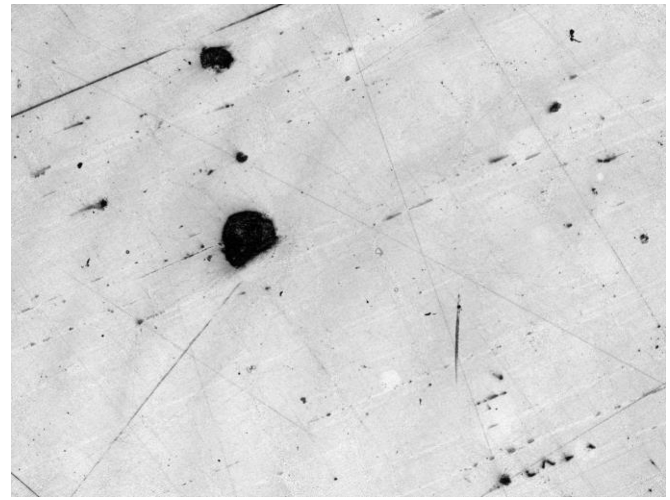


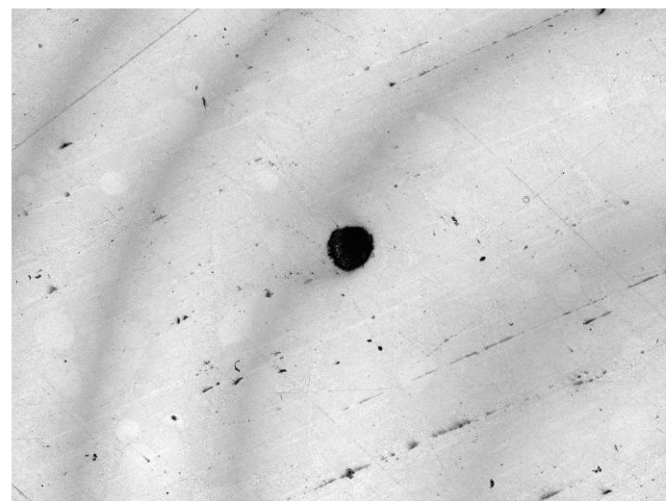
Defects at P180-V1000-H0.125-L0.03 (9)

Defects found:

- Spherical shape;



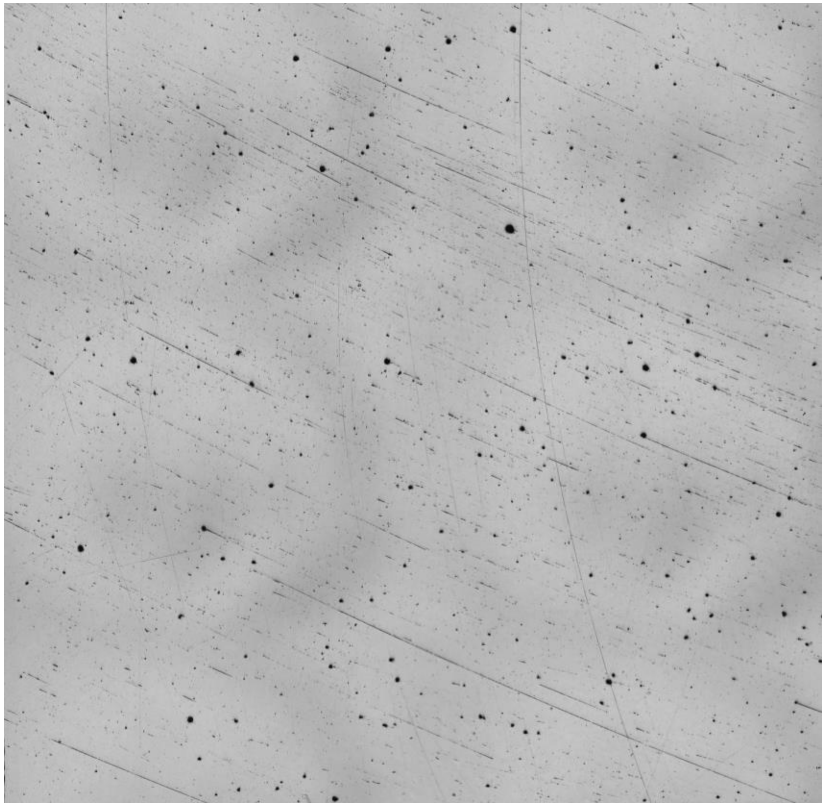


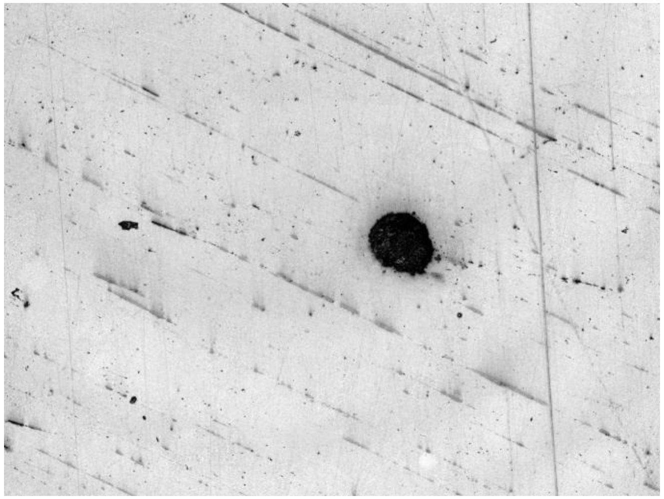


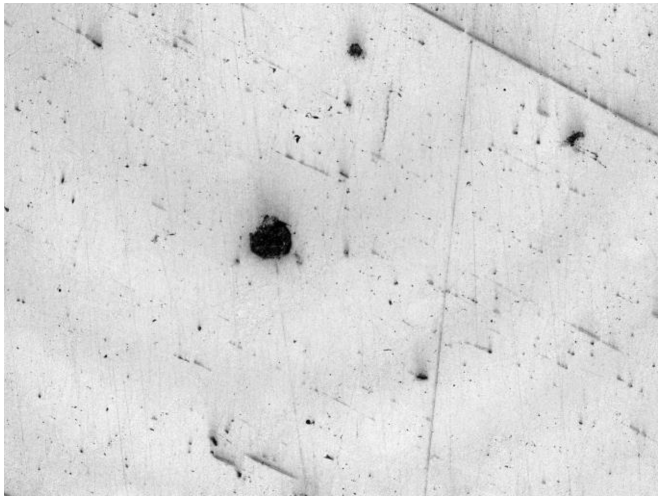
Defects at P180-V1000-H0.150-L0.03 (10)

Defects found:

- Spherical shape;



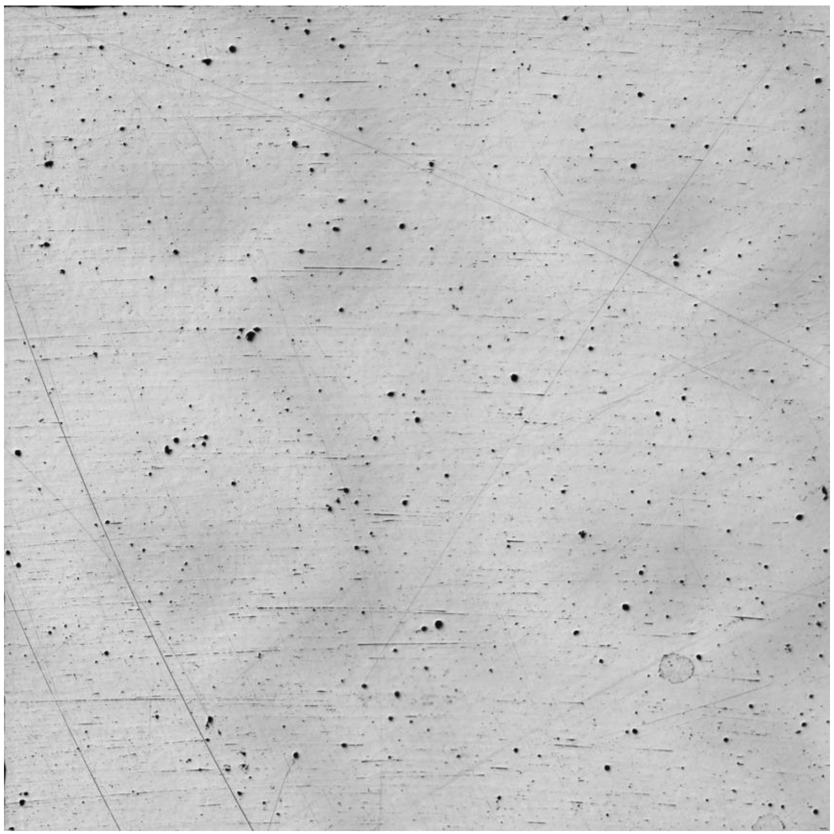


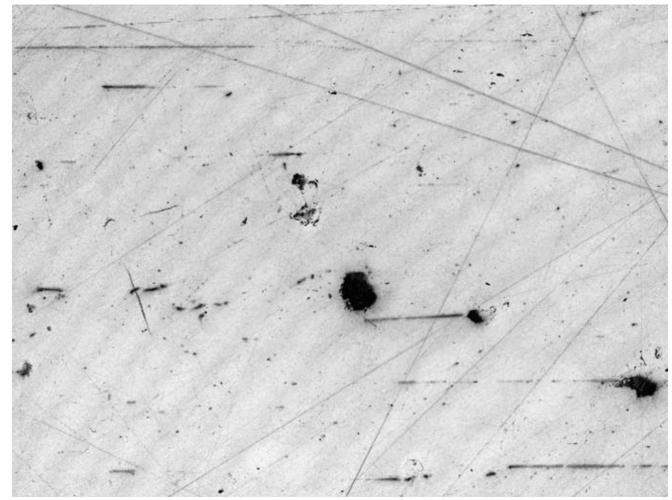


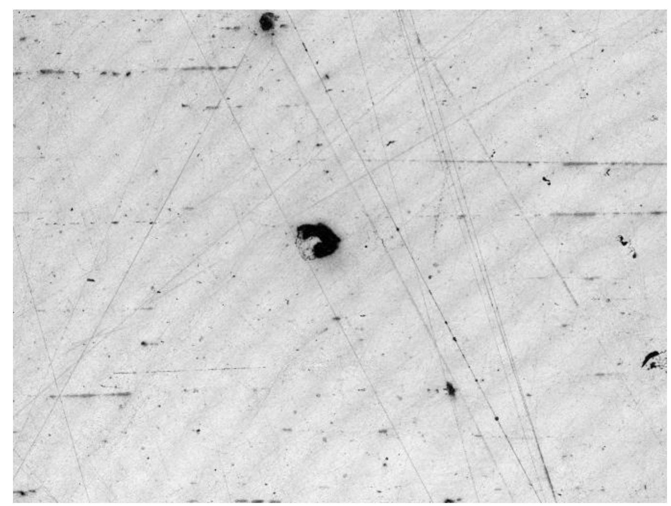
Defects at P180-V1000-H0.200-L0.03 (11)

Defects found:

- Spherical shape;



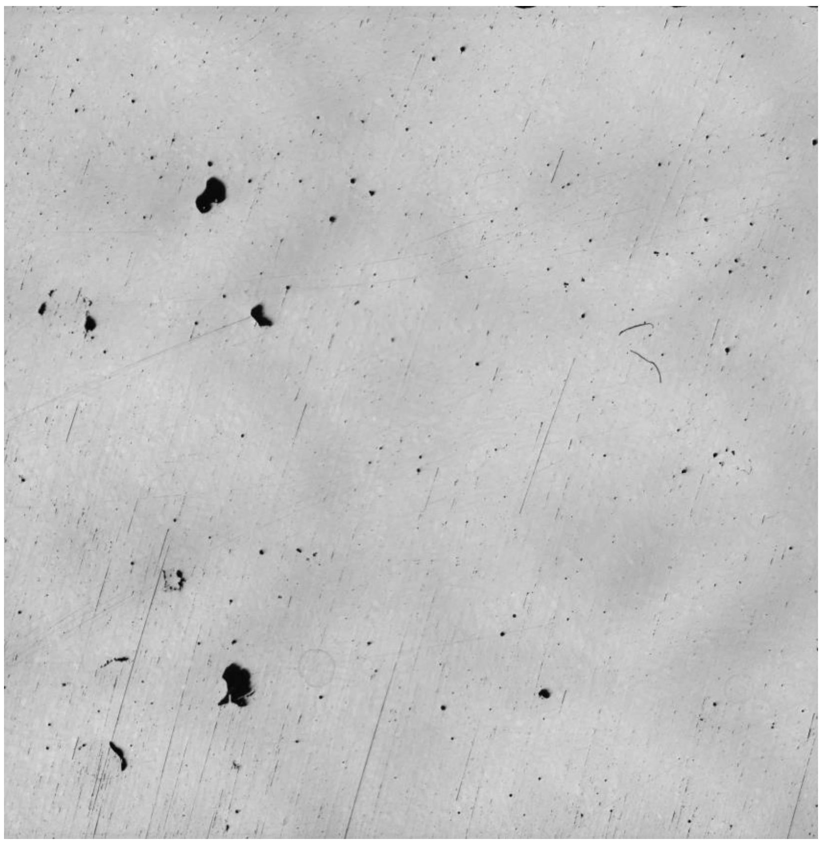


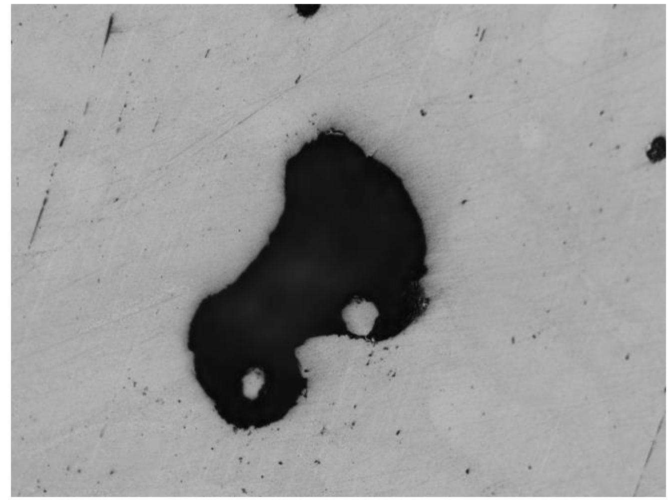


Defects at P170-V1056-H0.075-L0.03 (12)

Defects found:

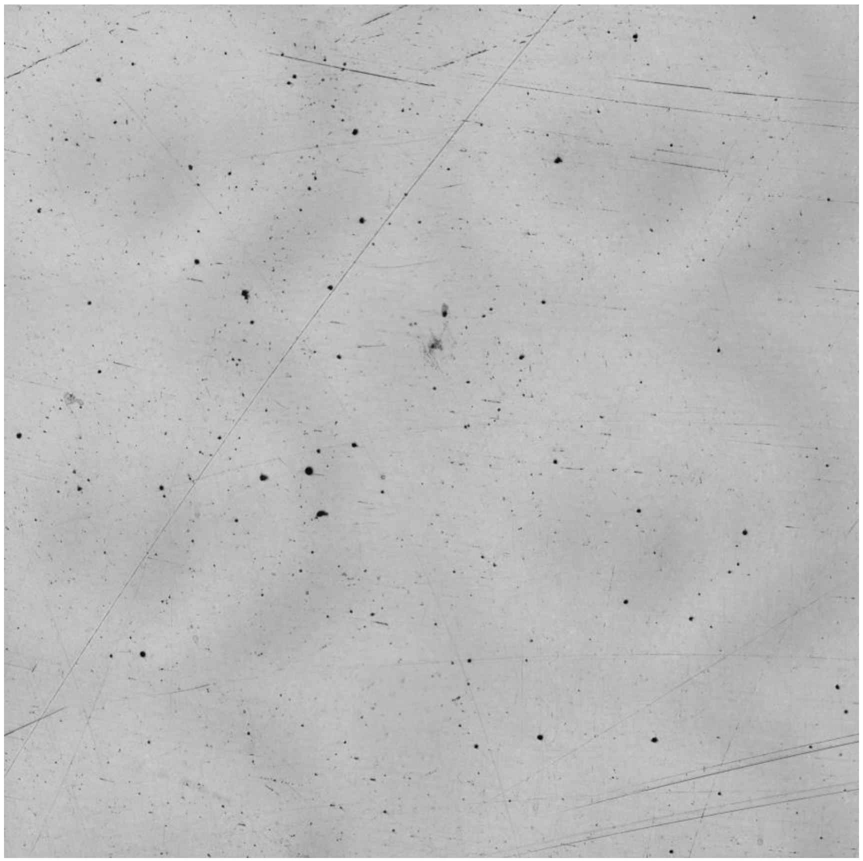
- Irregular shape
- Spherical shape;

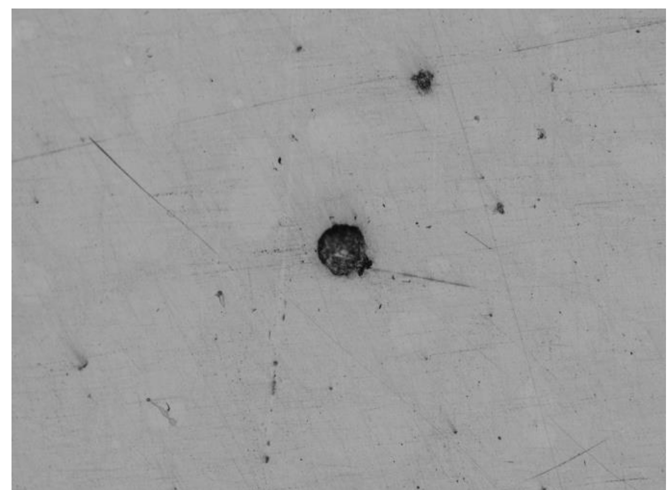




Defects at P170-V1056-H0.125-L0.03 (13)

Defects found:
- Spherical shape;

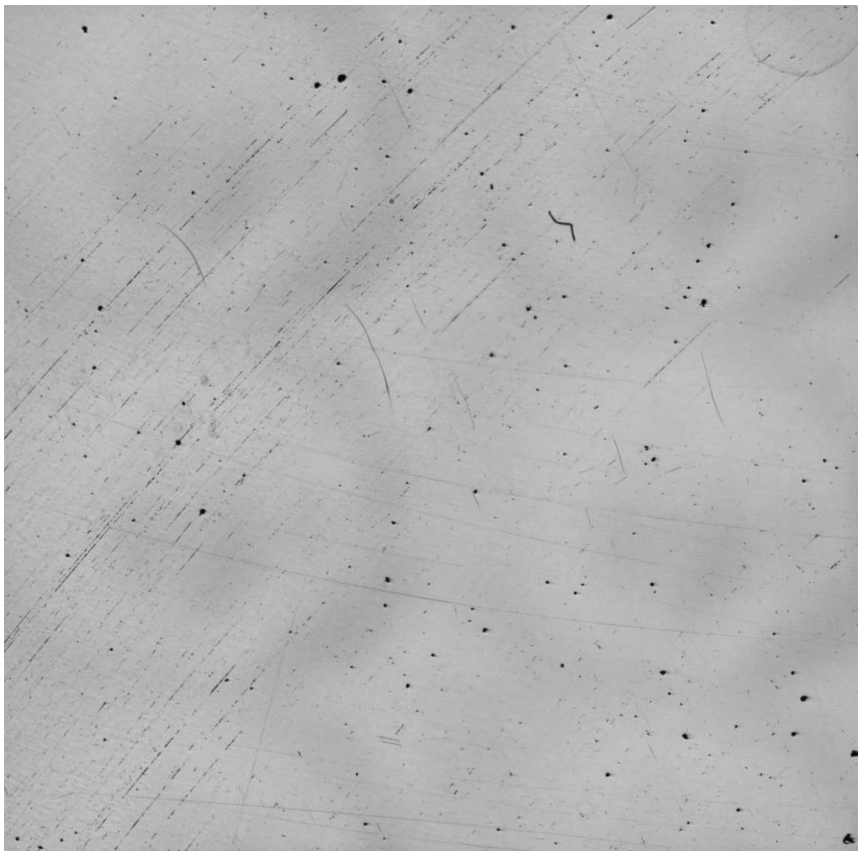


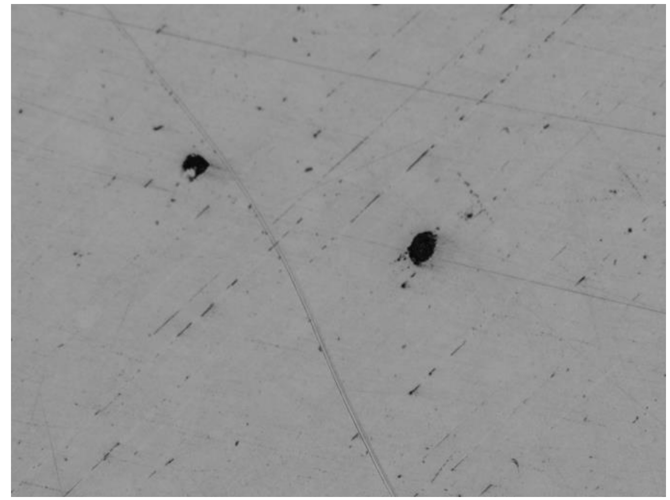


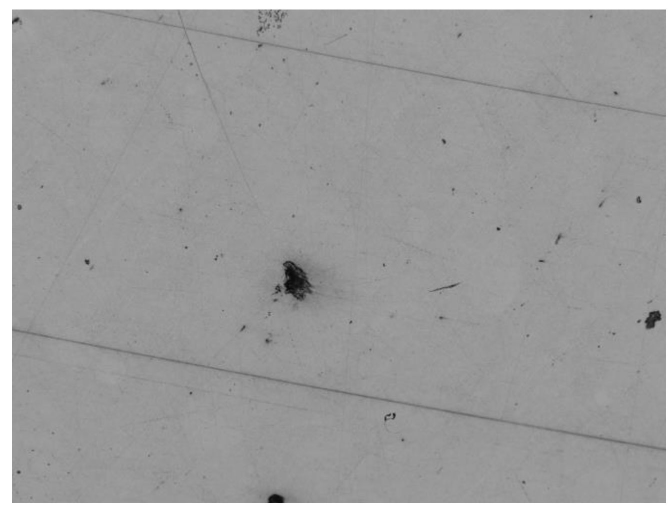
Defects at P170-V1056-H0.150-L0.03 (14)

Defects found:

- Spherical shape;

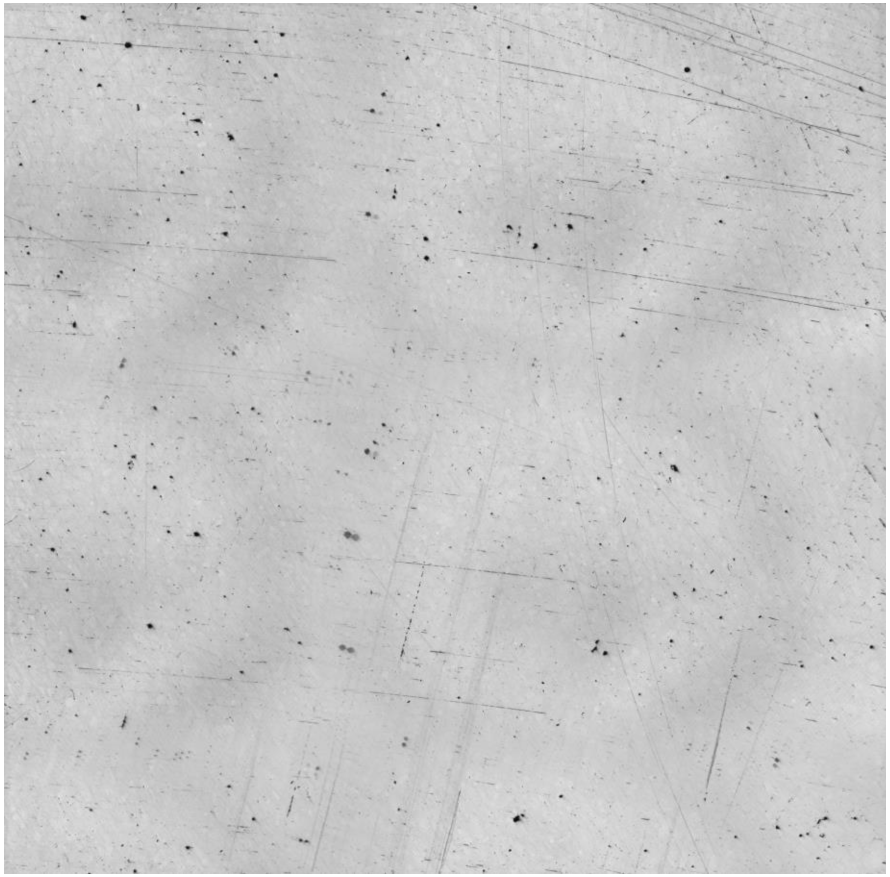


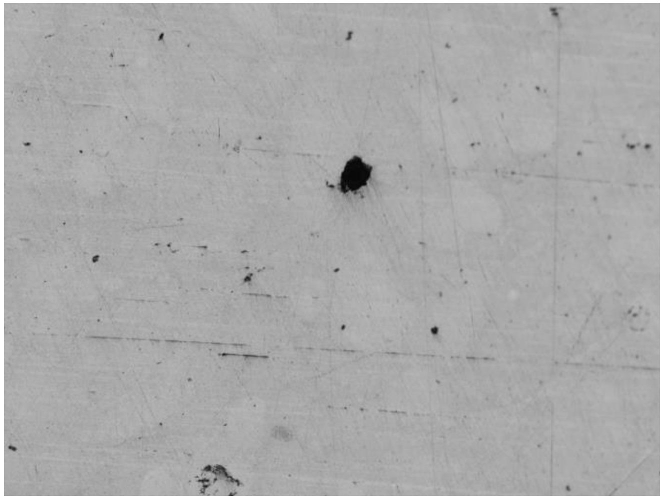




Defects at P170-V1056-H0.175-L0.03 (15)

Defects found:
- Spherical shape;





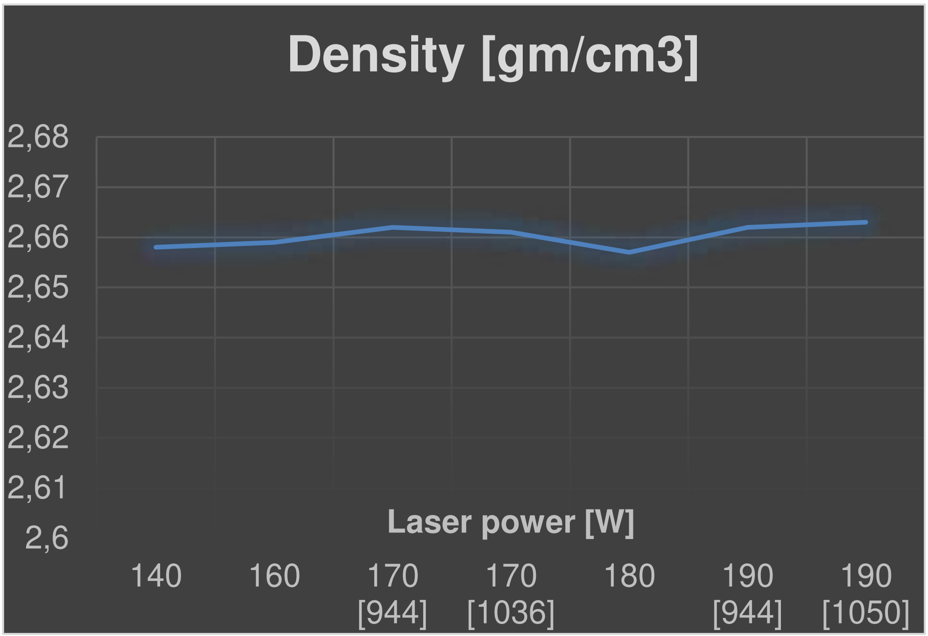
Density measurements

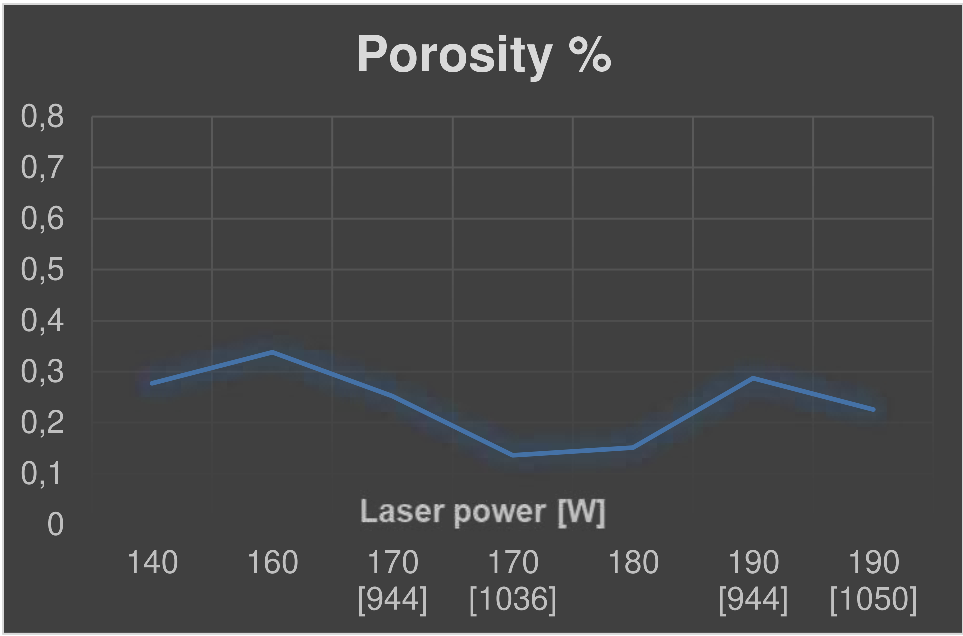
To obtain the density three measurements were performed for each sample and the results averaged.

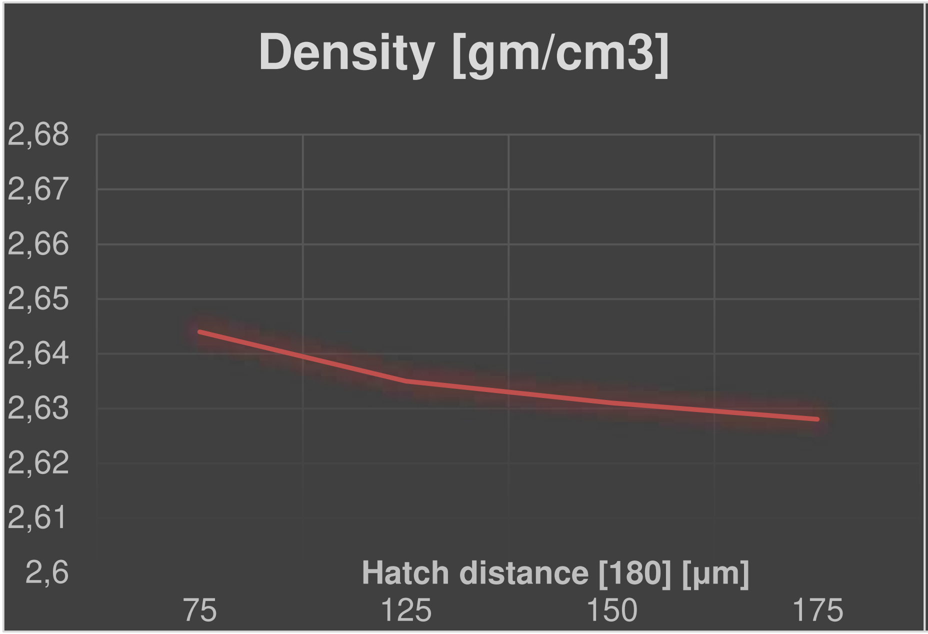
Sample [W]	140	160	180	170 [944]	170 [1036]	190 [944]	190 [1050]
Density [g/cm³]	2,658	2,659	2,657	2,662	2,661	2,662	2,663
Porosity [%]	0,277	0,338	0,151	0,252	0,136	0,287	0,226

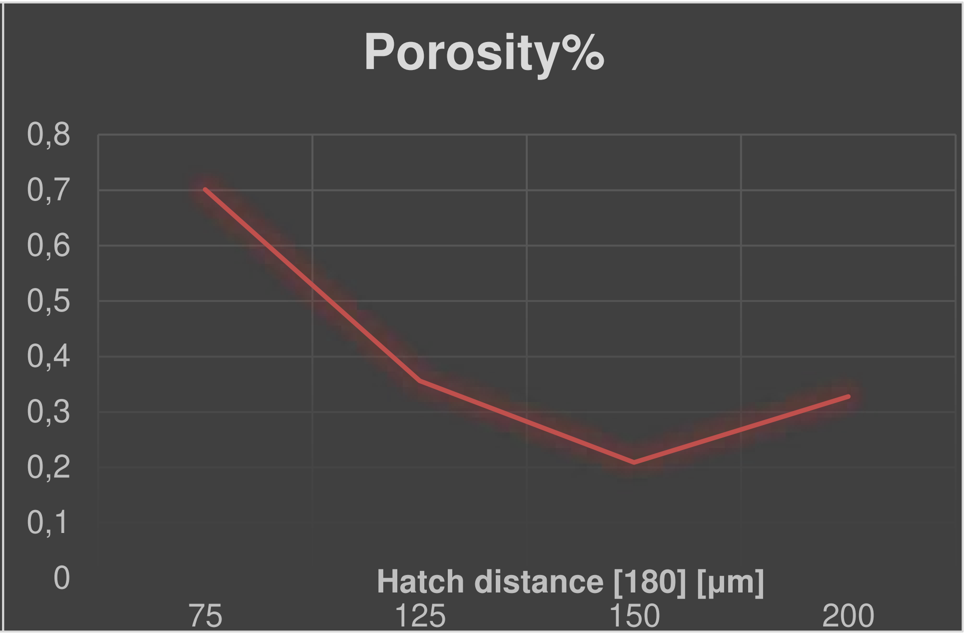
Sample [µm]	75 [180]	125 [180]	150 [180]	200 [180]	75 [170]	125 [170]	150 [170]	175 [170]
Density [g/cm³]	2,644	2,635	2,631	2,628	2,662	2,667	2,668	2,665
Porosity [%]	0,701	0,356	0,209	0,328	0,401	0,118	0,116	0,153

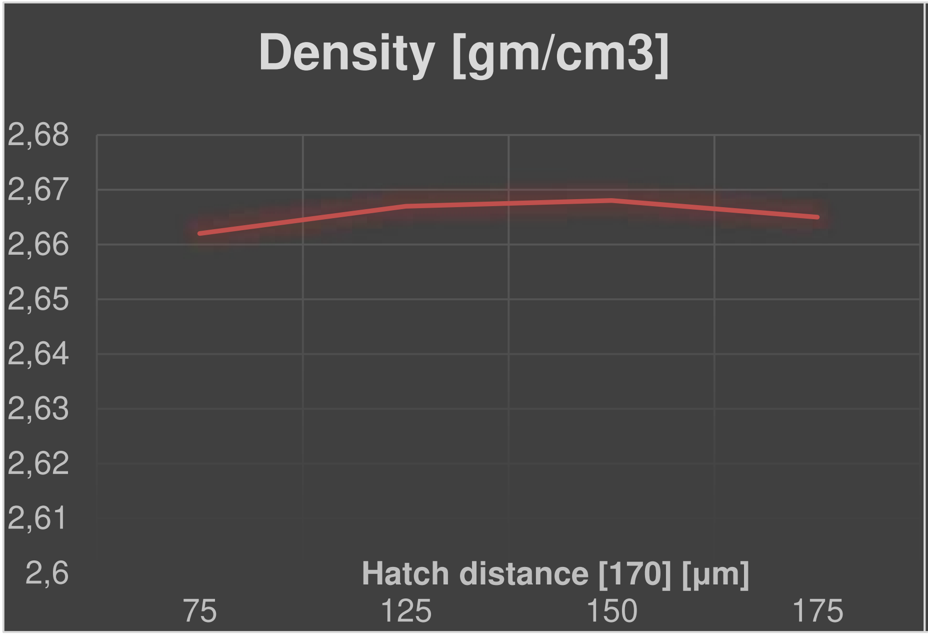
Graphs

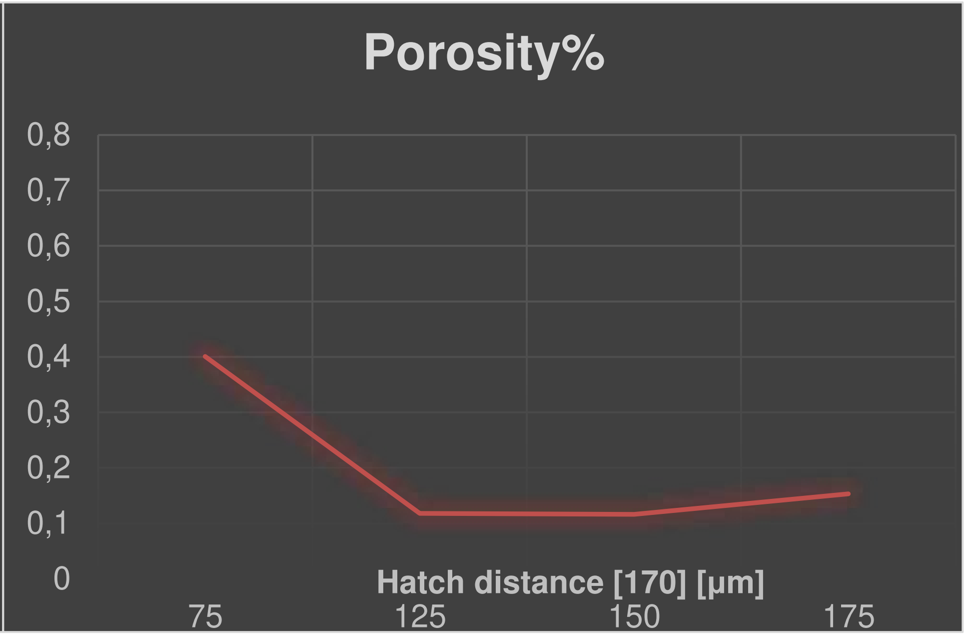

Density [gm/cm3]
2,68
2,67
2,66
2,65
2,64
2,63
2,62
2,61
2,6
Laser power [W]
140
160
170 [944]
170 [1036]
180
190 [944]
190 [1050]


Porosity %
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
Laser power [W]
140
160
170 [944]
170 [1036]
180
190 [944]
190 [1050]


Density [gm/cm3]
2,68
2,67
2,66
2,65
2,64
2,63
2,62
2,61
2,6
Hatch distance [180] [μm]
75
125
150
175


Porosity%
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
Hatch distance [180] [μm]
75
125
150
200


Density [gm/cm3]
2,68
2,67
2,66
2,65
2,64
2,63
2,62
2,61
2,6
Hatch distance [170] [μm]
75
125
150
175


Porosity%
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
Hatch distance [170] [μm]
75
125
150
175

Roughness (1)

Up

Power [W]	Scanning speed [mm/s]	Roughness [µm]
170	944	21,086
170	1036	18,848
190	944	20,851
190	1050	17,532

Side

Power [W]	Scanning speed [mm/s]	Roughness [µm]
170	944	15,079
170	1036	15,274
190	944	12,829
190	1050	13,142

Roughness (2)

Up

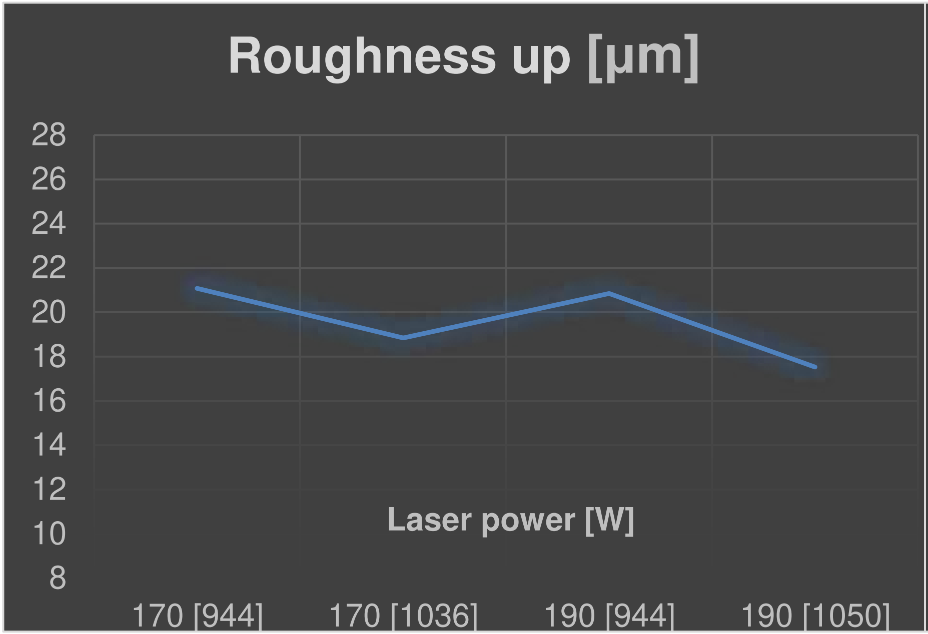
Hatch distance [μm] [180]	Roughness [μm]
75	22,357
125	16,889
150	12,957
200	20,341

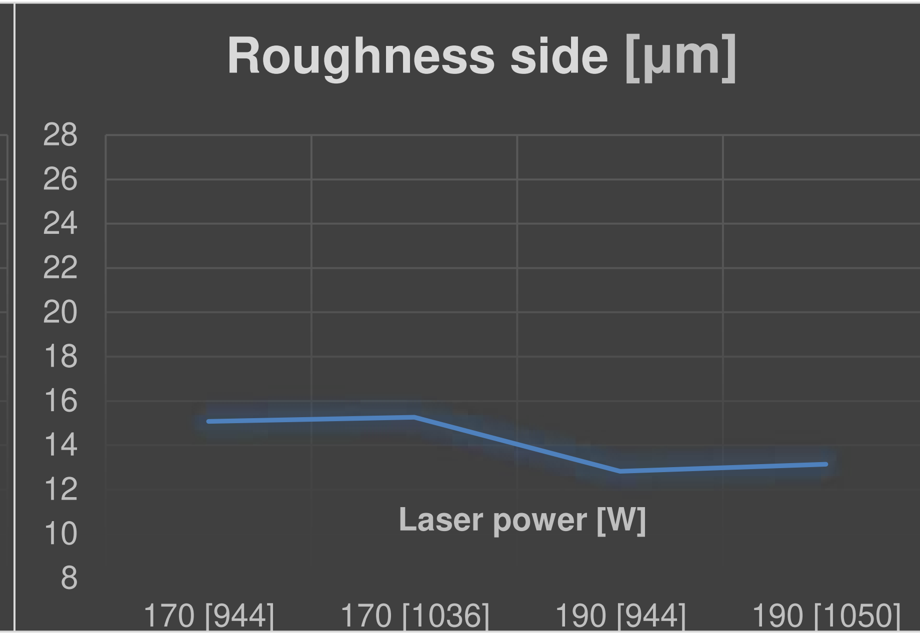
Hatch distance [μm] [170]	Roughness [μm]
75	26,690
125	22,049
150	22,136
175	22,858

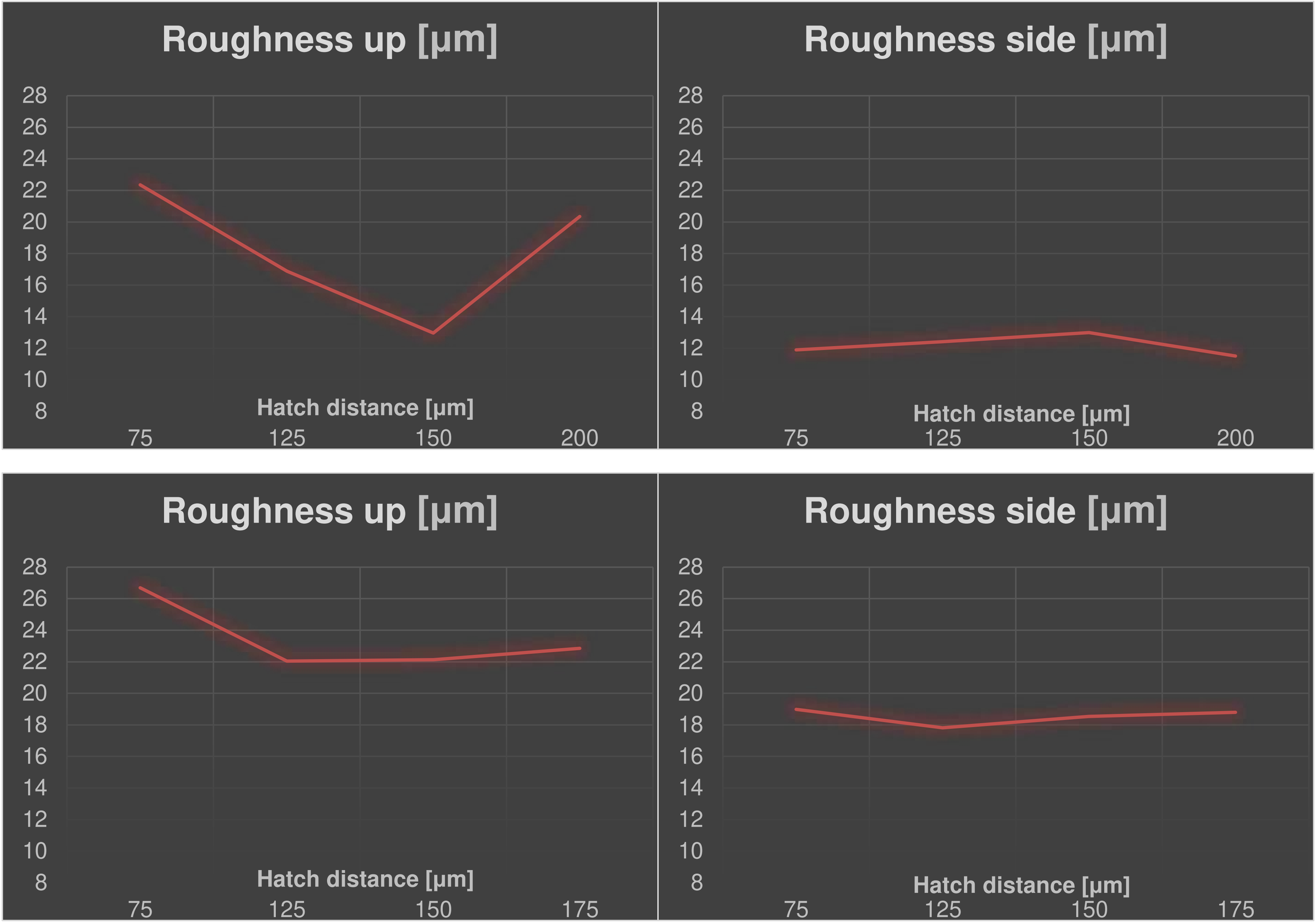
Side

Hatch distance [μm] [180]	Roughness [μm]
75	11,896
125	12,414
150	12,985
200	11,507

Hatch distance [μm] [170]	Roughness [μm]
75	18,978
125	17,822
150	18,537
175	18,791


Roughness up [µm]
28
26
24
22
20
18
16
14
12
10
8
Laser power [W]
170 [944]
170 [1036]
190 [944]
190 [1050]


Roughness side [µm]
28
26
24
22
20
18
16
14
12
10
8
Laser power [W]
170 [944]
170 [1036]
190 [944]
190 [1050]


Roughness up [µm]
28
26
24
22
20
18
16
14
12
10
8
Hatch distance [µm]
75
125
150
200
Roughness side [µm]
28
26
24
22
20
18
16
14
12
10
8
Hatch distance [µm]
75
125
150
200
Roughness up [µm]
28
26
24
22
20
18
16
14
12
10
8
Hatch distance [µm]
75
125
150
175
Roughness side [µm]
28
26
24
22
20
18
16
14
12
10
8
Hatch distance [µm]
75
125
150
175

References

- We researched some existing papers for better understanding the topic and to hopefully find some useful information regarding the process parameters and the mechanics of metal printing. The following is a list of all the information found that we consider useful to know when working with SLM 3D printers:
- 1) Density is strongly related to laser power and scanning speed. Increasing power at constant speed increases almost linearly the density. The inverse is also true, decreasing scanning speed at constant power increases the density.
- 2) Powder morphology matters, more spherical particles flow better, create less spatter and typically result in a denser sample.
- 3) High scanning speeds increase the amount of spatter porosities and high laser power increases the amount of gaseous porosities
- 4) Drying the powder at around 60°C beforehand can reduce the amount of trapped gas. It both reduces the quantity of gaseous porosities and the amount by which they enlarge after subsequent heat treatment.

- 5) Smaller layer thickness increase printing time quickly but seem to improve small details, samples density and surface roughness.
- 6) Hatch distance and overlap percentage are important to maximize density and reduce porosity but are strongly dependent on the laser spot diameter and the other parameters such as laser power and scanning speed.

- Effects of powders and process parameters on density and hardness of Al357 aluminum alloy fabricated by selective laser melting. https://link.springer.com/article/10.1007/s00170-019-04641-x
- The influence of processing parameters on aluminium alloy A357 manufactured by Selective Laser Melting. https://www.sciencedirect.com/science/article/pii/S0264127516309005#f0030
- Porosity formation mechanisms and fatigue response in Al-Si-Mg alloys made by selective laser melting. https://www.sciencedirect.com/science/article/pii/S0921509317315393
- Drying strategies to reduce the formation of hydrogen porosity in Al alloys produced by additive manufacturing. https://research.utwente.nl/files/187509456/Cordova2019drying.pdf
- Study on energy input and its influences on single-track,multi-track, and multi-layer in SLM https://link.springer.com/article/10.1007/s00170-011-3443-y
- Thermofluid field of molten pool and its effects during selective laser melting (SLM) of Inconel 718 alloy https://www.sciencedirect.com/science/article/pii/S2214860417300969
- Effects of laser processing parameters on thermal behavior and melting/solidification mechanism during selective laser melting of TiC/Inconel 718 composites https://www.sciencedirect.com/science/article/pii/S0030399215307349