Influence of parameters variations on AlSi10Mg samples manufactured by SLM technology

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Abstract

Additive manufacturing technology, applied to metallic materials, offers new design possibilities: higher shape complexity, deeper material microstructure and mechanical performances control are allowed, compared to traditional processes.

The aim of the project is to investigate the influence of different printing parameters in selective laser melted AlSi10Mg aluminium alloy and to correlate Energy Density (Ed) to microstructure, porosity, Ultimate Tensile Strength (UTS) and fatigue resistance. These results are carefully analysed in order to find optimal processing conditions that guarantee the maximum material density and the best mechanical properties.

Process Parameters Correlation Chart

Laser Power
Exposure Time
Hatch Distance
Point Distance
Layer Thickness

Energy Density

$$Ed = \frac{P}{v_S * h * d}$$

P = power [W]
v_s = laser scan speed [mm/s]
$v_s \simeq \frac{point\ distance}{exposure\ time}$
h = hatch distance [mm]
d = layer thickness [mm]

Properties

Internal Porosity
Tensile Strenght
Surface Roughness
Fatigue life

Strong and complex interaction between process parameters, building strategy, microstructure and mechanical properties characterises the SLM process.

Laser Power and Exposure Time are varied within three experimental campaigns: (I) Hatch Distance, Point Distance and Layer Thickness are constant, (II) Iso-Energy Density, (III)Different Hatch Distance and Point Distance values from (I).

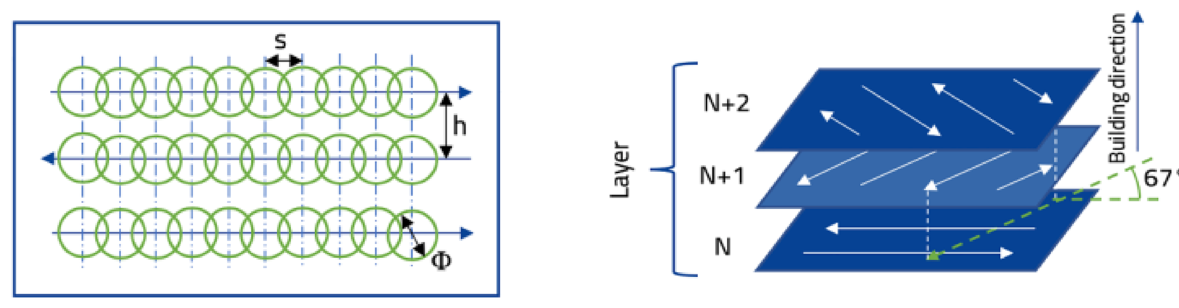
Materials & Methods

Chemical composition of **AlSi10Mg**

Al	Si	Mg	Fe	N	O	Ti	Zn	Mn	Ni	Cu	Pb	Sn
balance	9-11	0.25-0.45	<0.25	<0.2	<0.2	<0.15	<0.10	<0.10	<0.05	<0.05	<0.02	<0.02

SLM Machine: **Renishaw AM400**
Particle size : **15-45 μm**
Platform dimension: **250 mm x 250 mm x 300mm**
Laser maximum beam power: **400 W**
Spot diameter (Φ): **70 μm**
Gas: **Argon**

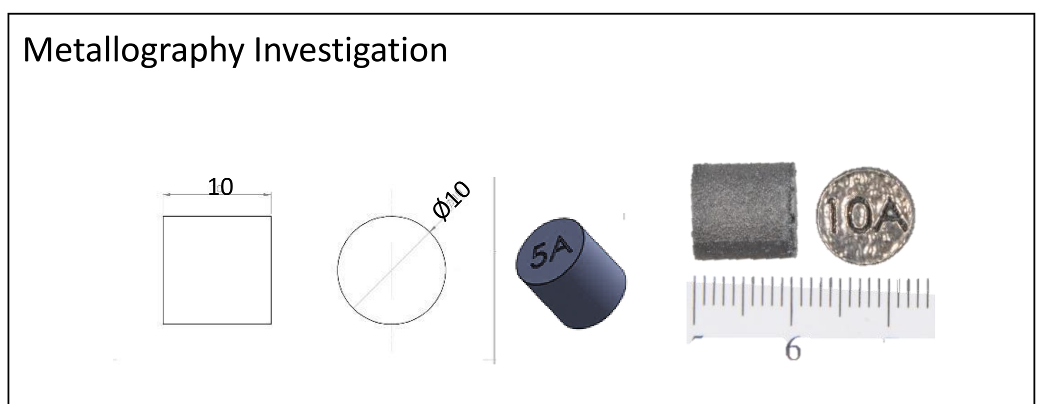
Platform temperature: **170 °C**
Layer thickness (d): **30 μm**
Point distance (s): **80 μm**
Hatch distance (h): **80 μm**
Laser power (P): **275 W**
Exposure time (t): **40 μs**

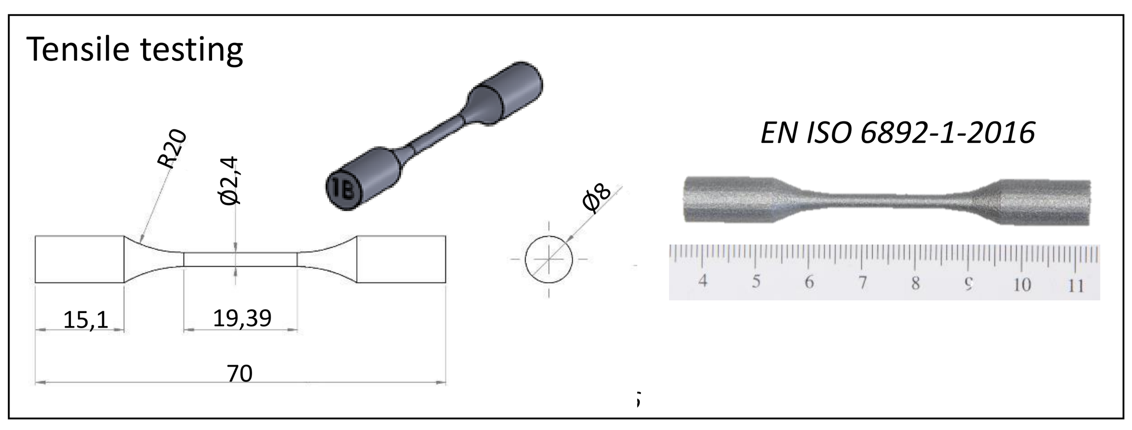


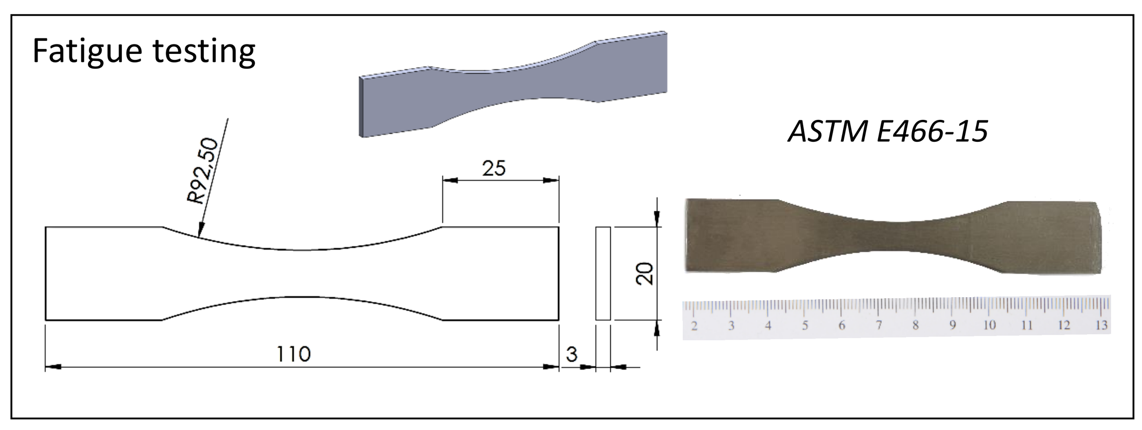
Laser Scanning Strategy

Process parameters are selected within: 200 W to 375 W (laser power), 30 μs to 120 μs (exposure time), 61 μm to 80 μm (hatch distance=point distance).

Specimens



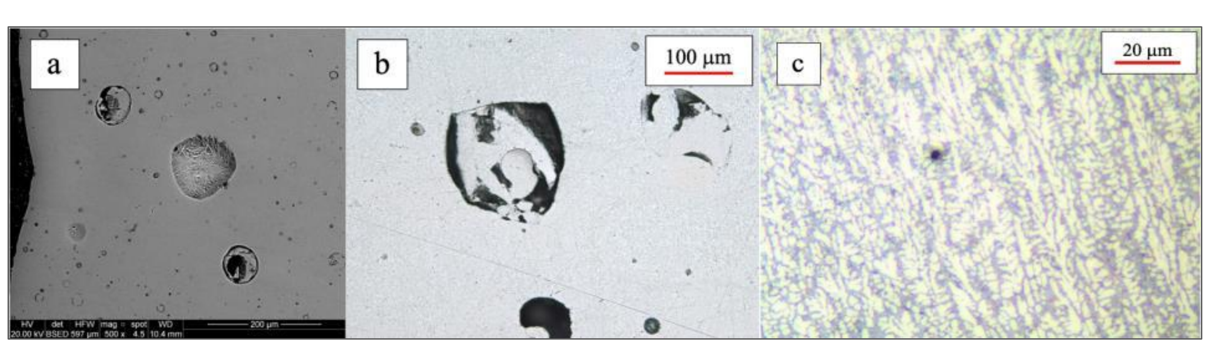




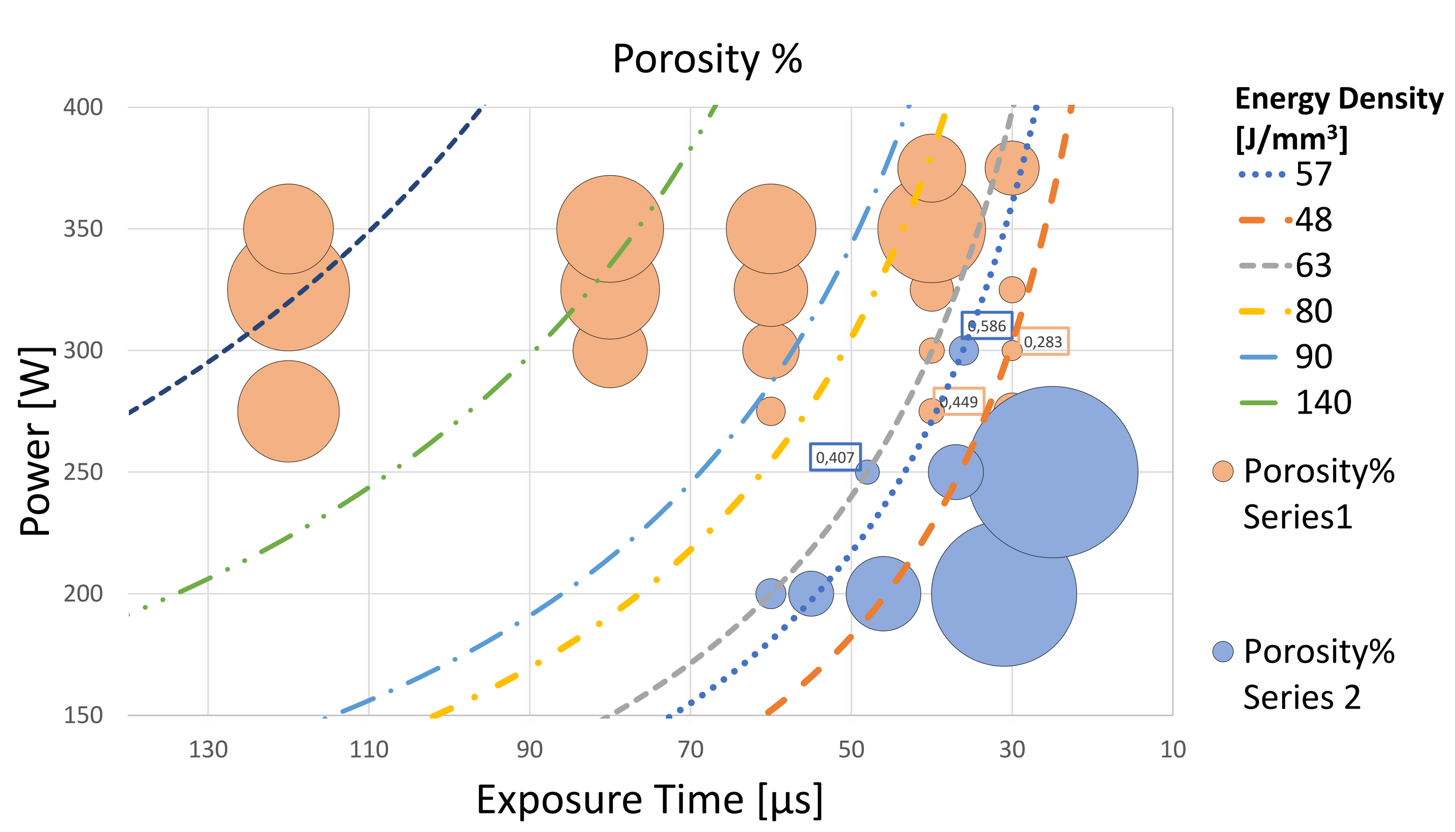
As built Roughness	Avg: 22,86 [μm]	SD: 10,2 [μm]	As built Roughness	Avg: 16,93 [μm]	SD: 6,1 [μm]	Roughness after machining	Avg: 1,9 [μm]	SD: 0,6 [μm]

Experimental Results

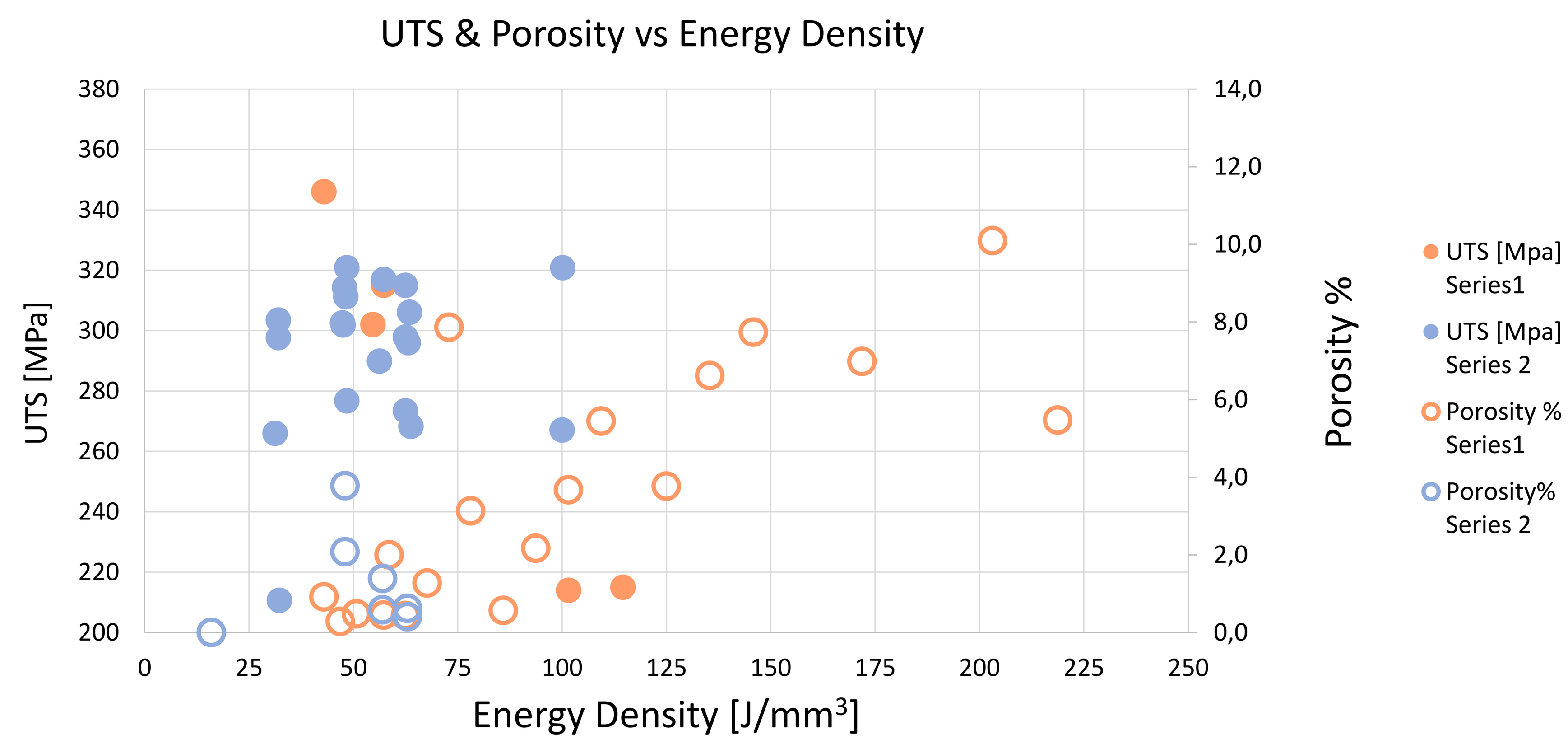
Microstructure morphology induced by SLM process:



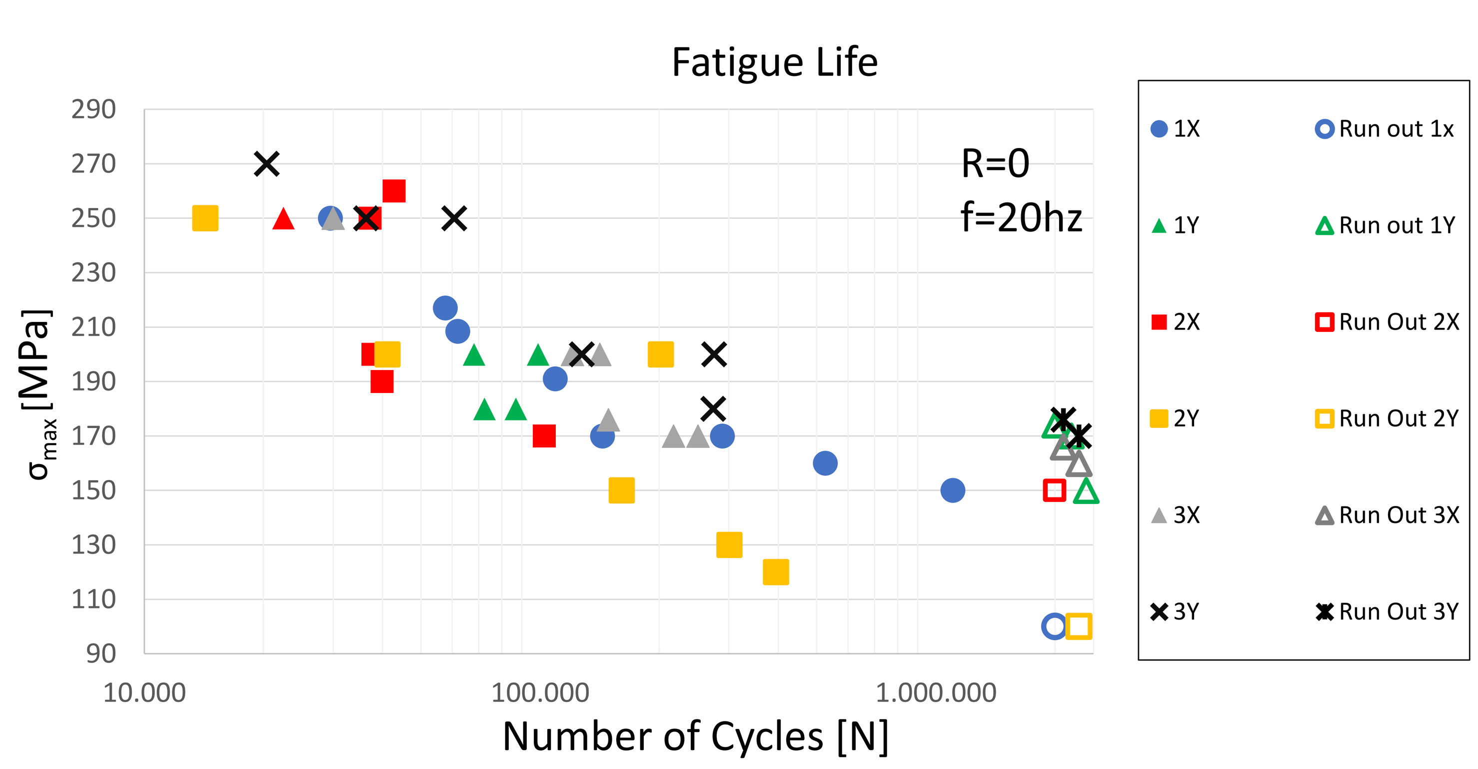
a. gas porosity
b. defect induced by 'balling'
c. α-Al dendrites inside an eutectic matrix constituted by α-Al and Si-particles



The porosity is influenced by process parameters (bubble areas are proportional to porosity percentage):
- in general, too high laser power values and very short exposure time have **negative effects on porosity;**
- a proper combination of the two parameters identifies an **optimal area of minimum porosity** values in the Ed range 40 ÷ 60 J/mm³.



The material tensile strength is correlated to microstructure morphology:
- a **direct proportionality** is shown between **energy density** and **porosity**; a minimum pores fraction is found at energy density equal to approximately 50 J/mm³;
- an **inverse proportionality** between **UTS** and **porosity** is assessed.



The fatigue resistance is characterized by a high scatter of results: two distinct behaviour are observed among samples manufactured in X, Y directions, under three different combination of laser power, exposure time, hatch distance and point distance.

Conclusions

The strong influence of process parameters on microstructural and mechanical properties is confirmed: gas porosity is the main defect detected in the microstructure. Porosity and UTS are heavily correlated; the energy density helps in understanding the effects of laser power and exposure time on porosity while it fails in describing the complex interaction with mechanical properties. Fatigue life assessment requires further investigation to validate the optimal building strategy.

Acknowledgements

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