UNIVERSITÉ CATHOLIQUE DE LOUVAIN

Study of the stress relieve heat-treatment of additively manufactured AlSi10Mg alloy:

Influence on microstructure and mechanical properties

Dissertation presented by

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Mec cool

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Gros betch à mes poules Aude Simar et Camille Van Der Rest et aux potos du labo

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List of Abbreviations

SLM	**S**elective **L**aser **M**elting

Symbols

D_a	Average particle size	$[\mu m]$
E_d	Volumetric energy density	$[\frac{J}{mm^3}]$
h	Hatch space	$[\mu m]$
P	Laser power	$[W]$
p_{Ar}	Argon pressure	$[mbar]$
t	Layer thickness	$[\mu m]$
v_s	Scanning speed	$[\frac{mm}{s}]$
$\phi_{99\%}$	Laser spot size at the 99% contour	$[\mu m]$
ρ_{rel}	Apparent relative density	$[-]$

Nous dédions ce travail à nos familles et amis

Chapter 1

Introduction

This is, with the concluding chapter, a significant portion of memory. This should especially present the context and objectives of the work. Generally, the memory structure (content of chapters) is briefly exposed

Chapter 2

State of the art

Parler de l'AlSi10Mg; quel est l'interet de travailler avec? Difficultés? (reflectivité etc)

Microstructure homogène, diagramme de phase

Fonctionnement du SLM

The properties of parts produced trough selective laser melting (SLM) stem from the coupled effects of a great deal of parameters (see figure 2.1) [1]. Results are very sensitive to their variations. The process parameters must thus be monitored thoroughly. This complicates the search for their optimisation, still not fully resolved for aluminium alloys.

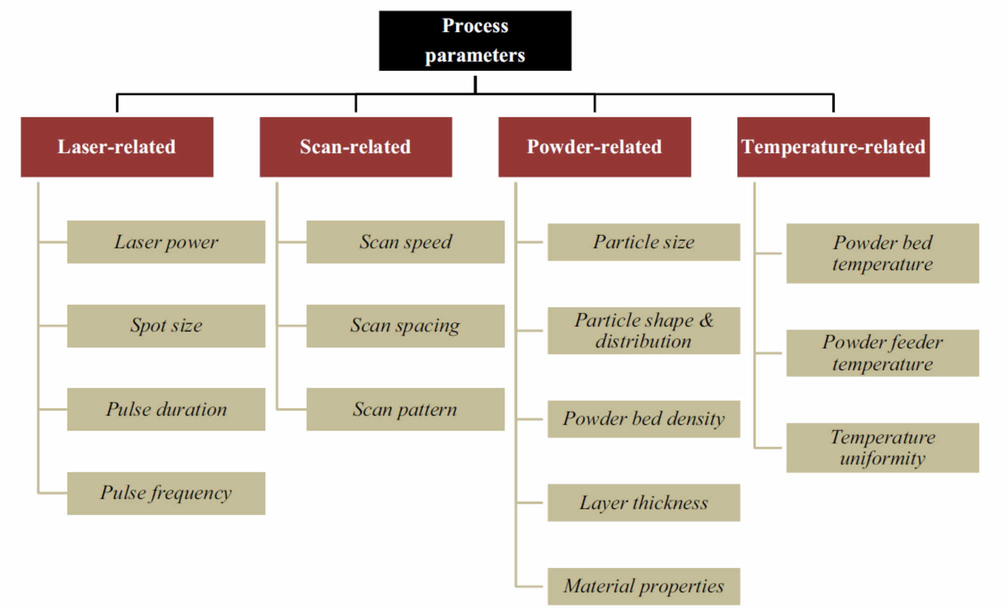

FIGURE 2.1: Parameters involved in SLM (from Aboulkhair et al, 2014)

In recent years, works aiming at facing this challenge multiplied. The minimisation of the porosity is at the center of attention. It is indeed closely related to the quality of the mechanical properties. As porosity contributes to lowering the load-bearing surface, it reduces the apparent material strength. It was also observed to have a critical influence on the fatigue life of the produced parts. Their lifetime is especially diminished if the values of pores amount and size go beyond a certain threshold [3]. Studies investigating the effects of various parameters on the AlSi10Mg fabrication trough SLM abound in the literature.

The analysis of the paired impacts of the laser power P and scan speed v_s provides a first insight. As depicted by figures 2.2 and 2.3, low P and high v_s lead to an insufficient energy input to melt the powder and re-melt the substrate, which causes the formation of droplets [4] . The opposite leads to good penetration but also to distortions and irregularities. A trend to use both high P and v_s rose in accordance with these findings. Doing so as the advantage to increase productivity. However, it also has multiple downsides including a decrease of the surface quality due to balling, excessive spatter, and an augmented gas induced porosity [6]. Therefore, a trade-off must be found.

A popular approach is to regroup multiple operating parameters into one, the volumetric energy density E. It is estimated trough the following formula:

$$E_d = \frac{P}{v_s h t}$$

where t is the layer thickness and h is the hatch space. As a rule of thumb, E_d should be chosen in the range between 60 and 75 [$\frac{J}{mm^3}$] [7]. However, the criterion is insufficient and others should be considered such as melt pools overlapping [8]. Almost no studies were carried out to optimize h and t independently. Their values lie generally respectively in the intervals [20 ; 60] [μm] and [50 ; 200] [μm].

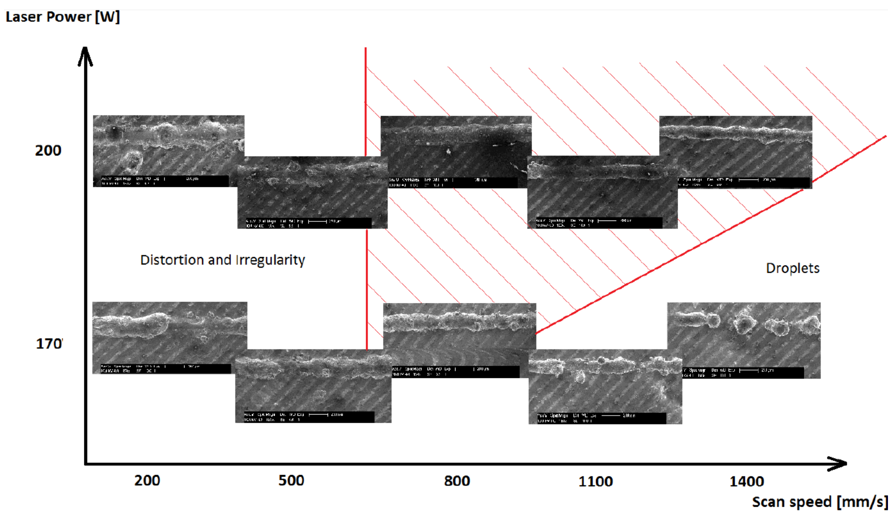

FIGURE 2.2: Process window for SLM of AlSi10Mg, based on the top view of single track scans (from Kempen et al, 2011)

The other process parameters will be covered for the sake of completeness. Let us first look into the particle-related parameters. The particle size D_a of the powder should be as small as possible to ensure a good flowability and allow for thin layers [4]. Typical values stretch from 15 to 60 [μm]. The size distribution is more delicate to outline. On one hand, wider distributions often generate better bed density and parts with higher density and better surface finish. On the other hand, narrower

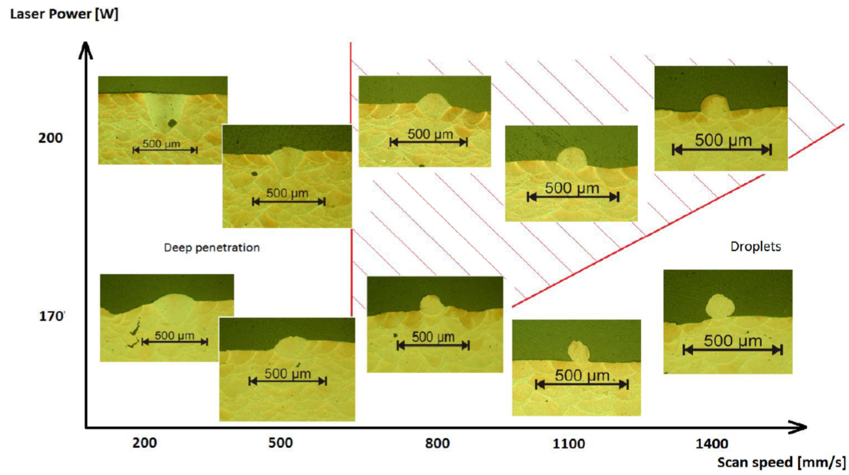

FIGURE 2.3: Process window for SLM of AlSi10Mg, based on the front view of single track scans (from Kempen et al, 2011)

ones usually provide better flowability and parts with better strength and hardness [5]. In most cases, a middle ground between the two should be sought. In SLM applications, powder is often successively recycled multiple times. This leads to their progressive contamination with moisture, which causes an increase of hydrogen porosity in the produced parts [9]. The problem can be overcome by drying the powder or using fresh one. Unfortunately - in the case of aluminium alloys - no findings were made regarding the prediction of a threshold at which measures should be taken [2].

Second, the choice of scan pattern is also of great importance. .. Building direction...

Other laser-related parameters - the spot size and the pulse properties - can also be tuned. Only the laser spot size at the 99% contour $\phi_{99\%}$ is frequently cited in literature. Its value lies between 100 and 200 μm.

Finally, pressure and temperature..

Comparer les résultats avec alliage coulé/forgé

Once the porosity problem is sorted out, other matters can be addressed such as productivity and surface roughness. The latter is problematic as the surface finish obtained with SLM is typically of such poor quality that all cracks initiate near the surface for a sample with apparent relative density $\rho_{rel} > 99\%$ [3]. Polir ou changement paramètres fab.

Post-traitements dont traitements thermiques, sur lesquels on se focalise. Expliquer

Chapter 3

Materials and methods

Description expériences et machines

Chapter 4

Results

Analyses statistiques etc...

Chapter 5

Discussion

Que conclure d'après les résultats? 5.1

FIGURE 5.1: An electron (artist's impression).

Chapter 6

Conclusion

They incorporate in a synthetic way the main results and compare them with the initial objectives. Generally, this final chapter also presents prospects for the continuation of the work undertaken.

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