

Master thesis : Design of High Entropy Alloys through Laser Powder Bed Fusion with the help of Differential Thermal Analysis

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Design of High Entropy Alloys through Laser Powder Bed Fusion with the help of Differential Thermal Analysis

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The use of metal alloys has been at the heart of many technological advances, from industry to electronics, throughout human history. Among recent advances, High Entropy Alloys (HEAs) stand out as a promising category, characterised by the balanced presence of several elements. These HEAs have attracted growing interest because of their exceptional properties, opening up new prospects for the design of high-performance materials. They offer promising opportunities in a range of applications, from aerospace to biomedical.

The emergence of additive manufacturing (AM) and laser powder bed fusion (LPBF) technology has created new opportunities for the design and production of complex metal components. LPBF's ability to produce parts with complex geometries and high density makes it an attractive technique in the HEA field.

This work focuses on the development of new HEAs by LPBF, with the support of differential thermal analysis (DTA). In a first step, a new HEA was investigated, exploring various combinations of elements to achieve optimal properties. The methodology involved the manufacture of HEA samples by DTA, followed by in-depth analysis of their microstructure, phases and hardness. Different analyses were carried out. Analyses of the DTA cooling curves helped to determine the solidification path. Characterisation was performed using an optical microscope (OM), a scanning electron microscope (SEM) and energy dispersive spectrometry (EDX). This confirmed the presence of specific phases in the microstructures, confirming the predictions made by the VEC theory. Vickers hardness was used for the hardness. In a second step, the LPBF technology was applied to manufacture a new HEA, in order to assess the feasibility and final properties of the parts produced.

In conclusion, this work confirms the help of theories in predicting present phases, as well as the benefits that DTA analysis can bring to the research for a new HEA design.

Table 1: VEC, ECC and phases observed of DTA samples.

Sample	VEC	ECC	Observed phases
$Al_{0.1}Cr_2Fe_{3.4}Mn_1Mo_{0.2}Ni_{3.2}Si_{0.1}$	8.02	21%	FCC
$CrFeMnNi$	7.75	25%	BCC and FCC
Cr_2Fe_2MnNi	7.5	33%	BCC and FCC
$CrFe_2MnNi_2$	8.17	13%	FCC
$CrFe_2MnMo_{0.3}Ni_2$	8.06	26%	FCC
$AlCrFeMnNi$	6.8	25%	BCC and FCC
$AlCrFe_2MnNi_2$	7.48	25%	BCC and FCC
$AlCrFe_2Ni_2$	7.5	25%	BCC and FCC
$AlCrFe_2MnMo_{0.3}Ni_2$	7.37	25%	FCC, BCC and sigma
$AlCrFe_2Mo_{0.3}Ni_2$	7.47	25%	FCC, BCC and sigma

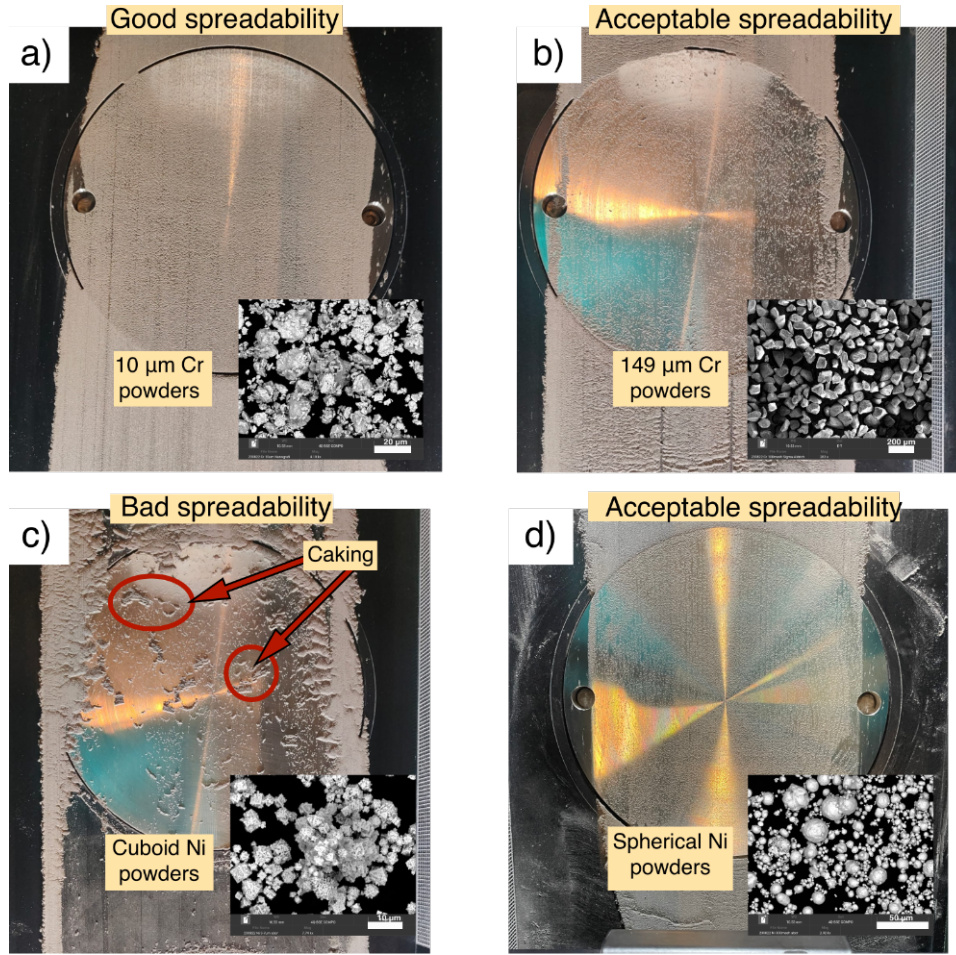


Figure 1: Test for spreadability. (a) $CrFe_2MnNi_2$ with 10 μm Cr powders, (b) $CrFe_2MnNi_2$ with 149 μm Cr powders, (c) $AlCrFe_2MnNi_2$ with cuboid Ni powder, (d) $AlCrFe_2MnNi_2$ with spherical Ni powder.

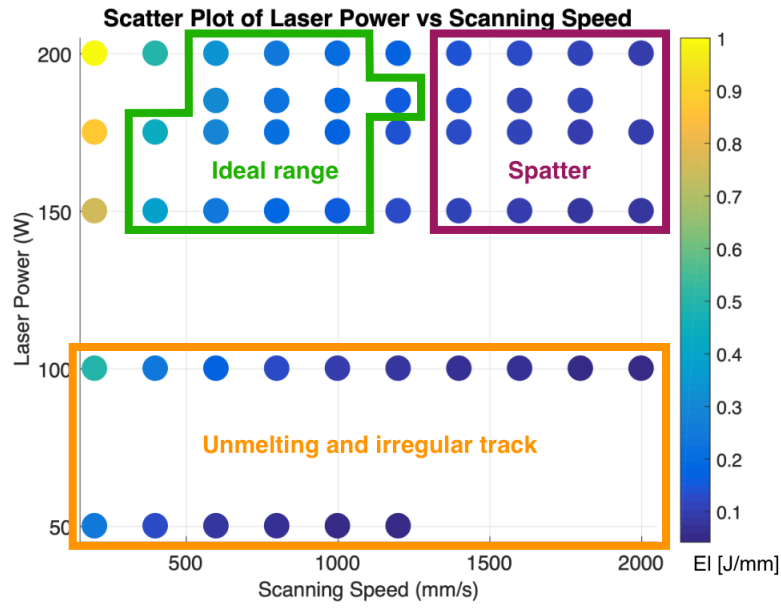


Figure 2: Process map with regards to the single track $AlCrFe_2MnNi_2$.

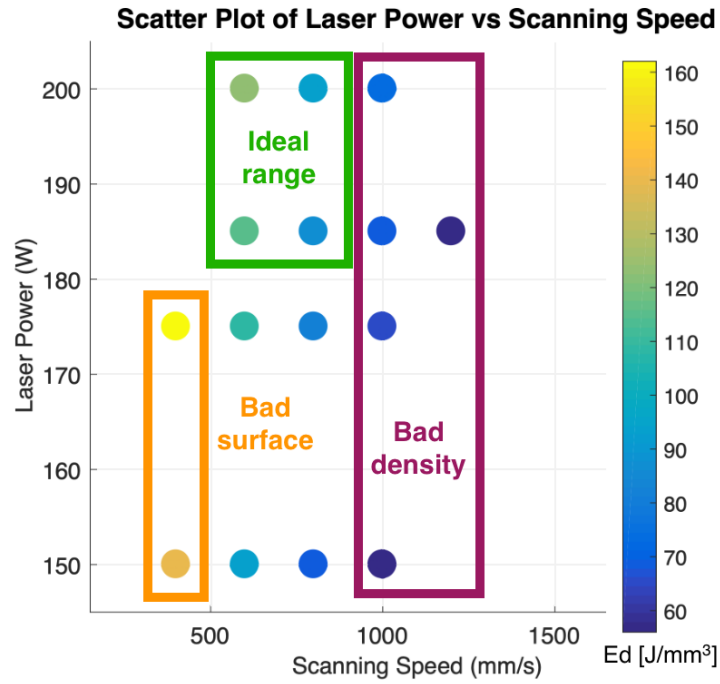


Figure 3: Process map with regards to the printing of $Al_{0.2}Cr_{0.68}Fe_{1.79}MnMo_{0.1}Ni_{1.47}$ alloy.