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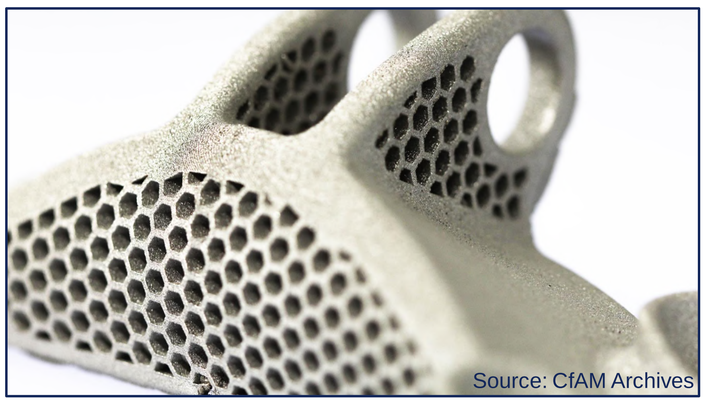
Centre for Additive Manufacturing

Aluminium Alloy Design Methodologies for L-PBF

1. L-PBF of Al-alloys: state of the art



Material Class	Examples	Processability	Mechanical Performances
Eutectic alloys	AlSi7Mg AlSi10Mg AlSi12	✓	Limited
High-strength alloys	AA2024 AA6061 AA7075	✗	High Y and UTS

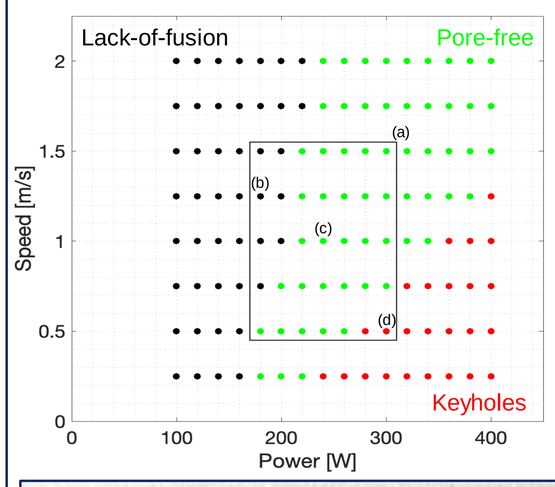
2. Aims: what is missing?

- develop a methodology to predict and quantify defects to **avoid** the printing of **high porosity samples**
- understand the **limits** of the currently **adopted parameters** to predict the presence of cracks (ΔT and HCS_{SK})

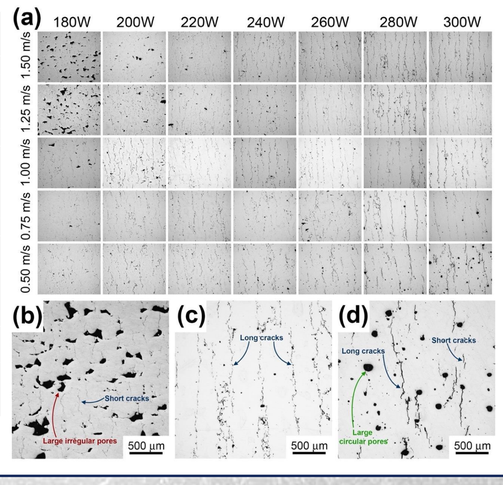
3. Case study: AA2024

Predict → ***Observe*** → ***Differentiate*** → ***Analyse***

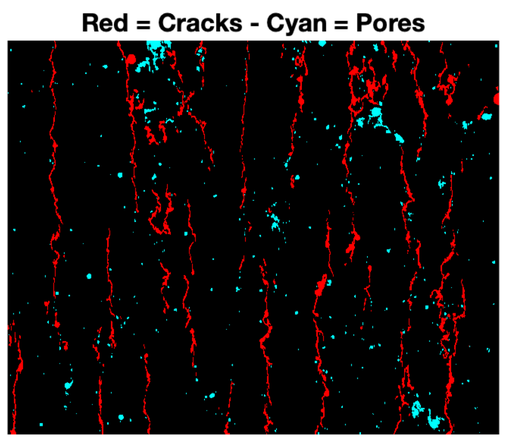
- Investigate the presence of defects in a **P-v design space**
- A **refined window (a)** is chosen to minimize the presence of pores



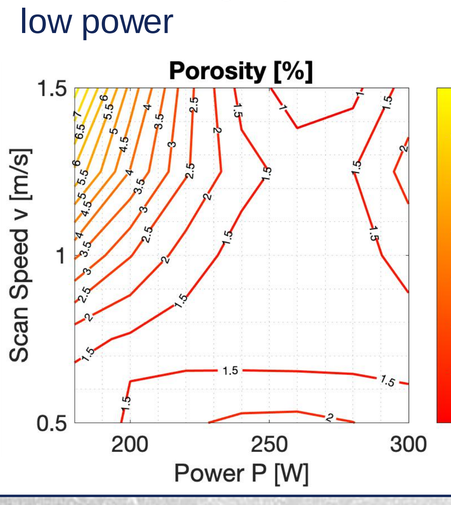
- **(a)** is **produced**
- Optical micrographs reveal **good match** between predictions and as-built microstructure (b-c-d)



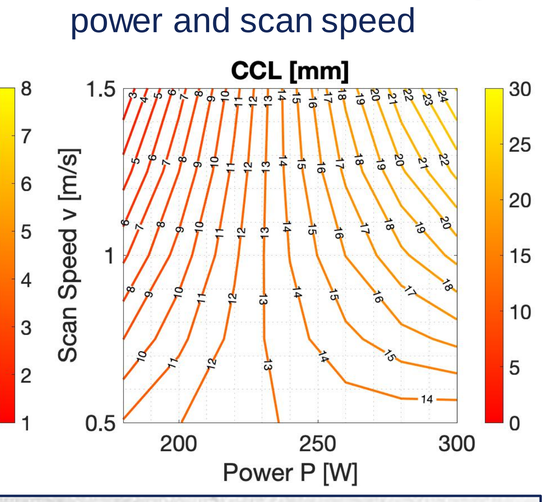
- **Binarization** → using geometrical parameters defects are subdivided in:
  - ❑ ***Pores*** (cyan)
  - ❑ ***Cracks*** (red)



The analysis of porosity is conducted using a **surface percentage** parameter which reveals the detrimental effect of LOFs at high speeds and low power



The cumulative crack length **CCL** is used to quantify cracks. These defects are minimized in areas with high LOFs and maximized at high power and scan speed



Discussion: dual cracking behaviour

★ Hot Cracks

- **nucleate** as a result of a single melting event
- presence of secondary phases in between crack's surfaces
- **poor liquid feeding** is not able to "heal" the crack after nucleation

♦ Propagation Cracks

- **propagate** in the solid through multiple layers
- clean surfaces aligned to the building direction
- promoted by the presence of **long columnar channels** in between grains

Implications to alloy design: new parameters

w_{ch}

- the **width of channel** w_{ch} is proposed to aid the prediction of hot cracks
- it represents a good measure of the amount of interdendritic liquid present at the last stage of solidification

Q

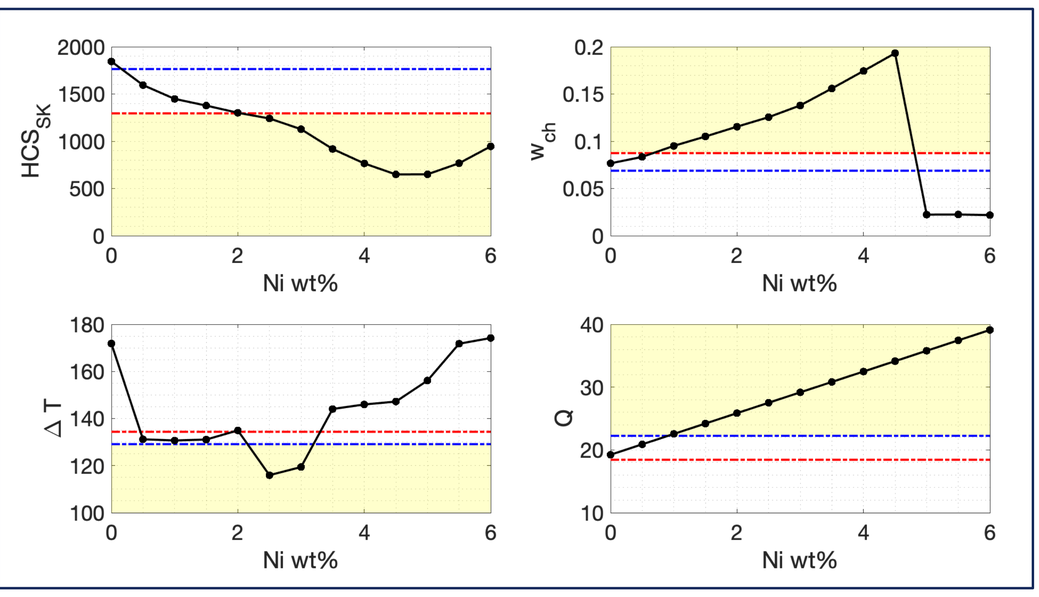
- the **growth restriction factor** Q is proposed to predict the morphology of grains
- this parameter measures the amount of solutes able to create great constitutional supercooling and so limit the grains growth

4. Proposed methodology and future works

AIM: modify the AA2024 chemical composition to avoid cracks

HCS_{SK} ΔT	**minimize**
w_{ch} Q	**maximize**

- using **Thermo-Calc** the solidification path of a specific chemical composition can be computed to evaluate the cited parameters
- **Nickel** (Ni) represents the best candidate because is able to reduce the HCS_{SK} parameter, reduce the solidification range ΔT and increase both w_{ch} and Q
- **AA2024 + 3 wt% Ni** will be studied to validate the proposed methodology!



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