Thermal Post-treatment of Alloy 718 produced by Electron Beam Melting

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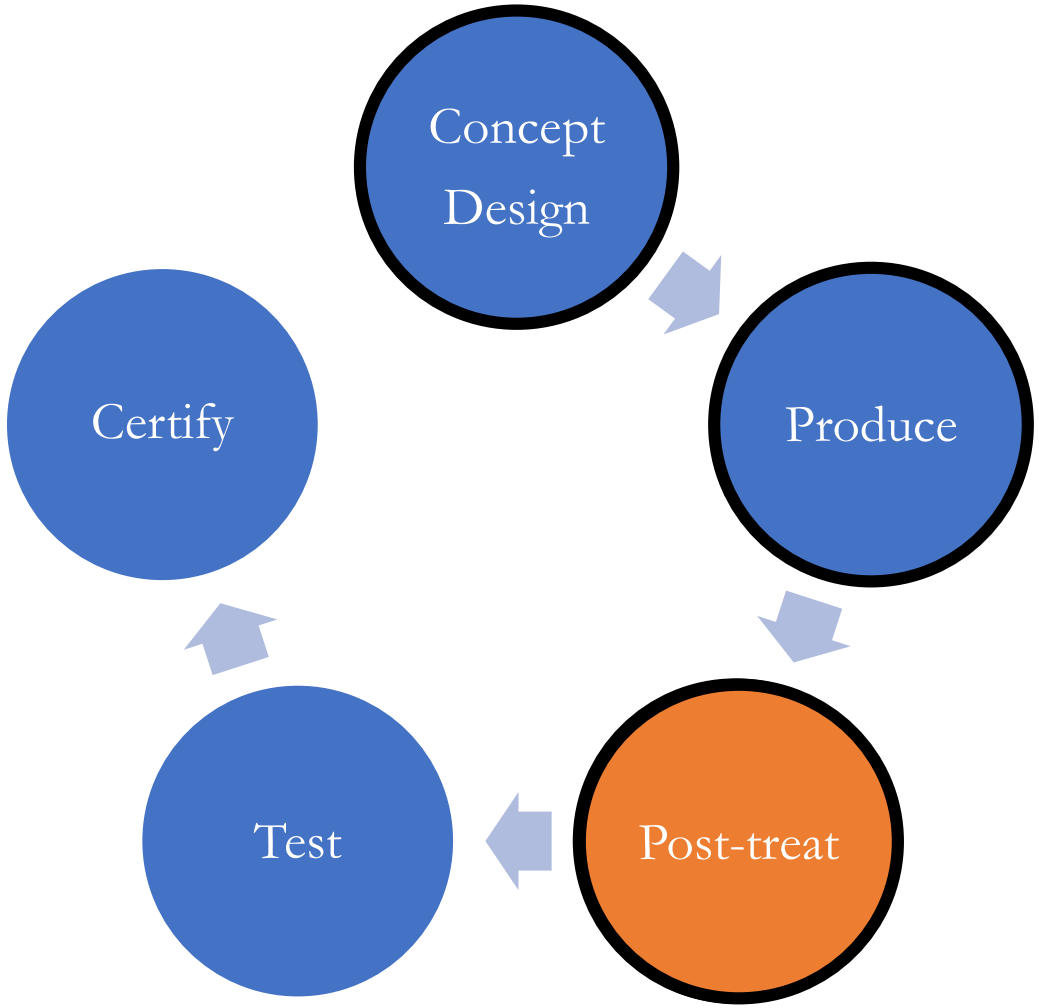
Metal Additive Manufacturing (AM)



Features of metal AM…

- Improved design
- Material wastage ↓
- # parts ↓
- Part complexity ↑
- Flying weight ↓
- Performance ↑

Bracket
-Airbus A380

Investment cast

AM

Features of metal AM…

- Improved design
- Material wastage ↓
- # parts ↓
- Part complexity ↑
- Flying weight ↓
- Performance ↑

Fuel nozzle
-GE Additive

20 parts → 1 part

25% lighter
5 times more durable

Alloy 718

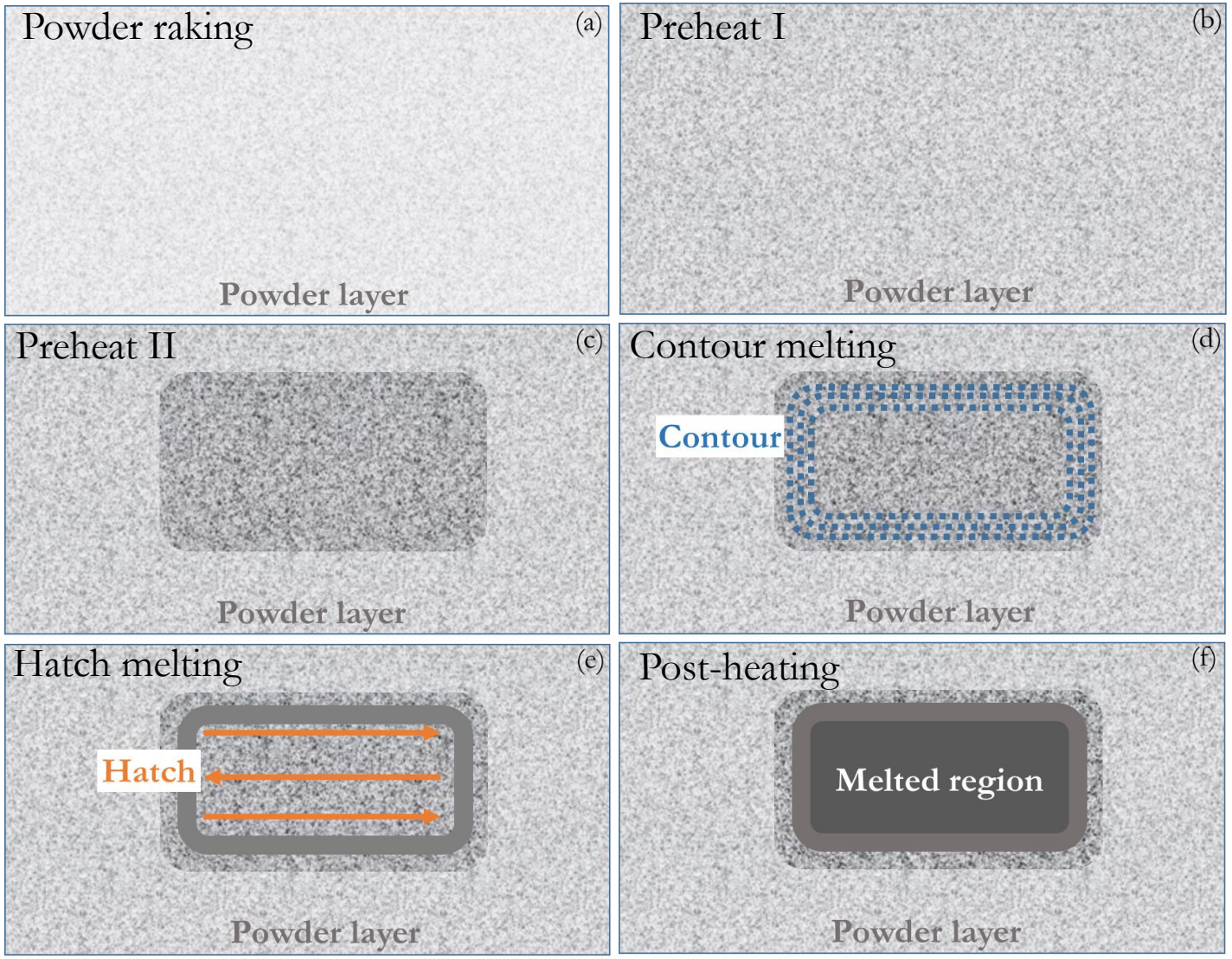
- Complex alloy
- Workhorse alloy of aircraft engine industry
- Precipitation strengthening:
  - Morphology, size, amount
  - Mainly coherent γ” (Ni_3Nb), some γ’ ($Ni_3(Al,Ti)$)
  - Carbides, δ (Ni3Nb): grain size control
  - Inclusions: unwanted

Alloy 718	
Ni	54.11
Cr	19.0
Fe	12.2
Nb+Ta	4.97
Mo	2.99
Ti	1.02
Al	0.52
C	0.03

Electron Beam Melting (EBM)

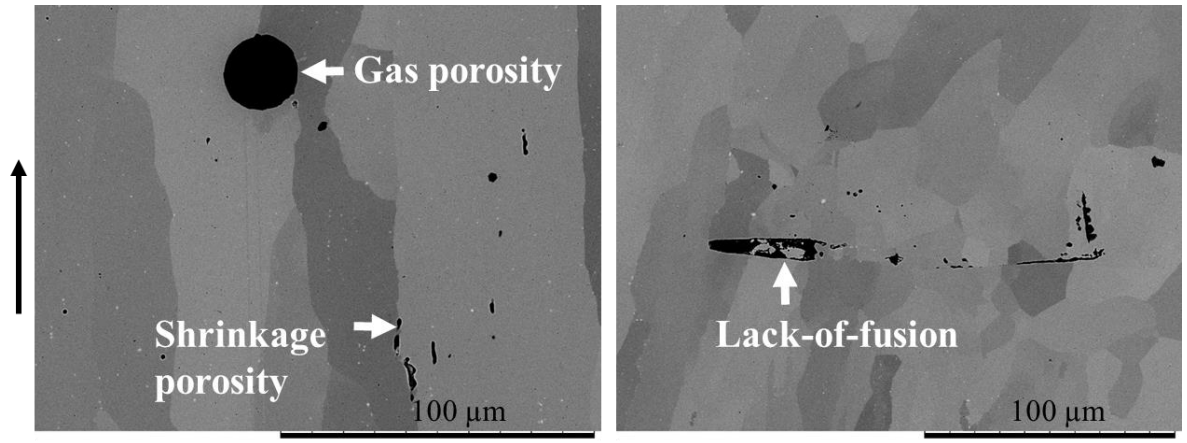
- Powder bed fusion
- Energy source: electron beam
- Process environment: vacuum

EBM processing of a layer

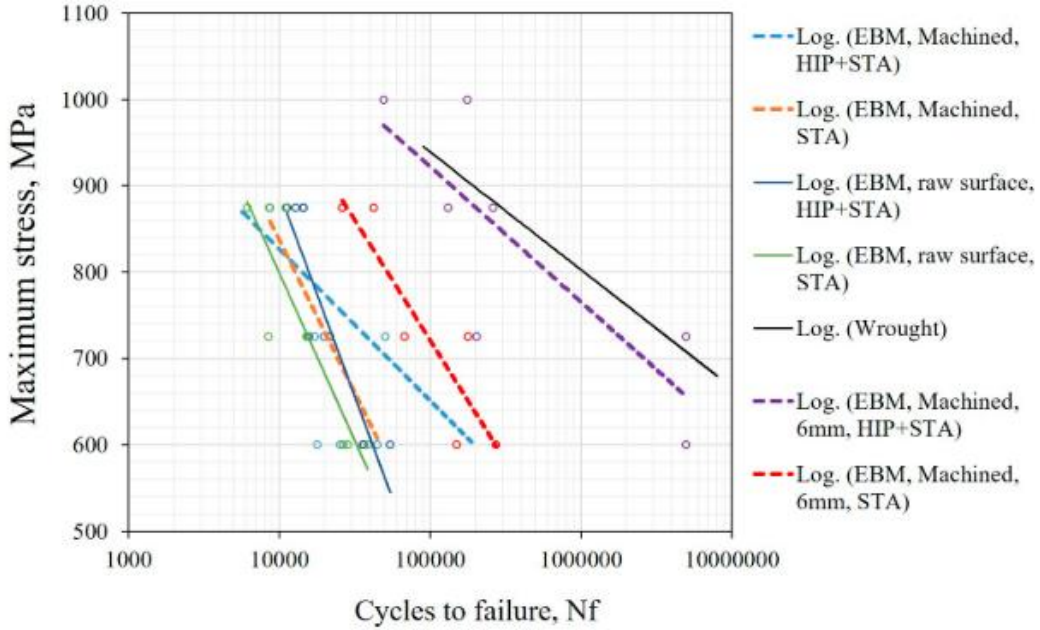


Motivation for Post Treatment

- **Defects**
  - **Porosity**
    - **Aligned: weak plane**
  - **LoF**
    - **Crack initiation site**
- Non-uniformity
  - e.g. δ
- Lack of required phase
  - e.g. strengthening phases (γ”)
- Detrimental phase
  - e.g. Laves
- Anisotropy
- Residual stress

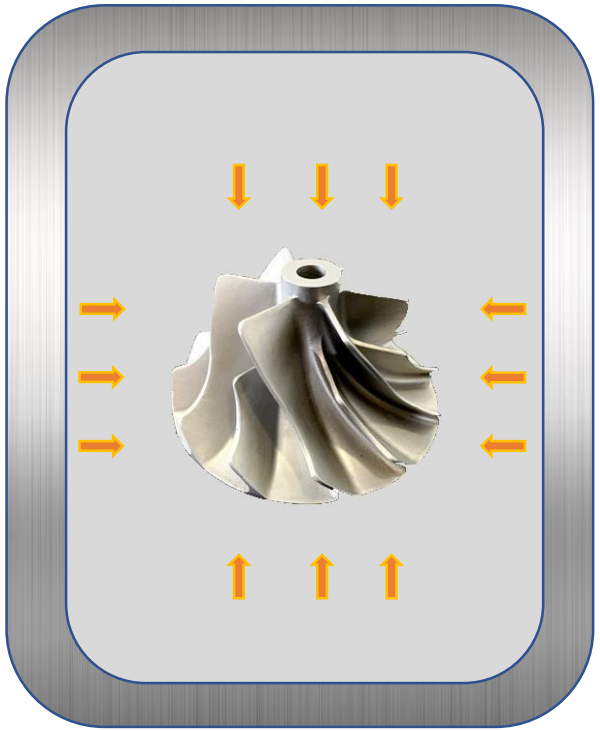


Goel S., et.al., *JMEP* (2019)



Balachandramurthi A.R., et.al., *Materials* (2018)

Typical thermal post-treatments



Reduce defects

Hot Isostatic Pressing

As-built

Alter secondary phases

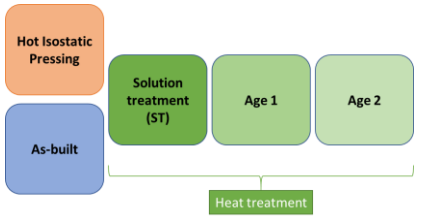
Solution treatment (ST)

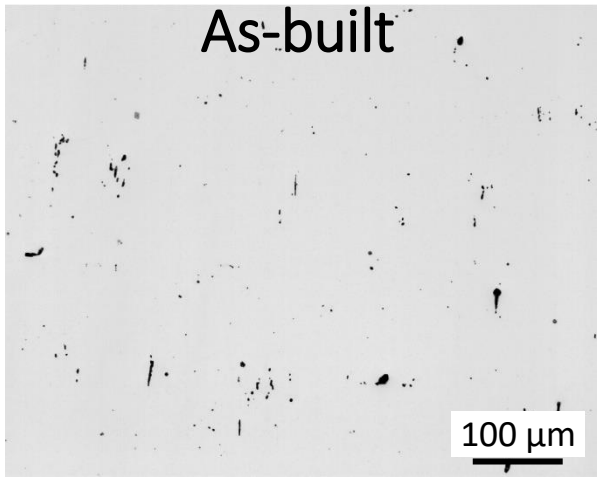
Age 1

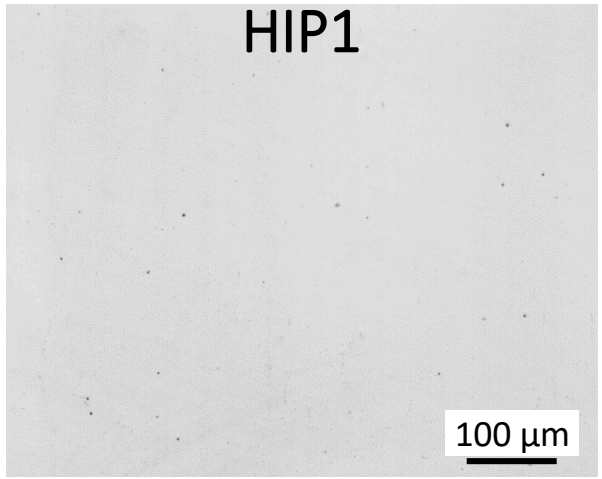
Age 2

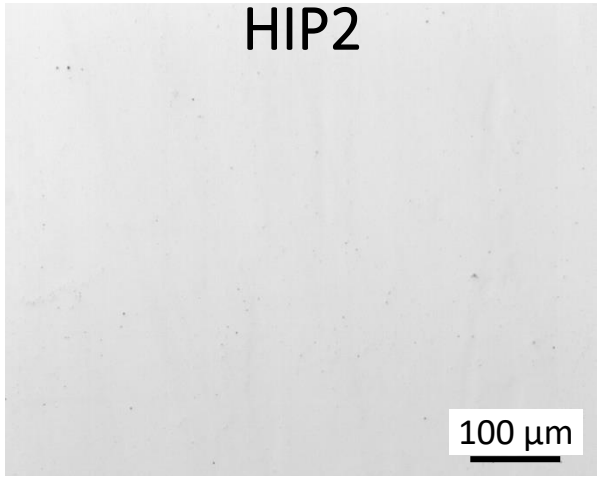
Heat treatment

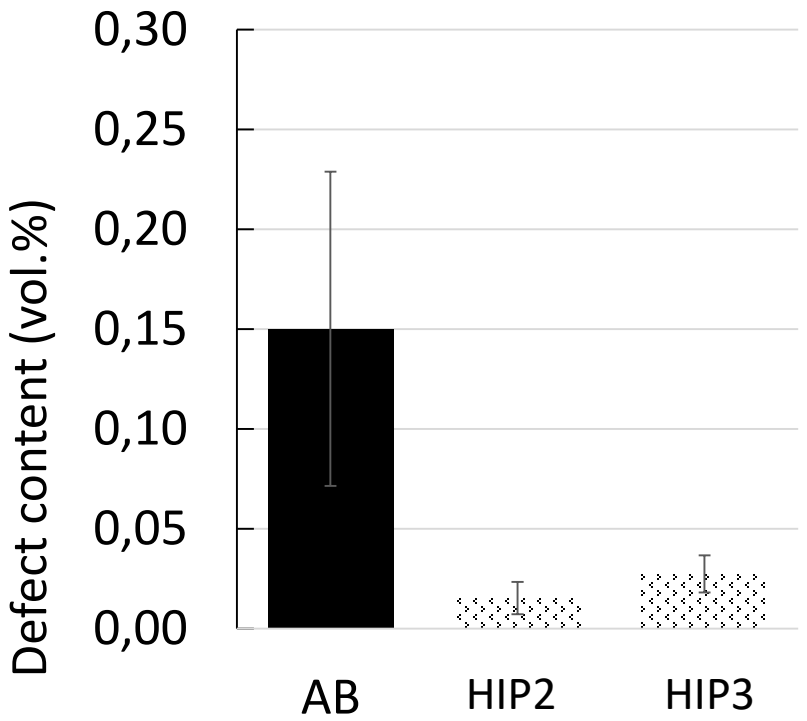
Reducing HIPing temperature







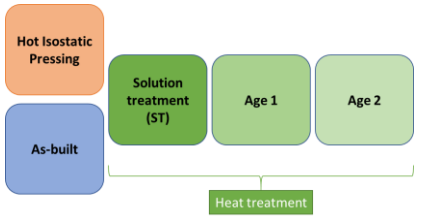




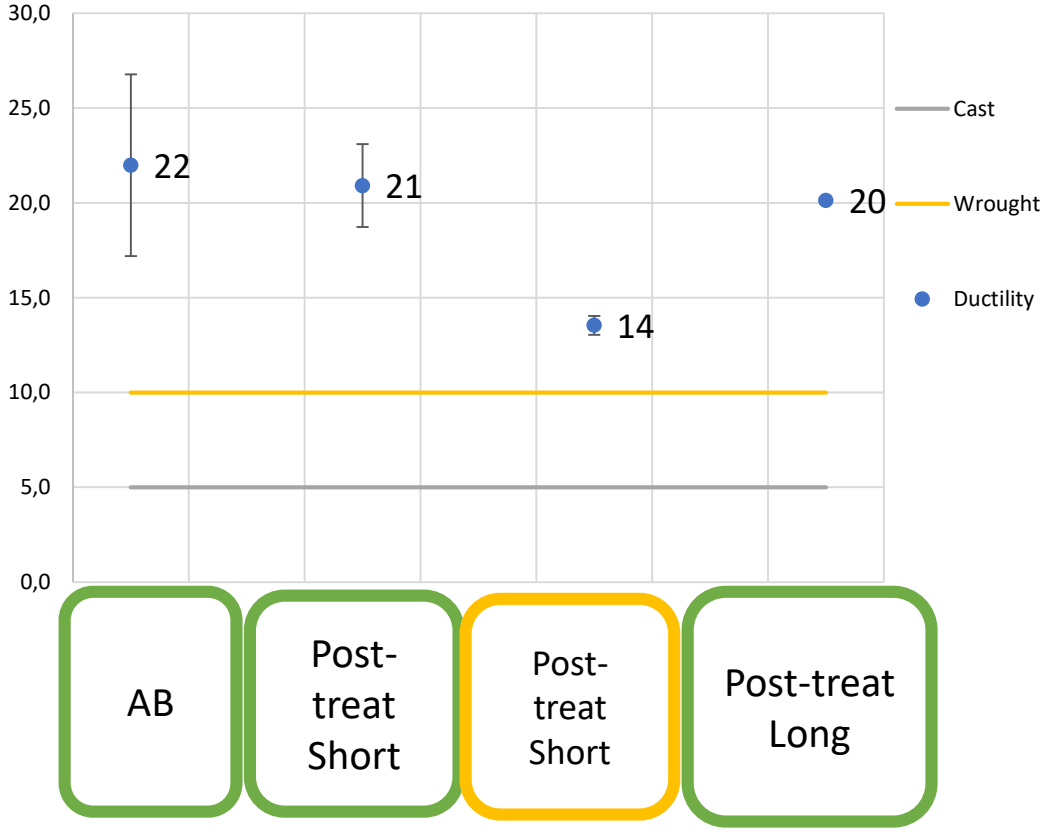
- **HIP resulted in porosity reduction by an order of magnitude**
- **Extent of porosity reduction by HIP2 ~ HIP3**

HIP1: 1120 °C, 4h, 100 MPa, RC
HIP2: 1185 °C, 4h, 100 MPa, RC

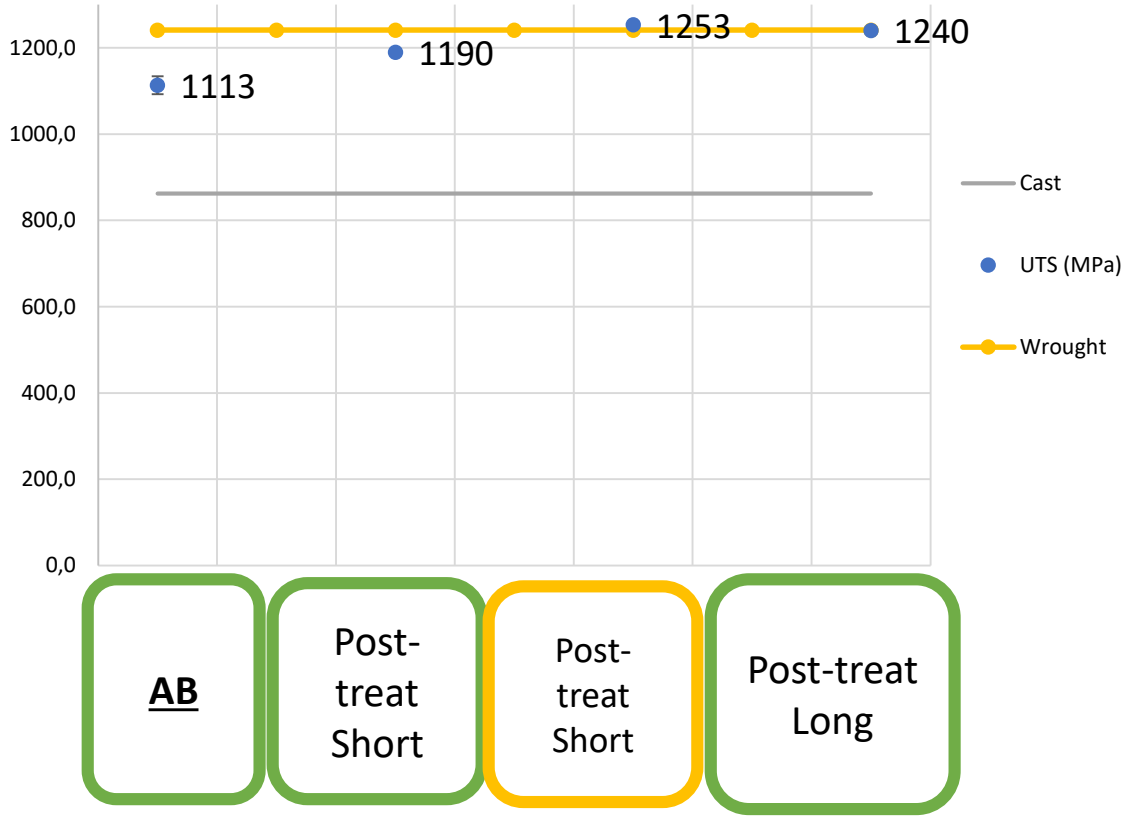
Shortening post-treatment (25 h → 10h)



Elongation (%)

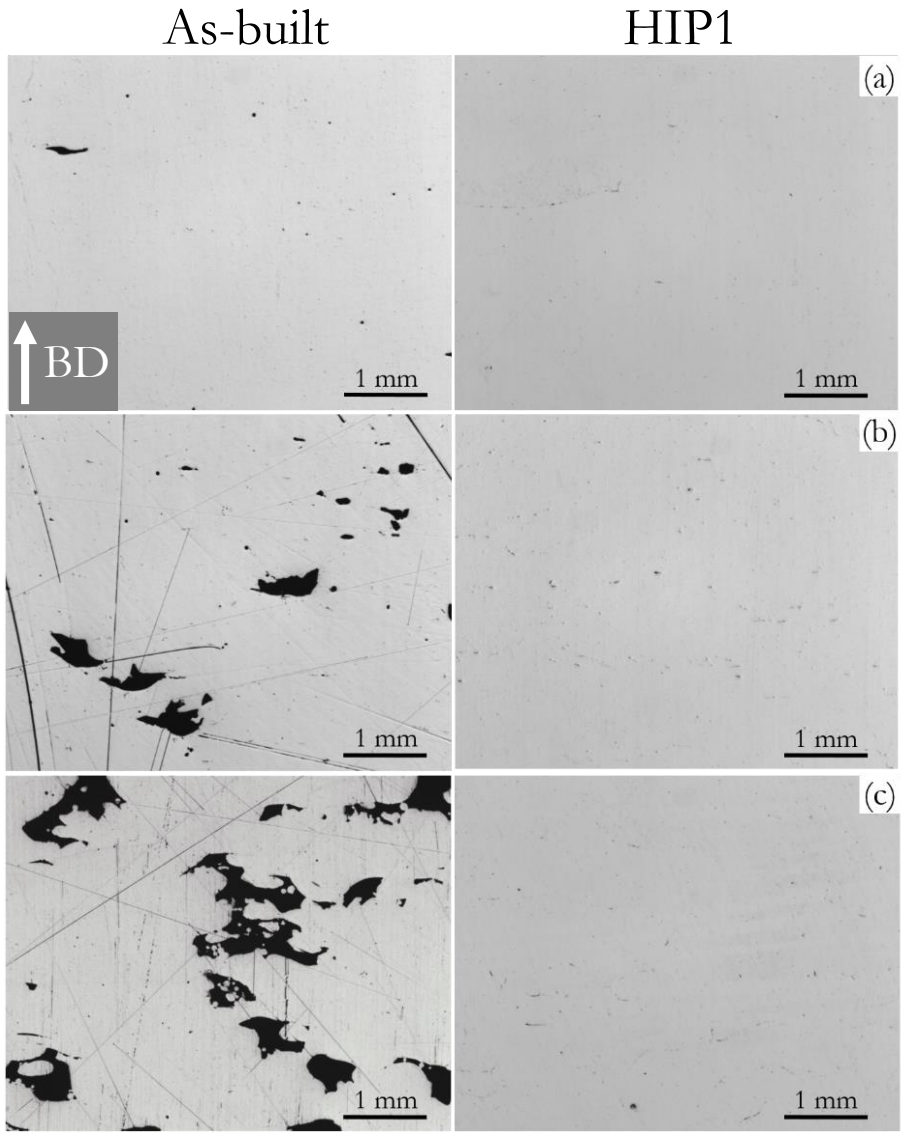


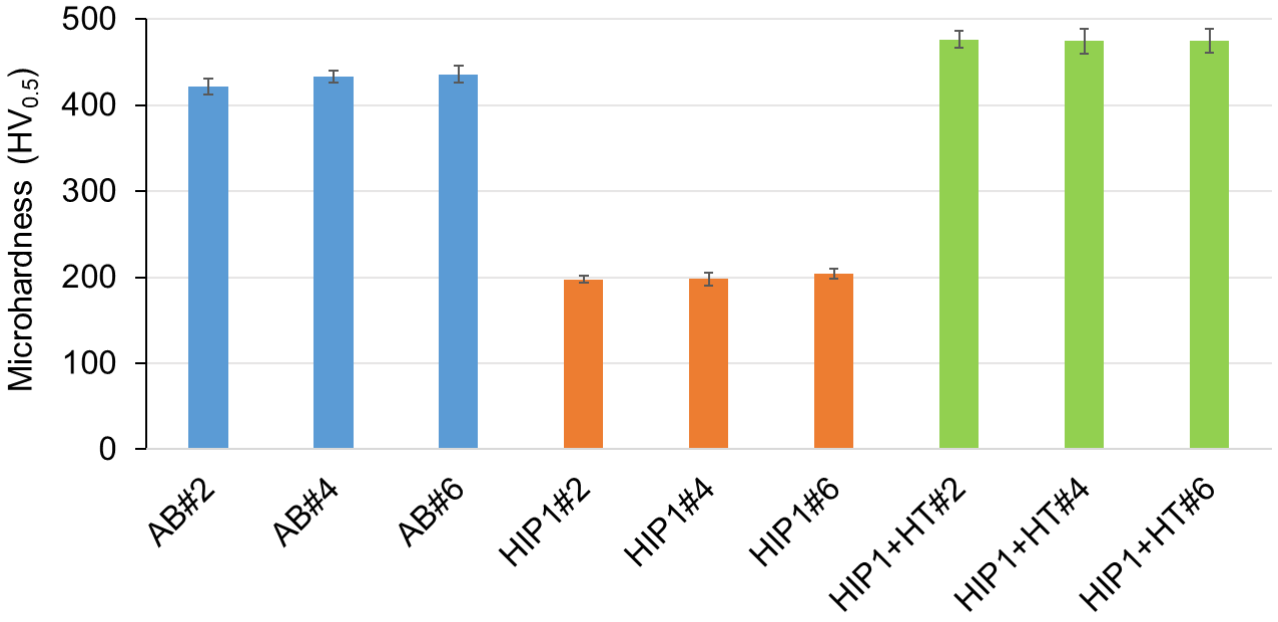
Tensile strength (MPa)

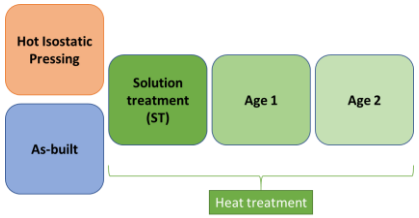


- **Short ~ long post treatment**
- **Tailored as-built microstructure can deliver higher strength**

Response of builds with varied defect contents







- Extensive defect reduction and high hardness after short post-treatment
- No evident thermally induced porosity

Thank you! ☺

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