Trade-off between microstructural evolution and alpha-case formation during post L-PBF heat treatments on the static properties of Ti-6Al-4V alloy

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Stakeholders

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La Région Auvergne-Rhône-Alpes
L'Europe s'engage en région Auvergne-Rhône-Alpes avec le FEDER
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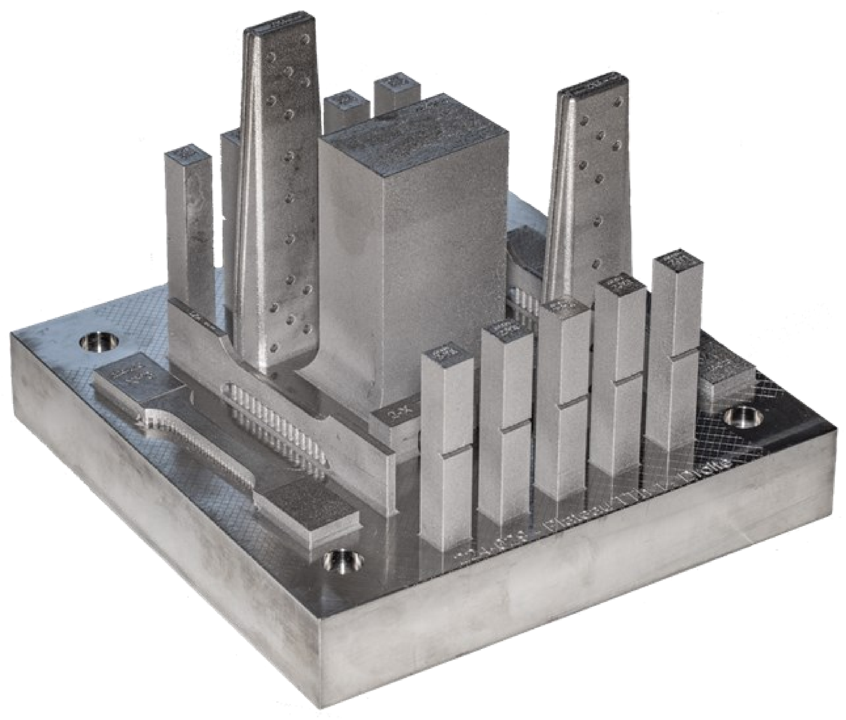


Ti-6Al-4V samples fabricated by L-PBF on a Ti-6Al-4V base plate

Optimisation of post L-PBF heat treatments

Laser Powder Bed Fusion, metal addtive manufacturing process

▶ **Stress-relieving:**
High **residual stresses** formed due to dramatic L-PBF thermal gradients
→ Post-processing heat treatments: **relaxation** of the internal stresses
→ Prevention of cracks and distortions of the Ti-6Al-4V components.

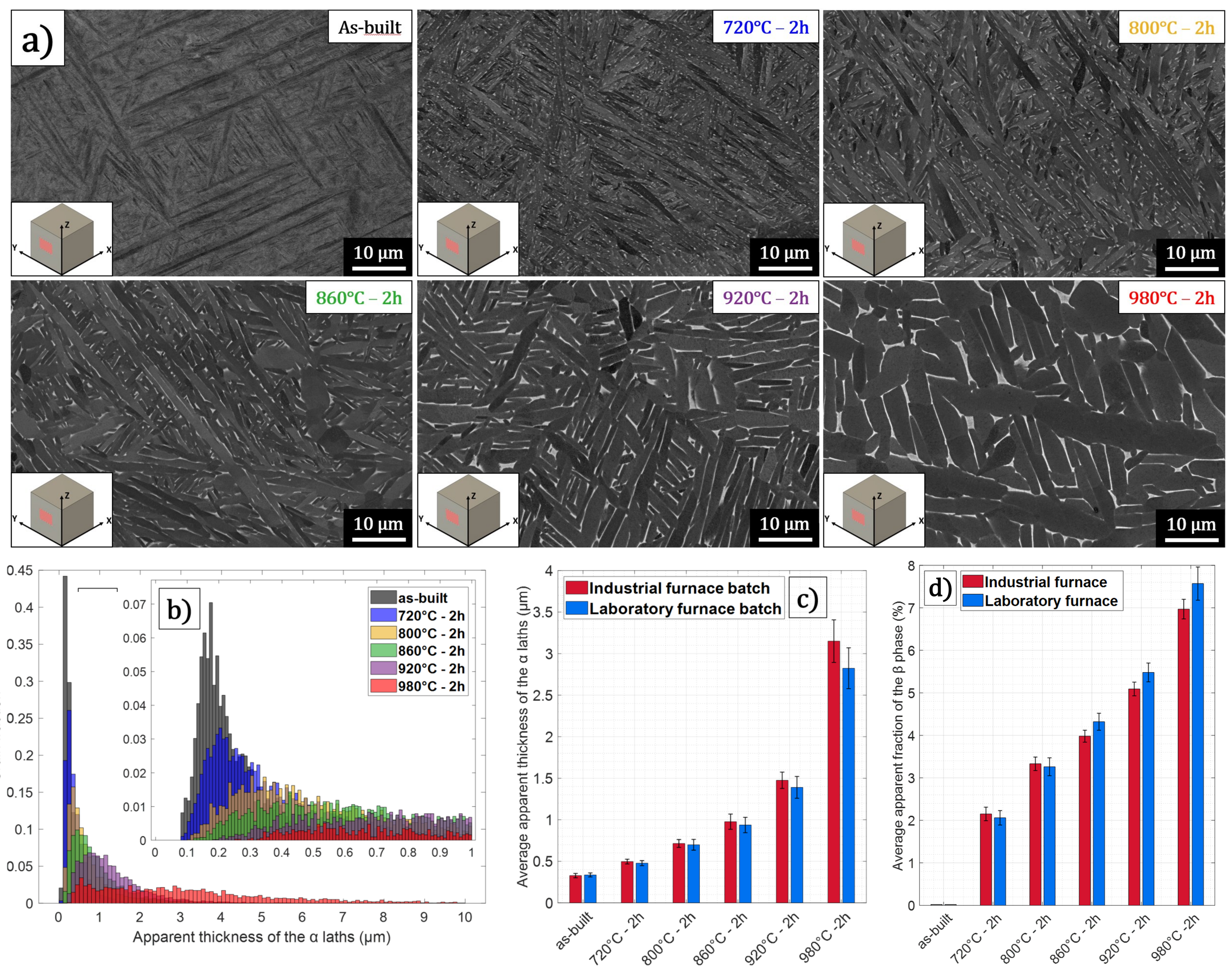
▶ **Microstructural evolution:**
Fine **martensitic microstructure** obtained in Ti-6Al-4V made by L-PBF
→ Detrimental for mechanical properties: high strength / poor ductility
→ Post-processing heat treatments: microstructrural evolution that helps to **balance the strength / ductility compromise.**

Microstructural characterizations

As-built / heat-treated (HT) conditions

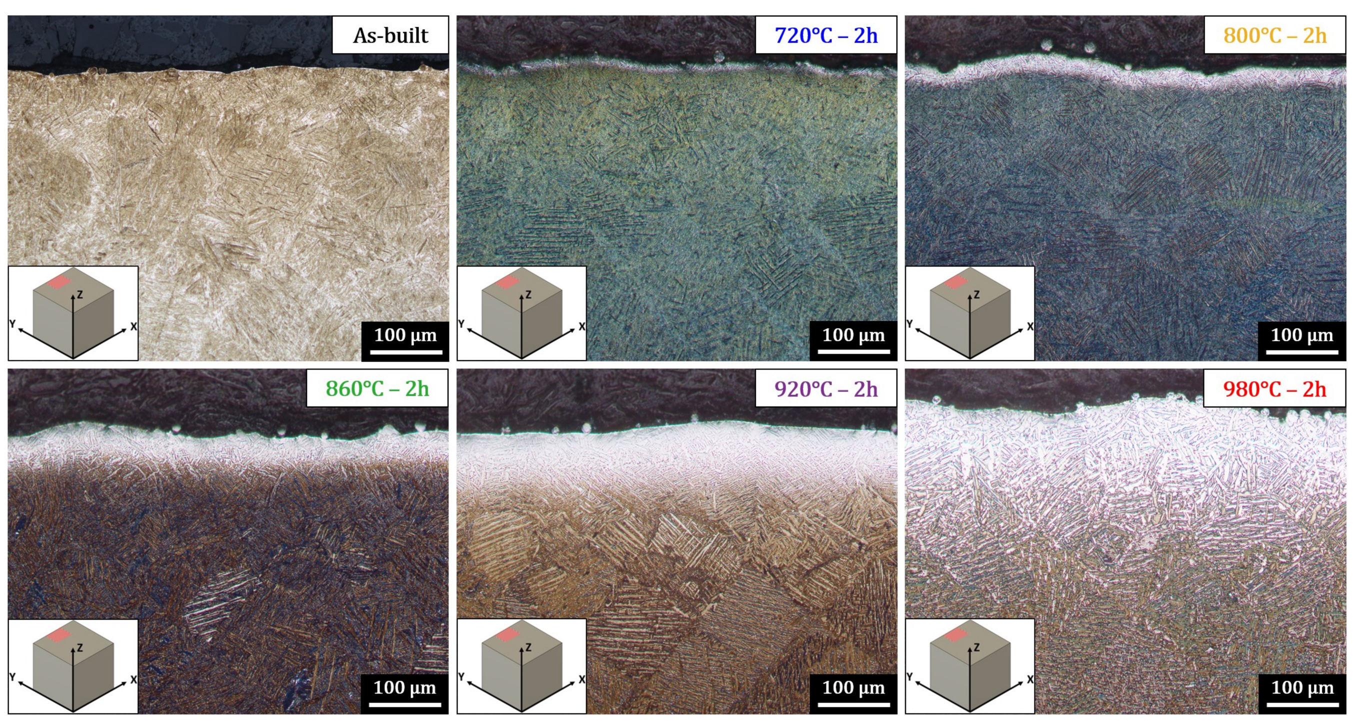
▶ **Post-processing heat-treatments:**
→ Industrial furnace (**IF-HT**) batches
→ Laboratory furnace (**LF-HT**) batches

▶ **Microstructural evolution:**
→ Phase transformation: $\alpha \rightarrow \alpha + \beta$
→ Growth of the α laths thickness
→ Increasing of the β phase fraction



(a) SEM-BSE micrographs of L-PBF fabricated Ti-6Al-4V in the as-built condition and submitted to various sub-transus IF-HT and LF-HT ; Distribution (b) and evolution (c) of the average α laths thickness ; (d) Evolution of of β phase fraction

▶ **Alpha-case formation:**
→ Oxygen diffusion in the sub-surface during IF-HT
→ No presence of alpha-case after LF-HT



Optical micrographs taken after etching with Weck reagent before and after various IF-HT. The chemical attack reveals the alpha case layer in white.

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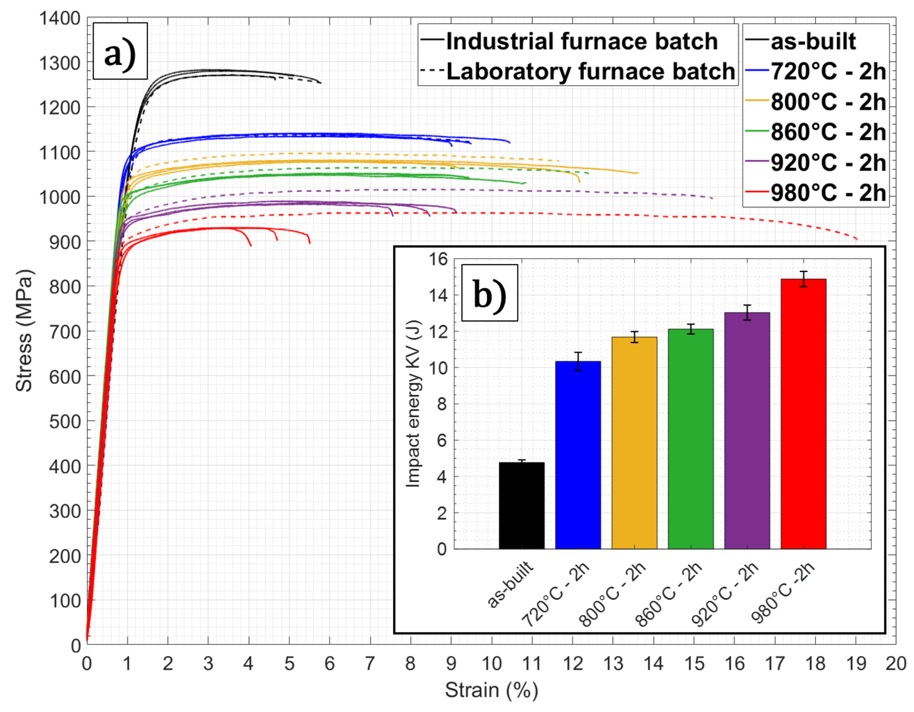
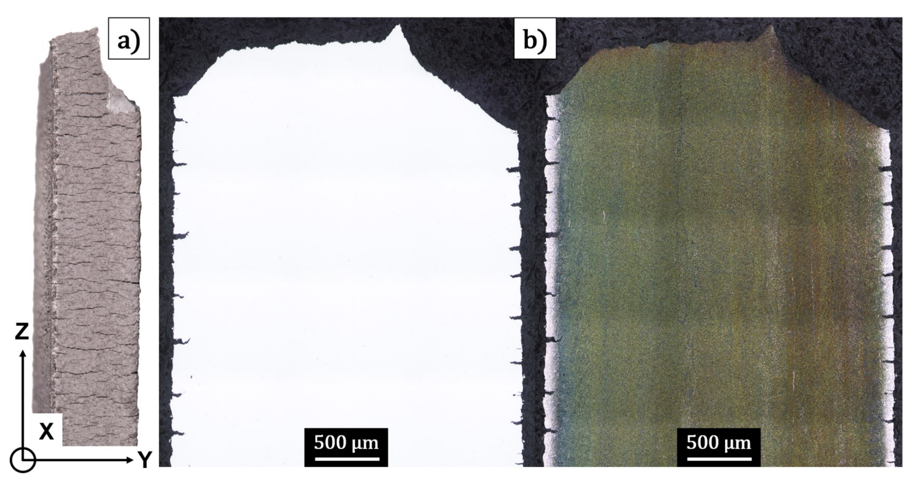
Mechanical characterizations

As-built / heat-treated (HT) conditions

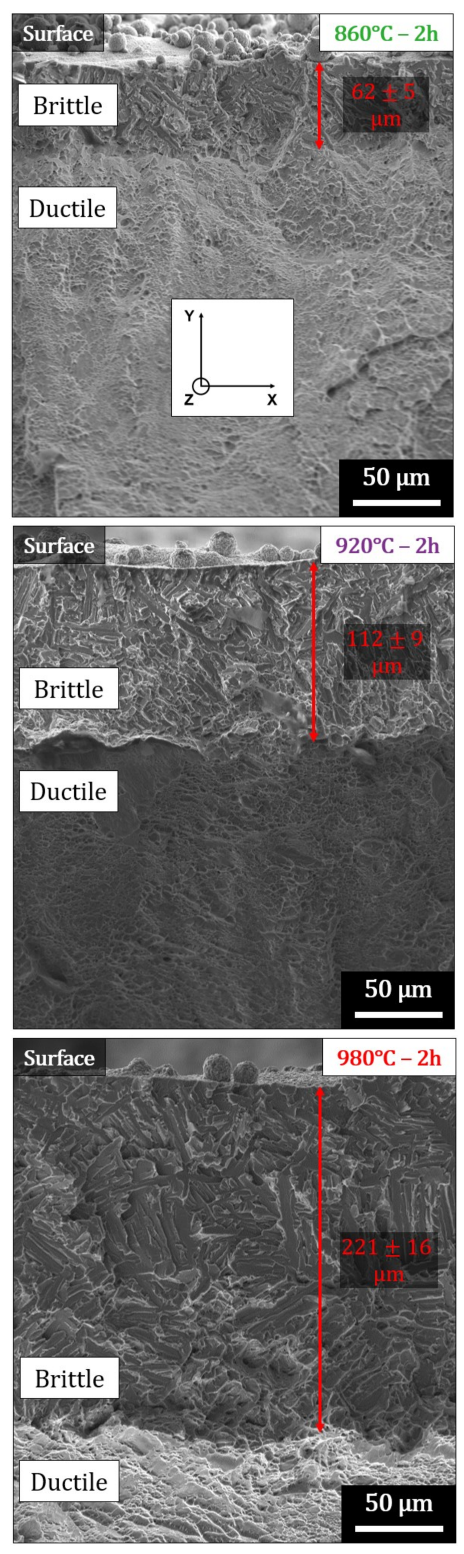
▶ **Mechanical properties evolution:**
→ $\boldsymbol{\sigma_y} - \boldsymbol{\sigma_u} - HV$: decreases with HT temperature
→ For HT > 860°C, $A\%(IF-HT) < A\%(LF-HT)$
→ Cracks and brittle layer at the edge of IF-HT tensile specimens: **alpha-case embrittlement**



Stress-strain tensile curves of the verticallty built IF-HT and LF-HT samples (a) ; Impact energy of IF-HT samples

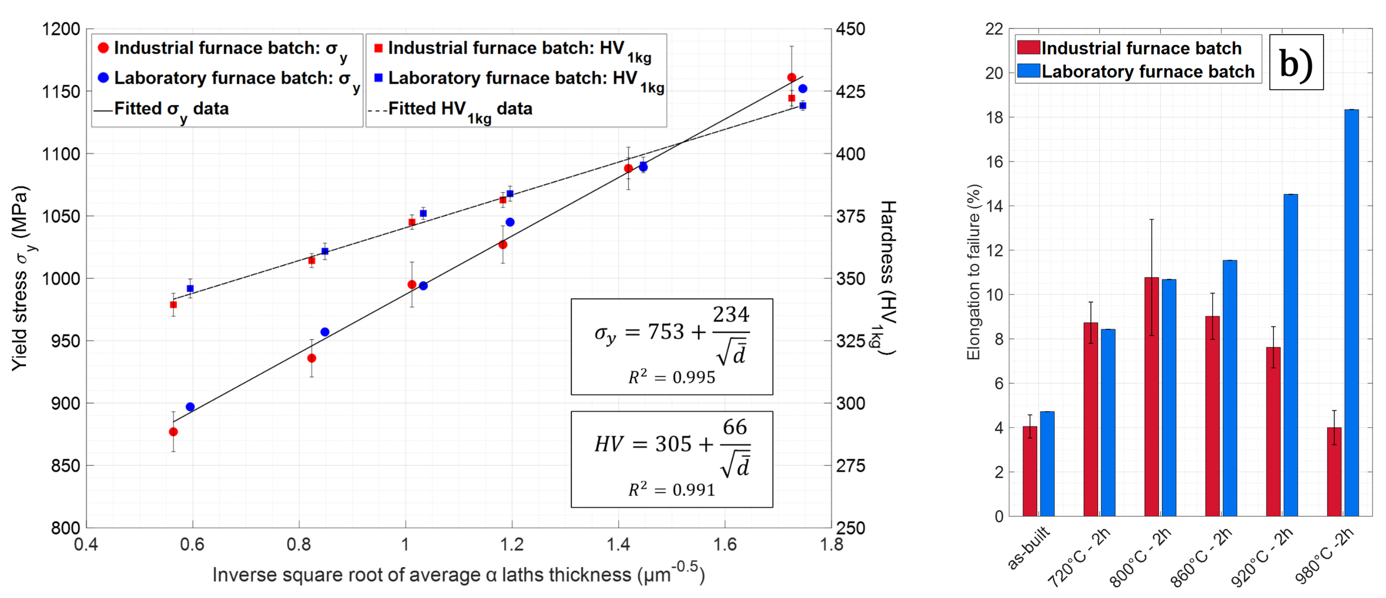


Cracks at the surface of 920°C/2h IF-HT tensile specimen before (a) and after (b) etching with Weck reagent.



SEM-SE images taken at the edge of the rupture surface of tensile specimens submitted to IF-HT (right pictures)

▶ **Impact of microstructural evolution:**
→ $\boldsymbol{\sigma_y}$ governs by α laths thickness: Hall-Petch law
→ IF-HT ≤ 800°C: minor effect of alpha-case on A%



Evolution of the measured yield stress and hardness as a function of the inverse square root of the measured α laths thickness (left) and evolution of elongation to failure A% for various IF-HT and LF-HT (right).

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