Application-specific process - microstructure - properties correlations for LPBF Inconel 718

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LPBF Manufacturing

Laser Powder Bed Fusion (LPBF) enables the printing of complex components quickly and cost-effectively, maintaining high quality.

For critical aerospace parts, optimizing the manufacturing process, considering build direction (BD) and heat treatments is essential to achieve desired properties (Fig. 1).

Key challenge: correlating phase evolution with forming microstructures and properties.

Methodology

Material: Inconel 718 (IN718) printed on a Concept Laser-M2 machine.

LPBF parameters: Optimized for minimal porosity.

Heat Treatments:

- Double Aging (DA);
- Hot-Isostatic Pressing (HIP): 0.1 GPa/ 1150 °C;
- HIP followed by Double Aging (HIP+DA).

Analysis: Phase evolution analyzed by high-energy diffraction (HEXRD) at synchrotron DESY (Hamburg, Germany).

Testing: Tensile testing of cylindrical specimens printed in 3 build orientations.

Results

Microstructure (Fig. 2a):

- 'as-built' (AB) IN718: fine cellular-dendritic structure with textured γ-grains framed by brittle Laves phase;
- 'as-built' and DA: moderately textured;
- Laves phase: transforms to δ and hardening γ'' during DA.

Heat Treatments (Fig. 2 b and c):

- HIP above δ-solvus dissolves Laves and δ, coarsens grains, and reduces texture.
- Post-aging HIP+DA increases γ''.
- All heat-treatments lead to MC growth.

Tensile Properties (Fig. 3):

- As-built and DA material: higher strength/reduced elongation at 0° versus 90° build direction:
- Texture and high residual stresses affect anisotropy in AB and DA.
- HIP and HIP+DA: Less anisotropy, texture and residual stresses reduced.
- DA: Increases strength after AB / HIP due to γ'' growth
- HIP: Reduces porosity and coarsens structure, improves elongation.

Conclusions

Understanding the interplay between process parameters, post treatment, phase distribution, and materials' properties enables the development of customized materials and processing chains tailored to specific applications.

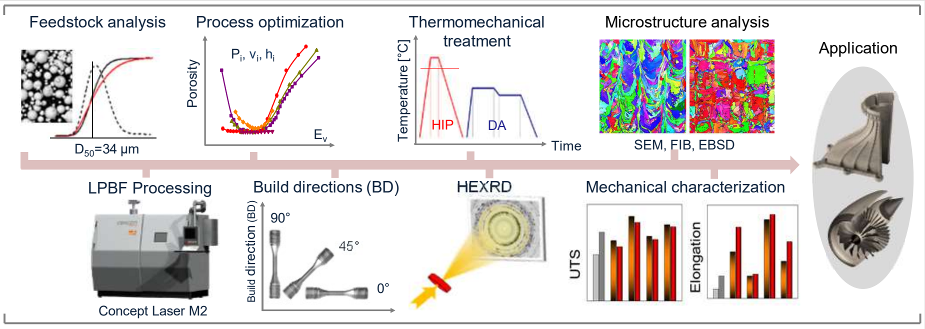

Fig. 1: Process chain for high LPBF performance with application-specific tailoring: from optimization of processing and post-operative heat treatment to correlation between structural evolution and resulting tensile properties.

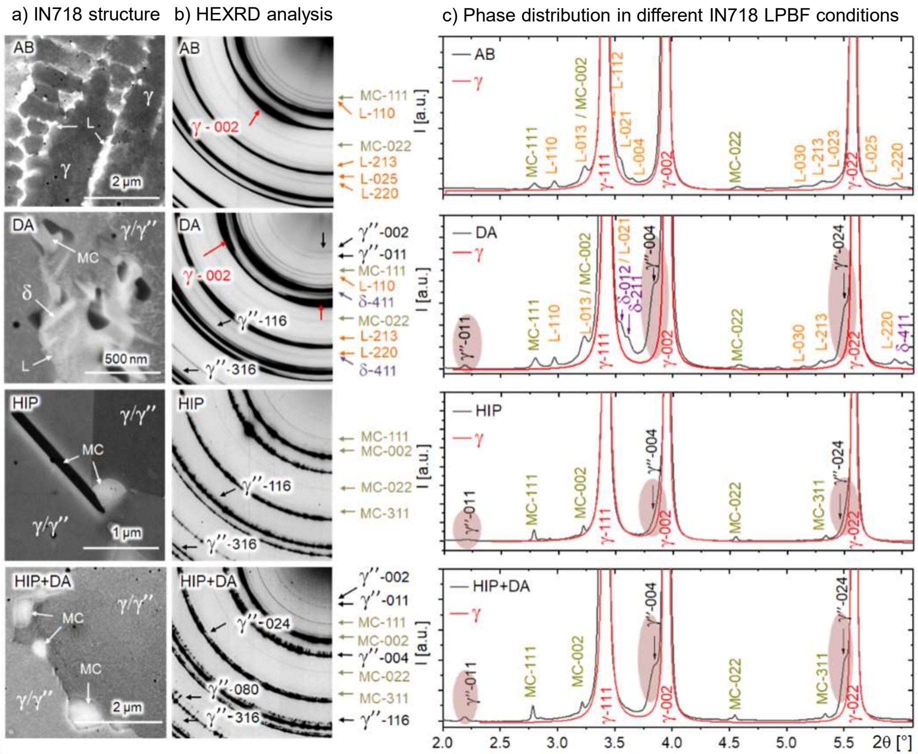

Fig. 2: Different heat-treated LPBF IN718 conditions (a, microsections II to BD), Debye-Scherrer rings from HEXRD (b) and phase identification (c): L (Laves), δ phase, γ – grains, γ/γ'' (γ - matrix with γ'' precipitates), MC-type carbides.

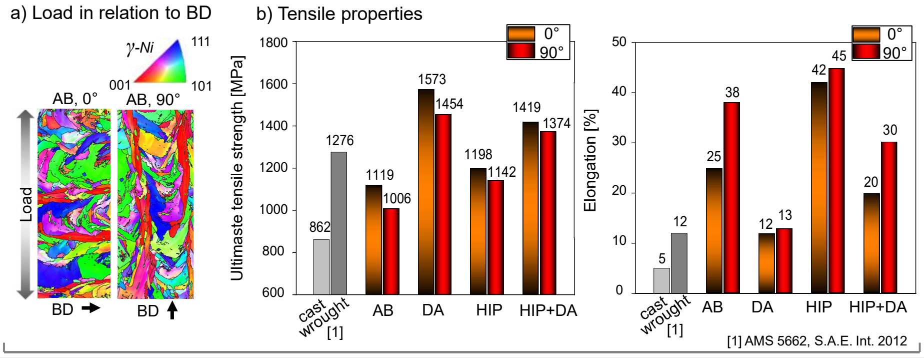

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Fig. 3: The load direction with respect to the as-built texture (a, EBSD) and tensile properties for different IN718 states versus reference material for horizontal (0°) and vertical (90°) building orientation (b, c).

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