Experimental report

28/04/2020

Proposal: **1-02-278**

Council: 4/2019

Title: Near-surface RS in LPBF IN718 for as-built samples with different scanning strategies

Research area: Materials

This proposal is a new proposal

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Samples: IN718
IN718-2

Instrument	Requested days	Allocated days	From	To
SALSA	6	4	27/09/2019	01/10/2019

Abstract:

Laser Powder Bed Fusion (LPBF) is and Additive Manufacturing (AM) method which allows the fabrication of complex structures that cannot otherwise be produced via conventional subtractive manufacturing methods. A large body of research has been dedicated in recent years to the optimization of LPBF process parameters. This proposal is part of an internally funded project at the Bundesanstalt für Material Forschung- und prüfung (BAM) that focuses on the influence of scanning strategies on the formation of residual stresses (RS) in an LPBF IN718 alloy. Due to the interaction of temperature gradients and build geometry, the RS fields can have complex variations from the surface to the bulk. The proposers have published a range of work on LPBF IN718 material, combining microstructural characterisation, energy dispersive synchrotron diffraction for subsurface RS and neutron for bulk stresses. In the literature, the near-surface RS are often blamed for the failure of components. Therefore, there is interest to determine the possibility of subsurface maxima not captured by the near-surface measurement techniques.

Final experimental report (proposal 1-02-278)

<u>Near-surface RS in LPBF IN718 for as-built samples with different scanning strategies</u>

This study aimed to bridge the spatial gap between XRD techniques and conventional neutron measurements in order to identify the position and magnitude of tensile stress maxima, by using partial immersion with subsequent pseudo-strain and geometric corrections. Prior to the experiment, the contour of the central cross sections of two samples (produced with X-Y alternating or 67° rotation scanning strategies) were investigated via laboratory energy dispersive diffraction technique. Since only four beamtime days were awarded (six days were initially requested in the proposal), it was decided upon the beginning of the experiment to concentrate the efforts on a detailed mapping of the sample produced with the 67° rotation scanning strategy, where the bottom surface was already released from the baseplate.

The diffraction angle 2θ=103.4° for the 311-reflection of nickel was used with the 0.6 mm horizontal and 2 mm vertical primary collimator and the 0.6 mm secondary collimator. The sample was mounted on the cradle, allowing rotation around the longitudinal axis in both the vertical (measurement of X and Y-direction components) and horizontal configurations (corresponding to Z-direction component, see Fig. 1a). As shown in Fig. 1b, depth immersion scans were performed over the four surfaces (i.e., Top, Surface 2, Surface 3, and Bottom) from 0.2- down to -2 mm (0.2 mm step size) and -2.5- to -4.5 mm (0.5 mm step size). The experiment started with the measurement of the X and Y-components from the Top surface in the vertical configuration, to subsequently rotate the sample allowing the other three surfaces, in turn, to face the beam.

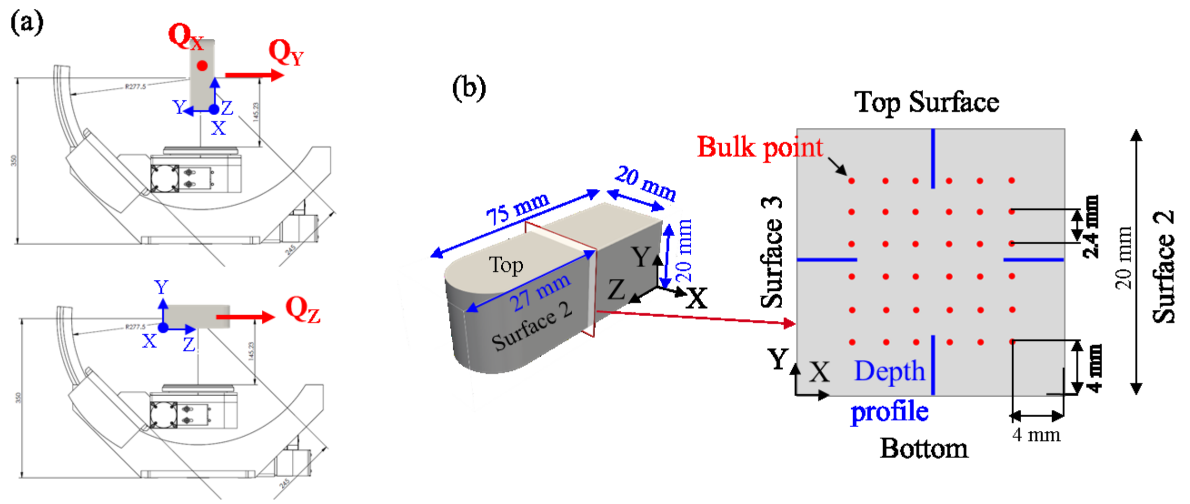

Fig. 1. (a) Schematic set-up of the 67° rotation-scan sample positioning during the X and Y-direction (top) and Z-direction measurements (bottom). (b) Central cross section showing the location of the depth profiles (in blue) and the bulk points (in red).

A really poor peak was observed when the Z-component measurements (transmission mode) started. After discussion with the local contact (T. Pirling) and given that the X-ray diffraction results indicated a small gradient of the Z-component along the Y-direction, it was decided to change the primary collimator to the 0.6 mm horizontal and 10 mm vertical. This allowed to obtain reasonable peaks that were, nevertheless, buried in a considerable background noise. A background correction function has been created for the fitting of the X-, Y-, and Z-direction data.

The last day of the experiment was dedicated to the bulk measurements. Due to the difficulties encountered during the depth scans, it was decided to change both the primary and secondary collimators to obtain a gauge volume of 2x2x2 mm^3. The core of the central cross section (Fig. 1b) was mapped using a matrix of 6x6 points with 2.4 mm step size.

The obtained diffractograms were fitted using the LAMP software with the Gaussian function. In order to obtain a spatially resolved d_0 reference, a slice was cut out of the flat end of the investigated sample to produce a grid consisting of 25 cubes with 3x3x3 mm^3 dimensions each (the cutting was performed with electrical discharge machining (EDM), Fig. 2a). While using the 2x2x2 mm^3 gauge volume, there was only time to measure the vertical central line of the grid (i.e., 5 cubes in total), with the scattering vector corresponding to the Y-direction. For the moment, the results presented in Fig. 2b are calculated using the average of all 5 cubes as d_0 reference value. The Z-direction component in the bulk region shows the highest compressive values (-300 MPa) at the centre of the cross section, with the region closest to the bottom showing the lowest values (-100 MPa). The error average of the bulk measurements is ± 40 MPa.

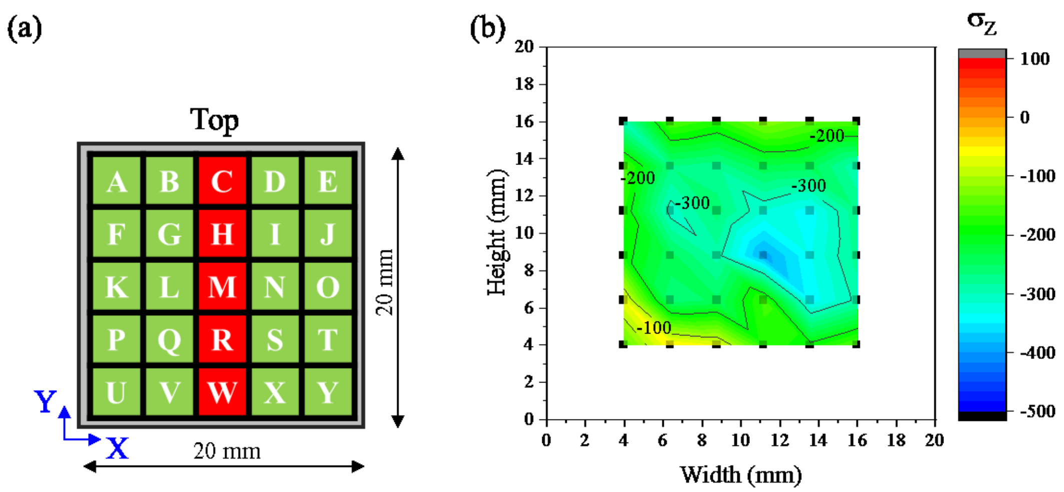

Fig. 2. (a) Schematic illustration of the cube grid used for the d_0 evaluation in the case of the 2x2x2 mm^3 gauge volume. Only one of the vertical arrays was measured (coloured in red). (b) Residual stress map corresponding to the Z-direction component.

The horizontal and vertical central lines of the d_0 grid were investigated during operation with the 0.6x0.6x2 mm^3 gauge volume (see Fig. 6a), and the X-direction and Z-direction components were evaluated in all nine cubes. Again, for the sake of brevity the results shown in Fig. 3b are calculated using the average of all the d_0 measurements. The stress results along the depth profile of Surface 2 are given as example. The highest tensile values are observed for the Y-direction component. Interestingly, the values of the principal components tend to converge in the range between -4.5- and -3 mm. Note that the error values of these results are quite elevated, with an average of ±70 MPa. The next action on these results will consist in the pseudo-strain correction of the points indicated with an orange rectangle.

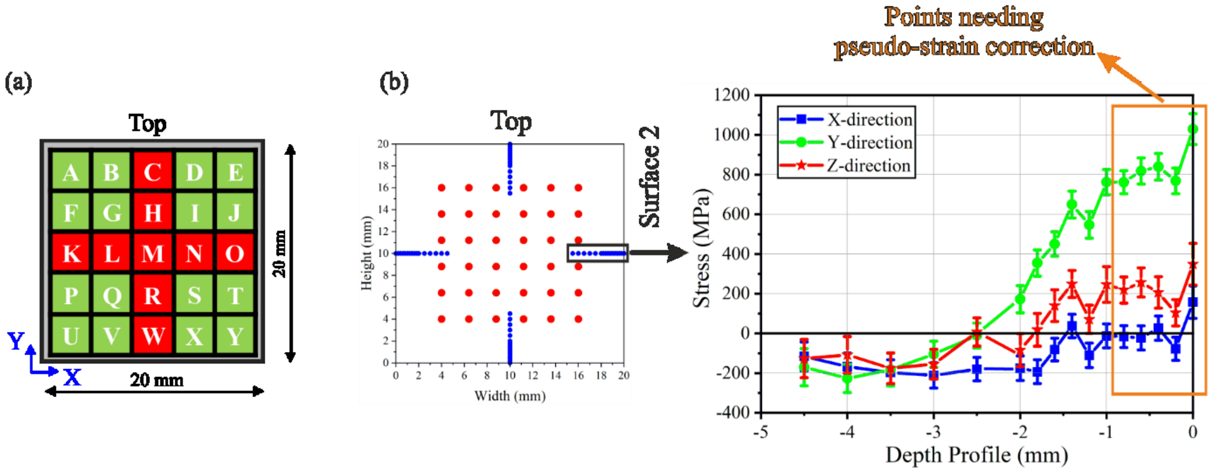

Fig. 3. (a) Schematic illustration of the cube grid used for the d_0 evaluation in the case of the 0.6x0.6x2 mm^3 gauge volume. Only the vertical and horizontal central lines (coloured in red) were investigated. (b) Residual stress depth profile of the principal components corresponding to Surface 2.