Experimental report

24/02/2021

Proposal:	**1-02-288**	**Council:**	10/2019
Title:	Length scale of residual stresses in 316L austenitic stainless steel components manufactured by laser based powder bed fusion		
Research area:	Engineering		

This proposal is a continuation of 1-02-276

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Samples: AISI 316L

Instrument	Requested days	Allocated days	From	To
SALSA	5	4	20/08/2020	24/08/2020

Abstract:

Recent advances in additive manufacturing have pushed the boundaries in the design and functionality of engineering parts. Especially the Laser based Powder Bed Fusion (L-PBF) process has enabled incredible weight and resources savings through organic designs and showed the potential to match or even exceed mechanical properties of conventionally manufactured components. Nonetheless, the formation of Residual Stress (RS) in L-PBF seems to be inherent and is highly depending on the multitude of process parameters as widely reported in literature. The proposed experiment design aims at determining the RS distribution solely as a function of geometrical changes to understand the length-scale of RS formation. Therefore, a set of 316L austenitic stainless-steel samples with changes in thickness and width were manufactured with identical process parameters by L-PBF. The Neutron diffraction results will complement x-ray diffraction measurements and the resulting high-density RS distribution will be used for modelling eigenstrains (inelastic strain) as the underlying source of RS. Furthermore, the neutron diffraction measurements will be compared with contour method results.

Length scale of residual stresses in 316L austenitic stainless-steel components manufactured by laser-based powder bed fusion

Proposal number: **1-02-288**	Main proposer: Maximilian Sprengel (BAM)
Instrument: SALSA	Experimental team: Maximilian Sprengel, Thilo Pirling
Dates: 20.08.19 - 25.08.2020	

1. Initial aim and experimental plan 1-02-288

The influence of the geometry on the magnitude and the distribution of RS in laser powder bed fused (LPBF) specimens was at the core of this proposal. Therefore, a set of samples with identical height of 40 mm were manufactured. The thicknesses were 2 mm, 5 mm, and 9 mm. The width were 13 mm and 26 mm. The lattice spacing was calculated for the 3 principal directions defined by the sample geometry using the 0.6 mm collimators. Additional angles were proposed to calculate the full tensor and subsequently calculate the principal stress directions. High point density maps (21 to 65 positions) were proposed to map the distribution of RS. The stress-free reference D0 was characterised with location specific cubes made using wire electric discharge machining taken from twin samples. The cubes dimensions were 1 mm x 1 mm x 1 mm and 3 mm x 3 mm x 3 mm.

The specimen orientation was set according to the shape of the gauge volume i.e. either 0.6 mm x 0.6 mm x 4 mm or 2 mm x 0.6 mm x 2 mm for the measurement of the three strain components.

2. Deviations from experimental plan

The first sets of measurement on the 13 mm x 5 mm cross section showed a symmetric distribution and it was decided to increase the point density to better map the RS gradients in the through-thickness (Y) and through-width directions (X) as shown in Figure 1. The point density was readjusted in the number of points and their location.

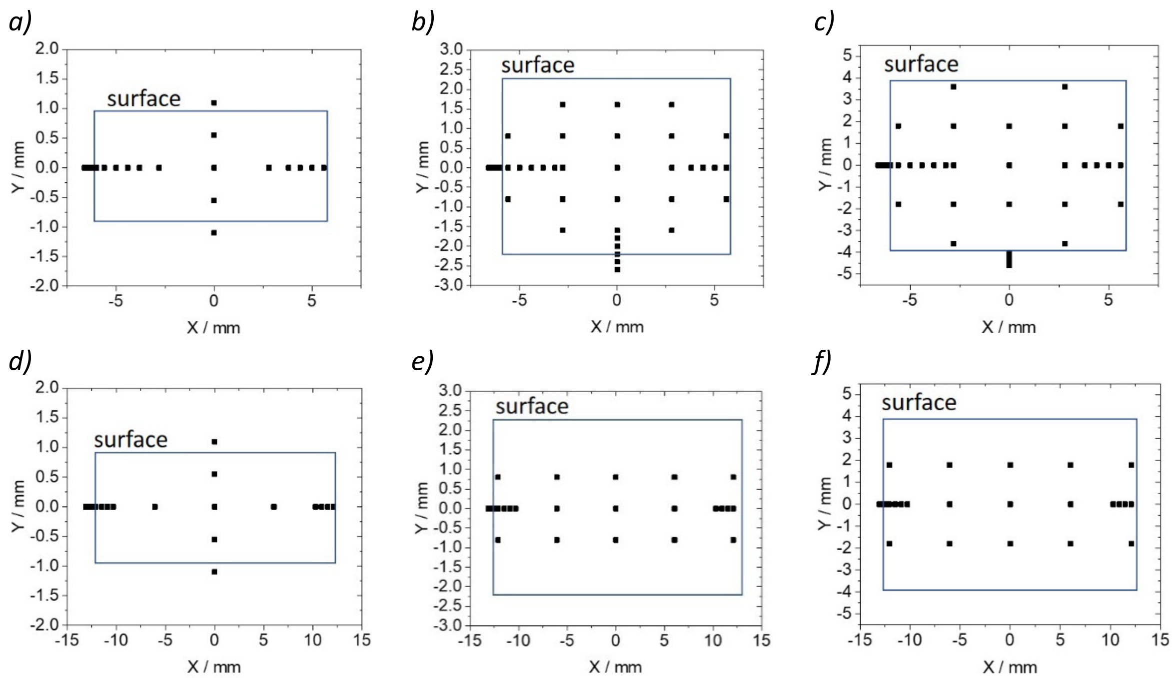


Figure 1: Measurement positions in the XY plane at a height of 20 mm in the 2 mm thick specimens in a) and d), in the 5 mm thick specimens in b) and e) and in the 9 mm thick specimens in c) and f).

Unfortunately, the repeat measurement of the Cu foil took a large portion of the beamtime in the first day as the 2θ was initially mistakenly set for ferritic steel. Furthermore, the y-axis of the hexapod tripped in the night of the 23.08 to the 24.08. Most of the measurements in this timeframe cannot be evaluated, as the diffraction pattern were acquired with a constantly moving y-axis. An additional day of beamtime was therefore granted and it was possible to retrieve some of the missing information. However, the encountered issues lead to the decision to not include the measurement of additional angles in the specimens for the determination of the principal stress directions.

3. D0 cubes results

Figure 2 shows the peak positions corresponding to the strain free lattice of the 316L LPBF material in the D0 cubes.

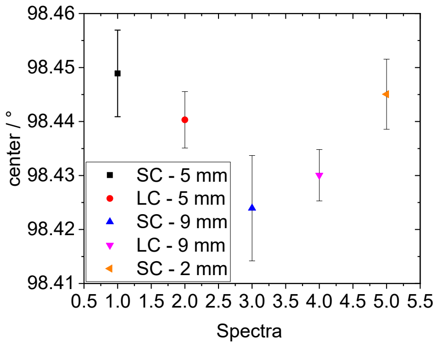
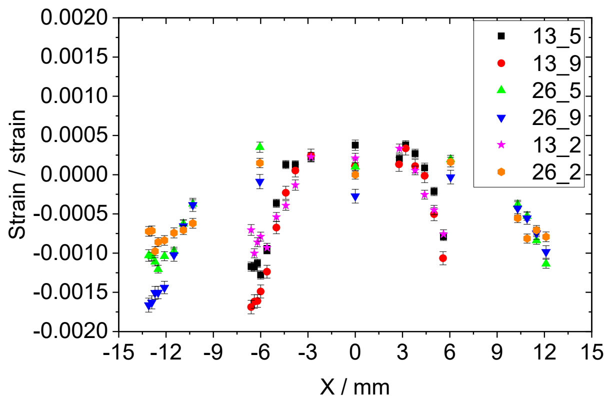


Figure 2: Peak position of the D0 cubes in the small cubes (SC) i.e. $(1\ mm)^3$ and large cubes (LC) i.e. $(3\ mm)^3$ as a function of fitting number (Spectra).

4. Strain

The longitudinal through-width and through- thickness strains are shown in Figure 3 a) and b) respectively. The strains are compressive towards the surfaces and slightly tensile in the centre of the specimen. Despite the corrections needed for the partially immerged surface points, it seems that the strain values are similar between the specimens. Increasing the width of the specimen changes the V-shaped profile to a more flattened U-shaped profile. In the y-direction, the longitudinal strains increase towards the surfaces. The gradients are less steep, and the magnitudes lower compared to the x-direction.

a) *b)*



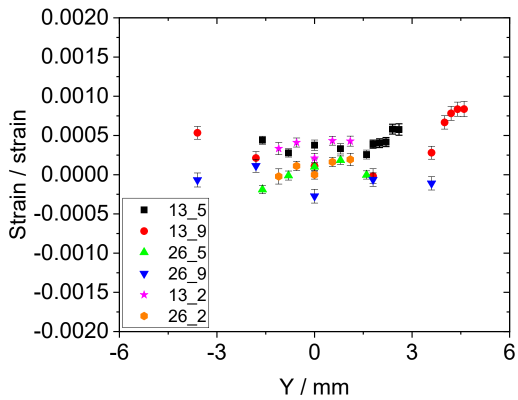


Figure 3: a) longitudinal strain (x-direction) at y = 0 in all specimens and b) in the y-direction at x = 0.