Experimental report

20/04/2020

Proposal:	**1-02-259**
Council:	10/2018
Title:	Measurement of Residual Stresses With Respect to Build Orientation inComponents Manufactured by Selective Laser Melting
Research area:	Engineering

This proposal is a resubmission of 1-02-239

Main proposer: **Catrin DAVIES**

Experimental team: Catrin DAVIES
Richard WILLIAMS

Local contacts: Thilo PIRLING

Samples: 316L stainless steel

Instrument	Requested days	Allocated days	From	To
SALSA	3	2	09/07/2019	11/07/2019

Abstract:

Selective laser melting (SLM) offers exciting new opportunities for the manufacture of engineering components. However, the use of SLM components is hampered by the need to prove their structural integrity. Large residual stresses are generated by the thermo-mechanical processes of SLM which compromise their structural integrity. These stresses are sensitive to the orientation in which the component is nested on the build plate. Numerical models are therefore required and have been developed to predict the residual stress and distortion in SLM components, supported through thermo-mechanical and creep testing to develop appropriate material models. These models are used to study the influence of building direction on the residual stress profile of parts and develop appropriate mitigation strategies. To validate these models residual stress and distortion measurements are essential. Hence neutron diffraction measurements are proposed on one horizontally built and one vertically built SLM component to provide the data required for model validation and quantify the influence of orientation. This work contributes to the PhD thesis of Mr Richard Williams at Imperial College London.

Measurement of Residual Stresses with Respect to Build Orientation in Components Manufactured by Selective Laser Melting

DOI: 10.5291/ILL-DATA.1-02-259

1 Project Aims and Experimental Details

The aims of the experiment were to quantify the residual stresses in two cylindrical (30 mm diameter and 80 mm in height) SLM samples (see Fig 1.), one built in the horizontal orientation and the other in the vertical orientation, with respect to the build direction. This was to quantify the influence of the different build orientation on residual stresses and provide stress validation for the numerical models developed. Neutron diffraction measurements were performed along a line in the radial direction, passing through the cylinders central axis, at the mid length of the samples height.

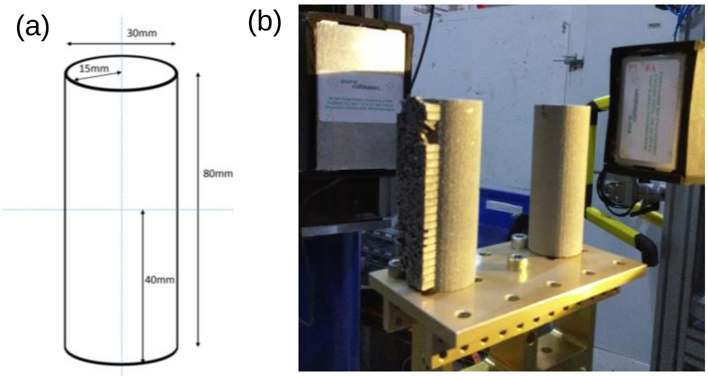


Figure 1: (a) Schematic illustration of the SLM geometry and measurement positions, (b) image of the horizontal sample (left) and vertical sample (right) set up for radial and hoop direction measurements.

Due to the large stress gradients at the surface of the sample, collimators were used to give a gauge volume of 0.2 mm × 0.2 mm × 2 mm (0.2 mm in the radial and hoop direction and 2 mm in the axial direction where little variation is expected) to give a high spatial resolution. The samples were orientated 2 orientations (i), as shown in Fig. 1b, to measure the radial and hoop directions and (ii) to measure the longitudinal (axial) direction. Note that the collimators were also rotated to ensure the gauge volume measurement was focused was sampling the same volume of material in both orientations.

2 Results

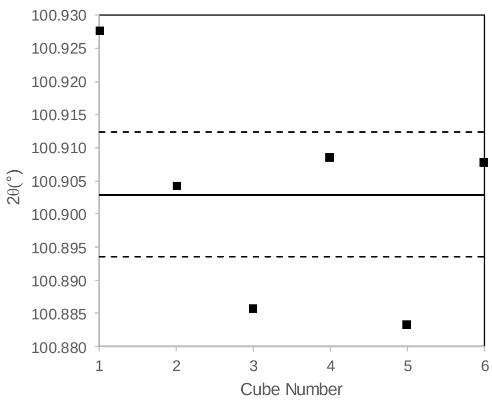


Figure 2: Measurements from the d0 cubes.

Cubes 2×2×2 mm^3 were manufactured from nominally identical samples to those measured. The results from these cubes are shown in Figure 2, where cubes 1-3 were from vertically built samples and 4-6 from horizontally built samples. There are no clear variations between cubes from both orientations, therefore a mean line fit (solid line in Fig. 2) has been made to the data and an estimate in the error in the mean calculated. The dashed lines in Fig. 2 illustrates the value of the mean ± the estimated error in the mean (100.9029° ± 0.009416). Significant scatter is seen in the d_0 cube measurements; thus a sensitivity study is required to optimise the appropriate d_0 value to use in the residual strain and stress calculations. The value used in the results shown here are the mean value + the error in the mean (100.9029° + 0.009416).

The residual strain distribution in the vertical and horizontal samples are shown in Figure 3. For the vertical sample, the strain is plotted against distance from both radially opposite surfaces measured as they are expected to show similar trends as they are on the same build height. The horizontal sample results plotted against distance from the top surface, where the top surface is the end of the build.

The corresponding residual stresses are shown in Figure 4 for the vertical sample and Figure 5 the horizontal sample. For the stress measurements the elastic modulus was taken to be 183 GPa and Poisson ratio to be 0.3. For the vertical sample shows similar strain and stress distributions from both sides, indicating that the residual stress distribution is symmetrical about the centre line. The principal stress is in the longitudinal direction (i.e. the build direction) for the vertical sample, with high tensile residual stresses at the surface balanced by compression towards the centre. For the horizontal sample, the peak stresses are approximately a factor of 3 less. The max principal stresses are tensile at the outer diameter, compressive in the bulk. For the Horizontal sample, the stresses tend to zero at the mid height. These measurements are being used to validated finite element models of the build process.

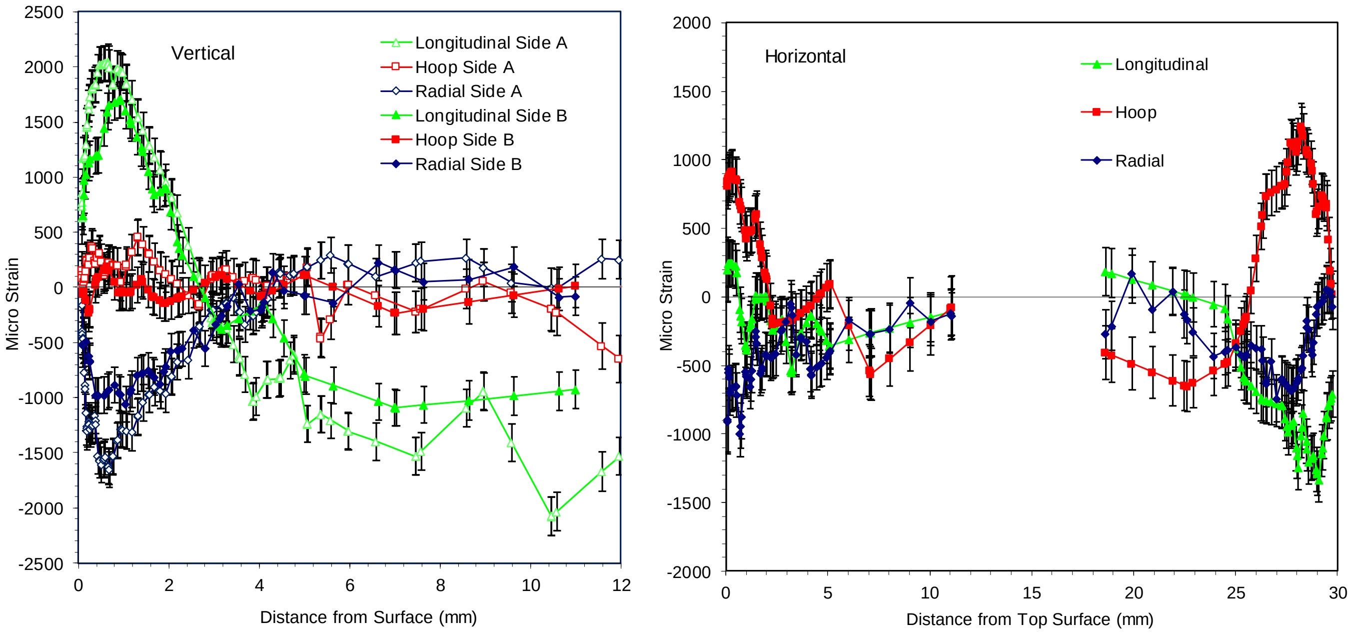
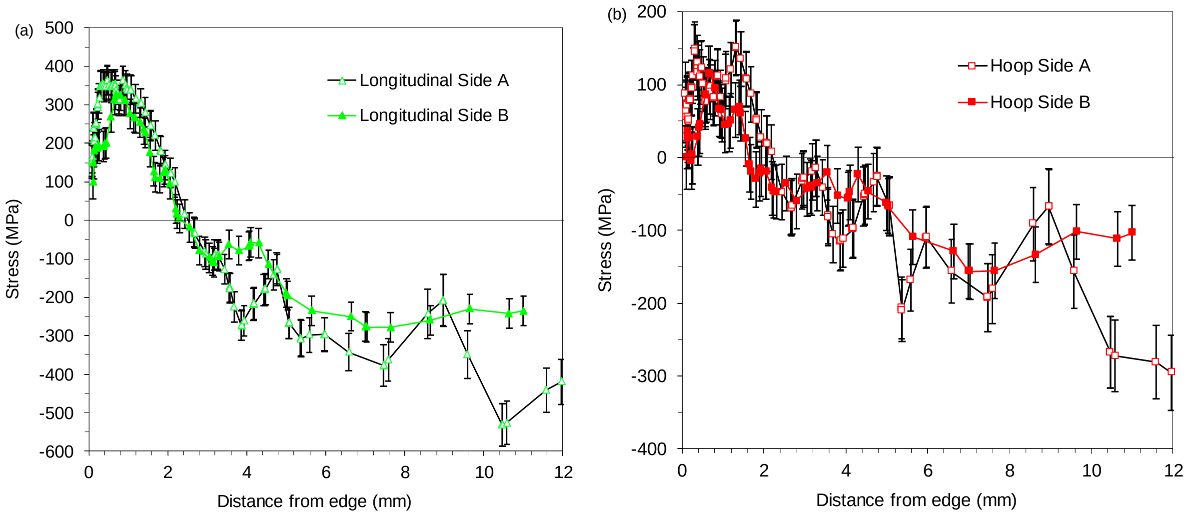


Figure 3: Strain distribution from both surfaces measured in the vertical and horizontal samples.



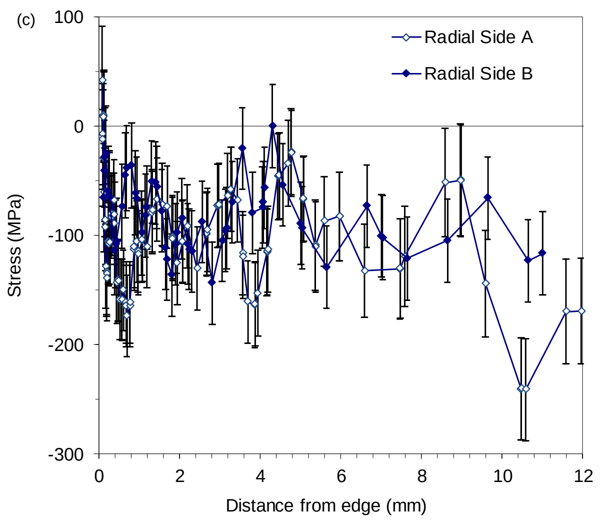


Figure 4: Residual distribution in the vertical sample.

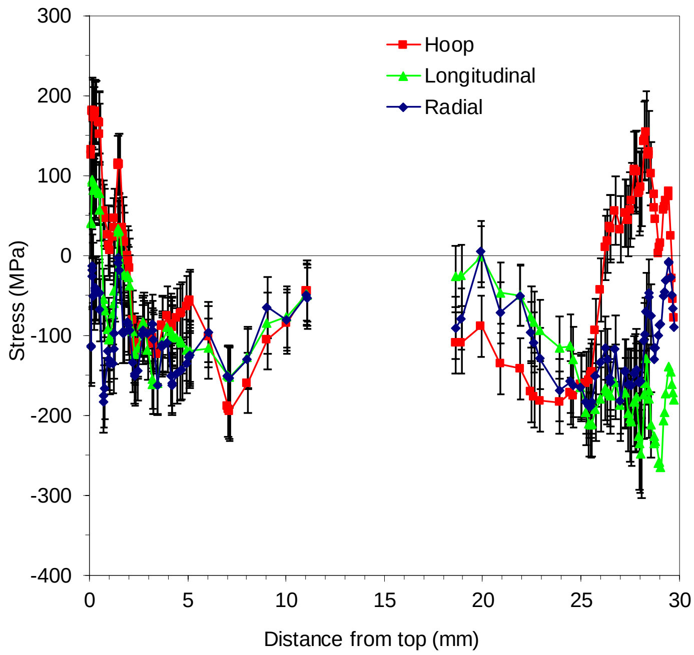


Figure 5: Residual distribution in the horizontal sample.