

Experimental report

02/02/2026

Proposal: EASY-1236

Council: 4/2023

Title: Time required to finish the prior experiment for comprehensive residual stress analysis in Ti6Al4V additive manufacturing

Research area: Materials

This proposal is a new proposal

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Samples: Ti6Al4V

Instrument	Requested days	Allocated days	From	To
SALSA	48	48	30/11/2023	02/12/2023

Abstract:

Ti6Al4V is a widely used alloy in additive manufacturing. Stresses is crucial for optimizing processing parameters and improving component quality. This study emphasizes the importance of comprehensive residual stress analysis to enhance Ti6Al4V manufacturing, offering potential benefits across various industries.

We kindly ask 2 days of measurements in order to achieve the characterization of the last one of strain components in 2 samples to obtain of final stress values.

Instrument SALSA

Samples: reference samples

Ti-6Al-4V cantilever samples, together with their stress-free reference samples, were characterized on the SALSA beamline (Strain Analyser for Large and Small scale engineering Applications) at the Institut Laue-Langevin in Grenoble, France.

SALSA, an angular- dispersive instrument, uses a Si-monochromator with a variable bending double-focusing device. It employs a hexapod stage, capable of six degrees of freedom (translations, rotations (ω), and tilts) with a precision of $\pm 5 \mu\text{m}$. Along with a cradle (χ) and a sample rotation stage (ϕ), this setup enabled mapping of the three geometric strain components in the plate: normal (N), transversal (T), and longitudinal (L).

The component under measurement is aligned along the scattering vector, bisecting the incoming and diffracted beams. Primary and secondary collimators on the source and detector induced a beam size of 0.6 mm horizontally and 2 mm vertically.

A wavelength of $1.9 \text{ \AA}$ (selected by Si-311) was originally chosen to measure the α -1013 peak at $2\theta = 90^\circ$ to optimise resolution and neutron flux. However, poor signal for this lattice plane required a change to α -1011, which scatters stronger than α -1013.

Ti α -1011 is a first order pyramidal plane with low sensitivity to intergranular (Type II) stress, meaning it is also suitable to calculate macroscopic (Type I) residual stress. Ti α -1011 scatters around $2\theta = 50^\circ$ at $1.9 \text{ \AA}$, resulting in a rhomboidal gauge volume (GV) with a 2 mm vertical and 1.55 mm diagonal horizontally (depicted in Figure below).

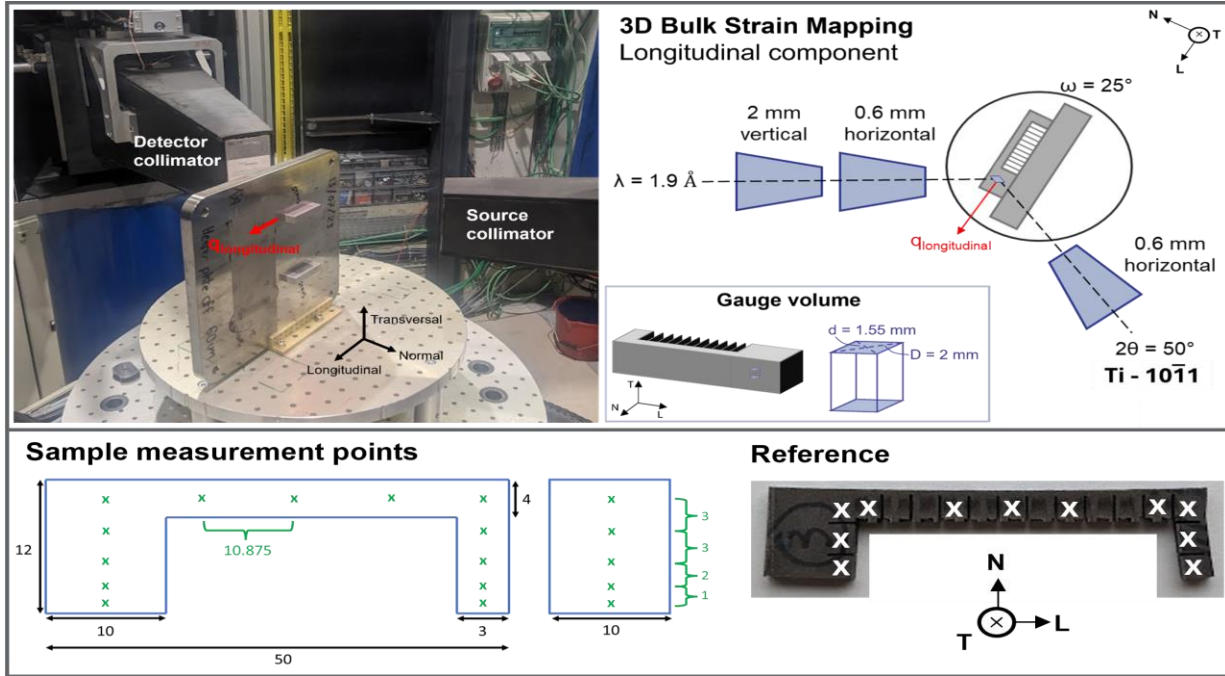


Figure 1: SC: annotate with a,b,c. Add one fig for each of 3 components setup, specifying omega and chi to describe 3 rotations and GV orientation. Merge sample and do points (mark latter with red circles). Clarify in text what black vs green dimensions represent. Missing dimensions for distances from edge (i.e. 2 mm from top and 1.5 mm from baseplate and 5 mm from edge).

Stress and strain were calculated along the three sample axes as follows: normal (parallel to the build direction), longitudinal (parallel to the longest dimension of the cantilever), and transversal (orthogonal to normal and longitudinal). The angular set-up for measuring each direction was $\omega = -155^\circ$ for the normal and longitudinal directions and $\omega = -65^\circ$ for the transversal. Longitudinal and transversal components were scanned in transmission, with the normal component scanned in reflection. For the orientation of the GV inside the sample, refer to Appendix. For the samples on their baseplates, 13 data points, as per Figure 3.4, were measured in the three directions at the mid-thickness of the samples. The separation between data points is lower where the cantilever legs meet the baseplate, as the residual strain gradient is suspected to be greater here.

For the cantilevers on their baseplates, acquisition was set to 5000 counts to obtain a sufficient peak height to background ratio, which corresponds to 2θ error of approximately

0.02°. The maximum acquisition time was capped to 1 hour, therefore the peak-to-background ratio varied depending on the location of the gauge volume inside the sample. Signal loss arising from sample absorptivity and background creation (i.e. via incoherent scattering) depended on the amount of material inside the neutron beam path. This meant that in transmission mode, the data points with the lowest peak-to-background ratio were found in the middle of the cantilever feet and the best peak-to-background ratio was found in the middle of the bridge. In reflection mode, the best peak-to-background ratio was found for the data points along the top of the samples (including the middle of the bridge), and the worst was found “deeper” into the sample (i.e. near the baseplate). Further differences in peak-to-background ratio were observed between baseplates, where the baseplate heat ON samples achieved 5000 counts within the 1 hour acquisition window. For the baseplate heat OFF samples, 5000 counts was generally only achieved across the middle of the bridge. The other sample positions had count ranges between 4000 to 5000, with the errors exceeding the target 0.02° in a few positions, namely, in the middle of the feet in transmission mode. This discrepancy could potentially arise from microstructural differences with baseplate preheating. For example, grain refinement with baseplate heating could lead to better diffraction signal with a higher number of grains satisfying the Bragg angle be due to smaller, more randomly oriented grains with baseplate heating, due to dissolved Vanadium with baseplate heating, or simply as a result of instrument flux variations between experiments (check w/ Sandra).

For the d_0 reference combs, the transversal and longitudinal components were measured. The trends were similar, so an average of these two components was taken as the d_0 reference. The impact of this will be assessed with the results. The acquisition for the d_0 combs was 3500 counts, where less background signal was produced in the comb samples compared to the samples on their baseplates.