Results from an interlaboratory comparison of areal surface texture parameter extraction from X-ray computed tomography of additively manufactured parts

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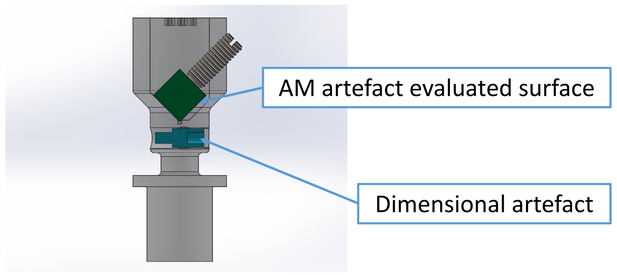
Stage 1: Four Labs

This Stage 1 interlaboratory comparison investigated the extraction of areal surface texture data per ISO 25178-2 from X-ray computed tomography (CT) reconstructions of a titanium additively manufactured (AM) part. Four laboratories were included, using similar machines: one Nikon XT H 225 industrial CT and three Nikon MCT225 metrology CTs. This low number of labs with similar machines were chosen for the purpose of providing knowledge and experience useful for the design and configuration of an expanded Stage 2.

Laboratory	XCT machine	Abbrev.
University of Huddersfield, UK	Nikon XT H 225	XCTHUD
University of Nottingham, UK	Nikon MCT225	XCTNOT
Nikon Metrology, UK	Nikon MCT225	XCTNIK
National Physical Laboratory, UK	Nikon MCT225	XCTNPL

Artefact Design

The CT measurement fixture included two artefacts, both manufactured from Ti6Al4V ELI, a material commonly used in medical and aerospace applications.



- One AM cube, 10 mm per side, manufactured using Electron Beam Melting, for surface texture measurement and analysis. The AM surface was measured five times using an Alicona G4 focus variation (FV) instrument prior to the XCT measurements.
- One machined dimensional artefact, for analysis of scaling and surface determination (results not reported here).

CT Machine Setup

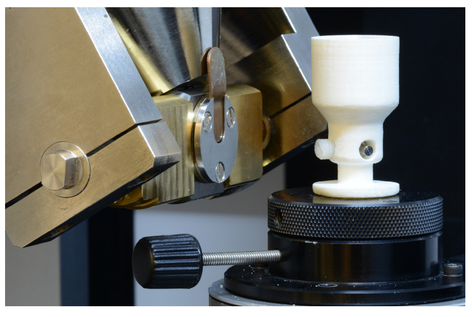
Parameter settings for the CT machines were kept as similar as possible. Five consecutive measurements were performed on each CT machine.

XT H 225 measurement settings. Parameters in bold differ between XT H 225 and MCT225 measurements

Parameter	Value	Parameter	Value
Filter material	Copper	**Voxel size**	17.3 µm
Filter thickness	1.0 mm	**Source to object distance**	84.2 mm
Acceleration voltage	160 kV	**Source to detector distance**	972 mm
Filament current	62 µA	**Number of projections**	1583
Exposure time	2829 ms	**Detector size (pixels)**	1008 x 1008

MCT225 measurement settings. Parameters in bold differ between XT H 225 and MCT225 measurements

Parameter	Value	Parameter	Value
Filter material	Copper	**Voxel size**	8.7 µm
Filter thickness	1.0 mm	**Source to object distance**	51.0 – 51.2 mm
Acceleration voltage	160 kV	**Source to detector distance**	1175 – 1180 mm
Filament current	62 µA	**Number of projections**	3142
Exposure time	2829 ms	**Detector size (pixels)**	2000 x 2000



Artefact mounted in an MCT225 CT

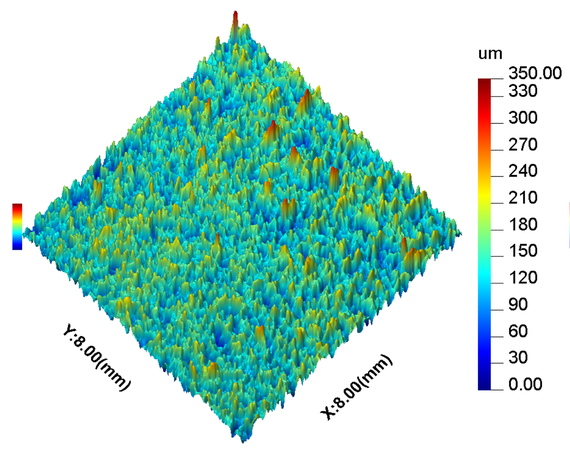
Nikon MCT225 metrology CT

Data Processing

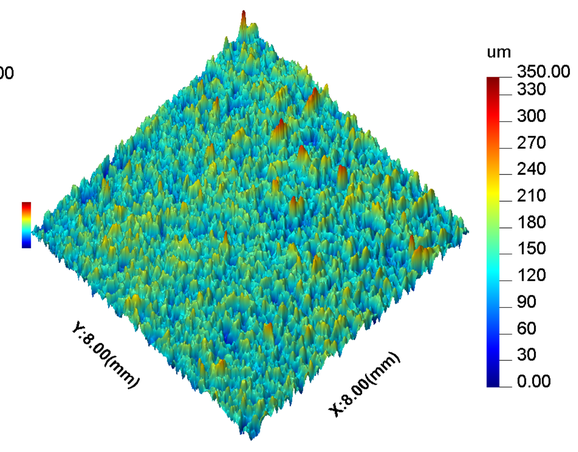
CT reconstruction was performed using Nikon CTPro 3D. Surface determination and extraction were performed using VGStudio MAX 3.0. Local iterative surface determination was performed with a search distance of 4.0 voxels. The AM surface was converted to PLY format using VGStudio MAX "Super Precise" setting. Aligning and cropping of the extracted surface areas was performed per Townsend et. Al. [1]. The surface evaluation area was 8 mm x 8 mm, with an L-filter nesting index 8 mm and S-filter nesting index 0.025 mm per ISO 25178-3. Areal surface parameter values per ISO 25178-2 were generated.

Results

False colour height maps for one Alicona G4 and one NPL CT measurement are shown, together with the results table for selected parameters per ISO 25178-2, including sample standard deviation figures (SD). Plots of mean roughness, *Sa* and maximum peak-to-valley distance, *Sz*, for the Alicona G4 measurements and all CT machine measurements are shown. **There was a 0.5% or less difference between the mean *Sa* and mean *Sz* from the extracted surface from all MCT225 machines and the Alicona G4.** The non-metrology XT H 225 machine figures were -5.2% for *Sa* and -3.4% for *Sz*.

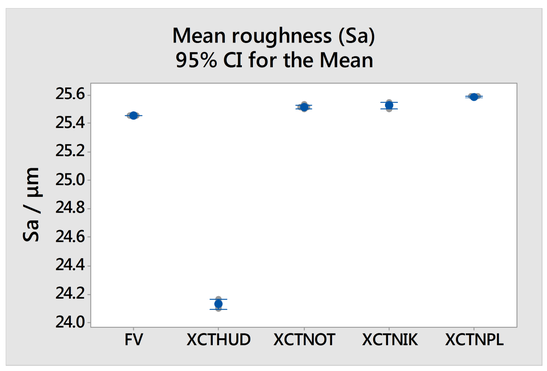


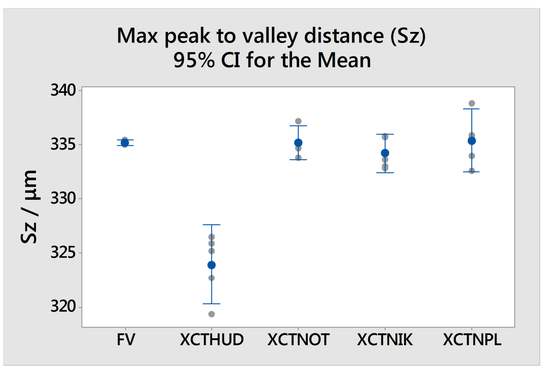
False colour height map, Alicona G4 FV



False colour height map, NPL CT

Parameter	Mean FV	SD FV	Mean XCTHUD	SD XCTHUD	Mean XCTNOT	SD XCTNOT	MEAN XCTNIK	SD XCTNIK	MEAN XCTNPL	SD NPL
Sa / µm	25.5	0.001	24.1	0.027	25.5	0.011	25.5	0.019	25.6	0.006
Sq / µm	32.6	0.002	30.9	0.032	32.5	0.009	32.5	0.023	32.6	0.007
Sz / µm	335.3	0.199	324.0	2.941	335.2	1.244	334.2	1.423	335.4	2.332
Ssk	0.26	<0.001	0.08	0.015	0.20	0.001	0.21	0.001	0.21	0.001
Sku	3.7	<0.001	3.7	0.010	3.6	0.004	3.6	0.005	3.6	0.003
Sdr (%)	40.2	0.014	28.3	0.131	41.9	0.117	42.4	0.137	43.8	0.103





Conclusions

- The results confirm the validity of using CT for the extraction of surface texture data from additively manufactured components.
- The surface extraction methodology and data analysis appears robust.
- These measurements were taken over a period of five months. There appears to have been negligible change of the fixture and artefacts over that time period.
- There is good repeatability and reproducibility of results, providing a good baseline for an expanded, Stage 2 interlaboratory comparison.

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References

[1] Townsend A., Pagani L., Scott P., and Blunt L., (2016), *Areal surface texture data extraction from x-ray computed tomography reconstructions of metal additively manufactured parts.* Precision Engineering. **48**: p. 254-264.