Extracting surface topography data of AM parts from computer tomography systems

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• Extraction of areal surface texture data per ISO 25178 from XCT scans
• Surface determination effects
• XCT internal / external surface result differences
• Surface-from-XCT interlaboratory comparison
• Analysis of XCT re-entrant features
Motivation for areal surface texture data from XCT

Moth head section (scanned using a Nikon XT H 225).

Useable surface texture data from inside the moth’s eye?


Areal surface texture data from XCT

AISi10Mg (a) surface artefact
(b) dimensional artefact in XCT fixture.

Areal surface texture data extraction from x-ray computed tomography reconstructions of metal additively manufactured parts.
Areal surface texture data from XCT

(a) Alicona G4 focus variation

(b) Nikon XT H 225 XCT

False colour height maps.

Circa -2.5% difference between XCT and Alicona mean Sa value (Sa ≈ 30 μm)

Areal surface texture data extraction from x-ray computed tomography reconstructions of metal additively manufactured parts.
Areal surface texture data from XCT

Rubert $Ra$ 25 μm comparator plate.

$Ra$ 25 μm Rubert sample focus variation mesh and XCT mesh. (CloudCompare).
Areal surface texture data from XCT

Rubert $Ra$ 25 $\mu$m comparator plate.

Selection of points (minimum three) for initial mesh alignment (CloudCompare).
Areal surface texture data from XCT

Rubert Ra 25 μm comparator plate.

Manual, followed by Iterative Closest Point (ICP) alignment.
Cropped meshes prior to conversion to height map (SDF) format (in Matlab).

Rubert Ra 25 μm comparator plate.
Rubert 50 µm plate surface determination (VGStudio Max 2.2)
(a) ISO 50 surface determination (b) local iterative surface determination

Rubert 50 µm plate extracted surface parameters per ISO 25178-2
Showing global surface determination methods, Manual, ISO 50 and Otsu
And iterative local surface determination (purple bars)
Error bars are 95% confidence interval for the mean.


Ti6Al4V SLM part (10 mm x 10 mm x 50 mm).
Percentage difference between the same surface section as an internal and external surface showing insignificant difference. (error bars are 95% confidence interval for the mean)


Sa 17.1 μm (internal)  
Δ external – internal 0.18%

Surface from XCT interlaboratory comparison

<table>
<thead>
<tr>
<th>Parameter (ISO 25178-2)</th>
<th>Mean FV</th>
<th>SD FV</th>
<th>Mean XCTHUD</th>
<th>SD XCTHUD</th>
<th>Mean XCTNOT</th>
<th>SD XCTNOT</th>
<th>Δ, XCTHUD to FV</th>
<th>Δ, XCTNOT to FV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sq/μm</td>
<td>32.40</td>
<td>0.001</td>
<td>30.77</td>
<td>0.036</td>
<td>32.03</td>
<td>0.252</td>
<td>-5.0%</td>
<td>-1.1%</td>
</tr>
<tr>
<td>Sa/μm</td>
<td>25.33</td>
<td>0.001</td>
<td>24.05</td>
<td>0.031</td>
<td>25.07</td>
<td>0.241</td>
<td>-5.1%</td>
<td>-1.0%</td>
</tr>
<tr>
<td>Sz/μm</td>
<td>330.59</td>
<td>0.306</td>
<td>322.27</td>
<td>2.889</td>
<td>327.80</td>
<td>1.644</td>
<td>-0.85%</td>
<td>-0.85%</td>
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<tr>
<td>Ssk</td>
<td>0.246</td>
<td>&lt;0.001</td>
<td>0.08</td>
<td>0.016</td>
<td>0.202</td>
<td>0.008</td>
<td>-0.238</td>
<td>-0.044</td>
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<tr>
<td>Sku</td>
<td>3.70</td>
<td>&lt;0.001</td>
<td>3.67</td>
<td>0.009</td>
<td>3.66</td>
<td>0.040</td>
<td>-0.03</td>
<td>-0.04</td>
</tr>
</tbody>
</table>

Artefact: Ti6Al4V ELI EBM
XCTHUD: Nikon XT H 225
XCTNOT: Nikon MCT225

Filtering per ISO 25178-3
L-filter nesting index 8.0 mm
S-filter nesting index 0.025 mm
### Surface from XCT interlaboratory comparison

<table>
<thead>
<tr>
<th>Feature</th>
<th>Mean CMM (mm) (10 ea)</th>
<th>SD CMM (mm)</th>
<th>Mean XCTNOT (5 ea)</th>
<th>SD XCTNOT</th>
<th>Δ XCT to CMM</th>
<th>After 3 µm surface determination compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>OD</td>
<td>2.97345</td>
<td>0.000053</td>
<td>2.9806</td>
<td>0.0002</td>
<td>+0.24%</td>
<td>+0.04%</td>
</tr>
<tr>
<td>ID</td>
<td>2.98457</td>
<td>0.001438</td>
<td>2.9796</td>
<td>0.0004</td>
<td>-0.17%</td>
<td>+0.03%</td>
</tr>
<tr>
<td>Length</td>
<td>4.62400</td>
<td>0.000377</td>
<td>4.6252</td>
<td>0.0008</td>
<td>+0.03%</td>
<td>+0.03%</td>
</tr>
</tbody>
</table>

Artefact: Ti6Al4V ELI

Overhanging and re-entrant features

Next stage: areal parameters from highly re-entrant AM surfaces

XCT reconstruction of Velcro®

Overhanging and re-entrant features

XCT reconstruction of a Ti6Al4V orthopaedic prototype lattice.
Conclusions

• Areal surface texture data per ISO 25178 can be extracted from XCT scans of AM parts
• 1% difference for value of $S_a$ between XCT and focus variation possible
• XCT surface determination will affect parameter value
• Insignificant difference between surface data from internal and external surfaces
• Calculation of actual surface area of component with re-entrant features can be calculated
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Thank you!