CT-based quality control of Laser Sintering of Polymers

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Laser Sintering of Polymers
Examples of laser sintered product

Adidas Futurecraft 3D
Examples of 3D printed products with lightweight structures

[1] 3D Printed bicycle helmet by Mattia Valle
[3] RSprint insoles
[4] Adidas Futurecraft 3D
Problem Statement

**Laser Sintering** (LS) is an Additive Manufacturing technique used for the production of functional parts.

**Lightweight structures** are increasingly being incorporated in products, in order to reduce the weight and locally tailor the mechanical properties. However it is not yet clear how the printing process is affecting the quality of the structural elements.

In this work X-ray Computed Tomography is used to investigate how the **printing orientation** and the **size of the structural elements** of the lightweight structure affect their **porosity content** and **geometrical deviation from design**. The polymeric powder used in the study is PA12.
• Pins oriented both horizontally and vertically
• Pins diameter range: from 0.6 mm to 6.0 mm
• Voxel size achieved in the CT scans: 20 µm
• Artefact printed in 4 replicas
Process variation for different orientations and sizes of the pins

Horizontal

Vertical

Mark vector
Jump vector
CT Work Flow for Porosity Analysis

CT scan

Reconstruction (CT Pro)

Voxel Volume (VGStudio max)

Further elaboration of exported pores statistics (Matlab)

Porosity Analysis

Volume alignment with the printing direction

Image processing of the exported slices
Influence of orientation and size of the pins on porosity

- Porosity increases with the size of the pin for both orientations up to a size where it stabilizes;
- Horizontal pins have a lower porosity.
Influence of orientation and size of the pins on pores count

Horizontal pins contain a higher number of pores
Influence of orientation and size of the pins on pores size

<table>
<thead>
<tr>
<th>Orientation</th>
<th>1,25 mm</th>
<th>4,00 mm</th>
<th>6,00 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>Vertical</td>
<td>![Image]</td>
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</tbody>
</table>
Pins oriented vertically contain larger pores
Porosity maps

a) Alignment of the volume with the printing direction
b) Export the slices along the printing direction (or other direction)
c) Thresholding of the CT-slices (Otsu’s threshold)
d) Creation of a map which resumes the porosity information of all the exported CT-slices
Porosity maps

- Presence of a denser skin independent on the orientation.
- Horizontal pins: the porosity is mainly located between the layers.
- Vertical pins: ring of porosity right inside the denser skin.
- These areas more affected by porosity could explain why the vertical pins are more porous.
Porosity maps (Vertical pins)

- Presence of a **denser skin** independent on the size of the pin; the different volume ratio between the more porous internal regions and the denser skin for different sizes could explain the increment of the porosity content with the size;
- **Ring of porosity** right inside the denser skin appears from a certain size.
Influence of orientation on pins shape deviation

Horizontal pins are affected by a larger shape deviation.  
2 main contributions:
• ‘Filleting effect’: the first layer is thicker because sintered directly on powder
• Slicing process: discretization process which introduces an error up to 1 layer thickness depending on the cut height
Influence of slicing process on shape deviation of horizontal pins
• Porosity increases with the size of the pin for both orientations up to a size where it stabilizes. This behavior can be explained by the different volume ratio between the more porous internal regions and the denser skin of the pins.

• Pins oriented vertically (printing direction) show overall a higher porosity value with larger average pore sizes, independently on the diameter.

• The horizontal pins look overall more ovalized when compared with the vertical ones, which is due to the different sintering conditions of the down facing surfaces which lead to a thicker sintered layer, and due to the slicing process.
Future Work

• Investigate the printing quality of cylindrical elements with other printing orientations, as well as the connections between them;

• Investigate the mechanical responses of the structural elements of the lightweight structures depending on their size and orientation.
• R&D Materialise NV
• Metrology group, PMA, KU Leuven
• Additive Manufacturing group, PMA, KU Leuven

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Thanks for the attention!

Any Question?