Additive Manufacturing Task Group: Progress on ULTEM 9085
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Agenda

• Outline
• Results
• Discussion
• Next steps
Additive manufacturing allows for material modifications impossible with conventional production techniques. It is unclear to what extent these modifications alter the flammability behaviour.

A task group was founded at the FAA Materials Fire Test Forum in June 2018 to investigate the influence of printing parameters.

Decision to start with Fused Deposition Modelling (FDM) and Polyetherimide Ultem 9085 CG as both printers and material were available at different locations.
Printing technology, materials and parameters

**Build**
- Printing directions
- Raster angle
- Layer thickness
- Thickness
- Infill (%)
- Single specimens vs. cut from bigger plate

**Part design**
- “Replica” of conventional part
- Bio-inspired (bone-like) complex structures

**Manufacturing technology**
- Fused Filament, laser sintering, powder bed etc.
- Printer manufacturer and type
- Layer thickness
- Print speed and temperature

**Material**
- Material itself is a variable
- ALM type vs. standard type of same material
- Filament thickness

**Post processing**
- For the specimen: e.g. removal of support, or for the part: e.g. grinding/sanding to certain surface quality
- Spatula, fillers, topcoats

**Part design**
- “Replica” of conventional part
- Bio-inspired (bone-like) complex structures
Results: 100% infill, influence of orientation

→ No influence of orientation for densest packing
Results: $XY \pm 45^\circ$, variation of infill

$\rightarrow$ Lower infill = higher burn length and after flame
Results: XY ±45°, variation of infill

12 s VBB \( n=10 \)

\[ \text{Burn length / mm} \]

- Lower infill = higher burn length and after flame

Next step: fill the gap
Results: XY ±45°, variation of infill
Results: XY ±45°, variation of infill

→ Lower infill = higher burn length

Next step: fill the gap
Results: variation of infill for different orientations

12 s VBB  n=5-10

- XY 1.5 mm $+45^\circ$ no gap
- XY 1.5 mm 0/90$^\circ$ no gap
- XY 1.5 mm $+45^\circ$ 1.2 mm gap
- XY 1.5 mm 0/90$^\circ$ 1.2 mm gap
- Limits

12 s VBB  n=5-10

- XZ 1.5 mm no gap
- XZ 4.0 mm 1.2 mm gap
- ZX 1.5 mm no gap
- ZX 2.0 mm 1.2 mm gap
- ZX 4.0 mm 1.2 mm gap
- ZX 6.0 mm 1.2 mm gap
- Limits
Results: variation of infill for different orientations

60 s VBB  n=5-10

- XY 1.5 mm +45° no gap
- XY 1.5 mm 0/90° no gap
- XY 1.5 mm +45° 1.2 mm gap
- XY 1.5 mm 0/90° 1.2 mm gap

Limits

After flame time / s

Burn length / mm

60 s VBB  n=5-10

- XZ 1.5 mm no gap
- XZ 4.0 mm 1.2 mm gap
- ZX 1.5 mm no gap
- ZX 2.0 mm 1.2 mm gap
- ZX 4.0 mm 1.2 mm gap
- ZX 6.0 mm 1.2 mm gap

Limits

After flame time / s

Burn length / mm
Discussion: Infill

- The pilot flame needs to warm up less material to the point of melting and gasification + air is present from all sides → combustion front can move quicker → higher burn length
- An after flame can stay lit longer due to the same reason. Cool down is prolonged, keeping the reaction intact for a longer time.
Discussion: orientation

- Densest packing leaves no room for particularities
- For lower infill, two types can be distinguished:

1. Inside XY plane, behaviour is similar
2. XZ and ZX resemble XY sandwich coupons in the cross section, hence results are similar
Discussion: DoE

- The number of different factors and their dependence or independence could be used in a DoE
  
  
  → Expand data base for other materials printed via FDM

<table>
<thead>
<tr>
<th>Infill</th>
<th>Gap size</th>
<th>Orientation</th>
<th>Thickness</th>
<th>Sandwich</th>
<th>Burn length</th>
<th>After flame</th>
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<td>100%</td>
<td>0</td>
<td>XY ±45°</td>
<td>1.5 mm</td>
<td>No</td>
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<tr>
<td></td>
<td>1.2 mm</td>
<td>XY, 0/90°</td>
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<td>Yes</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>XZ</td>
<td>4.0 mm</td>
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<tr>
<td></td>
<td></td>
<td>ZX</td>
<td>6.0 mm</td>
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<td>22%</td>
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Next steps

- Add infill between 40 % and 100 %. Coupons already in the Airbus laboratory
- Comparison to ULTEM 9085 from conventional production routes
- Comparison to ULTEM 1010 produced via FDM
- Check material change during processing steps: raw $\rightarrow$ filament on spool $\rightarrow$ printed filament
Thank you