

Relationship Between 3-D Printed Materials and Flammability

Presented to: International Aircraft Materials Fire
Test Forum

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Date: 3/10/2020



Federal Aviation
Administration



Introduction

- **3D printing introduces all new variables in material construction**
- **Variables include:**
 - Printing orientation
 - Infill percentage
 - Raster angle
 - Layer thickness
 - Raster width

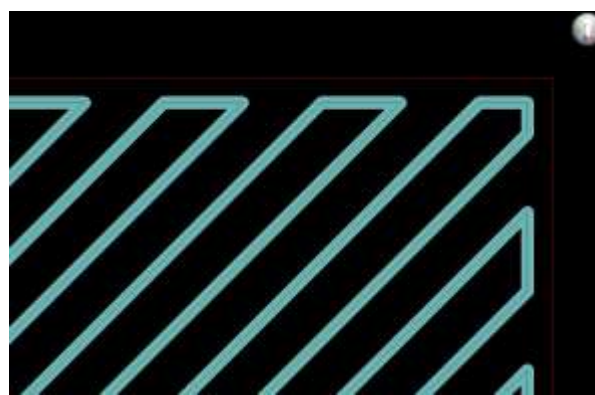
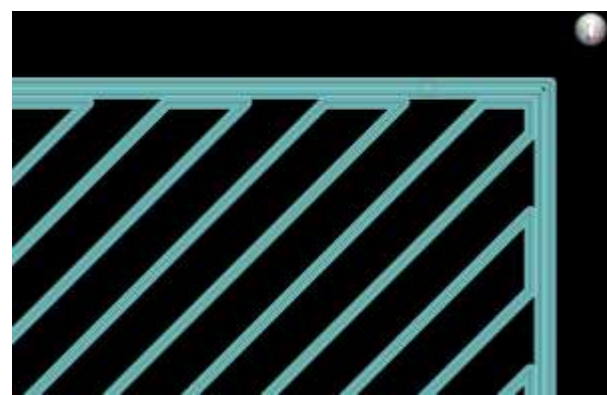


Test Plan

- **Determine worst case scenario for each variable in flammability testing in order to simplify future testing**
- **Vary printing parameters in several different materials and sample thicknesses**
- **Test using vertical Bunsen Burner**
- **Analyze test results to determine how future testing can be simplified and reduced**

Calculating Infill Percentage

- Infill percentage calculated from Insight program material estimate
- Create toolpath of single layer
- Delete outer contours to only calculate infill
- Divide material used by material used in solid sample to get infill %



Sparse: 0.100 in³ material

Solid: 0.435 in³ material

$$\frac{0.100}{0.435} = 23.0\%$$

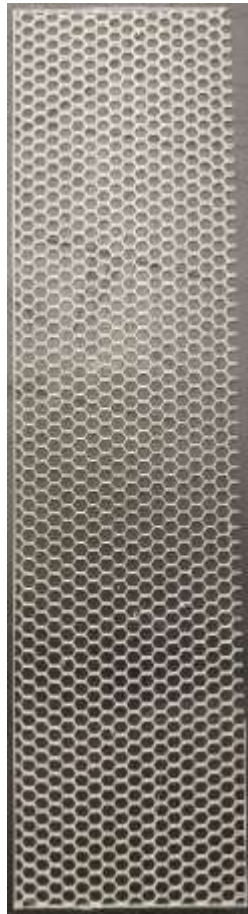
Print Infill Patterns

- **Tested with Ultem Support (PES) material**
- **10 infill patterns**
- **Tested infill by itself and with solid outer layers**

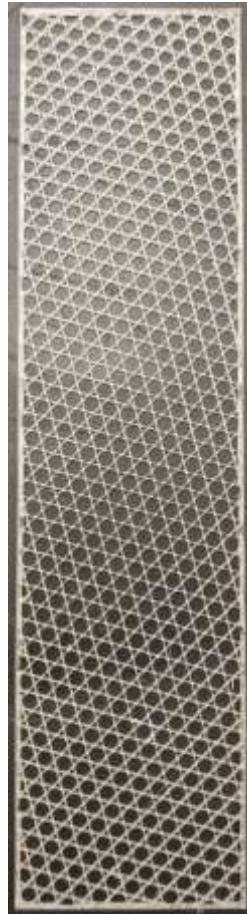
Print Infill Patterns



Sparse
(23.0%)



Hexagonal
(29.7%)



Hexagram
(32.4%)



Permeable
Triangular (32.4%)



Sparse DD
(44.8%)

Infill Only

- **0.060” sample thickness**
- **Every sample tested burned until chamber filled with smoke and put out fire**



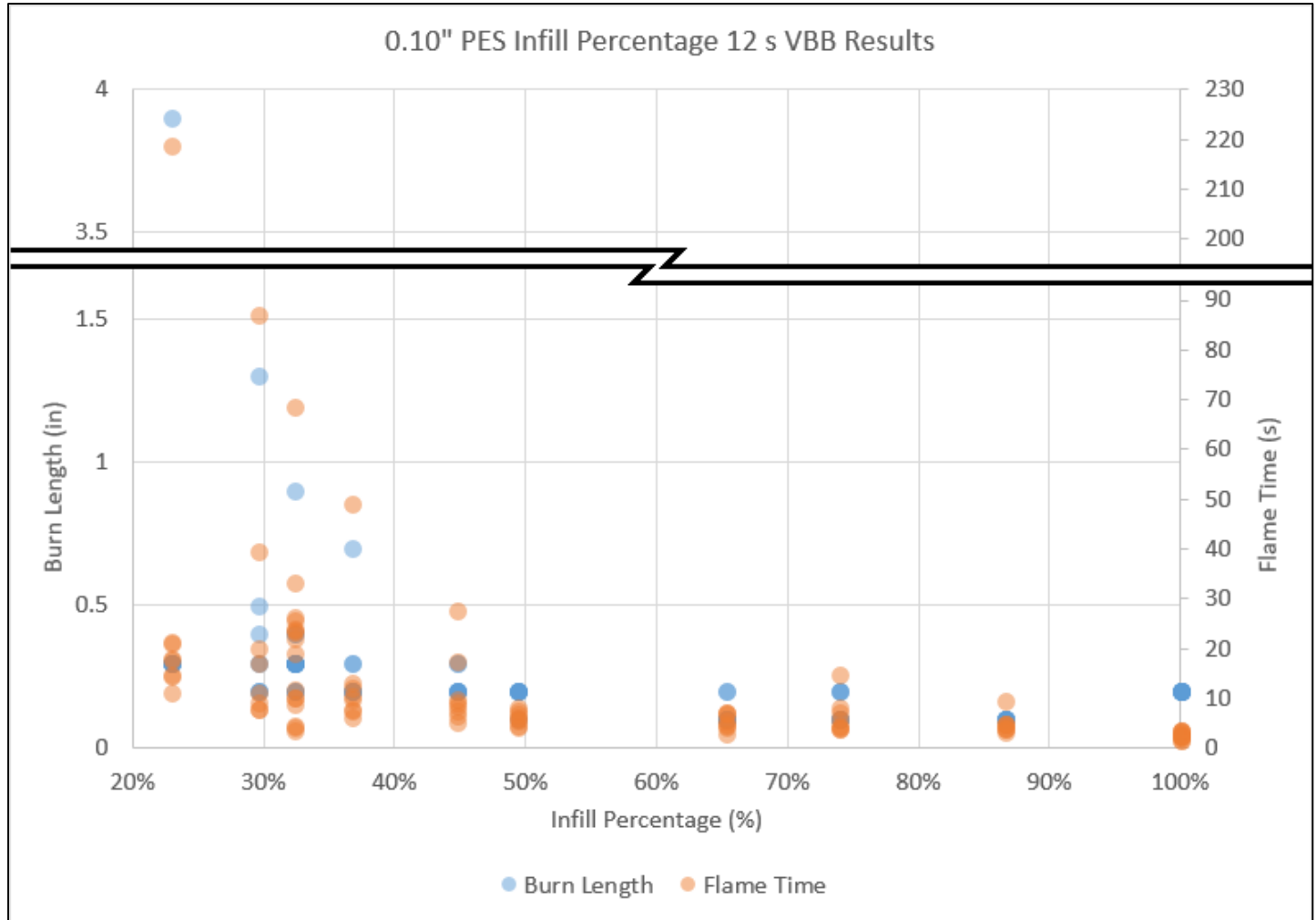
Varying Infill with Solid Outer Layers

- **Tested 0.10” thickness**
- **2 solid outer layers, rest is hollow infill**
 - On 0.10”, 2 solid layers, 6 infill, 2 solid layers
- **Two materials – Ultem Support (PES) and Ultem 9085 (PEI)**
- **12-second vertical Bunsen burner for both materials, 60s VBB for Ultem 9085**

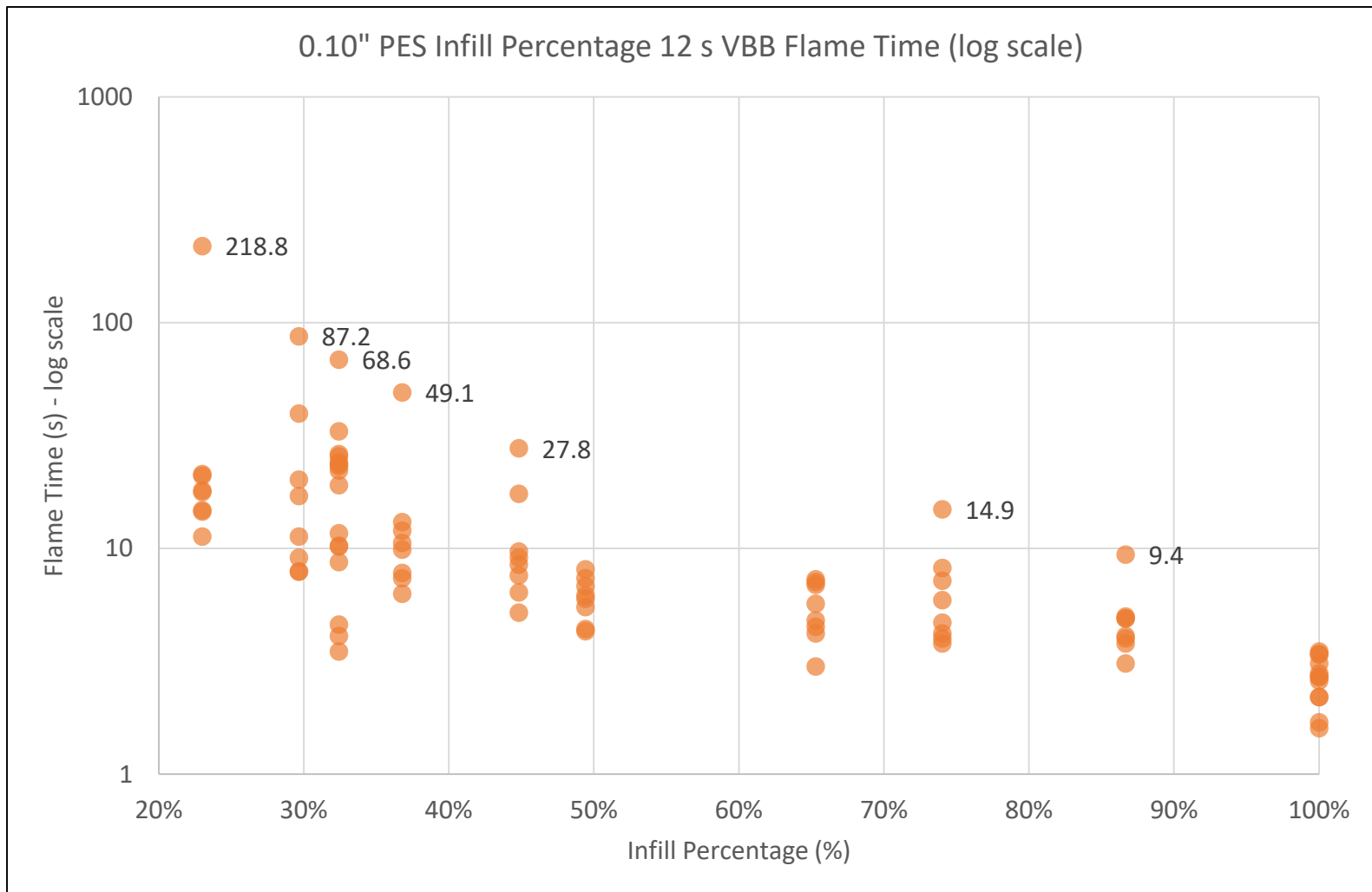


Varying Infill – Ultem Support

- 8 samples per infill pattern

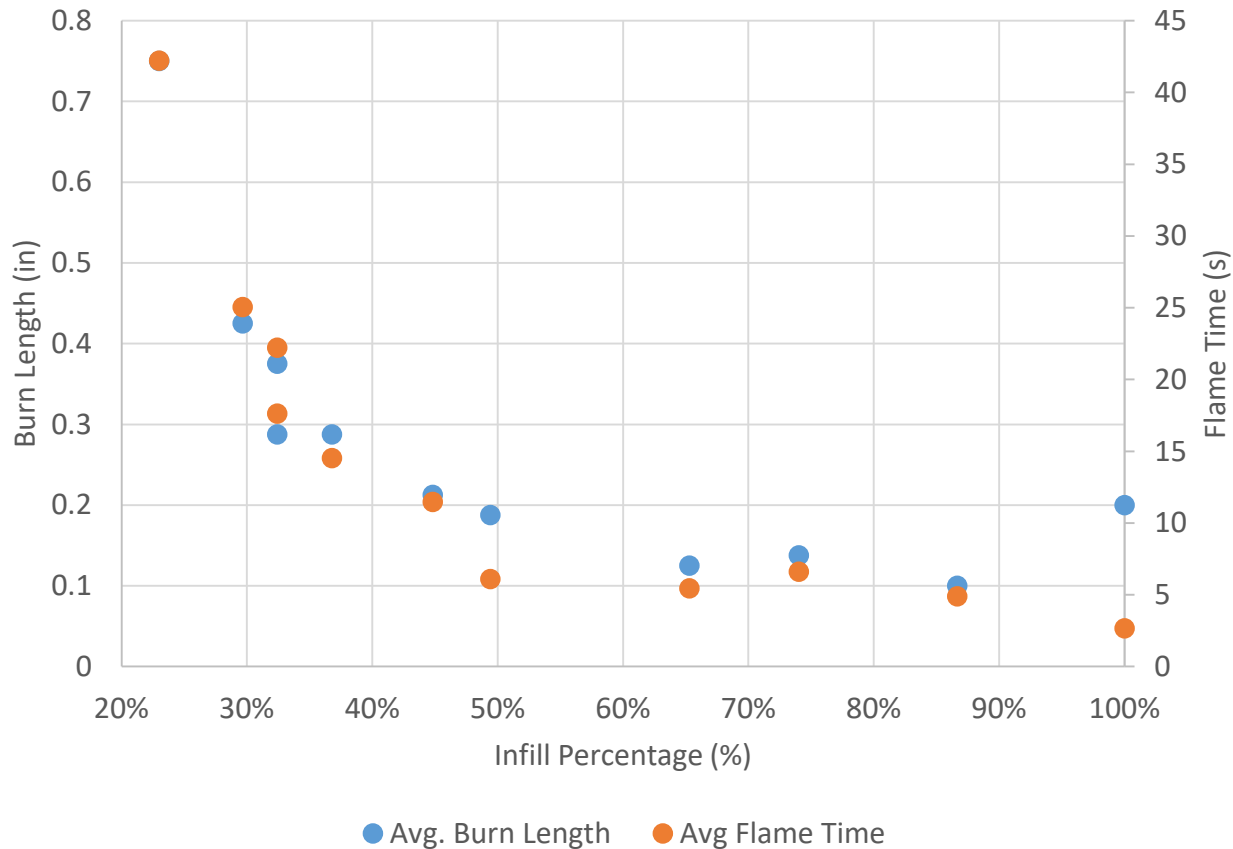


Varying Infill – Ultem Support



Varying Infill – Ultem Support

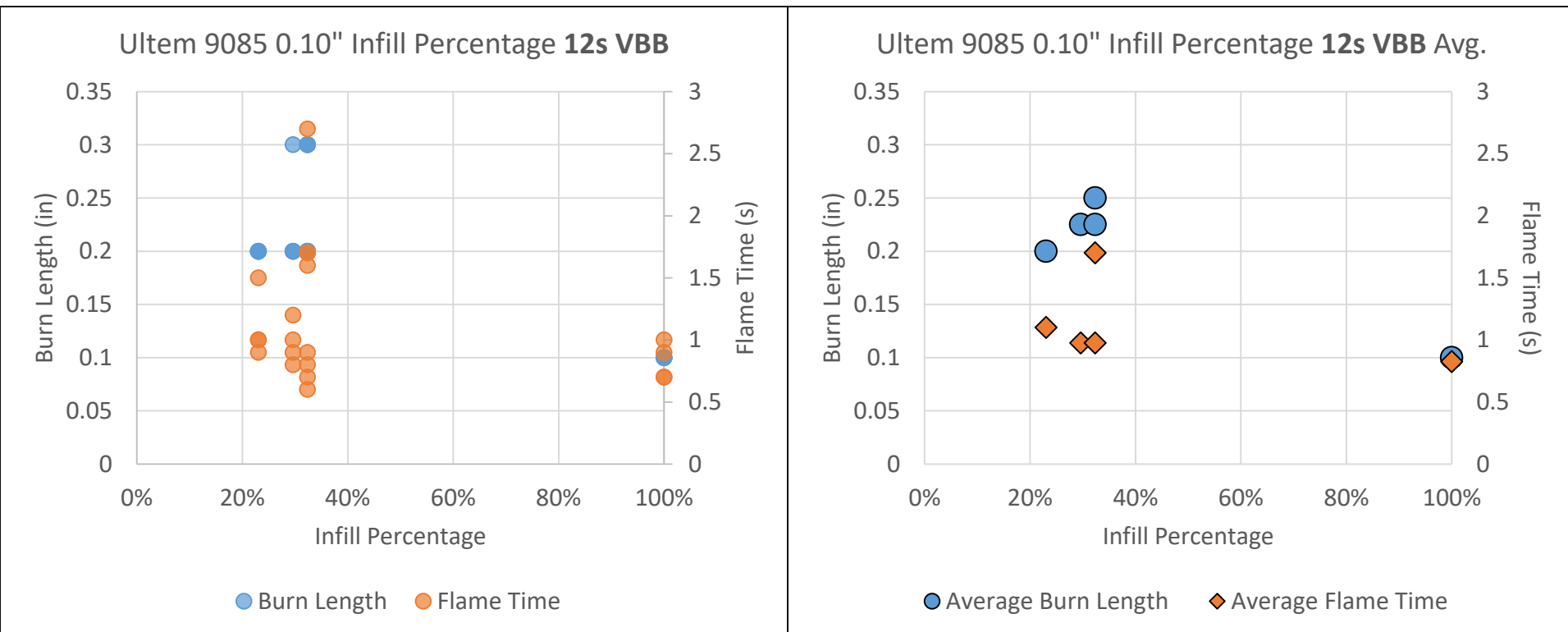
0.10" PES Infill Percentage 12 s VBB Results



- Good correlation between infill percentage and test results
- Less infill % causes more burning

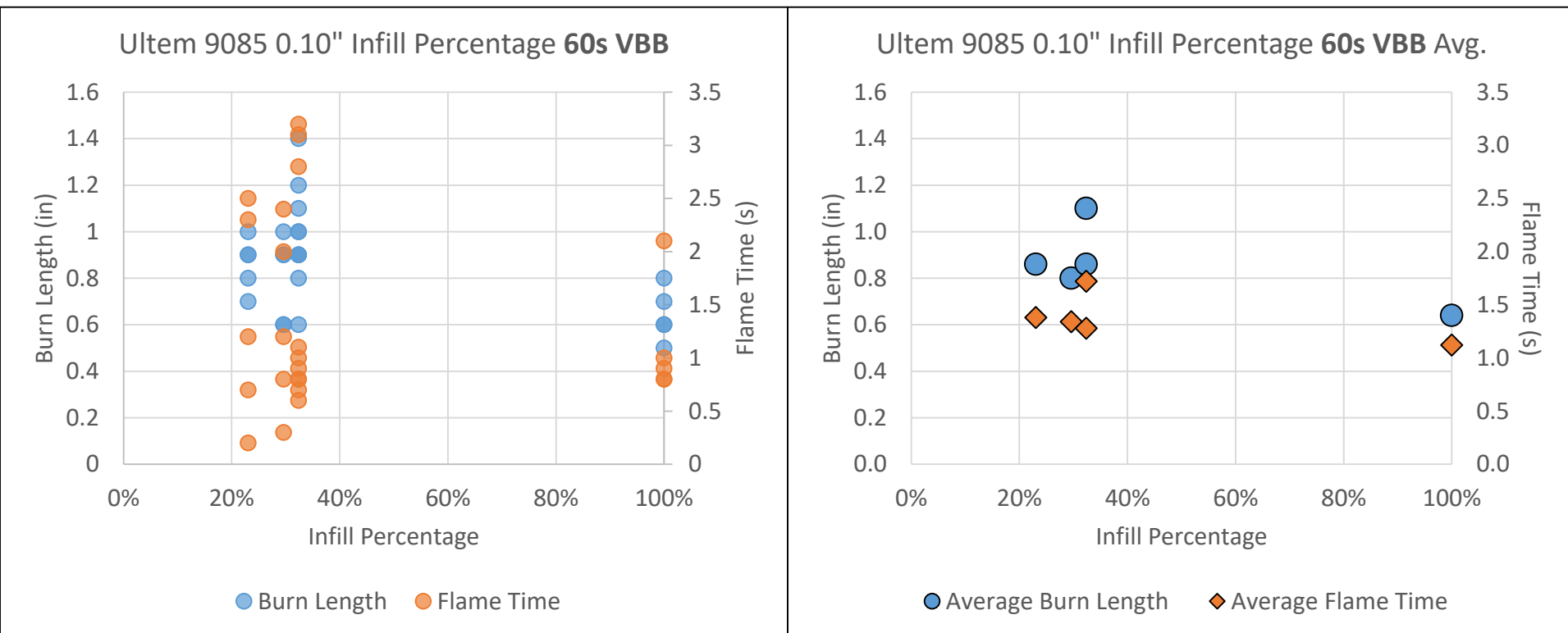
Varying Infill – Ultem 9085 (PEI)

- **Same layer configuration – 2 solid outer layers, 6 inner infill layers (0.10 inch thickness)**
 - 12-second test, 4 samples per infill pattern



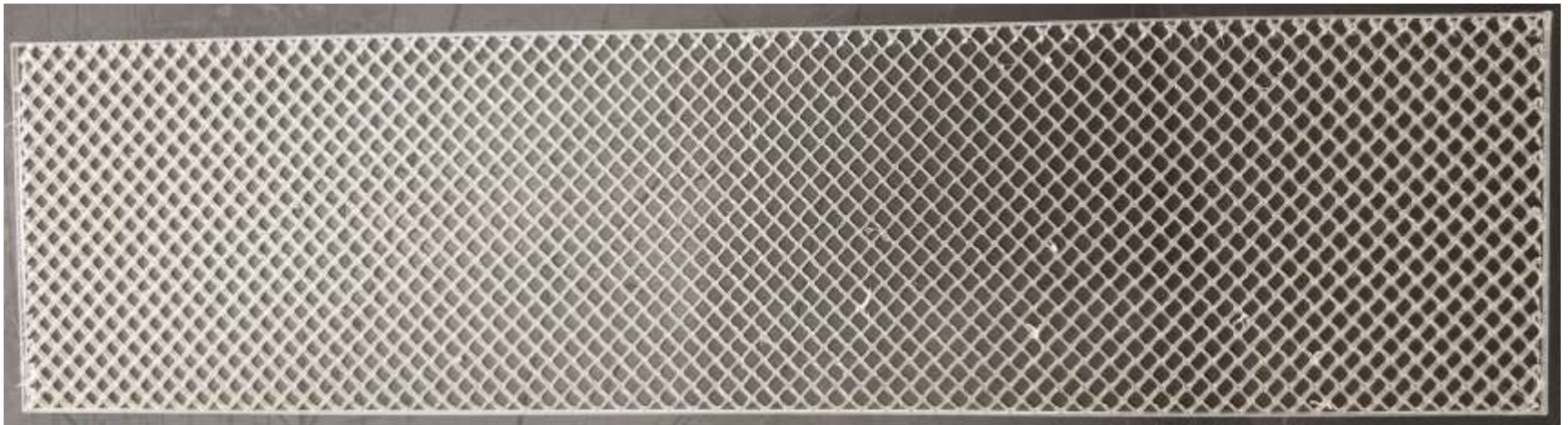
Varying Infill – Ultem 9085

- **Same layer configuration – 2 solid outer layers, 6 inner infill layers (0.10 inch thickness)**
 - 60-second test, 5 samples per infill pattern



Varying Infill – Ultem 9085

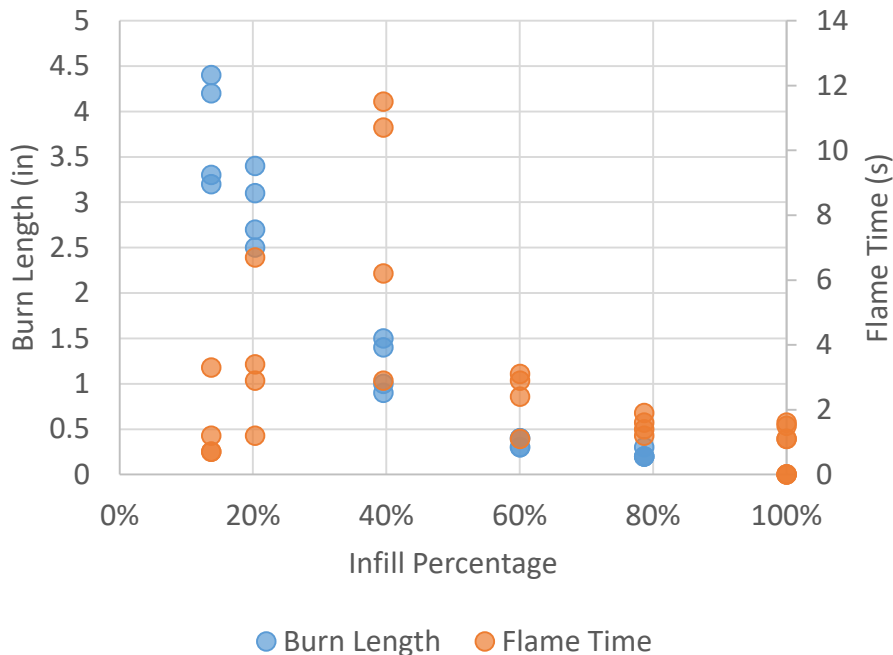
- **Infill only – 0.06 inch thickness**
- **Same tests as completed by Airbus**
 - Have not reconciled infill % calculation yet



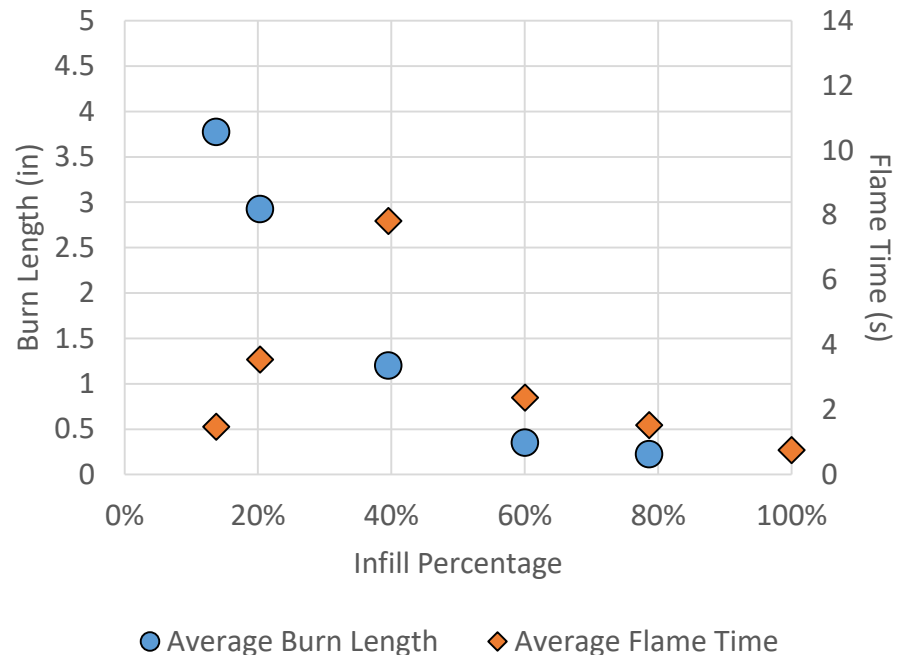
Varying Infill – Ultem 9085

- **Infill only, 0.06 inch thickness**
 - 12-second test, 4 samples per infill pattern

Ultem 9085 0.06" Infill Only 12s VBB



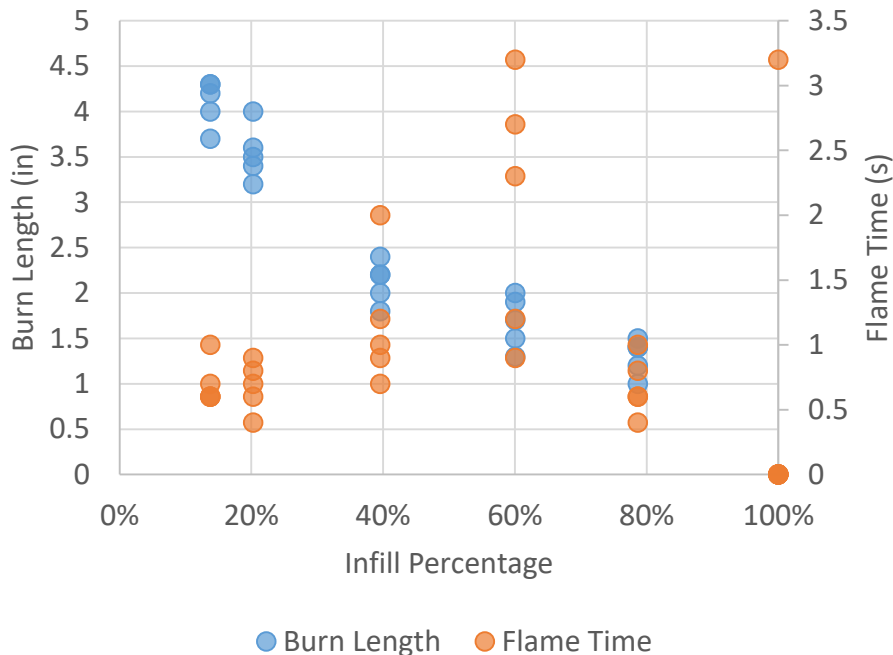
Ultem 9085 0.06" Infill Only 12s VBB Avg.



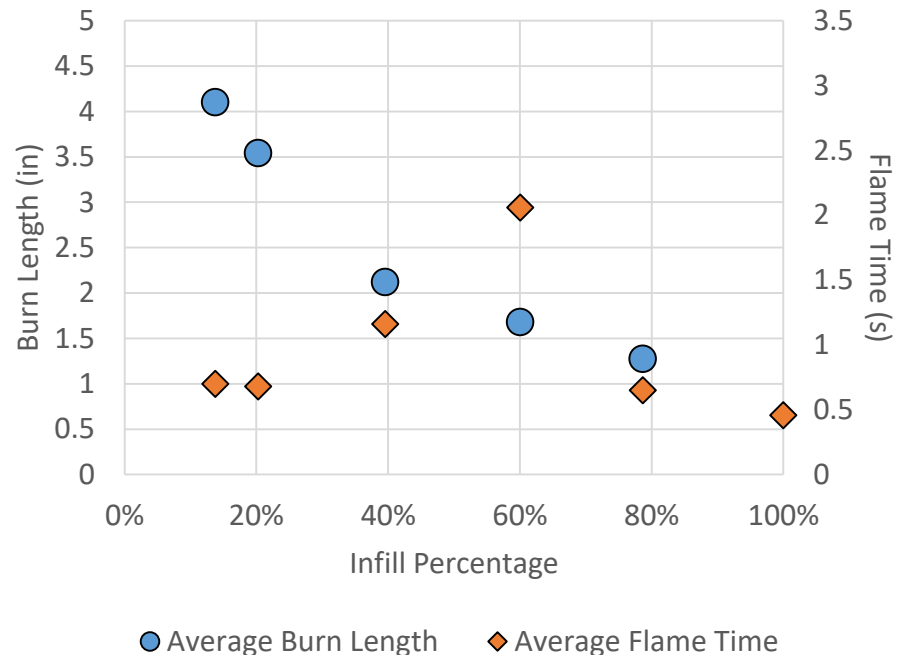
Varying Infill – Ultem 9085

- **Infill only, 0.06 inch thickness**
 - 60-second test, 5 samples per infill pattern

Ultem 9085 0.06" Infill Only 60s VBB



Ultem 9085 0.06" Infill Only 60s VBB Avg.



Conclusion

- **Less infill percentage is more severe case than more infill**
- **Agrees with Airbus test results using Ultem 9085**
 - Have not made direct comparison yet because of infill percentage calculation
- **Next parameter to test**
 - Raster angle?
 - Raster width?

Questions?

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