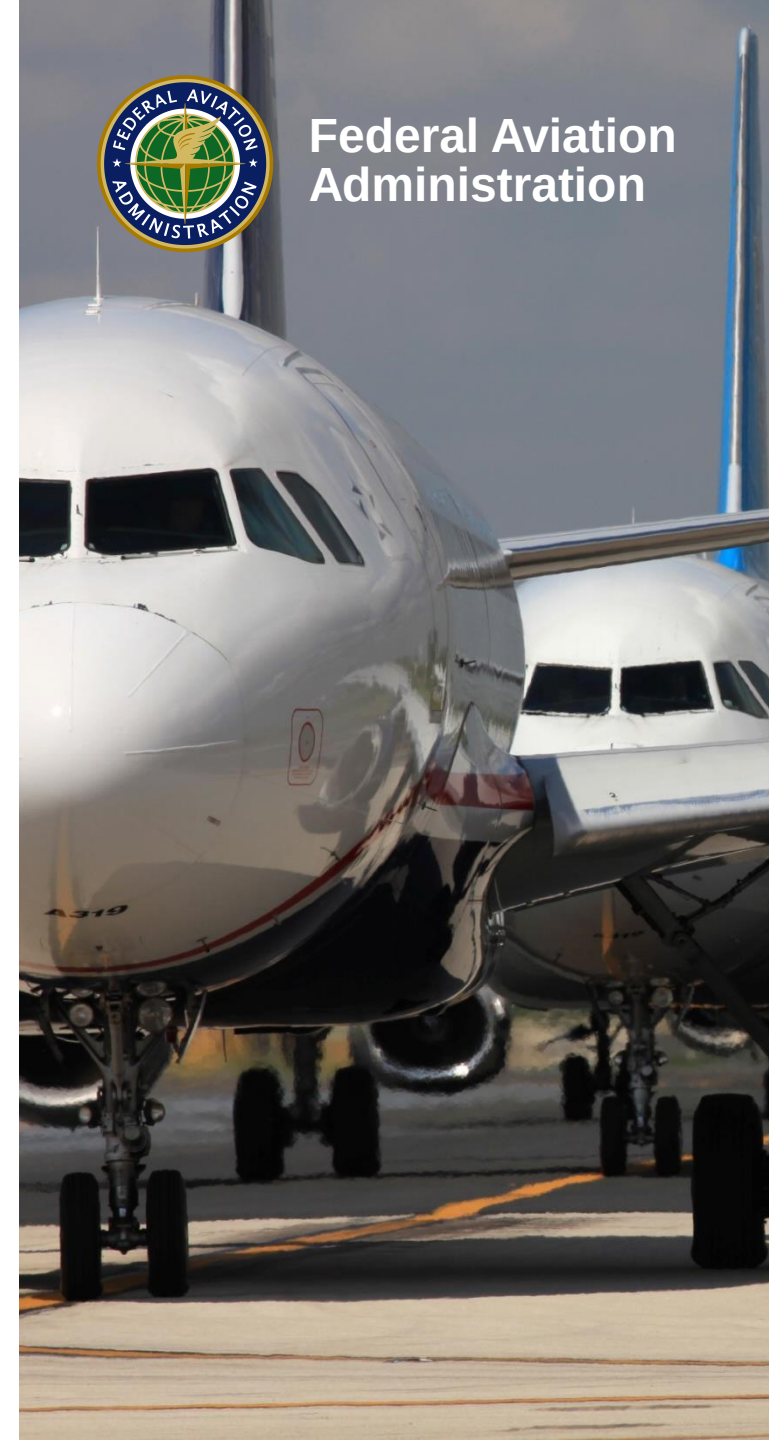


Relationship Between 3-D Printed Materials and Flammability

Presented to: International Aircraft Materials Fire Test Forum
By: Steve Rehn, Dan Keslar
Date: 04/19/2021

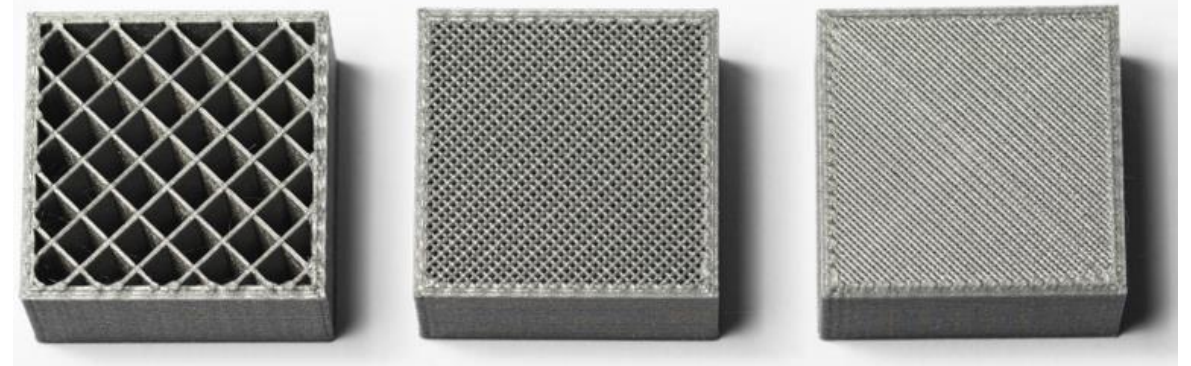


Federal Aviation
Administration



Introduction

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



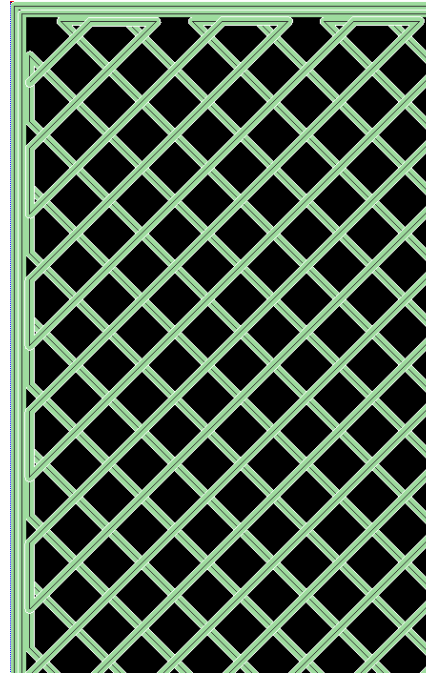
Test Plan

- **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**

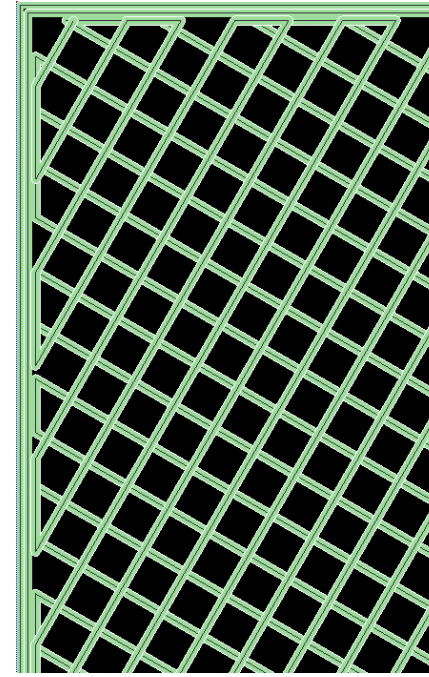
Raster Angle Tests

- **Ultem 9085 Material**
- **0.06 inch sample thickness**
- **0.010 inch layer thickness**
- **0.022 inch raster width**
- **Infill only (no solid layers)**
- **Raster angle varied**
 - 45°/45°
 - 60°/30°
 - 90°/0°
- **Tested at infill percentages of 19%, 47%, 77%, and 100%**

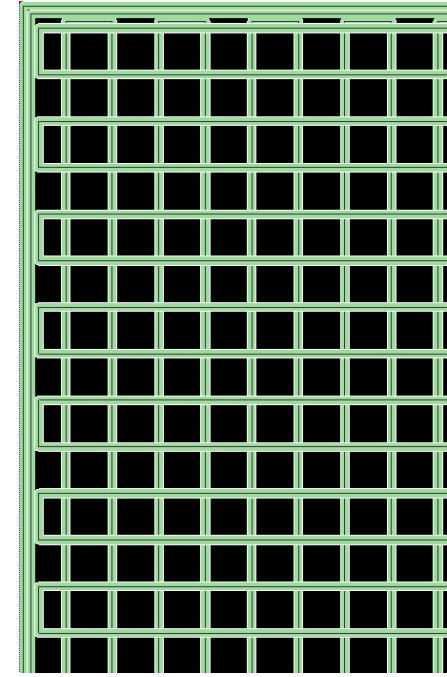
19% Infill, showing two layers



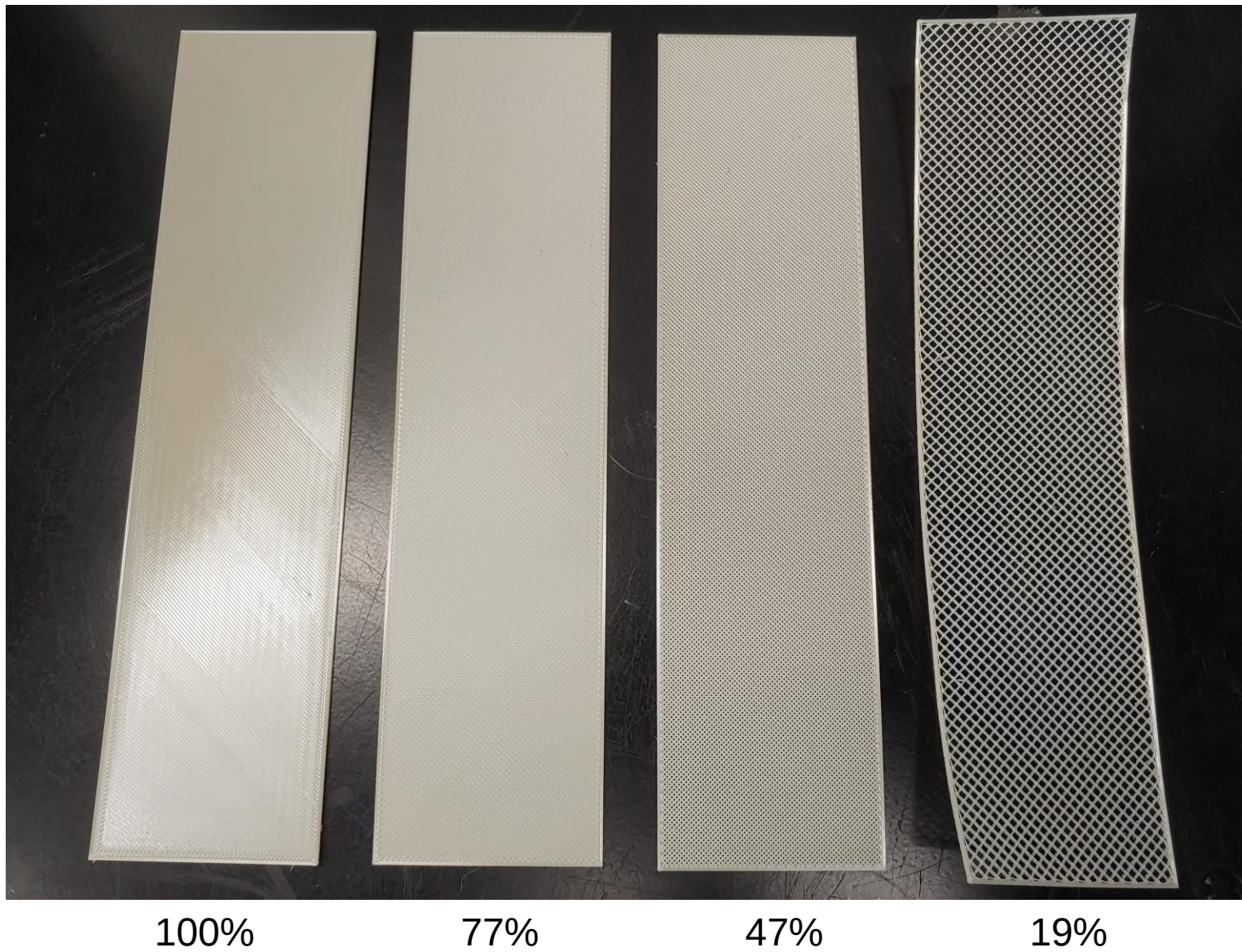
45°/45°



60°/30°



90°/0°



100%

77%

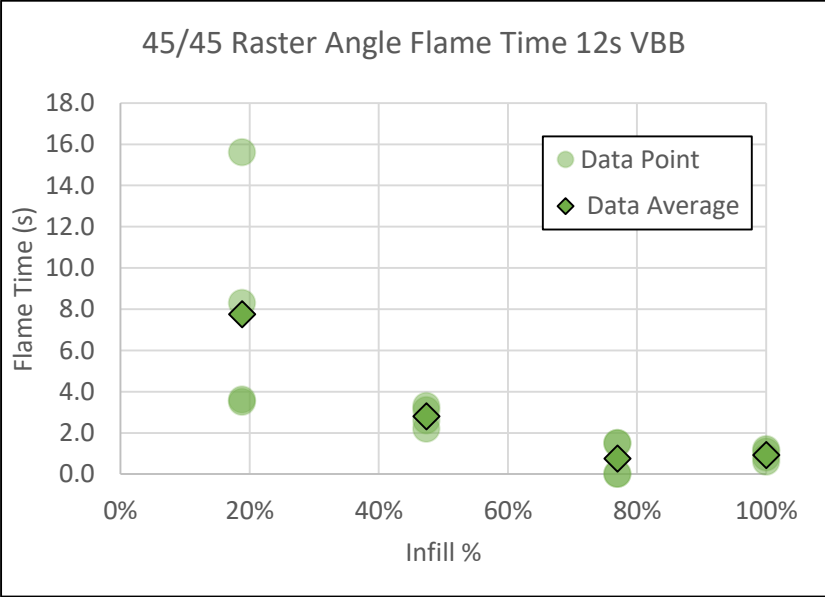
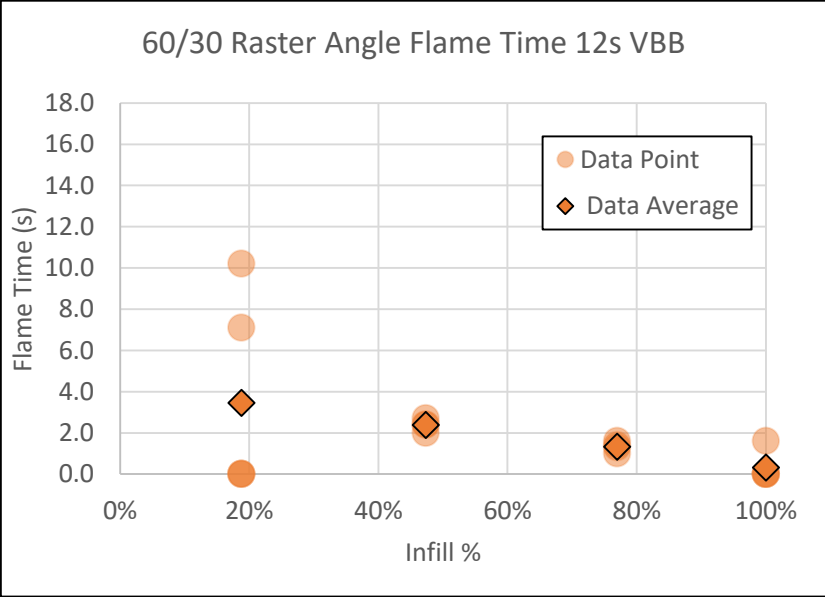
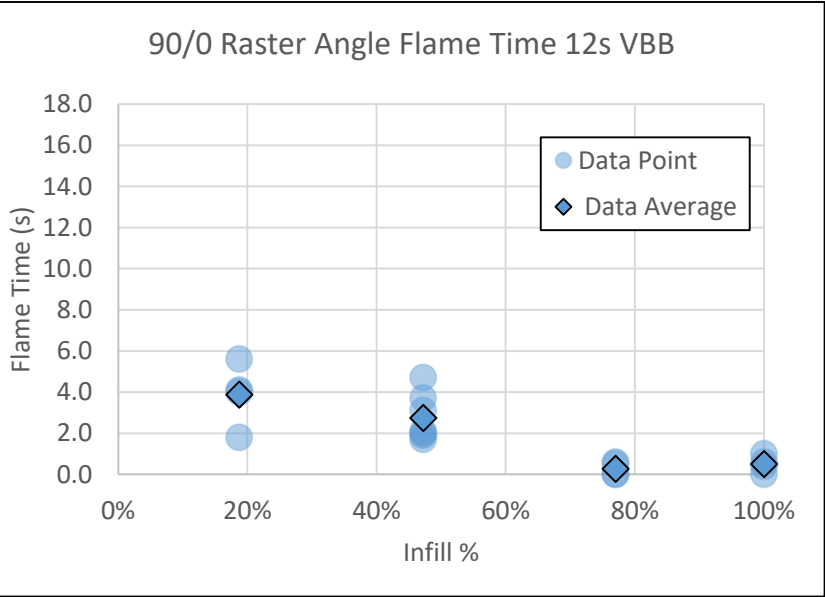
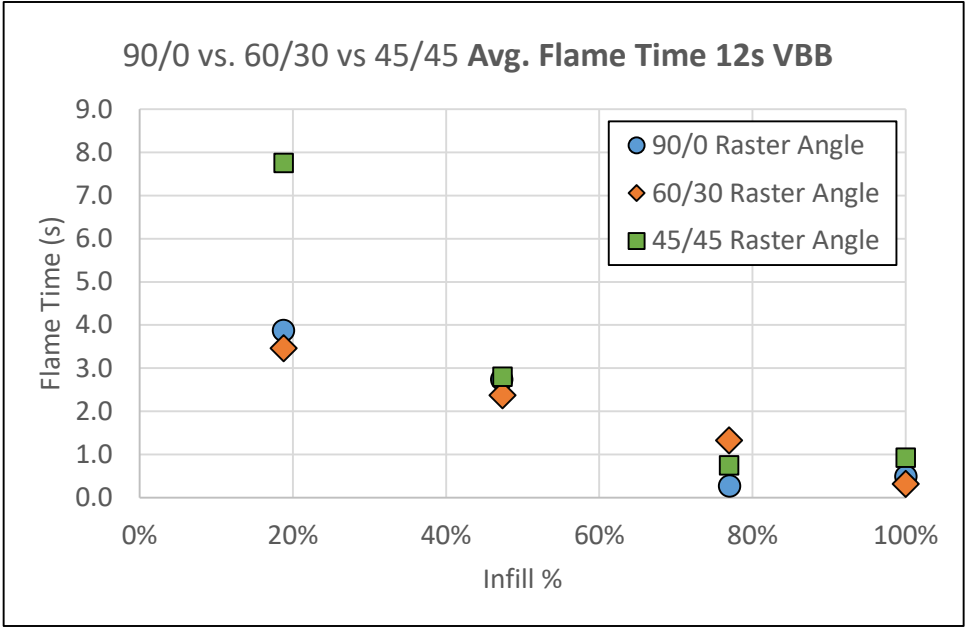
47%

19%

Raster Angle Tests

12s VBB

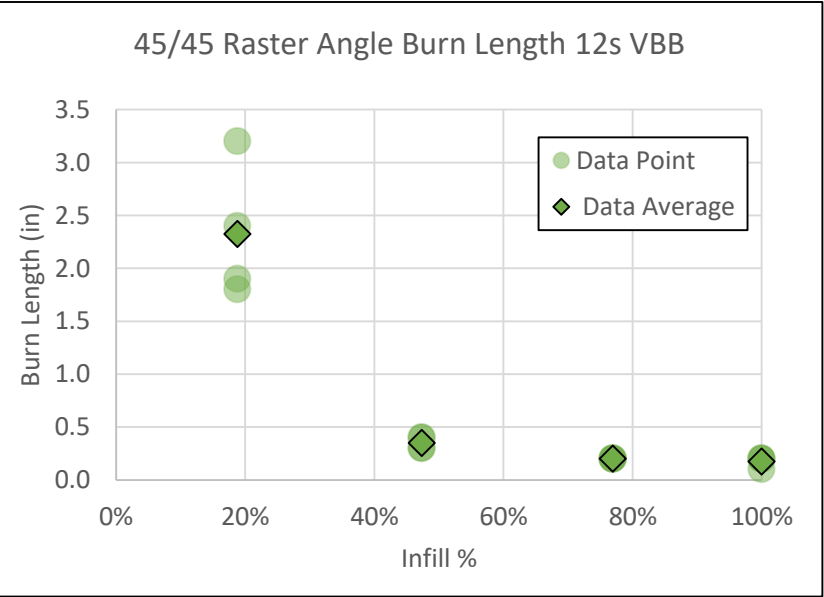
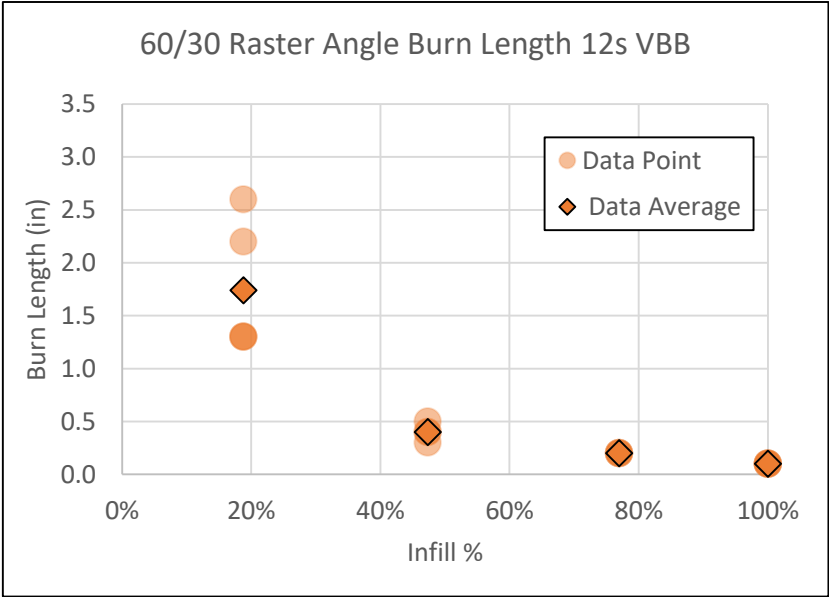
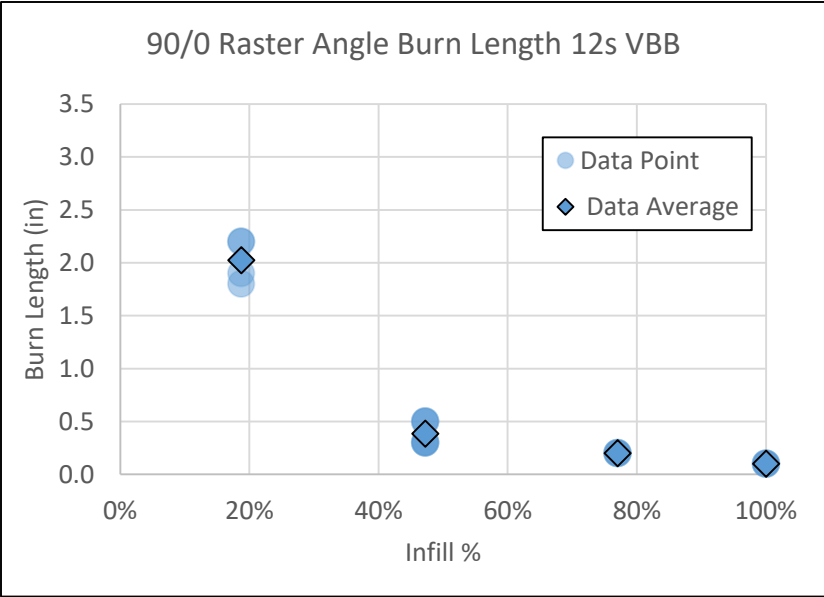
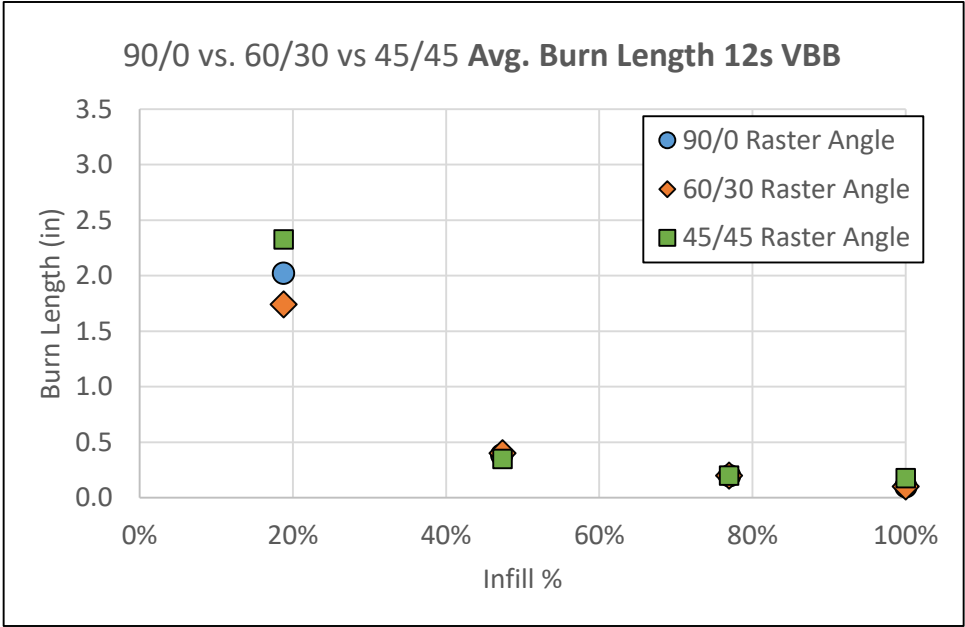
Flame Time



Raster Angle Tests

12s VBB

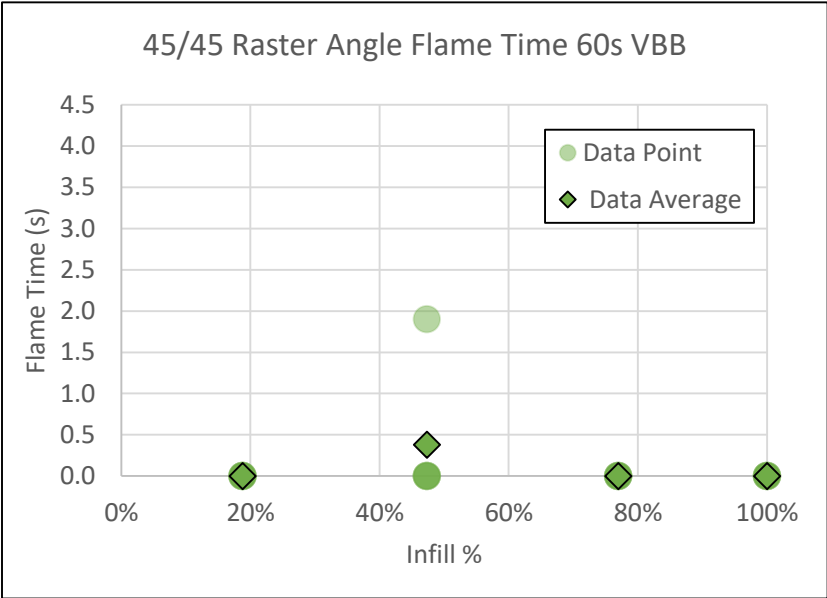
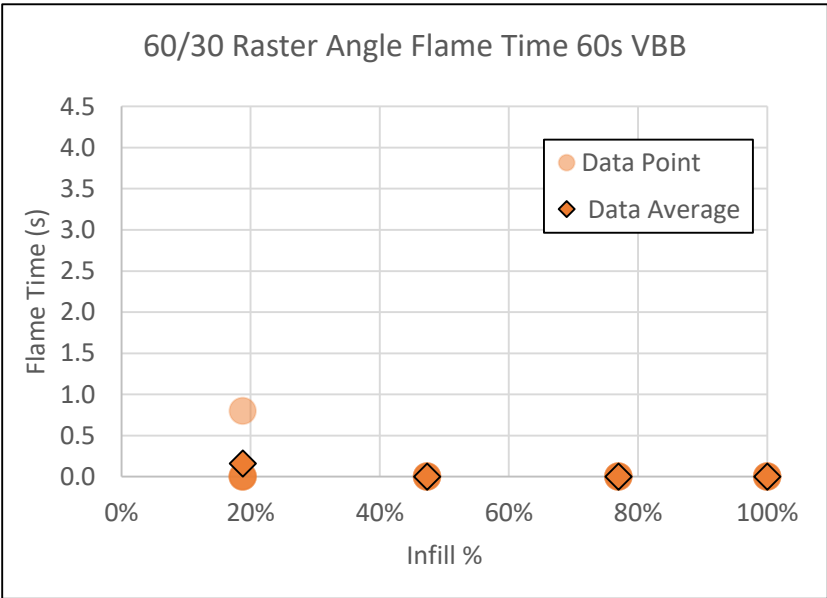
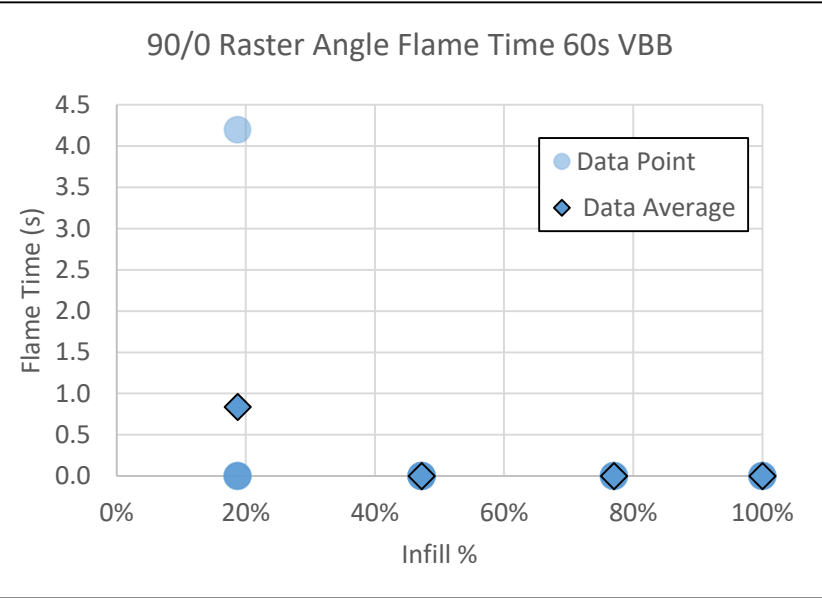
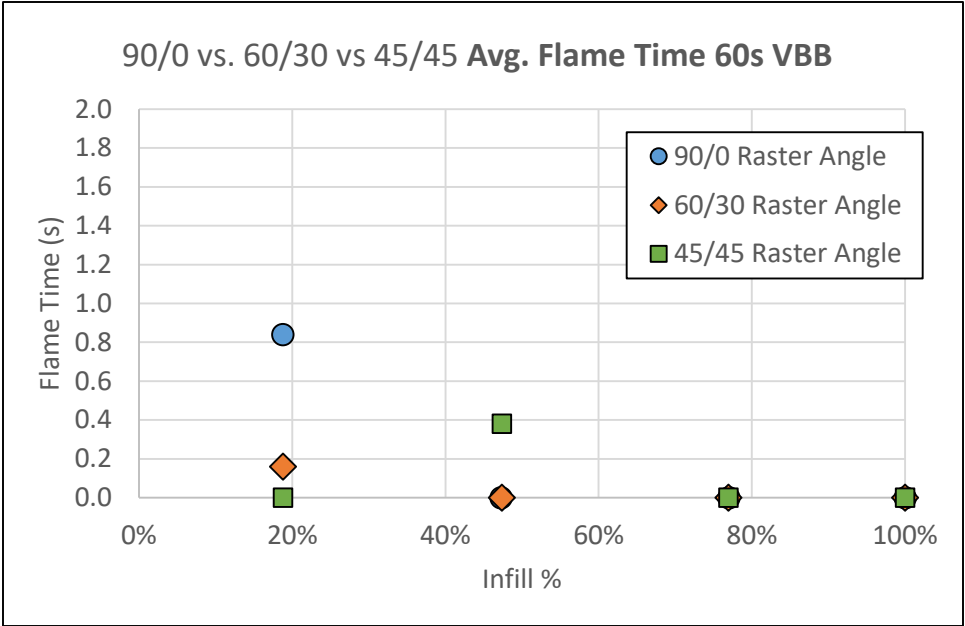
Burn Length



Raster Angle Tests

60s VBB

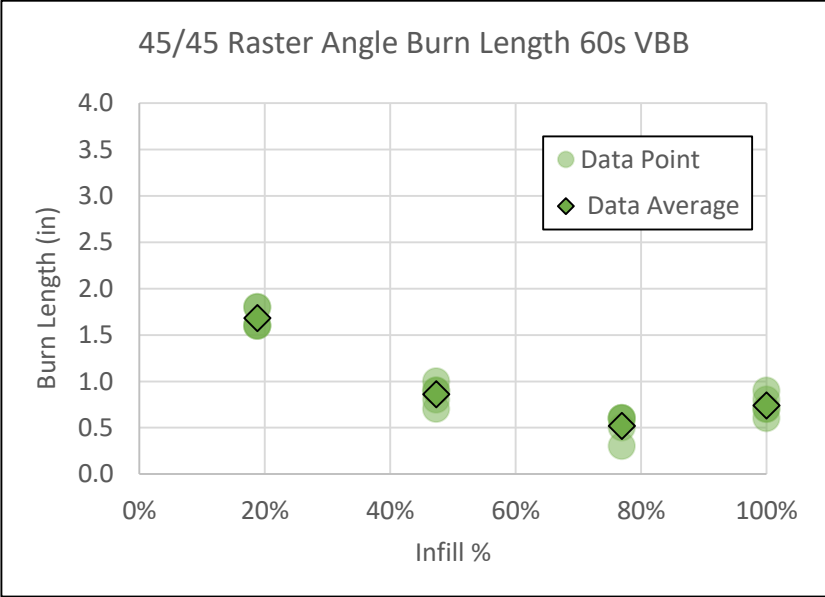
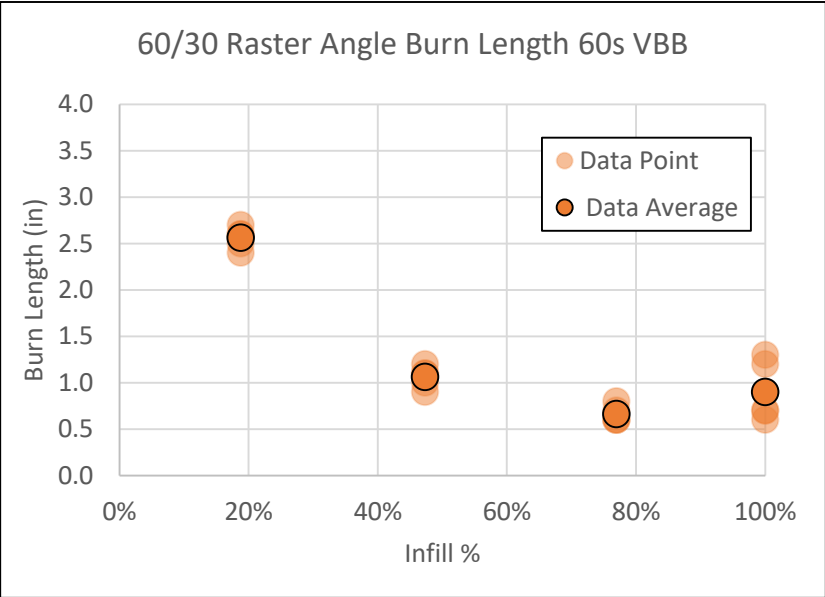
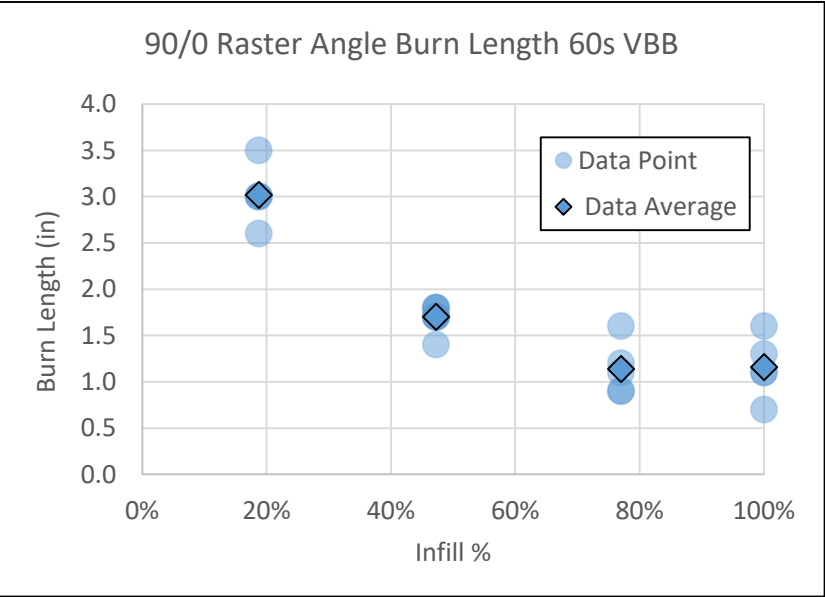
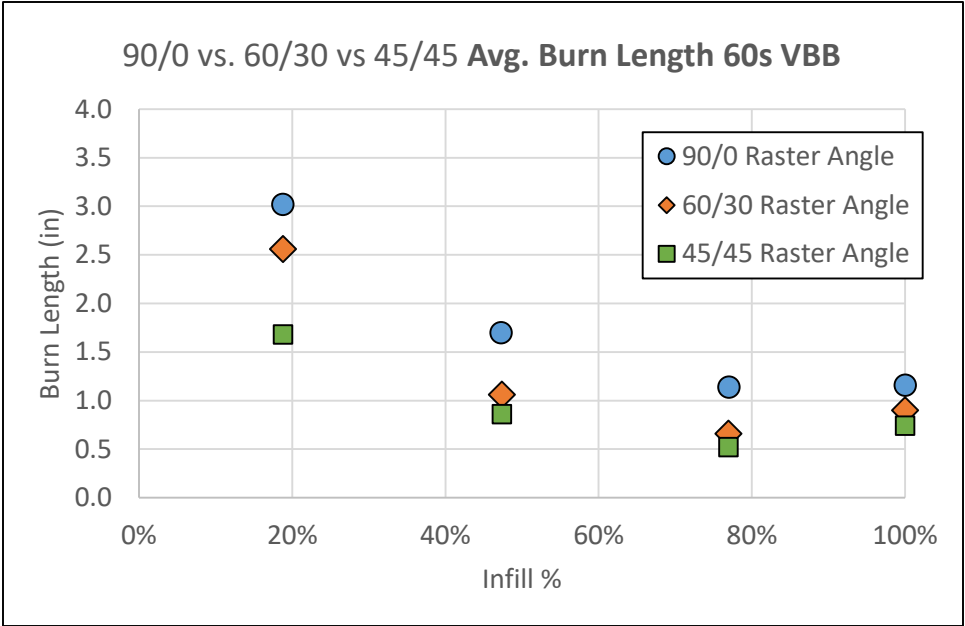
Flame Time



Raster Angle Tests

60s VBB

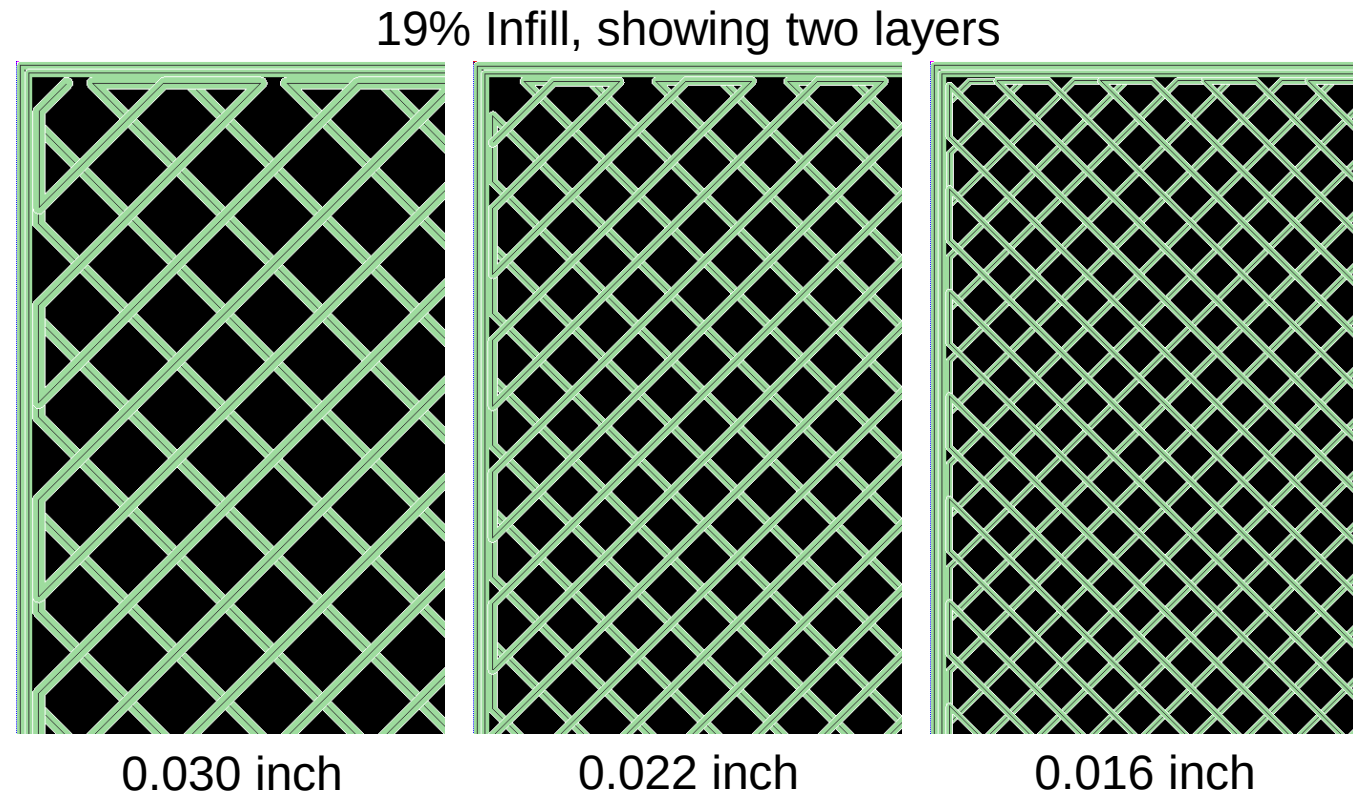
Burn Length





Raster Width Tests

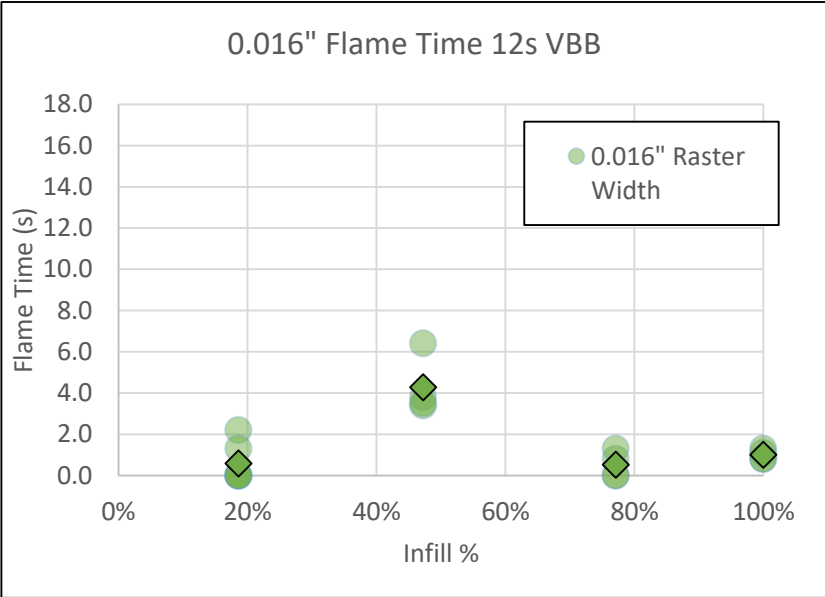
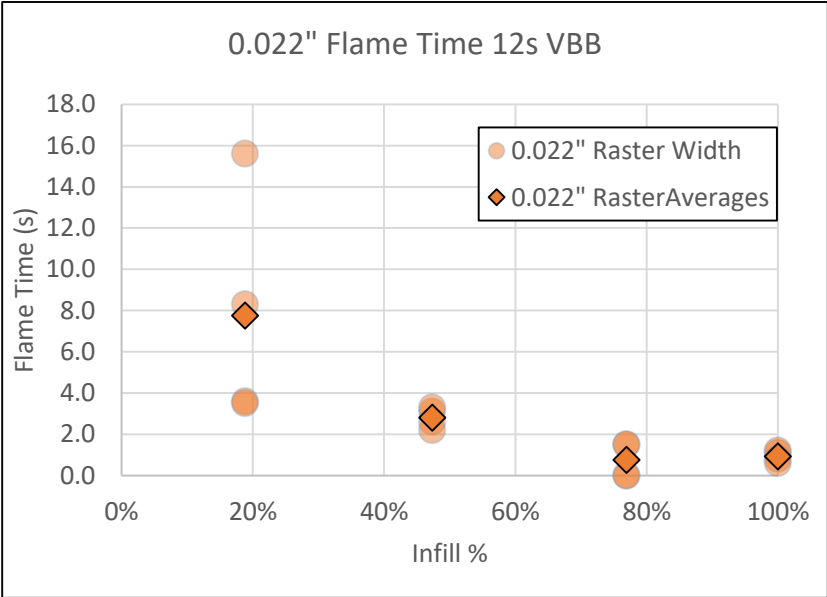
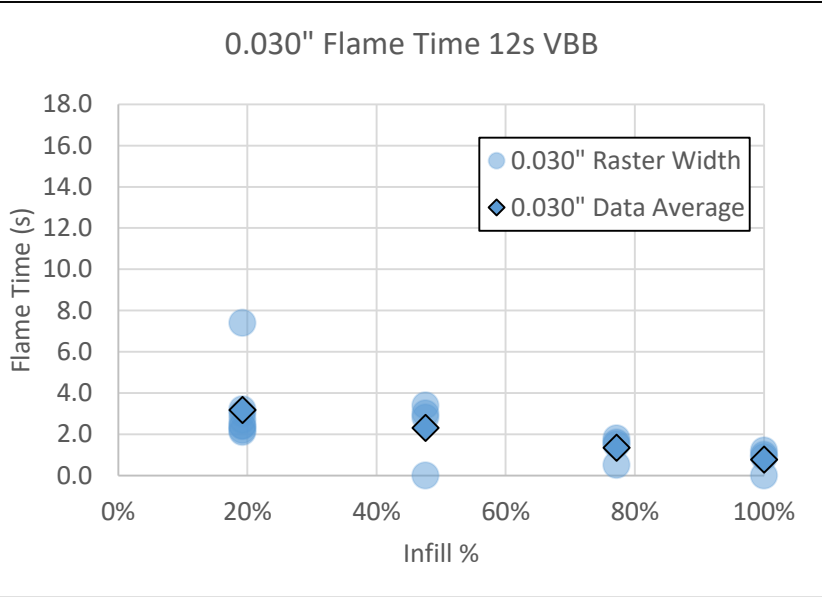
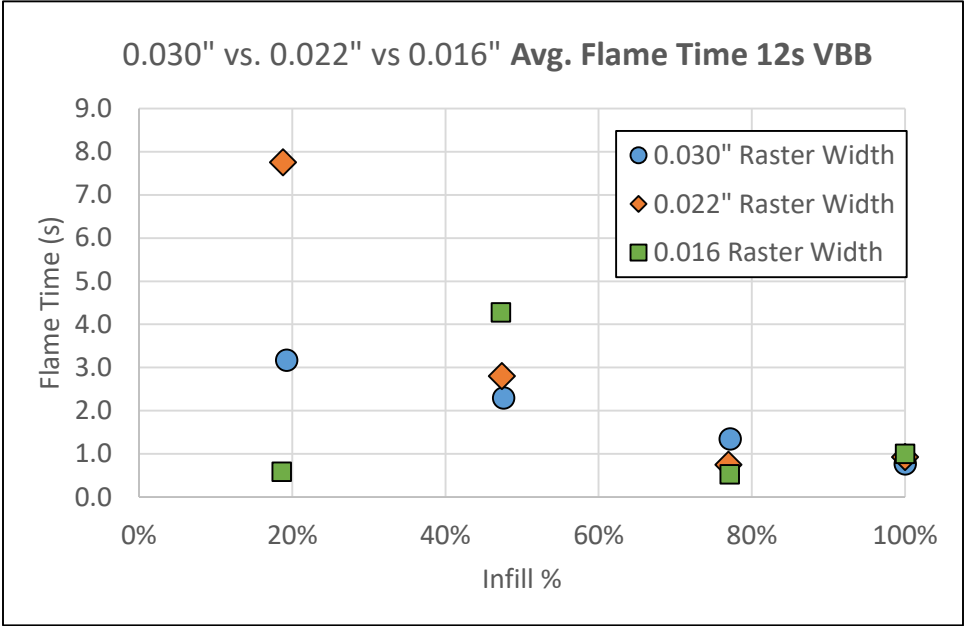
- **Ultem 9085 Material**
- **0.06 inch sample thickness**
- **0.010 inch layer thickness**
- **45°/45° raster angle**
- **Infill only (no solid layers)**
- **Raster width varied**
 - 0.030 inch
 - 0.022 inch
 - 0.016 inch
- **Tested at infill percentages of 19%, 47%, 77%, and 100%**



Raster Width Tests

12s VBB

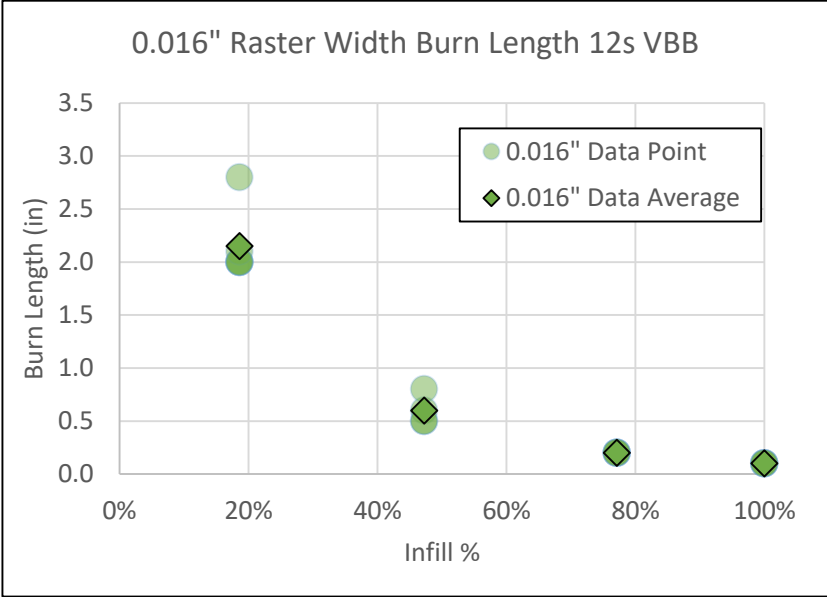
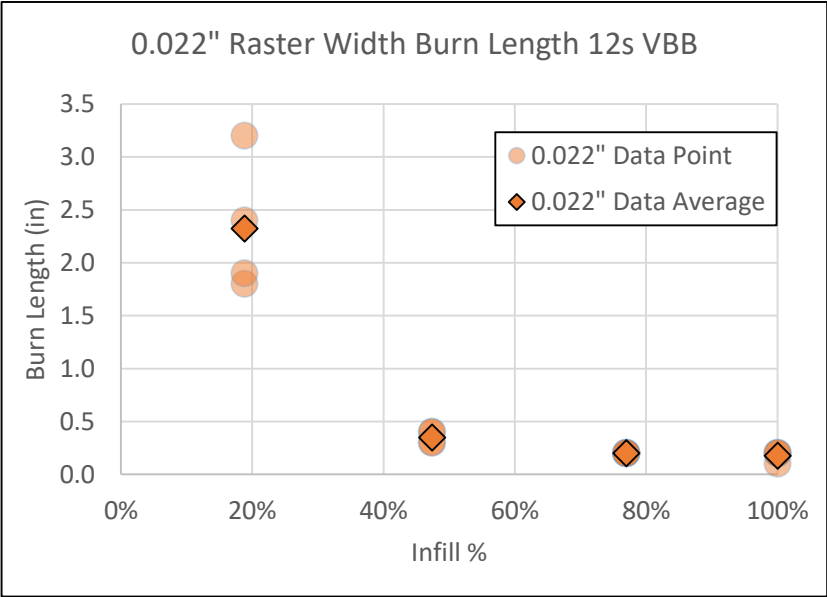
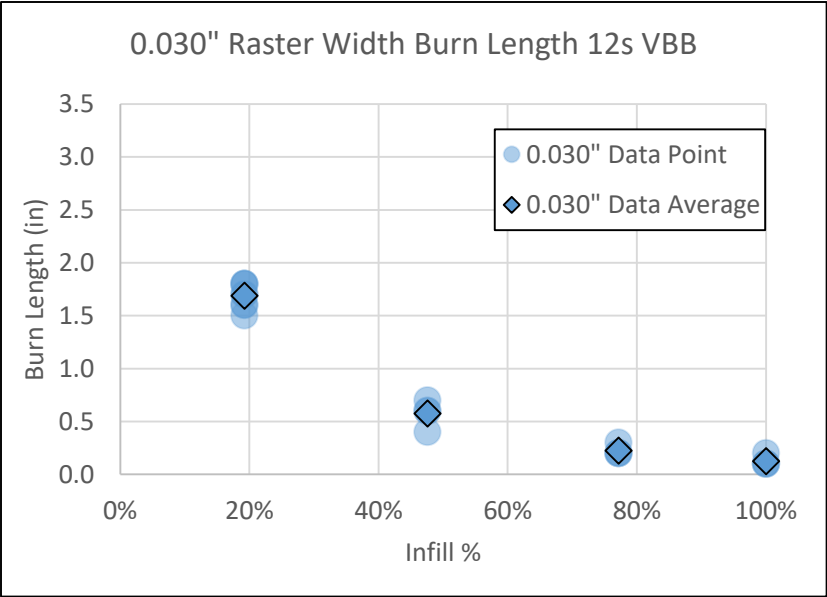
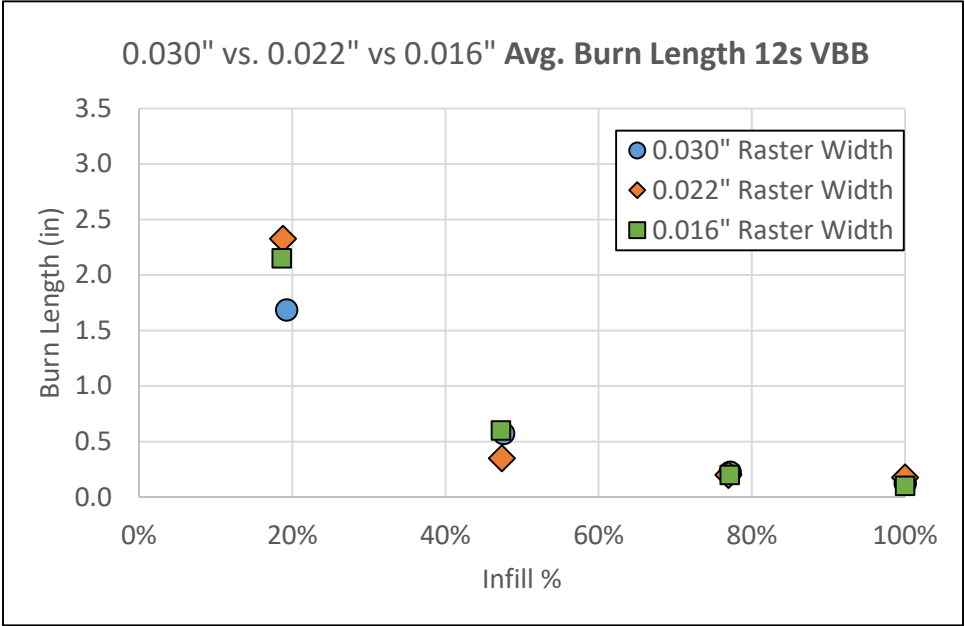
Flame Time



Raster Width Tests

12s VBB

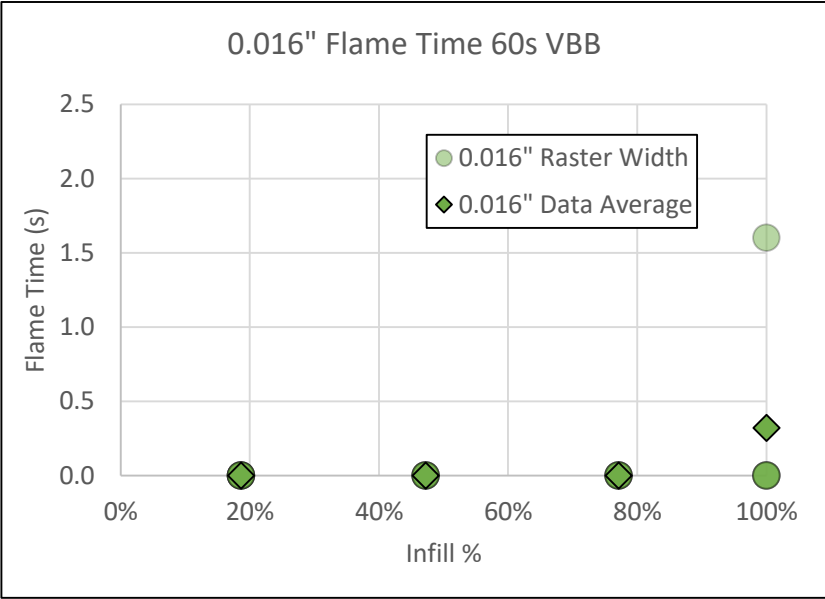
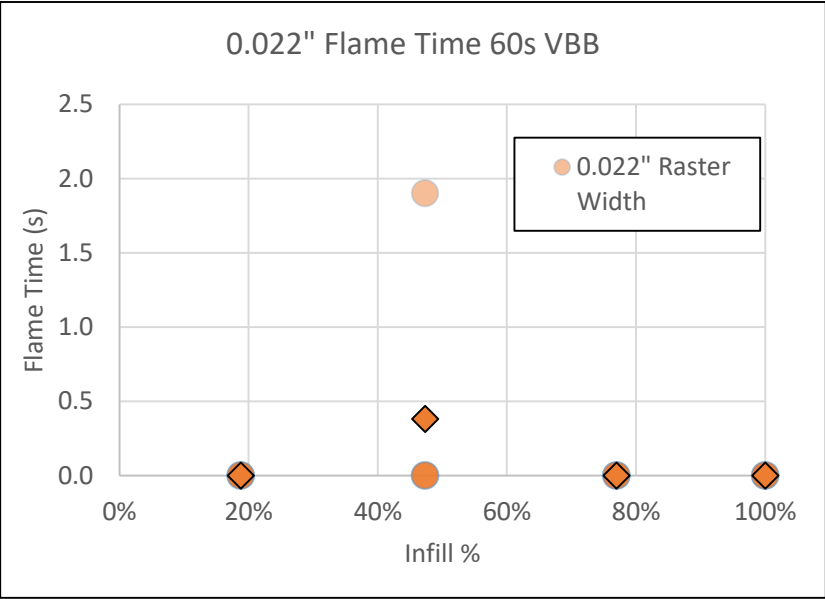
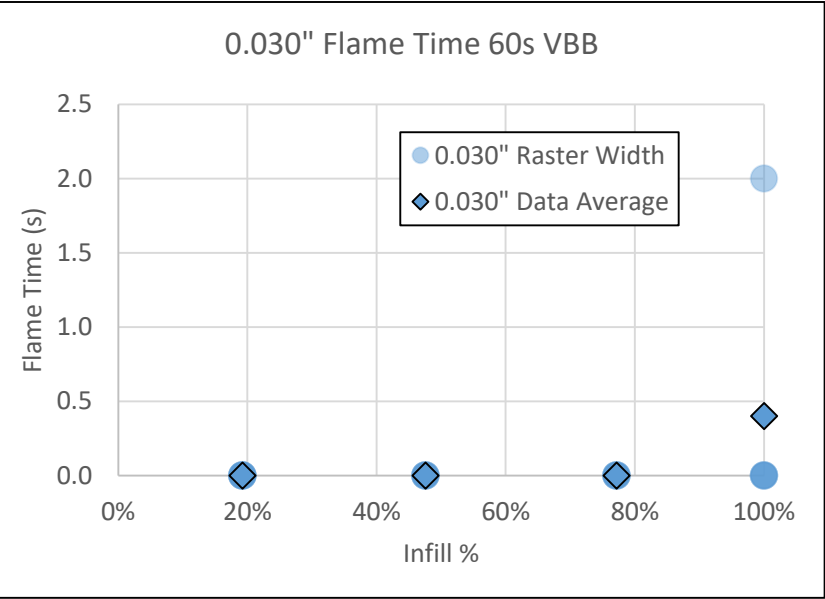
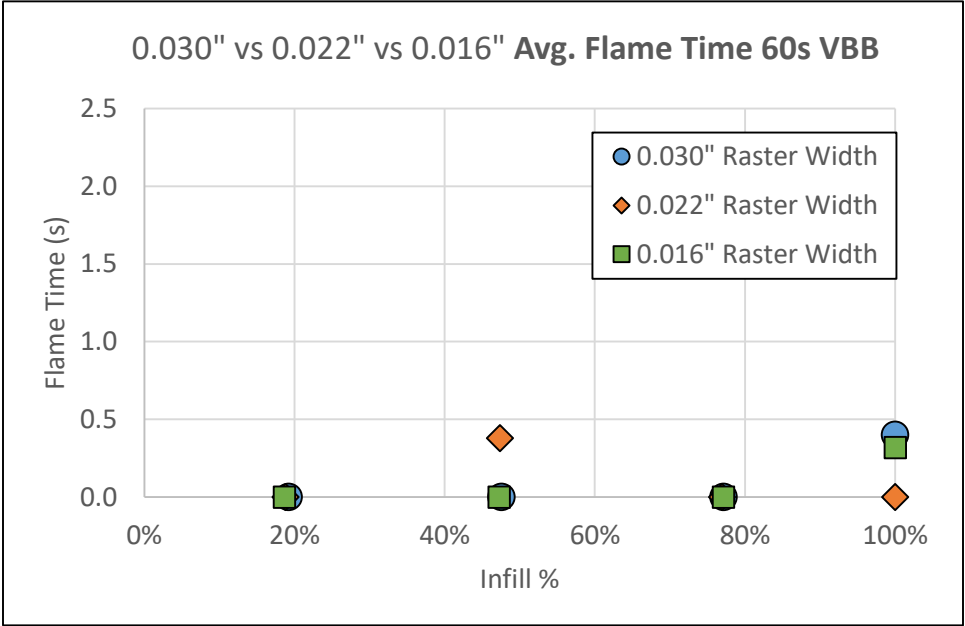
Burn Length



Raster Width Tests

60s VBB

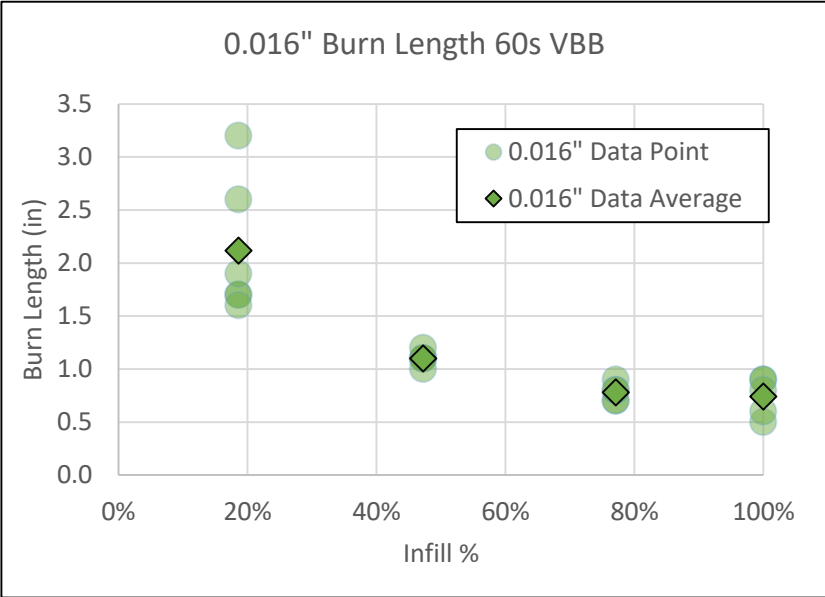
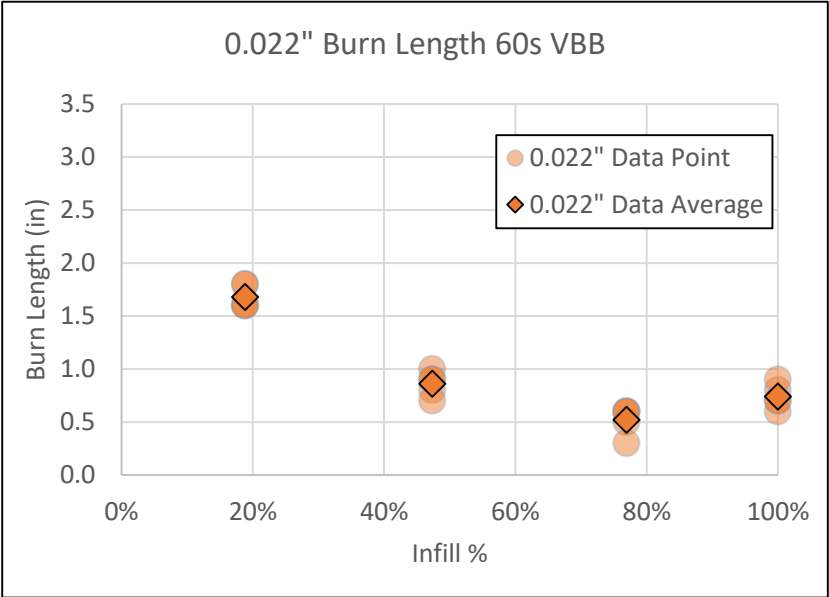
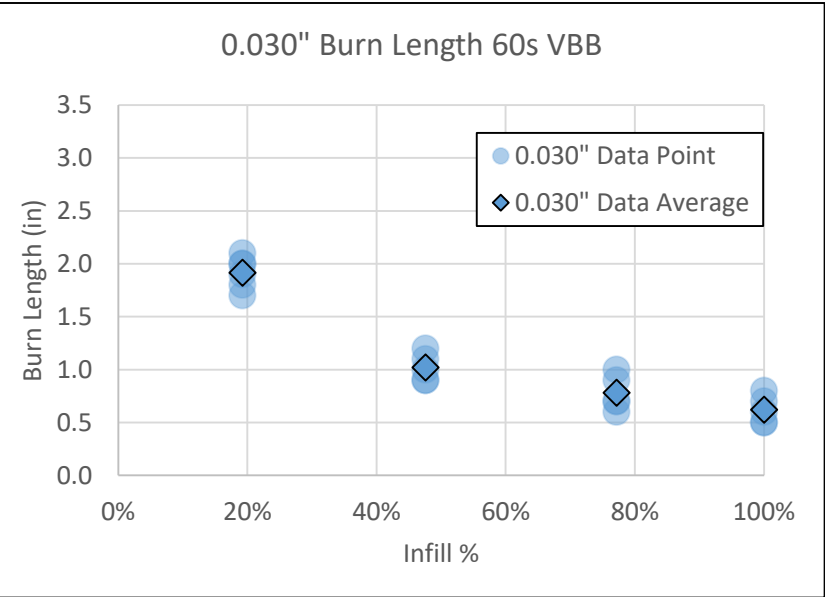
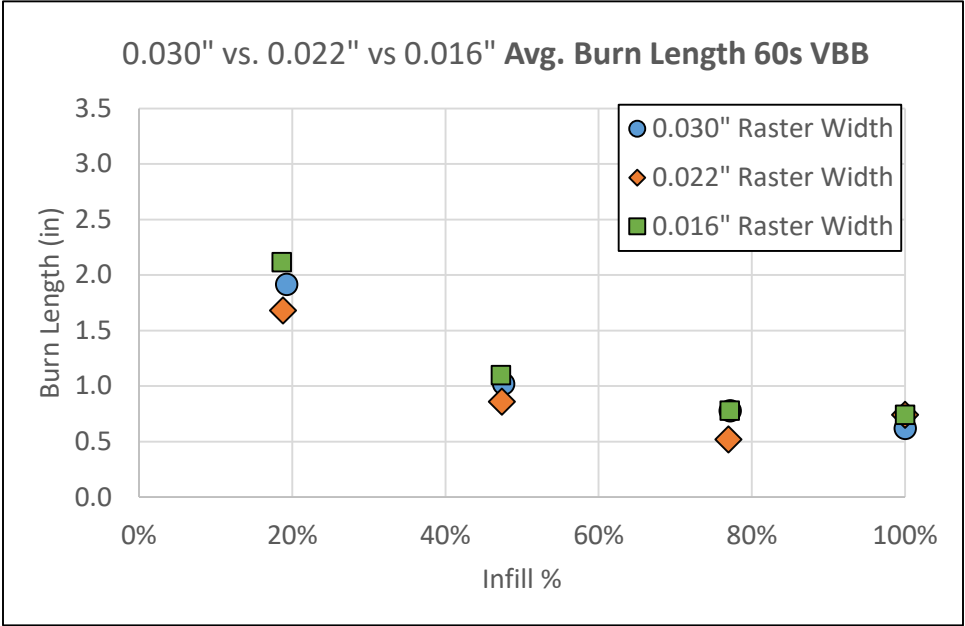
Flame Time



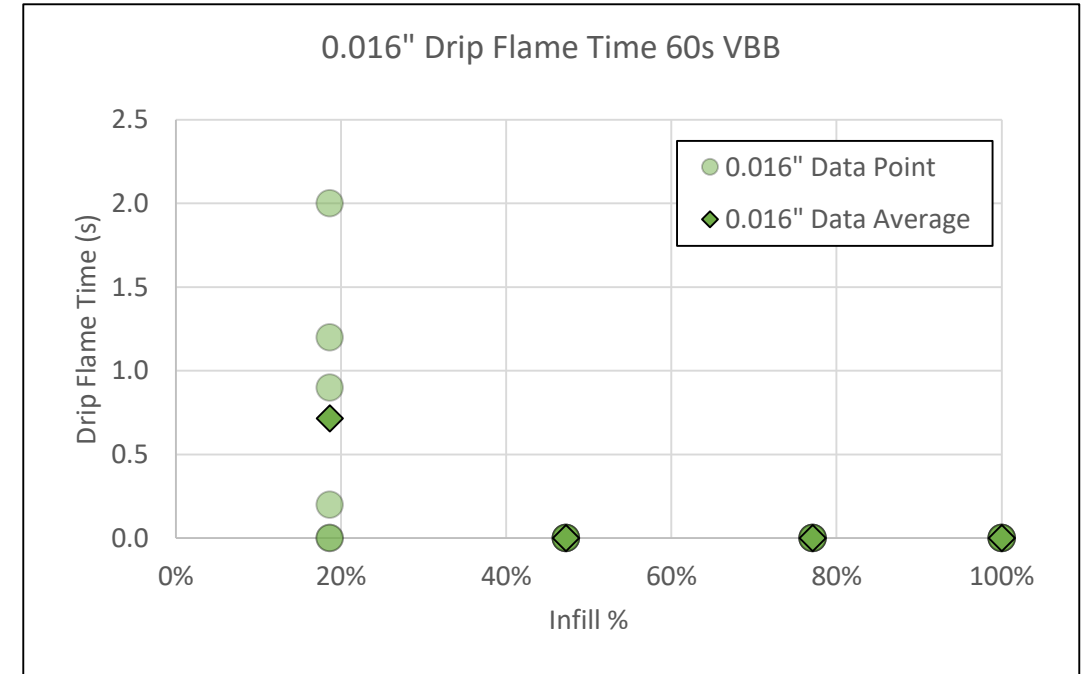
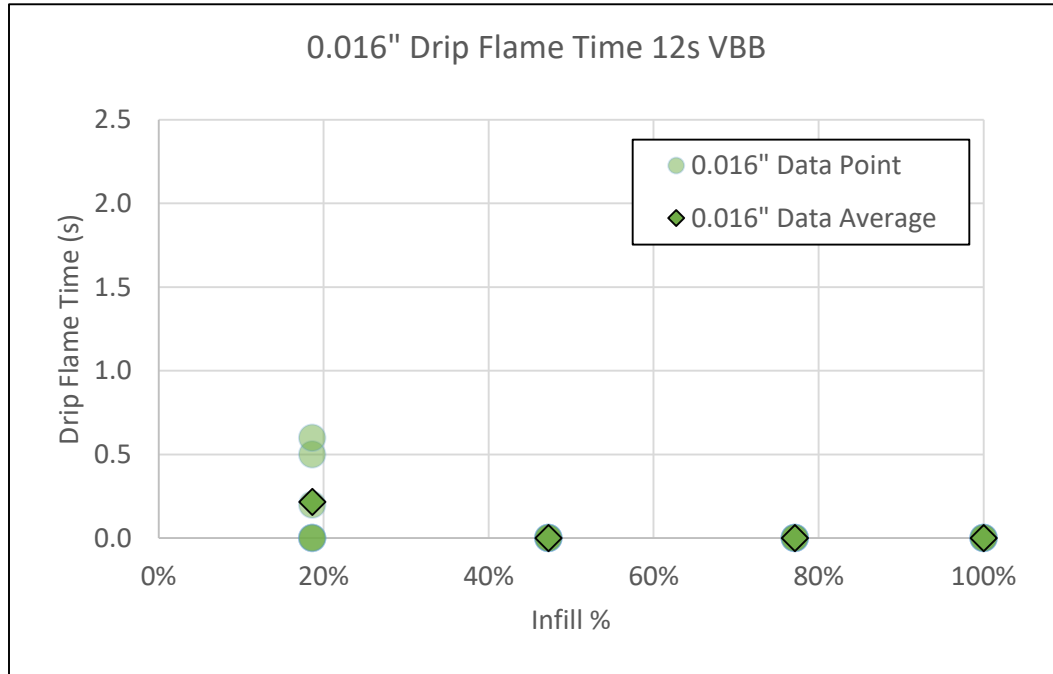
Raster Width Tests

60s VBB

Burn Length



Raster Width Drip Flame Time



* 0.030" and 0.022" samples did not have any material drip at any point

Ultem 1010 Tests

- 0.06 inch sample thickness
- 0.010 inch layer thickness
- 45°/45° raster angle
- 0.022 inch raster width
- Infill only (no solid layers)
- Varied infill percentages
- Compared with Ultem 9085 data



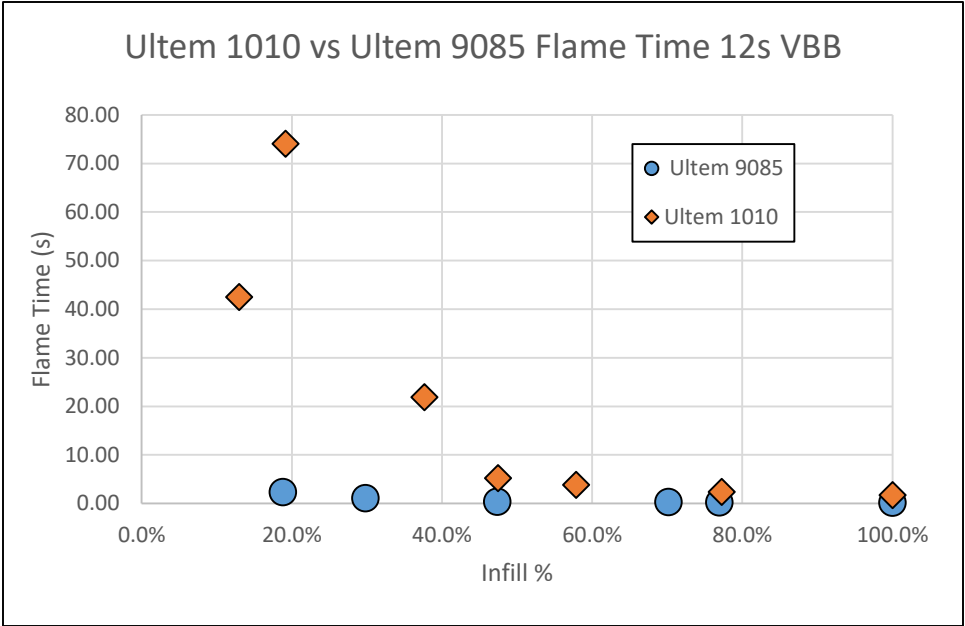
Ultem 9085

Ultem 1010

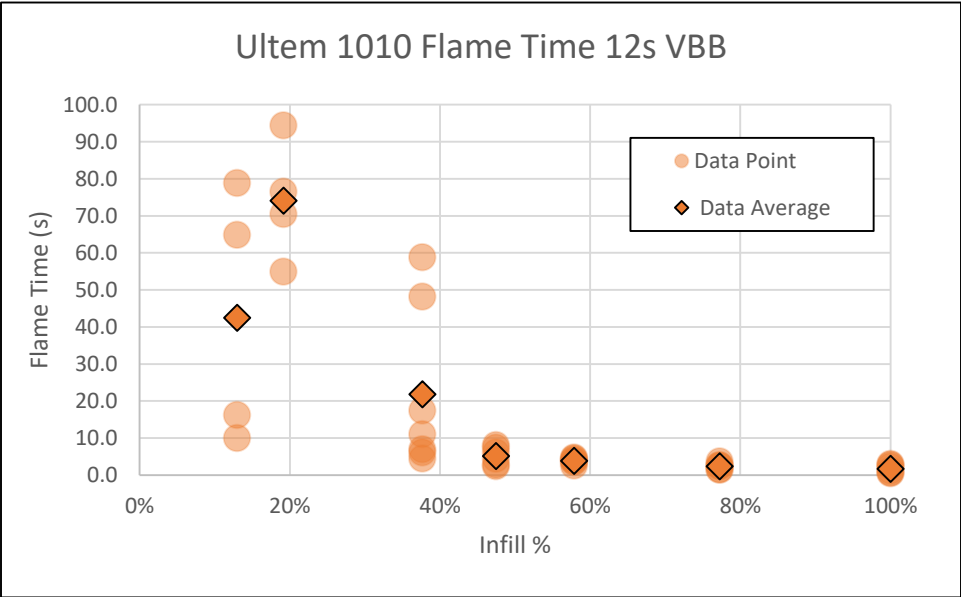
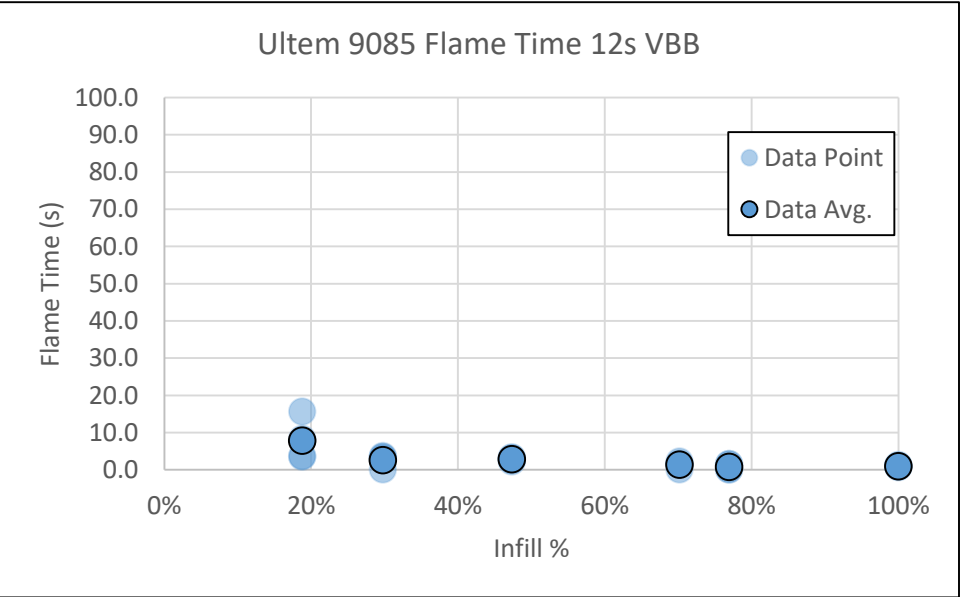
Ultem 1010 Tests

12s VBB

Flame Time



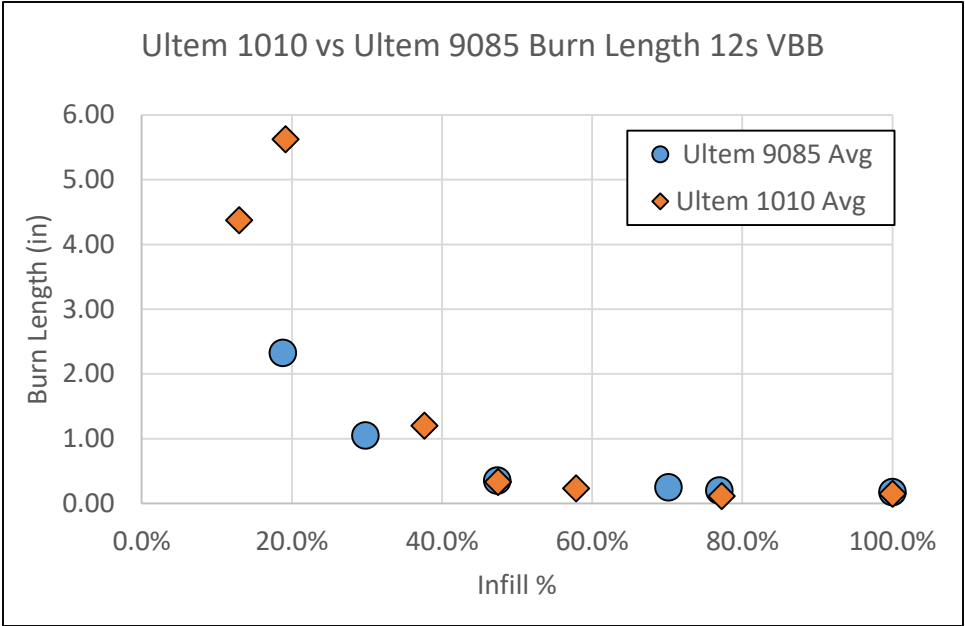
*Samples cut to 6 inch length



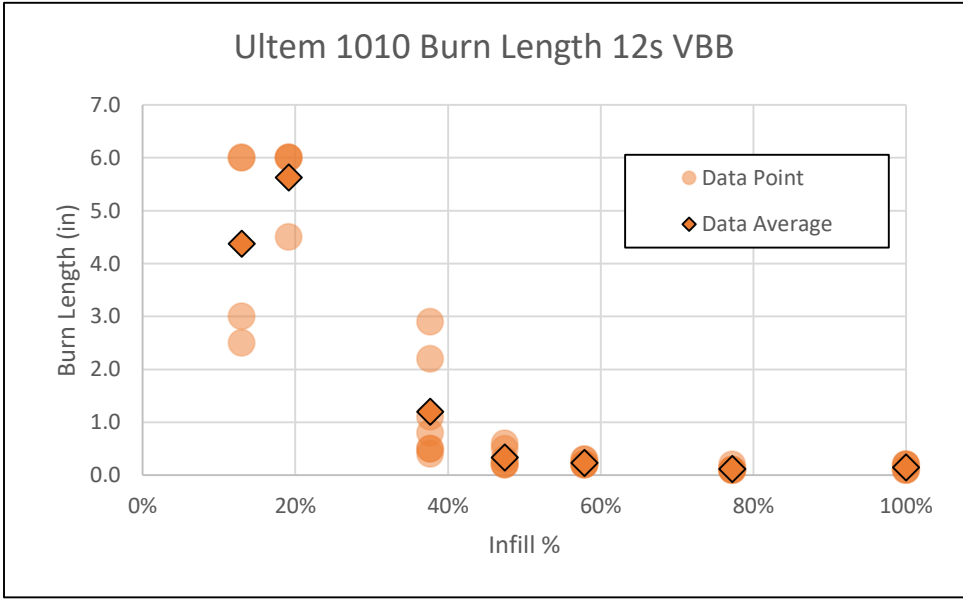
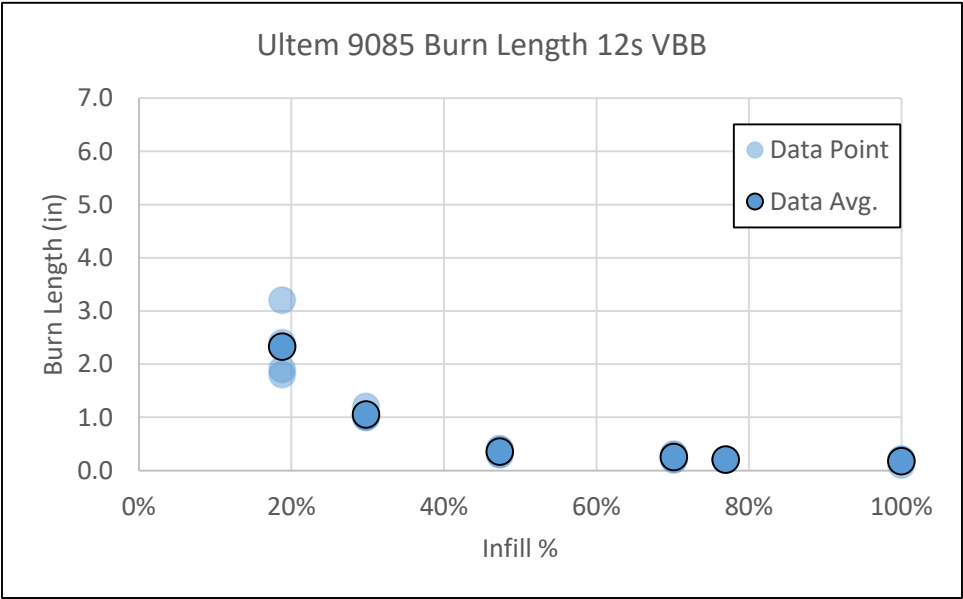
Utem 1010 Tests

12s VBB

Burn Length



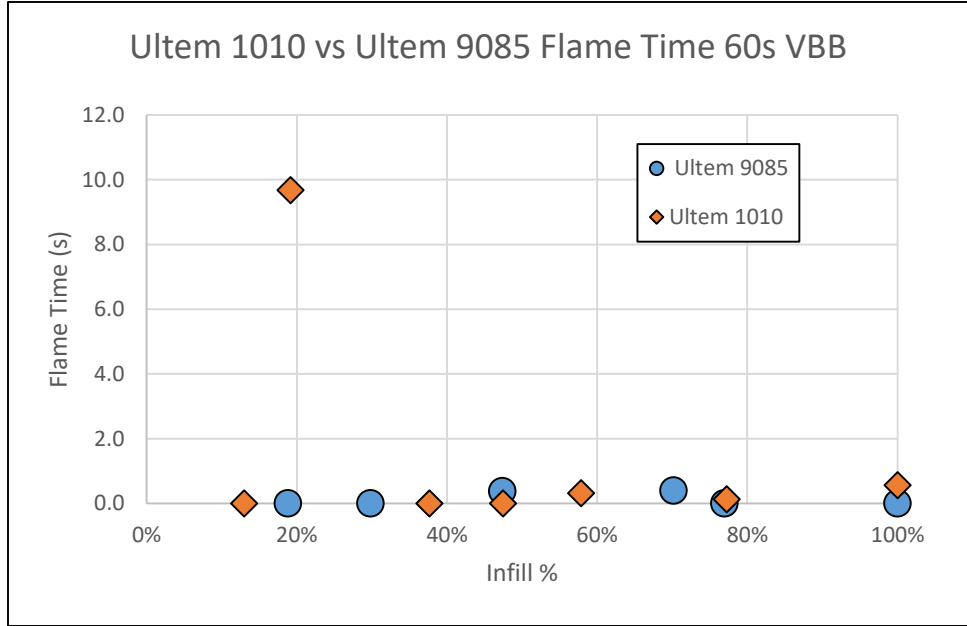
*Samples cut to 6 inch length



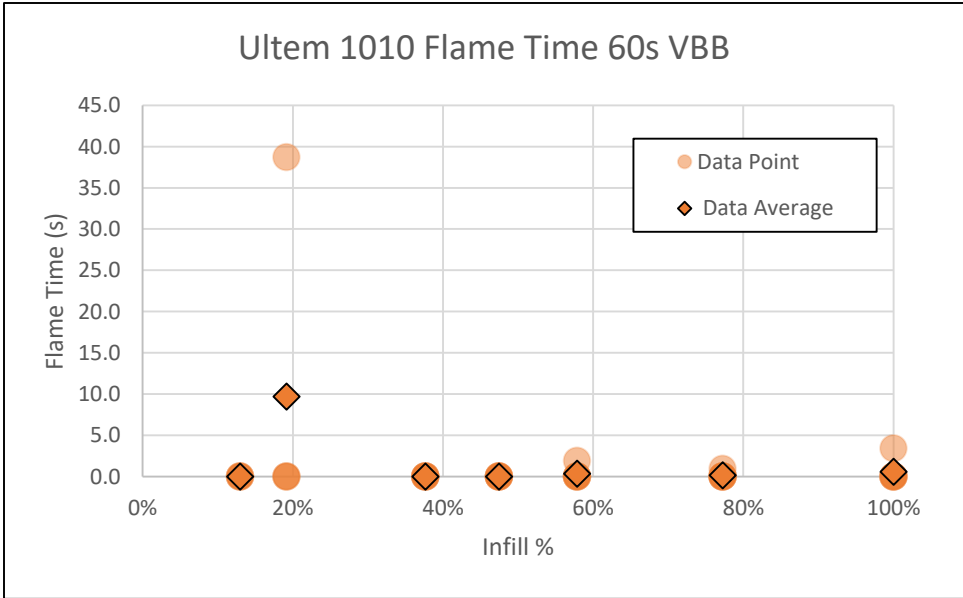
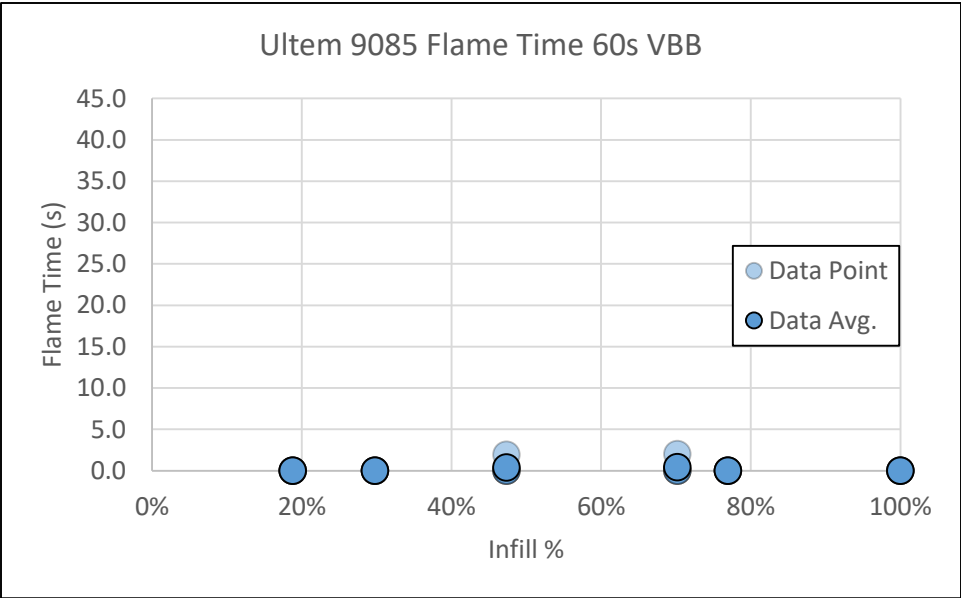
Ultem 1010 Tests

60s VBB

Flame Time



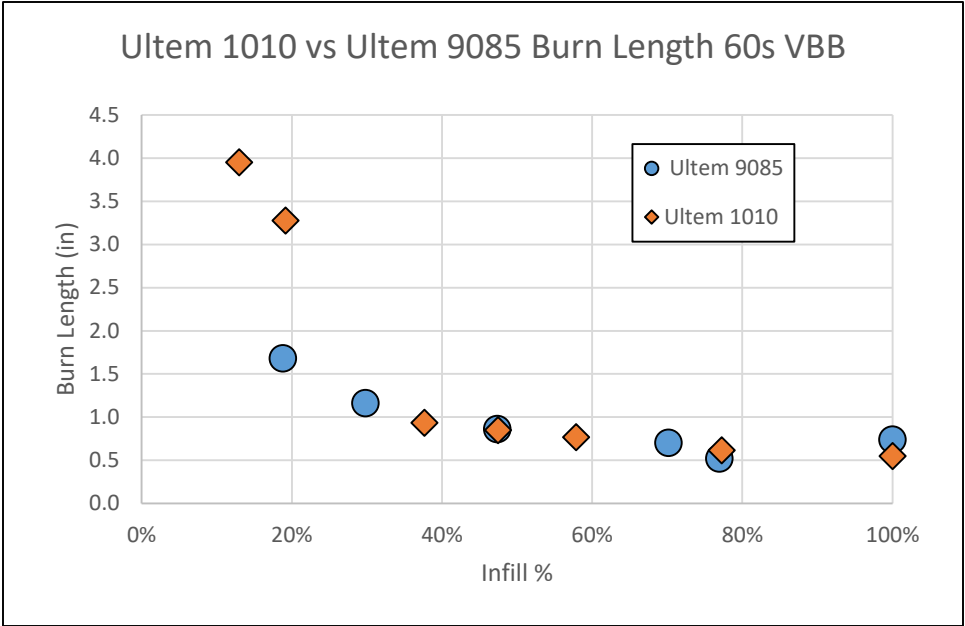
*Samples cut to 6 inch length



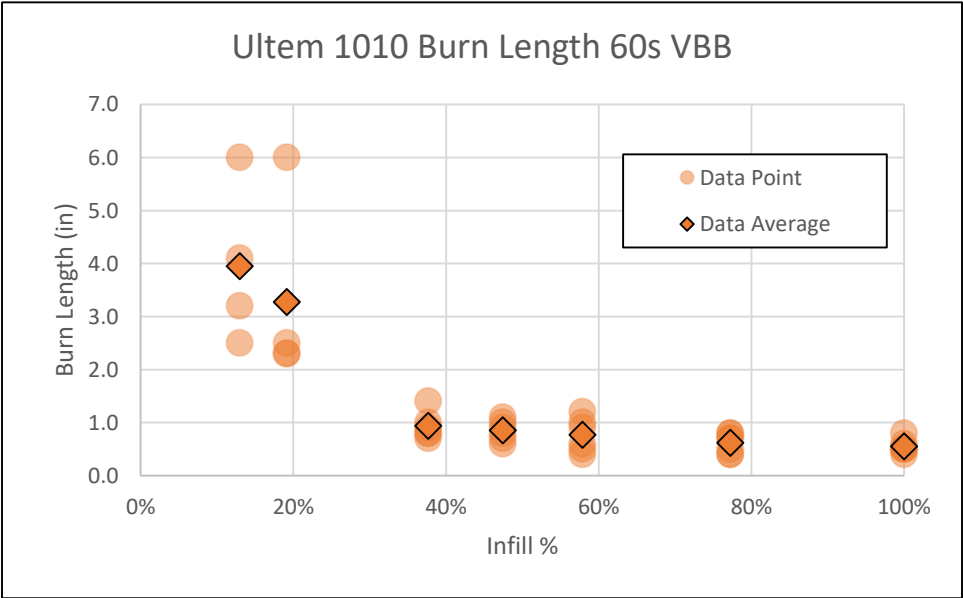
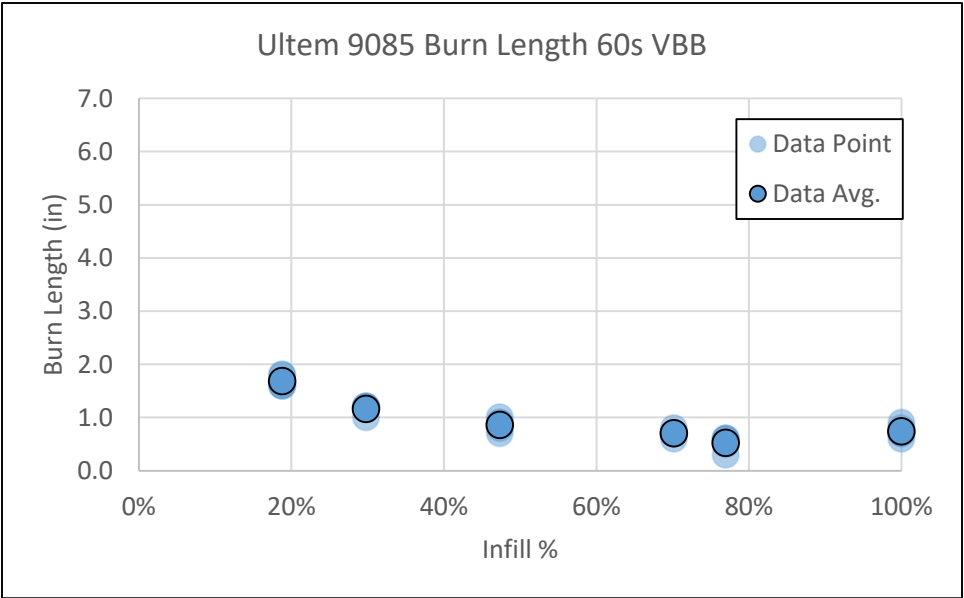
Ultem 1010 Tests

60s VBB

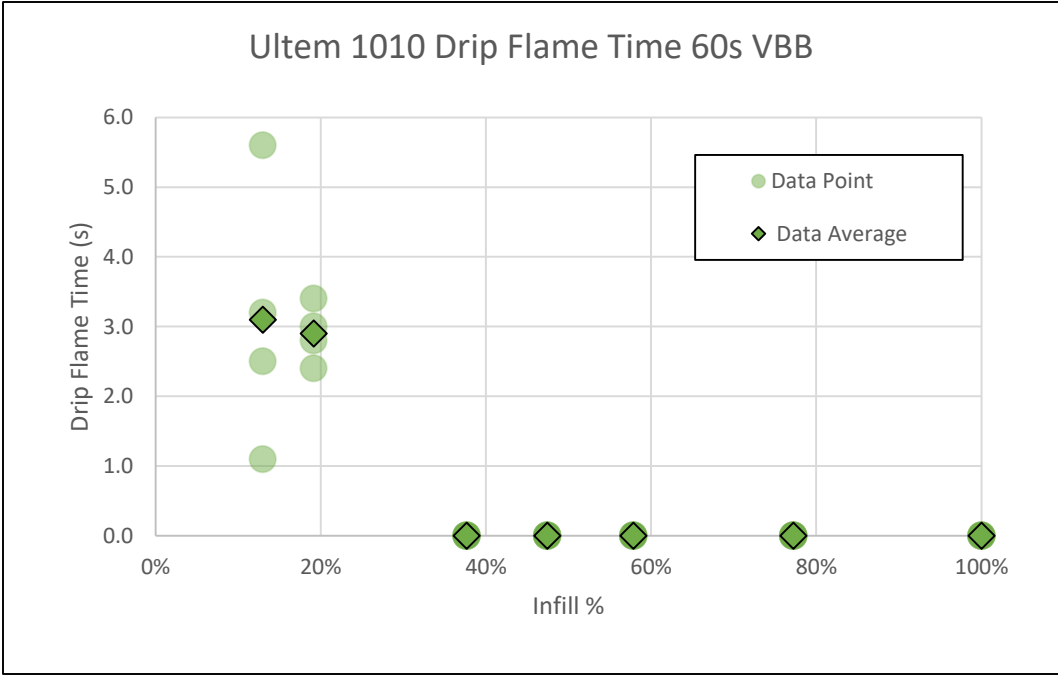
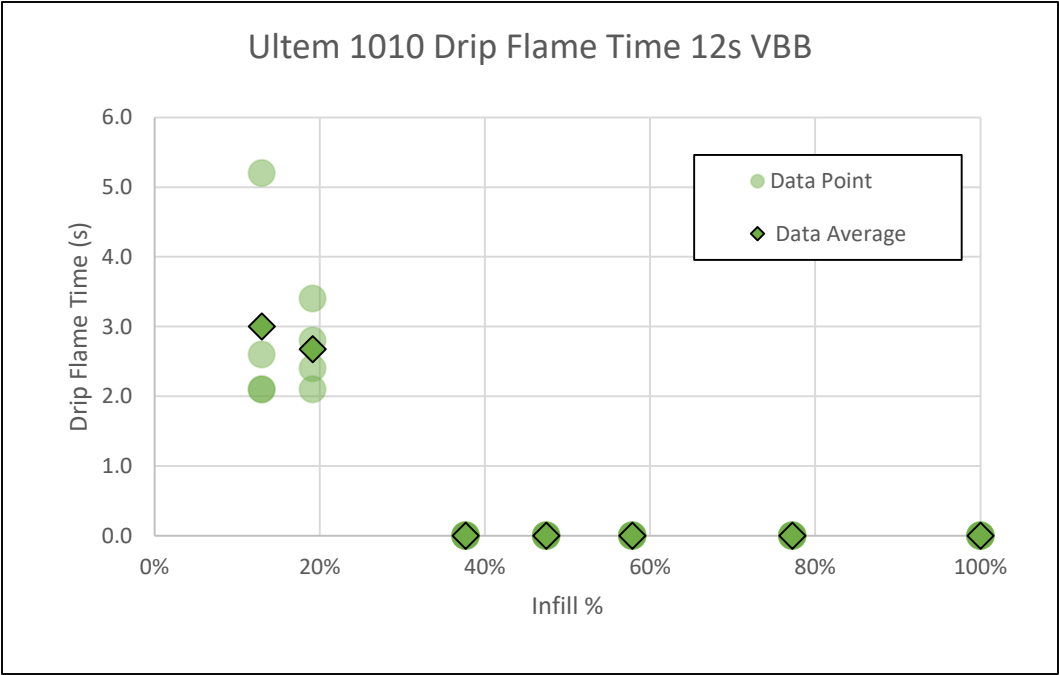
Burn Length



*Samples cut to 6 inch length



Ultem 1010 Drip Flame Time



Conclusion

- **For Ultem 9085:**
 - 90°/0° Raster angle performed worst, 45°/45° performed best, particularly with 60s burn length
 - 0.016 inch Raster width performed worst, particularly with drip flame time
- **For Ultem 1010:**
 - Performed worse than Ultem 9085 (as expected), especially at lower infill percentages
 - Could make good candidate for further testing

Future Work

- **Repeat raster angle and raster width tests with Ultem 1010 material**
- **Conduct similar tests with Ultem Support material (PES) varying raster angle and raster width**
- **Continue to add to the Additive Manufacturing Vertical Bunsen Burner AC started before the June 2020 meeting**

Questions?

Contact:

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