Influence of Printing Parameters on the Flammability Behaviour of 3D Printed Polyetherimide

Ninth Triennial International Aircraft Fire and Cabin Safety Research Conference, October 30th, 2019

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Agenda

- Outline
- Printing technology, materials and parameters
- Parameter variation and test procedure
- Results
- Discussion
- Summary

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Outline

- 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

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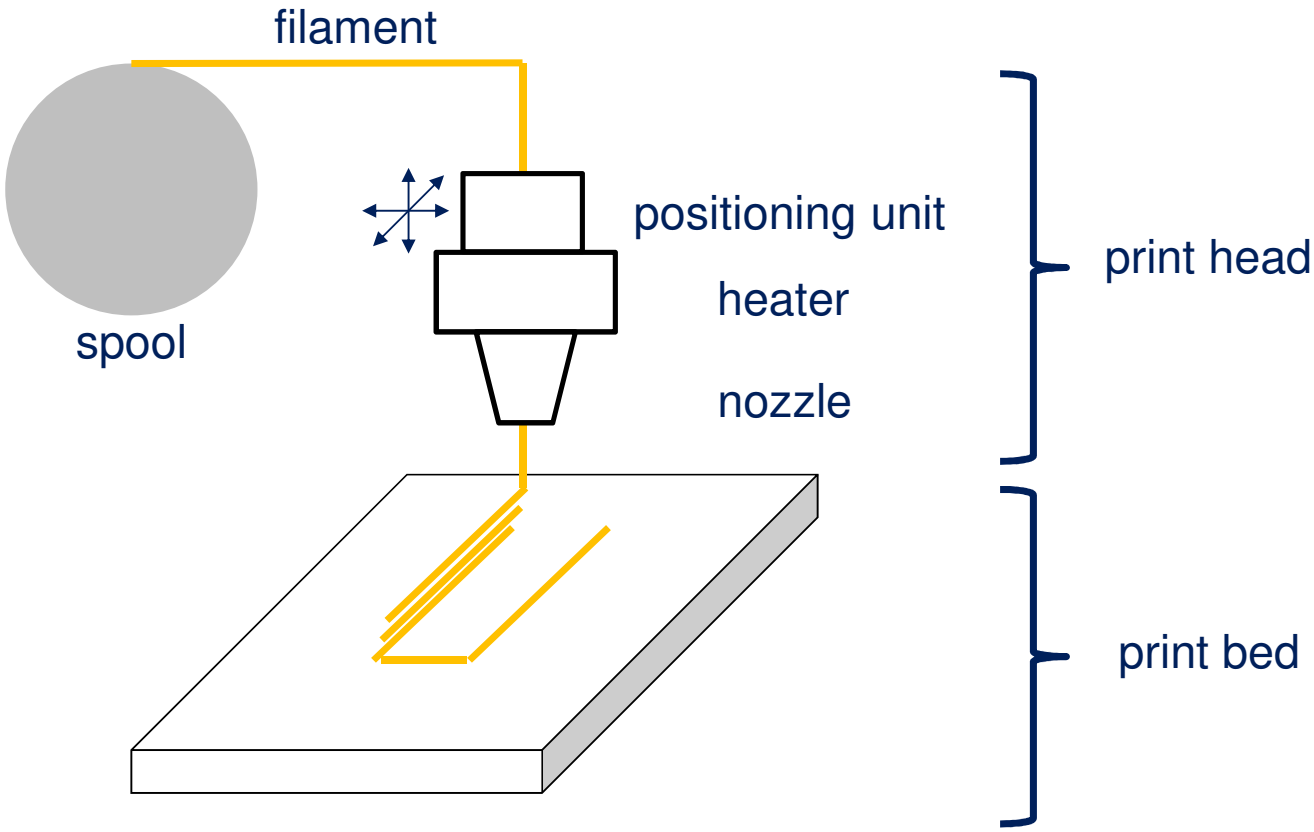
Printing technology, materials and parameters

Fused Deposition Modelling

Printer	Fortus 450mc & 900mc by Stratasys
Location	Stratasys, Eden Prairie Airbus, Hamburg
Material	Polyetherimide ULTEM 9085 by Sabic Certified Grade filaments by Stratasys
Build	6 layers, 0.254 mm per filament → 1.5 mm thickness Always: Seam of 1 filament with full infill



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Printing technology, materials and parameters

Part design

- "Replica" of conventional part
- Bio-inspired (bone-like) complex structures

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

Build

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

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

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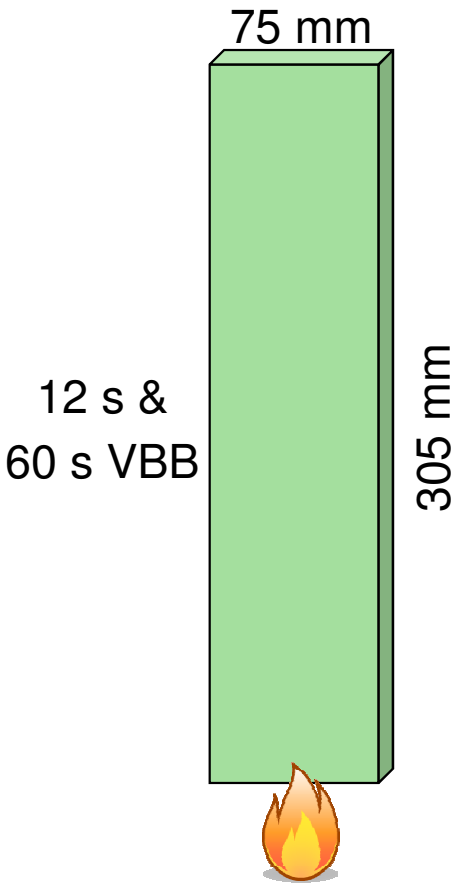
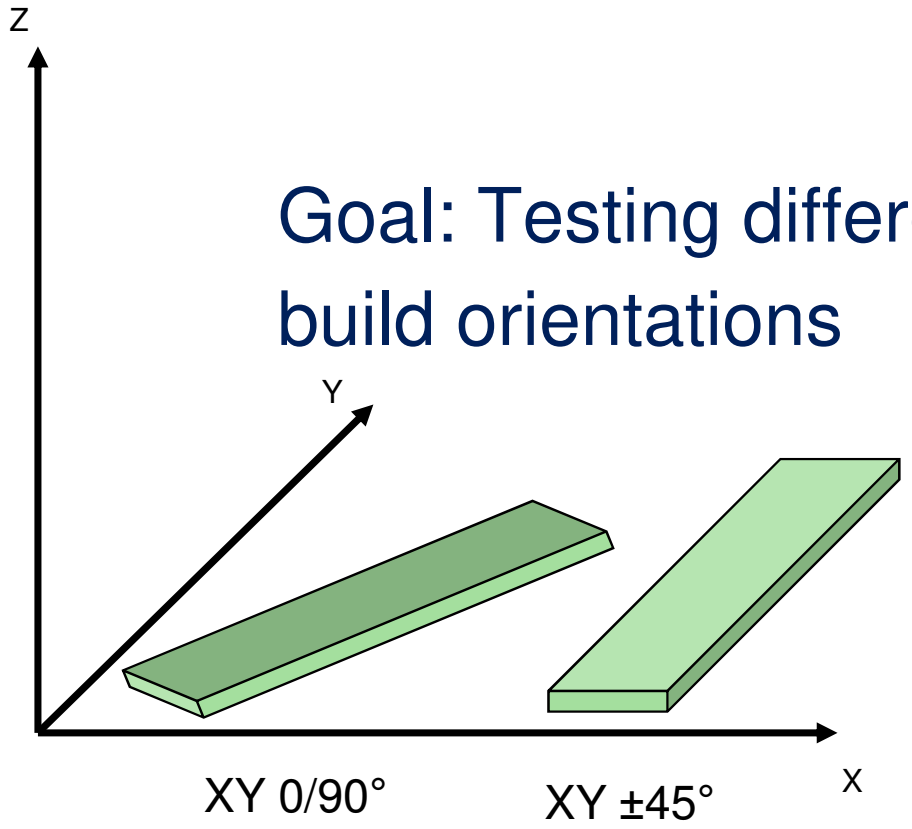
Parameter variation and test procedure: orientation





Goal: Testing different build orientations

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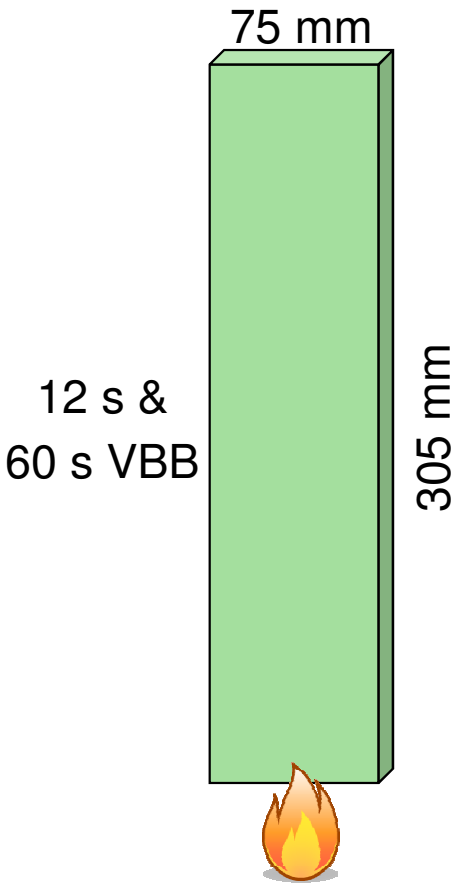
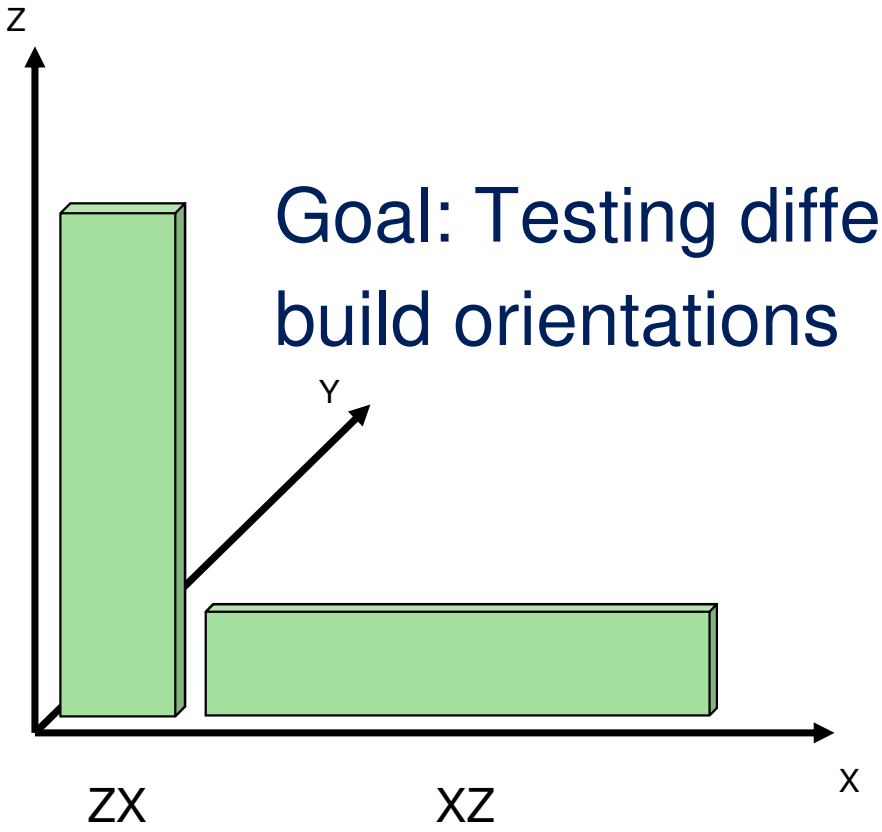
Parameter variation and test procedure: orientation





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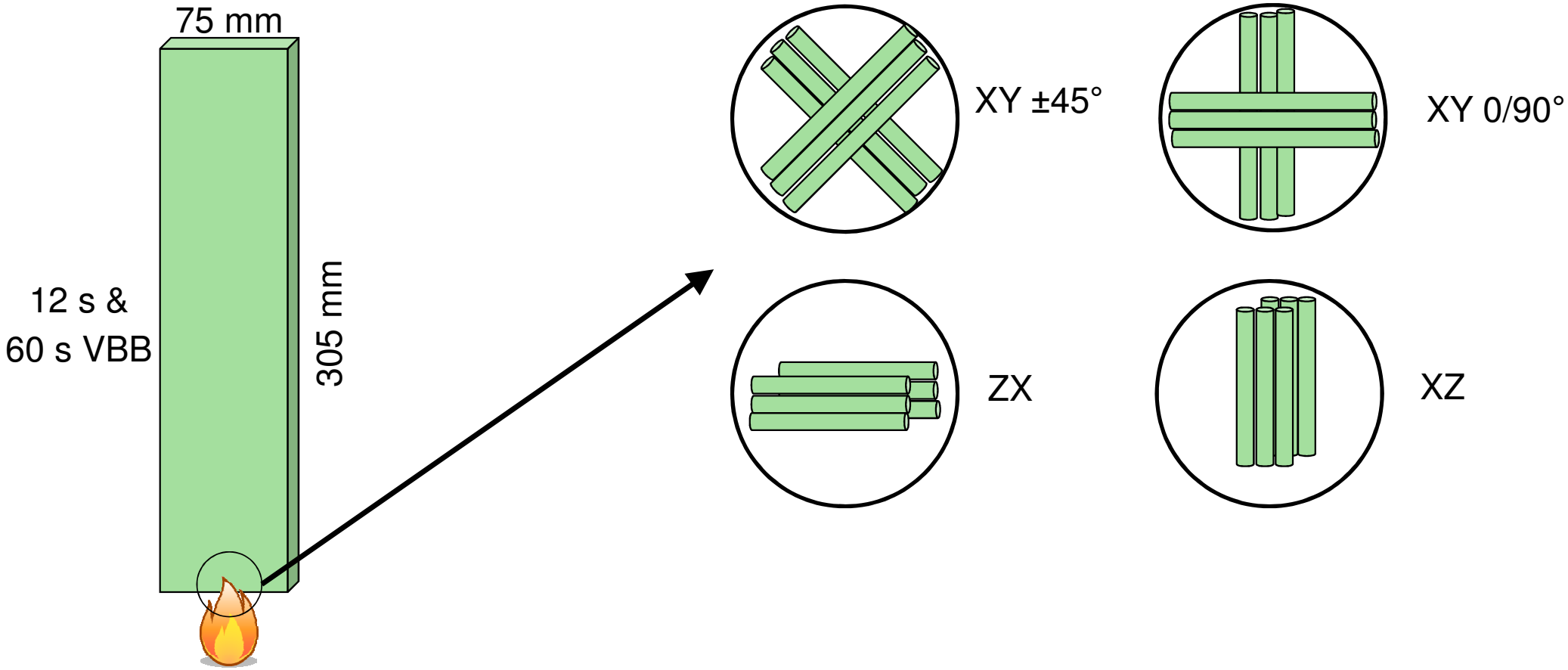

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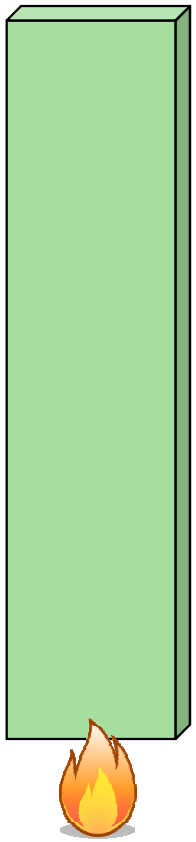
Parameter variation and test procedure: infill



Goal: Reduce amount of material whilst mainting the outer shape

Means: Vary the distance of filaments to each other

Infill: Ratio of coupon weight vs. weight of densest packed coupon, normalised by thickness

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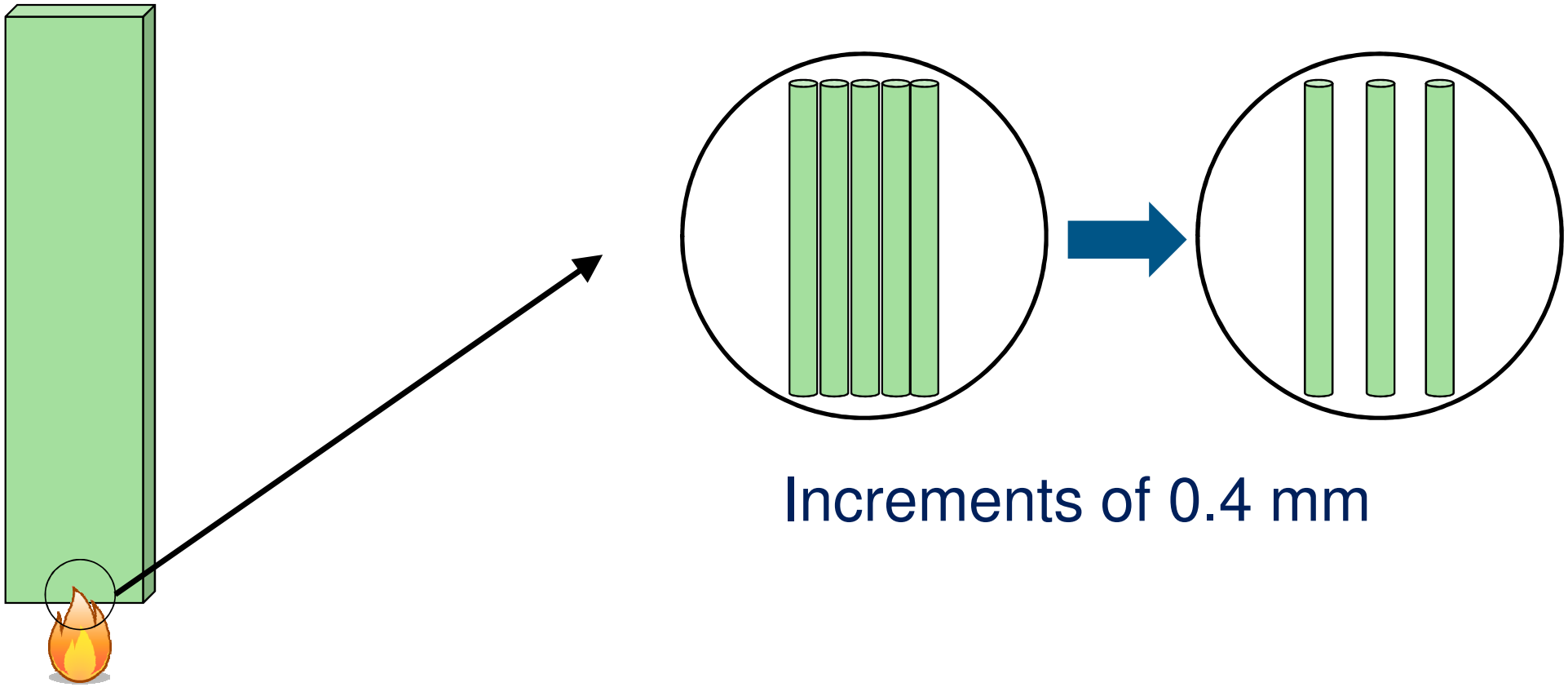
Parameter variation and test procedure: infill



Increments of 0.4 mm

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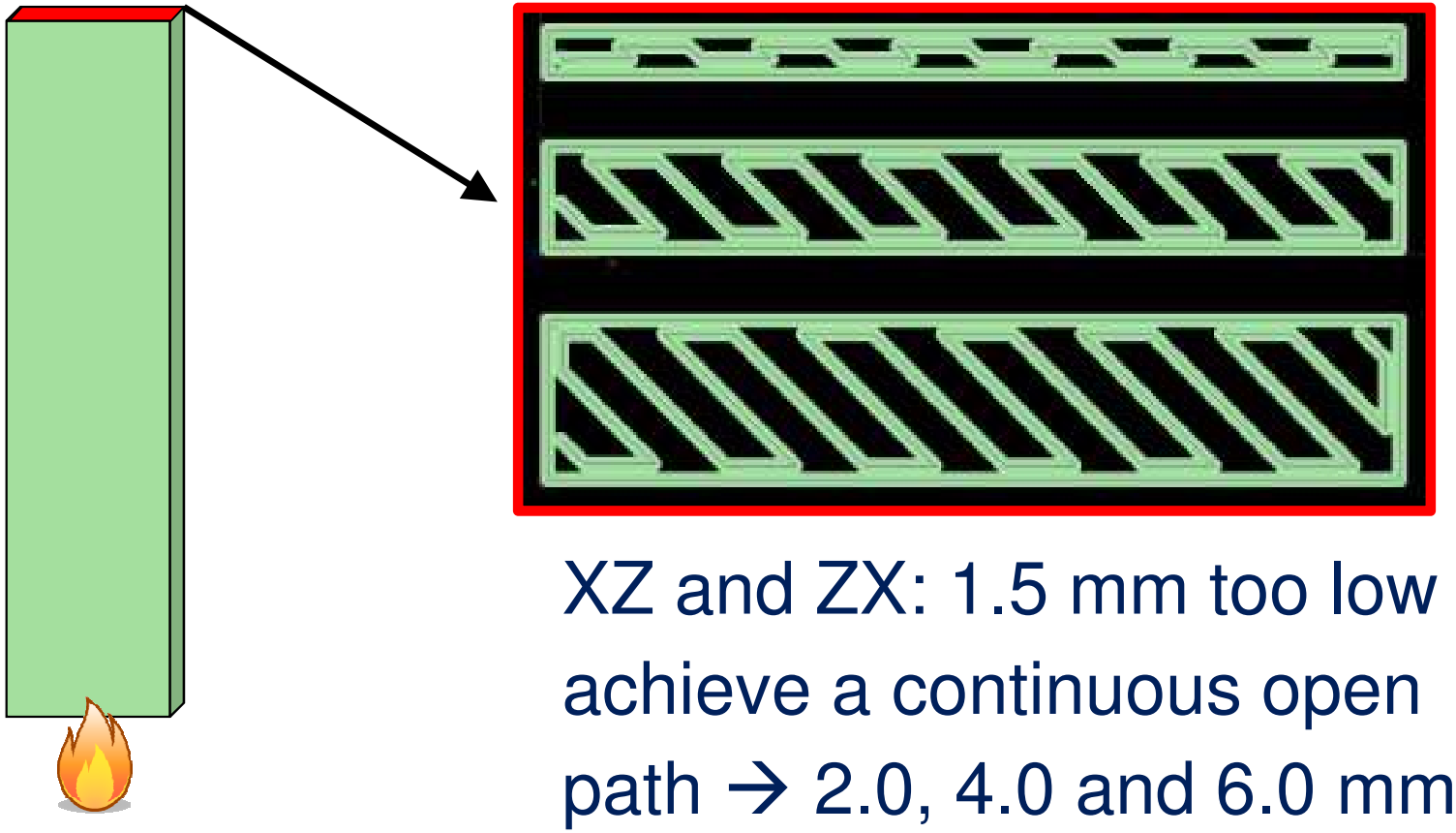
Parameter variation and test procedure: infill



XZ and ZX: 1.5 mm too low to achieve a continuous open path → 2.0, 4.0 and 6.0 mm

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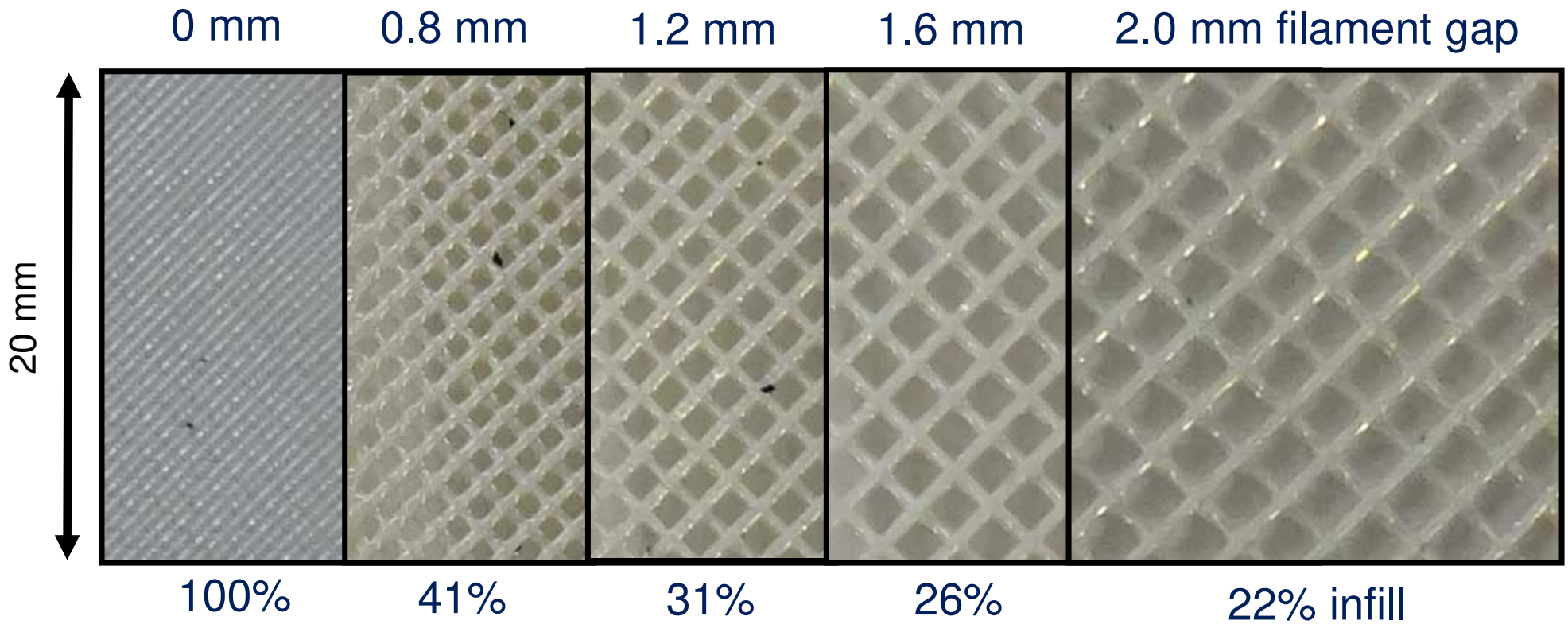
Parameter variation and test procedure: infill



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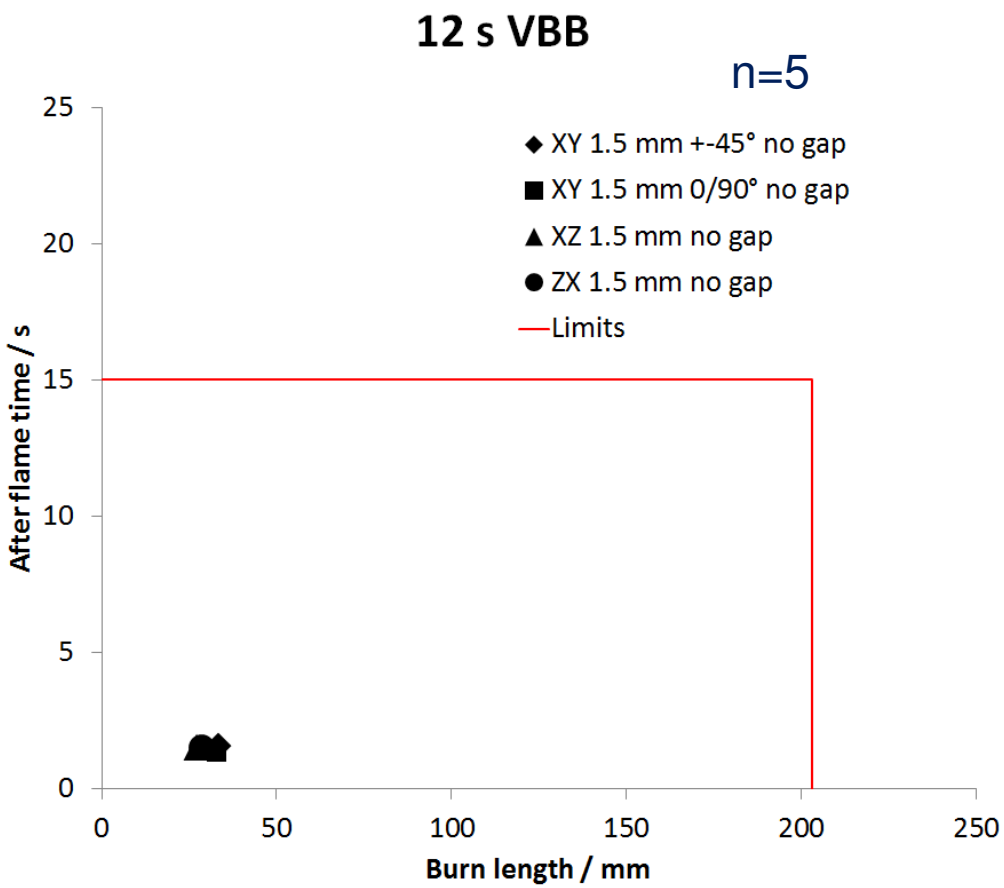
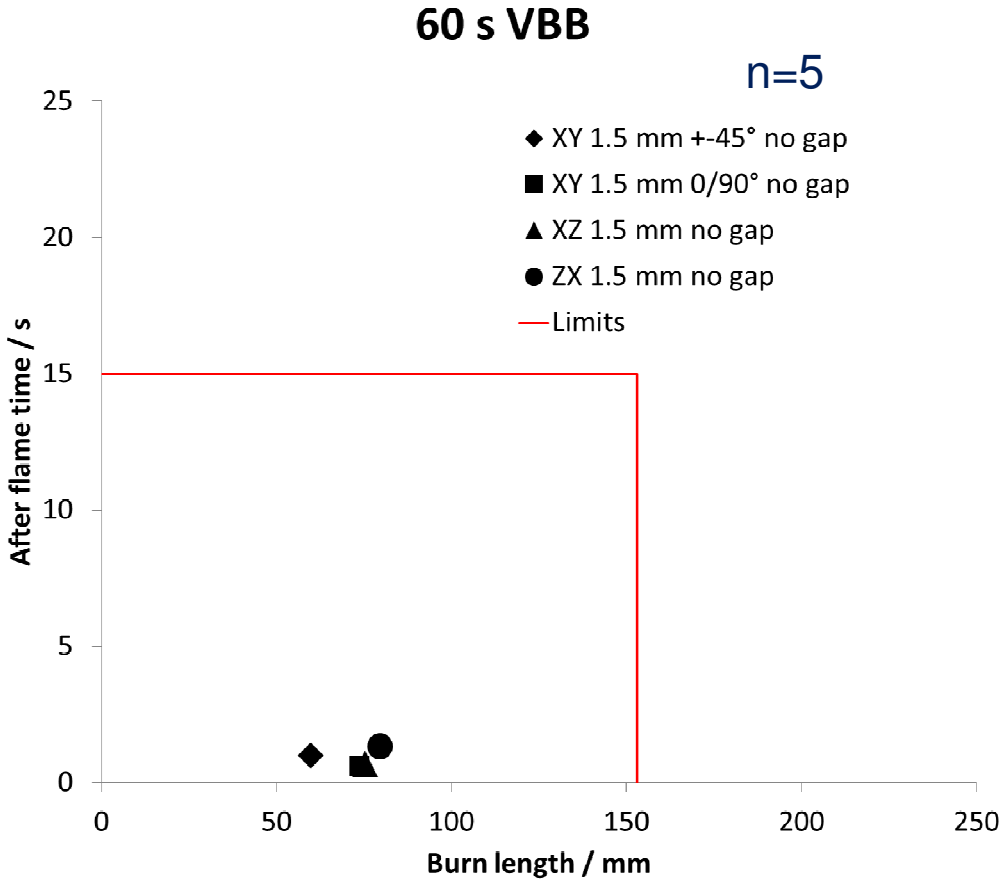
Results: 100% infill, influence of orientation





→ No influence of orientation for densest packing

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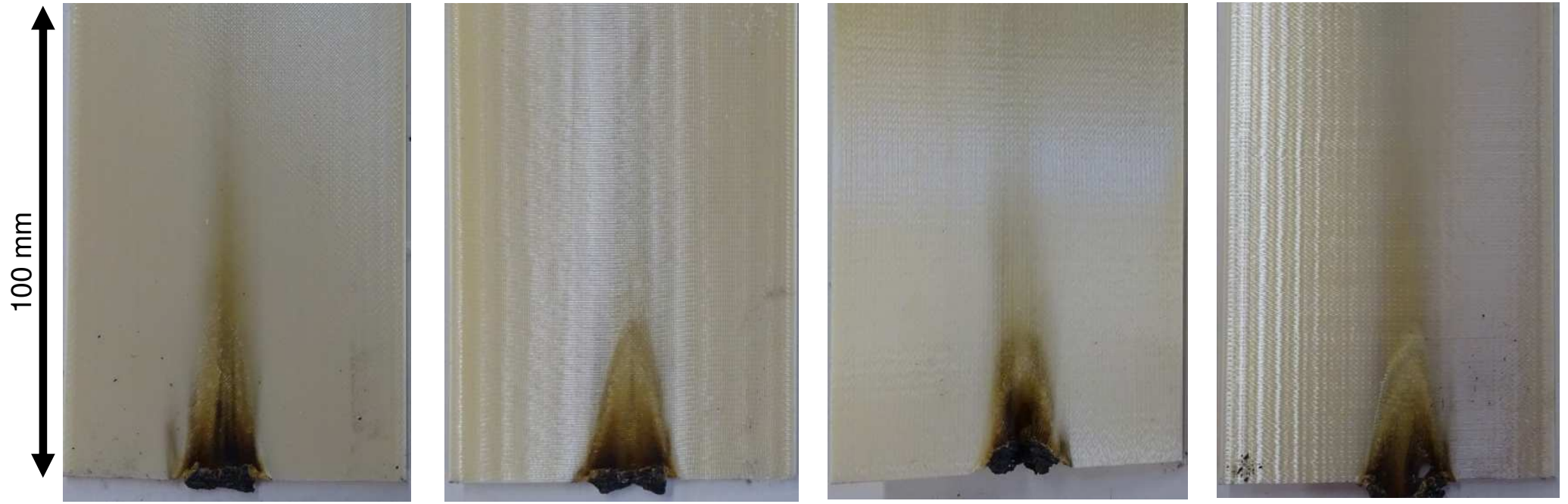
Results: 100% infill, influence of orientation

12 s VBB



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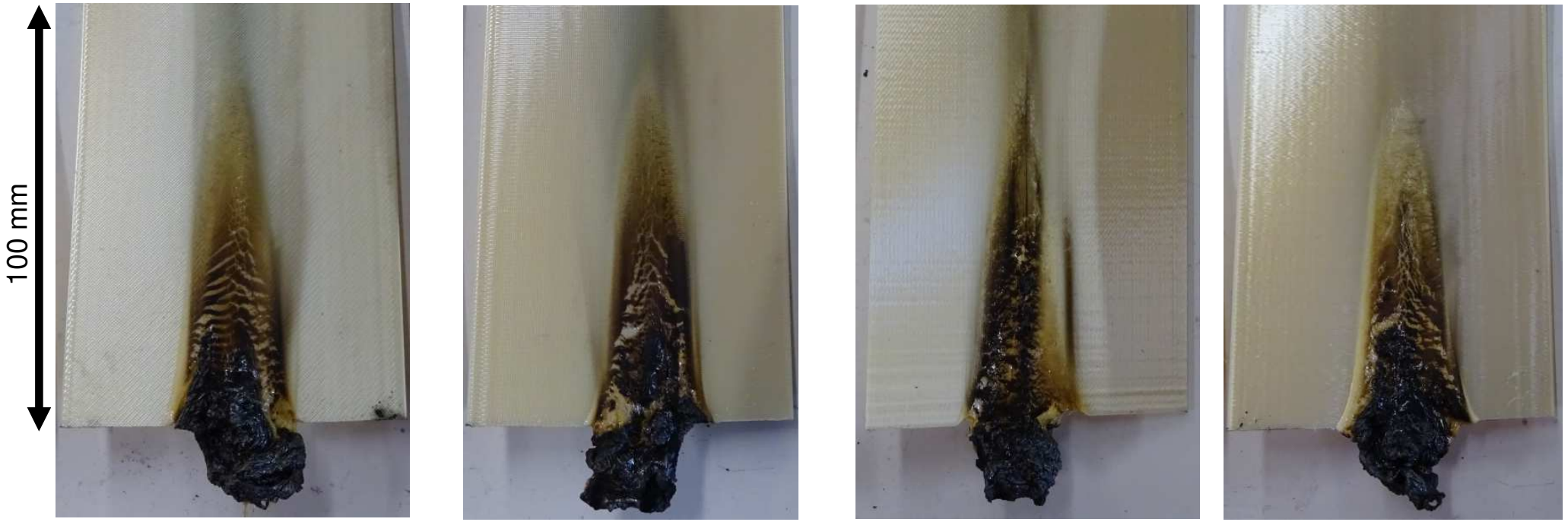
Results: 100% infill, influence of orientation

60 s VBB



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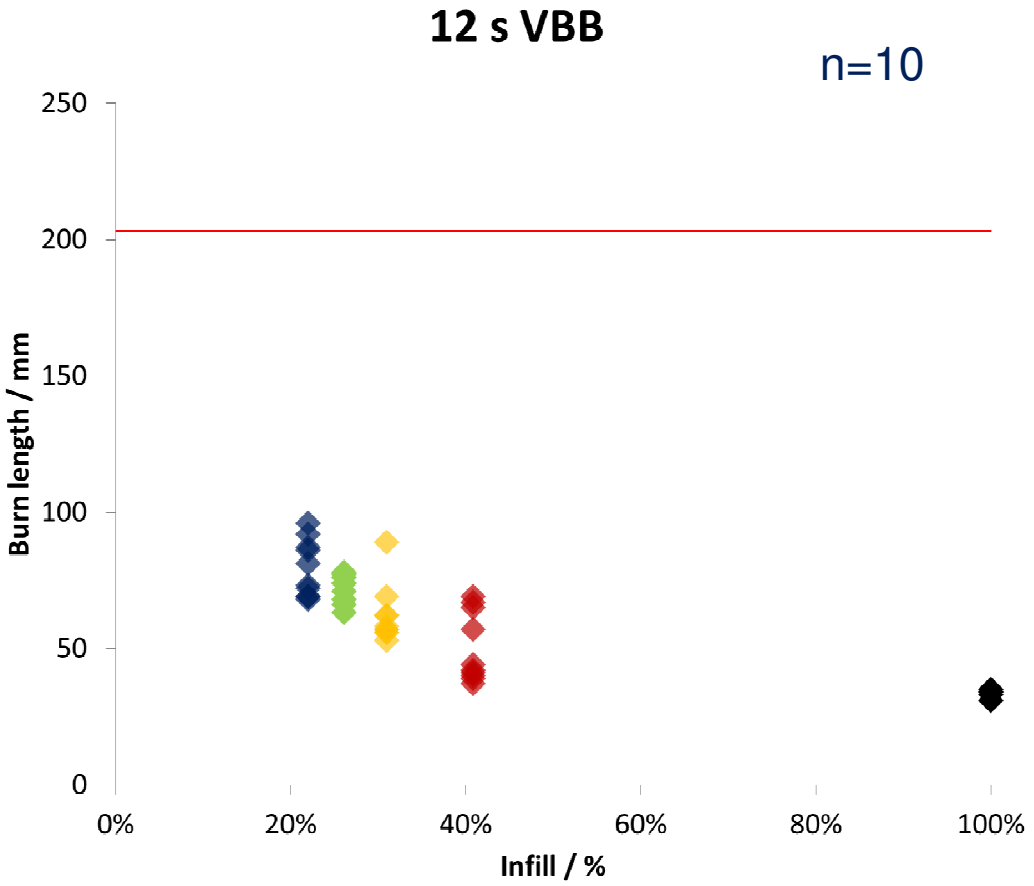
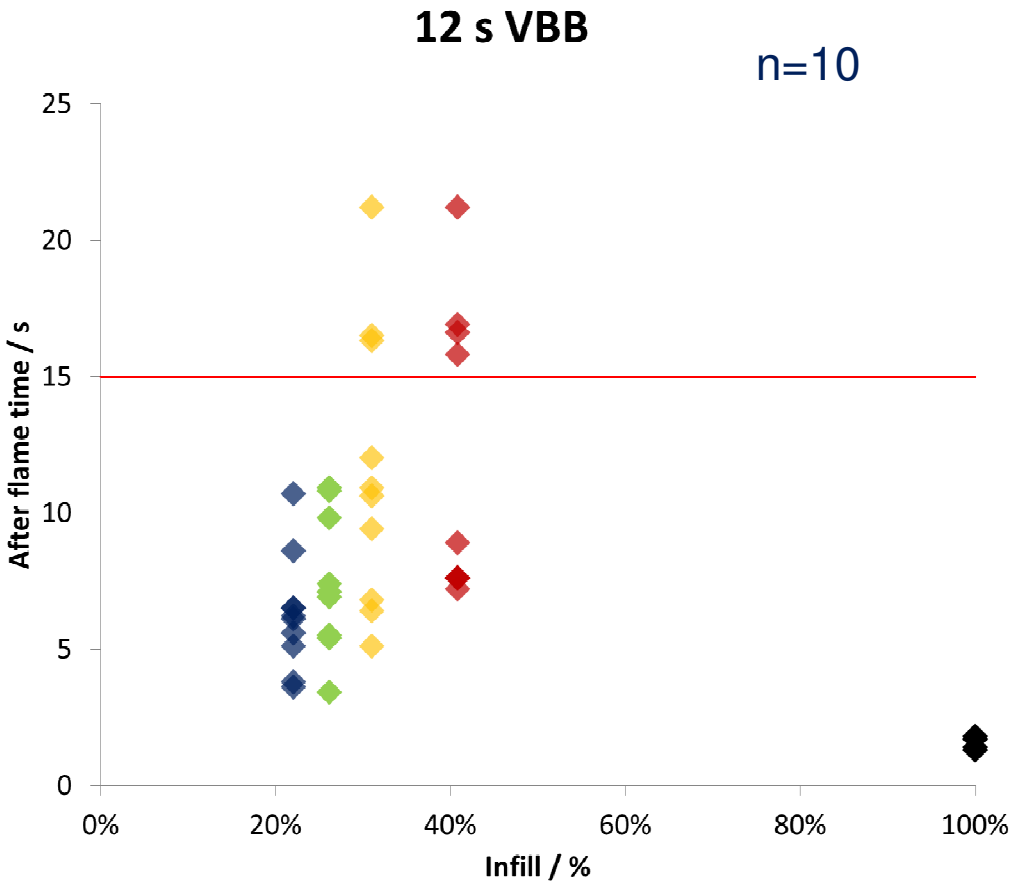
Results: XY ±45°, variation of infill





→ Lower infill = higher burn length and after flame

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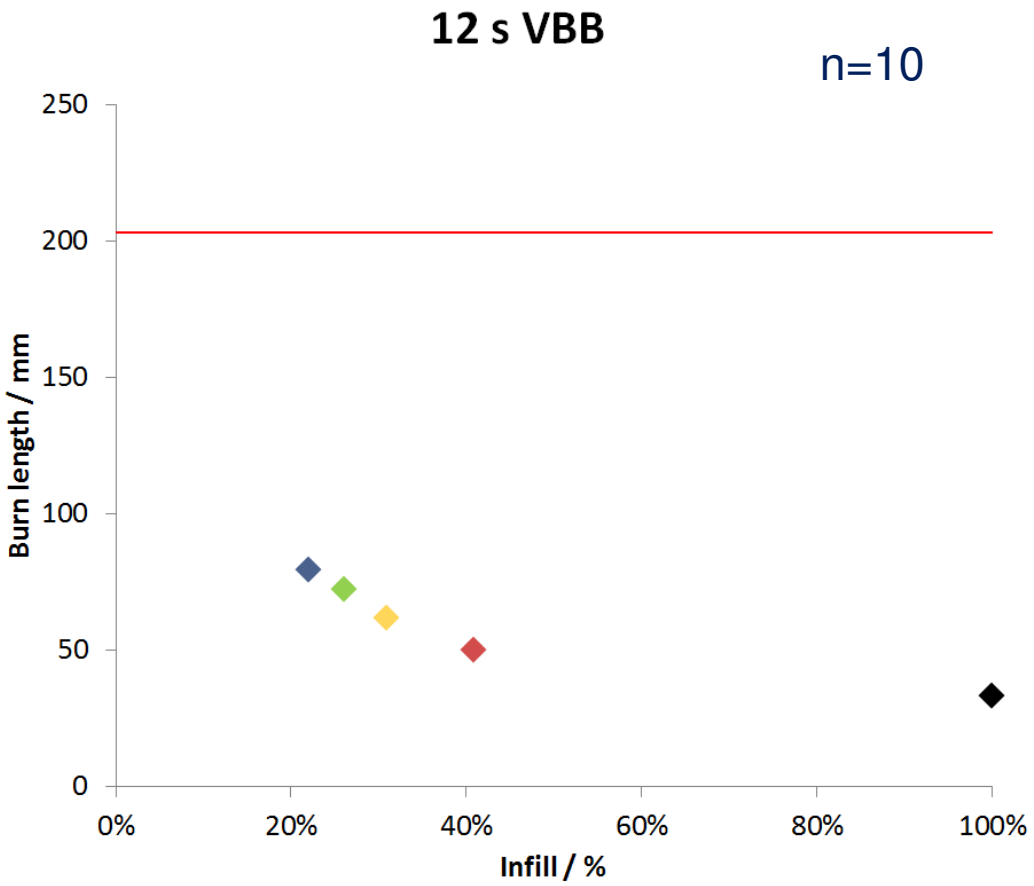

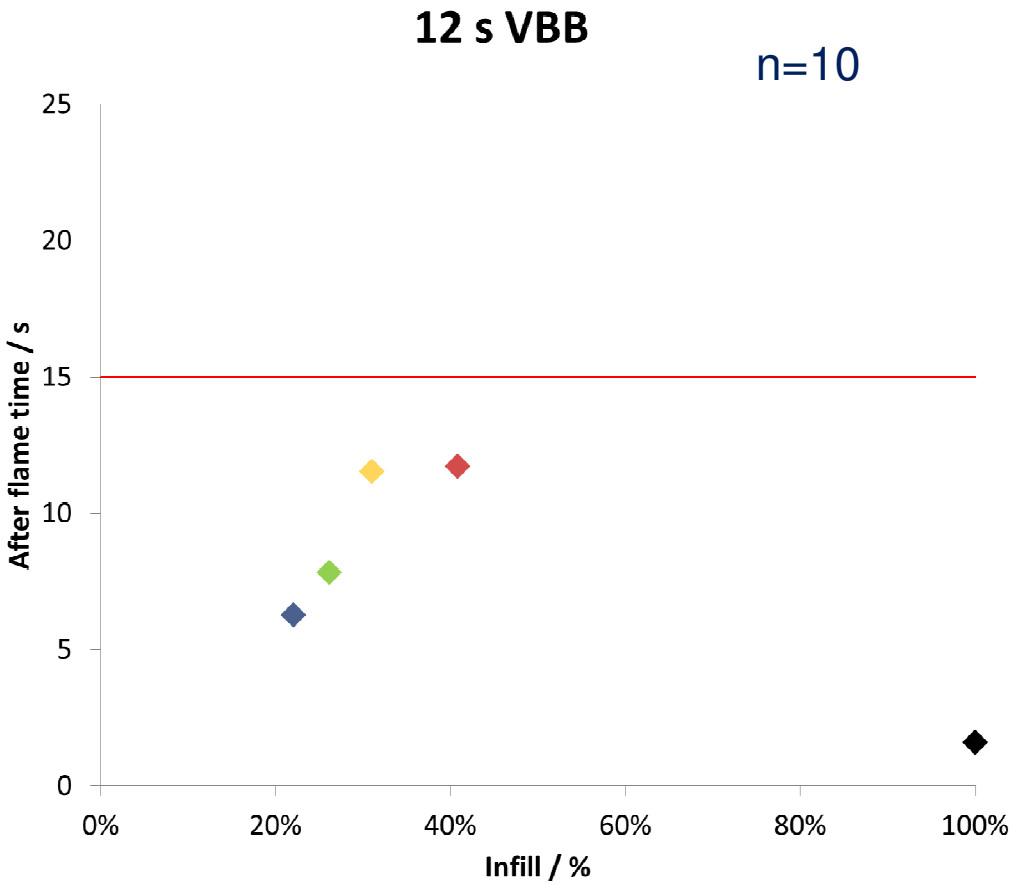

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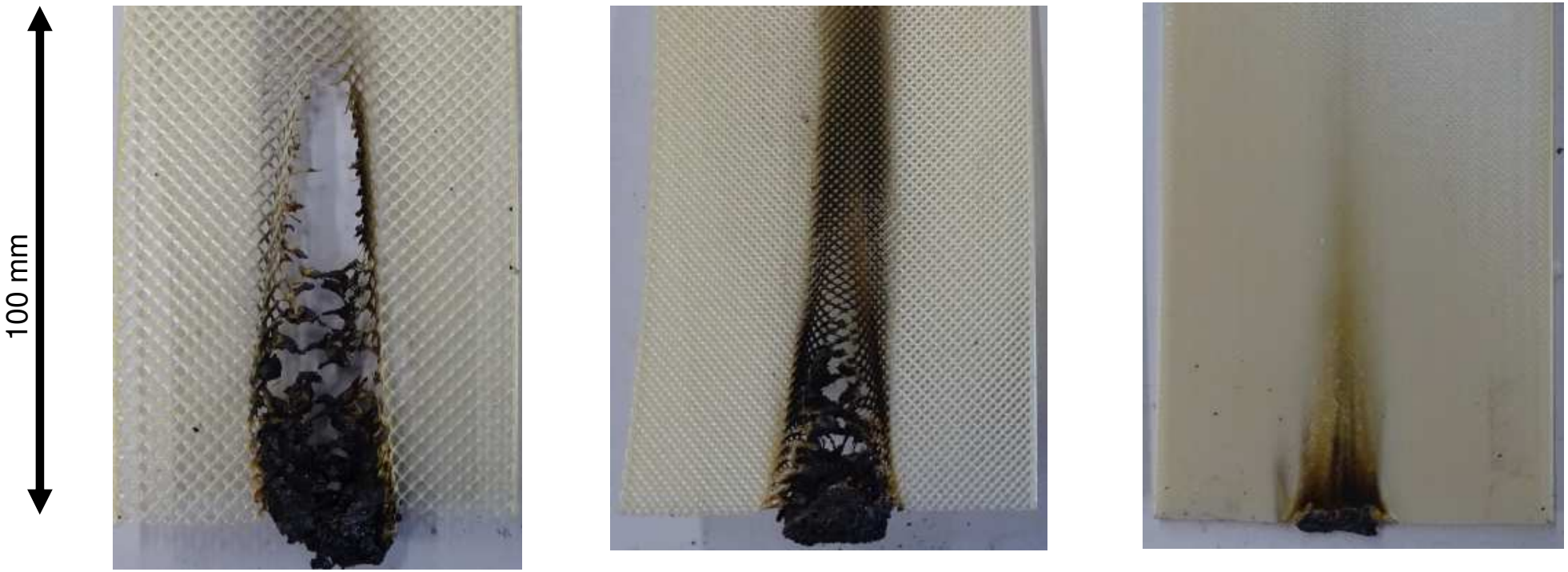

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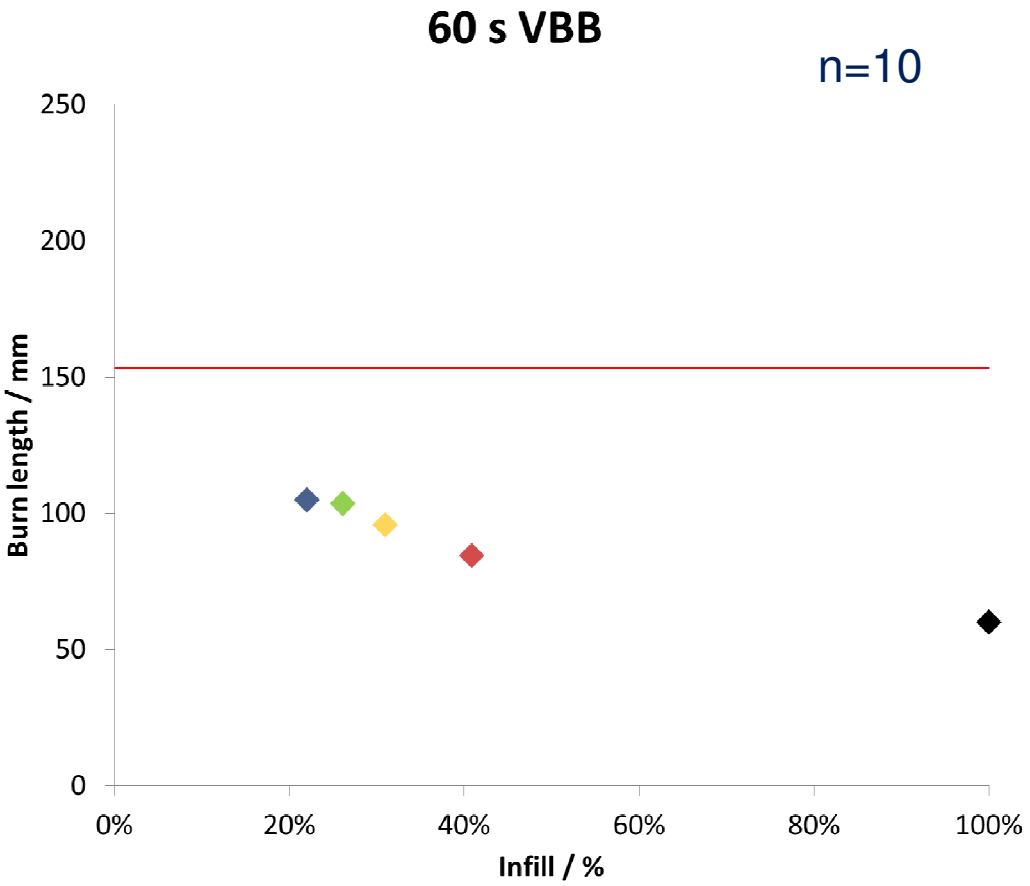

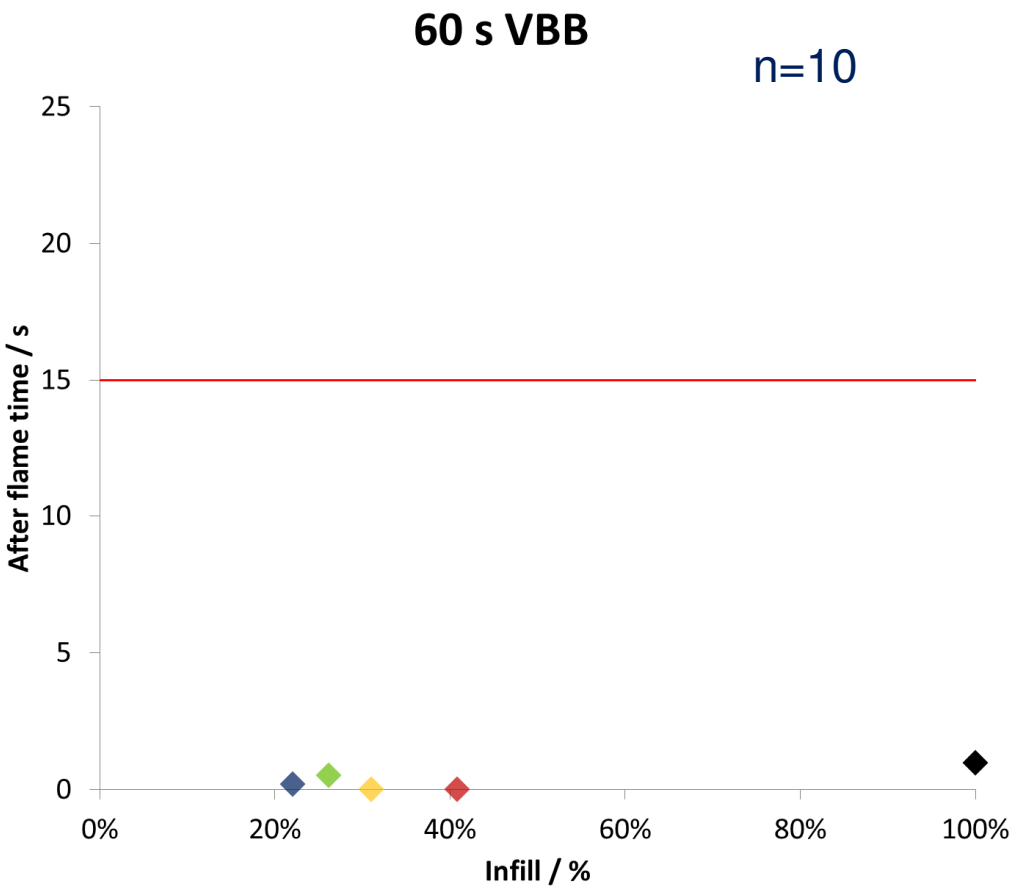

→ Lower infill = higher burn length

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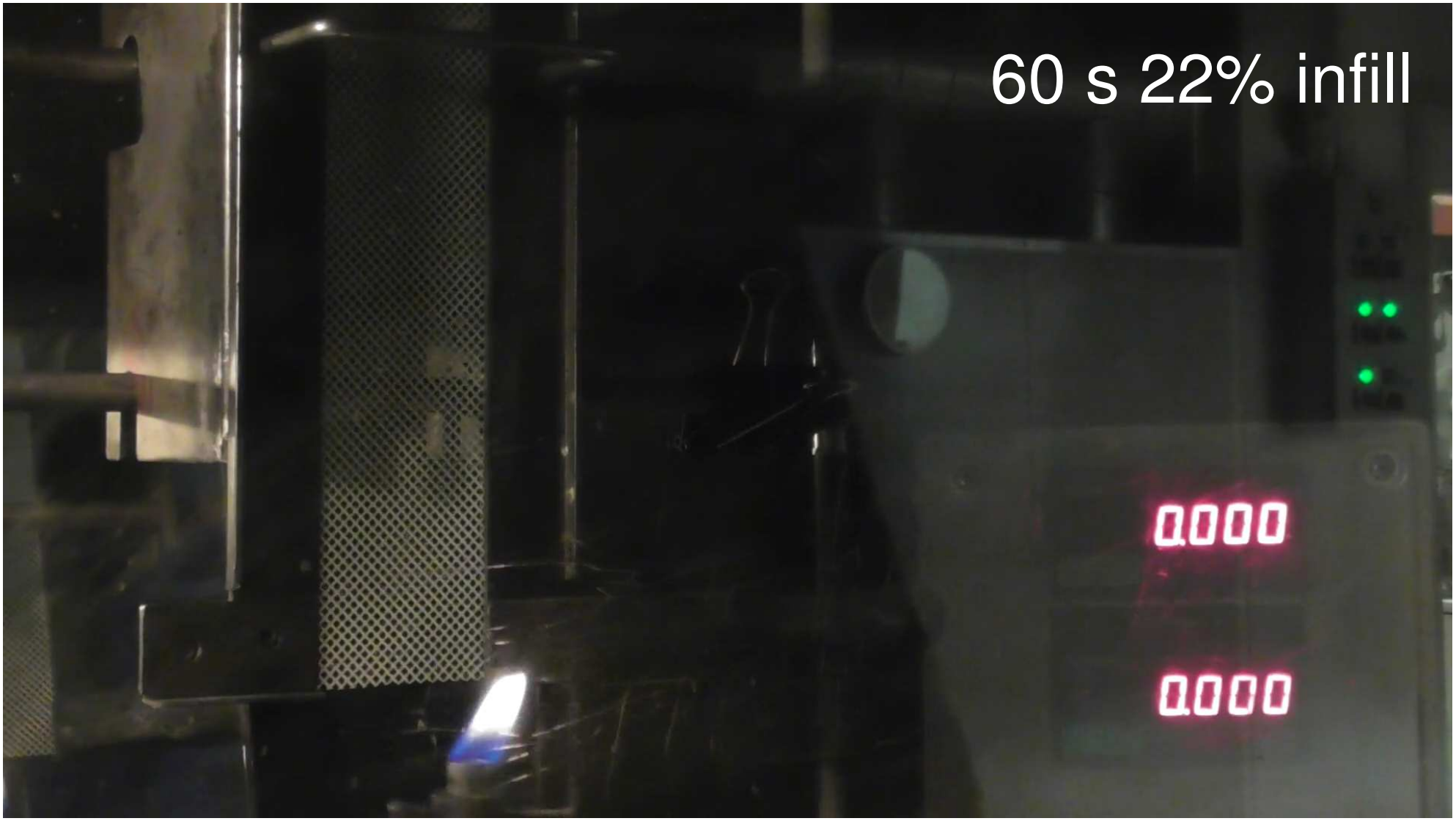

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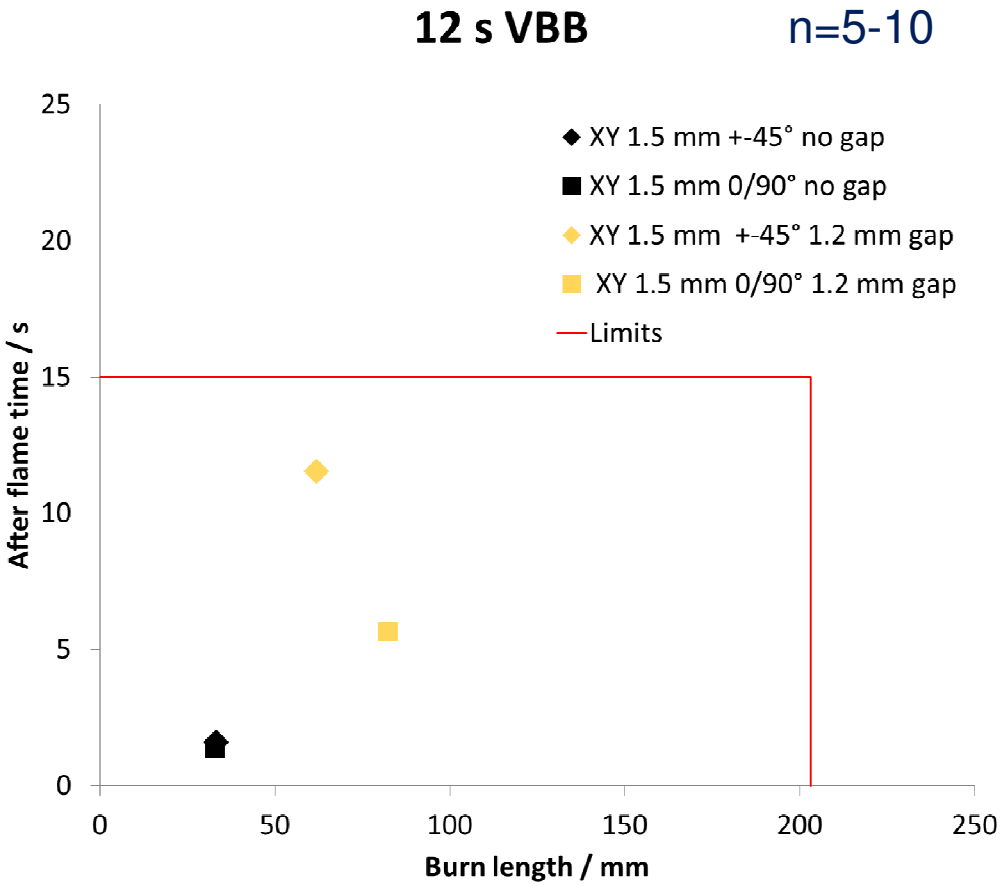
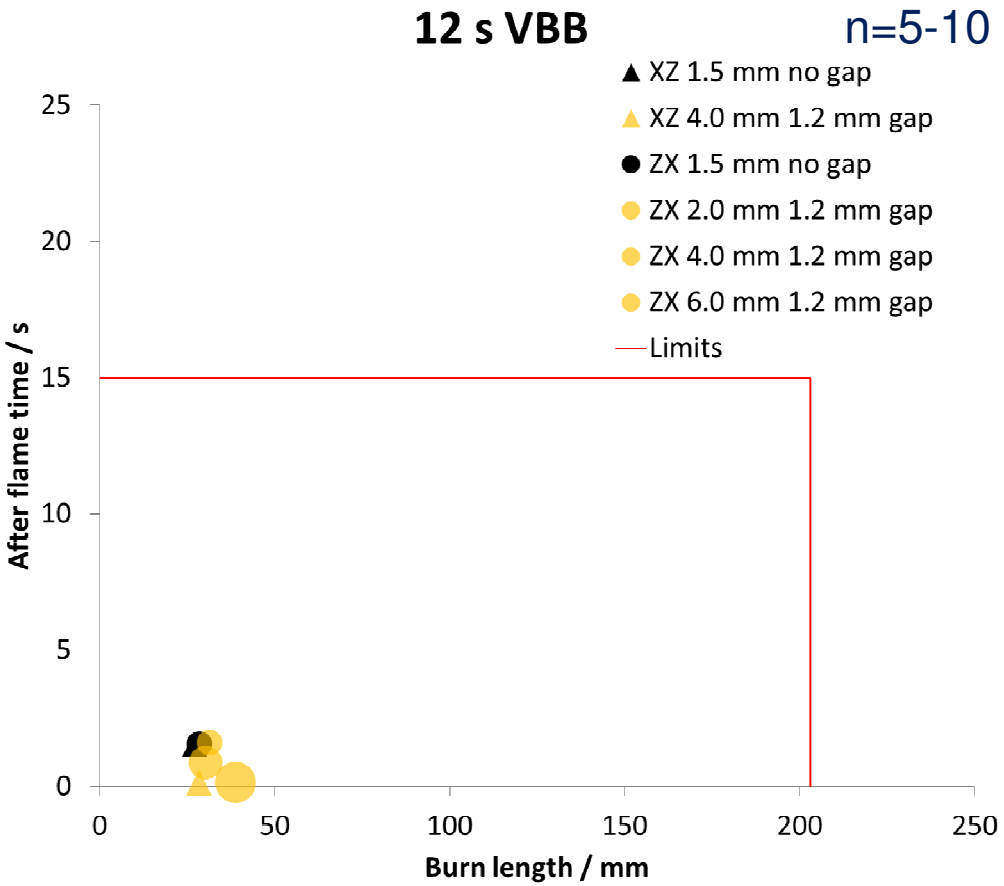
Results: variation of infill for different orientations





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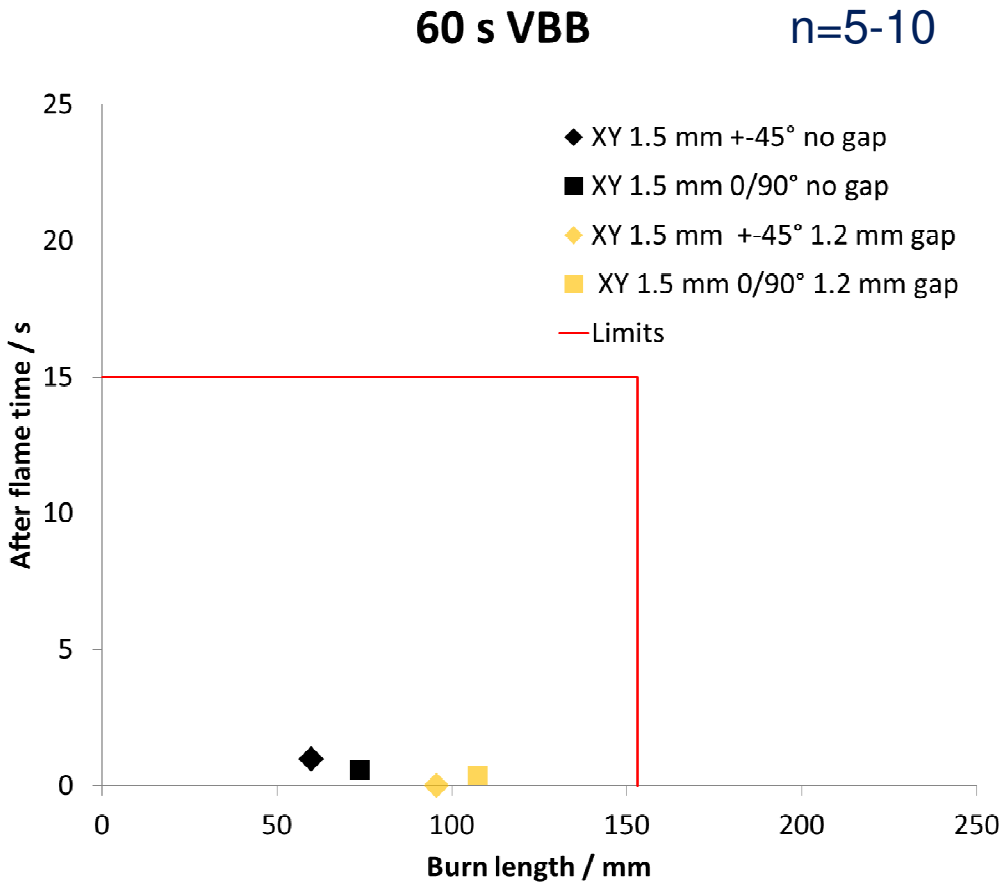

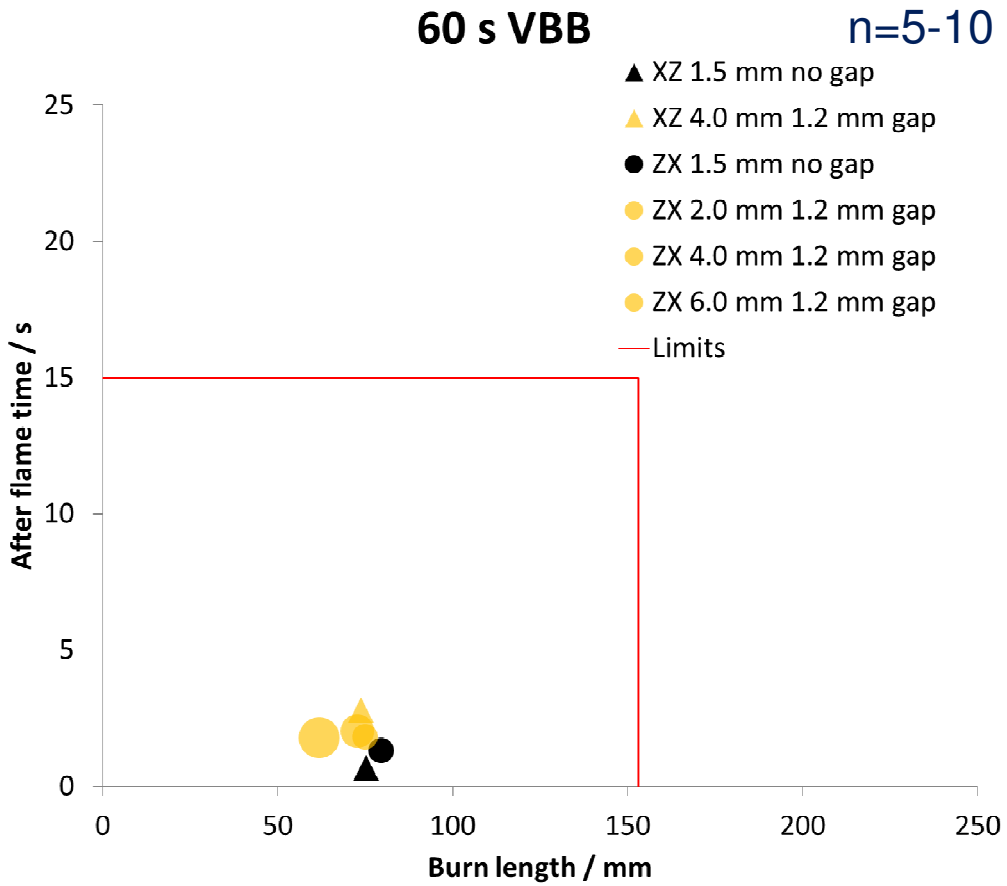

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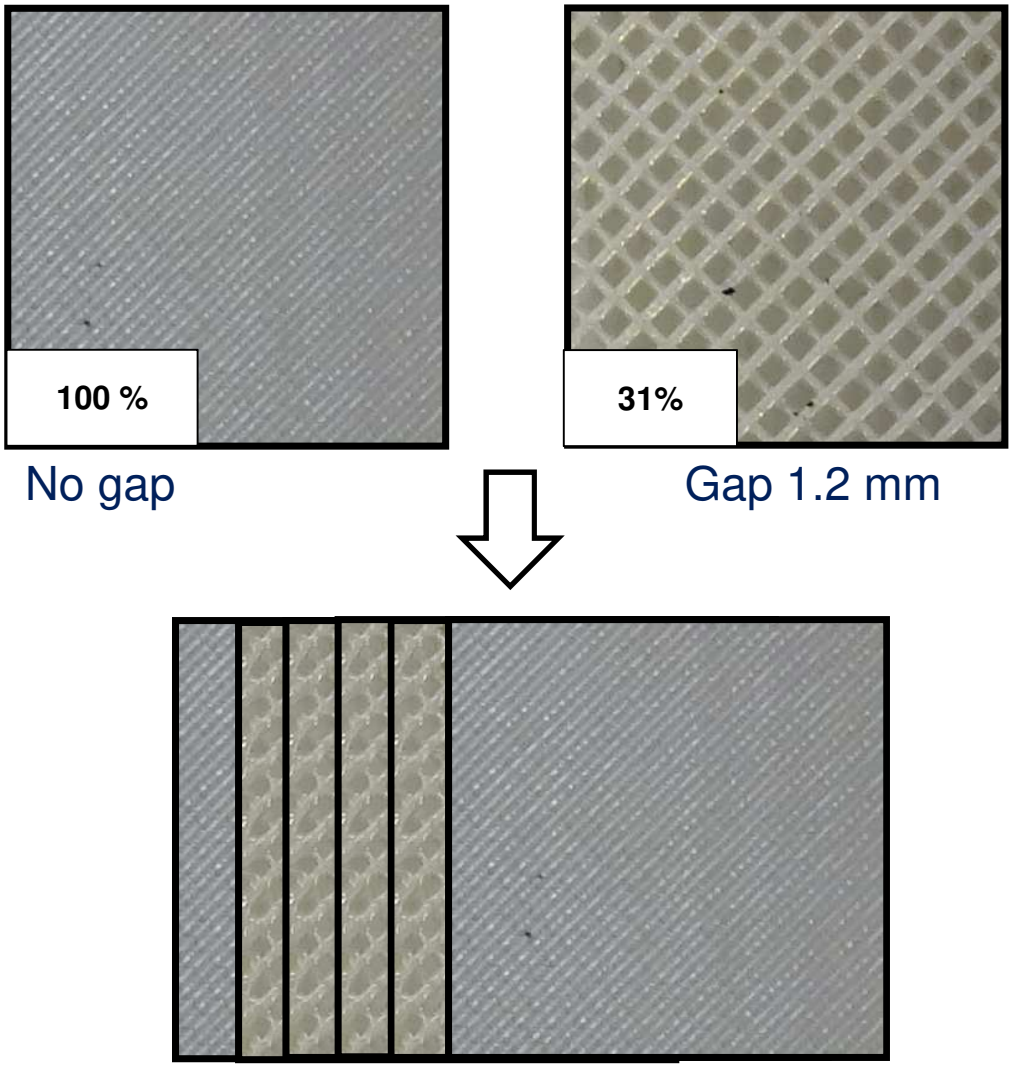
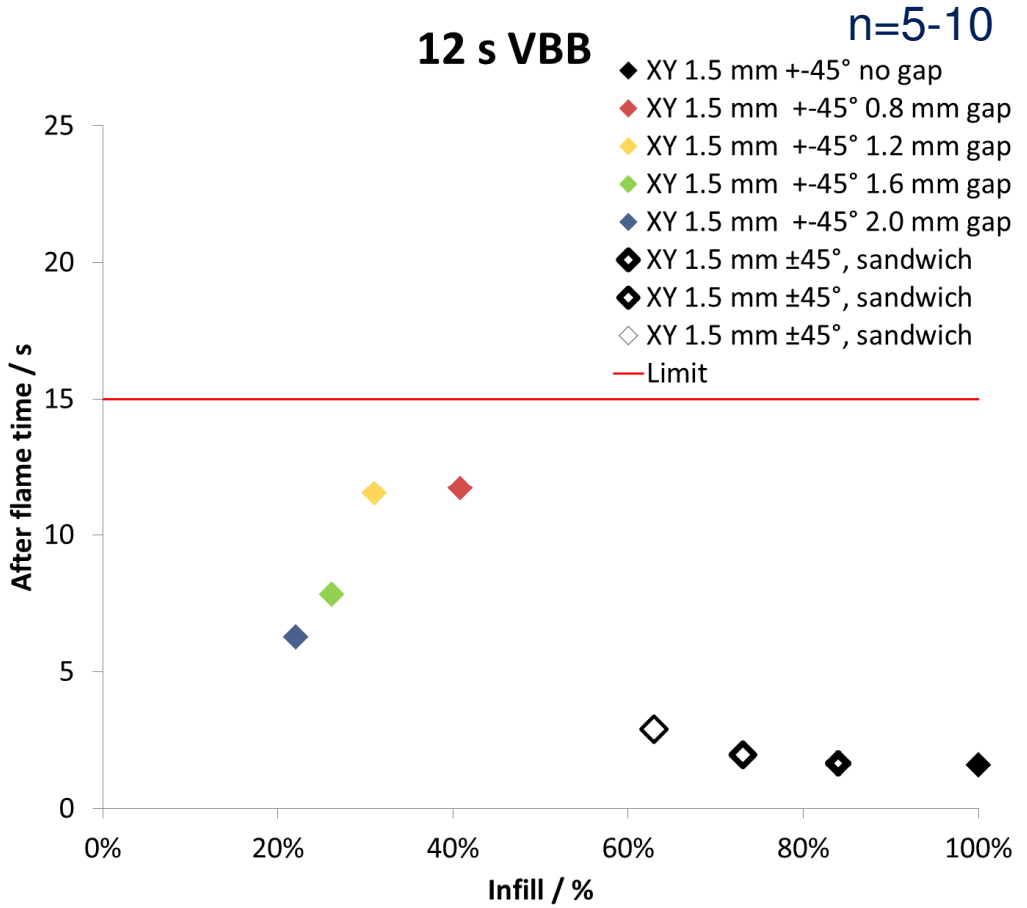
Results: sandwich coupons





→ BL ~ infill, low influence on AF

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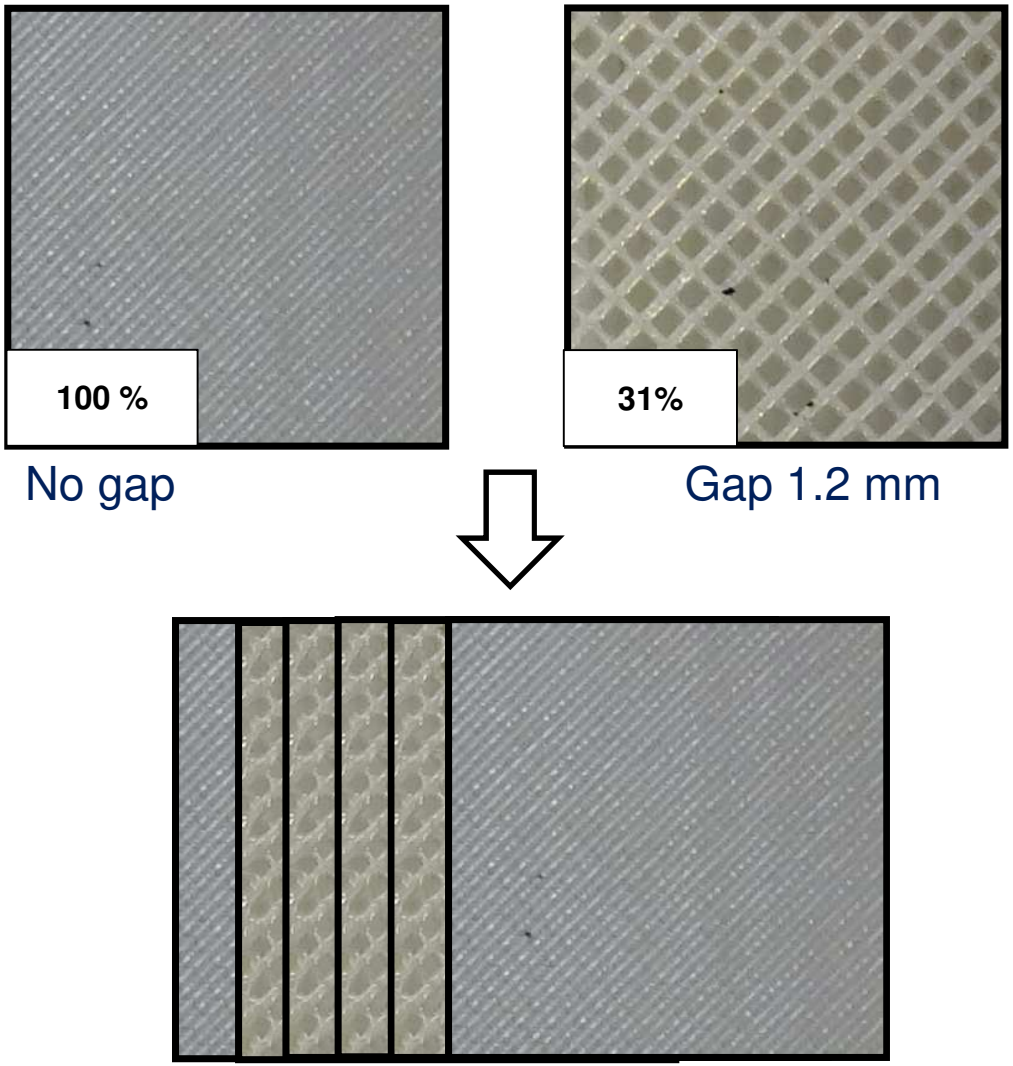
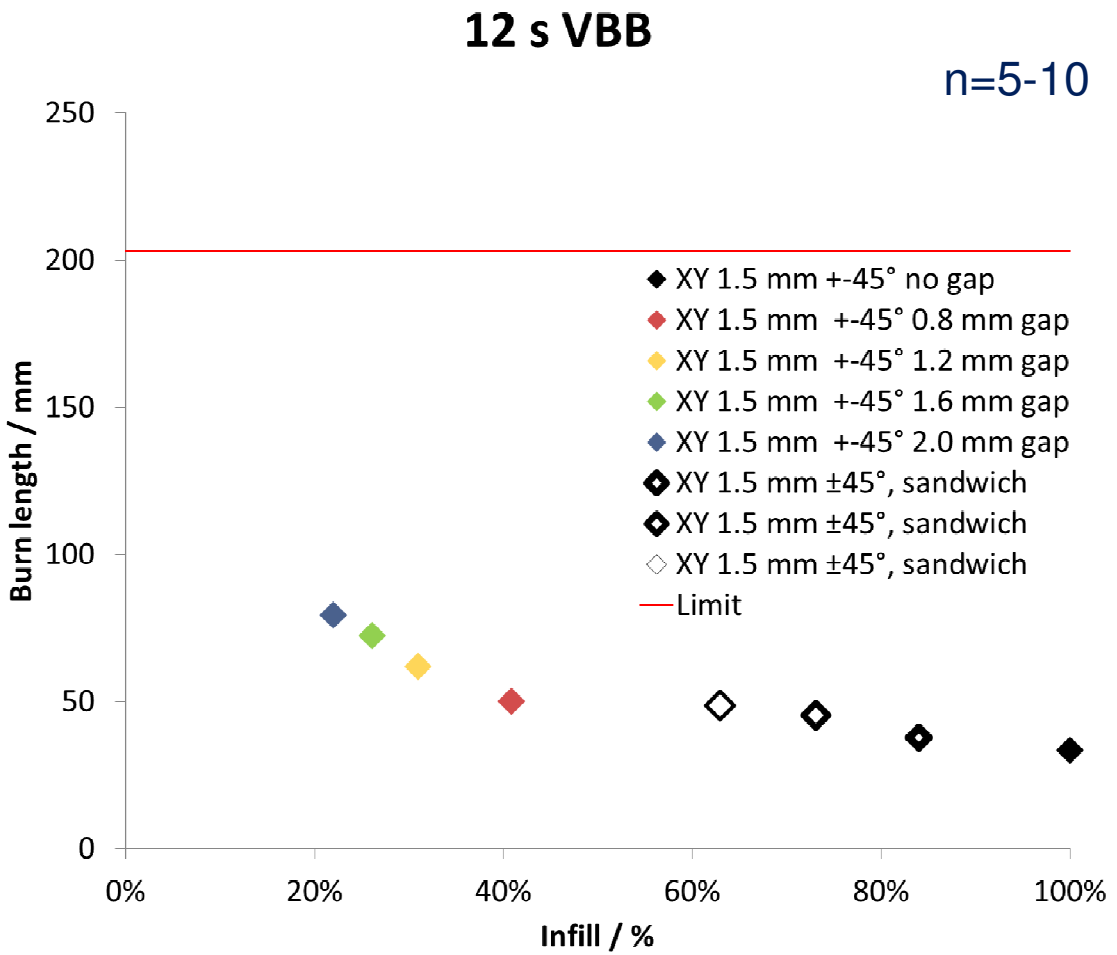
Results: sandwich coupons





→ BL ~ infill, low influence on AF

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Results: sandwich coupons

63% XY ±45° sandwich

31 % XY ±45°

→ Same burn length, but sandwich has shorter after flame

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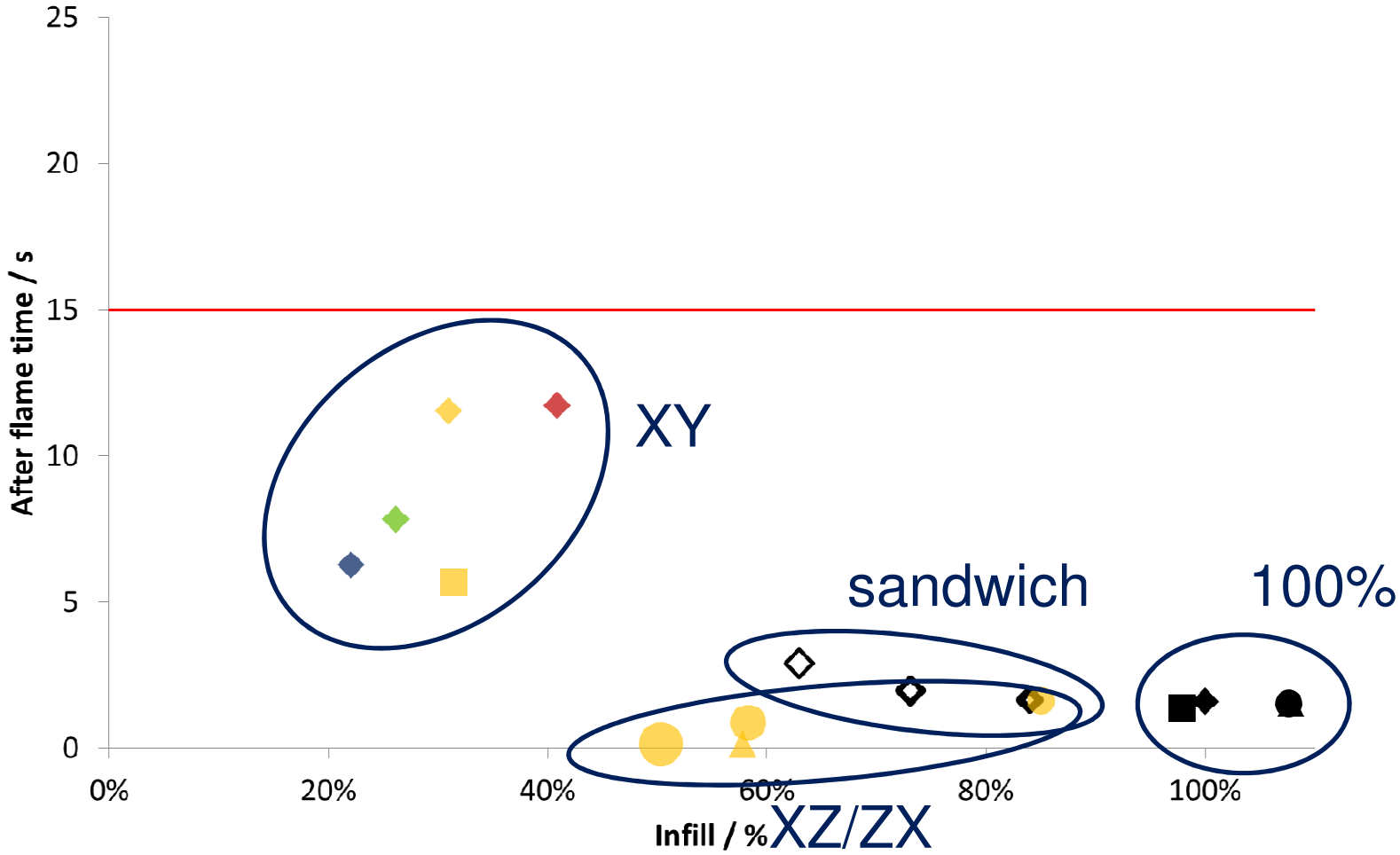
Results: Compilation



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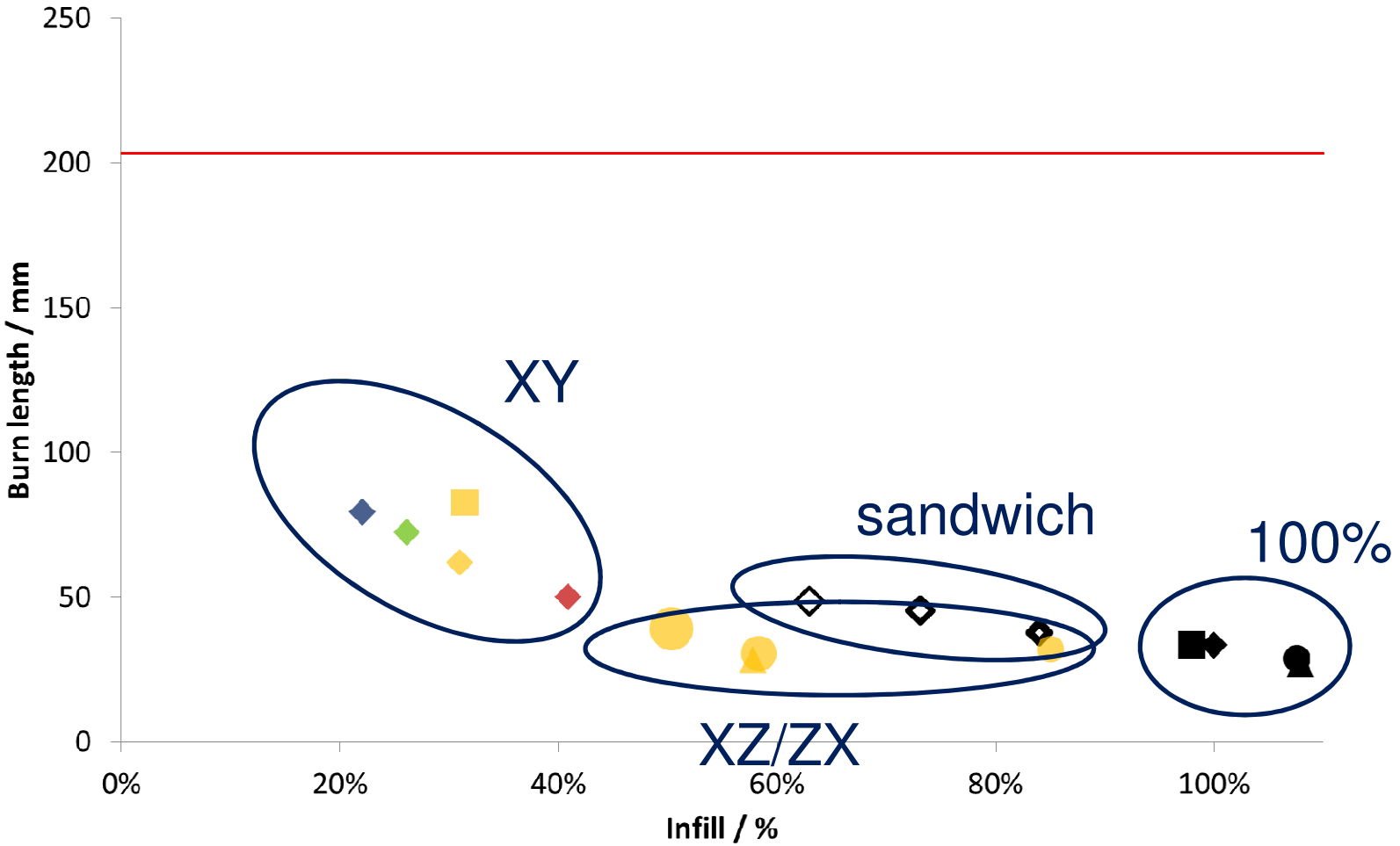

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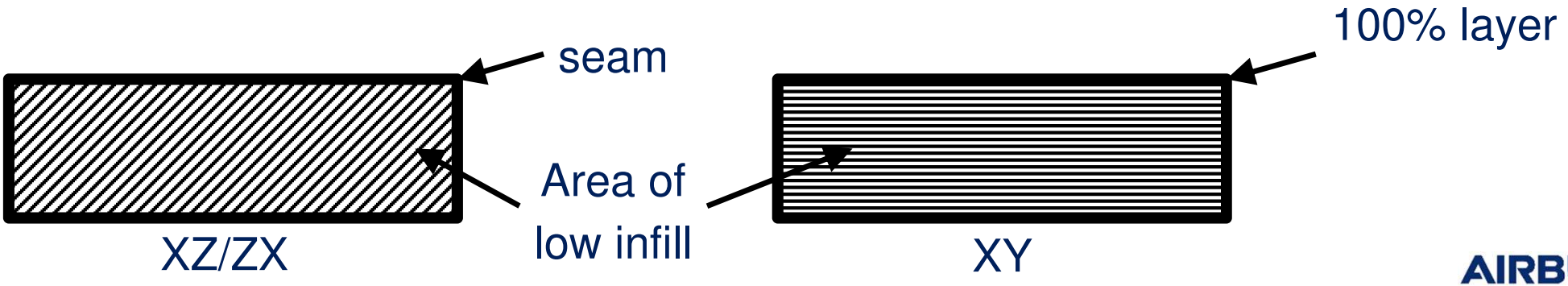
Discussion: Infill

- 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 lid 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



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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

Infill	Gap size	Orientation	Thickness	Sandwich	Burn length	After flame
100%	0	XY ±45°	1.5 mm	No		
⋮	1.2 mm	XY, 0/90°	2.0 mm	Yes		
⋮		XZ	4.0 mm			
⋮		ZX	6.0 mm			
22%						

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Summary

- Thank you to Stratasys & Airbus R&T for sponsoring the coupons!
- 12 s: Lower infill leads to (generally) higher burn length and after flame time
- 12 s: Orientation without influence for 100% infill
- 12 s: For sandwich configurations, burn length may be more dependent on the outer layer infill than after flame time
- 60 s: Shows low after flame times, burn length capped
- Go for further statistical analysis and other materials

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Thank you

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The Resorts Casino is older than the Tropicana. How many years were in between their openings?

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The Resorts Casino is older than the Tropicana.
How many years are in between their openings?

3½

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