3D Printing Durable, Light-Weight, and Flexible Elastomeric Components for Automotive Applications

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an Ontario Centres of Excellence project in collaboration with

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AUTOMOTIVE COMPOSITES CONFERENCE & EXHIBITION
Novi, Michigan • September 4-6, 2019
Presented by SPE Automotive Division and SPE Composites Division

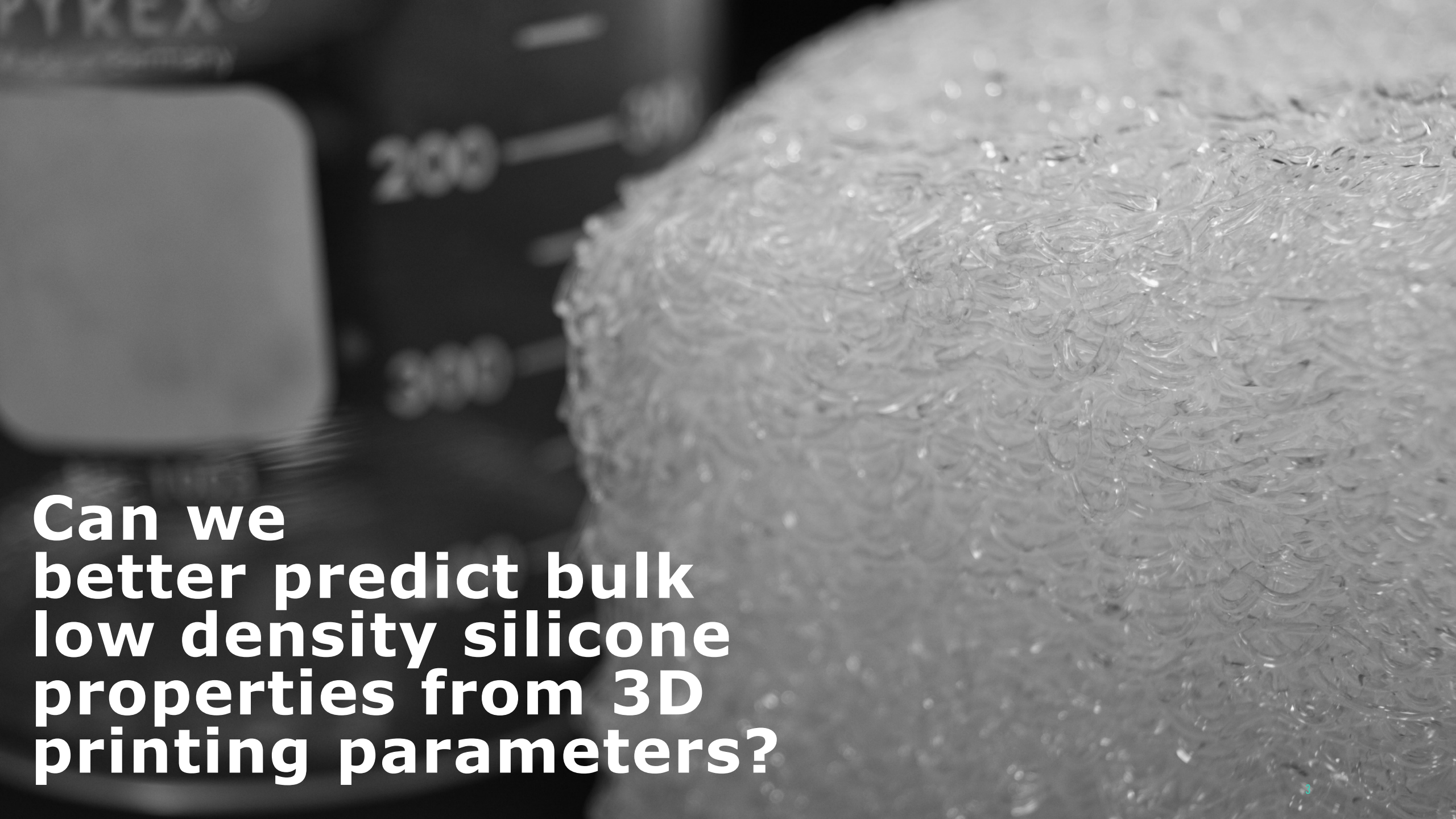
PROJECT MOTIVATION

My Talk Last Year
Tutorial on 3D Printing Paste
bit.ly/SPEACCE2018

Demonstrate advantages of 3D printing for automotive "cushioning" applications

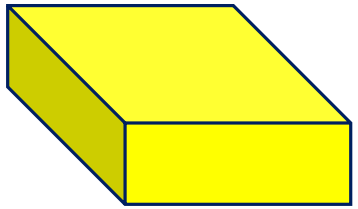
- **Advantages:** *Advanced Functionality*, Customizability, Rapid Prototyping, Inventory Management
- **Cushion Applications:** Seats/bolsters, Headrest, Arm Rest, Other touch points (steering wheel, doors, trim, etc.)

Develop proof-of-concept process and parts to showcase advanced functionality and customizability.

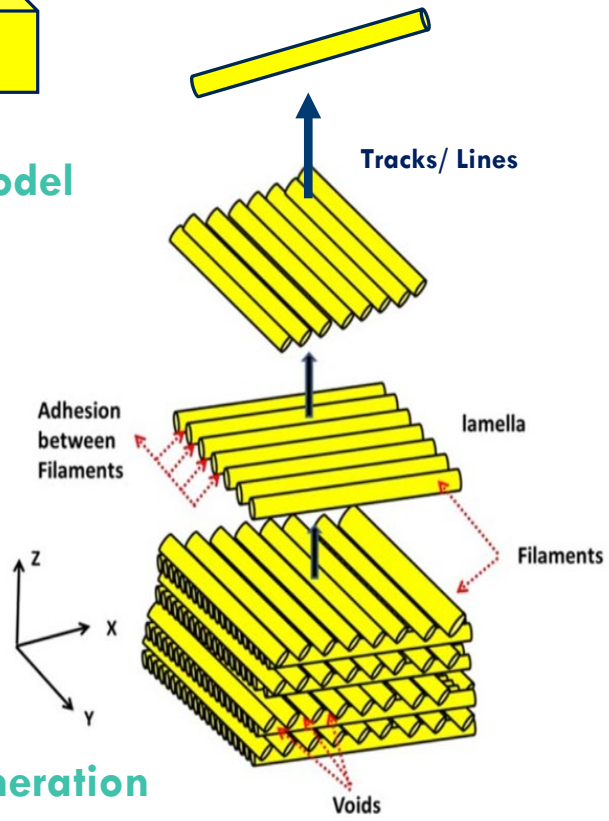


Can we better predict bulk low density silicone properties from 3D printing parameters?

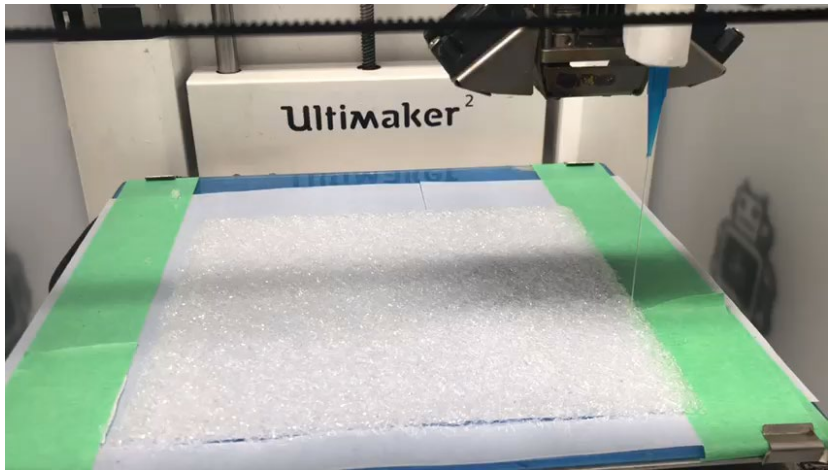
SILICONE WHIPPING ADDITIVE MANUFACTURING (SWAM)



1. Custom 3D Model



2. Gcode Generation via Slicing



3. Non-contact 3D Whipping of DAP 100% Silicone

4. Durable, Light-weight, and flexible elastomeric component.

- Low Density
- Faster cycle time
- Controlled Density
- Defect Mitigation

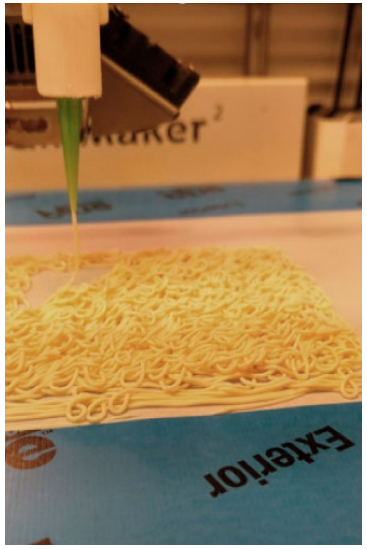
SCREENING PROCESS FACTORS

Factors

A. Gap Distance (5cm to 10cm)

B. Flow Rate (200% to 500%)

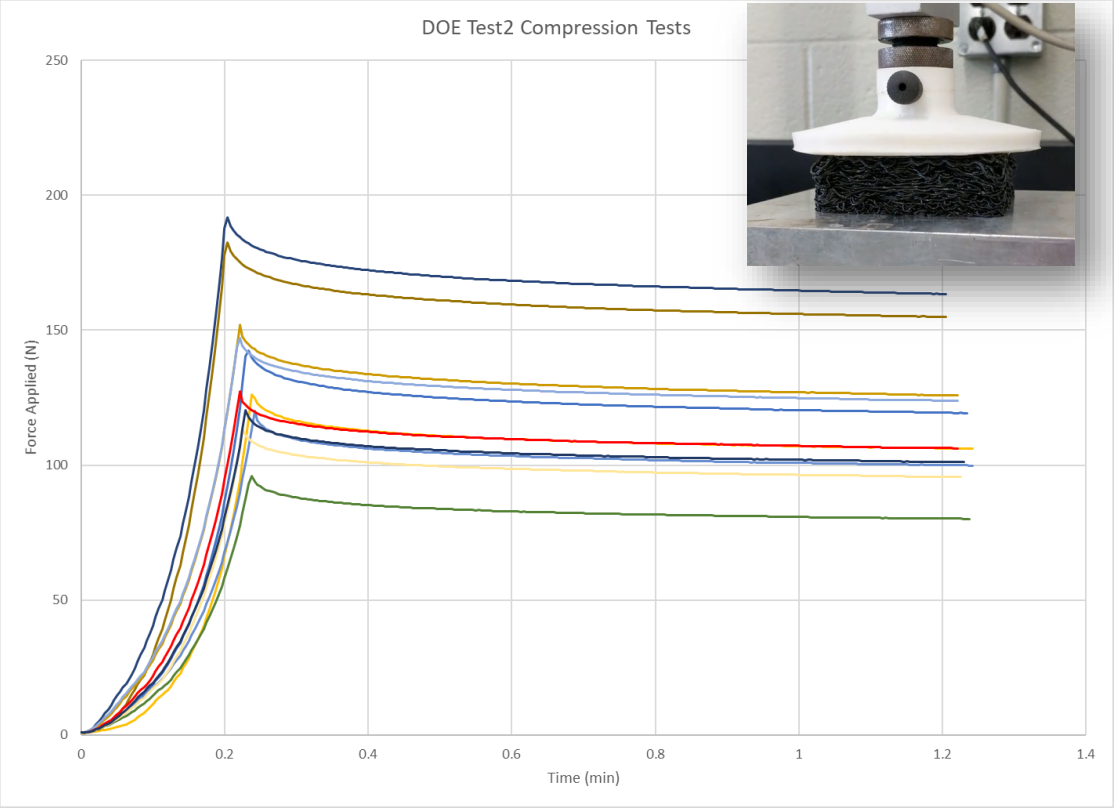
C. Print Speed (5mm/s to 10mm/s)



Responses

A. Force Deflection (N @ 50% comp.) [ASTM D3574]

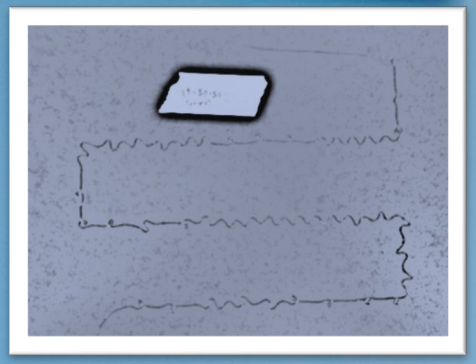
B. Density (g/cm^3)

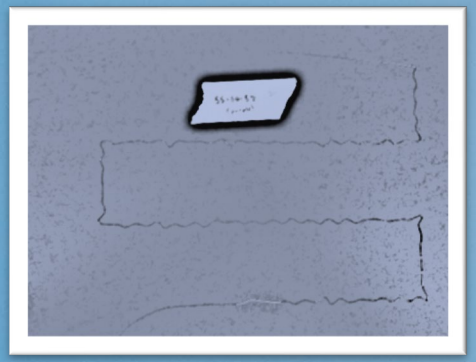


Density (g/cm3) = 0.6541 - 0.000570 FlowRate - 0.03792 GapDist. + 0.000063 FlowRate*GapDist.

F Defl. @ 50% (kPa) = 24.57 + 0.02003 FlowRate - 1.371 GapDist.

ISSUES ENCOUNTERED





Testing Nozzle Geometry

- Stainless steel - Purple
  - Inconsistent flow rate
  - Not designed for high visc.

Imaging

- Getting contrast (Black Paper)
  - Clear silicone samples were often difficult to take good pictures of
- Even light distribution
  - Shadows can cause the image analysis to be difficult

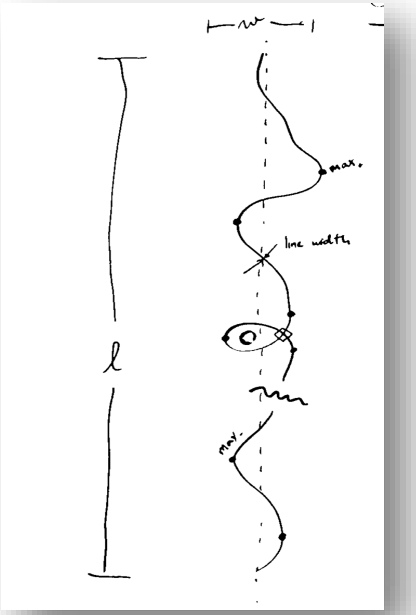
Image Analysis

- Precision of image analysis limited by the resolution of pictures taken

ANALYZING WHIPPED TRACKS

Factors

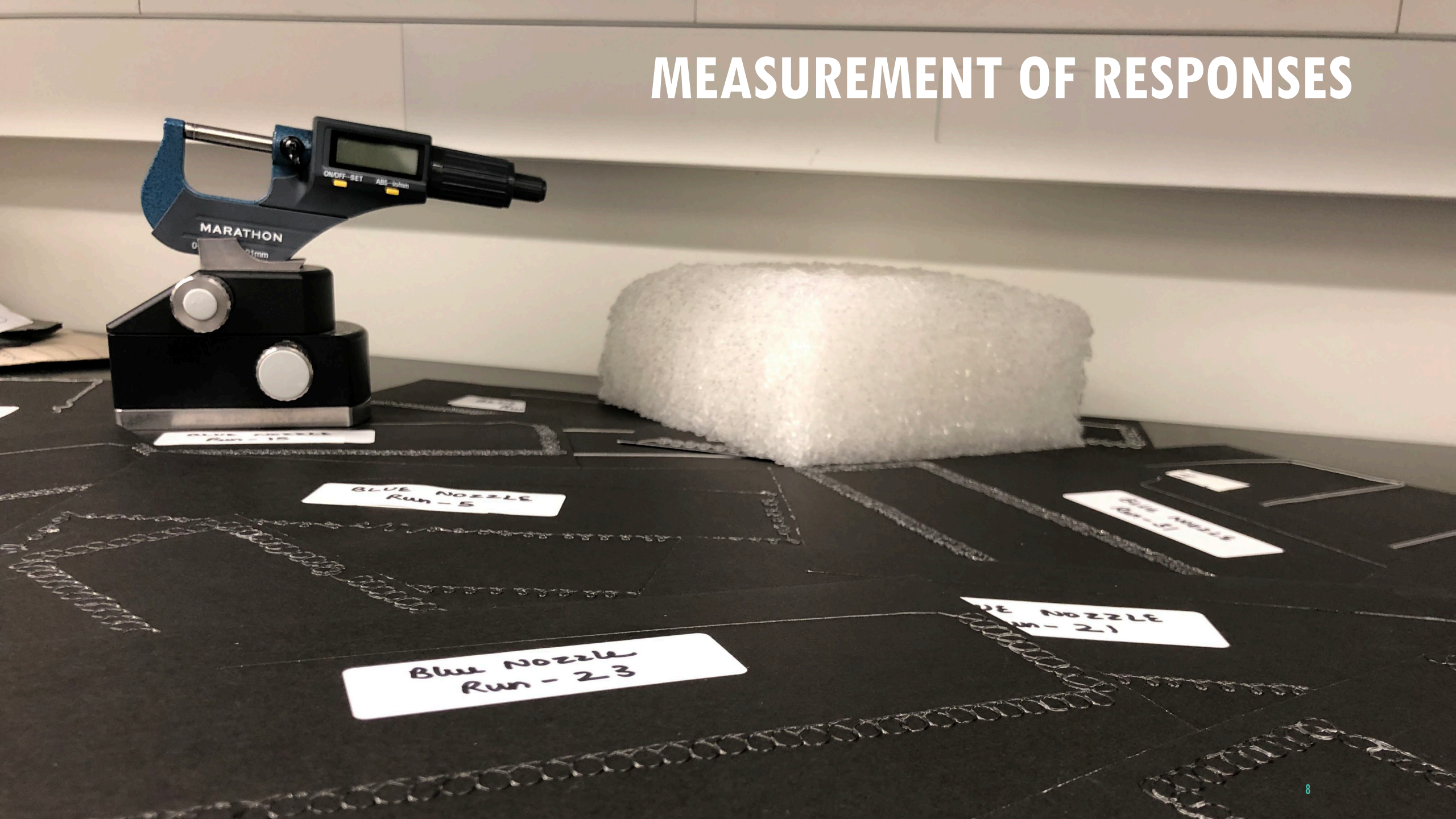
A. Nozzle Diameter (0.41 – 1.19mm)
B. Gap Distance (25 – 75mm)
C. Flow Rate (0.4 – 0.8ml/min)
D. Print Speed (5 – 10mm/s)



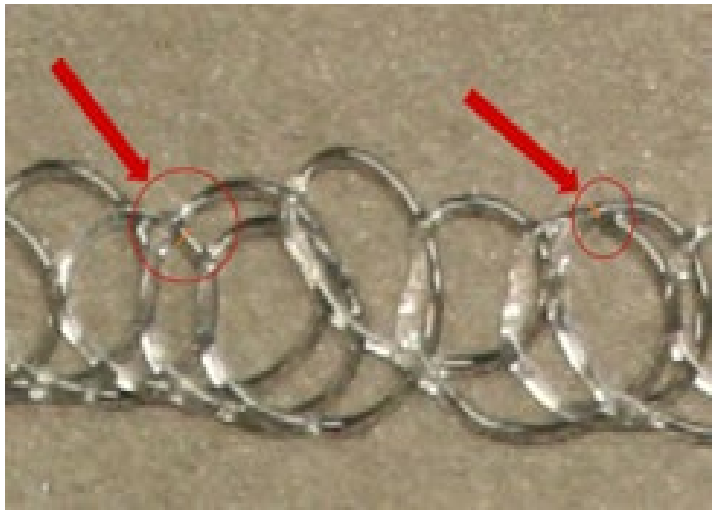
Responses (2^4 DOEs)

A. Fibre Diameter
B. Number of Loops
C. Line Width
D. Overlaps
E. Layer Height
F. Fibre Breaks

MEASUREMENT OF RESPONSES



RESPONSE 1: FIBER DIAMETER

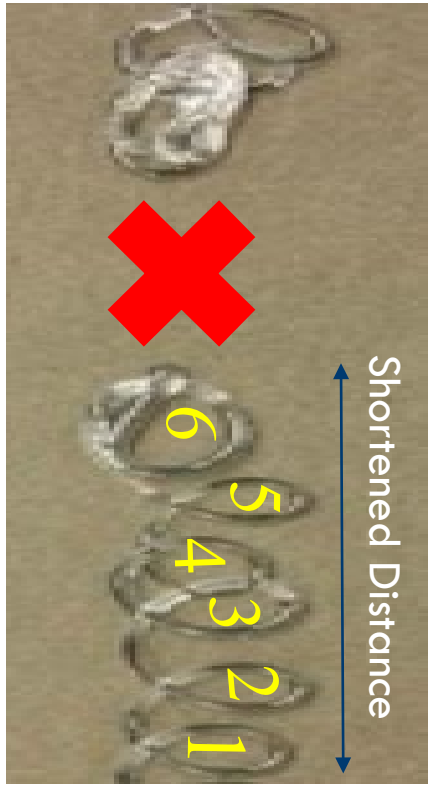


Filament measurement was taken at a right angle to the filament. If multiple filaments were at the same point on the ruler, then the upper-most filament measurement was used.

If the upper-most filament was difficult to see (ex. There was filament overlap at this point) then the filament immediately below was used for the measurement (if this was difficult to see, then this process happened again)

RESPONSE 2: NUMBER OF LOOPS

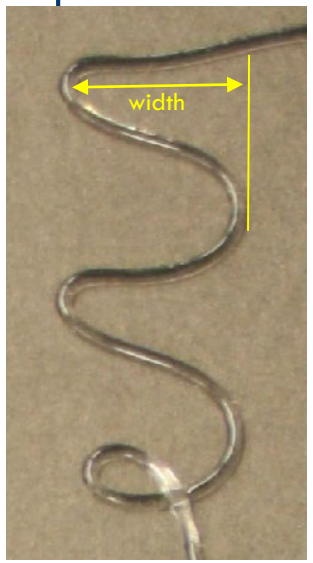
Number of Loops are defined as the count of the spiral forms made by the filament.



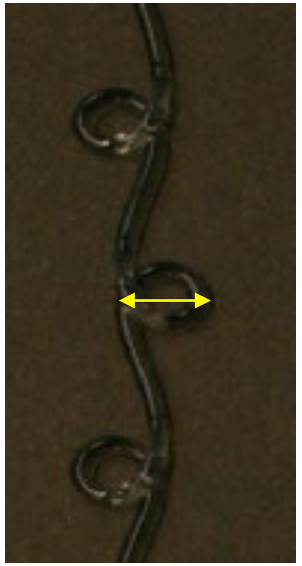
If there was a break due to an air bubble, then the distance was shortened so that this did not affect the loop density measured.

If a loop was partially inside the measured distance, then the loop was included in the count

RESPONSE 3: LINE WIDTH

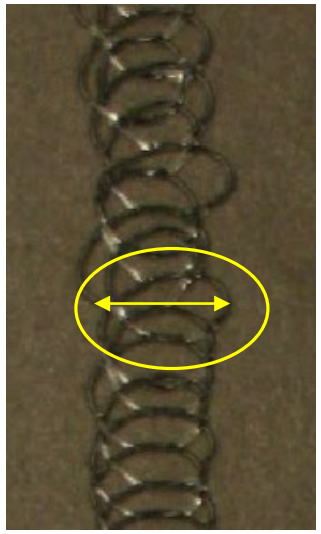


Line width is the distance between maximum and minimum point of the filament.

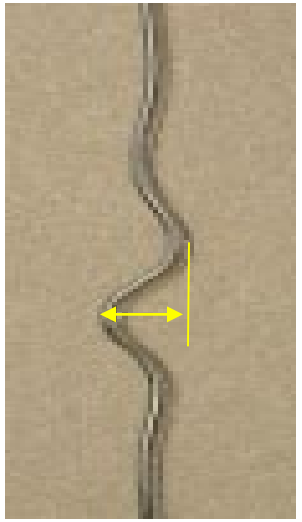


If there is a loop near the point of measurement, the maximum and minimum width of the loop is taken instead of that point of measurement.

If there is a smaller and larger loop near/on the point of measurement, the larger loop will be considered to measure line width.



If the point of measurement lies on a region of clustered loops, the largest of the group is considered for line width measurement.



If the filament is deposited in a wave form, the crest and the trough of the wave near/on the point of measurement are considered as maximum and minimum point of the line width respectively.

Standard Deviation: Is also evaluated which is the amount of divergence from the mainpoint.

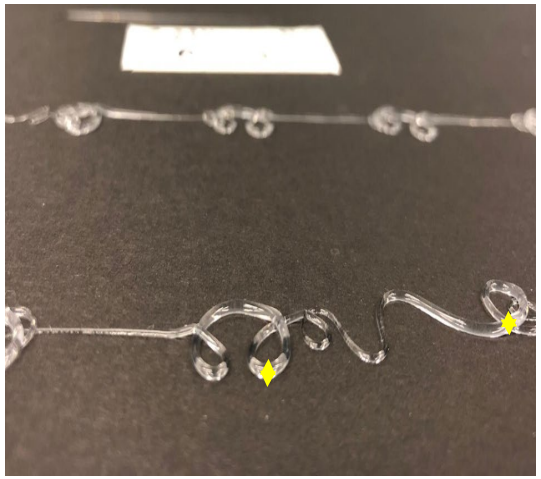
RESPONSE 4: OVERLAP

- Overlaps are categorized into two types:
  - Single and Multiple Overlaps.
- Multiple Overlapping further divided into two types:
  - Double and nested looping.
- Split measurements (0-3cm) are taken in case of clustered loops.
- Single overlap density (count/cm) and Multiple overlapping density (count/cm) are evaluated in a separate column for further DOE analysis.

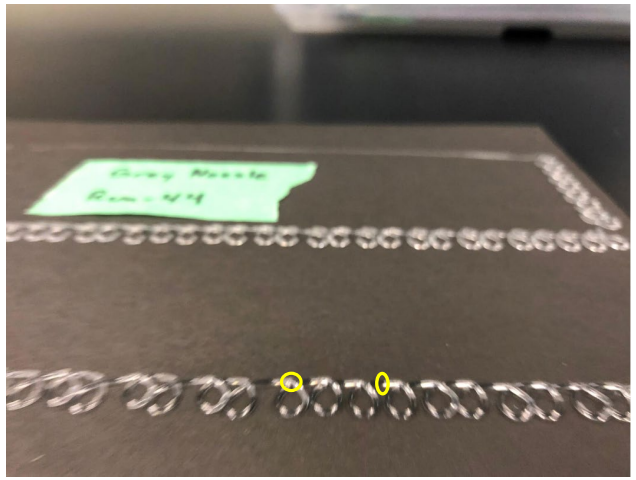
Various observations have been made in the following table:

S. Number	Single Overlap	Multiple Overlapping	Comments
1	0	0	Straight or zig-zag filament
2	x	x	Straight, consistent overlapping of the filament
3	0	x	Straight, clustered, and double looping effect of the filament
4	x	0	Distant, and straight or reversed (opposite side) overlooping of the filament
5	x	2x	Consistent and clear multiple overlooping of the filament
6	2x	x	Consistent or nested multiple looping effect of the filament

RESPONSE 5: LAYER HEIGHT



The response height represents the amount of the deposited material from the base of the paper, looking horizontally to it.



The points for the measurement were taken in two ways, one at the overlapping point, and other is on the non-overlapping point.

The average measurement is observed and calculated using micro screw gauge.

The width of the paper (which is 0.223mm) is excluded from the final measurement, hence the formula generated as: -

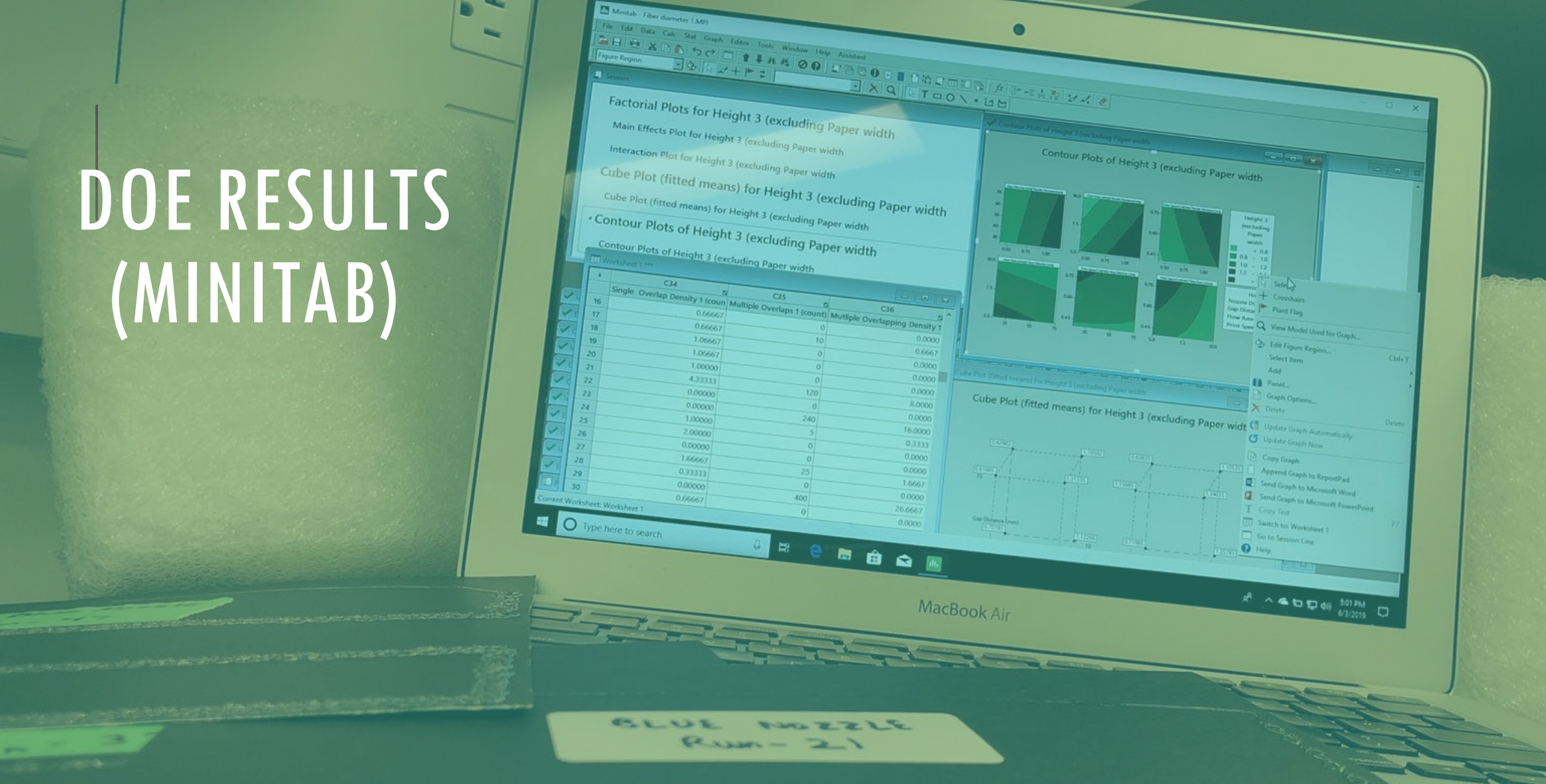
Desired average height (mm) = Total width (mm) - paper width (mm)

RESPONSE 6: NUMBER OF BREAKS

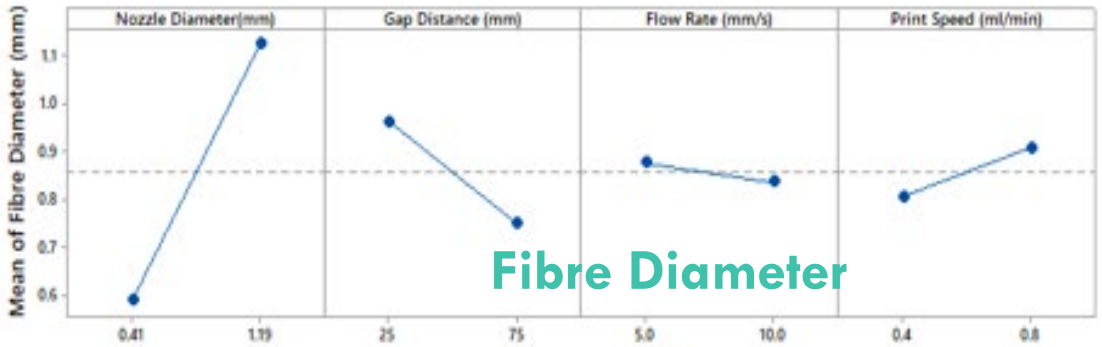
The breaks are defined as the discontinuity in the flow of deposited paste. This is due to various reasons:

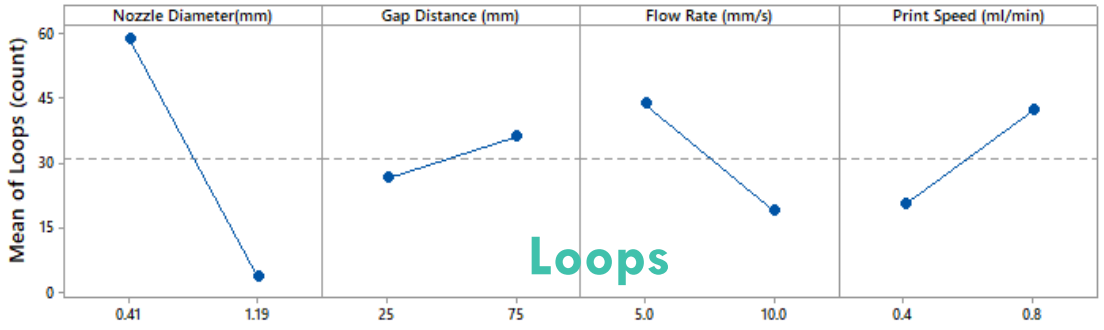
- Air bubbles: Presence of Air Bubble in Tube / syringe.
- Nozzle Clogging: - Accumulation of the material on the nozzle tip, thereby forming hanging loops.
- Air disturbance: - Improper covering might introduce a flow of air into the machine.
- Out of material: - No material left in the syringe.
- Machine malfunction: -Machine malfunctions during printing.

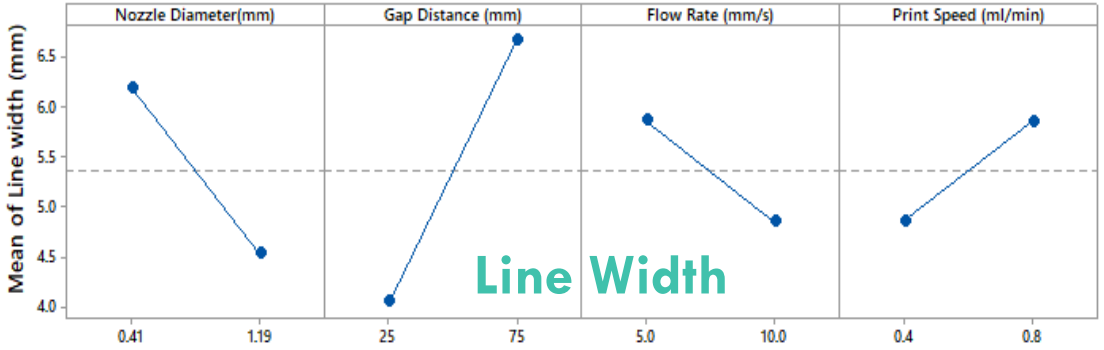
DOE RESULTS (MINITAB)

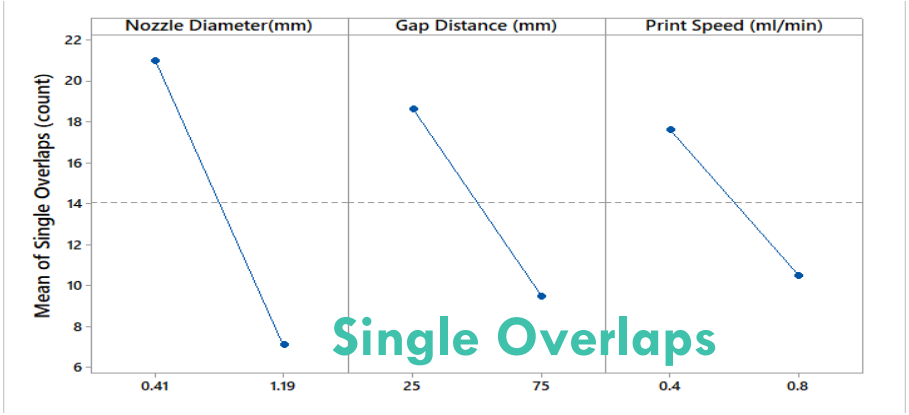


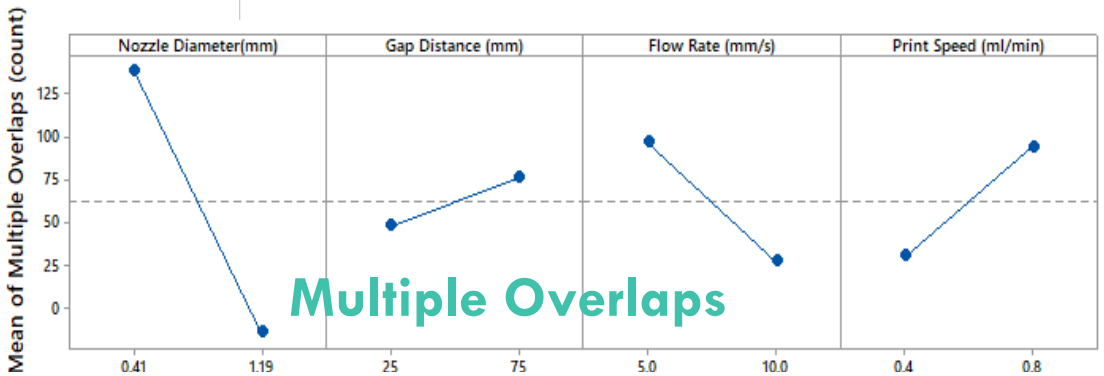
MAIN EFFECTS RESULTS

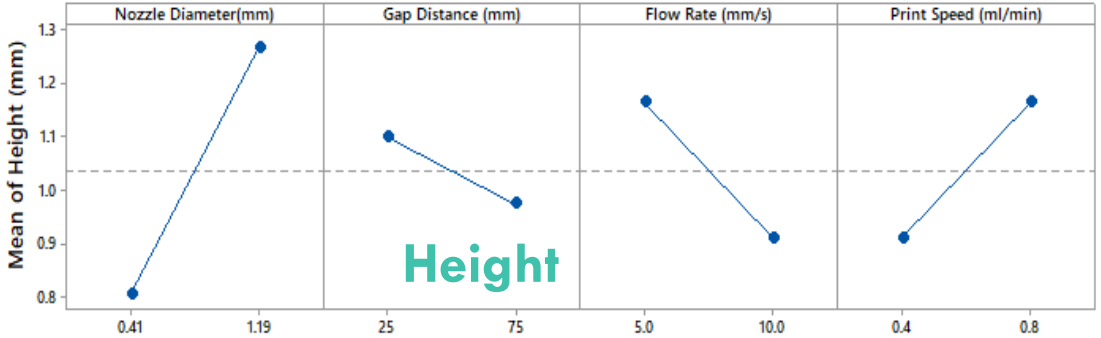












SUMMARIZING EFFECTS RESULTS

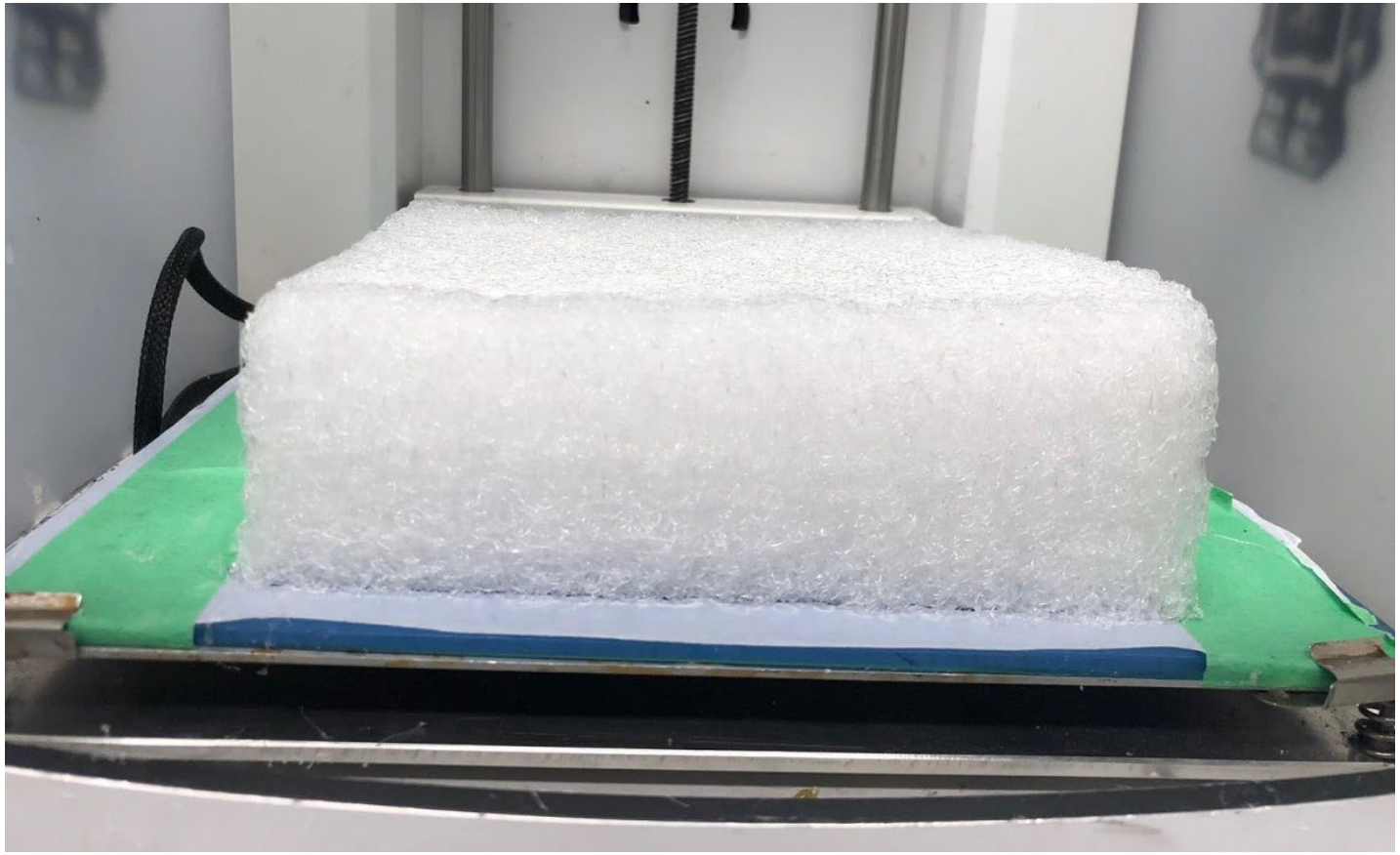
Interaction Label:	Interaction Name:
A	Nozzle Diameter (mm)
B	Gap Distance (mm)
C	Flow Rate (mm/s)
D	Print Speed (ml/min)

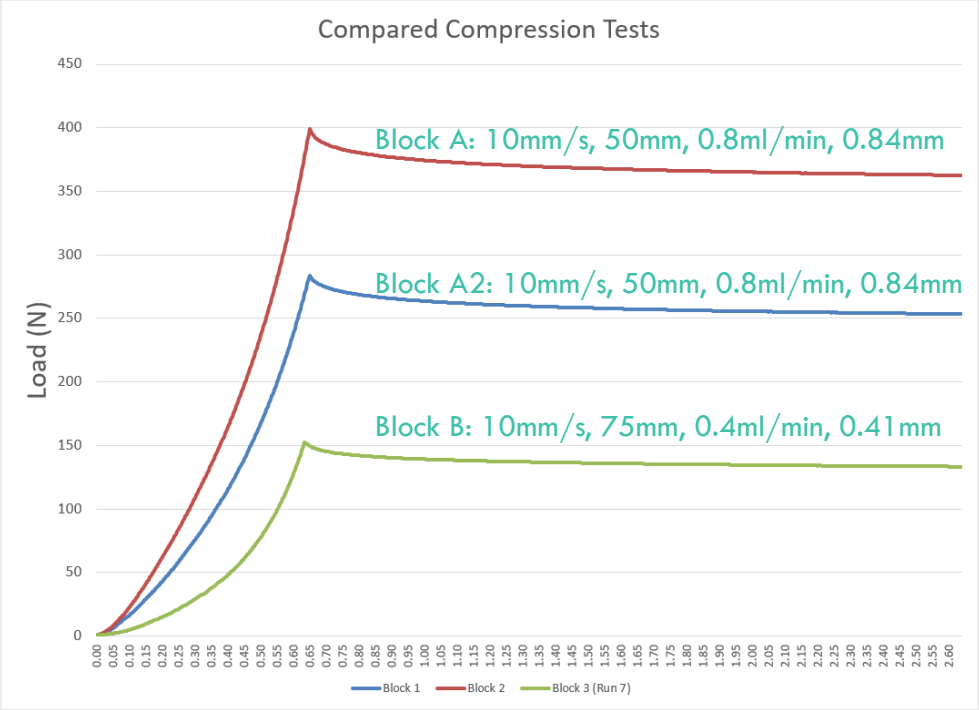
Interaction	Fiber Diameter	Loops	Line Width	Single Overlap	Multiple Overlapping	Height
A	+	-	-	-	-	+
B	-	+	+	-	+	-
C	-	-	-	NA	-	-
D	+	+	+	-	+	+
A*B	-	NA	+	+	-	NA
A*C	-	+	-	-	+	-
A*D	+	-	+	+	-	NA
B*C	+	NA	NA	NA	NA	NA
B*D	NA	NA	-	NA	NA	NA
C*D	+	-	NA	NA	NA	NA

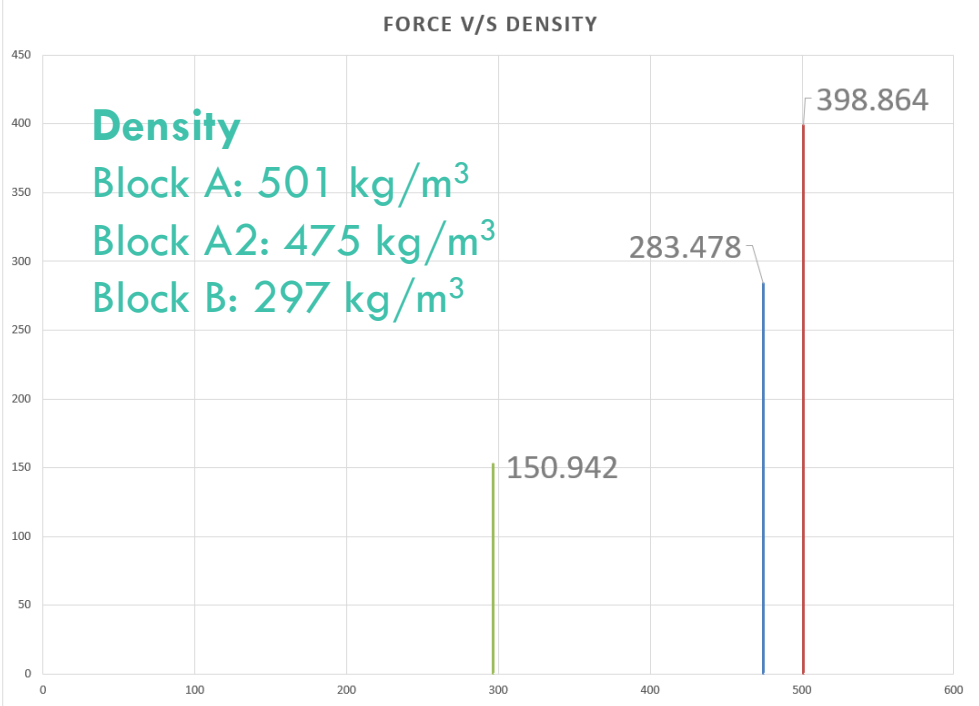
SUMMARIZING RESPONSES

Response:	High	Low	Mean
Fiber Diameter (mm)	1.421	0.511	0.855
Loops (count)	115	0	31.16
Line Width (mm)	7.9203	1.129	5.357
Single Overlap (count)	65	0	14.06
Multiple Overlapping (count)	310	0	61.9
Height (mm)	1.93	0.53	1.04

SCALE-UP AND CONTROLLING FORCE/DENSITY PROFILE







CONCLUSIONS AND MOVING FORWARD

Create and control the density and force deflection of elastomeric parts using Silicone Whipping Additive Manufacturing (SWAM).

Development of scaled-up samples based on benchtop limitations.

Determining best response parameters in accordance to customer needs and develop a factor set-up to achieve desired properties.

Create show-ready Prototype to demonstrate technology and secure funding to improve speed, desired properties, and customization.

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structur3D PRINTING

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(Masc. Chemical Engineering)

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Adnan Fakhouri - Undergrad Co-Op student

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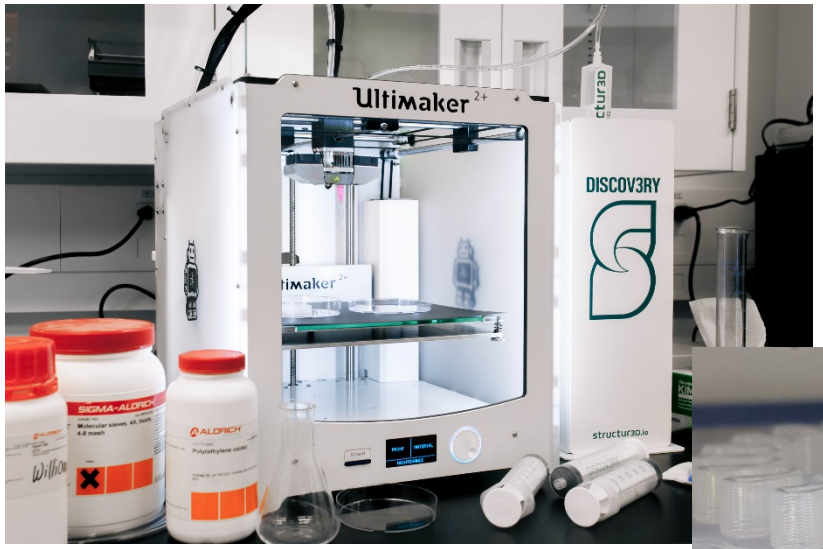
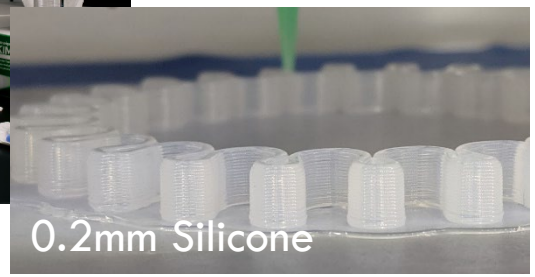
1 & 2-component Paste 3D Printing

Research and Develop with the materials you plan to go to production with.



Tutorial on 3D Printing Paste
bit.ly/SPEACCE2018



New product launch (K-Show 2019)

Improved prototyping and small batch manufacturing of parts with improved quality, geometry, and throughput using Structur3d's new Silicone line-up of materials.

Seeking beta customers for pre-launch access (see me or contact charles@structur3d.io)

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