BambuLabv.s MatterHackers PLA

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Report written by Brandon Hill, Ali Niazi, and Lior Sadan.

What is the goal of this comparison?

Terrapin Works' Fabrication Farm currently uses MatterHackers PLA filament. This report will focus on comparing Matterhackers PLA to the BambuLab Basic PLA. Bambufilament was chosen to be tested due to its lower cost per kilo and their use of reusable spools which drastically reduce waste.

Many of the applications in the Fab Farm are not dependent upon the mechanical strength of the PLA, but rather they are dependent upon "print quality". The procedures for testing remain unchanged from the previous "FDM Testing Process" document, observing and evaluating all of the factors in the document. These include dimensional accuracy, negative tolerance, and a multitude of visual quality tests in the form of a torture test.

Matterhackers PLA

BambuLabs PLA

Comparable Filament Specs:

Both the MatterHackers and BambuLabsPLA aim to be low cost filaments with many color options. Both filaments advertise no extra additives or changes to the PLA plastic so any difference in quality will come down to the difference in quality of the raw plastic sourced by the manufacturers and by the process which they use to turn raw plastic into filament spools.

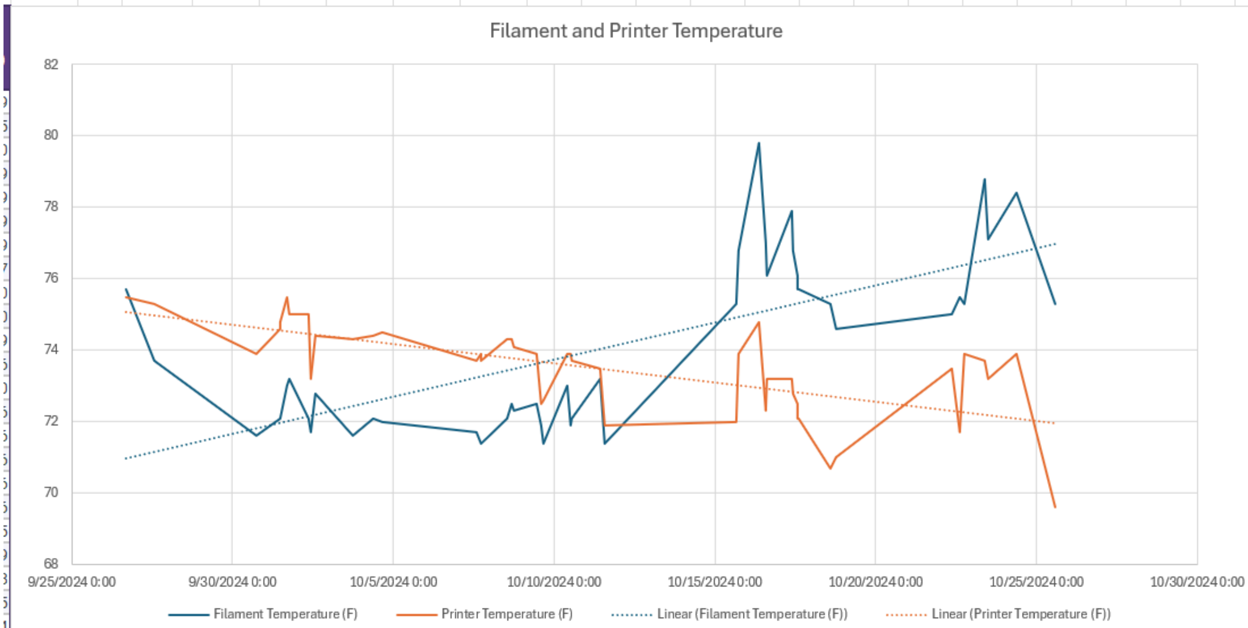
Specification	**BambuLabs Basic PLA**	**MatterHackers Build PLA**
Printing Temperature	190˚C - 230˚C (210C ± 20C)	205C ± 15C
Bed Temperature	35˚C - 45˚C (40C ± 5C)	40C ± 15C
Printing Speed	<300mm/s	40mm/s - 60mm/s
Diameter Tolerance	± 0.03mm	± 0.03mm

Assumptions & Disclosures

During the course of testing, measures were taken to mitigate sources of uncertainty and try to mimic “normal print farm treatment” of the filament. Therefore beyond the initial reception of filament, no special measures were taken to control humidity or dust contamination of the filament (no significant dust generating activities were performed during the testing duration, however).

Once each filament was loaded into the printer, all test prints for that filament were completed sequentially in the order as follows: 54x califlowers, 30x z-stairs (at the same time), 10x negative accuracy tests, and 5x torture tests. Other disclosures and assumptions are as follows:

- The printer we used for this test is a Prusa Mk3s with a E3D V6 hotend, PrusaSlicer firmware, using a brass 0.4mm nozzle. We chose default specifications to be representative of the Fabrication Farm’s printer fleet, or representative of other average printers that would be used for rapid prototyping.
- The “Generic PLA” default profile from Prusaslicer will be used for all tests and both filaments. Each filament would benefit from tuning, but current SOPs don’t include custom profiles.
- The temperature and humidity of the room during the month of October averaged 73.75F and 26.60% respectively. The actual day to day distributions are as follows:


Filament and Printer Temperature
82
80
78
76
74
72
70
68
9/25/2024 0:00
9/30/2024 0:00
10/5/2024 0:00
10/10/2024 0:00
10/15/2024 0:00
10/20/2024 0:00
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Filament Temperature (F)
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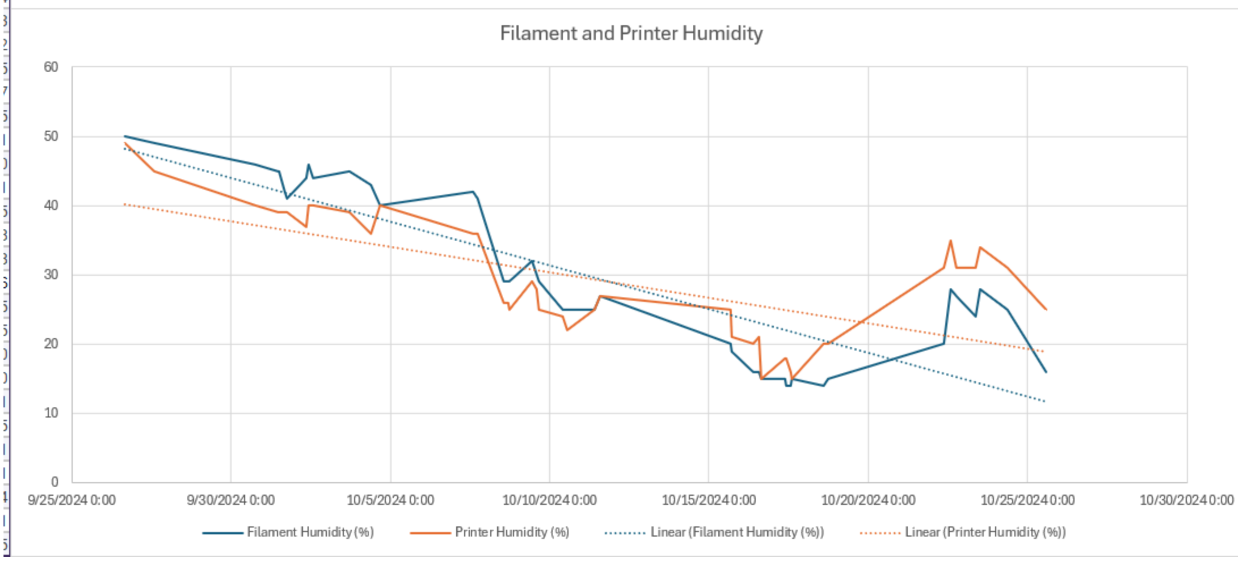
Linear (Printer Temperature (F))


Filament and Printer Humidity
60
50
40
30
20
10
0
9/25/2024 0:00
9/30/2024 0:00
10/5/2024 0:00
10/10/2024 0:00
10/15/2024 0:00
10/20/2024 0:00
10/25/2024 0:00
10/30/2024 0:00
Filament Humidity (%)
Printer Humidity (%)
Linear (Filament Humidity (%))
Linear (Printer Humidity (%))

Testing Procedures

These filaments will be put through a series of quantitative and qualitative tests to gauge their differences. These tests are designed to evaluate the parameters that make up “print quality”.

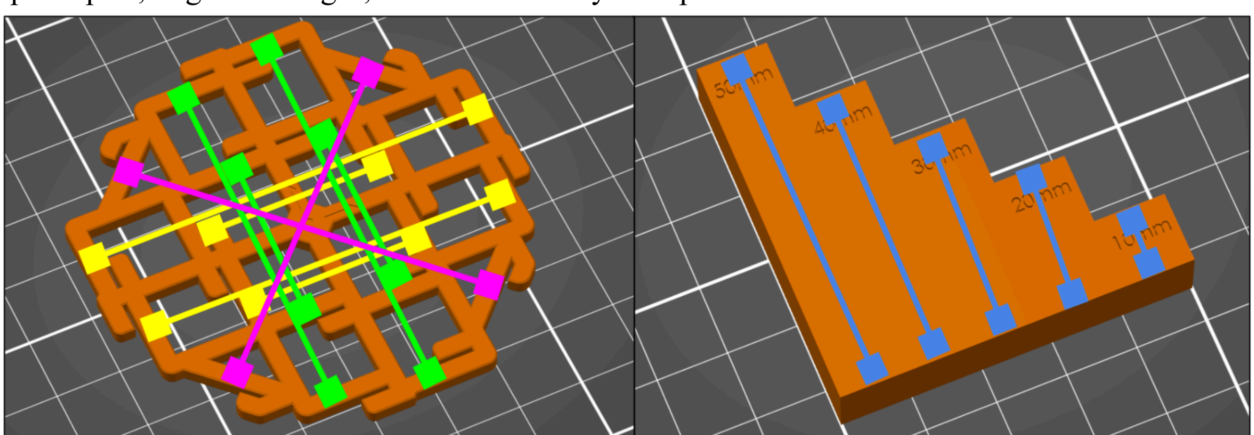
The first quantitative test, the Califlower, is a lattice structure designed to measure dimensional accuracy in the xy-plane. The second test is a stair structure for measuring the z-accuracy. The third test is a negative tolerance test which will gauge the ability of the filament to print parts close together without them fusing. The final test is an inclusive torture test which is designed to show surface, overhang, bridging, stringing, and fine detail quality. The results from the last test will be treated qualitatively, since many factors that comprise “print quality” are difficult to quantify and much easier to understand without numbers.

Dimensional Accuracy

Models: Califlower v29.stl & Z-Staircase.stl

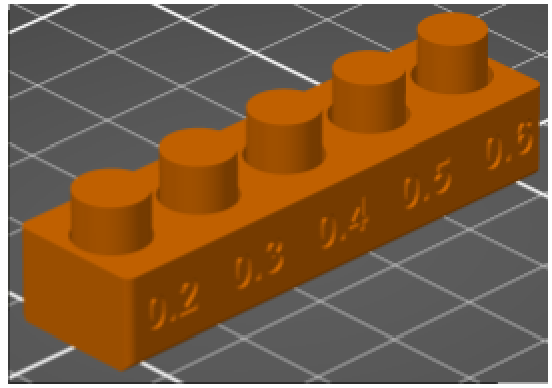
This model was created by Vector3d to more accurately measure the x and y dimensional accuracy of a printer, as well as the skew (how square the x and y axis are to each other). For measuring Z-Axis accuracy, a staircase model is printed standing up with each step being a specific height which will later be measured.

To acquire statistically valid results, at least 30 samples of each model will be printed. Furthermore, all samples will be measured using the Keyence VR-3200, an automatic 3D measurement system. With only one reference photo, one can take many scans of consecutive follow up samples, align the images, and automatically extrapolate dozens of measurements.



X, Y, Z, and diagonal measurements on the two models

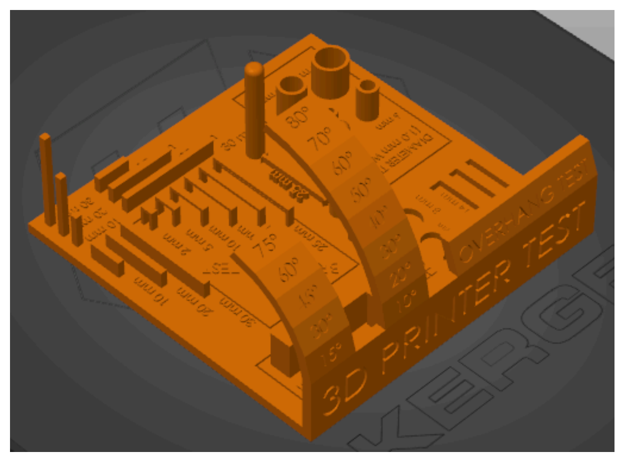
Negative Tolerance Test



The next test is about negative tolerance, or how close together different objects can be printed without fusing. This is important for printing features close together, making "print in place" assemblies that can have motion without assembly, and printing very small "negative" features.

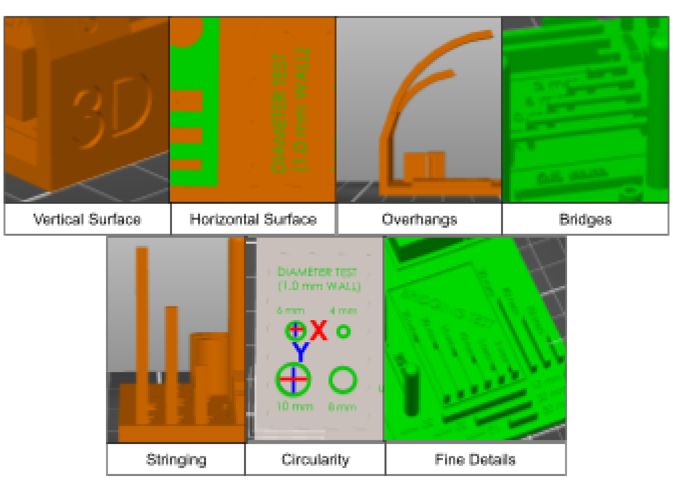
The test will be performed by one person, so keep qualitative assessments consistent. Each cylinder will be pushed on, and then rated on a scale of 0-5 for how difficult it was to separate from the main body, with 0 being "no force" (if it popped out when removing the part from the build plate), and 5 being the force required to break the plastic (or if it didn't separate). The scores will then be averaged for each gap and compared between brands.

Intangibles / Gen. Print Quality



The final test will be using a torture test model (pictured right) which pushes the limits of the printer and includes features and shapes that are designed to showcase any weakness in the system. There are a few qualitative factors that contribute to print quality and tolerance that are difficult to measure quantitatively. For each filament, the torture test model will be printed five times back to back to ensure consistent results. The parameters that will be observed are **bridging, stringing, surface finish, and top layer quality.**

Due to the qualitative nature of the test, it's hard to provide an exact benchmark for which features are better or worse. Ideally, the fewer comments about the print mean a better result, meaning as close to the original model as possible. Since there is no precedent for this test, we will simply compare the original model for each of the categories. Screenshots of the model and the relevant areas are shown below:



Results

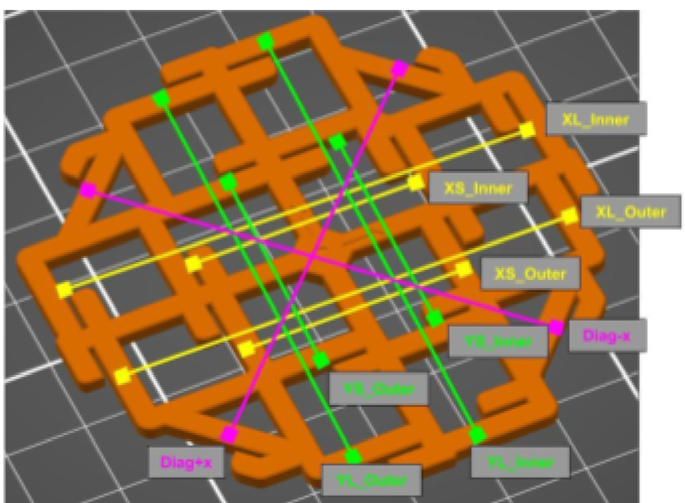
Overall, the Polymaker filament performed slightly- but noticeably- worse than Matterhackers across all tests. Polymaker consistently overshot in terms of dimensional accuracy, egregiously so in the Z dimension, whereas Matterhackers was more or less on target. Polymaker also had more difficult separation during the negative space tolerance test, and multiple subpar details that fell well below Matterhackers.

Dimensional Accuracy Test - Califlower

For each filament 54 Califlower samples were printed. Each sample was then measured with the Keyence using batch analysis. The table below shows the average and standard deviation of each measurement axis. The average difference per sample shows how far each measurement axis is from the ideal length for all 54 models.

The Mk3.9 stays within its +/-0.3mm tolerance for all axes. The 'YL_Outer' axis was the closest to being out of tolerance at -0.275mm average difference across all samples. However, twelve of the printed samples measured slightly out of tolerance on 'YL_Outer' with the worst sample measuring at 59.622mm, which is -0.378mm out of tolerance. These samples were likely within tolerance during printing but shrunk as the plastic cooled down.

Measurement Name		Number (in mm)	Avg. Difference per sample (mm)
XL_Outer	Average	59.929	
	Std.Dev	0.026	-0.071
XS_Outer	Average	30.002	
	Std.Dev	0.027	0.002
XL_Inner	Average	59.939	
	Std.Dev	0.025	-0.061
XS_Inner	Average	30.001	
	Std.Dev	0.022	0.001
YL_Outer	Average	59.825	
	Std.Dev	0.042	-0.275
YS_Outer	Average	29.871	
	Std.Dev	0.028	-0.081
YL_Inner	Average	59.825	
	Std.Dev	0.042	-0.175
YS_Inner	Average	29.871	
	Std.Dev	0.028	-0.129
Diag+x	Average	59.932	
	Std.Dev	0.022	-0.052
Diag-x	Average	59.948	
	Std.Dev	0.018	-0.068



Dimensions Labeled on the Califlower

Measurement Name		Number (in mm)	Avg. Difference per sample (mm)
XL_Outer	Average	59.929	
	Std.Dev	0.026	-0.071
XS_Outer	Average	30.002	
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XL_Inner	Average	59.939	
	Std.Dev	0.025	-0.061
XS_Inner	Average	30.001	
	Std.Dev	0.022	0.001
YL_Outer	Average	59.825	
	Std.Dev	0.042	-0.275
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	Std.Dev	0.022	-0.052
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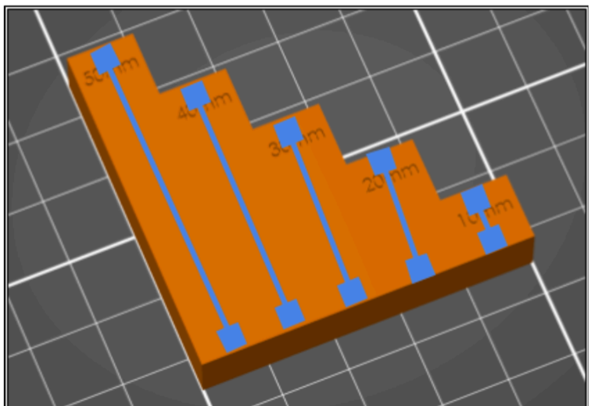
	Std.Dev	0.018	-0.068

Z-Staircase

For each filament 30 samples of the Z-Staircase model were printed. The samples were all measured using batch analysis on the Keyence.

The largest variance for the average difference of each sample was only -0.068mm, well within the +/-0.1mm Z tolerance stated by Prusa. The measured heights are all evenly divisible by the layer height (0.2mm) so this level of consistent accuracy is expected.

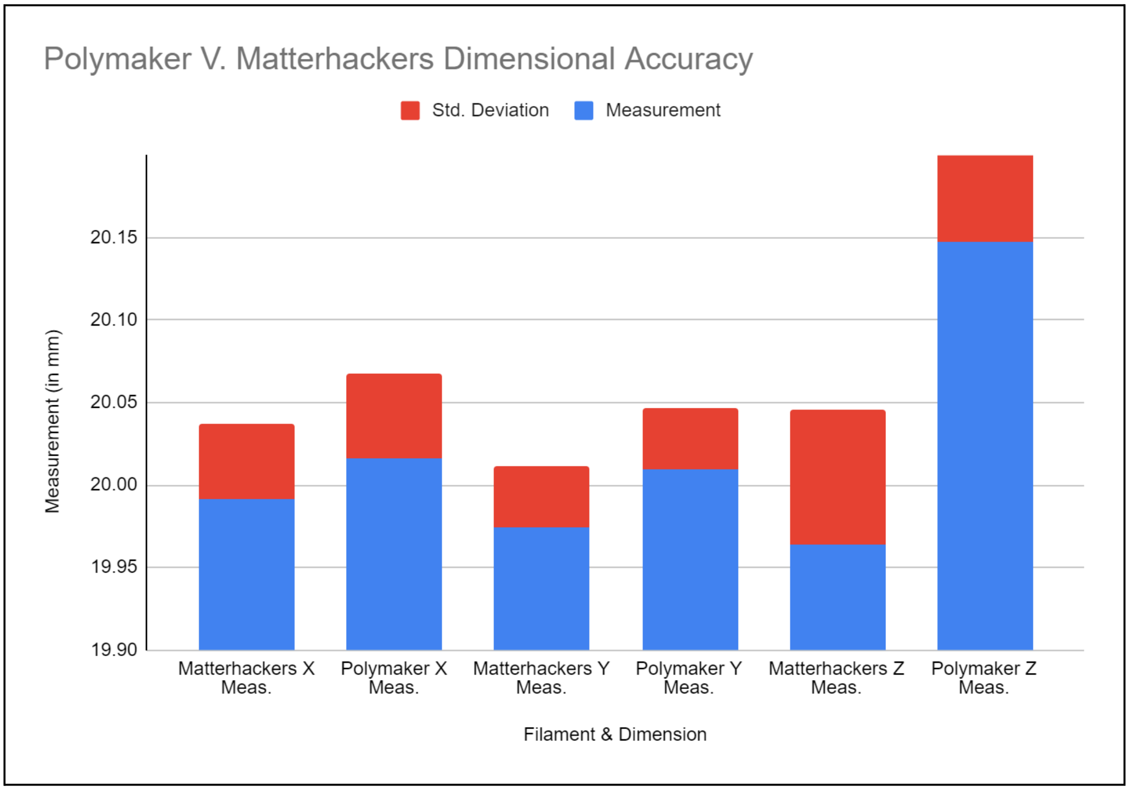


Z-Staircase heights

Measurement Name		Number (in mm)	Avg. Difference per sample (mm)
50mm	Average	49.941	0.059
	Std.Dev	0.041	
40mm	Average	39.969	0.031
	Std.Dev	0.050	
30mm	Average	30.003	-0.003
	Std.Dev	0.020	
20mm	Average	20.041	-0.041
	Std.Dev	0.124	
10mm	Average	10.069	-0.068
	Std.Dev	0.043	

Measurement Name		Number (in mm)	Avg. Difference per sample (mm)
50mm	Average	49.941	0.059
	Std.Dev	0.041	
40mm	Average	39.969	0.031
	Std.Dev	0.050	
30mm	Average	30.003	-0.003
	Std.Dev	0.020	
20mm	Average	20.041	-0.041
	Std.Dev	0.124	
10mm	Average	10.069	-0.068
	Std.Dev	0.043	

After all of the measurements were taken, it became clear that the Matterhackers filament- even after being composed of multiple different rolls- was consistently more dimensionally accurate than the Polymaker filament. Below is a chart that shows the measurement difference between the two filaments.



As shown, the Matterhackers filament was under the target dimension consistently, while also similar standard deviation as Polymaker. This is also reflected when running multiple z tests compared to multiple different expected averages.

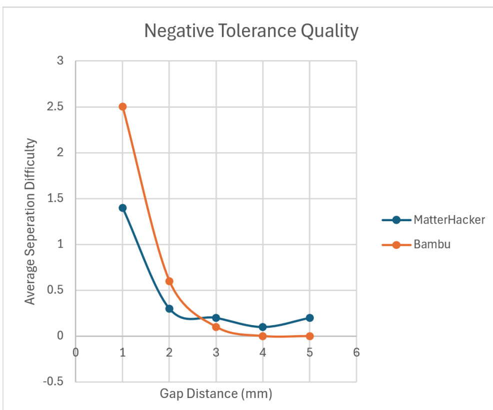
Polymaker Probability of the sample mean being greater than the sample population											
Dim. / Avg	19.95	19.96	19.97	19.98	19.99	20	20.01	20.02	20.03	20.04	20.18
X	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.75	1.00	1.00	1.00
Y	0.00	0.00	0.00	0.00	0.00	0.01	0.58	1.00	1.00	1.00	1.00
Z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

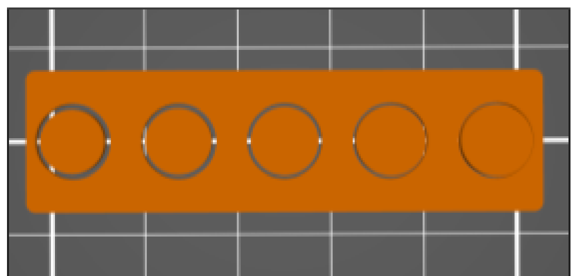
Matterhackers Probability of the sample mean being greater than the sample population											
Dim. / Avg	19.95	19.96	19.97	19.98	19.99	20	20.01	20.02	20.03	20.04	20.18
X	0.00	0.00	0.00	0.00	0.34	0.96	1.00	1.00	1.00	1.00	1.00
Y	0.00	0.00	0.12	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Z	0.04	0.31	0.76	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00

The p-values above show that the Matterhackers cubes are more likely to align with the 20mm target dimension on every dimension. Polymaker consistently overshoots, and drastically overshoots on the z dimension when compared to the Matterhackers filament. Despite this, both filaments mostly wall within accepted tolerances for FDM 3d printing, which is +/- 0.2mm at this scale.

Negative Tolerance Test

For each filament, ten tolerance tests were printed in a single batch to mitigate the effects of atmospheric conditions on the PLA. Then, the same technician took all of the models off the bed and felt the amount of force required to separate each cylinder from its slot. The force required was rated on a scale of 0 - 5, zero being no force required and 5 being impossible to





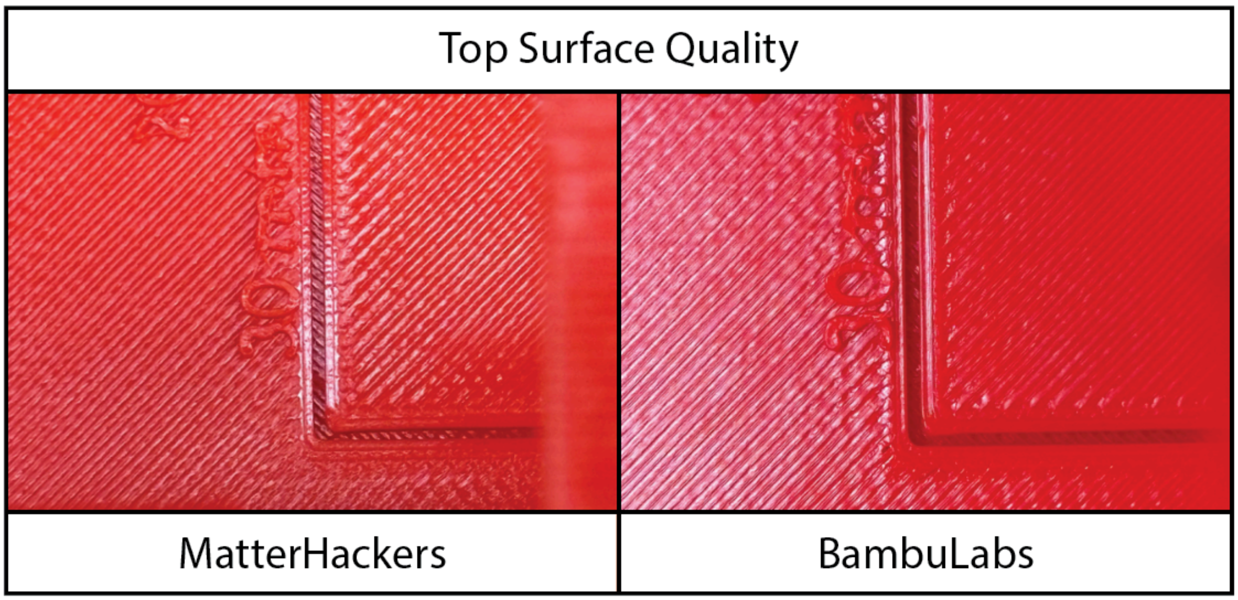
Original Model (Ideal)

remove. **In general, the lower the score, the better**.

Across all ten samples for each filament, the Matterhackers was consistently rated better by the technician, shown by the chart below. Matterhackers was able to achieve zero force separation starting at 0.3mm gap distance, while Polymaker only achieved zero force separation at 0.4mm gap distance. Matterhackers had an average rating of 4 at 0.2mm gap distance while Polymaker had an average rating of 5 for the same gap distance. This means that any parts printed close together or with “print in place” moving parts will more than likely turn out better when printed with Matterhackers compared to Polymaker.

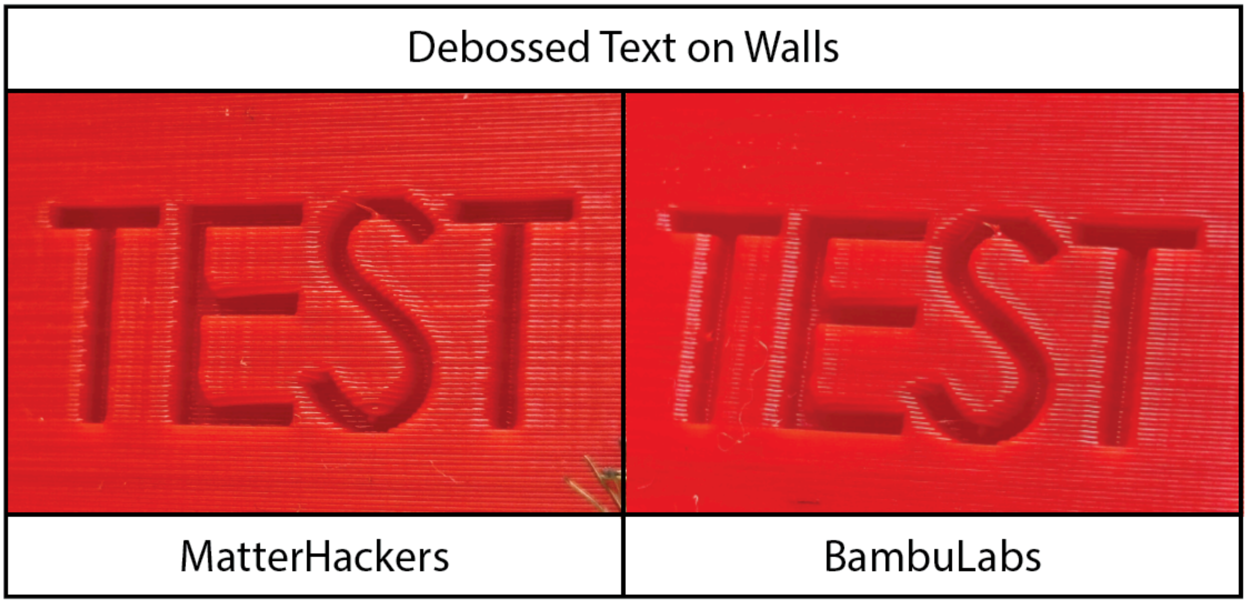
Torture Test

For each filament, the torture test model was printed five times in a row. Between the observed features of **bridging, stringing, surface finish, and top layer quality,** Matterhackers performed noticeably better in most categories. Highlighted below, are the features where a noticeable difference was observed in the results. Other features of the model not mentioned below either had a negligible difference or no difference at all.



Top Surface Quality

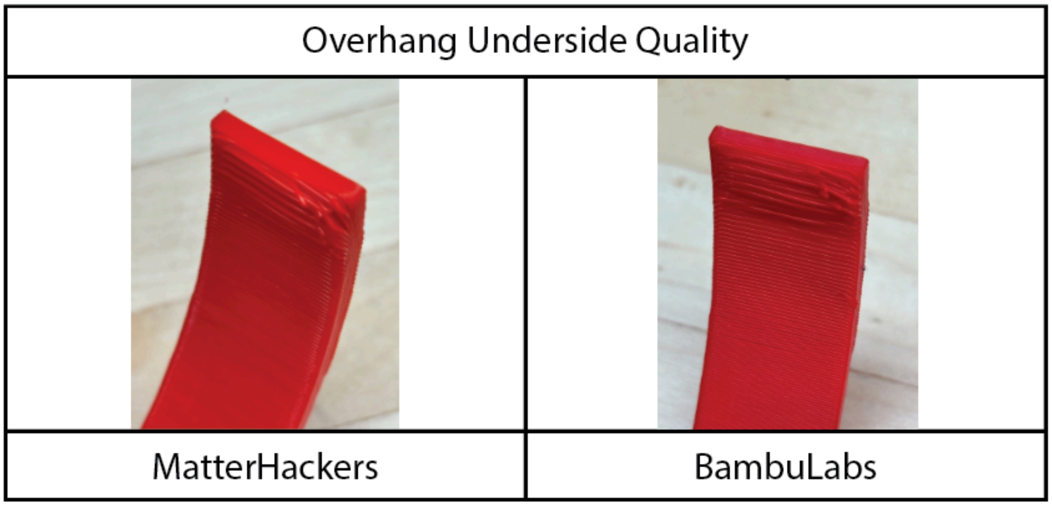
In this top surface quality example, the extrusion lines for the BambuLabs are more uniform and have less visible gaps. BambuLabs also presented with a “glossy” finish while MatterHackers was more “matte”. Matte finishes on materials are normally indicative of an inconsistent surface profile, while glossy correlates with more even surface profiles. These two observations exhibit that **BambuLabsextrudes at a more consistent flow rate,** which allows for better looking and stronger prints. This difference in quality could likely be remedied by adjusting the temperature and extruder flow in the slicer, however that would have to be done for every different model of printer the filament is used on.



Debossed Text on Walls

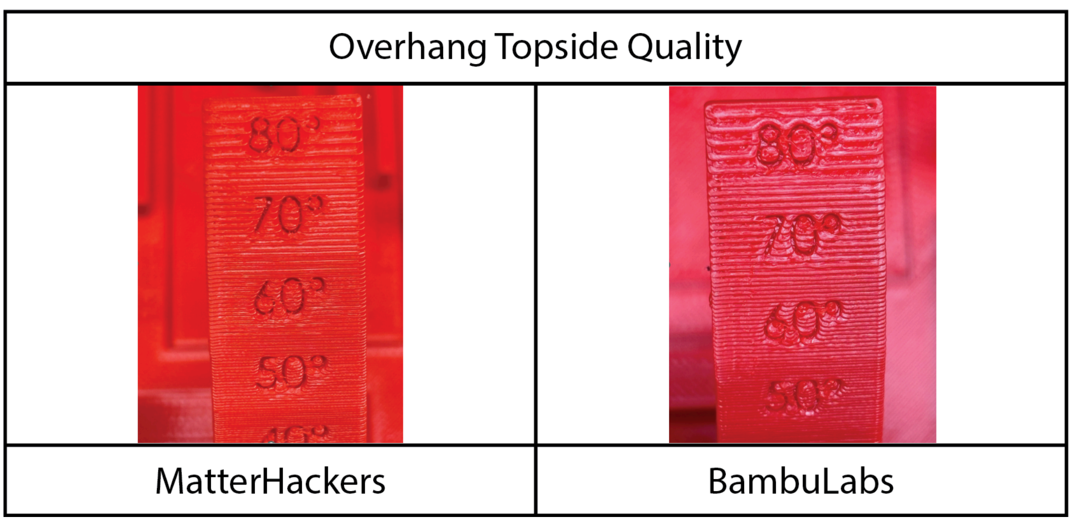
Moving on to debossed text quality on walls, BambuLabs once again produced a more visually pleasing and uniform result. Both filaments have normal artifacts at the edges of each letter and are relatively comparable in quality

This kind of artifact, referred to as “ghosting”, is attributed to excess pressure buildup in the hot-end. When the printhead has to slow down and accelerate again on corners, the pressure results in over-extrusion while the printhead is still accelerating back to its full speed. MatterHacker produced slightly more severe artifacts meaning greater pressure in the printhead. Given that all other factors were the same between prints, ghosting would be indicative of inconsistent extrusion- also observed in the top surface quality section.



Overhang Underside Quality

For the overhang feature on this model, BambuLabs performed *slightly* better than MatterHackers. Only at the most extreme overhang angle of 80 degrees, did the filaments struggle. However, BambuLabs filament produced slightly more consistent and relatively uniform layers. MatterHackers shows clear signs of layers failing to adhere to the previous. Once again, this can be **attributed to MatterHackers consistently poor extrusion as previously observed**. Once a layer is printed poorly, the following layers will not have a consistent base to build on. This domino effect, combined with the apparent extrusion issues, lead to MatterHackers producing overhangs which are geometrically inaccurate and mechanically



weaker than similar features on BambuLabs. Both filaments performed similarly in this test.

Overhang Topside Quality

The MatterHackers extrusion issues are further highlighted by difficult features such as debossed text on the top side of steep overhangs. While the BambuLabs text remained coherent and readable, MatterHackers produced shrunken text indicative of over-extrusion. Overall, MatterHackers produced a slightly less successful result in this feature.

Conclusion

Overall, the BambuLabs filament consistently showed better performance in measurable testing or it was just as good if not better than the MatterHackers in all tests. It had better dimensional accuracy, more consistent negative tolerances, and performed just as good or better performance than MatterHackers in every feature on the Torture Tests.

However, it's important to note the scope of this testing and report is limited to strictly following the Fab Farm SOP which is to use the default “Generic PLA” profile within Prusaslicer. The Polymaker prints can be notably improved by having a specific profile tuned to the filament. The testing framework encountered difficulties when Keyance equipment consistently failed which potentially led to loss of ~5 samples’ data. Overhang testing can also be expanded to include bridging tests to judge cooling capabilities of filament in a more controlled manner as compared to a semi-blind overhang. But as it stands, Matterhackers is much better suited for the generic profile.