Polymaker v.s Matterhackers PLA

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Report written by Brandon Hill and Ali Niazi

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 Polymaker PolyLite PLA. Polymaker filament was chosen to be tested due to its lower cost per kilo and their use of cardboard spools which help 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

Polymaker PLA

Comparable Filament Specs:

Both the Matterhackers and Polymaker PLA aim to be low cost filament with lots of options for colors. 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 the process which they use to turn raw plastic into filament spools.

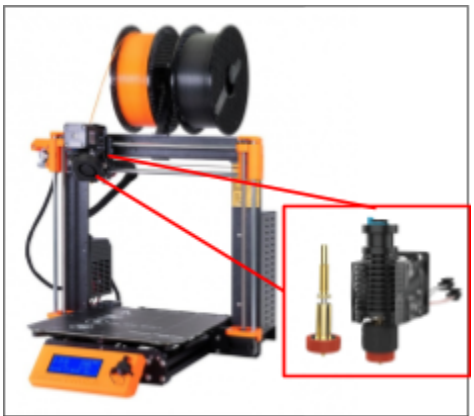
Specification	**Polymaker PolyLite PLA**	**Matterhackers Build PLA**
Printing Temperature	190˚C - 230˚C (210C ± 20C)	205C ± 15C
Bed Temperature	25˚C - 60˚C (42.5C ± 17.5C)	40C ± 15C
Printing Speed	40mm/s - 60mm/s	40mm/s - 60mm/s
Diameter Tolerance	± 0.05mm	± 0.03mm

Assumptions & Disclosures

During the course of testing, we took measures to control 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.)

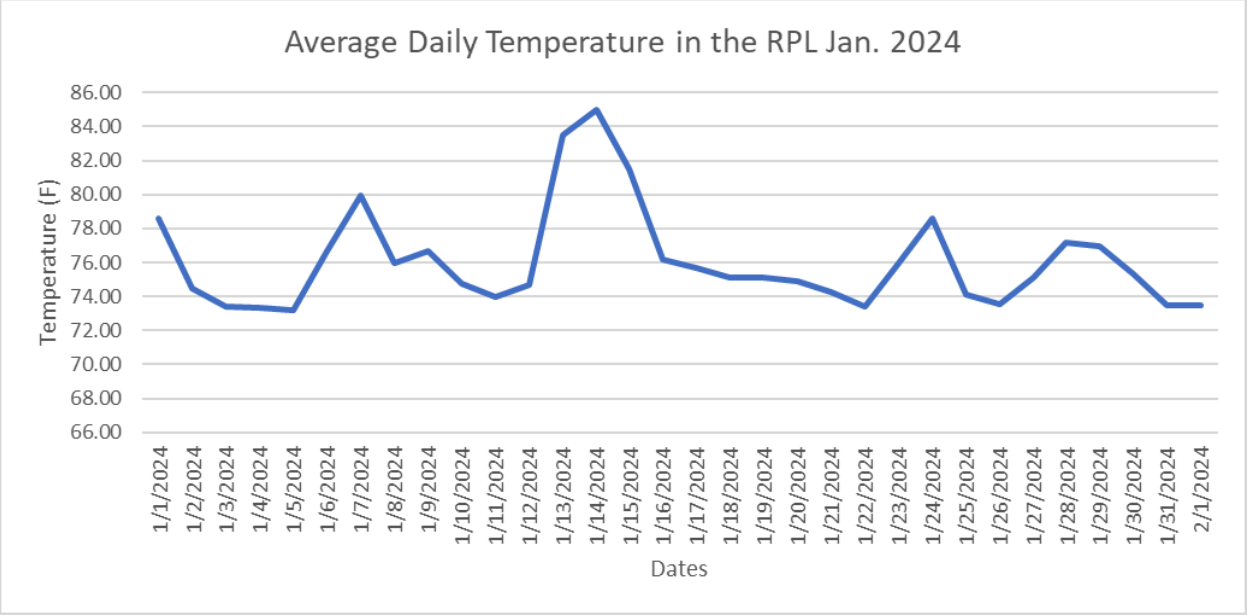
When filament was initially received, it was placed in a resealable plastic bag for 24 hours before being used. Once each filament was loaded into the printer, all test prints for that filament were completed sequentially in the order as follows: 5x torture tests, 5x negative tolerance tests (at the same time), and then 30x dimensional accuracy cubes. Other disclosures and assumptions are as follows:

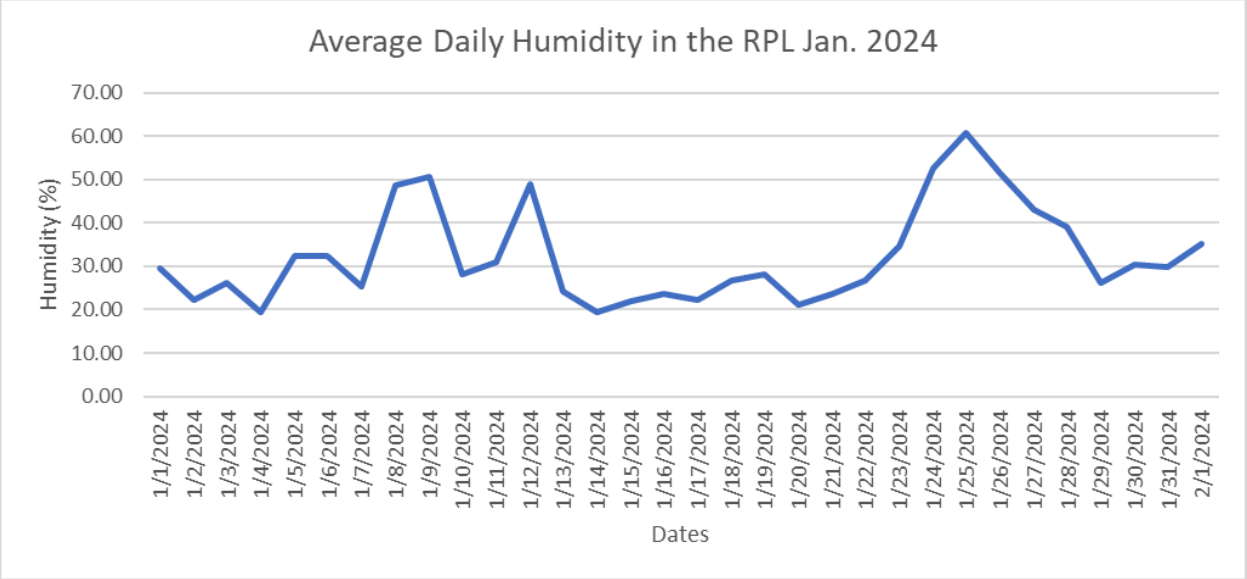
- The printer we used for this test is a Prusa Mk3s with a Revo hot-end and Revo firmware, using a hardened 0.6mm nozzle. We chose the 0.6mm nozzle to be representative of the Fabrication Farm’s printer fleet, or representative of other average printers that would be used for rapid prototyping.
- The “Generic PLA” default profile from Prusaslicer will be used for all tests and both filaments. Each filament would benefit from tuning, but most SOPs don’t include custom profiles.



Prusa Mk3s with Revo Hotend

- An issue arose during the Matterhackers testing where filament ran out overnight. Coincidentally, Terrapin Works ran out of black Matterhackers filament entirely. Therefore the Matterhackers cubes were printed with multiple rolls of black, and then finished off with gray, none of which beyond the initial one were placed in a plastic bag to dehydrate. **This is certainly the worst case scenario for dimensional accuracy, due to the multiple reloads done within the same print,** thus consistency between samples will be a better indicator of filament quality than dimensional accuracy overall.
- The temperature and humidity of the room during the month of January averaged 76.07F and 32.05% respectively. The actual day to day distributions are as follows:



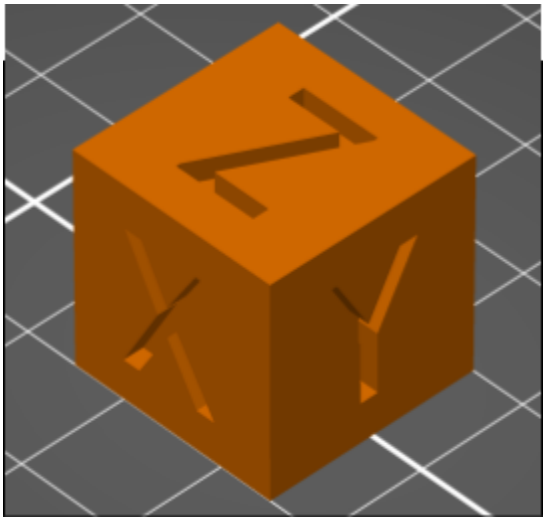


Testing Procedures

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”.

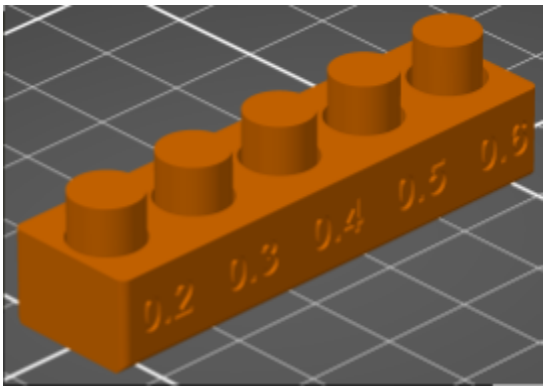
The first, and only truly quantitative test, is a 20x20x20mm cube which will then be measured to compare dimensional accuracy. The second test is a negative tolerance test which will gauge the ability of the filament to print parts close together without them fusing. The final test is an inclusive torture test which is designed to show surface, overhang, bridging, stringing, and fine detail quality. The results from the last two tests will be treated qualitatively, since many factors that comprise “print quality” are difficult to quantify and much easier to understand without numbers.

Dimensional Accuracy



To measure dimensional accuracy, we will be printing a cube similar to the one on the right, using the same printer .gcode file for each filament. This cube should be 20mm in all dimensions, so to verify this we will be taking nine measurements per cube- the width and height of each face, and each edge that intersects the faces. These results will then be compared to the expected dimensions, run through a Student t-test with a 95% confidence interval to conclude if the results are significantly different.

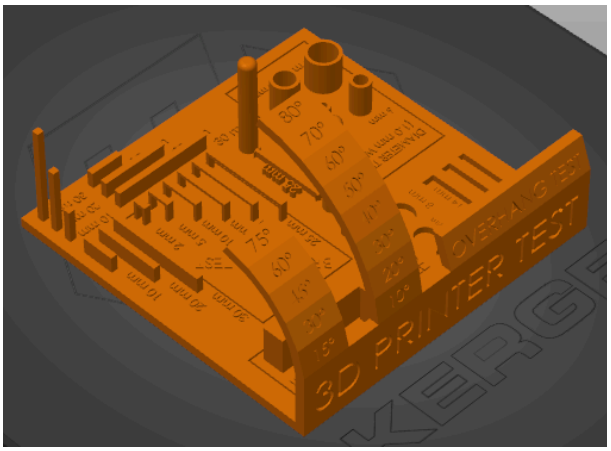
Negative Tolerance Test



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.

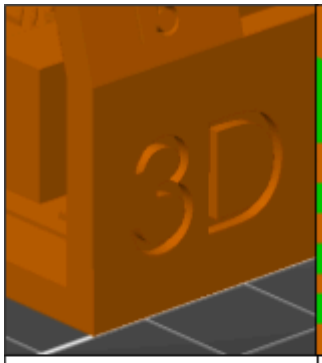
The test will be performed by one person, so keep qualitative assessments consistent. Each cylinder will be pushed on, and then rated on a scale of 0-5 for how difficult it was to separate from the main body, with 0 being “no force” (if it popped out when removing the part from the build plate), and 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



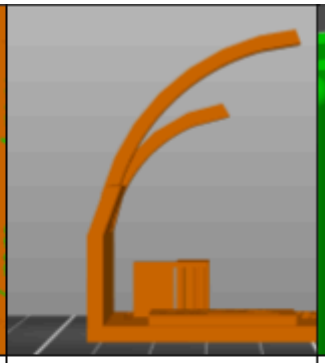
The final test will be using a torture test model (pictured right) which pushes the limits of the printer and includes features and shapes that are designed to showcase any weakness in the system. There are a few qualitative factors that contribute to print quality and tolerance that are difficult to 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:

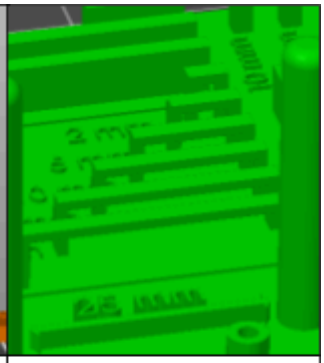


Vertical Surface

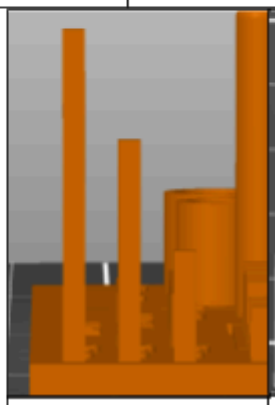
Horizontal Surface



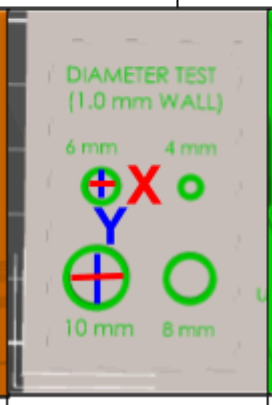
Overhangs



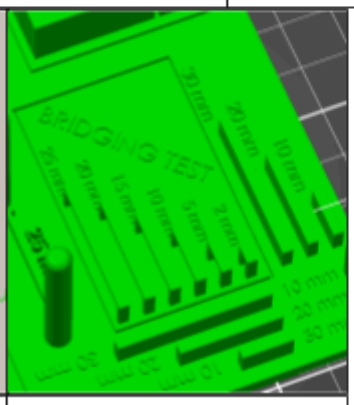
Bridges



Stringing



Circularity



Fine Details

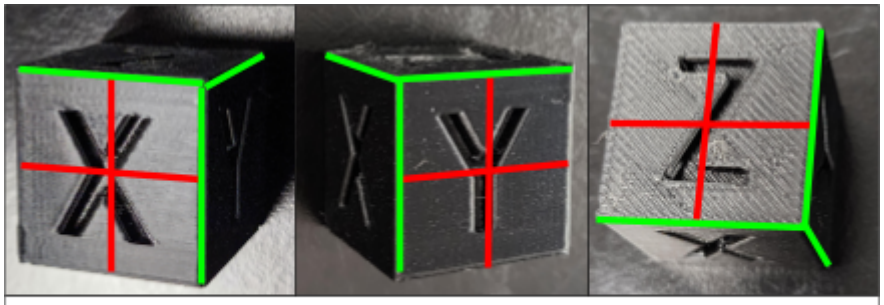
Results

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.

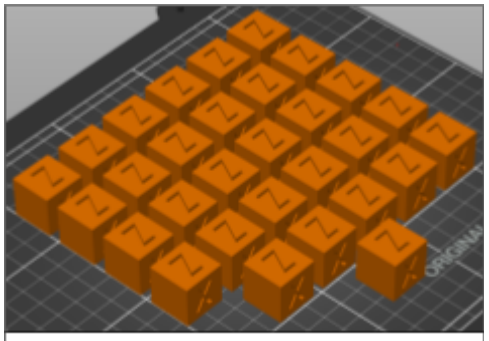
Dimensional Accuracy Test

For this test, 30 cubes were printed for each filament. The cubes were printed in a batch as previously mentioned under “Assumptions and Disclosures”. For each cube, nine different measurements were taken of various faces and edges (pictured below).

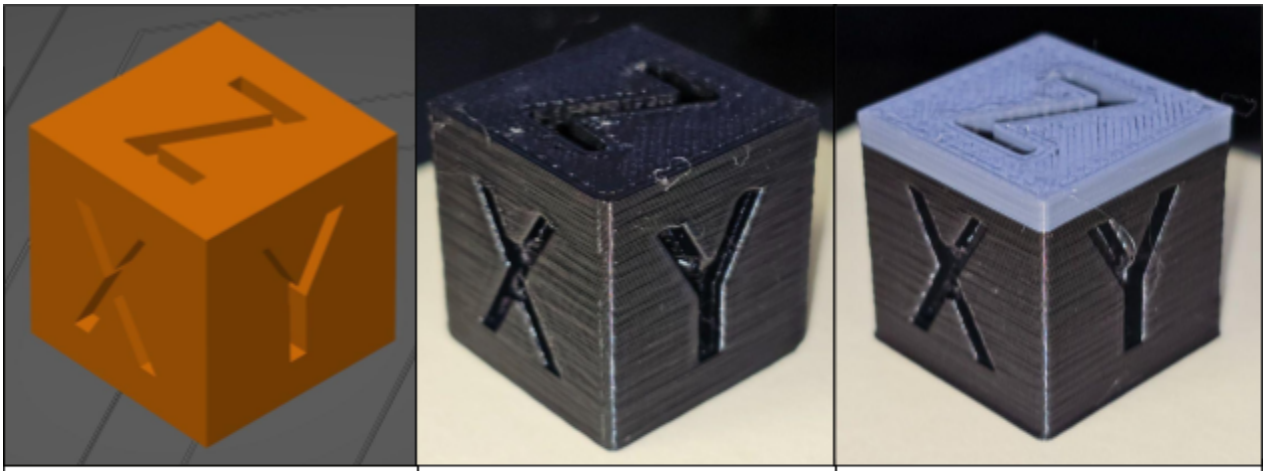
It is worth noting that the Matterhackers cubes should be markedly worse due to them being composed of 5 different rolls and 2 different colors. The history of the scrap rolls was also not accounted for nearly as well, meaning that effects from humidity and certain temperature storage can not be properly accounted for.



Relevant cube measurement faces, with middle lengths marked in red and edges marked in green. (not to scale)

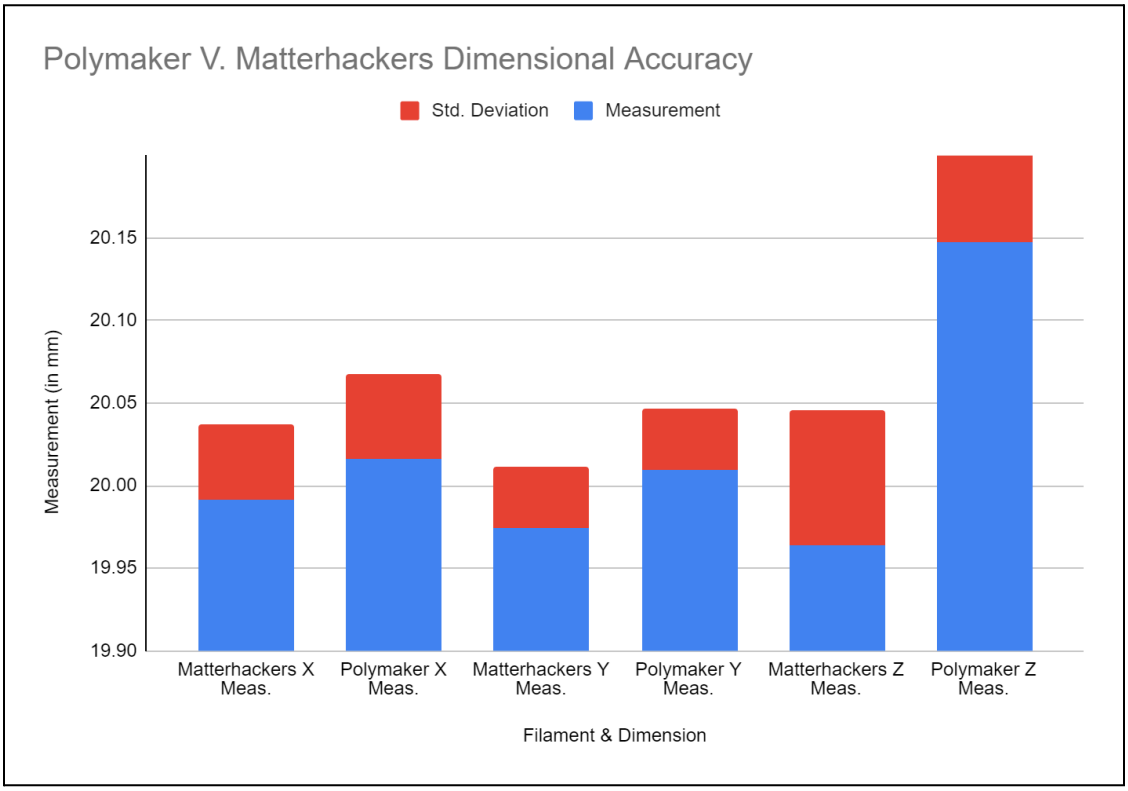


Batch print of Dimensional Test Cubes



Original Model (Ideal)	Polymaker	Matterhackers

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.

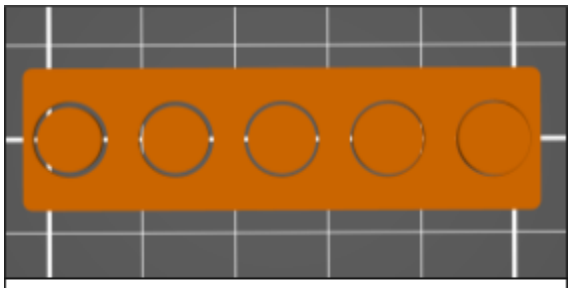
Polymaker Probability of the sample mean being greater than the sample population											
Dim. / Avg	19.95	19.96	19.97	19.98	19.99	20	20.01	20.02	20.03	20.04	20.18
X	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.75	1.00	1.00	1.00
Y	0.00	0.00	0.00	0.00	0.00	0.01	0.58	1.00	1.00	1.00	1.00
Z	0.00	0.00	0.00	0.00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

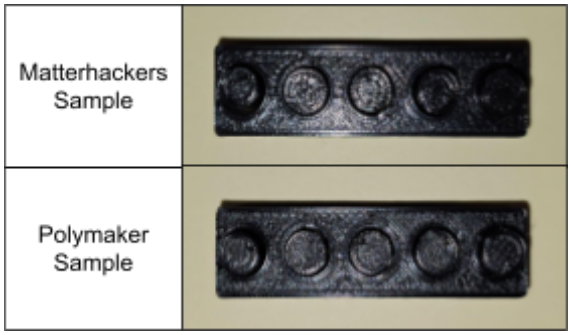
The p-values above show that the Matterhackers cubes are more likely to align with the 20mm target dimension on every dimension. Polymaker consistently overshoots, and drastically overshoots on the z dimension when compared to the Matterhackers filament. Despite this, both filaments mostly wall within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

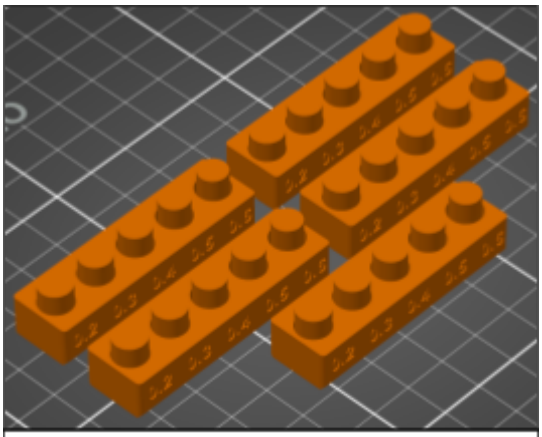
Negative Tolerance Test

For each filament, five 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 remove. **In general, the lower the score, the better**.

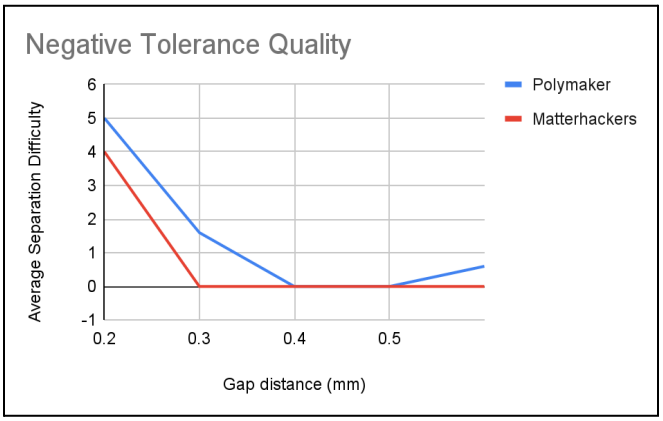


Original Model (Ideal)





Negative Tolerance test batch

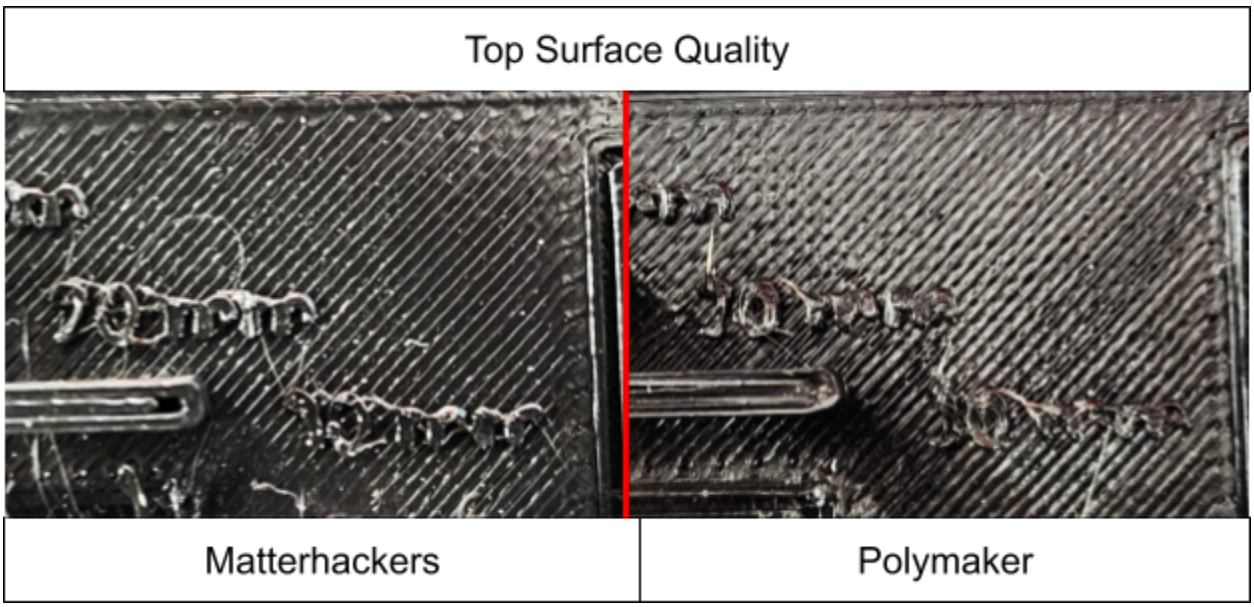


Across all five samples for each filament, the Matterhackers was consistently rated better by the technician, shown by the chart below. Matterhackers was able to achieve zero force separation starting at 0.3mm gap distance, while Polymaker only achieved zero force separation at 0.4mm gap distance. Matterhackers 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

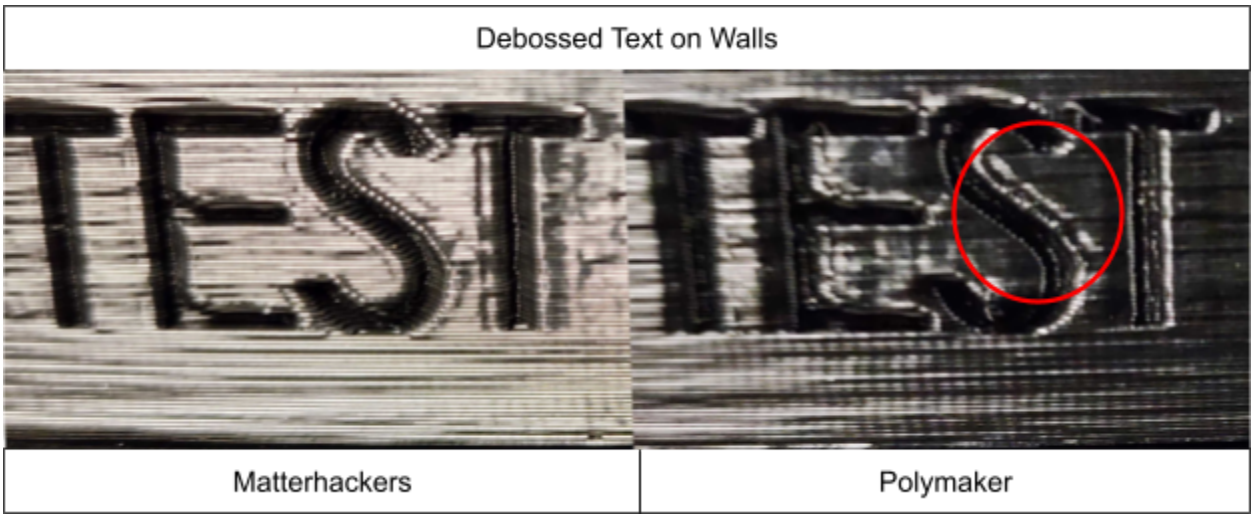
For each filament, the torture test model was printed five times in a row. Between the observed features of **bridging, stringing, surface finish, and top layer quality,** Matterhackers performed noticeably better in most categories. Highlighted below, are the features where a noticeable difference was 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



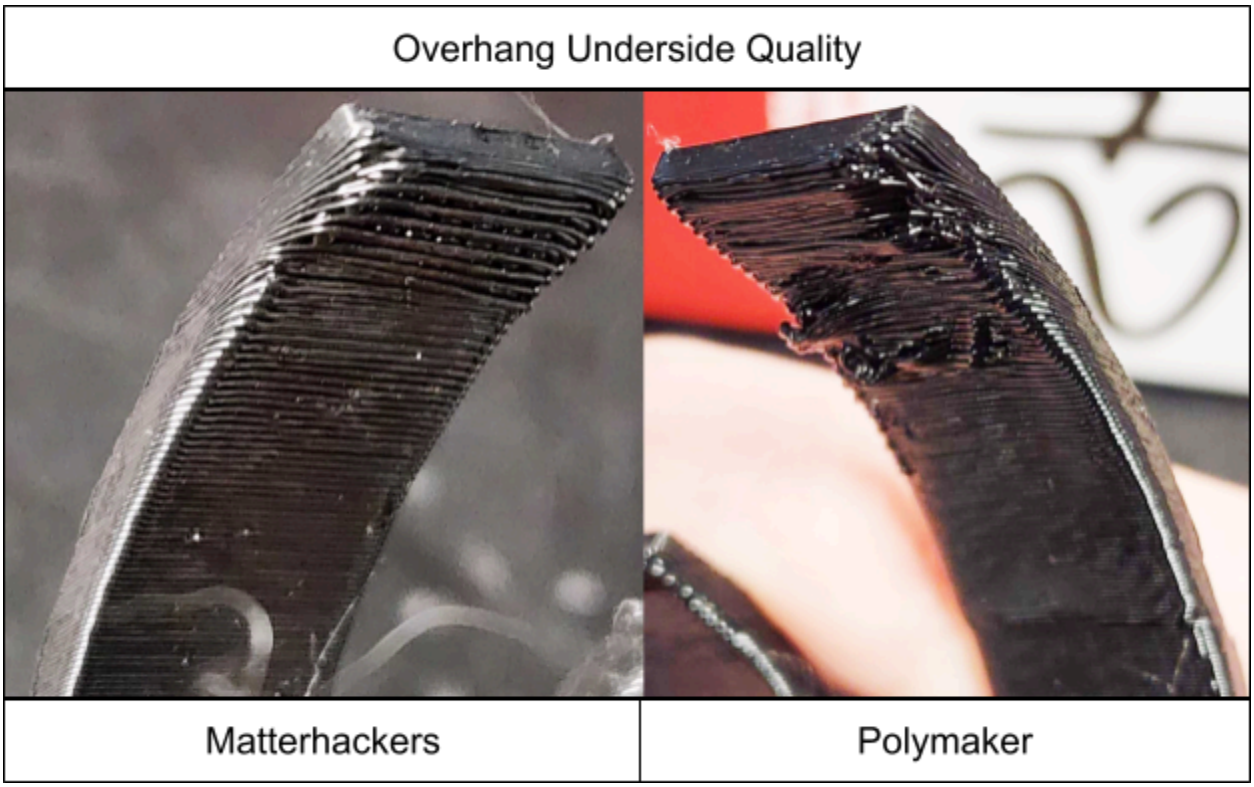
In this top surface quality example, the extrusion lines for the Matterhackers are more uniform and have less visible gaps. Matterhackers also presented with a “glossy” finish while Polymaker was more “matte”. Matte finishes on materials are normally indicative of an inconsistent surface profile, while glossy correlates with more even surface profiles. These two observations exhibit that **Matterhackers extrudes 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



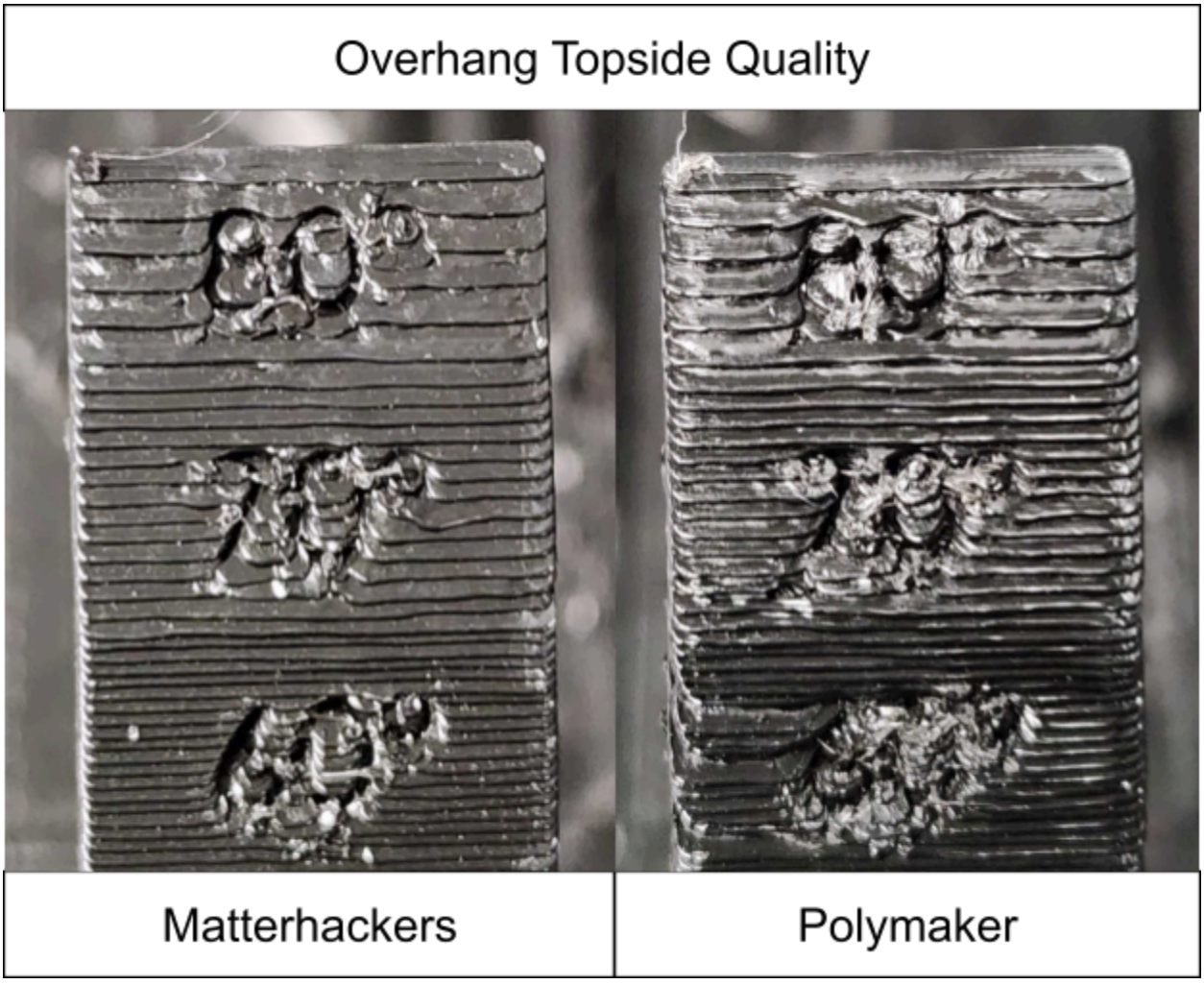
Moving on to debossed text quality on walls, Matterhackers once again produced a more visually pleasing and uniform result. While both filaments have normal artifacts at the corners of each letter, Polymaker's artifacts (circled in red) are noticeably larger and have a greater impact on visual quality.

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. Polymaker produced bigger 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.



For the overhang feature on this model, Matterhackers performed *significantly* better than Polymaker. Even at the most extreme overhang angle of 80 degrees, Matterhackers produced consistent and relatively uniform layers. Polymaker shows clear signs of layers failing to adhere to the previous. Once again, this can be **attributed to Polymakers 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 Polymaker producing overhangs which are geometrically inaccurate and mechanically weaker than similar features on Matterhackers.

Overhang Topside Quality



The Polymaker extrusion issues are further highlighted by difficult features such as debossed text on the top side of steep overhangs. While the Matterhackers text remained coherent and readable, Polymaker produced unreadable results. There is a wide range of extrusion inconsistencies visible on this section, from under-extrusion in the “8” at the top to over-extrusion on the degree symbol. Overall, Polymaker did not produce a successful result in this feature.

Conclusion

Overall, the Matterhackers filament consistently showed better performance in measurable testing or it was just as good if not better than the Polymaker in all tests. It had better dimensional accuracy, more consistent negative tolerances, and performed just as good or better performance than Polymaker 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. But as it stands, Matterhackers is much better suited for the generic profile.