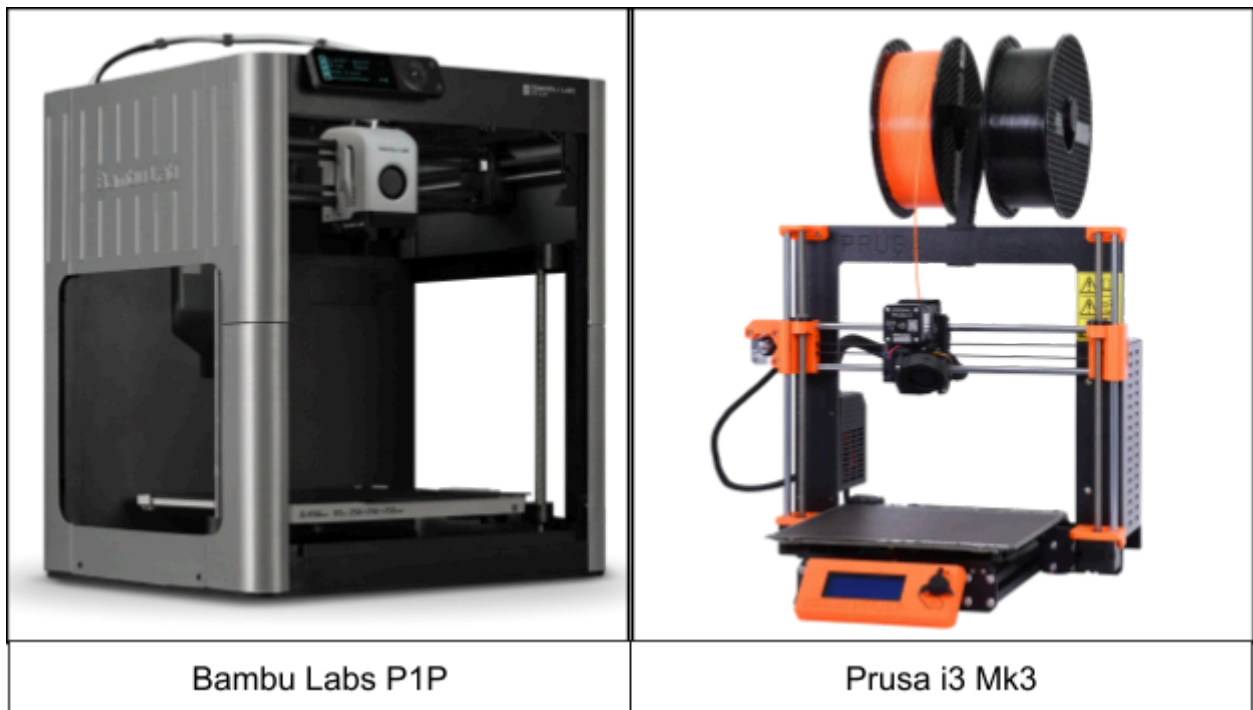


Bambu Labs P1P v.s Prusa Mk3 Comparison

Tests and measurements performed by Brandon Hill and Ali Niazi

What is the goal of this comparison?

The goal of this comparison is to establish whether the Bambu Labs P1P is a significant upgrade over the Prusa Mk3 for the purposes of Keystone usage. The default slicer profiles for each machine will be compared, and how they stack up against each other in a variety of different tests. Profiles will not be tuned to be better, since default profiles are confirmed to work from the manufacturer and should be used by ENES 100 students.



Comparable Printer Specs:

The Bambulabs P1P will be in its default configuration, with the manufacturer slicer “Bambu Studio.” The Prusa Mk3 will be run slightly off of its manufacturer configuration, with an E3D Revo nozzle instead of a standard E3D nozzle, but still using Prusaslicer and manufacturer default profiles. This will mean the Prusa should extrude slightly better than a normal Prusa Mk3 due to the increased volumetric flow, but otherwise it will likely perform the same as any other Prusa Mk3.

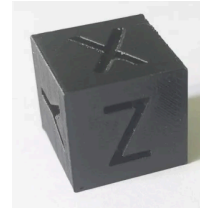
| Specification / Printer | Bambu Labs P1P | Prusa i3 Mk3 |
|-------------------------------------|---|--|
| Build Volume | 256x256x256mm build volume | 250x210x210mm build volume |
| Max Speed & Acceleration | 500mm/s & 20000 mm/s ² | 200 mm/s & 1000 mm/s ² |
| Physical Dimensions (without spool) | 386×389×458mm | 500×550×400mm |
| Motion System | CoreXY w/ lightweight toolhead | Bed-slinger |
| Gcode Delivery Method | Cloud, SD Card | SD Card |
| Bed Leveling Method | 5x5 point touch, load cells within the bed: leads to very consistent first layers. | 3x3 - 7x7 point touch, Induction sensor: requires nozzle offset calibration |
| Additional Notable Features | <ul style="list-style-type: none"> - Vibration Compensation - Input shaping: more consistent extrusion shape - 720p 0.5fps remote monitoring camera - All- Metal hot-end - Magnetic Build Plates | <ul style="list-style-type: none"> - Nearly entirely 3d printed: very repairable. - Open source hardware: very modifiable - Magnetic Build Plates |

Testing Procedure

The first issue with designing a testing procedure is that the Mk3 and the P1P don't necessarily use the same layer heights for their default profiles. Therefore a variety of different default print profiles will be tested from each printer, using Matterhackers 1.75mm Gray PLA.

Keeping in mind the knowledge and capabilities expected of most ENES 100 students, this test will consist of only a few simple test prints to compare and verify features of the printers that will likely be consistently used in the ENES 100 course. The following will be looked into:

- **Dimensional Accuracy:** This is for the sake of ensuring that assemblies fit together well, and parts that need to be a certain weight or dimension actually end up as such.
 - For this, five 20mm x 20mm x 20mm calibration cubes will be printed, such as the one to the right.
 - After they are printed, the X, Y, and Z dimensions will be measured using calipers.
 - These measurements will then be averaged across all 5 samples and compared between each print profile for each printer.
 - **Lower average difference is better**, but dimensions within one half nozzle width ($\pm 0.2\text{mm}$) are considered acceptable for most FDM 3d printers.
 - The following print profiles will be tested: excluding the very finest setting from each printer, due to them normally being used for model printing.



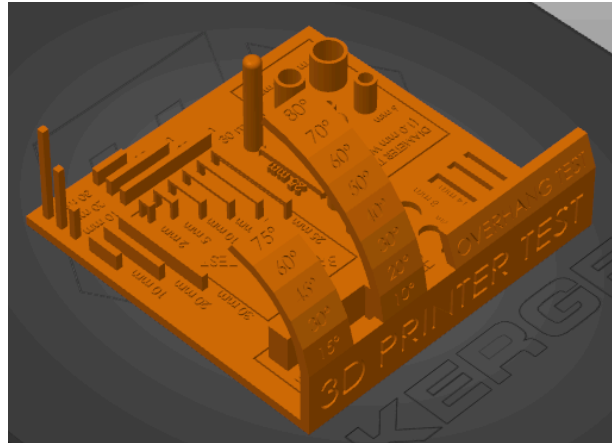
| | |
|---|---|
| <p>Bambu Profiles to test:</p> <ol style="list-style-type: none"> 1. 0.12mm Fine 2. 0.16mm Optimal 3. 0.2mm Standard 4. 0.2mm Strength 5. 0.24mm Draft 6. 0.28mm Extra Draft <p>Other Notes: Using the “standard” speed on the printer. It has a “sport” and “ludicrous” mode to go faster.</p> | <p>Prusa Profiles to test:</p> <ol style="list-style-type: none"> 1. 0.15mm Quality 2. 0.15mm Speed 3. 0.20mm Quality 4. 0.20mm Speed 5. 0.3mm DRAFT <p>Other Notes: Prusa Mk3 has a Revo nozzle, which should have similar characteristics to the normal E3D nozzle, but not identical.</p> |
|---|---|

- **Negative Tolerance**, if parts are printed closely together, or there are “print-in-place” assemblies, the parts should be able to print distinctly and not fuse together. The test will be done with a part such as the one on the right, with each disc in the ring having a different spacing from the main body.



- For this, three of these pieces on each 0.2mm layer height profile for each printer.
- After the parts are printed, each of the discs will be rotated, noting which ones either don't rotate or rotate with difficulty.

- **The more discs that can rotate directly off of the printer, the better.** This would mean that more parts can be printed extremely close together without fusing, allowing more complex designs.
- **Print Time:** The slicers have print time estimates accurate within 5%, so the time estimates will be used as the print times.
 - **Lower print time is better**, of course.
- **Qualitatives:** There are a few qualitative factors that contribute to print quality and tolerance that are difficult to measure quantitatively. Instead of measuring each of these features, a “torture test” will be printed that makes most printers struggle, and then observing and noting print defects. The parameters that will be measured are bridging, stringing, and fine detail resolution. The model will be the one pictured to the right.



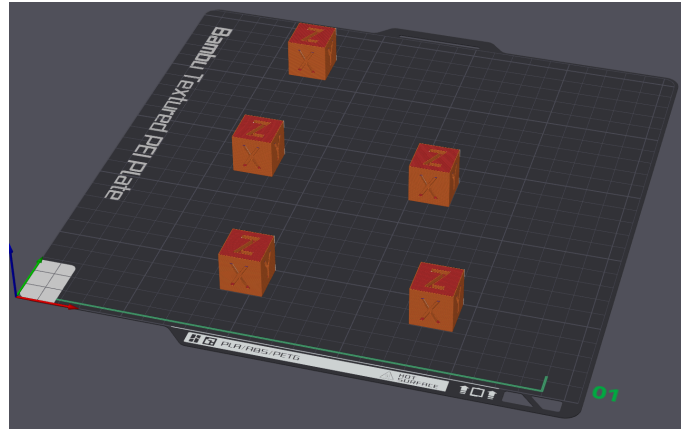
- **The fewer comments, the better.** Due to the qualitative nature of the test, it's hard to provide an exact benchmark of which features are required to be better or worse, but for the most part, the closer it is to the STL, the better.

Results

Overall, the Bambu Labs P1P and the Prusa i3 Mk3 performed very similarly in all categories, with the Bambu Labs P1P having slightly better visual features with similar dimensional accuracy. The Bambu had drastically improved print times, however, to the extent of outputting parts twice as fast.

Dimensional Accuracy Test

It was decided to slice each file with 5 different cubes printed sequentially (pictured right), and measured as such. Each slicer has an option to print objects individually. The difference of the average to the 20mm baseline was measured, the closer it is to 0 the better the printer is. To find this number, the dimensions of 5 cubes were averaged and subtracted from 20mm.



| | | | | Average Difference | | | |
|------------------------|-------|-------|-------------|--------------------|--------|--------|--------|
| Target Dimension: 20mm | | | | X (mm) | Y (mm) | Z (mm) | |
| Bambu Labs P1P | | | | 0.12mm | -0.106 | -0.090 | 0.040 |
| | | | | 0.16mm | -0.104 | -0.088 | 0.084 |
| | | | | 0.2mm STD | -0.102 | -0.078 | 0.036 |
| | | | | 0.2mm STR | -0.046 | -0.016 | -0.008 |
| Min. | Range | Max | 0.24mm | -0.092 | -0.070 | 0.132 | |
| -0.106 | 0.238 | 0.132 | 0.28mm | -0.064 | -0.042 | 0.020 | |
| Prusa i3 Mk3 | | | | 0.15mm Qual | 0.010 | 0.006 | 0.088 |
| | | | | 0.15mm Spd | 0.032 | 0.016 | 0.094 |
| | | | | 0.2mm Qual | -0.004 | 0.016 | 0.104 |
| | | | | 0.2mm Spd | -0.014 | -0.040 | -0.112 |
| Min. | Range | Max | 0.3mm Draft | 0.022 | 0.056 | -0.120 | |
| -0.120 | 0.224 | 0.104 | | | | | |

The results show that the Bambu Labs P1P has consistently worse dimensional accuracy than the Prusa Mk3. It has a slightly higher range, but it is within human measuring error. Despite that, the P1P still consistently falls within ± 0.2 mm of the target dimension of 20mm, as well as the Mk3. Neither printer has an edge over the other in terms of dimensional accuracy.

Negative Tolerance Test

The tolerance test ended up very similar between the two printers, with a notable difference between the efficacy of their “faster” and “slower” 0.2mm profiles. None of the 0.05mm or 0.1mm tolerance disks were able to spin, either directly off of the plate or with any amount of force applied (barring breaking the plastic).

All individual results were recorded, but for simplicity it was pared down to this chart. A one point was given to the profile if it could spin, a half point if it could spin with force, and no points if it couldn't. The results are as follows:

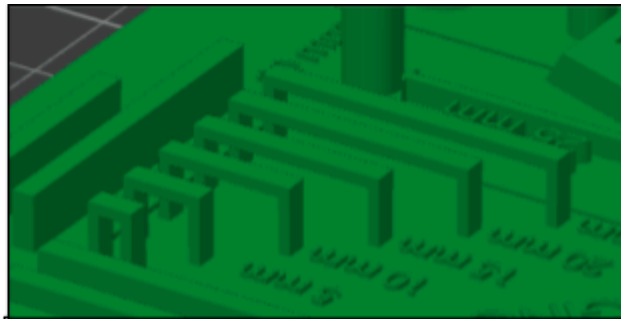
| Profile | Tolerance (mm) | How many spun? | Profile | Tolerance (mm) | How many spun? |
|----------------|----------------|----------------|---------------|----------------|----------------|
| Mk3 0.2mm Qual | 0.05 | 0 | P1P 0.2mm STR | 0.05 | 0 |
| | 0.1 | 0 | | 0.1 | 0 |
| | 0.15 | 0 | | 0.15 | 0 |
| | 0.2 | 3 | | 0.2 | 0 |
| | 0.25 | 3 | | 0.25 | 0 |
| | 0.3 | 3 | | 0.3 | 0.5 |
| Mk3 0.2mm Spd | 0.05 | 0 | P1P 0.2mm STD | 0.05 | 0 |
| | 0.1 | 0 | | 0.1 | 0 |
| | 0.15 | 1.5 | | 0.15 | 0.5 |
| | 0.2 | 3 | | 0.2 | 3 |
| | 0.25 | 3 | | 0.25 | 3 |
| | 0.3 | 3 | | 0.3 | 3 |

The 0.2mm Strength profile on the Bambulabs performed the worst, with the pieces barely being able to spin in place at all. This is likely due to the excessive size of the Z seams, which will be visible in a later test. This causes the tightly spaced parts to be fused together, and therefore unable to spin. Nevertheless, the Mk3 and P1P performed very similarly.

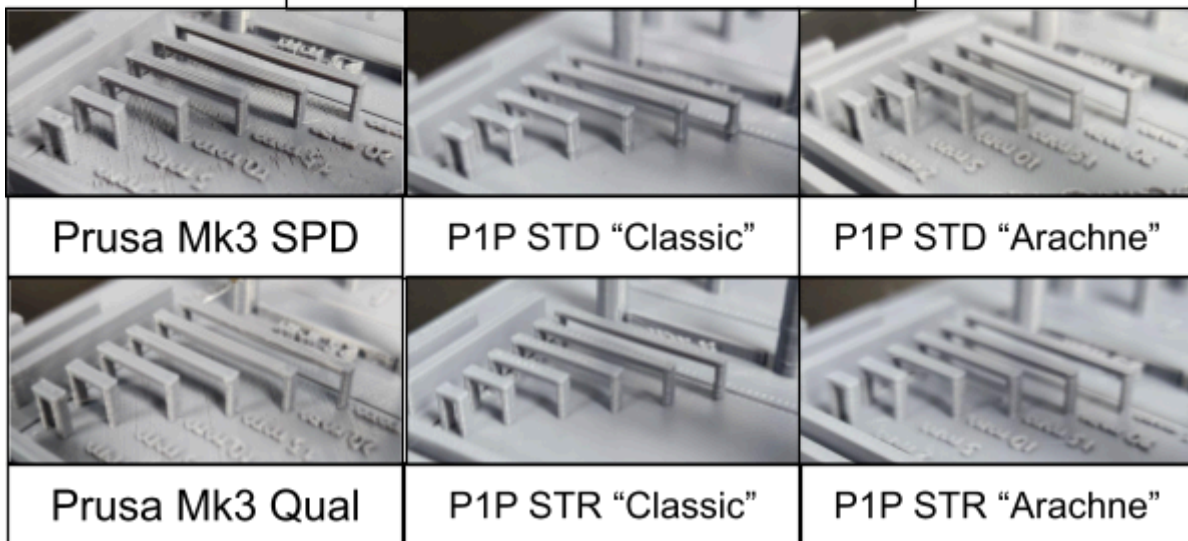
Torture Test

The torture test was printed in the same set of profiles as the negative tolerance test, with 0.2mm layer height default profiles for each printer. A significant deviation was not observed, however, it was discovered that the default “classic” wall generation algorithm on the Bambu Labs P1P was culling out features smaller than the nozzle width, so the models were instead reprinted with the same algorithm that Prusaslicer uses (“Arachne”) in order to compare details. This will be mentioned in the comparisons, and the effects of it are extremely well documented in the Bambu Labs wiki.

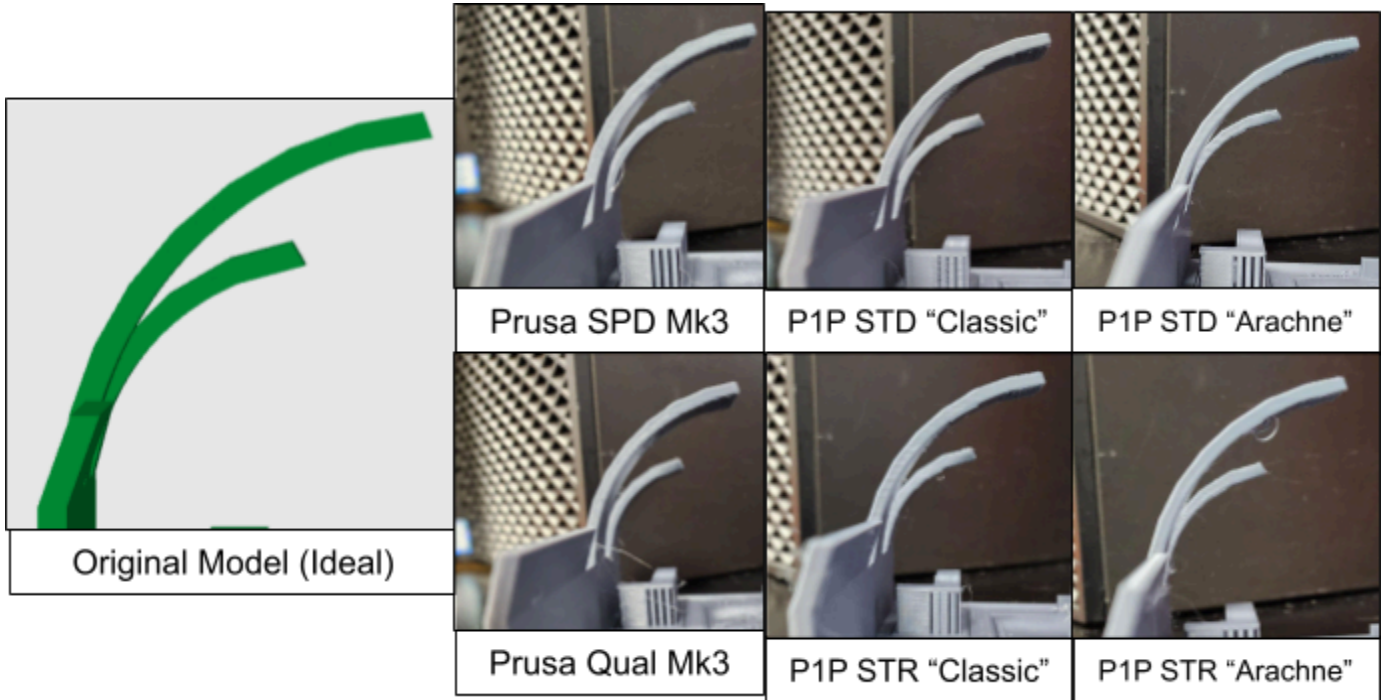
Starting off Bridging, it is the ability for the printer to extrude plastic over a gap, and is better when there is minimal drooping. It was significantly better on the P1P on every profile. The P1P was able to bridge a 25mm gap with little to no drooping and there was no noticeable difference between profiles. The Mk3 still performed well on both profiles, with drooping only starting at the 20mm gap on “Speed” and the 25mm gap on “Quality”. **Overall bridging was very good on both printers, but still noticeably better on the P1P.**



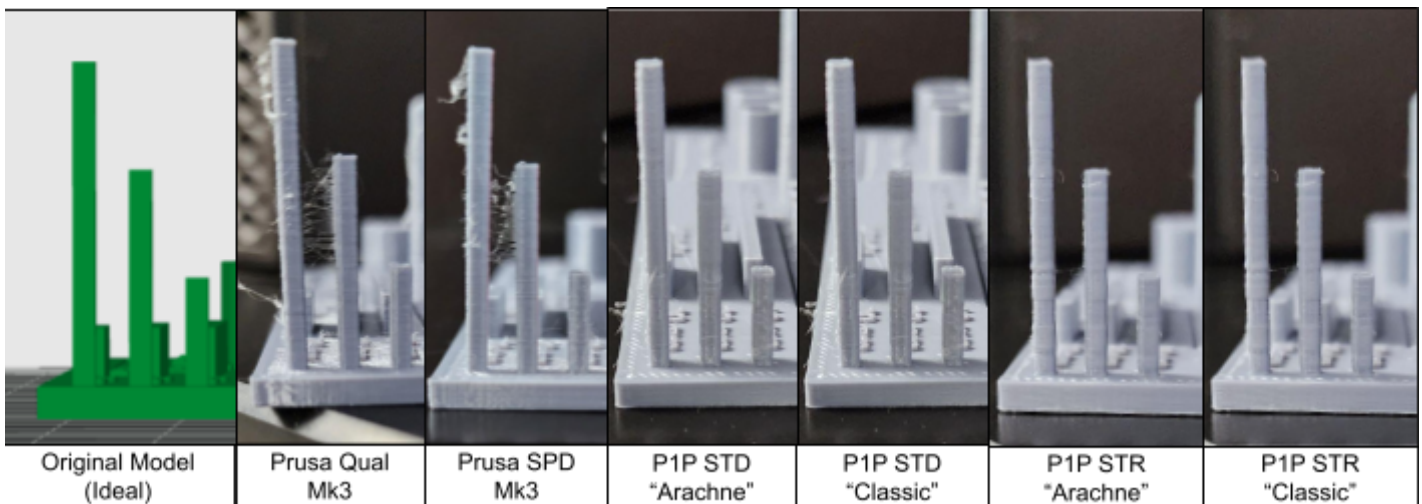
Original Model (Ideal)



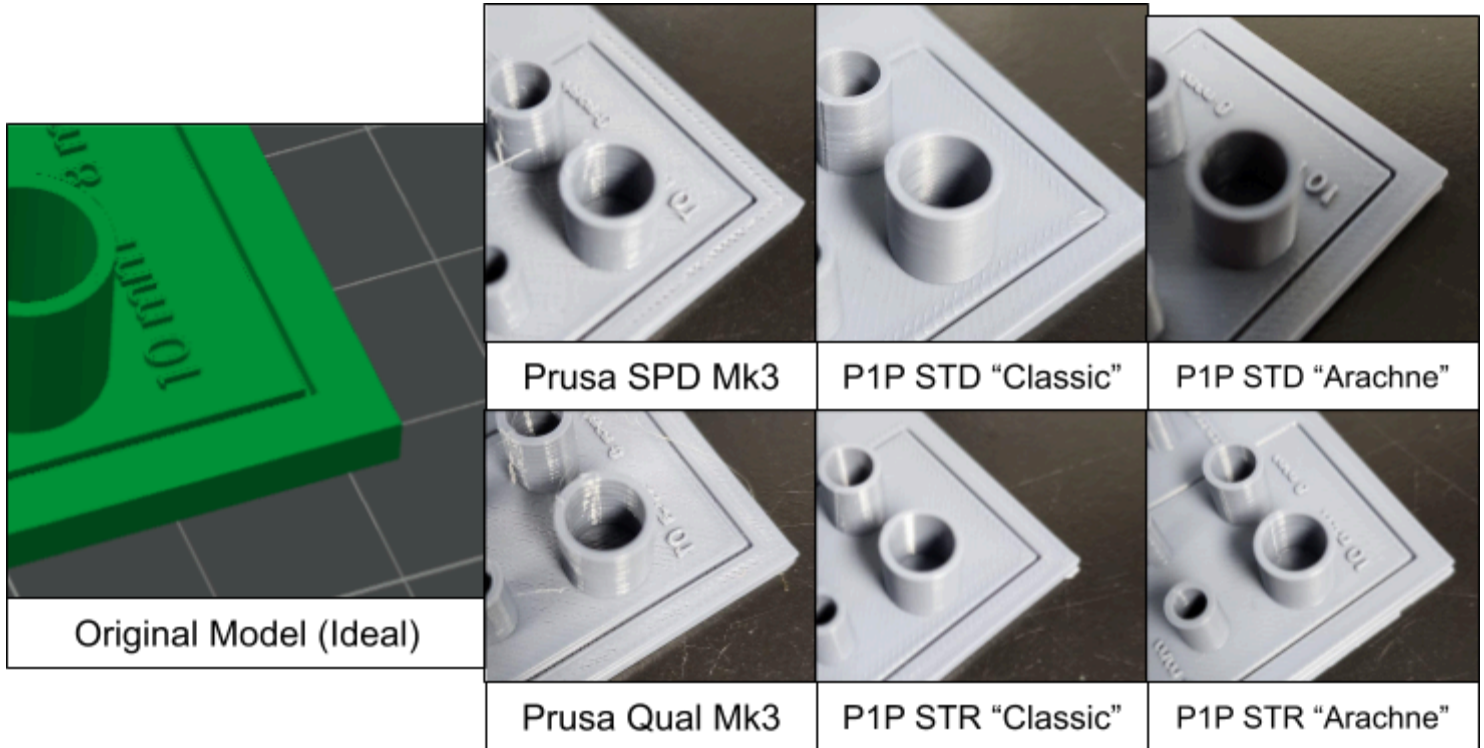
Overhanging is the ability for the printer to create shapes that have nothing underneath them, and is measured by the angle from vertical. The higher the angle at which the printer can create a coherent shape, the better. **The P1P was able to consistently create better overhangs, with steeper angles rendering more coherently than the Mk3.** This is observable in the following pictures, where the Mk3 started to create less coherent shapes at 70 degrees, that then became fully misshapen at 75 degrees and higher.



Next is “stringing”, a phenomenon where very thin strings go between different contours extruded on the same layer. This is mostly a visual issue, but in severe cases it can mean over-extrusion that does not contribute to strength. Fortunately, **neither printer had severe enough stringing with default profiles to be a significant obstruction to complicated prints.** The worst case was the 0.2mm Quality profile on the Prusa Mk3, but even then the stringing was not significant enough to cause structural issues, only surface finish issues.

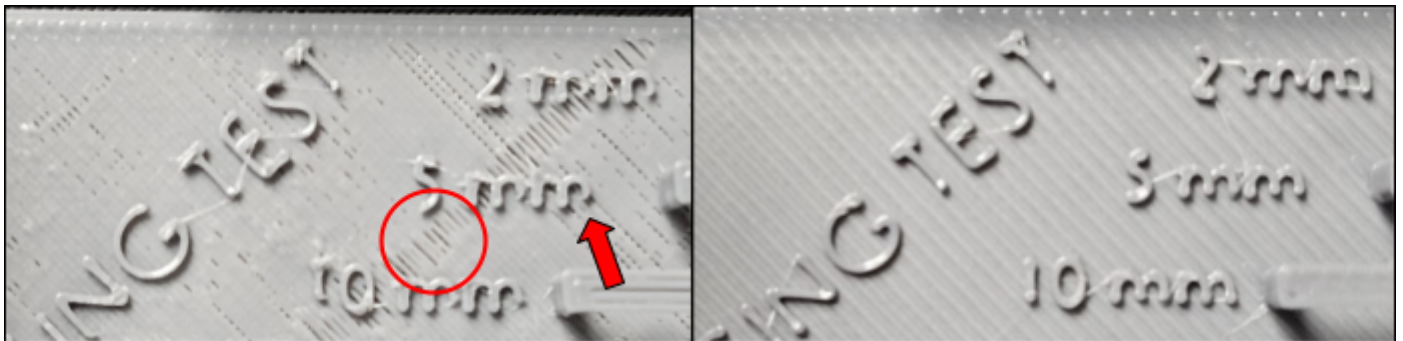
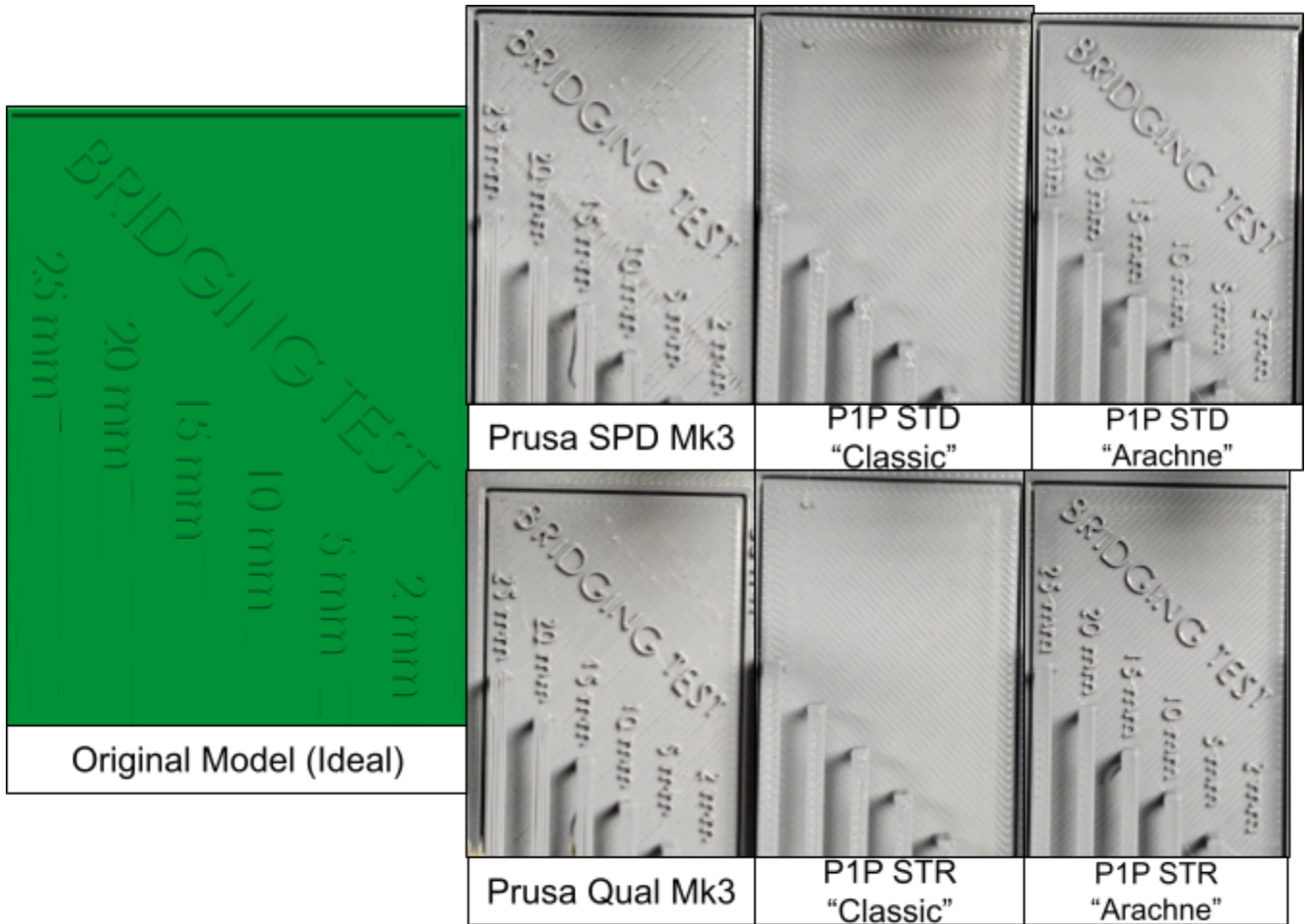


One of the more important structural parameters on a print is “under-extrusion”, where the printer may not extrude plastic where it is supposed to. This can result in gaps in the print, or thinner lines that have less cross sectional area- and are therefore weaker. The Mk3 had pretty consistent under extrusion, which was very visible on the top layer and the side walls near where seams were. This is potentially because of the Revo nozzle not being tuned, however the manufacturer for the Revo nozzles has the same default setting recommendations that the default settings in Prusa Slicer already have. Bambu’s tuned parameters definitely pay off here, as **the P1P has no visible under or over extrusion anywhere on the part.**



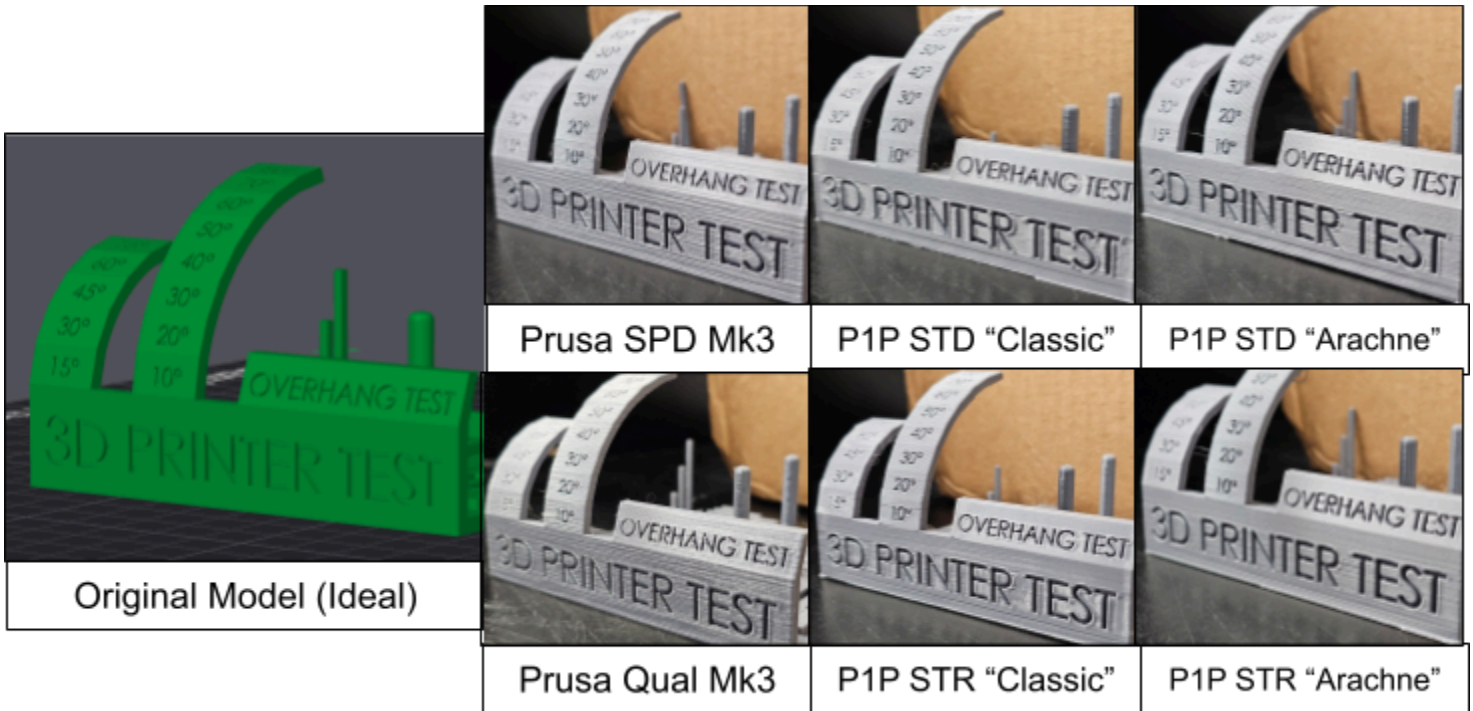
Top surface of Prusa Mk3 (left) and top surface of the P1P (right). The presence of the gaps in between in the lines on the Mk3 indicate under extrusion. In comparison, the P1P shows an even and smooth top layer.

Students may also use text or other very fine details (1 line width or less) on their parts, despite often not offering a structural advantage. In this respect, **the P1P with Arachne wall generation does much better at rendering fine details such as text or single line width features.** Prusaslicer- and therefore the Mk3- does use Arachne by default, but the under extrusion carries over and makes all of the fine details turn out notably worse, on extruded and embossed text.



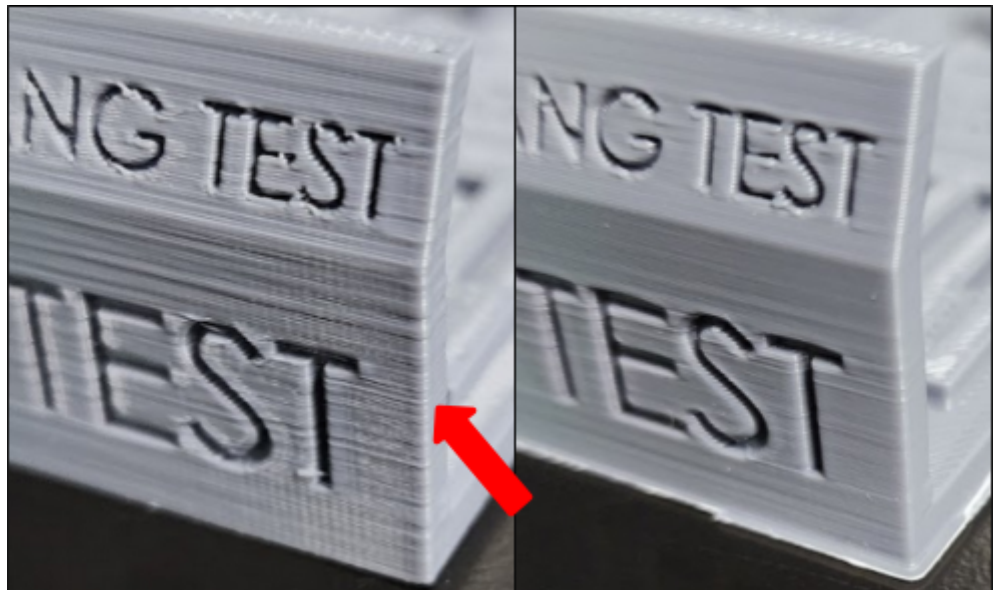
The Prusa Mk3 (left) was unable to recreate the text as accurately as the P1P (right). Additionally, the previously mentioned under extrusion is clearly visible on the Prusa Mk3 print.

Finally, there was one notable observation that was not originally anticipated. Mainly, there was a notable difference in the “waviness” of vertical walls between the two printers, caused by “Z-resonance”, or vibrations causing the lead screws to vibrate and translate in the X/Y direction as it moves in the Z direction. This will matter if students are doing any applications where they need a part to have consistent horizontal dimensions over a height- such as a peg for a slot or an insert for a rail. **The P1P has nearly perfect Z-resonance, with no visible “waviness” over any of the prints.**



The Prusa Mk3 (left) shows uneven layers along the edge of the model while the P1P (right) shows even and smooth layers.

The P1P is able to compensate through software for these unwanted Z-resonances.



Print Time

Aside from getting printed parts as close to the original design as possible, students will likely care about how *fast* they can get their printed parts from the machines after starting a print. To test this, each print would be timed from the start of the GCode to the end. However, the slicers actually give a time estimate for each print- so it was confirmed that the print time is within 5% of the estimated time using three one hour prints, and then used the slicer estimates from there. The results for each printer are as follows:

| Bambu Labs P1P | | |
|----------------|----------------------------------|-----------------|
| Number | Print Desc. | Time (hh:mm:ss) |
| B1 | 0.2mm STD Torture Test "Classic" | 1:58:00 |
| B2 | 0.2mm STR Torture Test "Classic" | 2:14:00 |
| B3 | 0.2mm STD Torture Test "Arachne" | 2:03:00 |
| B4 | 0.2mm STR Torture Test "Arachne" | 2:24:00 |
| B5 | 0.2mm STD Negative Tolerance | 0:17:39 |
| B6 | 0.2mm STR Negative Tolerance | 0:21:03 |
| B7 | 5x 0.12mm Dimension Test | 2:09:00 |
| B8 | 5x 0.16mm Dimension Test | 1:39:00 |
| B9 | 5x 0.20mm STD Dimension Test | 1:21:00 |
| B10 | 5x 0.20mm STR Dimension Test | 1:27:00 |
| B11 | 5x 0.24mm Dimension Test | 1:09:00 |
| B12 | 5x 0.28mm Dimension Test | 1:01:00 |

| Prusa Mk3 | | |
|-----------|-------------------------------|-----------------|
| Number | Print Desc. | Time (hh:mm:ss) |
| P1 | 0.2mm SPD Torture Test | 4:16:00 |
| P2 | 0.2mm Qual Torture Test | 4:47:00 |
| -- | -- | -- |
| -- | -- | -- |
| P3 | 0.2mm SPD Negative Tolerance | 0:31:00 |
| P4 | 0.2mm Qual Negative Tolerance | 0:32:00 |
| -- | -- | -- |
| P5 | 5x 0.15mm SPD Dimension Test | 2:34:00 |
| P6 | 5x 0.15mm Qual Dimension Test | 2:38:00 |
| P7 | 5x 0.20mm SPD Dimension Test | 2:03:00 |
| P8 | 5x 0.20mm Qual Dimension Test | 1:58:00 |
| P9 | 5x 0.3mm Dimension Test | 1:22:00 |

As visible from the tables, the Bambu Labs P1P has an overwhelming speed advantage over the Prusa Mk3 using default print profiles. The difference is ~2x speed on average, with the gap closing on lower print times because of the Bambu's significant start up and calibration times. The Mk3 takes ~2m 30s to complete its calibration routine before each print, whereas the Bambu Labs P1P takes 5m flat. **This significant advantage in speed should allow Keystone to generate prototyped parts faster**, and therefore increase the amount of iterations that students can do per project- or even open the possibility of designing, modeling, printing, and testing a part within the space of a single lab period.

| P1P v.s Mk3 Delta | | | |
|-------------------|------------|------------------|--------------|
| Desc. | Comparison | Delta (hh:mm:ss) | % time saved |
| Torture Tests | B1 v P1 | -2:18:00 | 53.91% |
| | B3 v P1 | -2:13:00 | 51.95% |
| | B2 v P2 | -2:33:00 | 53.31% |
| | B4 v P2 | -2:23:00 | 49.83% |
| Neg. Tol. | B5 v P3 | -0:13:21 | 43.06% |
| | B6 v P4 | -0:10:57 | 34.22% |
| Dim. Acc. | B8 v P5 | -0:55:00 | 35.71% |
| | B8 v P6 | -0:59:00 | 37.34% |
| | B9 v P7 | -0:42:00 | 34.15% |
| | B10 v P8 | -0:31:00 | 26.27% |
| | B12 v P9 | -0:21:00 | 25.61% |

Conclusion

Through our testing, it's been proven that the P1P has multiple small advantages over the Mk3 in regards to final part quality, but a massive advantage in throughput. Prints were overall more consistent, especially when using similar path generation algorithms. Vertical walls were straighter, fine text turned out very well, and there were minimal cases of over or under extrusion. The only significant point against the P1P is the slightly higher dimensional inaccuracy compared to the Mk3, but even that is within normal tolerance for FDM 3D printers.