Prusa Mk3.9 Evaluation

Tests and measurements performed by Brandon Hill and Ali Niazi

What is the goal of this report?

The goal of this testing is to establish the performance and capability of the Prusa Mk3.9 printer. The Mk3.9 started its life as a Prusa Mk3 printer which was then upgraded to Mk3.9 using an official Prusa upgrade kit. The Mk3.9 is feature equivalent to the Prusa Mk4 and should perform similarly if not the same.

Prusa Mk3

Prusa Mk3.9

Comparable Upgrade Specs:

The Mk3.9 kit by Prusa is intended to upgrade the Mk3 printers to Mk4 spec with new features. Relevant specs are shown below, which are any that changed or upgraded in the new generation of printer.

Specification / Printer	**Prusa Mk3**	**Prusa Mk3.9**
Electronics	8-bit Einsy MCU, Trinamic 2130 drivers	32-bit xBuddy ARM, Trinamic 2130 drivers
Interface	Monochromatic LCD, rotary encoder	3.5” graphic 65k color LCD, rotary encoder
Firmware	Open-Source Marlin	Open-Source “Buddy” developed by Prusa
Hot-End	E3D V6	Nextruder system, compatible with E3D V6
Bed Leveling	Induction Probe	Load Cell Sensor integrated into hot-end
Gcode Delivery Method	SD Card	USB Stick, Local Network, Prusa-connect (cloud based)
Networking	N/A	Wi-Fi, RJ45 Ethernet
Additional Notable Features	N/A	Input Shaping, Quick-Swap Nozzles

Testing Procedure

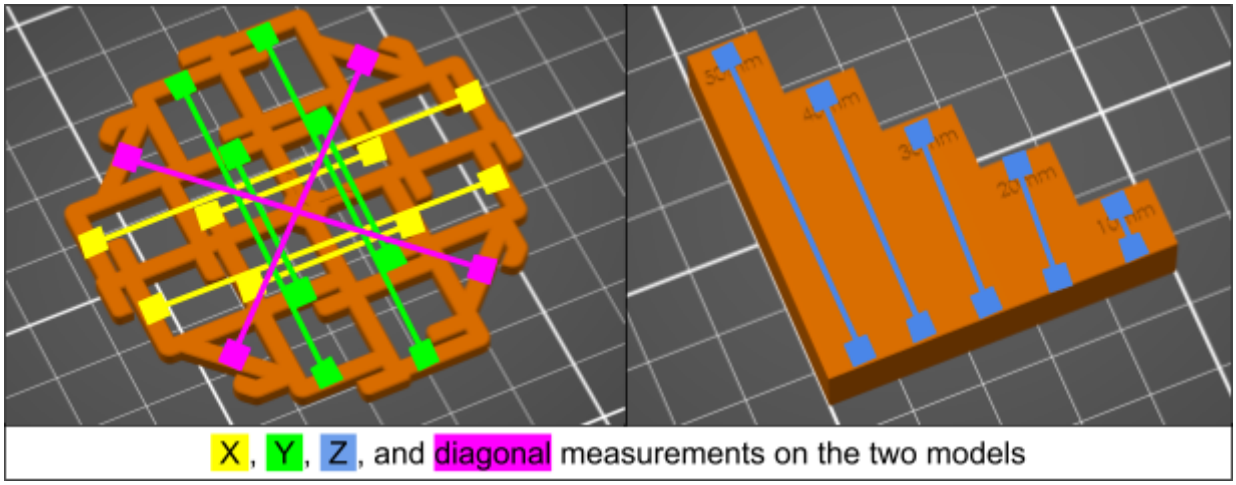
The testing procedures will mainly focus on quantitative tests that will be used for dimensional and statistical analysis and qualitative tests that will be used to analyze print quality and subjective details. Print quality is made up of bridging, stringing, and fine detail consistency.

For consistency, the same filament and slicing profile will be used for all prints. The Prusaslicer 0.2mm Speed profile was selected and all prints were done using Matterhackers Red PLA from the same batch. The Mk3.9 has been calibrated with procedures from Prusa and is equipped with the default 0.4mm nozzle.

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.

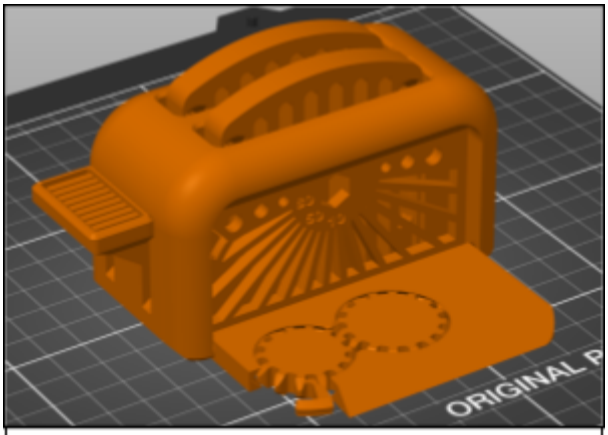


X, Y, Z, and diagonal measurements on the two models

To acquire statistically valid results, 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.

Negative Tolerances

Model: Clockspring3D Torture Toaster v24.stl



Torture Toaster Model

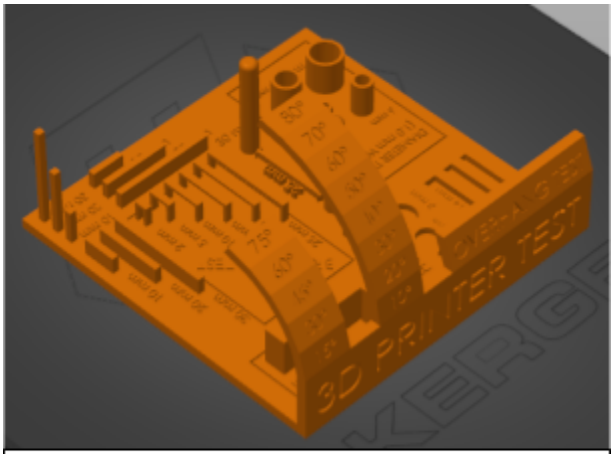
Created by user clockspring on printables.com, this will test the capability of the printer to deal with tight negative tolerances. It has a variety of tests for this purpose, mainly being the internal tolerance columns, the side doors with gears, and the main toaster mechanism.

In an **ideal print**, all of these moving parts will be able to move freely right off of the print plate. Having to break them free is also acceptable as long as it's doable by hand but not an ideal result.

This model has a variety of tests on it, but it is almost entirely qualitative. Therefore, only 10 copies of this model will be printed. This should be enough to get an accurate assessment of whether or not the Mk3.9 can produce parts with tight tolerances consistently.

Torture Test

Model: tortureTest.stl



Torture Test Model

The final qualitative test, this torture test model is intended to test the limits of the printer in recreating certain features of a model such as bridging, stringing, ghosting, and fine detail resolution.

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

As stated by Prusa, The precision tolerance of a well-assembled Prusa printer is +/-0.1mm on the Z-axis and +/-0.3mm on the XY-axes. The Mk3.9 remained well within this tolerance range in all averaged measurements.

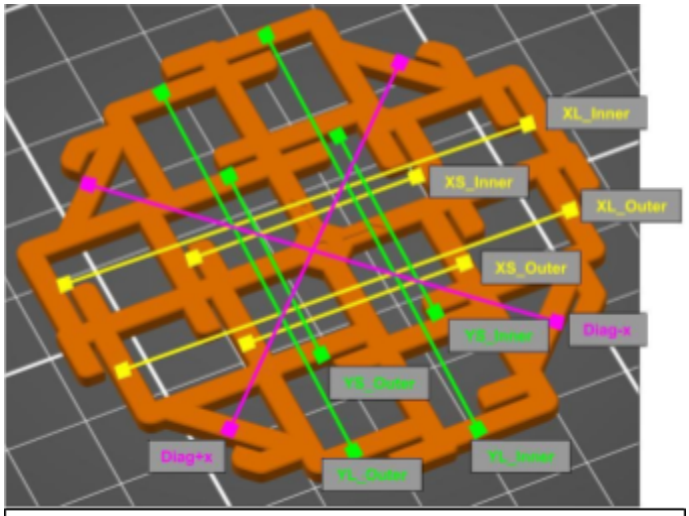
The print quality of the Mk3.9 is noticeably improved from the Mk3 with fewer noticeable defects and more consistency throughout the whole print. The torture test model is very similar in quality and speed to the Bambu P1P which is a top performer from previous testing.

Dimensional Accuracy - Califlower

In total, 30 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 30 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**



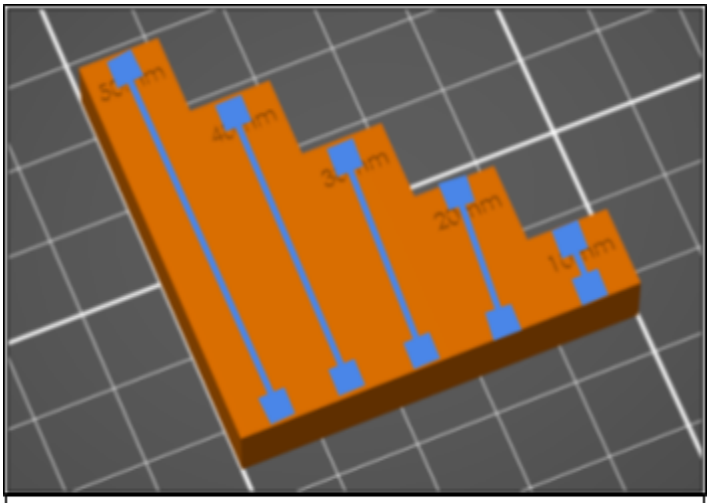
Dimensions Labeled on the Califlower

Z-Staircase

In total, 50 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.

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



Z-Staircase heights

Negative Tolerance

The Torture Toaster samples all printed very well, as expected from the Prusa Mk3.9. Of the 10 numbered samples, all 10 were completely functional. Of the inspected features, here are the results that every sample shared:

Feature	Inspection Question	Average Result
Left Door Hinge	Does the left door open freely?	Yes, with little to no resistance
Right Door Hinge	Does the right door open freely?	Yes, with little to no resistance
Left Gears	Do the left gears spin freely?	Yes, with little to no resistance
Right Gears	Do the right gears spin freely?	Yes, with little to no resistance
Left Latch	Does the left door lock easily?	Yes, with little to no resistance
Right Latch	Does the right door lock easily?	Yes, with little to no resistance
Negative Tolerance Incremental	Which Tolerance pins slide?	0.1mm- (3/3) Does not slide 0.2mm- (2/3) Slides with notable resistance 0.3mm- (3/3) Does not slide 0.4mm- (1/3) Slides with little to no force. 0.5mm- (1/3) Slides with little to no force
Overhang Angle	At what point do the overhangs start to droop?	6/10 had 80 degrees, 4/10 had 70 degrees
PiP assembly	How easily does the main “toast” mechanism move?	7/10 had little to no force, 3/10 had significant force

As seen above, many of the tests had little to no deviation in the functional result of the print. This does not mean there were no print defects, however. One of the most notable and repeatable defects was on the 0.5mm tolerance pin. This was likely due to the small surface contact with the bed, allowing the pin to lose adhesion mid print. This did not significantly affect the sliding of the pin, however.

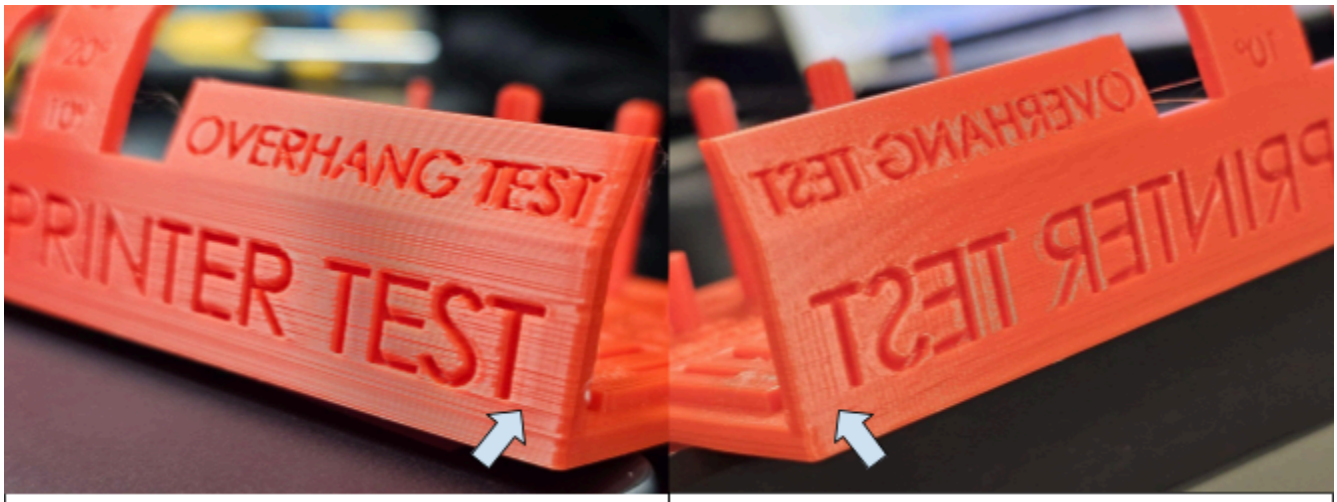
0.5mm Layer Shift defect highlighted on toaster

Another notable print failure during this test occurred which the Prusa recovered while preserving functionality of the print. The gears on the left door of sample number 9 lost adhesion due to some random under-extrusion, but the latch and the gears still worked perfectly.

Sample #9 print error- gears still functioned.

Torture Tests

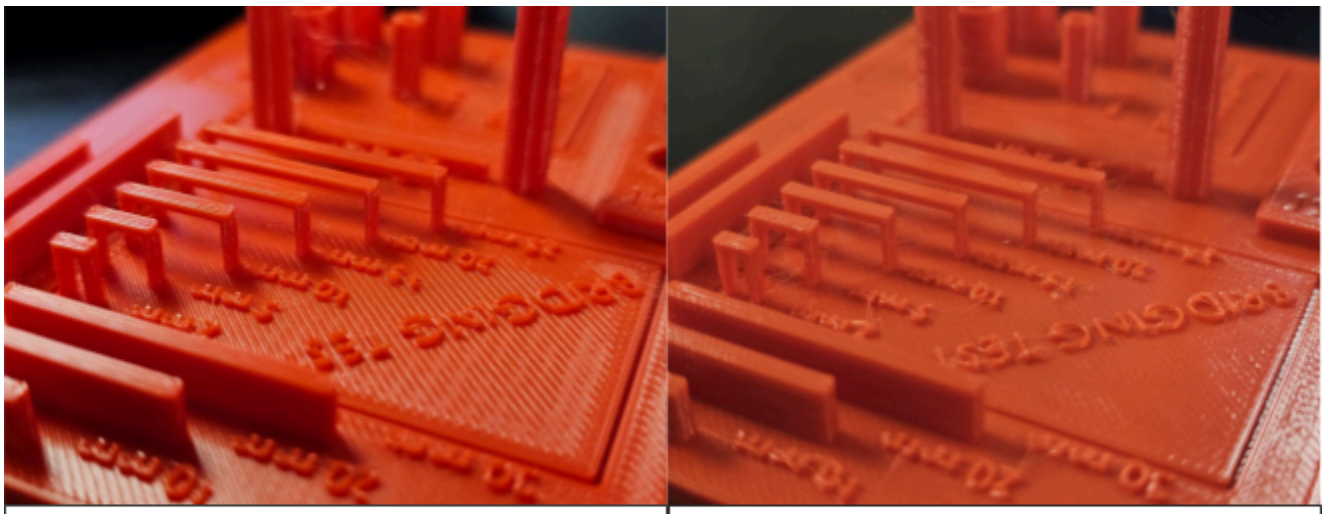
In comparison to the previously tested Prusa Mk3, the Mk3.9 printed each torture test noticeably better. All 10 samples were consistently indistinguishable from each other.



Prusa Mk3.9	Prusa Mk3

Debossed Text

Debossed text usually shows signs of "ghosting" at the corners of each letter. The Mk3.9 manages to produce clean and sharp corners with little to no signs of ghosting whereas the Mk3 clearly shows ghosting artifacts.



Prusa Mk3.9	Prusa Mk3

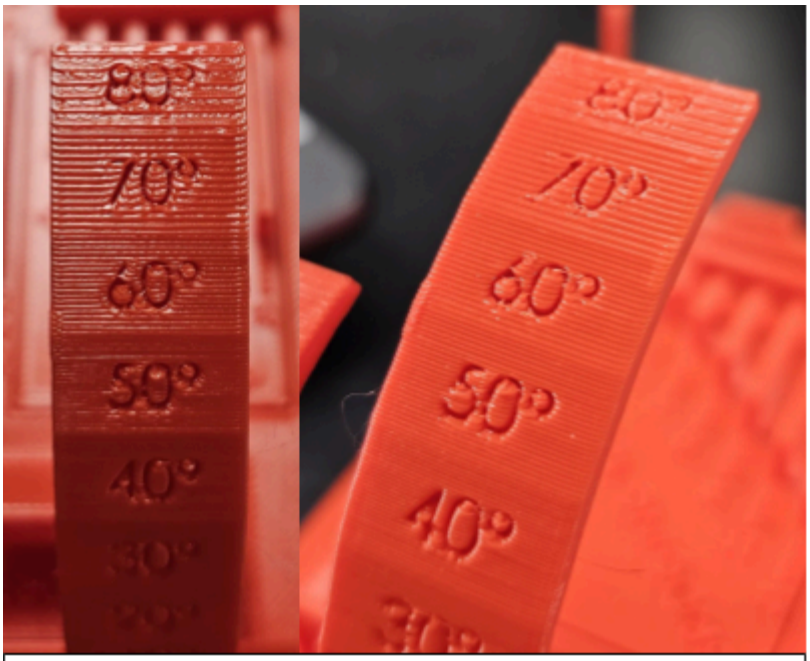
Bridging & Fine Details

The bridges show no signs of failing or drooping on either printer. Even though some stringing is expected with basic PLA, the Mk3 has noticeably more stringing between the bridges and between the letters. The fine details, such as the text on the top surface, are easier to read on the Mk3.9 due to less stringing.

Prusa Mk3.9	Prusa Mk3

Top Surface Quality

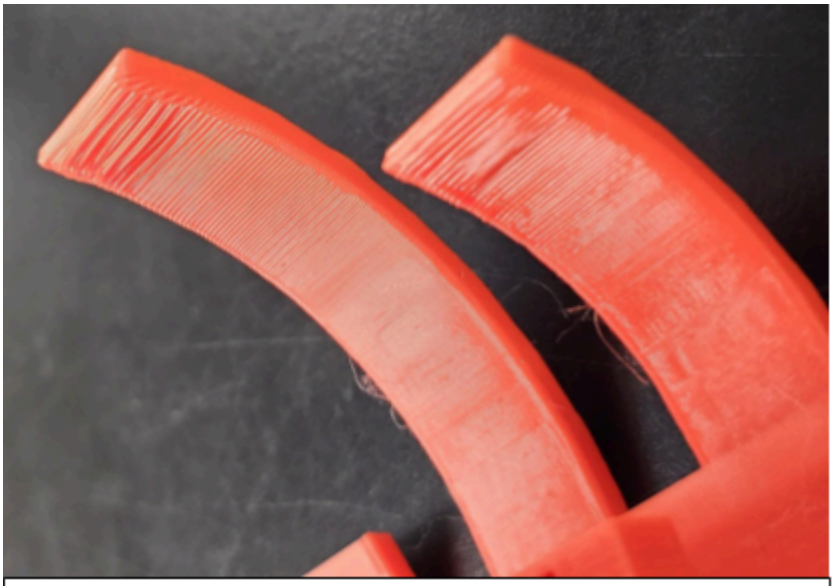
The Mk3.9 produced a smoother top surface compared to the Mk3. The lines are consistent in width and appear uniform whereas the Mk3 has inconsistencies which makes the top surface look jagged.



Overhang Topside & Debossed Text

As the overhang angle increases, it becomes increasingly difficult to print details such as debossed text. The 80 degree mark can easily become distorted and unreadable.

The Mk3.9 was able to produce a visually satisfying result with every number remaining easily readable.



Overhang Bottom Side

The Mk3.9 shows little signs of struggling with the outer perimeter of each layer as it approaches the limits of FDM printing.

Each layer has decreasingly less surface area to rest on as the overhang angle increases, therefore, part cooling and bridging performance are crucial to maintaining quality overhangs.

The Mk3.9 produced a satisfactory result with minor degradation to the visual quality. Any functional parts with these overhang angles should not be affected.

Fine Surface Details

The text in this feature is about the same width as the nozzle. Proper flow rate and retractions settings are key to producing good details. The Mk3.9 produces an overall excellent result indicating it is properly calibrated from Prusa.

There are some minor defects at some edges of the smallest text. These defects are also present on both the Mk3 and Bambu P1P.

Speed

Alongside improvements in print quality, the Mk3.9 upgrade also significantly increases the printing speed of the machine due to a combination of a new hot-end and the addition of input shaping.

Input shaping allows the printer to generate resonances which cancel out the natural resonances of the printer while it is printing. The net result is that you are able to print at a much faster speed with no degradation to visual print quality.

The default profiles for the Mk3 and Mk3.9 in Prusa Slicer and P1P in Bambu Studio include acceleration, jerk, and print speed control. This means the slicer is able to accurately predict every movement of the printer and therefore, accurately predict the print time. Each slicer was verified to be producing accurate time estimates by timing actual prints on each machine.

Prusa Mk3

Number	Print Desc.	Time (hh:mm:ss)
P1	0.2mm SPD Torture Test	04:19:00
P2	0.2mm SPD Torture Toaster	13:08:00
P3	0.2mm SPD 10x Z-Staircase	06:05:00
P4	0.2mm SPD Califlower	01:51:00

Prusa Mk3.9

Number	Print Desc.	Time (hh:mm:ss)
P1	0.2mm SPD Torture Test	02:15:00
P2	0.2mm SPD Torture Toaster	06:02:00
P3	0.2mm SPD 10x Z-Staircase	02:36:00
P4	0.2mm SPD Califlower	00:56:00

Bambu P1P

Number	Print Desc.	Time (hh:mm:ss)
P1	0.2mm Standard Torture Test	02:03:00
P2	0.2mm SPD Torture Toaster	05:16:00
P3	0.2mm SPD 10x Z-Staircase	02:22:00
P4	0.2mm SPD Califlower	00:49:00

Prusa Mk3.9 vs Mk3 ΔT

Number	Print Desc.	ΔT	% Difference
P1	0.2mm SPD Torture Test	-02:04:00	-49%
P2	0.2mm SPD Torture Toaster	-07:06:00	-54%
P3	0.2mm SPD 10x Z-Staircase	-03:39:00	-57%
P4	0.2mm SPD Califlower	-00:55:00	-50%

Prusa Mk3.9 vs P1P ΔT

Number	Print Desc.	ΔT	% Difference
P1	0.2mm Torture Test	+00:12:00	10%
P2	0.2mm SPD Torture Toaster	+00:46:00	15%
P3	0.2mm SPD 10x Z-Staircase	+00:14:00	10%
P4	0.2mm SPD Califlower	+00:07:00	14%

The Mk3.9 was on average 53% faster than the Mk3 and only marginally slower than the P1P. This is very impressive considering the P1P is a CoreXY design with a lightweight toolhead intended for fast movements whereas the Mk3.9 still uses a cartesian motion system and relies on moving the heavy print bed for the Y-axis. The speed difference is increased in large parts that are not restricted by part cooling and/or fine details and decreased in those that are.

Conclusion

The Prusa Mk3.9 is an impressive upgrade to any Prusa Mk3 machine. The all new hot end and load cell bed leveling ensure consistent prints each time with no hassle or tuning, and the new electronics enable quality of life features such as printing over WiFi and remote monitoring. The print quality sees a noticeable improvement compared to the Mk3 due to the new extruder, hot-end, and input shaping. An upgrade kit retails for $499 + shipping and took about 6 hours to assemble. All components were included and a comprehensive guide is provided. It is valuable to note that a Mk3.5 kit is also available for the price of $250 + shipping. The main difference is that it does not upgrade the hot end assembly. Testing would need to be performed to assert its benefits of the Mk3.5 upgrade kit.