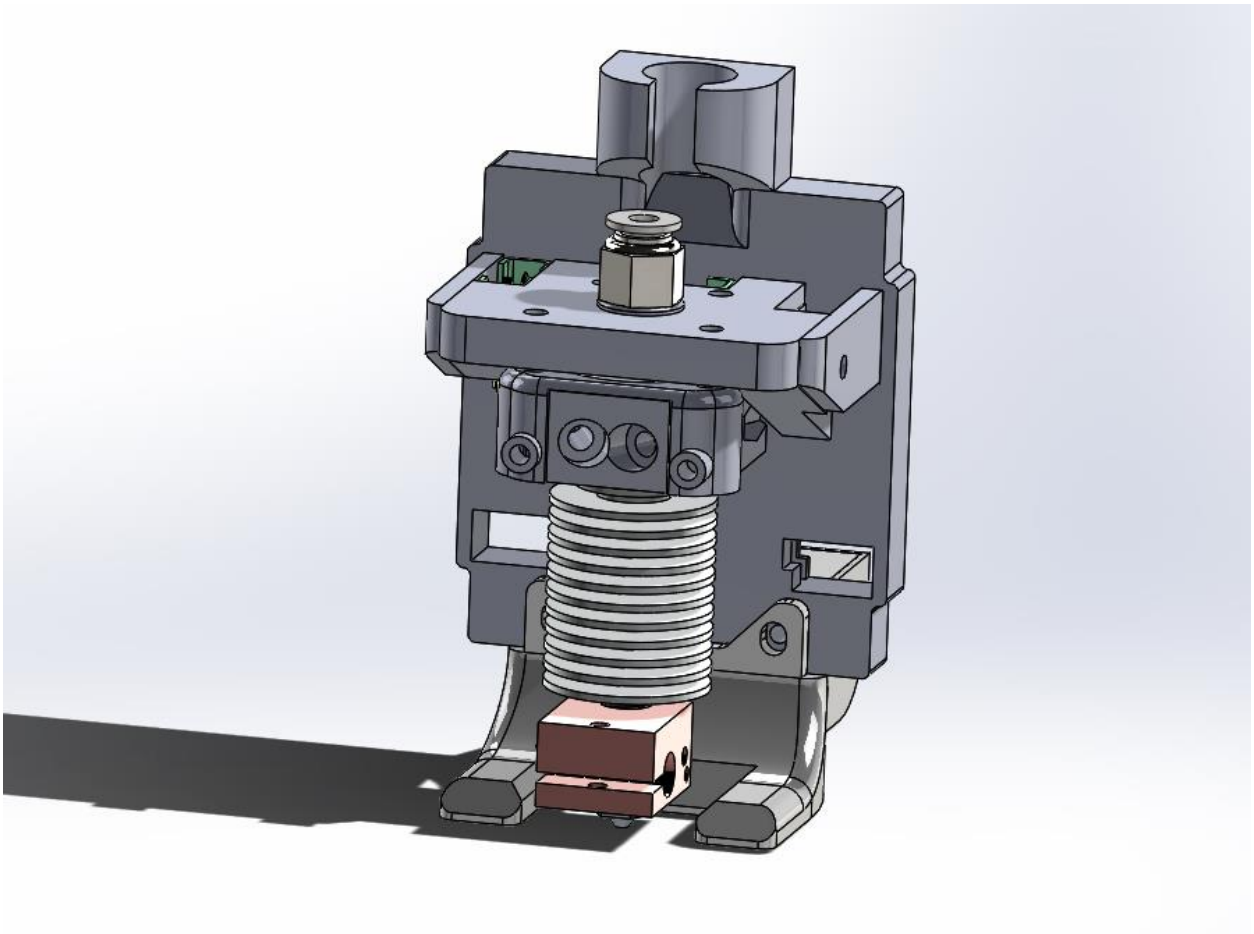
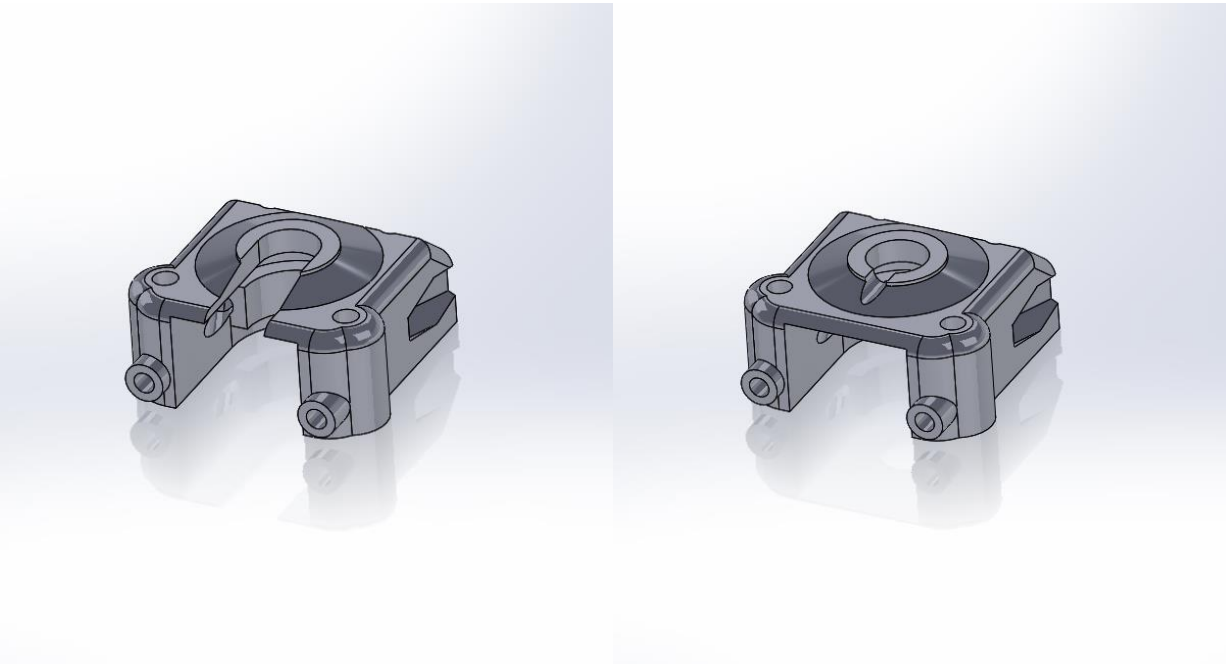
Hypercube Evolution
Precision Piezo Hotend
Assembly Mount
20180128

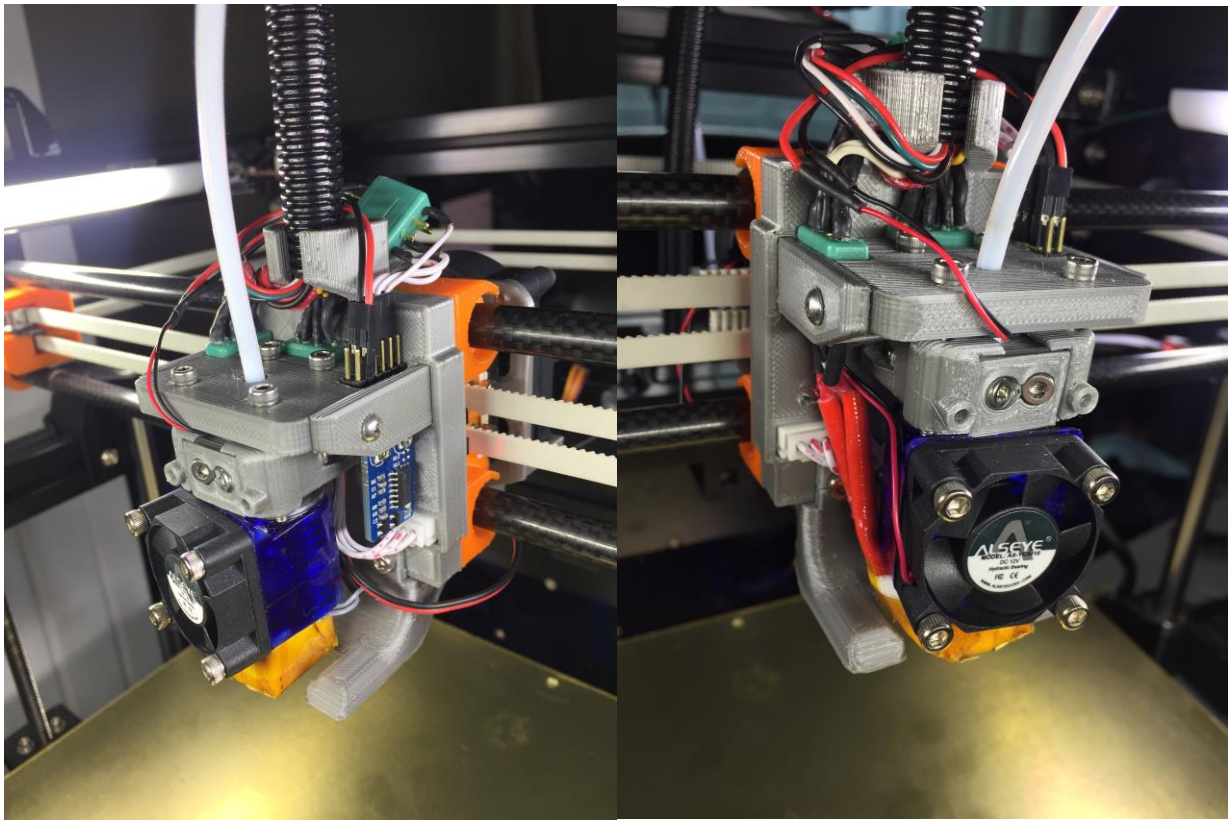
Test Results
vergienc



This mount is designed for the Hypercube Evolution printer by SCOTT3D to accommodate a Precision Piezo sensor disk for the hot end sensor system. There are two extruder mount options for either an embedded Bowden connector or the typical clones with a PC4-01 (Thread Diameter: 9.729mm). In addition, there are two options for mounting the heatsink.



The part on the left is to accommodate an embedded Bowden heatsink with a collet clip while the part on the right will allow for a clone type heatsink with the PC4 connector removed. The Precision Piezo disk has the wires coming out the front as shown below.



The circuit board can either be mounted in the front, or on the side as shown above.
Once the mount was installed with the Precision Piezo sensor, several tests were performed to validate the operation and accuracy of the sensor. The first test was to use bilinear bed leveling to create a bed mesh. The chosen mesh was 5x5 which created 25 points on the bed. This was performed 10 times which allowed for enough statistical data to show the range and standard deviation between each point. The commands that were executed in the GCODE was G29 and M48 which corresponds to the bed leveling command and repeatability test respectively in Marlin 1.1.6.

The first test performed was to generate 10 individual sets of grid meshes which then was calculated using MATLAB and graphed to show the performance of the Precision Piezo System. The data was constructed in matrix form, thus providing a simple way to calculate the range (accuracy) and standard deviation for the surface plots.

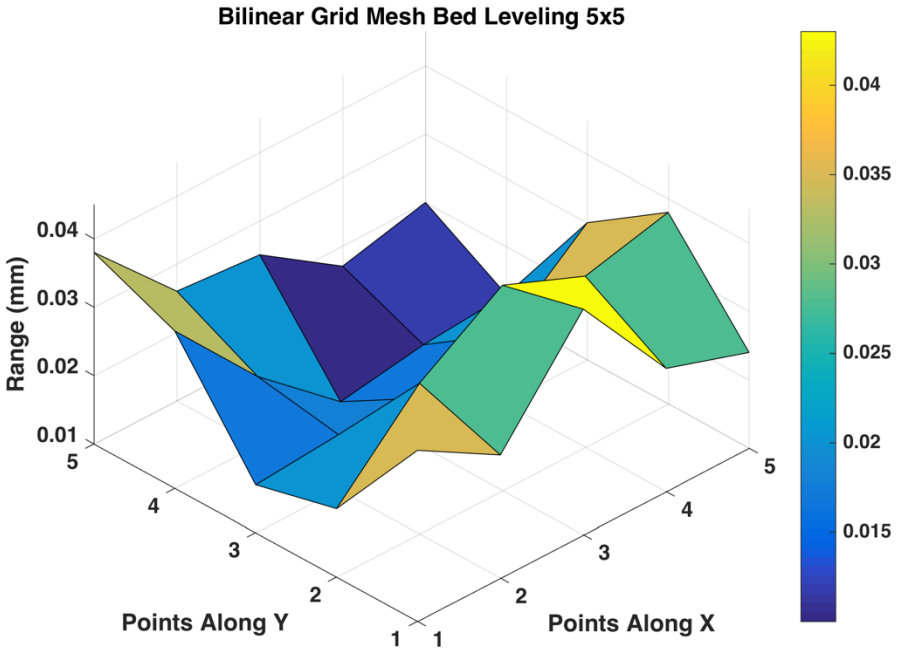


Fig. 1 – A surface plot displaying the range of 10 Bilinear grid mesh bed leveling sets with a 5x5 grid to generate 25 points for each mesh set.

As a reminder, the range (accuracy) of a set of data is the difference between the min and max values; therefore, within the 10 sets of data, the range was calculated for each point and displayed in Figure 1. It is clear the Precision Piezo hot end assembly varied slightly at each point, but considering these are 10 independent full grid measurements with the hot end moving around each time, this system is quite robust and accurate for 3D printer bed leveling. Despite this variation and considering a typical layer height of at least 0.2 mm, the variation shown in Figure 1 is approximately an order of magnitude better at the visual midrange of 0.02 mm in Figure 2.

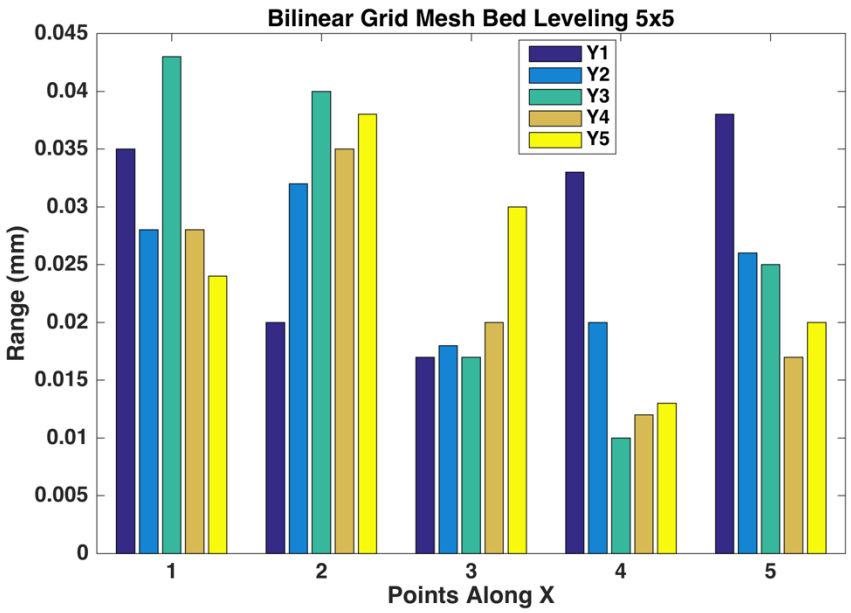


Fig. 2 – The range (accuracy) 10 Bilinear grid mesh bed leveling sets with a 5x5 grid to generate 25 points for each set. There are 5 points along the x-axis and the 5 points along the y-axis is shown by Y1, Y2, Y3, Y4, and Y5. As shown from the plot, the average range was between 0.015 mm – 0.025 mm.

To further understand the repeatability of the piezo disk, a surface plot of the standard deviation (amount of variation of a set of values) is noteworthy.

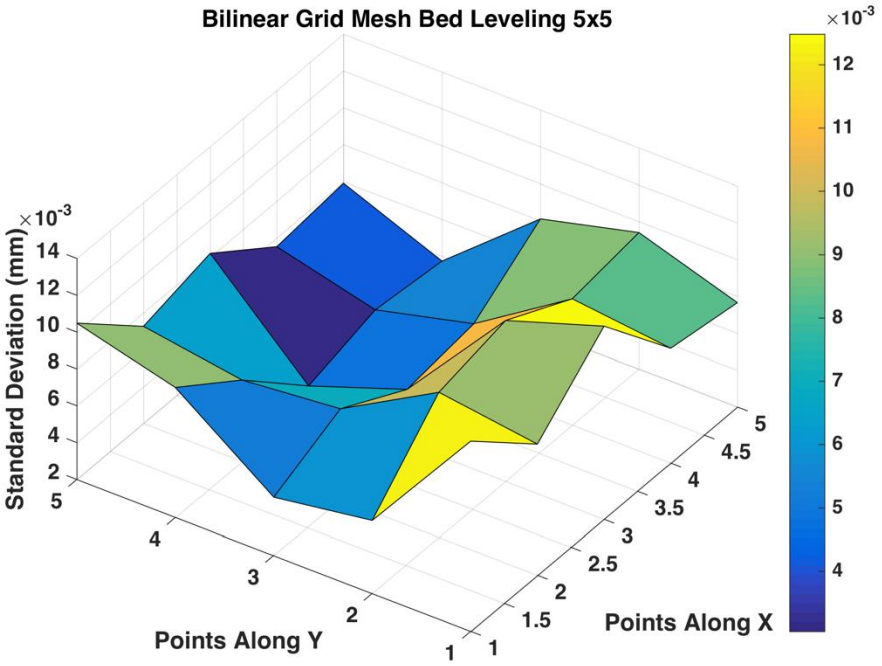


Fig. 3 – The standard deviation of 10 Bilinear grid mesh bed leveling sets with a 5x5 grid to generate 25 points for each mesh set.

In spite of the bed variations shown in Figure 3, the results of the standard deviation from the 10 data points is approximately 0.006 mm by visually evaluating the bar plot in Figure 4. The information in Figure 3 is displayed alternatively in Figure 4 as a bar graph to clearly highlight the standard deviation at each of the 25 points for the 10 sets of mesh data collected.

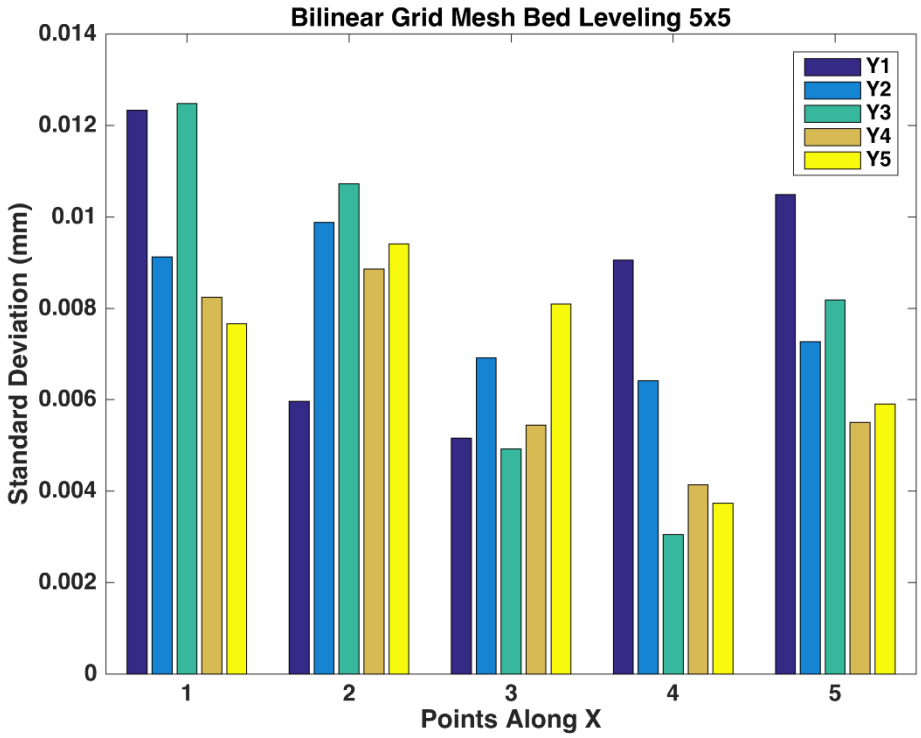


Fig. 4 – The standard deviation 10 Bilinear grid mesh bed leveling sets with a 5x5 grid to generate 25 points for each set. There are 5 points along the x-axis and the 5 points along the y-axis is shown by Y1, Y2, Y3, Y4, and Y5. As shown from the plot, the average value was between 0.004 mm – 0.008 mm.

The second test performed was several repeatability tests (M48 in Marlin) executed near the center of the bed. These tests were performed 20 times to obtain more data for comparison. There are two sets of data graphed to illustrate the performance of the Precision Piezo system. Figure 5 shows the range while Figure 6 shows the standard deviation as calculated from Marlin 1.1.6.

The achieved range (accuracy) as shown in Figure 5 was between 0.002 mm – 0.004 mm with one outlier at test 12, which skews the average data slightly. The calculated mean is 0.0036 mm.

Although there were several times when the standard deviation was close to 0.002 mm, most of the data resided between 0.001 mm and 0.015 mm, which demonstrates the high precision repeatability of the Precision Piezo sensor with this mount. The calculated mean is 0.0013 mm.

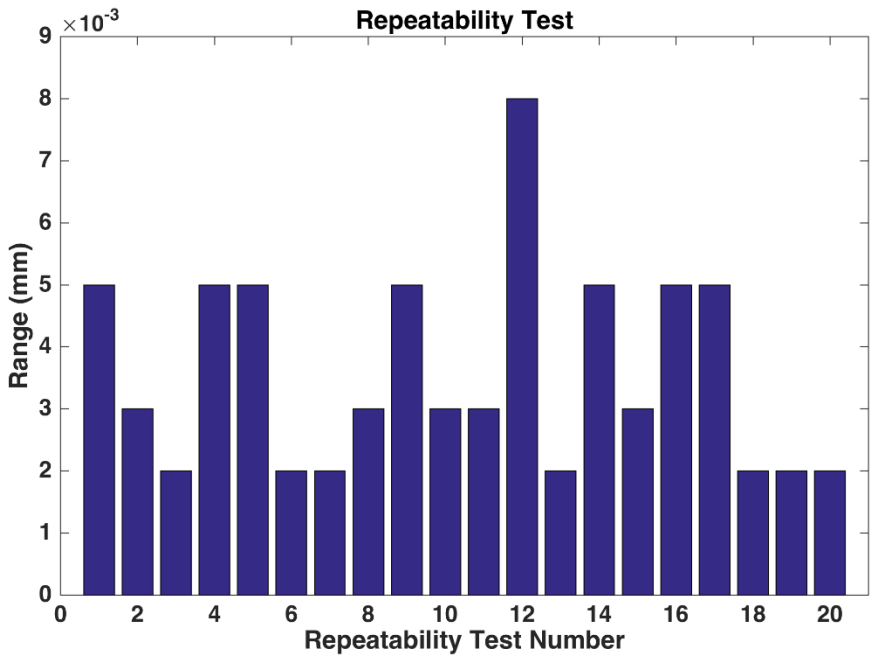


Fig. 5 – A series of repeatability tests performed mid-bed with the range (accuracy) calculated from the Marlin 1.1.6 version software. The calculated mean is 0.0036 mm.

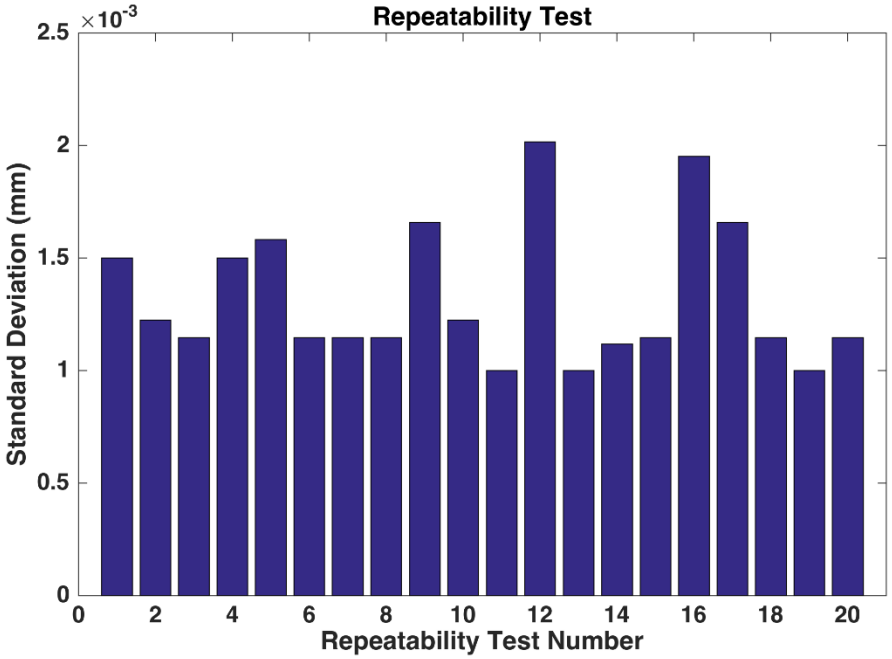


Fig. 6 – A series of repeatability tests performed mid-bed with the standard deviation calculated from the Marlin 1.1.6 version software. The calculated mean is 0.0013 mm.

In conclusion, the Hypercube Evolution Precision Piezo hot end assembly performed well and within the manufactures design specifications. There is parity between the printed parts, piezo disk, and amplifier board where care must be taken during assembly and tuning.

The performance from generating 10 sets of bilinear grid mesh data achieved a calculated range (accuracy) of 0.0256 mm or 25.6 μm and standard deviation of 0.0076 mm or 7.6 μm. This test was most representative of results when executing a bed level prior to starting a print. Moreover, it is noteworthy to mention here that the kinematics of each machine will play a significant role in the grid mesh accuracy. The repeatability tests yielded a calculated range (accuracy) of 0.0036 mm or 3.6 μm and standard deviation of 0.0013 mm or 1.3 μm. Since this machine has a z-axis that is driven by a trapezoidal leadscrew and the probe is striking the same point, this test typically yields more favorable results.

Furthermore, to place these numbers into perspective, a typical first layer height of 0.2 mm or 200 μm, which at the 25.6 μm accuracy shown in Figure 2, is a factor of ~8 better. If we consider the results from the repeatability tests, the accuracy is orders of magnitude below a typical first layer height. These results prove this mount performs to the design specifications of the Precision Piezo System and well suited as an accurate bed leveling device for 3D printers.