Analysis of the Adjusting Bolts System's Contribution to Levelling Error of the Heated Bed in FDM 3D Printer

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Abstract. The 3D printer as one of the key technologies in industrial revolution 4.0 has developed rapidly to improve manufacturing efficiency. Various printing machines and methods are invented and the Fused Deposition Modelling (FDM) 3D printer is one of them that works by depositing melted polymer materials layer by layer to form a product. Several problems are still found behind this process where one of which was the difficulties in levelling the heated bed. Small bolts used to adjust the levelness heated bed's platform indicated to contribute to the error during the bed levelling. This research is to analyze how difficult is the levelling setup process and how the adjusting bolt might involve in leveling error of the heated bed. This research examines three levelling methods to adjust the levelness of a heated bed. Each method was performed three times then the results were checked using the Coordinate Measurement Machine (CMM). The experiment shows all levelling methods resulting levelness deviation that higher than the maximum allowance. The mathematical equation also claimed that the adjusting bolts system may cause the levelness difficulties.

Keywords: FDM 3D Printer, Heated Bed, Surface Levelness, Rapid Prototyping.

1 Introduction

The 3D printing technology as one of the key technologies in industrial revolution 4.0 has developed rapidly to improve manufacturing efficiency [1], [2]. Products made by the 3D printing process are not only limited to prototype purposes but also can be used as final end-products [3]. Various printing machines and methods are invented and the Fused Deposition Modelling (FDM) processis one of them. The FDM processworks by depositing melted polymer materials layer by layer to form a product [4]. This type of printer has become the cheapest one that makes it possible for everyone to purchase [5].

Problems lie behind so much expose about the creation made by desktop FDM 3D printer. Plenty of problems still take place during the operation of the FDM 3D printer where one of them was the levelling of the heated bed. Failure caused by the lack of bed levelness and human error is relatively high during the FDM 3D printing process [6] [7]. Most FDM 3D printers are equipped with small bolts as bed levelness adjusters, this condition might contribute to the error during the bed levelling, therefore a new system is needed [8]. This research will analyze how the adjusting bolt is involved in leveling error of the heated bed.

2 Experiment Methods

This research was performed using a low-cost Desktop FDM 3D printer machine. The experiments examine three levelling methods to adjust the levelness of the heated bed. Each method was performed three times then the results were checked using the Coordinate Measurement Machine (CMM) (Fig.1). Measurement results of each method were then compared and analysed to conclude.

A common levelling method for FDM 3D printers is manual adjustment by using plain paper. This is a simple method where no equipment is required, therefore this method is widely used among the printer users and became the first method to be analysed. This method highly depends on the operator's sense during the setup. Secondly, a spirit level tool as tool to detect the level surface condition was also observed. Lastly, a dial indicator tool was also used in this experiment. The experiment result were measured using CMM to evaluate the levelness of the heated bed's surface by comparing the height of each corner of the heated bed measured from the CMM table as a measurement datum. The measurement results then analysed to examine how big is the levelness deviation occurs in this method. The result should be less than 80% of nozzle diameter which is 0,3mm for a standard 0,4mm nozzle hole.

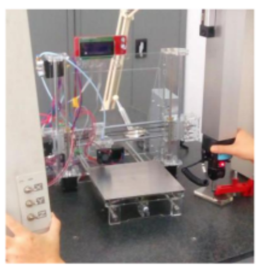

Fig. 1. Levelness examination using CMM

2.1 Manual Adjustment Method

A plain 70gsm white paper is used to adjust the gap between the nozzle and the heated bed's platform. as gap adjuster (Fig.2). First, the nozzle position must be set to home all position (0,0,0), then move upward for 10mm (0,0,10). The setting position is decided at 10mm from every side of the bed, therefore the position for the first corner should be; 10,10,10. The next step is to put the plain paper below the extrusion head then move the extrusion head down for 10mm (10,10,0) or use Home Z menu. Pull the paper to check the gap, the paper must be easy to pull but with little friction sensed. Too loose will produce a high gap while too hard will produce less or no gap. These activities were performed while adjusting the adjuster screw below the heated bed and applied to each corner of the heated bed.

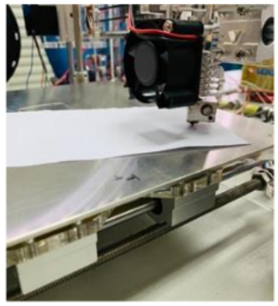

Fig. 2. Levelling method using plain paper

2.2 Spirit Level Method

Another common tool to examine the surface levelness is a spirit level (Fig.3). Even though this tool is easy to use and inexpensive the result shown is less accurate since no detailed measurement unit is shown.

A feeler gauge is compulsory for this method where the hard materials could use to adjust the gap between the heated bed and nozzle. The first step of this method is to set the extrusion head to home all position (0,0,0), then move upward for 10mm (0,0,10) then move to the centre of the bed (100,100,10). The feeler gauge is placed exactly under the nozzle before lowering it down for 10mm (10,10,0) or selecting Home Z. The spirit level is placed to examine the levelness of each side of the heated bed while adjusting the adjuster bolts.

Fig. 3. Levelling method using sprit level tool

2.3 Dial Indicator Gauge Method

The dial gauge indicator is used as a quality control tool to precisely check the levelness of a surface (Fig.4). A dial gauge with 0,01mm of accuracy is used for levelling and feeler gauge to adjust the gap. Firstly, the nozzle is set to home all position (0,0,0), then moved upward for 10mm (0,0,10) then to the centre of the bed (100,100,10). The feeler gauge is placed below the nozzle then select the Home Z menu. The dial indicator gauge dragged around on the edge side of the heated bed while adjusting the adjuster screw. A good and levelled surface indicated if the needle is standing still even if the dial is moving around.

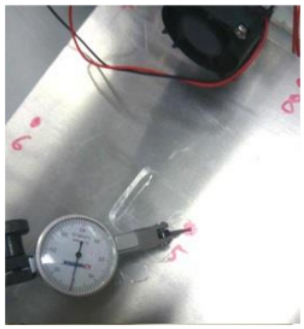

Fig. 4. Levelling method using dial indicator gauge

2.4 Bolts Adjustment Error

Another source of failure is the unprecise screwing of the small adjusting bolts. The M3 sized adjusting bolt works by converting the rotation movement into linear movement[9]. Different stop position on each bolt could result in the bed height differences that lead to unlevel conditions. The movement's distance can be checked using the thread's lead angle (ß) equation as follows:

$$\beta = arctan((1 - P)/(d2.\Pi)) \qquad (1)$$

Thread arch length equation is used to calculate length of travel;

$$L = \theta(\Pi/180).r \qquad (2)$$

Height of translation calculated using trigonometry equation:

$$h = tan\,\beta\,.L \qquad (3)$$

Where:
ß = Lead angle.
P = Pitch.
d = Nominal diameter of thread.
L = Length of travel.

h = Height of translation or movement.

The equations above explain that the adjusting bolt will move upward or downward if the adjusting nut is rotated. Small error in rotating the adjusting nut in opposite direction will double the distance and create huge unlevel surface's gap of the heated bed platform.

3 Experiment Results

3.1 Result of Experiment using Manual Levelling Method

In this method, the nozzle gap is adjusted by using plain paper to create levelness of the bed surface. The adjusting bolt adjusted to press the paper until it feels not too loose and not too tightly pressed. This method highly depends on the sense and experience of the operator.

Table 1. Levelling deviation using manual setup method

Check point	Height deviation from datum		
	1st	2nd	3rd
1	0.4870	1.7480	1.3623
2	0.8807	0.6437	1.1636
3	0.6584	1.6827	1.5701
4	1.3553	0.7104	1.4152

As a result, average 0.8683mm differences were obtained from the first experiment, following 1.1043mm and 0,4065mm (Table 1). Total average deviation obtained is 0,793mm that exceed maximum nozzle distance which is 0,3mm [10].

3.2 Result of Experiment using Dial Indicator Gauge

The second experiment was using Spirit Level, one of the easiest tools for levelling, to maintain the levelness of the heated bed.

Table 2. Levelling deviation using spirit level setup method

Check-point	Height deviation from datum		
	1st	2nd	3rd
1	-2.6259	-2.7187	0.8672
2	0.1205	0.0269	0.5673
3	-2.9059	-2.7397	1.0317

4	-1.9331	-1.7907	0.6067

As a result, average 3.0264mm differences were obtained from the first experiment, following 2.7666mm and 0.4644mm (Table 2). Total average deviation obtained is 2.0858mm that exceed maximum nozzle distance which is 0,3mm.

3.3 Result of Experiment using Dial Indicator Gauge

Dial indicator gauge is one of the precision levelness inspection tools to perform quality inspection and this tool is expected to evince better levelling setup results.

Table 3. Levelling deviation using dial indicator setup method

Checkpoint	Height deviation from datum		
	1st	2nd	3rd
1	0.8503	0.2616	0.8715
2	0.4858	-1.9196	0.5702
3	1.4752	0.3947	1.0330
4	0.5981	0.0519	0.6112

As a result, average 0.9894mm differences were obtained from the first experiment, following 2.3143mm and 0.4628mm (Table 3). Total average deviation obtained is 1.2555mm that exceed maximum nozzle distance which is 0,3mm.

3.4 Bolts Adjustment Error

To setup the heated bed levelness by screwing the adjusting nut is one of the trickiest works to perform. The height shall adjust by rotating the nut, and this relies on the operator's feelings. Too much or too less rotating degree may cause different translation movements and affected to a dissimilar height of the heated bed platform.

The theoretical calculation result of adjusting bolt movement found that:

$$ß = 3.38°$$
$$\mathrm{L} = 0.026\ mm$$
$$\mathrm{h} = 0.0015\ mm$$

This result expalins that the adjusting bolt will move by 0,0015mm for each 1° of rotation. A full 360° of adjusting nut rotation will lift the heated bed platform for 0,54mm, this could create bigger gap than the maximum allowance. This experiment shows the tendency of the bolt and screw system to be the cause of difficulties in levelling setup.

4 Conclusion

Derived data from the experiments, with three manual methods conducted, shows the difficulties to obtain accurate and better levelness condition of the heated bed. Out of the 3 levelling methods, the manual method provides the best result, however, it is still over the maximum allowance.

Theoretical analysis using the mathematical formula for adjusting the bolt's translation movements also indicated the difficulties in levelling the heated bed using the bolts system. The equation indicated the occurrence of a large gap deviation if the setup was performed carelessly by an inexperienced operator. These experiments confirmed the difficulties of obtaining a good levelness condition using the current bolt adjuster system. Even though further analysis and observation shall be conducted, this research provides the ground for further development of new adjustment tools to replace the bolts system.

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