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 have been invented and the Fused Deposition Modelling (FDM) 3D printer as one of it. It works by depositing melted polymer materials layer by layer to form a product. Difficulties in setting up the levelness of the heated bed is one of the difficulties faced by the users. A tiny bolts that used as the levelness adjuster of the heated bed's platform has contribution to the error of the levelness setup. This research analyzes 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 obtained levelness deviation that higher than the maximum allowance. The mathematical equation also explained 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 [1] to improve manufacturing efficiency [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 process, works 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 existed 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 [6] and human error is relatively high during the FDM 3D printing process [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) as shown in Fig.1.

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. This method highly depends on the operator's sense during the setup. Secondly, a spirit level tool that widely used 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 where this result should be less than 80% [9]. Maximum deviation for a standard 0,4mm nozzle hole shuld be 0,3mm.

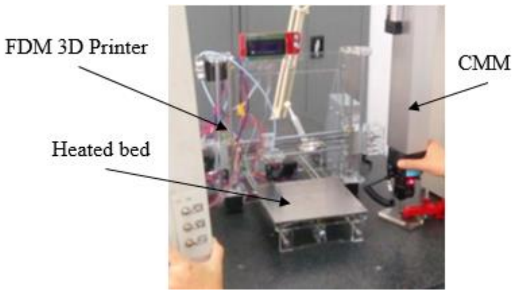

Fig. 1. Levelness examination using CMM

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 as shoen in Fig.2 a. 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. The paper need to be pulled to check the gap, it should be easy to pull with light friction sensed. These activities were performed while adjusting the adjuster screw below the heated bed and applied to each corner of the heated bed.

2.2 Spirit Level Method

Another common tool to examine the surface levelness is a spirit level as shown in Fig.2 b. 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.

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 as shown in Fig.2 c. 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 moved 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 by a stand still needle although the dial is moving around.

(a) (b) (c)

Fig. 2. (a) Levelling method using plain paper, (b) using sprit level tool, (c) using dial indicator

2.4 Bolts Adjustment Error

Another source of failure is the unprecise screwing of the small adjusting bolts. The M3 adjusting bolt works by converting the rotation movement into linear movement [10]. 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 explain that the adjusting bolt move upward or downward if the adjusting nut is rotated. Errors in rotating the adjusting nut in opposite direction could 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

Table 1 shows the result, an 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 [9]. In averange one corner of the bed printer is lower or higher by 0,793mm from the others, this condition may cause difficulties of the filament to stick to the bed. The results still exceeded maximum allowance eventhough this setup performed by a experienced user and this shows the diffciulties of this task. This also explained the innacurate of this method and requires to developed further.

3.2 Result of Experiment using Sprit Level Gauge

The second experiment was using Spirit Level, one of the easiest tools for levelling, to maintain the levelness of a flat surface.

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

The experiment resulting deviation's average of 3.0264mm from the first experiment, following 2.7666mm and 0.4644mm as shown in Table 2. Total average deviation obtained is 2.0858mm that exceed maximum nozzle distance which is 0,3mm. High deviation of the levelness could cause worst printing result. This method should produce better levelness but this experiment shown contrary result, this may cause by the adjusting system that could easily cause human error during adjusting the bed.

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. This method may not applicable to be used by the FDM 3D printer user since this tool relatively expensive and special skill is required. Theoretically this method should produce better levelness condition but this experiment shown contrary result, this may cause by the adjusting system that could easily cause human error during adjusting the bed, therefore chance for human error during the bolts adjustment should be analized.

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 resulting differencess in the heated bed platform's height.

The theoretical calculation result of adjusting bolt movement found that:

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

This result explains 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 and produce bad product, therefore the operator should perform this setup carefully. This experiment shows the tendency of the bolt and screw system to be the cause of difficulties esperienced in levelling setup and might be the cause of failure of the levelling methods above.

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 of 0,3mm.

Theoretical analysis using the mathematical formula to 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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