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Auto-level System on 3D Printer Bed Using Arduino and 3D Touch Probe Sensor

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***Abstract*— The development of technology today has emerged the latest technology in three-dimensional (3D) printer machines. Problems faced by 3D printers include the position of the printer bed that is not horizontal. The position of the printer bed that is not horizontal will cause the 3D print to be skewed. To overcome the problem of tilting the bed of a 3D printer, the auto-level system is needed, which is a system that can correct the position of the base so that it becomes horizontal.**

In this study, an auto-leveling system was designed and made for four 3D printing base support positions. The drive for the printing press uses a stepper motor with a worm gear transmission. The controller uses an Arduino board and tested various position sensors to determine the slope of the base. The sensor tested is a 3D touch probe sensor. From the test results, the 3D touch probe sensor has a height value difference of not more than 0.05mm from each measurement position. The print base slope reference point is at the center point of the print base. The position of the other corner of the base will be adjusted in height with a stepper motor drive.

***Keywords*— 3D printer, auto-leveling, 3D touch probe, worm gear transmission**

I. INTRODUCTION

The auto-level feature on the 3D printer bed makes it easy for users to adjust the alignment of their 3D printer bed. This feature was created because the leveling bed process was first carried out manually, which had many shortcomings, namely the subjectivity of the measurement between the bed and the nozzle tip in the 3D printer bed alignment calibration and the length of the leveling process.

Then the bed leveling feature developed into Mesh auto-level which adds a probe to the 3D printer head which is integrated with the 3D printer controller to perform the leveling process automatically at points on the surface of the 3D printer bed. The measurement results from the leveling process are stored in the controller for data processing and used to engineer the movement of the Z-axis (vertical axis) of the 3D printer head as compensation in the process of printing 3D model objects so that they can follow the flatness of the 3D printer bed surface.

This feature has also been developed by Kim [1] regarding the development of an optical auto-level system using a quarter photodetector sensor. In the system developed by Kim using a quarter photodetector sensor, this sensor optically measures the alignment on the surface of the 3D printer bed just like a level measurement in a plane. After the bed alignment measurements are made, the measurement data is processed on the controller and then the controller with its algorithm instructs the motor to adjust the bed height at each corner of the 3D printer bed surface. The problem with this research is that the quarter photodetector sensor is still manually installed on the 3D printer bed to measure the surface alignment.

Using this principle, a 3D printer will be added to an auto-level system on a 3D printer bed based on an Arduino microcontroller and a 3D Touch sensor probe. The working principle of this auto-level system is that leveling is done automatically with the help of the 3DTouch probe sensor to measure the alignment of the 3D printer bed. This system also uses 4 stepper motors as actuators to adjust the height of the bed on a 3D printer as research developed by Kim. Thus, this auto-leveling system is expected to be the ideal auto-level system for today's 3D printer bed.

II. SYSTEM DESIGN

A. Block Diagram

This block diagram is divided into 2 parts, namely the main part of the 3D printer and the additional part of the auto-level system on the 3D printer bed. In the main part of the 3D printer, the main components are Arduino Mega 2560, RAMPS 1.6, stepper motor driver, stepper motor, heater/heater, fan, limit switch, 3D Touch probe sensor, thermistor, LCD module, and control panel. Then in the additional part, the auto-level system on the 3D printer bed has the main components, namely the Arduino Mega 2560, stepper motor driver, and stepper motor. Communication between the main and auxiliary parts of the auto-level system on this 3D printer bed uses UART / USART (Universal Synchronous / Asynchronous Receiver Transmitter) serial communication. According to Andrianto [2], this UART serial communication is used for communication between the Arduino Mega 2560 microcontroller in the main part of the 3D printer as well as an additional part of the auto-level system on the 3D printer bed so that auto-level commands can be implemented on the 3D printer.

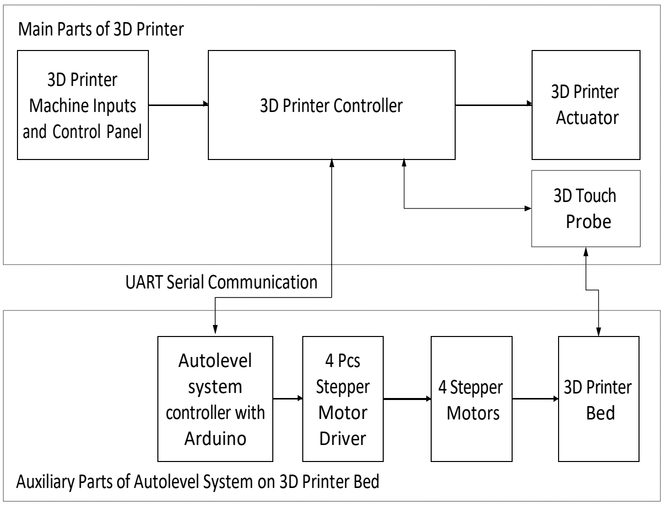


Fig. 1 System block diagram

B. Hardware Design

1) 3D Printer Main Part Design

The design of the main part of the 3D printer is a connection system between Arduino Mega 2560 and RAMPS 1.6 with the existing devices on the 3D printer consisting of stepper motors, heaters, fans, limit switches, 3DTouch probe sensor, thermistors, and LCD modules.

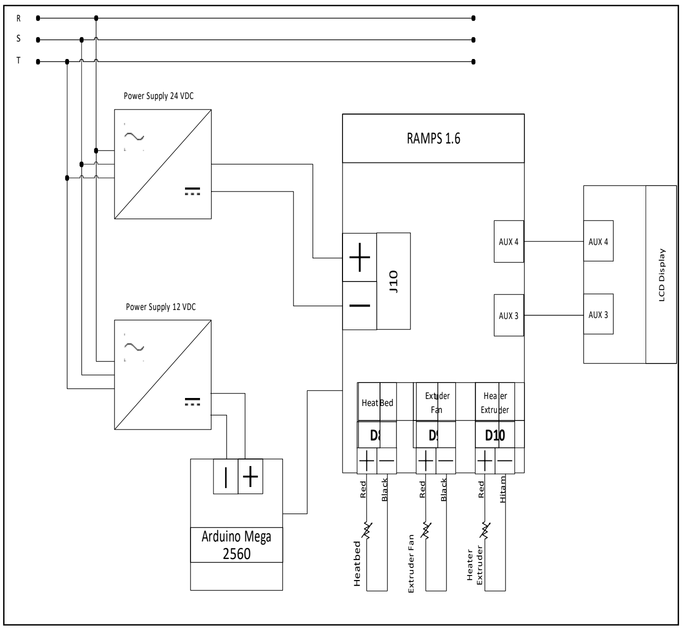


Fig. 2 3D Printer Main Parts Connection System Part 1

Figure 2 above describes the overall connection used in the main parts of a 3D printer. It is shown that the Arduino Mega 2560 microcontroller is connected to RAMPS 1.6 which is installed with main power in the form of 2 power supplies 24 VDC and 12 VDC, Heatbed heater, Extruder fan, Extruder heater, and LCD module are also connected.

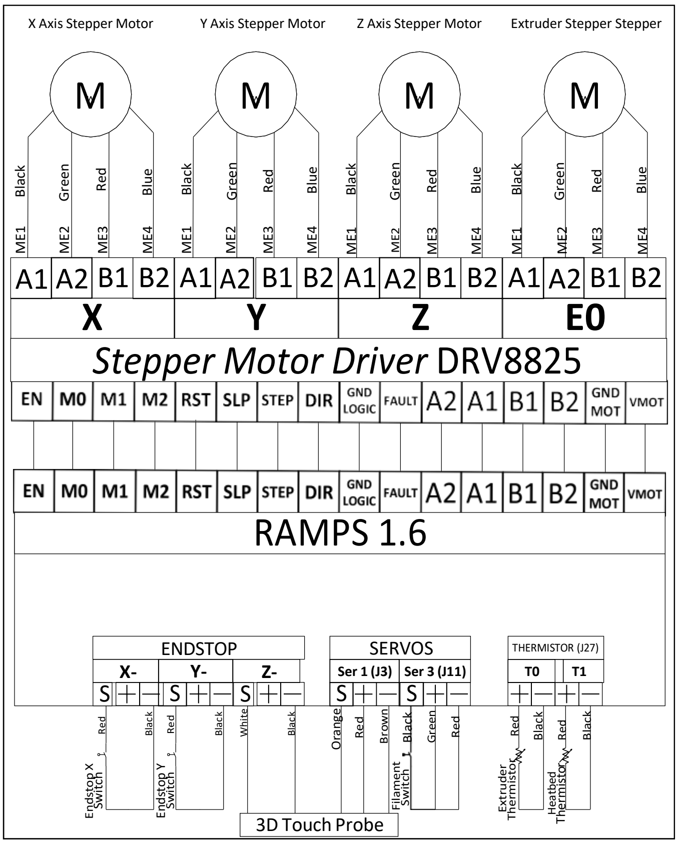


Fig. 3 3D Printer Main Parts Connection System Part 2

The connection system for the main part of the 3D printer is continued in Figure 3 which is shown by RAMPS 1.6 which is installed with 4 DRV8825 stepper motor drivers, namely the stepper motor driver for the X-axis, the stepper motor driver for the Y-axis, the stepper motor driver for the Z-axis, and the last stepper motor driver for the extruder stepper motor. Other parts of a 3D printer include the thermistor extruder, head bed thermistor, X end-stop switch, Y end-stop switch, Z end-stop switch, filament switch, and the 3DTouch probe sensor.

2) Design of Auto-level System Additional Parts on 3D Printer Bed

The design of the additional auto-level system on this 3D printer bed has several components, namely the Arduino Mega 2560, 4 DRV8825 stepper motor drivers, and 4 Nema 17 stepper motors. Design of Arduino Mega 2560 microcontroller I/O pins with components - The components in the additional part of the auto-level system on this 3D printer bed are described in Table 1 below.

TABLE I
ARDUINO MEGA 2560 I/O PIN SETTING

Pin Number	I/O	Description
2	O	DIR Driver Motor Stepper A
3	O	STEP Driver Motor Stepper A
4	O	ENABLE Driver Motor Stepper A
5	O	DIR Driver Motor Stepper B
6	O	STEP Driver Motor Stepper B
7	O	ENABLE Driver Motor Stepper B
8	O	DIR Driver Motor Stepper C
9	O	STEP Driver Motor Stepper C
10	O	ENABLE Driver Motor Stepper C
44	O	DIR Driver Motor Stepper D
45	O	STEP Driver Motor Stepper D
46	O	ENABLE Driver Motor Stepper D
14	O	RXD from 3D Printer Machine Main Parts
15	I	TXD from 3D Printer Machine Main Parts

C. Software Design

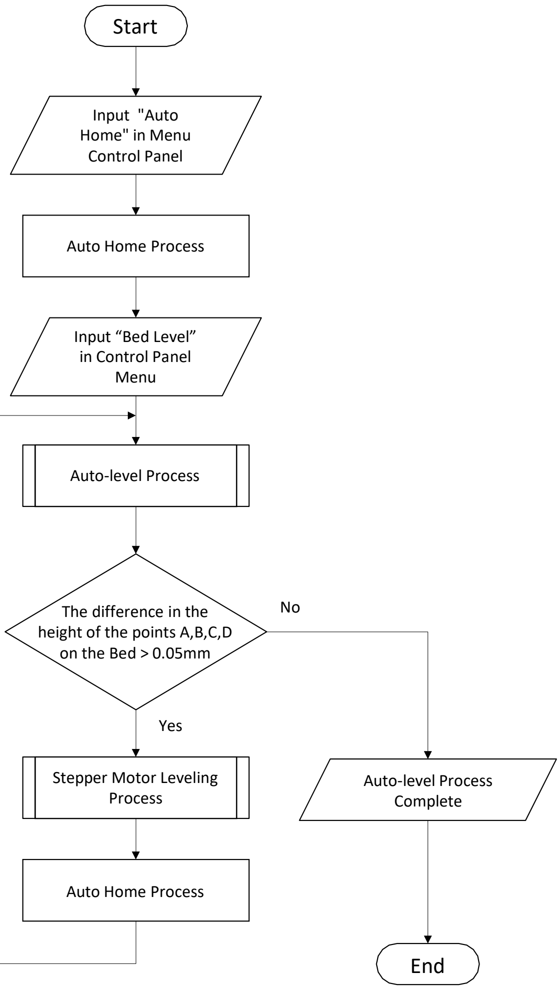


Fig. 4 System flow chart

The software design for the auto-level system is described in the overall flow chart in Figure 4. The first step is the auto-home process which aims to determine the zero point of the Z axis. Then the "Bed Level" feature is selected to start the auto

-level process. At this stage, the 3D Touch probe will measure the height of 4 points on the surface of the 3D printer bed, namely points A, B, C, and D. The height data will be processed and the difference calculated by Arduino. If the height difference is more than 0.05mm, the system will perform the stepper motor leveling process.

In this stepper motor leveling process, the system will command four stepper motors to rotate according to a predetermined height, namely the maximum bed height minus half the difference in height from the 4-bed surface points. Then the process continues with the auto home process and returns to the auto-level process that has been described previously. If the height difference is less than equal to 0.05mm, the system will state that the auto-level process is complete.

III. RESULTS AND DISCUSSION

A. Hardware Physical Form

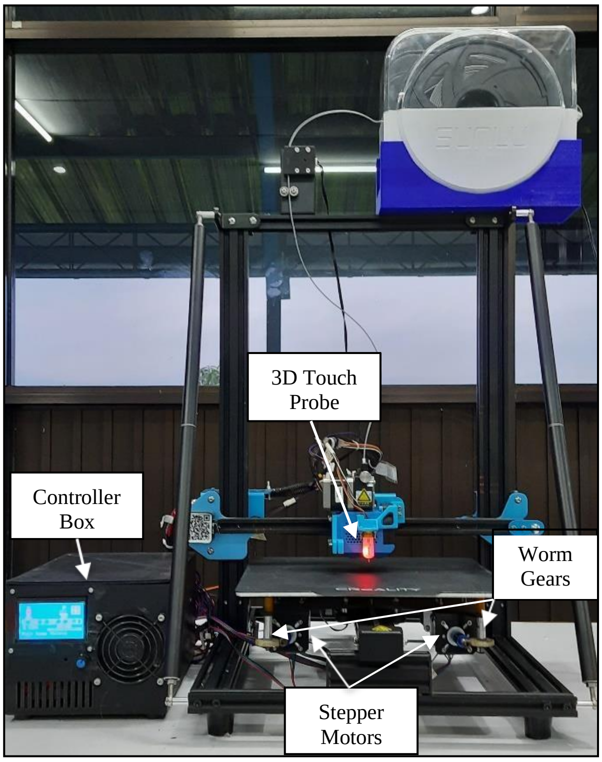


Fig. 5 Hardware physical form

Based on the hardware design described earlier, namely the main part of the 3D printer and the additional part of the auto-level system on the 3D printer bed, the physical form of the hardware consists of electronic and mechanical parts as shown in Figure 5 which consists of electronic and mechanical parts. The electronic part is in the form of a control box that contains the controller for the main part of the 3D printer which consists of an Arduino Mega 2560 microcontroller with RAMPS 1.6 and an additional part controller for the auto-level system on the 3D printer bed along with other components. Meanwhile, the mechanical part consists of the 3D Touch probe position sensor, stepper motor, and worm gear mounted on a 3D printer. According to Falendra [3], the worm gear was chosen as a transmission element that can transmit power and rotation on the crossed shaft of the stepper motor with 3D printer bed fixing bolts.

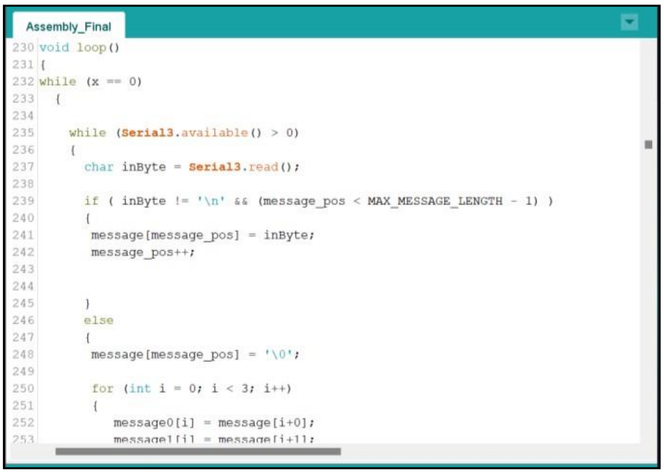
B. Software Discussion

TABLE II
MARLIN CONFIGURATION

Line	Code	Description
128	#define BAUDRATE 250000	
136	#define MOTHERBOARD BOARD_RAMPS_14_EFB	
315	#define TEMP_SENSOR_0 1	100k thermistor
320	#define TEMP_SENSOR_BED 1	100k thermistor
533	Const bool X_MIN_ENDSTOP_INVERTING = false	Depending on the switch configuration of endstops
534	Const bool Y_MIN_ENDSTOP_INVERTING = false	
535	Const bool Z_MIN_ENDSTOP_INVERTING = false	
613	#define DEFAULT_AXIS_STEPS_PER_UNIT {160, 160, 800, 764.28 }	Scale steps/milimeter {x,y,z,e}
620	#define DEFAULT_MAX_FEEDRATE {1000, 1000, 5, 25 }	Speed mm/sec
849	#define INVERT_X_DIR false	Homing towards the end-stop is
850	#define INVERT_Y_DIR false	
851	#define INVERT_Z_DIR false	
856	#define INVERT_E0_DIR false	Direct drive extruder

1) 3D Printer Main Parts Program: in the form of the Marlin firmware configuration in the Configuration.h [4] code shown in Table II. The configuration is carried out so that the 3D printer can run properly and enable the auto-level feature. The configuration includes baud rate, motherboard type, temperature sensor, endstop logic, stepper motor rotation scale in steps/millimeter, axis movement speed in mm/second, the direction of movement of homing, and extruder.

2) Auto-Level System Additional Part Program on 3D Printer Bed: consists of a UART serial program from a 3D printer controller, a bed surface difference calculation program, and a stepper motor program shown in Figure 6. The UART serial program contains a program for serial communication between the Arduino Mega 2560 microcontroller as a 3D printer controller and the Arduino Mega 2560 microcontroller as an auto-level system controller on a 3D printer bed. The bed surface difference calculation program functions to calculate the difference in 4 points of the 3D printer bed surface height where the difference value is used as the maximum flatness of the bed surface. The set difference value is 0.05 mm which is safe not to create a new layer in the processing of printing 3D model objects. Finally, there is also a stepper motor program that functions to control 4 stepper motors under the bed to adjust the height of the 3D printer bed.




```
void loop()
{
while (x == 0)
  {

    while (Serial3.available() > 0)
    {
      char inByte = Serial3.read();

      if ( inByte != '\n' && (message_pos < MAX_MESSAGE_LENGTH - 1) )
      {
       message[message_pos] = inByte;
       message_pos++;


      }
      else
      {
       message[message_pos] = '\0';

       for (int i = 0; i < 3; i++)
       {
          message0[i] = message[i+0];
          message1[i] = message[i+1];
```

Fig. 6 Auto-level system program listing

C. Testing the Dimensions and Perpendicularity of 3D Model Objects

This test aims to determine the quality of the prints from a 3D printer that has added the auto-level feature in this study compared to the auto-level mesh feature that is currently developing. In Figure 7 there are 20 printed samples consisting of 4 prints using the auto-level system in this study in the form of a cube with a size of 20 x 20 x 20 mm and printed with placement in the positions shown in the figure. Then there are also 16 other printed samples using an auto-level mesh which is a cube with a size of 20 x 20 x 20 mm which is printed on the bed surface of the 3D printer with a bed height change of +0.1mm in each position. Figure 8 shows the measurement of the dimensions of the cube with the Dial Caliper and checking the squareness of the cube with the Square Line.

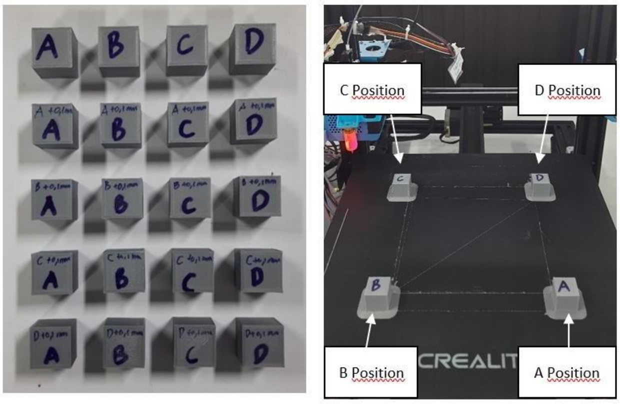


Fig. 7 Printed objects with dimensions and perpendicular measurements

Fig. 8 Printed objects with dimensions and perpendicular measurements

TABLE III
DIMENSIONAL MEASUREMENT AND PERPENDICULAR 3D MODEL OBJECTS

Cube Label	Dimension Measurement (mm)			Perpendicular
	Length	Width	Height	
A	20.02	20.00	19.60	Good
B	20.05	19.98	19.62	Good
C	20.02	20.00	19.64	Good
D	20.06	20.00	19.60	Good
A+0.1mm **A**	19.92	19.90	19.50	Good
A+0.1mm **B**	20.04	19.92	19.60	Good
A+0.1mm **C**	19.98	19.88	19.68	Good
A+0.1mm **D**	19.94	19.90	19.60	Good
B+0.1mm **A**	19.94	19.92	19.50	Good
B+0.1mm **B**	20.00	19.86	19.60	Good
B+0.1mm **C**	19.98	20.02	19.74	Good
B+0.1mm **D**	20.03	20.03	19.60	Good
C+0.1mm **A**	19.94	19.92	19.60	Good
C+0.1mm **B**	19.98	19.86	19.70	Good
C+0.1mm **C**	20.00	19,98	19.60	Good
C+0.1mm **D**	19.98	19.90	19.60	Good
D+0.1mm **A**	20.00	20.02	19.54	Good
D+0.1mm **B**	20.00	19.98	19.70	Good
D+0.1mm **C**	19.98	19.96	19.78	Good
D+0.1mm **D**	19.98	19.88	19.62	Good

Based on Table III, the test of dimensions and dimensionality of 3D model objects with the auto-level system in this study has a difference in dimension size between each cube of not more than 0.05mm. While the results of measurements of the tilted bed condition with an increase in height in each position on the bed according to Figure 7 and Table III and using the auto-level mesh system have a difference in dimensions between each cube of more than 0.05mm. Then all the printouts have good conditions.

D. Looping Testing on Auto-level Process

This test aims to determine the number of loops that occur and the length of time in the auto-leveling process. This looping can occur because in the flow chart the auto-level process shown in Figure 4 will be considered complete if the difference in the height of the points from points A, B, C, D is not more than equal to 0.05mm. So that when these conditions have not been met, the process will check again by carrying out the stepper motor leveling process, then proceed with the auto home process, and finally carry out the auto-level process. The number of repetitions of this check is called looping. The following data loops along with the length of time the auto-level system process in this study are shown in Table IV.

TABLE IV
AUTO-LEVEL LOOPING AND RUNTIME DATA

The tilted bed height position	Height change distance (mm)	Number of looping	Auto-level processing time (minutes)
A	+0.032	3	4’
B	+0.032	3	4’ 21”
C	+0.032	3	3’ 51”
D	+0.032	1	1’ 49”
A	-0.032	1	1’ 59”
B	-0.032	1	1’ 53”
C	-0.032	1	1’ 55”
D	-0.032	4	5’ 32”

E. Bed Alignment Test with Dial Indicator

This test aims to determine the alignment of the bed on a 3D printer by using a Dial Indicator measuring instrument. Dial Indicator or often called Dial Gauge is a tool for measuring the flatness of a flat surface, measuring the surface flatness and roundness of a shaft, and measuring the flatness of the cylinder wall surface (Rinoza, 2018) [5]. With this Dial Indicator measuring tool, the alignment of the 3D printer bed after auto-leveling can be known.

Table IV shows the results of alignment measurements at positions A, B, C, D before and after which were previously tilted by changing the height at one of these positions. Figure 9 shows a 3D printer bed alignment measurement before auto-leveling using the Dial Indicator. And Figure 10 shows the measurement of the 3D printer bed alignment after auto-leveling using the Dial Indicator.

TABLE IV
AUTO-LEVEL LOOPING AND RUNTIME DATA

Tilted Bed Height Position	Height change distance (mm)	Bed alignment before auto-level (mm)				Bed alignment after auto-level (mm)			
		A	B	C	D	A	B	C	D
A	+0.032	0	+0.03	+0.04	-0.03	0	+0.02	+0.02	-0.02
B	+0.032	0	-0.03	-0.03	-0.06	0	+0.02	+0.01	-0.02
C	+0.032	0	+0.03	+0.03	-0.01	0	+0.02	-0.02	-0.02
D	+0.032	0	+0.03	+0.04	-0.03	0	+0.03	+0.01	-0.01
A	-0.032	0	+0.06	+0.07	-0.02	0	-0.02	-0.02	+0.01
B	-0.032	0	+0.02	+0.01	-0.03	0	+0.02	+0.02	-0.02
C	-0.032	0	+0.04	+0.04	-0.02	0	+0.01	+0.02	-0.02
D	-0.032	0	+0.03	-0.02	+0.01	0	+0.01	+0.02	-0.02

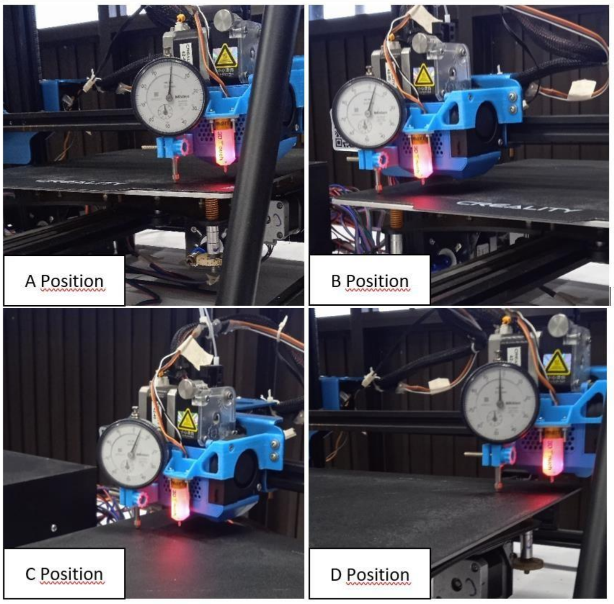


Fig. 9 Dial indicator measurement before auto-level

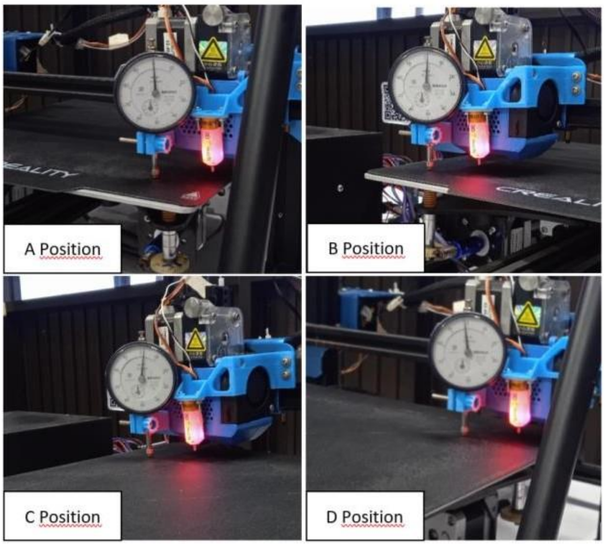


Fig. 10 Dial Indicator measurement after auto-level

Based on Table IV, the results of the 3D printer bed alignment measurements were carried out before and after auto-level. Alignment of the 3D printer bed which was carried out before the auto-level was tilted at one of the positions with the values listed in Table IV and shown in Figure 9 has a difference in height values of more than 0.05mm from each measurement position from the Dial Indicator. Meanwhile, the 3D printer bed alignment which was carried out after auto-level and the alignment measurements shown in Figure 10 has a difference in height values of not more than 0.05mm from each measurement position from the Dial Indicator.

IV. CONCLUSIONS

From the results of testing and retrieval of data from the auto-level system on the 3D printer bed, it can be concluded that the results of testing the dimensions and angles of 3D model objects have a difference in dimensions of not more than 0.05mm and good angularity. So that the resulting 3D model objects can be judged well in terms of quality. Then looping can also occur every time the auto-level is carried out because the system requires a repeated checking process to ensure the alignment is not more than 0.05mm. Finally, the 3D printer bed alignment results have a height value difference of not more than 0.05mm from each measurement position from the Dial Indicator. So that the bed printer can be used to print 3D model objects with maximum results.

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