Jurnal Teknik Mesin
Mechanical Xplore (JTMMX)
Mechanical Engineering
Vol. 3 No. 1 (2022) pp. 26-33
p-ISSN: 2746-0045 e-ISSN: 2746-3672
https://journal.ubpkarawang.ac.id/index.php/JTMMX

Performance Analysis of The 3D Printer Corexy FDM Type With Area X=200 Y=200 Z=200 mm

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ABSTRACT

A 3D printer is the result of the development of automated machining technology, which progresses from the creation of a design to the printing of a product with a complex shape and high precision for optimal printing results. The 3D printer design process begins with the creation of a design to determine the machine's dimensions, followed by the determination of specifications for the required motors, the design of electrical wiring to select the specifications for a controller, and finally, the testing of the tools when 3D printing. The accuracy of 3D corexy printers and 3D Cartesian printers are compared experimentally in this study. The printing process using a 3D printer produced two values that exceeded the tolerance limit, one in each dimension's length and width, according to the results of ten tests. The printing process results in a 3D Printer Cartesian exceeding the tolerance limit by four values: one for the length dimension, two for the width dimension, and one for the height or depth dimension. The 3D Printer Corexy is consequently more precise than the 3D Printer Cartesian because it fails less frequently.

Keywords: *Automated machining technology, 3D Printer Corexy, 3D Printer Cartesian.*

Article information:
- **Submitted:** 15/07/2022
- **Revised**: 22/07/2022
- **Accepted:** 29/07/2022

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Type of article:

☑ Research papers

☐ Review papers

1. INTRODUCTION

Manufacturing companies must develop new products to meet consumer demands. Some manufacturers work on product development, which is the process of translating product concepts from technical drawings into physical products[1]. The process of creating the first physical model or prototype of a product is known as prototyping. Prototyping is critical because it represents the final step in the process of modifying a product's form, suitability, and function. Rapid prototyping is building a product layer by layer or layer by layer, adding raw materials so that the finished product conforms to the model.

A 3D printer is a printer that uses sophisticated technology to shape three-dimensional objects with near-perfect accuracy. A 3D printer is a printer that creates three-dimensional objects from digital files [2]. One of the primary benefits of a 3D printer is the ability to create prototypes in a relatively short period. 3D printers have become an essential tool in the manufacturing industry for speeding up the prototyping process. However, due to the high cost of the product, the Indonesian industry has been slow to adopt this technology. As a result, only a small percentage of large industries and an even smaller percentage of small industries use 3D printers. A low-cost 3D printer is required to compete with more significant industries. As a result, using open source software, a 3D printer with the exact specifications of a less expensive 3D printer has been developed, allowing the industry to expand and improve product quality. From now on, a 3D printer will be built with corexy hardware, Marlin firmware, and an Arduino Mega 2560 controller [3]. Pagaraf will go over some of the 3D printer research that has been done. 3D printing, also known as additive manufacturing, is a method of producing a three-dimensional solid object from a digital model. The 3D rendering process is an iterative procedure created by layer-by-layer material modification [4].

A 3D printer is the primary focus of manufacturing companies, particularly for developing new products, and it uses advanced technology to print nearly identical 3D objects. A 3D printer is a device that produces three-dimensional objects from digital files [5]. One of the benefits of using a 3D printer to create a model is rapid prototyping. 3D printers are an essential industrial tool for accelerating prototyping. However, because of the high cost of these tools, the Indonesian industrial sector has yet to use this cutting-edge technology widely. As a result, 3D printers are used by only a small number of small and medium-sized businesses, as well as a minority of large industries. To compete with large industries, an innovative and cost-effective 3D printer design is required for the lower-middle industry. To boost the competitiveness of low- and middle-income industries, a 3D printer machine with the same hardware design and specifications as existing 3D printers but at a lower price is created using open source supporting software [6]. A 3D printer will be built using mechanical corexy, Marlin firmware, and an Arduino mega 2560 controller. The following is a discussion of some of the 3D printer research that has been done.

A 3D printing machine, called additive manufacturing, converts a digital model into a three-dimensional solid object. Because 3D printing is additive, objects can be created by adding or placing material layer by layer. Traditional machining methods, also known as subtractive processes, differ significantly from 3D printing. Products are manufactured in subtractive processes by reducing the starting material through cutting. The first paper on 3D printing was published in 1982 by Hideo Kodama of the Nagasaki Municipal Industrial Research Institute. In 1984, 3D Systems Corp's Charles W. Hull's work enabled the first 3D printer to function [7]. Prototyping for the mobile phone industry, jewellery, aviation, automotive, footwear, industrial design, architecture, construction, dentistry, the medical industry, education, and civil machineering are typical applications of 3D printing technology. Designers can use this technology to quickly convert their ideas into 3D objects, allowing them to assess the viability of a product based on factors such as ergonomics and others. FDM-based 3D printing machines are made up of several critical components [8]. Varieties of 3D printers

Darsin et al. expanded on the research by creating a 3D printer machine with an Arduino mega 2560 controller that can store executable files on a memory card, eliminating the need for the printing process to be constantly connected to a PC [9]. A prototype 3D printer machine will be built using research and development techniques. 3D printers can create prototypes faster and more affordably than conventional methods. This rapid prototyping machine is an essential piece of industrial equipment. As a result, it is critical to developing less expensive 3D printer manufacturing techniques. Li et al. investigated 3D Cartesian printers operating in three dimensions (X, Y axis on the rail to the left-right, and Z axis up-down) on a rectangular 3D Printer Cartesian bed [10]. The Cartesian model is pushed to the leadscrew on the z-axis via the belt and pulley on the X and Y axes [8]. The structure of a 3D Printer Cartesian is depicted in **Figure *1***.

For the research, a 3D printer with a square Cartesian design and a print bed that only moves along the vertical Z axis was used [11]. Because the nozzle is powered by a stepper motor and moves horizontally towards X and Y, the 3D printer is called corexy. The 3D Printer Corexy works on the same principles as the 3D Printer Cartesian, with a belt and pulley guiding the X and Y axes [12]. The Corexy employs two stepper motors to drive the X and Y axes simultaneously, whereas the 3D Printer Cartesian employs only one. **Figure *1*** depicts the corexy printer in 3D.

Figure 1. Model 3D Printer: (a) 3D printer Cartesian (b) 3D printer Corexy.

2. METHODOLOGY

This study employs an experimental approach to compare the accuracy of Corexy and 3D Printer Cartesians with identical test parameter settings. **Figure *2*** illustrates the research methodology.

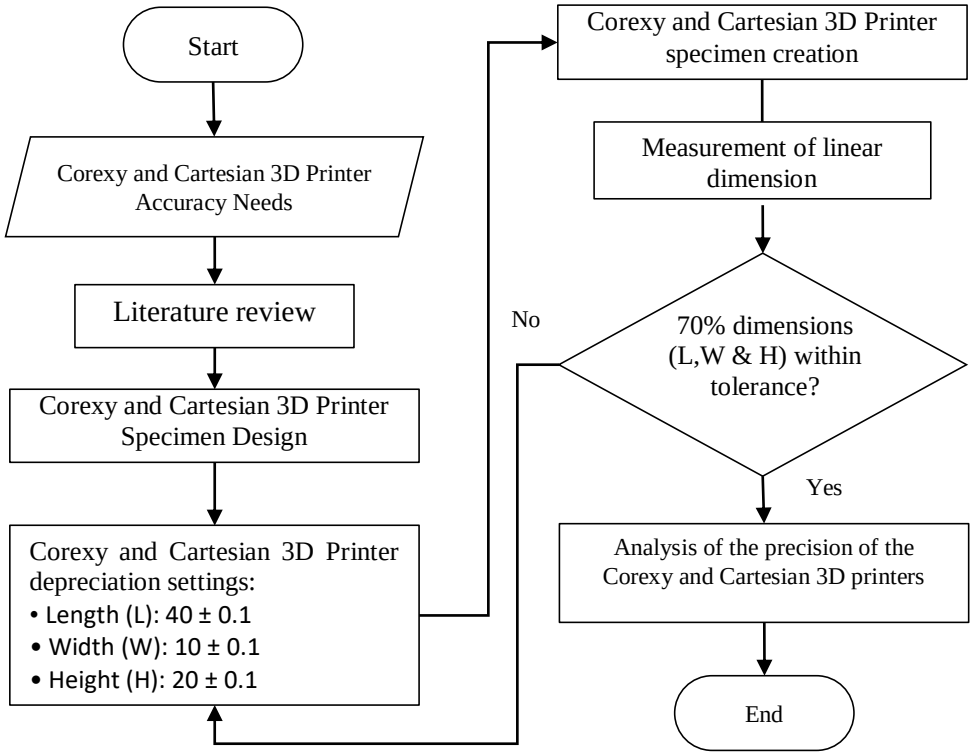

Figure 2. The research flowchart methodology.

2.1. Poly Lactic Acid Material

The material used in this study is of the PLA (Poly Lactic Acid) variety. In Simplify 3D software, set the 3D printer to 0.2000 mm layer, 20% infill percentage, 210°C extruder temperature, 50°C temperature bed, and 3000 mm/min speed. The design that will be tested is one that will be used to determine the tool's accuracy. By creating geometric objects, specifically block objects, where each tool prints a block ten times, accurate results from the 3D Printer Corexy and the 3D Printer Cartesian can be obtained. The precision of printing block objects is defined as the object not being less or greater than the tolerance limit. Figure 3 illustrates the test equipment used in this study, which includes a 3D Printer Corexy and a 3D Printer Cartesian. **Figure 3**.

Figure 3. 3D printer machine: (a) 3D printer corexy (b) 3D printer Cartesian

2.2. Arduino Mega 2560

Arduino is a microcontroller-based board or open-source electronic circuit board whose primary component is an AVR-type microcontroller chip manufactured by Atmel. This microcontroller consists of a computer-programmable chip or IC (integrated circuit). The objective is to incorporate the programed into the microcontroller so that it can read the input, process the input, and then produce the desired output. Therefore, the microcontroller controls the input and output processes of electronic circuits (Arduino, 2022). It is of the Arduino Mega type 2560 variety [13]. The Arduino Mega 2560 is an ATmega2560-based Arduino-compatible microcontroller development board. This board has a significant number of I/O pins, including 54 digital I/O pins (15 of which are PWM), 16 analogue input pins, and 4 UART (serial port hardware) pins. The Arduino Mega 2560 features a 16 MHz oscillator, USB port, DC power jack, ICSP header, and reset button. This board is extremely comprehensive and already contains everything required for a microcontroller.

The Arduino Mega 2560 can be powered by an external power supply or a USB connection. The Arduino Mega 2560 specifications are shown in **Table 1**. The power source is automatically selected. AC-DC adapter or battery may be used as an external power source (non-USB) The adapter can be connected by inserting a 2.1 mm plug with a positive center terminal into the board's voltage source jack. If the voltage is supplied by the battery, it can be connected directly to the Gnd pin header and vin pin of the power connector. The Arduino ATmega 2560 board can operate from a 6 to 20-volt external power supply. If the voltage is below 7 volts, the 5 volt pin 12 will likely produce less than 5 volts, causing the board to become unstable.

Table 1. Specifications for the Arduino Mega 2560 [14]

Part	Specifications
Chip microcontroller	ATmega2560
Operating Voltage	5V
suggested input voltage (via DC jack)	7V - 12V
Input voltage (limit, via DC jack)	6V - 20V
Digital I/O pin	54 units, with 6 providing PWM output
Analog *Input pin*	16 units
DC current per I/O pin	20 mA
3.3V. pin DC current	50 mA
Flash Memory	256 KB, 8 KB already used for bootloader
SRAM	8 KB
EEPROM	4 KB
Clock speed	16 MHz
Dimension	101.5 mm x 53.4 mm
Mass	37 gram

2.3. Motor Stepper

Stepper motors are electromechanical devices that convert electronic pulses into discrete mechanical movement. The stepper motor moves in response to the given sequence of pulses. Therefore, a stepper motor must control it that regularly emits pulses [15]. The use of stepper motors has several advantages over conventional DC motors. The stepper motor is a DC motor without a commutator. Typically, stepper motors have only a coil on the stator and a permanent magnet on the rotor (ferromagnetic material). The stepper motor can be positioned in a specific location and rotated in the desired direction, clockwise or counterclockwise. There are three stepper motors: permanent magnet, variable-reluctance, and hybrid. These types perform the same fundamental functions, but their applications differ significantly.

2.4. Firmware Marlin

Marlin is an open-source firmware for the RepRap family of 3D printers replicating rapid prototypes. Under the GPLv3 license, Marlin is free for all applications. Marlin was designed by and for RepRap enthusiasts to be a straightforward and dependable printer driver. A low-cost 8-bit Atmel AVR microcontroller powers Marlin [16]. Marlin now supports 32-bit boards as of version 2. x. This chip is the heart of the popular open-source Arduino and Genuino platforms. The Arduino Mega2560 with RAMPS 1.4 and the Re-Arm with RAMPS 1.4 serve as Marlin's reference platforms.

2.5. Printing Process

In this study, the specimens were printed using different mechanics on Corexy and 3D Printer Cartesians. The printing procedure for a Corexy and 3D Printer Cartesian is as follows:

a. Solidworks 2018 is utilized for design preparation.
b. Save the design file as an stl. -formatted file.
c. Open the simplify3D software and load the stl. -formatted file.
d. Setting the 3D printer's density and speed.
e. Insert a USB from the 3D printer into the laptop, or save the file in G-code format to a memory card to print a file after the initial setup. **Table 2** displays the configurations of the parameters.

Table 2. 3D Printer Corexy and Cartesian test parameters

Parameter	3D Printer Corexy	3D Printer Cartesian
Primary Layer height	0,2000 mm	0,2000 mm
Internal infill pattern	Rectilinear	Rectilinear
External infill pattern	Rectilinear	Rectilinear
Interior infill percentage	20%	20%
Temperature primary extruder	210℃	210℃
Temperature bed	50℃	50℃
Speeds	3000,0 mm/min	3000,0 mm/min
Beam Length	40 mm	40 mm
Beam Width	20 mm	20 mm
Beam Height	10 mm	10 mm
Time	± 18 minutes	± 20 minutes

3. RESULT AND DISCUSSION

3.1. Linear dimensional analysis

The tests consisted of experiments in which identical specimens were created using different machines, and the results were later compared. The results of testing the manufacture of beams with the dimensions of the specimen in the figure, namely 40 mm in length, 20 mm in width, and 10 mm in height, are presented in Table 3.

Table 3. The measuring beam result in comparison to the results of both 3D printers

Sample No.	3D *Printer* Corexy			3D Printer Cartesian		
	Length	Width	Height	Length	Width	Height
1	40,05	20,05	10,00	40,20	20,00	9,95
2	40,02	20,00	10,05	40,03	20,00	9,95
3	40,01	20,00	10,00	40,02	20,00	9,97
4	40,00	20,05	9,99	40,05	20,12	9,96
5	40,00	19,95	10,00	40,05	19,95	9,97
6	40,20	20,15	9,98	40,13	20,13	10,12
7	40,00	20,00	10,00	40,02	20,00	10,00
8	40,00	20,05	9,98	40,04	20,05	9,96
9	40,00	20,07	10,00	39,99	20,07	10,00
10	39,99	20,00	9,95	40,00	20,00	9,95

It was correctly known that the printed data from the Corexy and 3D Printer Cartesians have a difference of approximately 0.2 mm. These results demonstrated that the mechanical 3D Printer Corexy machine could be juxtaposed with the 3D Printer Cartesian machine, allowing this mechanical 3D Printer Corexy can be used as a tool to aid in the production process and practical work performed by an agency that employs a 3D printer machine. **Figure 4** depicts the data for

comparing the length dimensions of the 3D Printer Corexy and the 3D Printer Cartesian. **Figure 4** demonstrates the length difference between the block objects produced by the two 3D printers is 0.3 mm.

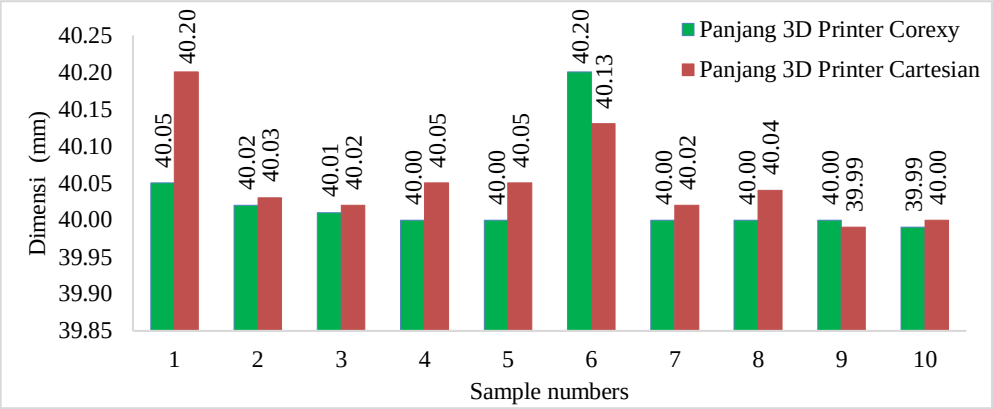

Figure 4. A comparison of the length of the beam dimensions

In terms of width dimensions, **Figure 5** compares the 3D Printer Corexy and the 3D Printer Cartesian. The width of the printed beam's sides differs by 0.2 mm between Corexy and 3D Printer Cartesians, as illustrated in Figure 5.

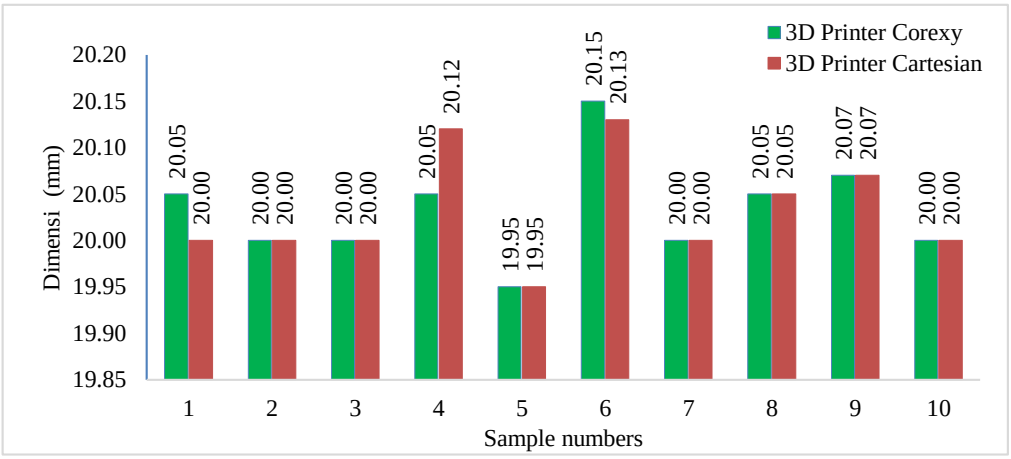

Figure 5. A comparison of the width of the beam dimensions

The height dimensions of the 3D Printer Corexy and the 3D Printer Cartesian are compared in **Figure 6**. According to **Figure 6,** the side height difference between the Corexy and Cartesian 3D printed beams is 0.17 mm.

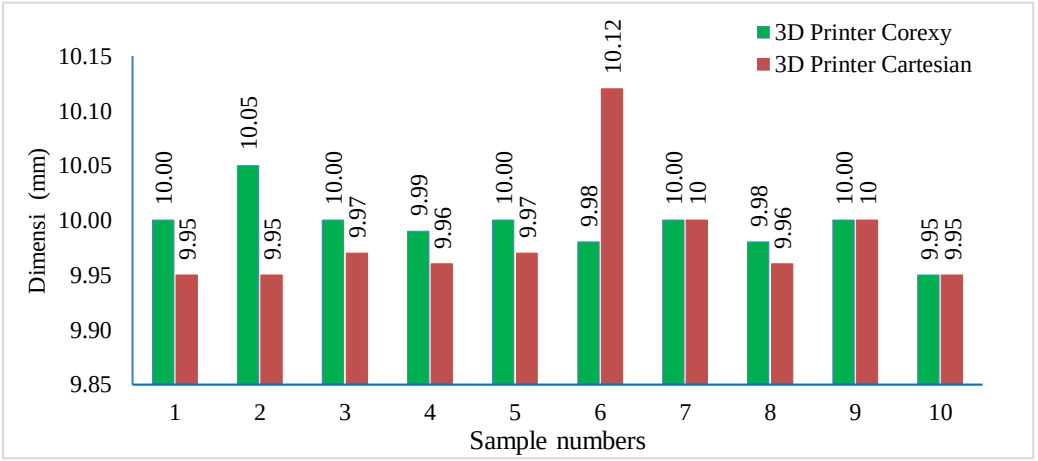

Figure 6. Comparative analysis of the second 3D printer's height dimensions

3.2. Analysis of result accuracy

Comparing the two 3D printers requires an evaluation of the linear dimension accuracy. According to the data in Table 3, it is known that several dimensions exceed the specified linear tolerance. Sample number 6 revealed an inaccuracy in the results of the 3D Printer Corexy. With linear dimensions of length and width measuring 40.20 mm and 20.15 mm, respectively, sample number 6 exceeds the tolerance of 0.1 mm. The 3D Printer Cartesian also produced inaccurate results, as determined by samples 1, 4, and 6. The results' inaccuracy is explained as follows:

a. With a value of 40.20 mm in the linear dimension of the length sample number 1, it is known that the value exceeds the tolerance of 0.1 mm.
b. In sample number 4, it is known that the linear dimension of the width exceeds the tolerance of 0.1 mm, with a value of 20.13 mm.
c. It is known that sample number 6 exceeds the tolerance of 0.1 mm in the linear dimensions of length, width, and height, with values of 40.13 mm, 20.13 mm, and 10.20 mm, respectively.

The results above prove that the researcher's 3D Printer Corexy was adequate for this study. The 3D Printer Corexy generates two inaccurate size values, whereas the 3D Printer Cartesian generates four inaccurate size values that do not fall within the specified tolerance. The result confirmed with previously result that 3D Printer Corexy has good performance [12]. The results mentioned above can also be used as evidence that the 3D Printer Corexy machine that the researcher created for this study was successful.

4. CONCLUSIONS

Based on the research findings regarding the design of an FDM-type 3D Corexy Printer with an area of 200 x 200 y 200 z 200 mm, the following conclusions can be drawn:

a. Two values exceed the tolerance limit or are declared inaccurate based on the results of ten trials conducted with a 3D Printer Corexy. Four values for the 3D Printer Cartesian exceed the tolerance limit or are deemed inaccurate. Based on these results, it can be concluded that the 3D Printer Corexy is more accurate than the 3D Printer Cartesian because the size value outside the tolerance is less for the Corexy printer.
b. Both 3D printers produced the best results during the printing process, with a record time of 18 minutes for the same specimen design. Cartesian achieves the best printing results with a record time of 20 minutes for the same design. Based on the information above, the 3D Printer Corexy machine with mechanical can be used as a practical tool or a production tool by small industries and educational institutions that utilise a 3D printer machine as a practical tool to save space and production costs.

AUTHOR'S DECLARATION

Authors' contributions and responsibilities

The authors contributed significantly to the conception and design of the study. The authors were responsible for data analysis, results interpretation, and discussion. The authors read the final manuscript and gave their approval.

Availability of data and materials

The authors have made all data available.

Competing interests

The authors declare that they have no competing interests.

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