Analysis of 3D Printer Program Design Using 5 Volt DC Motor and Arduino Mega 2560

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ABSTRACT

The design of a program to control a 3D printer using a 5volt DC motor and Arduino Mega 2560 aims to create a system that can control the movement and printing process with high precision. In this study, Arduino Mega 2560 is used as the main controller that connects various components such as a 5 volt DC motor, sensors, and actuators to drive the 3D printer platform and extruder. The 5 volt DC motor was chosen because of its ability to provide sufficient torque to accurately move the X, Y, and Z axes on the 3D printer. The design process involves writing program code using the C++ programming language to control the movement of the motor according to the instructions from the G-code file received from the slicing software. This program is expected to minimize errors in printing and increase the operational efficiency of the 3D printer. The results of this study indicate that the use of Arduino Mega 2560 with a 5 volt DC motor can provide fairly accurate and stable control in the operation of the 3D printer, while maintaining optimal print quality. Thus, this system can be used as an alternative solution in the development of a cheaper and more efficient micro-controller-based 3D printer.

Keywords: 3D printer, 5-volt DC motor, Arduino Mega 2560, Precision, Micro Controller.

Introduction

Rapid technological advances have had a major impact on various sectors of human life, including in the world of manufacturing and production. One of the important innovations that has emerged is 3D Printing technology or three-dimensional printing. This technology allows the creation of three-dimensional objects by gradually assembling materials (additive manufacturing) from digital data, which is different from traditional methods that use subtractive techniques such as material cutting. Thus, 3D Printing offers time and cost efficiency in the production process, especially for prototyping, which often requires quite a lot of time and cost in conventional methods.

The application of 3D Printing has grown rapidly and is used in various sectors, such as industry, education, health, and art. In industry, this technology allows the creation of prototypes and products with a very high level of precision and allows for more complex designs without the need for expensive tools or materials. In the medical world, 3D printing is used to print prosthetics that are customized to the patient's body shape, as well as for the creation of artificial organs. In the fields of education and research, 3D printing opens up opportunities for the development of more effective and efficient experimental models and designs.

The main advantage of 3D printing lies in its ability to reduce production time and costs, as well as provide a greater degree of flexibility in product design. However, in Indonesia, the adoption of 3D printing technology is still constrained by the high price of commercial 3D printer devices and the difficulty in obtaining the necessary components, which limits the accessibility of this technology among small industries and business actors in Indonesia.

In facing these challenges, efforts to create more affordable solutions are essential. One innovation that can overcome the cost and accessibility constraints is to create a 3D printer using cheaper and more readily available components, such as used DVD-ROMs that still function as motors and floppy disks. The Arduino Mega 2560, which is a relatively inexpensive microcontroller, can be used as the main controller in this system. The use of these used components can significantly reduce the cost of building a 3D printer, as well as providing a more affordable alternative for individuals and small businesses to utilize 3D printing technology.

Thus, the purpose of this study is to design and develop a 3D Printer that uses cheap and affordable components, such as used DVD-ROMs and floppy disks, and integrates them with Arduino Mega 2560 as the main controller for printing prototypes. This effort is expected to open up opportunities for more small industry players and the general public in Indonesia to utilize 3D Printing technology to increase efficiency and creativity in making products and prototypes.

The development of technology has increased very rapidly along with the development of the times. The development of this technology is directly proportional to the development of modern human civilization. Current technology helps humans in carrying out all daily activities, especially in the industrial sector. The industrial sector in this modern era has entered Industry 4.0, where the industry continues to experience rapid development, especially in the manufacturing sector. Product design is very important considering the tight competition and the rapid innovation issued by manufacturers to get a sales market.

In the product development process, realizing a design into a prototype is very important, especially in the manufacturing sector. In general, making a prototype takes a long time, so the industry needs a machine with good accuracy and fast manufacturing time in making a prototype. One of the efficient machines to cut the time in making a prototype is a 3D Printer.

3D Printer is a printer that has advanced technology and special capabilities to print three-dimensional objects with almost 100% similarity. 3D printer is a printer that processes digital files in the form of prints. One of the advantages of using a 3D Printer to make prototypes is its ability to make prototypes in a very short time. 3D printers are an important tool needed in the industrial world to speed up the process of making prototypes. However, the industry in Indonesia still does not use much of this advanced technology because the price of the tool is very expensive. Therefore, 3D Printers are only used by some large industries, while small to medium industries still use them a little. In order for small to medium industries to be able to compete with large industries, it is necessary to innovate the design of 3D Printers that are not too expensive.

Formulation of the problem:

1) How to design a 3D printer that utilizes readily available components?
2) How to integrate a 5-volt DC motor with Arduino Mega 2560 as the main control in a 3D printing system?
3) How to test a 3D printer is designed to have a good level of precision?

Literature Review

1. 3D Printer Technology

3D printers are automated machining technologies that enable the design and printing of products with complex shapes and high precision. Faris Dwi Mulyanto (2022) revealed that the 3D printer design process begins with the creation of a design to determine the dimensions of the machine, followed by determining the motor specifications, electrical wiring design to select the controller specifications, and ending with tool testing. This study compares the accuracy of the print results between the CoreXY and Cartesian types of 3D Printers.

2. Use of FDM Technology in 3D Printers

Herda Agus Pamasaria et al (2019) revealed that 3D printers are here to answer the need to print digital designs into real products. The most commonly used technique in 3D printing is Fused Deposition Modeling (FDM), because this technique is easy to use and inexpensive. Important factors that affect the quality of print results using FDM are surface roughness, dimensions, and geometry. This study compares various variations of 3D printing process parameters with the FDM technique to find the most appropriate parameters in producing the best product quality.

3. Development and Use of 3D Printers in the Modeling

World Maulana Abdul Malik Amrullah (2018) stated that 3D printers, as part of Additive Manufacturing, are a new trend in the modeling world. This technique uses solid materials such as plastic with numerically controlled machines or CNC. One type of printer is Cartesian, which uses the X, Y, and Z axes that move in one direction. The research includes the design, assembly, and testing of 3D printer systems to print three-dimensional objects.

4. Design and Manufacturing of Cartesian 3D Printer Model

Romario A Wicaksono et al (2021) discussed the design and manufacturing of FDM-based 3D printers with the aim of producing machines that can print accurately and quickly. This study includes three main stages, namely design using CAD software, printing and assembly of 3D printer machine components, and mechanical structure analysis. The designed printer has a printing area of 180 x 180 x 150 mm and uses Polylactic Acid (PLA) material. The simulation results using the Finite Element Method show that the machine is suitable for printing with a mass of up to 40% of the maximum load.

5. Important Components of a 3D Printer

Several main components of a 3D printer, such as the extruder and nozzle, affect the quality of printing. The extruder functions to melt and move the filament, which consists of a nozzle, heater, and fan. The nozzle is the part that releases semisolid material after being heated by the heater. The quality of the nozzle affects the ability of the material to be melted properly, especially for materials such as polycarbonate, nylon, and other high-temperature plastics. In addition, the build platform or bed is a flat surface where the printing process takes place. Some printers are equipped with a heated bed to maintain the temperature of the material during the printing process. The control electronics on a 3D printer consist of a microprocessor and a board that controls the program on the machine.

Research Method

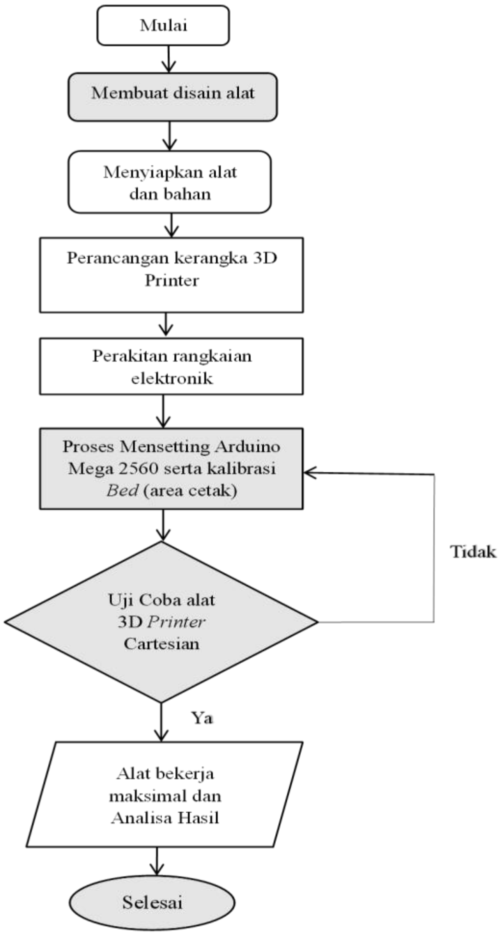

Figure 1. flowchart

1. **Getting Started:** The 3D Printer design process begins with defining the goals and requirements of the system. At this stage, the main goal is to design a 3D printer that can perform well and meet the precision standards in printing objects. It is important to define parameters such as the size of the print area, the type of motor used, and the required electronic components.
2. **Creating a Tool Design:** Once the objectives are set, the next step is to create a tool design. This design includes sketches or drawings of the entire system, including the movement mechanism, component sizes, and the arrangement of other elements such as the extruder and bed. A good design will help in preparing the components to be used and optimizing the overall performance of the tool.
3. **Preparing Tools and Materials:** At this stage, all the necessary components must be prepared. The main components needed include a 5 Volt DC motor, Arduino Mega 2560, cables, circuit boards (PCB), sensors, and printing materials (such as PLA filament). This tool preparation ensures that all the necessary materials are available and ready to be assembled.
4. **3D Printer Frame Design:** The design of the frame or chassis of the 3D printer is very important to ensure the stability and durability of the machine during the printing process.

The printer frame must be strong enough to withstand the load and vibration during the printing process. In addition, the frame also needs to be designed to be easy to assemble and arrange other components.

5. **Electronic Circuit Assembly:** At this stage, the electronic circuit will be assembled to connect all the components. This involves installing DC motors on the X, Y, and Z axes, as well as connecting these motors to a motor driver controlled by an Arduino Mega 2560. In addition, the extruder and sensors for temperature regulation must also be installed correctly. All cables must be connected correctly according to the planned circuit design.
6. **Arduino Mega 2560 Setup Process and Bed Calibration (Print Area):** Arduino Mega 2560 will be programmed to control the motor, extruder, and sensor. At this stage, the appropriate programming code will be written to control the motor movement on the X, Y, and Z axes as well as temperature control on the extruder and bed. After programming, bed calibration is performed to ensure that the print area is flat and balanced. An uneven bed can affect the print quality and accuracy of the printing process.
7. **Cartesian 3D Printer Tool Testing:** After the entire system is assembled and programmed, a tool test is performed to ensure that the tool works as expected. At this stage, testing is carried out on the motor movements on the X, Y, and Z axes as well as checking the temperature on the extruder and bed. This test also ensures that the tool can produce 3D objects that match the design entered into the system.
8. **If the Tool Works Optimally:** Analyze the Results After ensuring that the tool is functioning properly, the next step is to analyze the print results. The print results will be evaluated based on precision, surface roughness, and conformity to the desired design. If the tool successfully produces objects with high accuracy and quality, then this stage is considered complete. Completed The process of making a Cartesian 3D Printer tool can be considered complete if the tool successfully functions optimally and is able to produce prints according to the initial objectives.
9. **If the Tool Doesn't Work Optimally:** Repair If the tool doesn't work optimally, the problems found must be identified and corrected. For example, if the motor movement is inaccurate, check the motor control system and calibration. If the extruder temperature is unstable, check the temperature control settings and check the electrical circuit. Retest After the repairs are made, a retest is performed to ensure that all components are working properly. This test is carried out with the same steps as the previous tool test phase. The results of the test will be reanalyzed to ensure that the repairs have successfully improved the tool's performance.

Results and Discussion

This circuit uses Arduino Mega 2560 as a microcontroller and RAMPS 4.1 as a motor controller. All of these components are connected directly to the Arduino Mega 2560. The overall circuit can be seen in the picture.

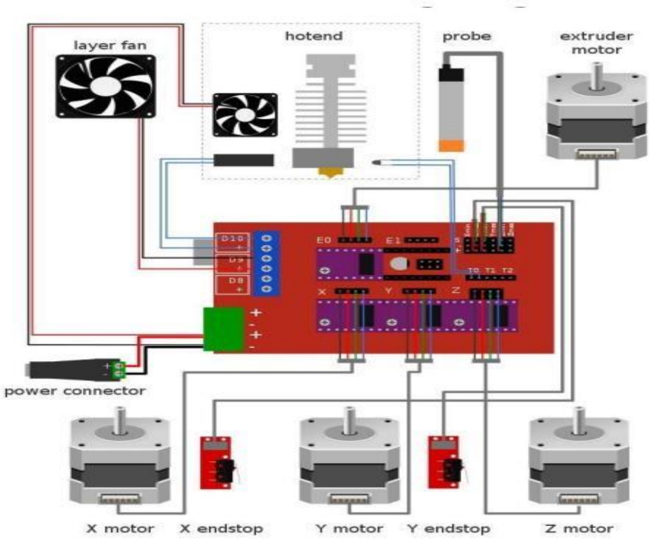

Figure 2. Circuit diagram of the entire system

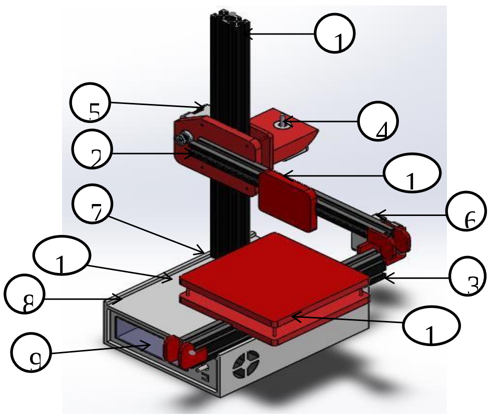

Figure 3. 3D *Printer Design*

Z-axis frame, Y-axis frame, X-axis frame, Extruder filament Stepper Motor, Y-axis Stepper Motor, X-axis Stepper Motor, Z-axis Stepper Motor, Base frame, LCD display, Bed or Build platform, Extruder mount, Arduino Mega 2560.

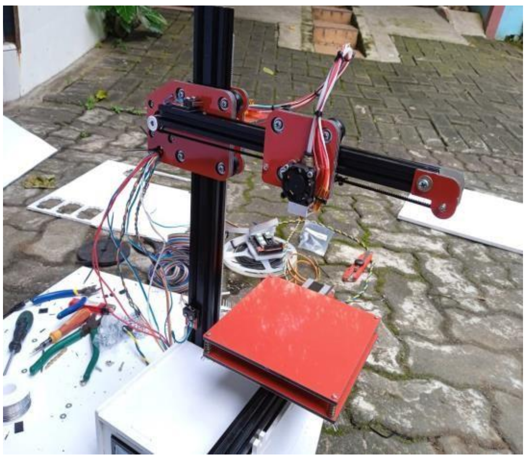

Figure 4. 3D *Printer* tool test

1. **Specimen Material and Design:**

The material used in this study is PLA (Poly Lactic Acid). The 3D printer settings in the Repetier Host software are set with an extruder temperature of 200 °C and a printing speed of 50 mm / s. The design to be tested aims to measure the accuracy of this tool. The specimen design used is a geometric object in the form of a block, where each printer will print the block 10 times. This aims to obtain accurate results from the Cartesian 3D Printer and the Anycubic Mega Zero Cartesian 3D Printer. An object is said to be precise if the print results do not exceed or fall below the specified tolerance limit. The following is a picture of the geometric object that will be tested and printed using the Cartesian 3D Printer and the Anycubic Mega Zero Cartesian 3D Printer.

2. **Specimen Design Process Using SolidWorks 2020**

The next process is the creation of a specimen design using SolidWorks 2020 software, where the design file is then converted into stl format for use on a 3D printer. The process of creating this design can be seen in Figure 3.13 and Figure 3.14.

- Beam Test Object:

In this experiment, the test object made is a block with dimensions of length (p) 30 mm, width (ℓ) 20 mm, and height (t) 15 mm. The following is the process of making a block design using SolidWorks 2020 software. This block design aims to test the accuracy and precision of the 3D printer tool in printing objects with specific sizes and according to the specified tolerances.

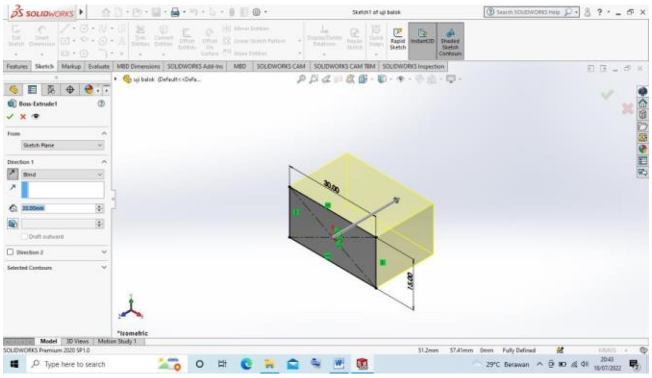

Figure 5. Making the beam design

3. **Printing Simulation**

The next process is the printing simulation process using the repeater host software and getting a 3D file ready to print. The simulation used can be seen in the image below:

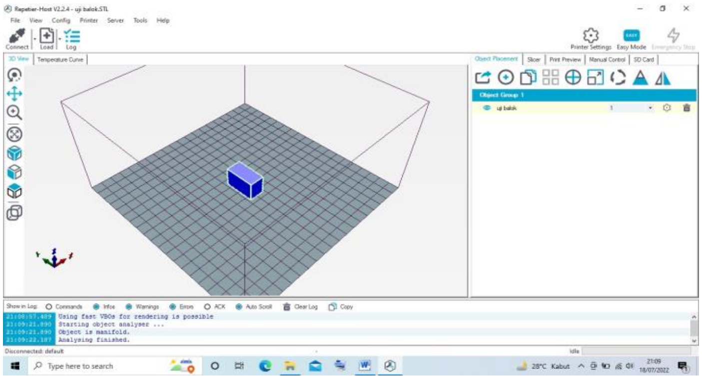

Figure 6. Printing Simulation

In the process of setting up the repeater host software, we need to determine how much print speed is needed for the design of the object we want to print. In this study, we used a print speed of 50 mm/s.

In the next process, namely perfecting the layer by layer stage where there are layers that are not completely closed so that they are all closed so that the results are maximized. After the simulation process is complete and seeing the results are maximized, the next process is to select “Save Toolpaths to Disk” and the software will save the file in gcode format. Then copy the file into the memory card of the 3D Printing machine used.

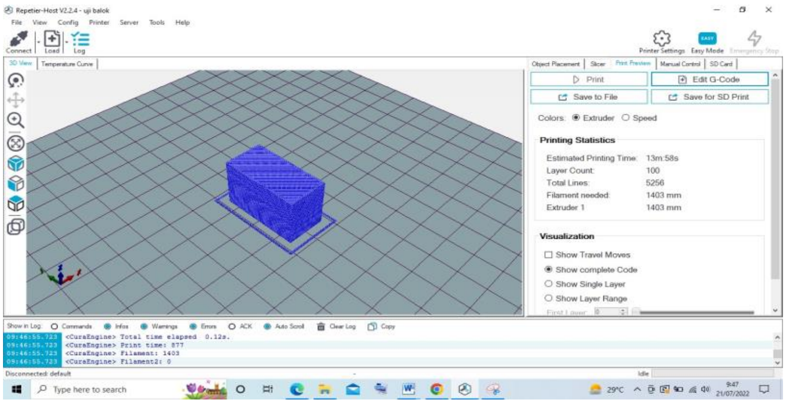

Figure 7. Final result simulation

4. Tool design results

The results of the design of the Cartesian 3D Printer tool using the Arduino Mega 2560 controller with a print area of 150 mm for the X axis, 150 mm for the Y axis, and 200 mm for the Z axis.

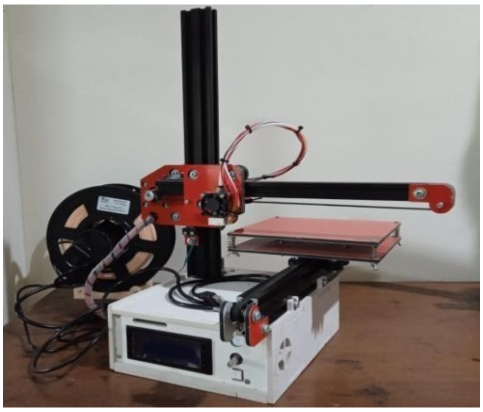

Figure 8. Final result of the Cartesian 3D *Printer*

5. 3D Printer machine printing

From the printing process, the specimen results are obtained as shown in the image below. For the process of using a Cartesian 3D printer, a trial process is carried out repeatedly because this Cartesian 3D printer is a new control so that to get the right results, it is necessary to do the trial many times.

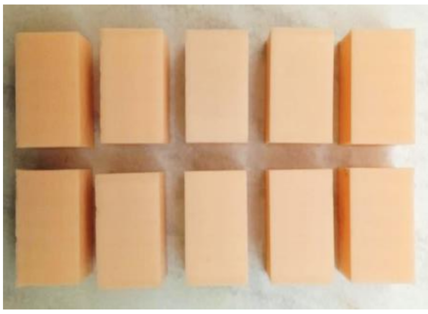

Figure 9. Printing results using a 3D printer

6. Results and Discussion of Experimental Testing

The test conducted was an experiment to make specimens with the same size, but using different machines. The results from the two machines will be compared to obtain clearer conclusions regarding the accuracy and precision of each 3D printer. The specimens tested had dimensions of 30 mm in length, 20 mm in width, and 15 mm in height for the block.

The following are the test results on the Cartesian 3D Printer machine which were measured in the dimensions of length, width, and height of the specimen:

Table 1. Results of Measuring Block Objects with a Cartesian 3D Printer

No	3D Printer Cartesian		
	Length (mm)	Width (mm)	Height (mm)
1	30.00	20.03	15.00
2	30.02	20.00	15.02
3	30.00	20.00	15.01
4	30.05	20.01	15.00
5	30.00	20.02	15.00
6	30.02	20.00	15.03
7	30.12	20.01	15.10
8	30.00	20.10	15.01
9	30.00	20.03	15.00
10	29.99	20.00	15.00

These measurement results show small variations in the length, width, and height of the specimens printed using the Cartesian 3D printer, with the variations being within the established tolerance limits.

7. 3D Printer Beam Length Tolerance Limit Graph

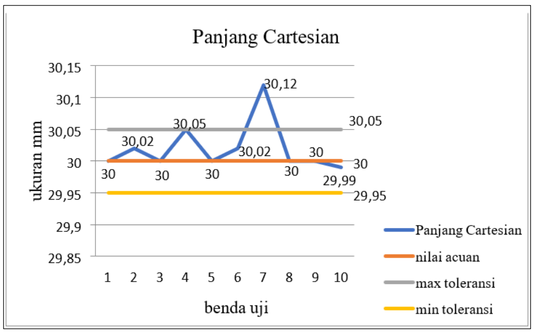

Figure 10. Tolerance Limit Graph

From the graph shown, it can be seen that the length of the beam printed using the Cartesian 3D printer shows good consistency in achieving the desired dimensions, but there is one case where the beam length exceeds the maximum tolerance limit. In the 7th test object, the beam length was recorded at 30.12 mm, which is slightly longer than the desired length of 30 mm. This indicates a deviation in the printing process that needs to be considered, although this deviation is relatively small.

Overall, the test results showed an error of 1.2%. This error reflects the difference between the printed length and the expected size, which can be caused by factors such as machine accuracy, printer calibration, or printing parameter settings such as temperature and print speed.

Conclusion

Based on the test results conducted using a Cartesian 3D printer, it can be concluded that this machine has the ability to print objects with fairly accurate and precise dimensions, although there are slight variations in the size of the printed specimens. The results of measuring the length, width, and height of the specimens show that although there are small deviations in the dimensions, they are still within acceptable tolerance limits.

Specifically, the test of the beam length showed one case where the beam length exceeded the maximum tolerance limit, namely on the 7th test object which was recorded at a length of 30.12 mm. However, this deviation only occurred once and overall, the error that occurred in printing was 1.2%. This error is influenced by several factors such as machine accuracy, calibration, and printing parameter settings, such as temperature and print speed.

In general, Cartesian 3D printers show good performance in terms of precision and accuracy, but to get more optimal results, further improvements and calibrations are needed on the machine, especially in setting more precise printing parameters. Thus, this machine can be used effectively for printing specimens with the desired tolerance, although there are slight deviations that are still within reasonable limits.

References

[1] Anief, ANA, & Wirawan, S. (2018). Design of XY Type 3D Printer Based on Fused Deposition Modeling (FDM) Using Autodesk Inventor 2015 Software. UNNES Vocational Engineering Dynamics Journal Volume 3 Number 2 October 2018 Pages 110-115.

[2] Ayi, R, & Mochammad, AF Extruder Design of Rapid Prototyping Machine Based on Fused Deposition Modeling (FDM) for Polylasctic Acid (PLA) Filament Material with Diameter 1.75 mm. Allegro MicroSystems, LLC. A4988 Microstepping Driver. 2014, pp. 1-22.

[3] Charles W. (2011) 3D System. Hull Executive Bio. Retrieved from www.3dsystems.com

[4] Cam, CA D, & Yanbing, W. (2015). Application of Additive Manufacturing on Marine Diesel Industry. 4(6), 8-10.

[5] Deepa, P. (2014). Fused Deposition Modeling – A Rapid Prototyping Technique for Product Cycle Time Reduction Cost Effectively in Aerospace Applications. IOSR journal of Mechanical and Engineering, 5, 62 – 68.

[6] Dede, S. (2012). Improving the Performance of Rapid Prototyping Machine Based on Fused Deposition Modeling (FDM), University of Indonesia, Jakarta.

[7] F, L. Pasaribu., & I, Roza, (2019). Design Control System Expand Valve On Water Heating Process Air Jacket. IOP Conference Series: Materials Science and Engineering.

[8] Mochamad, DM, & Gatot, E. P, (2017). Design and Construction of Cartesian 3D Printer Machine Frame Based on Fused Deposition Modeling (FDM). Journal of Mechanical Engineering Vol. 06, No. 4, October 2017. ISSN: 2549-2888.

[9] Moh, D., & Budi, G., & F. Shoufika, H. (2017) Design and Construction of a 3D Printer Using the Arduino Mega 2560 UMK Controller ISBN: 978-602-1180-50-1.
[10] Tseng, AA 2000. " Apparatus and method for freeform fabrication of three dimensional objects". US Patent No. 6030199.February 29.