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Design and construction of the 3D printer two-stand, controlled Arduino Mega 2560 R3 CH340G

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Abstract: The need to show the geometry of a workpiece of a component or system on a certain scale and three-dimensionality can be realized through a three-dimensional printing press. This paper explains the techniques and how to design a three-dimensional printing machine and test product printing. The three-dimensional printing machine has been successfully created and built, and the printing test shows the results corresponding to the machine's specifications.

The design and fabrication of printer 3D printing machine for PLA filament thermoplastic material has been successfully done. This machine implements an Arduino Mega 2560 R3 CH340G-based control system. The specifications of the 3D printing machine are as follows: Layer height = 0.2 [mm]; Infill density = 20%; Maximum Printing temperature = 240°C; Build plate temperature = 60°C; Print speed = 60 [mm/s]. The input comes from an AC power source that is converted to DC with an Input Power supply of 12 Volt 20 A. The machine has been tested, and parts with geometry are produced according to the machine's specifications.

Keywords: 3D printer; Fused Deposition Modelling; Arduino

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1. Introduction

This paper explains the design of a three-dimensional printing machine or 3D printer for PLA filament thermoplastic materials. The design and construction of three-dimensional printing machines are aimed at producing components or parts made of thermoplastic by the modeling method or fused deposition modeling (FDM), as the beginning of preparation for the application of electrically conductive thermoplastic composite filaments, and as multi-disciplinary applied research of mechanical design, control systems based on the Arduino Mega 2560 R3 CH340G, and the application of thermoplastic filament materials.

Fused Deposition Modelling (FDM) is one of the methods in three-dimensional (3D) printing technology. This method works by extruding thermoplastic materials, such as PLA or ABS, in the form of filaments through a heated nozzle. The material is melted and placed layer by layer on the building platform to form the desired 3D object. FDM is often used due to its simplicity, diverse availability of materials, and ability to print strong and durable objects.

Several applied studies on three-dimensional printing have been done by other researchers so far.

This article evaluates the influence of process settings on the dimensional accuracy of objects in 3D printing, especially cylindrical and rectangular shapes. The study also examined the effect of process setting and filament colour on the precision of the weight of the printed part. Most previous studies have focused more on the accuracy of rectangular 3D prints. 3D printing technology, especially the Fused Deposition Modelling (FDM) method, provides new possibilities in the creation of complex-shaped objects [1]. This research improved the extrusion system on the Model 1 printer from "cold" to "hot" to improve the quality of building model manufacturing with ABS and PLA resin materials. Process parameters are investigated, and the upgraded system is calibrated for hot extrusion techniques [2]. Additive manufacturing technology or three-dimensional (3D) printing has transformed the industry by replacing traditional manufacturing processes. The results of this study show the impact of the addition of conductive particles on mechanical performance and electrical conductivity in composites. The research also identified significant thermo-electro-mechanical interactions in 3D CB-PLA printing, contributing to the advancement of functional electro-mechanical components in additive manufacturing [3]. The study is a pioneer in exploring the tribological properties of 3D-printed PLA polymers, focusing on color differences. Using Fused Deposition Modelling (FDM) technology, this study created a tribology test specimen to analyze the friction and wear properties of PLA in three different colors (white, black, and grey). This experiment provides in-depth insights into the tribological performance of PLA materials in the context of 3D printing [4]. The study involved the creation of 3D objects using the Ultimaker 2+ 3D printer by creating a replica of bolts and nuts. The design was created using SOLIDWORKS and analyzed with ANSYS for deformation, equivalent stress and shear stress. The results of PLA and ABS analysis of bolts and nuts are correlated and evaluated [5]. The study explores the influence of fiber orientation on material properties, including stiffness, strength, and toughness. Using PLA as a base material, this study shows that the printed material can be brittle or flexible, depending on the orientation of the layer. Fused Deposition Modelling (FDM) technology is used, where thermoplastic filaments are melted and ejected by nozzles, forming objects gradually. ABS and PLA are common filament materials in this technology [6]. This study introduces a learning case that aims to make it easier for students to improve the accuracy of low-cost 3D printers. The goal is to provide an easily accessible method for students of the Master of Industrial Engineering program, especially in the Precision Engineering and Additional Manufacturing courses [7]. Fused Deposition Modelling (FDM) is used to create a 3D model from CAD data by extruding a thermoplastic material using a heating tip. To overcome the cost constraints and difficulties in understanding the process parameters of commercial 3D printers, an open-source 3D printer was designed. The Design of Experiments (DOE) method is used to obtain the tensile strength of the specimen by varying the thickness of the layer, the orientation of the Infill, and the temperature of the extruder [8]. This study explored the effects of printing speed and temperature on the mechanical behavior and dimensional quality of 3D-printed PLA materials using Fused Deposition Modelling (FDM) technology. 3D printing has opened new opportunities with the advantages of automation, design freedom, and better mechanical performance. This study aims to understand how variable speed and temperature affect PLA 3D printing results [9]. In this study, we discuss the process of selecting machine construction using FDM technology. We detail the steps of printer reconstruction, restoration of technical documentation (Reverse Engineering), as well as calibration and measurement results. 3D printing is additive in nature, builds shapes gradually without initial shapes, and uses plastic materials. FDM technology works on the principle of "additives," putting the material in a layer to form a part [10]. The study focuses on the use of PLA as the main filament. Additional Manufacturing (AM) technology is used to reduce waste by building parts through the addition of materials. To improve the mechanical properties and temperature resistance of the PLA filament resulting from FDM printing, an experimental study was carried out by applying the aniline process [11]. FDM in 3D printing uses thermoplastics to create dimensionally strong and stable parts. This research focuses on the use of carbon fiber (15% volume) and polylactic acid (85%) to create 3D printing filaments through the extrusion process. The goal is cheaper and faster production, especially for automotive and aerospace applications [12]. The deployment of low-cost 3D printing machines is accelerated by the expiration of Stratasys' Fused Deposition Modelling (FDM) patent. This article discusses the comparison of dimensional performance between the original Prusa i3 3D printer and the improvements made by students, highlighting the differences in accuracy and shape errors in the geometric features of the reference artifacts [13]. This research focuses on Fused Deposition Modelling (FDM) in 3D printing, where process parameters affect the print result. This study experimentally and statistically studied the effects of various molding parameters, such as building orientation, raster orientation, nozzle diameter, extruder temperature, infill density, shell count, and extrusion speed, on tensile strength using Polylactic acid (PLA) filament [14]. This research focuses on Fused Deposition Modelling (FDM) in 3D printing, where process parameters play an important role in determining the print result. Through an experimental and statistical approach, the study investigated the impact of various printing parameters, including building orientation, raster orientation, nozzle diameter, extruder temperature, infill density, shell count, and extrusion speed, on tensile strength using Polylactic Acid (PLA) filaments [15]. Four-dimensional printing is a process in which 3D objects can be deformed in response to external stimuli such as temperature. In this study, experiments were carried out on three types of common 3D printing filaments, namely ABS, PETG, and PLA, by heating at different temperatures and observing the curving effect. The focus is to thoroughly understand the behavior of FDM 3D filaments, with analysis of not only the radius of the arc but also the velocity [16]. This study explores the role of additive manufacturing (AM) technologies, especially Fused Deposition Modelling (FDM), in Industry 4.0, with an emphasis on flexibility and low cost. The aim is to examine the relationship between AM parameters and environmental factors on the quality of the final product, focusing on the impact of environmental humidity, working temperature, and material pigments in the PLA [17]. This research focuses on optimizing the parameters of the 3D printing process to achieve optimized compressive strength in PLA parts. The influence of process parameters such as processing speed, processing temperature, and nozzle diameter was studied, and the results showed that the nozzle diameter had a significant impact on the final compressive strength, significantly increased compared with the original PLA filament [18]. The article discusses the role of additive manufacturing (AM) technologies based on the type of material used in FDM 3D printers. Focus on optimizing process parameters such as layer thickness, infill density, and temperature to improve mechanical properties and product quality. Taguchi's analytical approach is used for parameter-process optimization [19]. This study tested the ability of multi-extruder printers to print with different materials in a single product. The experiment was carried out by combining rigid PLA and elastic Carbon-PLA in a multi-material laminate. Flexural and shore hardness tests are carried out to evaluate the interaction of the two materials. The purpose of the study is to explore the potential for improving the mechanical properties of products through variations in laminate formation [20]. In this paper, the design and implementation of a suitable sensor set for 3D printers is presented. This range of sensors includes sensors for movement/vibration, temperature, orientation, and hygrometry. This sensor series is designed as a wireless sensor system that is easy to deploy in a client-server form [21]. The study explores the potential of open-source 3D printing with a focus on infill pattern parameters. Four infill patterns were evaluated for their impact on the mechanical properties of the prints. Research shows that the infill pattern affects the mechanical strength of the 3D-printed product [22]. This study explores the impact of temperature and annealing duration on the mechanical properties of PLA produced using a 3D printer. The samples were annealed at a wide range of temperatures and durations, and the results showed a significant influence on the mechanical properties of PLA plastics. The research focuses on the effect of the annealing process on the tensile strength, modulus of elasticity, hardness, and flexural strength of PLA parts produced by FDM [23]. This research focuses on 3D printing technology, especially the commonly used Fused Deposition Modelling (FDM) method. The effect of extruder temperature and layer thickness on the surface roughness of PLA is studied, depending on the printing orientation [24].

2. Design, Material and Construction method

The 3D printing machine in this article is designed with solid work (SW) aids. The design and construction steps follow Figure 1.

- Design planning, this step performs planning that explains how the entire design process is carried out.
- Design specifications, this step shows the performance of the designed 3D machine.
- Sketch drawing is a 3D machine sketch drawing of a design idea.
- Schematic drawings, drawings that contain all the information needed for 3D machine fabrication.

- Parts drawings are final working drawings and are instructions to manufacturers to fabricate 3D printing machine parts, complete with a parts list.
- Assembly drawings, drawings that explain the assembly sequence of a 3D printing machine.

The step shown in Figure 1 is the stage of designing a 3D printing machine that produces documents as shown in Figure 2 Exploded view of a 3D printer.

The stages of fabrication, assembly, and inspection are shown in the following explanation.

- Fabrication of parts is done based on the working drawings of each part at the design stage.

The assembly was carried out based on the assembly drawings from the planning stage, the results of the assembly are shown in Figure 3.

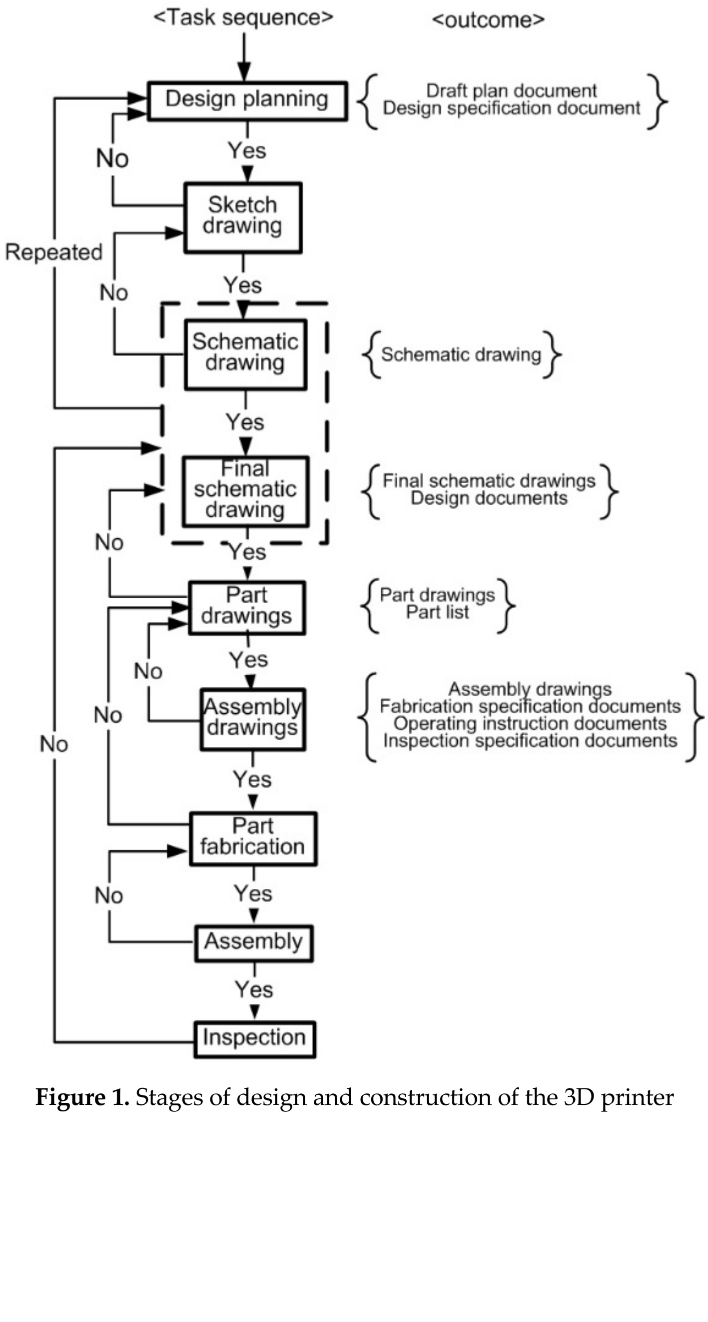

Figure 1. Stages of design and construction of the 3D printer

3. Results and Discussion

3. 1 Design

The design of the 3D printing machine has produced the shape shown in the exploded view image from Figure 2. In the exploded view picture, the dimensions of each part are not shown as copyright protection from the designer. Some of the elements of the 3D printing machine in the design are available on the commercial market. Some parts are fabricated by designers, especially frame holder bracket parts and between parts.

This design article groups the components of a 3D printing machine into several components:

a) Frame components: as a stand and support for other components and parts. The components and parts supported by the frame components are the Z-Axis Bracket Top Bracket, Nema 17 Stepper Motor, Z-Axis Connector, and X-Axis Bracket. Figure 2 and Figure 3 show the explanation. Frame assembled from Aluminium Profile Material Model: 2020 T-Slot Material; Al Alloy 6063-T5; Dimensions: 20×20 [mm] Hole: 5 [mm]. Column pole holders and horizontal supports are used as couplers.

b) The drive system components, as the drive of the plastic filament guide components follow the X, Y, and Z axes, according to the geometry of the printed object. The drive in the X and Y axes uses a Nema 17 stepper motor to move the Y axis, with a specification of 80 step/mm, step angel 1.8°, vref stepper motor 0.6 volts, rated current 1.5 amperes, moves the Timing Belt model GT2 with a pitch of 2 mm and a width of 6 mm through the timing pulley GT2 with a bore hole of 5 mm, the number of teeth is 20, The stepper motor is connected to the Arduino mega shield pin Y axis which has been installed on the stepper driver model A4988 + heatsink, with a specification of vref 0.6 volts, micro-step 1/16. It is moved by entering input from the display of the RepRap model. Drive in the direction of the Z axis: Nema 17 stepper motor to drive the Z axis, with a specification of 80 step/mm, vref stepper motor 0.6 volts, rated current 1.5 ampere, drive Lead Screw model T8 8 mm, pitch 2 mm, lead 8 mm, Length 200 mm with stainless steel material, through flexible type couple with outer diameter 19 mm, 25 mm long, 5 mm – 8 mm model, held with T8 8 mm model screw nut with brass material, with additional support linear road diameter 8 mm with 304 stainless steel material, stepper motor connected to Arduino mega shield ramp pin Z axis which has been installed stepper driver model A4988 + heatsink, with 1.2 volt vref specification, micro-step 1/16. It is moved by entering input into the display of the RepRap model. Extruder drive: Nema 17 stepper motor to move the filament, with a specification of 80 step/mm, vref stepper motor 0.6 volt, rated current 1.5 amperes, move the filament using a timing pulley, the filament enters the hot end.

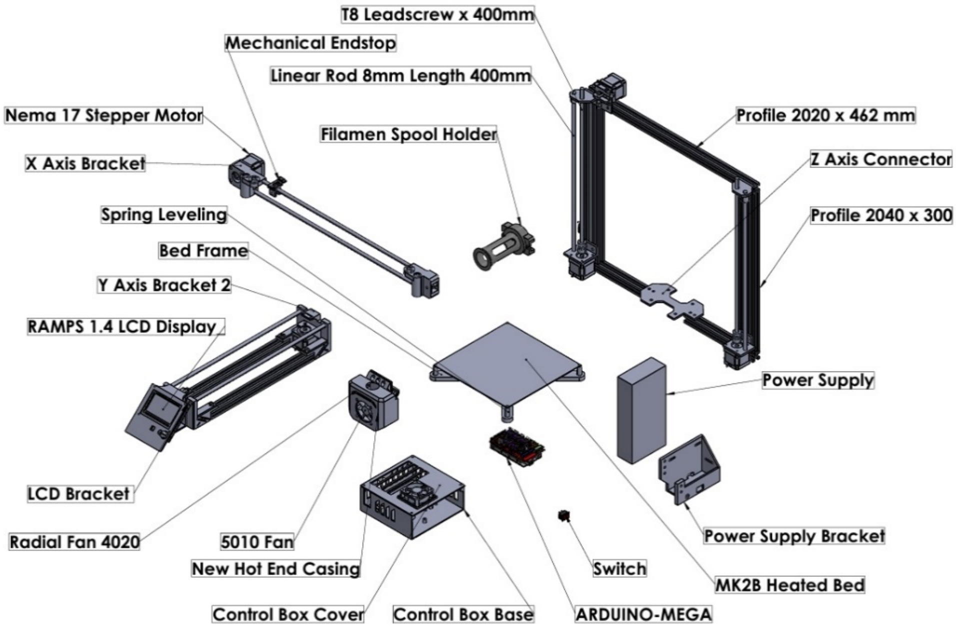

Figure 2. Exploded view of 3D printer

c) Electronic system and control, Arduino as a microcontroller on a 3D printing machine. The Arduino mega shield works to customize all the electronic devices needed for the 3D printing machine. The stepper driver sets many steps on the stepper motor. The display of the RepRap Discount Full Graphic Smart Controller model as an interface gives commands to the 3D printing machine. The power supply gives power to the 3D printing machine. End stop detects when an axis has reached the minimum or maximum limit. The heated bed heats the bed so that the filament from the 3D printing machine does not come off the bed. Switch for on/off 3D printing machine. Thermistor to monitor the temperature of heated blocks and heated beds.

d) The extrusion system consists of a hot-end melting filament, and a Hot end fan to cool the existing heatsink in the hot end, The Extruder works by pushing the filament into the hot end.

e) Software: Marlin software is used to run the 3D printing machine system.

3. 2 Fabrication and assembly

Parts and tools prepared, aluminum profile size 2040×300 mm, tap screw M6. Aluminum profile 2020×462 mm, in the drill Ø5 through and the drill Ø12 for the M6 bolt head mount. 2020×200 aluminum, in the drill Ø5 through and in the drill Ø12 for the M6 bolt head mount.

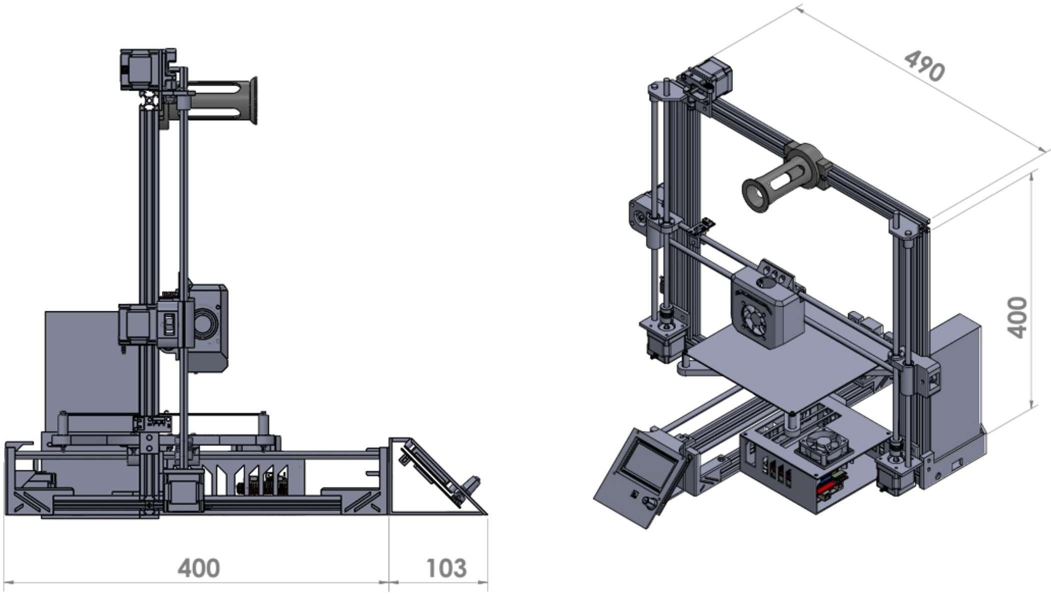

Figure 3. Assembly drawing of 3D printer

Y-axis assembly steps.

a) Assembly of the 2020×300 mm profile with Y-axis bracket, using M5 bolts and T nuts
b) Assembly of the 2020×200 mm profile in the center of the Y-axis profile, and locking of the Z-axis connector bracket, locking with M5 bolts and T nuts.
c) Assembly of 8×800 mm Linear road on Y axis, and install bed frame and installed linear bearing, lock with M5 bolt nut.
d) Stepper assembly of Nema Motor 17 to Y Axis Bracket, locked with M3 bolts.
e) GT assembly pulley bore 6 mm, belt width 7.4 mm to Y axis bracket, locked with M5 bolt nut.
f) Assembly of Y-axis timing belt with bed frame, Y-axis stepper, and Gt pully attached to the Y-axis bracket.
g) Assembly of the LCD Bracket on the Y-axis bracket, and lock with M5 bolt nut.
h) Assembly of the LCD Display on the LCD bracket, and lock with M3 bolts.
i) Spring leveling assembly together with Heated bed, and locked by M3×40mm bolt nut on Bedframe.
j) End-stop assembly on the Y-axis bracket.

Z-axis assembly steps

a) Assembly of 2040×300 mm profile with 2020×200 mm profile and locked using M6 bolts.
b) Z-axis bracket assembly on profile 2040×300 mm, bolt nut locked M5.
c) End stop assembly on profile 2040×300 mm, bolt nut locked M5.
d) Assembly of the 2020×462 mm profile on the 2040×300 mm profile according to the hole, M6 bolt locked.
e) Z-axis stepper motor assembly locked using M3 bolts.
f) 8×300 mm rod linear assembly on Z-axis bracket, locked with Z-axis top bracket by M5 bolt nut.
g) Assembly of the stepper motor couple and Lead Screw on the couple.

X-axis assembly steps.

a) Assembly of X-axis brackets 1 and 2 on 8×300 mm linear rod and install leadscrew locking nut leadscrew.
b) Assembly of X-axis stepper motor with GT pully assembly on X-axis bracket, locked with M3 bolt.
c) GT pulley assembly on X-axis bracket 2, locked with M5 bolt nut.
d) 8×500 mm linear rod assembly on hot end bracket base assembly with linear bearing, and with X-axis bracket 1 and 2 assemblies.
e) X-axis end stop assembly, locked with M5 bolt nut.

Extruder and hot-end system assembly steps

a) Extruder bracket assembly on aluminum profile 2020 × 462 mm
b) Assembly of the extruder motor stepper on the extruder bracket
c) Hot end assembly on Hot end bracket

3. 3 Installation of electronic diagrams

The input from the Power supply 12 Volt 20 A to the Arduino Mega Shield transmits power to all electronic devices, from the LCD128 adapter drives the 3D print system, the X-axis pin moves the stepper motor X axis, the Y-axis pin moves the stepper motor Y axis, the Z axis pin moves the stepper motor Z axis, the end stop pin turns on the end stop to limit the movement of each axis,   The pin thermistor turns on the thermistor on the heated bed and cylinder block. The extruder pin moves the stepper motor on the Extruder system, pin D10 turns on the heater on the cylinder block, pin D9 turns on the additional fan on the control box, and pin D8 turns on the heater on the heated bed. The relay SSR40DD is connected with the D8 pin which connects between the Arduino, the heated bed, and the power supply. The diagram electronic is shown in Figure 4.

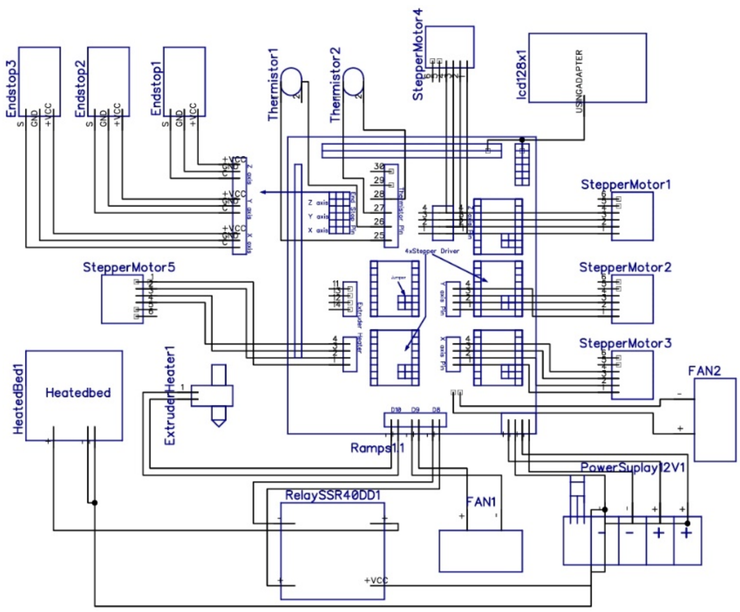

Figure 4. Skema diagram electronic

3. 4 Operation

Connect an outlet to a power source. The input comes from AC electricity converted to DC through a 12V 20A power supply. Press the "on" button on the switch in the power supply. How to start the machine, switch the power in the on position for the DC from the power supply to the Arduino. Insert the SD card into the SD card connector on the LCD. The SD card that has recorded the G code that you want to print. Press the roller on the LCD to enter the menu. The roller ad on the LCD functions to regulate the 3D printing machine. Select the print from the media menu, by rotating and pressing the roller on the LCD can set the menu and input data. Select the file rendered by Ultimate Cura file that has been customized in the Ultimate Cura software inside the SD card. Click "OK, " and select print and OK will make the 3d print-making process run.

3. 5 Printing test

This bridging test to determine the ability of the 3D printer to print filaments without any support underneath, shown at point A, in Figure 5.

This Hole Test is to determine the ability of the 3D printer to print holes, this is important because the hole can determine the ability of the 3D printer to print holes can be in the form of clearance, transition, or interference fit, shown at point B, shown in Figure 5. This overhang test is to determine the ability of 3D printers to print models with arc geometry. This test model tests the printer's 3D capabilities by printing the arch up to a 60° tilt, at point C, shown in Figure 5.

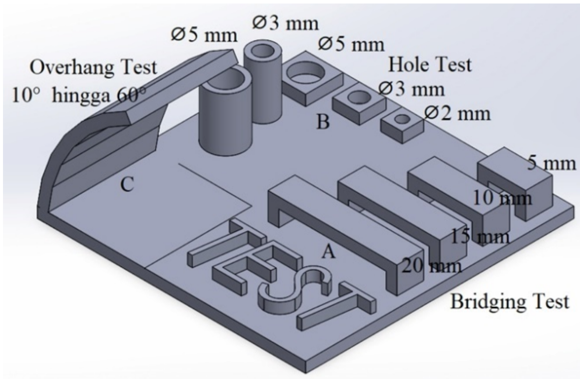

Figure 5. Design product

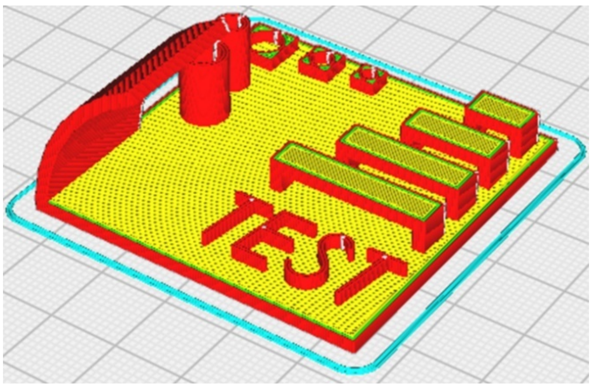

Figure 6. G-Code making

The product printing test program is shown in Figure 6 with the print settings shown in Table 1.
The program is run on this 3D machine, and the results of the printing test are shown in Figure 7.

Table 1. Setting printing

Layer height	0.2 [mm]
Wall thickness	0.8 [mm]
Top/Bottom thickness	0.8 [mm]
Infill density/Pattern	20%/Grid
Printing temperature	270°C
Build plate temperature	60°C
Print speed	60 [mm/s]
Enable retraction/mm	On/2 [mm]
Build plate adhesion type	Skirt

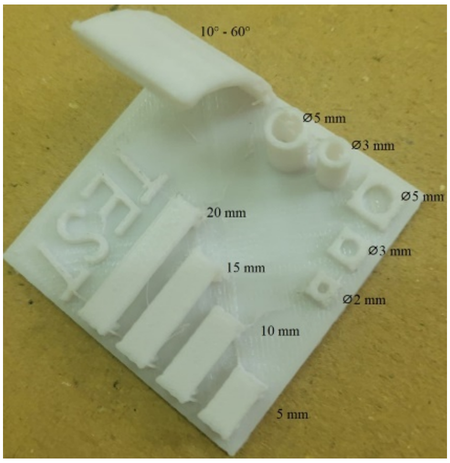

Figure 7. Printed model

4. Conclusions

The design and fabrication of printer 3D printing machine for PLA filament thermoplastic material has been successfully done. This machine implements an Arduino Mega 2560 R3 CH340G-based control system. The specifications of the 3D printing machine are as follows: Layer height = 0.2 [mm]; Infill density = 20%; Maximum Printing temperature = 240°C; Build plate temperature = 60°C; Print speed = 60 [mm/s]. The input comes from an AC power source that is converted to DC with an Input Power supply of 12 Volt 20 A. The machine has been tested, and parts with geometry are produced according to the machine's specifications.

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Conflicts of Interest: "The authors declare no conflict of interest."

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