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DESIGN, CONSTRUCTION AND PERFORMANCE TEST OF A FUSED DEPOSITION MODELING (FDM) 3D PRINTER

Maksudul Alam [1], **Md. Golam Kader** [2], **Md. Harun-Or-Rashid Molla** [3], **A.S.M. Rokonuzzaman** [4]

[1-4] Department of Mechanical Engineering,
Khulna University of Engineering & Technology, Khulna-9203, BANGLADESH
maksudulalam.kuet.me@gmail.com*, mdgolamkader@gmail.com, harunrashid@me.kuet.ac.bd
rokonuzzamanbasit96@gmail.com

***Abstract**-3D printing is a processes in which material is joined layer by layer under computer control to make a 3D object. The main target of this project is to study and development of a low-cost small Fused Deposition Modeling (FDM) 3D printer. This machine has used three stepper motors as linear actuators on each axis and NEMA 17 Stepper motor as a feeder of the filament, which is called extruder. Arduino, ramps 1.4 shield and motor drivers have been used for controlling the motors accurately of the printing machine. The print quality of the model is not highly accurate as desired due to improper mounting of the axis-systems, poor quality of the printing filament, improper leveling of the print bed, but all the components are working perfectly as desired from a 3d printer and it is able to print the imported design of the maximum dimension of 25mm×32mm×35mm.*

Keywords: Stepper Motor, 3D Printer, FDM, Arduino, Print Bed.

1. INTRODUCTION

3D printing is a procedure in which material is joined or cemented under computer control to make a three-dimensional item [1]. USA and worldwide specialized principles use the official term additive manufacturing for this in more extensive sense. 3D printing is utilized in additive manufacturing and fast prototyping. 3D printing or additive manufacturing fabricates a three-dimensional object from CAD model or AMF file, normally by progressively including material layer by layer. Fused Deposition Modeling (FDM) is a 3D printing procedure that utilizes a nonstop fiber of a thermoplastic material [2]. This is fed from an extensive curl, through a moving, warmed printer extruder head. The liquid material is constrained out of the print head's nozzle and is stored on the developing work-piece. The head is moved, under PC control, to characterize the printed shape. Generally, the head moves in layers, moving in two dimensions to store one level plane at any given moment, before moving somewhat upwards to start another slice. The speed of the extruder head may likewise be controlled, to stop and start deposition and form an interrupted plane without stringing between sections [3]. The main objective of this project was to construct a low-cost small Fused Deposition Modeling (FDM) 3D Printer and to print a 3D object by the constructed 3D printer.

2. LITERATURE REVIEW

Fused Deposition Modeling (FDM) is an additive manufacturing (AM) technology regularly utilized for displaying, prototyping, and creation applications as trademarked. FDM is also known as a solid-based AM technology. FDM starts with a product procedure which forms a STL file (STereoLithography file format), scientifically slicing and orienting the model for the construction procedure. Whenever required, support structures might be created [4]. The model or part is created by extruding little flattened strings of liquid material to shape layers as the material solidifies following expulsion from the nozzle. A plastic filament is unwound from a coil and supplies material to an extrusion nozzle which can turn the flow on and off. There is typically an accurately controlled drive that pushes the filament into the nozzle. The nozzle is heated to melt the material. A plastic filament is supplied from a reel, commercially or at home, and is placed in a hot liquid where it melts. This melt is then extruded from a nozzle while the incoming filament, still in the solid phase, acts as a "plunger". The nozzle is mounted on a mechanical platform, which can be moved in the x-y plane. When the nozzle moves on the table according to a predetermined geometry, it deposits a thin bead of extruded plastic, called "road" which solidifies rapidly in contact with the previously deposited paths [5]. Once the level is completed, the platform is lowered in the z direction to start the next level. This process continues until the object production is completed. To be able to join the roads in the process it is necessary to control the thermal environment. Figure 2 shows the schematic representation of FDM printing process.

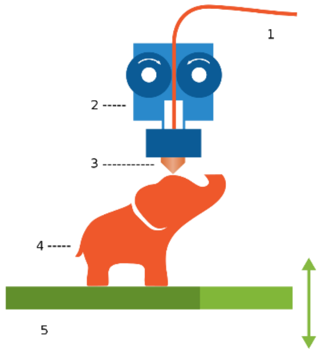

Fig 2: FDM 3D printing process [6].

3. ESSENTIAL COMPONENTS

The basic components that were used to construct this model are described below:

3.1 Arduino MEGA

Arduino MEGA is a microcontroller board dependent on the ATmega2560. It has 54 digital input/output pins, 16 analog inputs, 4 UART (serial hardware ports), a 16 MHz crystal oscillator, a USB connection, a power connector, an ICSP head, and a reset button. It contains everything needed to support the microcontroller; simply plug it into a computer with a USB cable or turn it on with an AC-DC adapter or a battery to boot. The Mega also includes shields (items that can be attached to a card to provide additional functionality) and kits.

3.2 RAMPS 1.4 Shield

RAMPS 1.4 acted as an interface between the arduino mega 2560 and various devices such as stepper motors. It could control up to 5 stepper motors with 1/16 stepping precision and interface with a hotend, a heatbed, a fan (or a second hotend), a LCD controller, a 12V (or 24V with fitting change) power supply, up to three thermistors, and up to six end Stops.

3.3 A4988 Stepper Driver

The stepper motor controllers were specifically designed to drive stepper motors, which were able to rotate continuously with precise position control, even without a feedback system. They operate from 8 V to 35 V and can supply about 1 A per phase without a heat sink (they have a nominal capacity up to 2 A per coil). Four motor drivers had been used for stepper motors.
Figure 3.1 Shows arduino with motor drive and ramps 1.4 shield which were very important for this project.

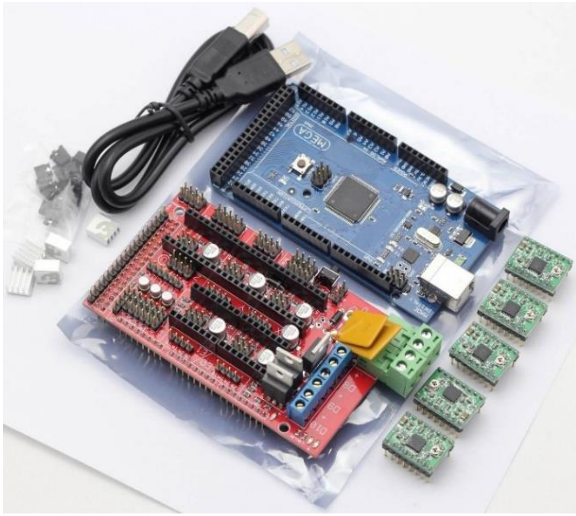

Fig 3.1: Arduino with motor drivers and ramps 1.4 shield [7].

3.4 Aluminum Extruder Kit (1.75mm)

It was an extruder kit which was used to control the flow of the filament precisely of the diameter of 1.75 mm/3 mm. It was made of aluminum alloy. The extruder kit is mounted on the stepper motor which is controlled by the arduino mega. The main parts of the extruder were screw, spring, bearing ball and pulley. It is a DIY type accessories kit. Figure 3.2 shows all the components in disassembled condition.

Fig 3.2: Aluminum Extruder Kit 1.75mm [8].

3.5 Hotend

Hotend was used in the 3D printer in order to melt the filament for constructing the 3D object. The type used in this 3D printer was J type. It included thermistor which sensed the desired temperature and maintain the temperature depending on the melting temp of the filament. Figure 3.3 shows the hotend assembly.

Fig 3.3: Hotend with Fan, Thermistor & Teflon Tube [9].

3.6 DC 12V 500W Power Supply

DC 12 V 500W power supply was used for powering up the ramps 1.4 as shown in figure 3.4. Ramps 1.4 transmitted required power to control all the motors, motor drivers and hotend.

Fig 3.4: 12 V 500 Watt power Supply [10].

3.7 PLA Filament (1KG)

3D printing filament is the thermoplastic feedstock for FDM 3D printers. There are numerous sorts of filament accessible with various properties, requiring diverse temperatures to print. The filament is accessible in two standard widths; 1.75 mm and 3 mm. 1kg PLA filament of 1.75mm width was used in this project for less printing difficulties and low cost. Besides it didn't require heating bed for printing purpose. Figure 3.5 shows a PLA Filament.

Fig 3.5: PLA Filament [11].

3.8 NEMA 17 Stepper Motor

This NEMA 17-stepping motor could be utilized as a unipolar or bipolar stepper engine and has a 1.8° advance step angle (200steps/revolution). The extruder kit was mounted on the Stepper motor to control the filament flow as shown in figure 3.6.

Fig 3.6: Extruder assembled with NEMA 17 [12].

3.9 Stepper Motor

A stepper motor or stepping motor is a brushless DC electric motor (brushless) that isolates a full revolution into various equivalent advances. The motor's position would then be able to be directed to move and hold at one of these means with no feedback sensor (an open-loop controller), as long as the motor is deliberately measured to the application in regard to torque and speed. The stepper motors had been used as linear actuators on each axis

3.10 End Stop

End stops were used to control the distance travel by the by rotating of the steppers motor at X, Y and Z axis. They were mechanical switch type end stops. Figure 3.7 shows a mechanical type end stop.

Fig 3.7: End stop (Mechanical switch type) [13].

4. NECESSARY SOFTWARES

The software platforms used to operate the 3D printer are described below:

4.1 Arduino IDE

The arduino open-source software (IDE) simplifies the writing of the code and loads it into the arduino board. It works on Windows, Mac OS X and Linux. The necessary code to control the printer was encoded in this platform.

4.2 Slic3r

Slic3r is a free 3D software design engine for 3D printers. It generate the G code of the 3D CAD files (STL or OBJ). Once the code is generated, the appropriate G-code file for the production of the 3D modeled part or object was sent to the 3D Printer for the production of a physical object.

4.3 Printrun

Printrun is a platform of G-code sending applications, composed by Kliment. It comprises of printcore (imbecilic G-code sender), pronsole (featured command line G-code sender), pronterface (included G-code sender with graphical UI), and a little gathering of accommodating contents. Together with Slic3r they structure a powerful printing tool chain. Pronterface gives all the visual information required for starting and controlling the printing process.

5. DESIGN & CONSTRUCTION

5.1 Geometrical Construction

The base of the 3D Printer was constructed by a 1ft*1ft steel bar on which the whole body of the printer was standing as shown in Fig 5.4. Angle bars were used for supporting the Z axis and the Hot End with the nozzle as shown in Fig 5.4. Thee angle bars of the length of 10 inch had been used. Steel bars of the length of 4 inch had been used for mounting the Z axis Stepper motor with the angle bar. Two drills were done on the angle bar for mounting operation and two steel bars had been used for proper mounting of the z axis. For the purpose of the stepper motor at the X, Y and Z axis, Old DVD writer had been used. The internal DVD feeder mechanism had been used for the movement of the individual axis as shown in Fig 5.1. This project could be called a recycled project as Scrap material had been used for axis movements. The Internal DVD feeder had a moving body which moved forward and backward with the rotation of the steeper motor as it was connected with the motor by screw mechanism as shown in figure 5.1 the motors were bipolar motor and each had two windings. All the windings were soldered by jumpers for connecting with the ramps 1.4 shield.

Fig 5.1: Axis with motor

Mirror was used as the print bed of the 3D printer and mounted on the X axis as shown in Fig 5.4. As PLA filament was used for printing purpose, so heating bed was not so necessary for this project. The maximum area of the print bed was 25mm×32mm. The hot end was in joint with the plastic wood by glue gun and connected with the Z axis motor as shown in figure 5.2

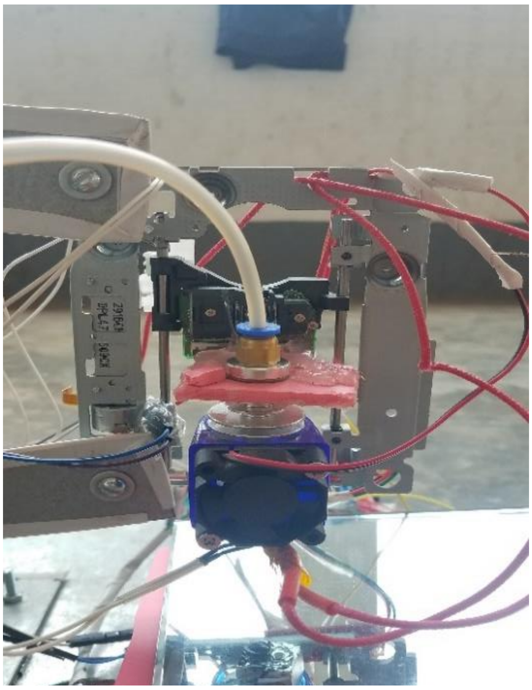

Fig 5.2: Hot End on Z axis

The X axis of the 3D printer mounted on the Y axis stepper motor by glue gun and the print bed was connected on the X axis stepper motor by screw as shown in figure 5.3.

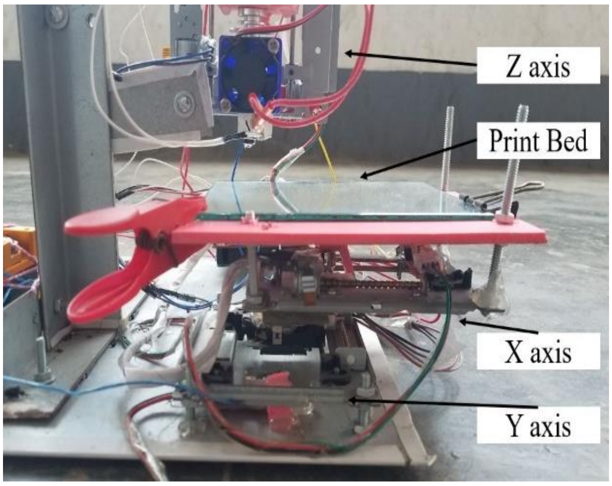

Fig 5.3: Print bed on X axis and Y axis

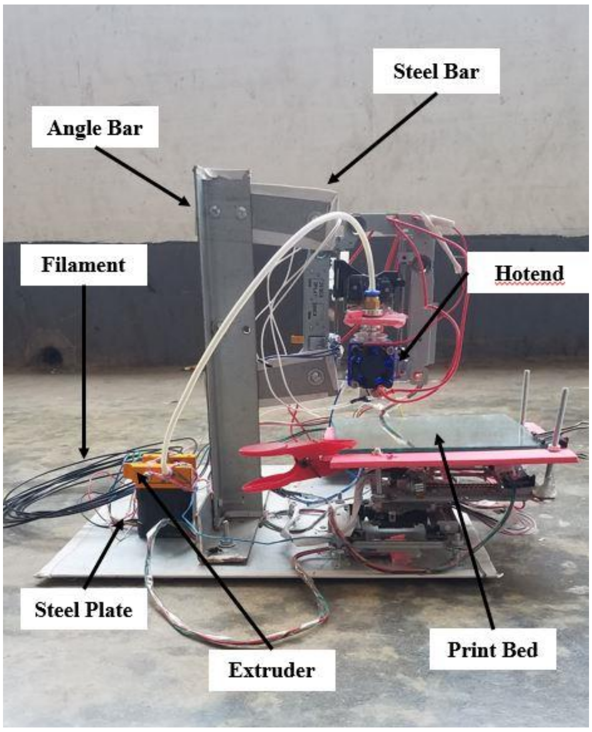

Fig 5.4: Constructed model (Front view)

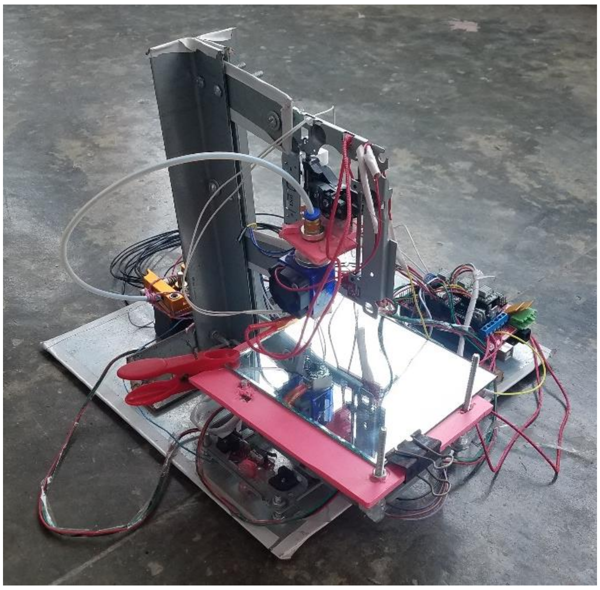

Fig 5.5: Constructed model

5.2 Circuit Connection

At first, the arduino mega and ramps 1.4 shield were joined with each other as shown in and all the connections of the axis stepper motors, motor drivers, extruder, hotend and end stops were done on ramps 1.4 shield. The ramps 1.4 shield were are mounted on the arduino mega board directly as shown in the fig 5.6. The connection of the four motor drivers, hotend, power supply, end stops stepper motors on the ramps 1.4 shield had been done as shown in figure 5.7.

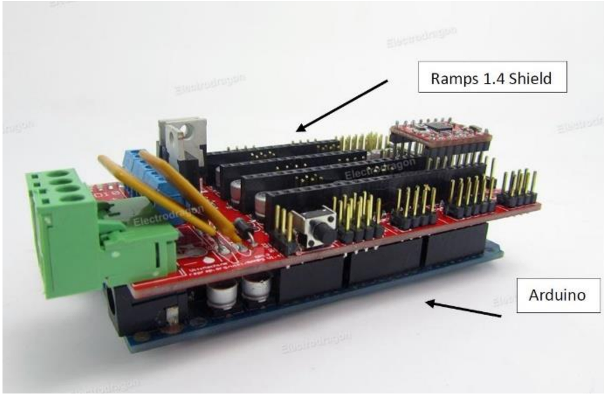

Fig 5.6: Connection of arduino with ramps 1.4 Shield [14].

The connection of the motors and the hotend with the ramps 1.4 shield pins in given below:
X axis motor: (2B; 2A1; A1; B)
Y axis motor: (2B; 2A1; A1; B)
Z axis motor: (2B; 2A1; A1; B)
Hotend heater: D10
Hotend thermistor: (T0: T1)
Hotend Fan: D9
End stop of X axis: X minimum end stop.
End stop of Y axis: Y minimum end stop.
End stop of Z axis: Z minimum end stop.

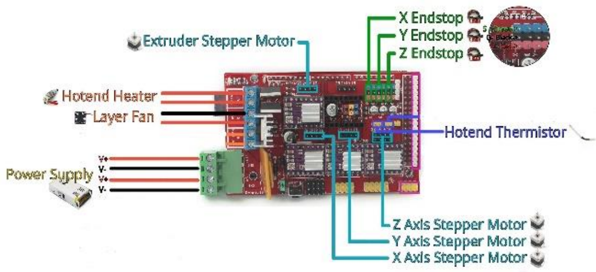

Fig 5.7: 3D Printer connections [15].

6. RESULT & DISCUSSION

6.1 Performance Evaluation

Each parts of the printer were assembled rigidly and screws and glue gun were used for joining the assembled part and all the circuit connection were done properly and checked several times.
X, Y and Z axis motors ran properly and accurately according to the steps of creating the design imported into Printrun software.
The extruder of the printer was working properly as the requirement speed to feed the filament for the printing process and all the components were working perfectly as desired from a 3D printer.
The printer was able to print an object of the maximum dimension of 25mm*32mm*35mm.

6.2 Discussion

The main objective of the project was to construct a 3d printer able to print a 3D object imported in printrun. The

3D printer was able to print an imported design within its limit range. A figure of the printed simple object is given in figure 5.8.

Fig 5.8: 3D Printed Model

The print quality of the model was not so much accurate as desired due to the following reasons:

• Low quality of the filament.
• The Z-axis of the 3D printer was not mounted at right angle properly with the X-axis and Y-axis, because the stepper motor of Z-axis had burned several times and had to be changed several time, which had effected the printer geometry a lot and in the final Z-axis also.
• Leveling of the print bed was very difficult to done due to the small space between the X-axis stepper motor and print bed (mirror). And as the whole X-axis assembly was mounted on the Y-axis assembly by simple glue, the movement of the X-axis was not so precise on the Y-axis which had affected the bed leveling.
• The filament presented inside the nozzle got warmed and started to flow even before starting the print process, the pre presented filament got stuck on the nozzle end and effects the print quality.

7. CONCLUSION

With the rising demand of small scale high precision automations and operations, number of small scale automated machines like 3D printers are increasing in the top fabricating work for the industries. Using 3D printer machine to fabricate small scale parts can offer both flexibility and efficiency in manufacturing approaches and reduce cost of manufacturing, which is favorable for industry owners. The priorities are being given to produce those machines in affordable price and size. Here in this study it has been studied and constructed a 3D printer machine which is simple in construction and affordable.

8. ACKOWLEDGEMENT

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