ISSN No.: 2454- 2024 (online)

International Journal of Technical Research & Science

# DESIGN AND CONSTRUCTION OF A BOWDEN EXTRUDER FOR A FDM 3D PRINTER USES 1.75MM FILAMENT

**Md. Muzammal Hoque[1], Dr. Md. Hasnat Kabir[2], Md. Mehedi Hashan Jony[3]**
**Email Id: mmhoque94@gmail.com[1], hasnatkabir11@gmail.com[2], jonyvueee15@gmail.com[3]**
**[1]Student, Information and Communication Engineering, University of Rajshahi, Bangladesh**
**[2]Associate Professor, Information and Communication Engineering, University of Rajshahi, Bangladesh**
**[3]Student, Electrical and Electronics Engineering, Varendra University, Rajshahi, Bangladesh**

**Abstract-**3D printing is a process of making three dimensional solid objects from a digital file. In this process, an object is created by laying down successive layers of material until the object is created. Each of these layers can be seen as a thinly sliced horizontal cross-section of the eventual object. The printing process is done by using a 3D printer. It has several parts. They are frame, head movement mechanics, motors (stepper), the print head/extruder, firmware, 3D software etc. The aim of this work is to describe the design and construction process of a bowden extruder for 3D printer. In this case, it was used a RepRap (Replicating Rapid-prototyper) 3D printer of Fused Deposition Modeling (FDM) technology, where 3D models are built by heating and extruding thermoplastic material through a narrow nozzle. Easily maintainable and usable bowden extruder of FDM technology was designed and implemented on a 3D printer. The results are presented here. Two models of different material (ABS & PLA) were printed at different temperature (230$^{o}$C & 185$^{o}$C), when the bed temperature was fixed. It is observed that, the printer with this extruder prints the model almost accurately. Although, in some cases a deviation is observed at the thin and sharp edge of the model. A little wraping problem is also found occasionally.

**Keywords:** Extruder, 3D Printer, Bowden Extruder, FDM, 3D Printing Technology.

## 1. INTRODUCTION

3D printing is an additive manufacturing process that creates a physical object from a digital design. The creation of a 3D printed object is achieved using additive processes. In this process, several layers of material are formed one by one under computer control until a desired object is created [1]. Each of these layers can be seen as a thinly sliced horizontal cross-section of the eventual object.

3D printing is the opposite of subtractive manufacturing which is cutting out / hollowing out a piece of metal or plastic for instance a milling machine [2]. In the manufacturing area, this technology has proven to be very promising and is called rapid prototyping. This technology has been substantially improved and has evolved into a useful tool for many fields like researchers, manufacturers, designers, engineers and scientists. [3]

In some traditional Rep-Rap, insertion of input material is somewhat tricky, this is why they are not so much friendly to all user. In this work, by using computer-aided design (CAD) software and an FDM Rep-Rap 3D printer, it was attempt to design and construct an effective, user friendly and unique extruder for a 3D printer.

## 2. RESEARCH ELABORATION

### 2.1 What is an Extruder?

The extruder is one of the most important components for a 3D printer. It sends the correct amount of filament to the hot end where it's melted and extruded down in thin layers to make desired parts.

**Fig. 2.1 A Conventional Extruder**

There are two basic types of extruders currently available, they are direct and Bowden. In direct extruder, the filament is directly inserted into the hot end, where it melts and emerges from the nozzle in a precise extrusion line. Direct extruders are slow and have too much backlash.

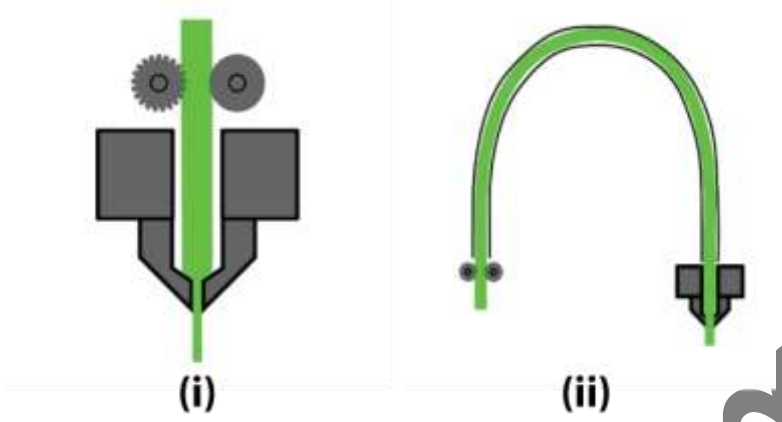



**Fig. 2.2 (i) Direct Extruder (ii) Bowden Extruder**

In a bowden extruder, a tube extends from the extruder body to the hot end. This is called a bowden tube. It is most commonly a section of PTFE (Teflon ™) [4] tubing. The filament is constrained by the tube and travels through it to the hot end. Bowden extruders can't handle flexible filament and they have too much stringing.[5]

### 2.2 Method

There are different 3D printing methods that were developed to build 3D structures and objects. However, in the present study, the most popular Fused Deposition Modeling type printer is considered which uses thermoplastic type (ABS, PLA) materials to print the objects. Fused deposition modeling (FDM) is an additive manufacturing (AM) technology commonly used for modeling, prototyping, and production applications as trademarked by Stratasys Inc. [6], [7]. FDM works on an "additive" principle by laying down material in layers; a plastic filament or metal wire is unwounded from a coil and supplies material to produce a part. Thus, FDM is also known as a solid-based AM technology [8].

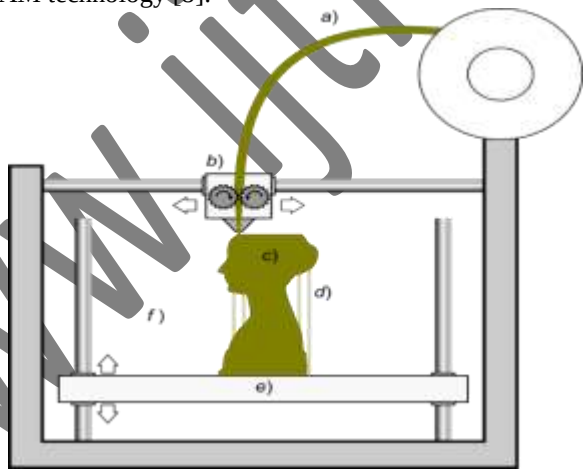


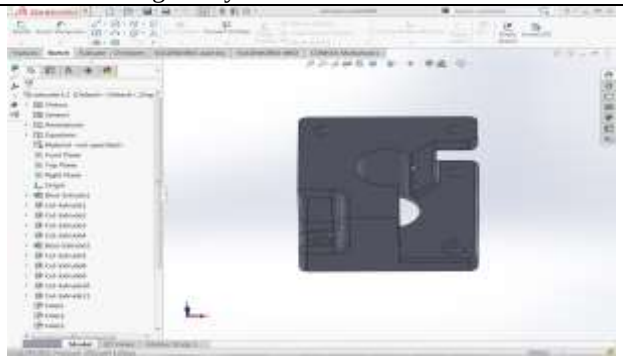
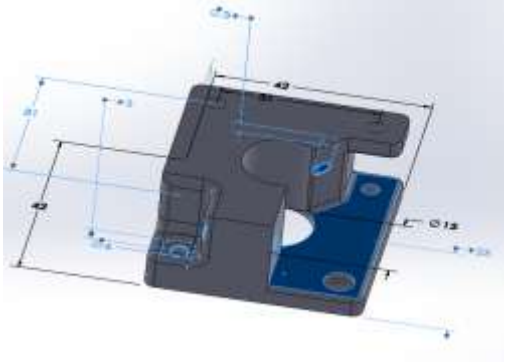
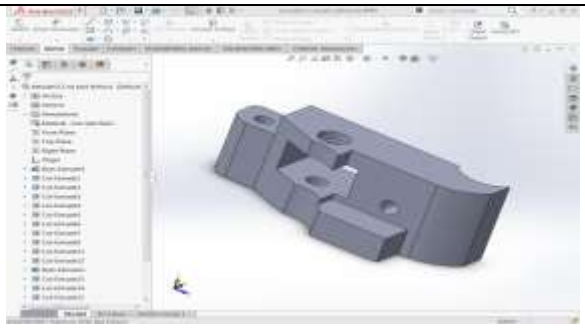
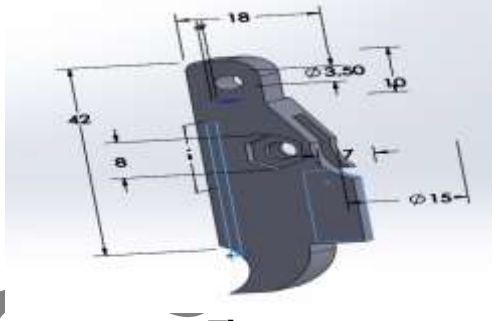

**Fig. 2.3 Schematic Representation of the FDM 3D Printing Technique**

Fig. 2.3 shows Fused Deposition Modeling Technique, where a) is a filament of plastic material which is fed through a heated moving head b) that melts and extrudes it depositing it, layer after layer, in the desired shape c). A moving platform e) where each layer is deposited. For this kind of 3D printing technology additional vertical support structures d) are needed to sustain overhanging parts.[9] And we have done this construction by three steps, they are designing, printing and assembly. We used Acrylonitrile Butadiene Styrene (ABS) as printing material and the nozzle and Bed Temperature were 230$^{o}$C 60$^{o}$C.

### 2.3 Design

The first and foremost step in the process of 3D printing is to design the part or model to be printed in any of the 3D modeling software such as Autodesk AutoCAD, Pro-E, Catia, Solidworks etc. In this case, it was used SOLIDWORKS3D modeling software to design the desired parts of the bowden extruder. We designed two parts, first one is the static part, which is attached with a stepper motor and the other is a moveable part, which is attached to static part and it can be moved when the material insertion is required. The static part is 25 millimeter in height and 42 square millimeters in width. And the moveable part is 20 millimeter in height and its length is 52 millimeters. The 3D models, shape and parameters of these parts are shown in Table-2.1.

**Table-2.1 The designed 3d Model and Parameters of the Model**

| 3D model designed by SOLIDWORKS | The shape and Parameters |
|---|---|
|  **Fig.2.3.1 (a) 3D Model of the Static Part** |  **Fig.2.3.1 (b) The Static Part** |
|  **Fig.2.3.2 (a) 3D Model of the Moveable Part** |  **Fig.2.3.2 (b) The Moveable Part** |

Then the designed part is exported in .STL format. STL (an abbreviation of "stereolithography") is a file format native to the stereolithography CAD software created by 3D Systems [10-12]. This file format is supported by many other software packages; it is widely used for rapid prototyping, 3D printing and computer-aided manufacturing [13]. STL files describe only the surface geometry of a three-dimensional object without any representation of color, texture or other common CAD model attributes. The STL format specifies both ASCII and binary representations. Binary files are more common, since they are more compact [14].

### 2.4 Output 3D Model of the Extruder Part

We used Up-mini 3D printer to print the designed extruder parts. Acrylonitrile Butadiene Styrene (ABS) was used as the printing material. The printed mode is shown in Fig.2.4.

**Fig.2.4 Printed part of the Extruder**

### 2.5 Electronic & Other Equipment

The equipment needed for this project are given below:

- 1xNEMA 17 Stepper Motor
- 1xMK7 Extruder Drive Gear Bore 5mm For 1.75mm and 3.0mm Hobbed Gear
- 1x 6001ZZ Ball Bearing Mayitr Double Shielded Radial Miniature Deep Groove Ball Bearings 12mm
- 1x.5 meter PTFE Tube Teflon
- 2xPneumatic Connector PC4-01
- 2x M3x30mm Allen Hex Socket Head Screw
- 1x M3x8mm Allen Hex Socket Head Screw
- 1x M3x12mm Allen Hex Socket Head Screw

- 1x M4x35mm Half tooth flat head countersunk head grade 12.9 plate with nickel Steel Hex Screw
- 2xM3 Stainless Steel Hex Nut Hexagon Nut
- 8x M10 Stainless Steel Washers
- 1x8mm OD 20mm Long Light Load Stamping Compression Mould Die Spring Yellow
- 1xhot end with 0.4mm extruder nozzle

**2.6 Assembly**

The assembly of the bowden extruder is shown step by step:

- Stepper motor is attached to Hobbed Gear and the static part is attached with stepper motor by a 30mm and two 5mm Allen Head Screw is shown in Fig.2.5.

**Fig. 2.5 The Static Part is Attached to the Stepper Motor**

- A 6001ZZ Ball Bearing with four M10 stainless steel washers, two washers at each side are inserted into 15 mm rectangular hole of moveable part and attached them using a M3x5mm Allen Head Screw and a M3 Hexagon Nut.

**Fig. 2.7 The Moveable Part Setup**

- The moveable part is then attached with the static part at the top right corner of the static part using M3x30mm Allen Head Screw and a 10mm washer.

**Fig. 2.8 The Moveable Part is Attached to the Static Part**

- A M4x35mm half tooth Screw and a M3 Nut adjoins a 20mm Spring (8mm OD) with two M10 Washers at its two terminals at the beneath point of static and moveable part together. This will help to create appropriate pressure on input material between bearing and Hobbed Gear of the stepper motor.

**Fig. 2.9The Implement of Spring**

- Two Pneumatic Connectors are connected to the two terminal of a 0.5 meter PTFE Tube Teflon. One of the Connector is joined to the static part and another connector is connected to the hot end. It will be used to lead the input material to the hot end.

**Fig. 2.10 PTFE Tube Teflon is Attached to the Static Part by 2xPneumatic Connector**

**Fig. 2.11 The Hot-end of a 3D Printer**

- After completing the assembly it is implemented on 3d printer. The implementation on 3d printer is shown in Fig. 2.12.

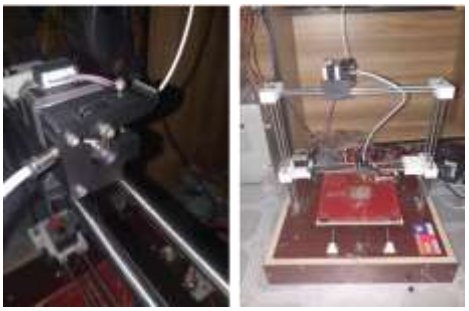


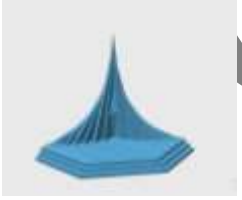
**Fig. 2.12 Implementation on 3D Printer**

### 2.7 Operation

After completing the proposed bowden extruder setup, two print was done with two different input materials (ABS & PLA) at same bed temperature (60$^{o}$C) and two different nozzle temperatures (230$^{o}$C & 185$^{o}$C), respectively. The print operation is done by an open source software called Pronterface. It is a graphical interface. It is part of a set of software from Printrun, a group of G-code utility applications [15]. With this software one can operate a 3D Printer easily [16].


**Fig. 2.12 Pronterface Software**

**Table-2.2 Shows the 3D Model and Corresponding Printed Output of the Proposed Extruder Model**

| 3D Model of test data | Printed output of test data | Used material and different parameters |
|---|---|---|
|  **Fig.2.7.2 (a) 3D model of test Data** |  **Fig.2.7.2(b)** Printed output of test Data | Used material: ABS<br>Nozzel Temperature: 230$^{o}$C<br>Bed Temperature: 60$^{o}$C<br>Height & Width of 3D Model: 58.3 &71.183 mm<br>Height & Width of Printed output: 58.2 &71.18 mm<br><br>Required Time: 1.45 hour |
|  **Fig.2.7.3 (a) 3D model of test Data** |  **Fig.2.7.3 (b) Printed output of test Data** | Used Material : PLA<br>Nozzel Temperature: 185$^{o}$C<br>Bed Temperature: 60$^{o}$C<br>Model Height & Width: 15.32 & 52.83 mm<br><br>Height & Width of Printed output: 15.3 & 52.8 mm<br>Required Time: 1.15 hour |

We used ABS & PLA material for Fig.2.7.2 & Fig.2.7.3 respectively. The bed temperature was 60$^{o}$C in both cases. The nozzle temperature for ABS was 230$^{o}$C & 185$^{o}$C for PLA, respectively.

## 3. RESULT AND DISCUSSION

In this work, a Bowden extruder for a 3D printer was designed and constructed. All the necessary steps in designing, printing and assembling an extruder are also described. This extruder was made based on FDM technology and supports thermoplastic materials filament of 1.75 mm diameter. This extruder is very easy to implement with a 3D printer, low cost and less complexity. It was required only few components to construct this extruder and the important parts of this extruder are made by 3D printer.

It is observed from Fig.2.7.2 (a),(b) and 2.7.3 (a),(b) the 3D test data and printed output data are almost similar. A slight deviation is observed in both printed model compared to 3D model.

From the Table 2.7.1, it is observed that, the height & width of printed model of Fig.2.7.2 (b) are 58.2 &71.18 mm that are negligibly less than the 3D model of Fig.2.7.2 (a) and they are 58.3 &71.183 mm.

Similar result observed at the model of Fig.2.7.3 (a) and 2.7.3 (b), where the height & width of printed model of Fig.2.7.3 (b) are 15.3 & 52.8 mm that are slightly less than the 3D model of Fig.2.7.3 (a) and they are 15.32 & 52.83 mm.

It is founded that, the deviation of height & width occurred at the thin and sharp edge of the 3D model.

Deviation is a common problem in 3D printing technology. Even if we consider the most accurate 3D printer on the market, it's possible that there's a slight deviation. It might be too small to spot with the human eye.

Therefore it's important to know that there are three types of possible deviations when we speak of the 3D printer resolution: machine-, material- and end result deviation.[17]

A little wrapping problem is also observed occasionally. Warping is a common issue that can occur in 3D printing. As the extruded plastic cools and the hot nozzle moves around the build plate, thermal gradients can be induced, when the thermoplastic is heated it expands slightly. Following this, the material cools and contracts. Room temperature fluctuations can cause layer separation, print lifting and warping. It may happen with larger prints, or having multiple objects on one print bed.[18]. Fig.3 shows A Warped Part and the Wraping we found in our study.


**Fig.3.1 (i) A Warped Part [18] (ii) The Wraping we found.**

## CONCLUSIONS

The 3D printing technology is becoming popular day by day in the field like researchers, manufacturers, designers, engineers and scientists and FDM is the most used 3D printing technology. The aim of this project was to design and construct a FDM based Bowden Extruder. We constructed a simple and user friendly Bowden extruder. We observed that, with this extruder the prints print almost accurately. Although, in some case a deviation is observed at the thin and sharp edge of the model. A little wrapping problem is also observed occasionally.

## REFERENCES

[1] "3D Printer Technology – Animation of layering". Create It Real. Retrieved 2012-01-31.
[2] https://3dprinting.com/what-is-3d-printing
[3] Bob Hayward, David Moschella, Jon Schreiber, Simon Wardley, Howard Smith, "3D printing and the future of manufacturing" CSE, the rise of 3D printing
[4] Teflon ™| Chemours Teflon™ Nonstick Coatings and Additives". www.chemours.com. Retrieved 2016-03-01
[5] http://www.fabbaloo.com/blog/2015/11/11/bowden-or-direct-a-primer-onextruder-styles.
[6] www.stratasys.com. "Stratasys Legal Information". stratasys.com. Retrieved 2016-07-20.
[7] uspto.gov. "Trademark Status Document Retrieval (TSDR)". uspto.gov. Retrieved 2017-08-20.
[8] Taufik, Mohammad; Jain, Prashant K. (2016-01-05). "A Study of Build Edge Profile for Prediction of Surface Roughness in Fused Deposition Modeling". Journal of Manufacturing Science and Engineering, Transactions of the ASME. 138 (6): 061002. doi:10.1115/1.4032193.
[9] Scopigno R., Cignoni P., Pietroni N., Callieri M., Dellepiane M. (2017). "Digital Fabrication Techniques for Cultural Heritage: A Survey". Computer Graphics Forum 36 (1): 6–21. DOI:10.1111/cgf.12781.
[10] StereoLithography Interface Specification, 3D Systems, Inc., July 1988
[11] StereoLithography Interface Specification, 3D Systems, Inc., October 1989

[12] SLC File Specification, 3D Systems, Inc., 1994
[13] Chua, C. K; Leong, K. F.; Lim, C. S. (2003), Rapid Prototyping: Principles and Applications (2nd ed.), World Scientific Publishing Co, ISBN 981-238-117-1Chapter 6, Rapid Prototyping Formats. Page 237, "The STL (STeroLithography) file, as the de facto standard, has been used in many, if not all, rapid prototyping systems." Section 6.2 STL File Problems. Section 6.4 STL File Repair.
[14] Burns, Marshall (1993). Automated Fabrication. Prentice Hall. ISBN 978-0-13-119462-5.
[15] StereoLithography Interface Specification, 3D Systems, Inc., July 1988
[16] StereoLithography Interface Specification, 3D Systems, Inc., October 1989
[17] https://tractus3d.com/3d-printer-resolution
[18] https://3dprinting.eng.unimelb.edu.au/pdf/3D-printing-tips-and-tricks.pdf