International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 05 | May - 2022 Impact Factor: 7.185 ISSN: 2582-3930

Design & Development of a Plastic Filament Extrusion Machine

Mr. Nilesh Sangamwar, Mr. Ramankumar Thakre, Mrs. Jayashri Bhojane , Mr. Saddam Patel & Prof. Mukesh Mane

Department of Mechanical Engineering SRTTC Pune.

---***---

Abstract - The objective of this project was to produce plastic filament suitable for use with Rep Rap 3D printers from raw plastic pellets or recycled plastic waste for the UBC Rapid student team. The specifications for the filament required that it be of similar quality to commercial filaments, smooth and with minimal bubbles with a constant diameter of about 3mm.To accomplish this end, a prototype plastic extruder was designed, constructed and tested. The prototype was tested running at different speeds and temperatures to determine a good operating point. The investigation showed that extrusion of plastic filament of comparable quality to commercial filaments is possible with careful operation. The diameter is the most critical feature and is dependent on the rate at which the filament is drawn away from the die as well as a steady input to the heating pipe. With an out feed mechanism, the filament could be drawn at constant rate to form a constant diameter.

***Key Words*:** recycled plastic, 3D Printer filament, Extrusion etc

1. INTRODUCTION

The construction and operation of the plastic extruder is largely based on existing designs used in both industrial and hobby applications. The basic mechanism is comprised of a screw that transports raw plastic pellets from a hopper through a heating zone in a metal pipe where the plastic is melted. The raw plastic pellets are gravity-fed from the hopper into the screw. Inside the pipe the molten plastic is forced through a die at the end of the pipe to form a filament. The extruded plastic can be drawn from the die to determine the final diameter of the filament. The die is shaped to form the extruded plastic into the desired cross-section. Figure 1 below shows a schematic of the basic extrusion system.

2. Body of Paper

Aim of Project: Implementation of proposed work into practical experimental model as follow:

1. Hopper for material storage.
2. Utilization of Lead screw for feeding the plastic granules in forward direction.
3. Use of Electric DC motor with speed controller to drive lead screw.
4. For heating barrel use of Electric heater with temperature controller to maintain the required temperature inside the barrel and avoid over heating of plastic.
5. At discharge point nozzle is fitted which can be replaced as per user requirement i.e **Dia 1.75 & Dia 2.5.**
6. For cooling the extruded filament utilization of forced air cooling.

PROBLEM DEFINITIONS: With the development of the portable filament making machine, the dependency of the manufacturing units and other organization on 3rd party supplier for filament will be reduced. i.e in market PLA filament are available easily, but ABS, PP material are made available only with prior order

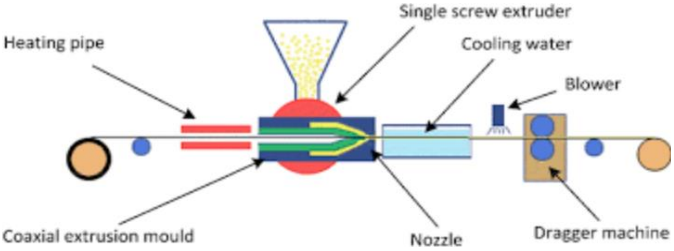


Fig 1: Working Principle

OBJECTIVES:

1. To design and develop a plastic filament extruder for 3D printing.
2. The focus was specifically on creating 1.75 mm diameter filament from ABS pellets.
3. To develop a 3D printing filament making extruder that can be used by small scale manufacturing units, companies, colleges who have portable 3D printer in-house.
4. To Perform design calculations to base the development of filament making extruder.
5. Analysis of mechanical fabricated structure.
6. Calculation of production rate vs motor speed at time dependency variable.

MOTIVATION

3D printing is growing technology and is used worldwide. 3D printing requires filament to process and the cost of filament governs the cost of 3D printing product. Filament extrusion machines are usually available for industrial use, capable of creating hundreds of feet of long filament in a day. So these filaments are expensive for many end users. This work will make easily available filament extruder to small scale industries and colleges. Block Diagram of Prosed Experimental Setup:

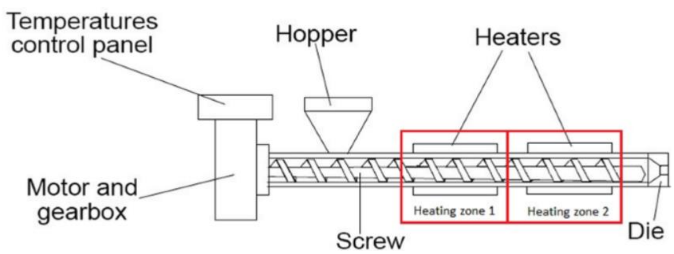


Fig: 2 Block Diagram

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 05 | May - 2022 Impact Factor: 7.185 ISSN: 2582-3930

METHODOLOGY:

The methodology and stages in designing of the proposed model is shown in the Figure

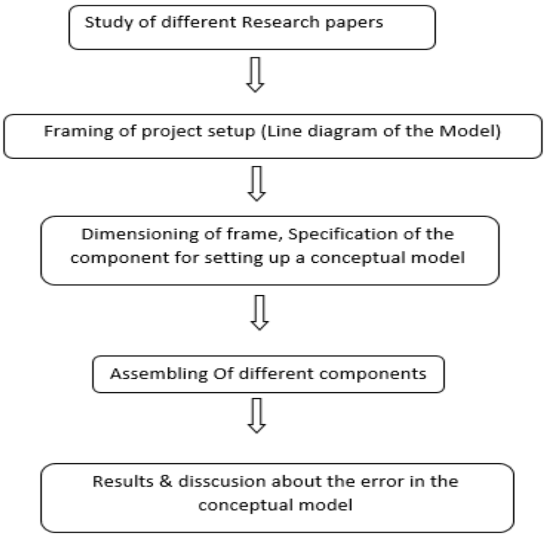


Fig: 4

SYSTEM DESIGN:

Based upon the design calculations and according to the need as required in the project, the components are carefully selected and listed in the Table.

Sr. No	Component name
1	Extruder screw & Barrel
2	Dc motor
3	Die Nozzle
4	Base Frame
5	Square tube
6	Temperature controller
7	Heaters
8	PT 100 sensor (temp Sensor)
9	Acrylic sheet
10	Speed Controller
11	Battery

Table: 1

.

EXTRUDER SCREW:

There are two basic characteristics that the screw should satisfy in order to perform his function correctly. It has to be hard enough to bear with the possible erosion and to be able to handle with high temperatures.

The high temperatures will be caused by the movement that the screw has, the friction against the cylinder and the heating system. The material chosen for the screw is steel F-174, which is a nitriding steel. This material is typically used in extruders screws and cylinders and reaches a vickers hardness of 1048-1064 HV. In addition, it is able to handle with the high temperatures reached inside the extruder, which will be around 200ºC. Steel pieces which have been treated with a nitriding process are usually prepared to stand temperatures up to 500ºC. Also the nitriding process gives the piece an extra layer of protection against the corrosion. For the properly development of the extrusion process it is necessary that the screw surface is as smooth as possible, to avoid friction and to allow the plastic slide on it.

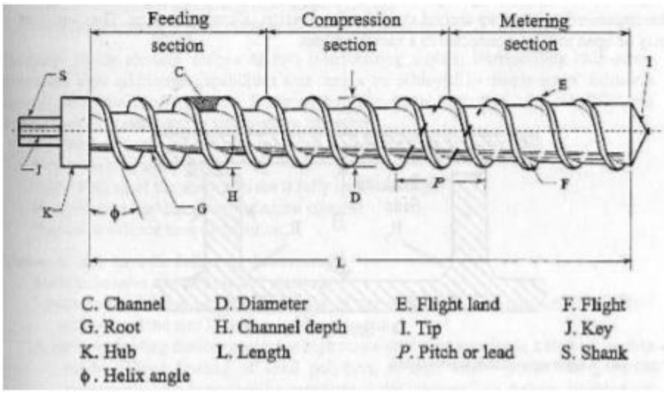


Fig. 5 : Screw Geometry Details.

The diameter we decide to work with is 38 mm and for the relation between the length and the diameter we choose, 12/1. The reasons to take these measures and not any others are based basically on the fact that the screw has to be the smallest size possible without increasing very much the price. So we consider 38 mm to be the smallest diameter with reasonable price and with precise usefulness. In addition, we choose 12/1 for the relation L/D because we consider 300 mm the maximum length keeping a light screw in terms of weight, taking into account that if the relation L/D is bigger, the price will be lower. Therefore, I have defined the first parameters of our screw D =38 and L=300.

Screw lengths

For amorphous thermoplastic, the feeding zone is between 20% and 25% of the screw length, the compression zone between 32% and 38% and for the metering zone between 40% and 45% . We based our decision of the zones lengths on the percentage from the total length that normally has each zone. The percentages used in each zone are obtained as follows:

Feeding Zone

Length: $L1 = 0.217 * 300 = 65$mm

Compression Zone Length: $L2 = 0.348 * 300 = 105$mm

Metering Zone Length: $L3 = 0.435 * 300 = 130$mm.

Channel depth and screw clearances

The clearances inside the screw and with the cylinder are also defined by the diameter I have chosen. The channel depth h1, is the space between the cylinder and the soul of the screw. It is related with the screw diameter with the equation

$h1 = 0.2 * D \quad h1 = 5$ mm

The filet clearance is the space between the thread and the interior surface of the cylinder. It should be small enough to avoid the plastic to come back while extruding.

The equation to calculate it is:

δ = 0.002 * D δ = 0.05mm

The depth of the channel at the end of the screw is defined by the compression ratio (Z). The compression ratio relates the depth of the channel at the beginning and at the end of the screw.

Fig. 6: Extruder screw

BARREL OR CYLINDER

Just as for the screw, the material chosen for the cylinder is steel F-174, for the same reasons. The cylinder must also be able to handle with high temperatures and be hard enough to resist degradation due to the friction generated between the inner face of the cylinder and the plastic flow. The cylinder is the part in charge of keeping the material inside while going throughout the screw. For this reason, its inner diameter is the sum of the screw diameter and the clearance calculated above, to a total of 25.05 mm. Considering tolerance and according to the availability of standard tube, 1" ID tube meets our requirement, so we have selected 1"ID tube for the cylinder.

Fig.7: Barrel & Barrel extension

BARREL EXTENSION

Barrel Extension material is same as Barrel for the same reasons. It is manufactured by turning operation. It is welded to the end of the Barrel. This extension is used to couple barrel piece to die and to give sufficient thickness to fit the secondary heater. In addition, 4 mm thick aluminum strainer is attached to smoothen the flow and 3/8" nut to control the flow.

DIE OR NOZZLE

The material most commonly used for die is brass because it has to withstand high temperatures. Likewise, is a good conductor of heat, quality that is needed to heat fast and uniform the nozzle as the printing material needs to be printed around 200ºC. Brass is one of the material with best characteristics and this is why we are choosing it for the nozzle. The nozzle is also one of the most important elements of extruder, as it defines the final shape of the plastic. Between its characteristics we are going to remark its hardness and the fact that it perfectly keeps its conditions for a long period of time. Also, it doesn't get affected by the external conditions. Its characteristics make it one of the best materials in the market but with a lower price. The die that is used is M12 Brass plug with 2mm hole

Fig.8: Die

HOPPER

Hopper is made up of stainless steel sheet metal. There are no specifications for hopper design. Its size varies depending on the application or quantity of production. So the hopper design is just to fulfill the requirement of this project. Hopper is designed as gravity fed hopper. Hopper is wedge type and the flow of solid in the hopper is mass flow. It is cut and manufactured from 6"x4"

HEATER SYSTEM DESIGN

Heaters are located along the barrel, with thermocouples in each zone to control the heaters and barrel temperature. The heaters cover as much barrel surface area as practical, minimizing hot and cold spots along the barrel length. In an individual extruder temperature zone, there may be one, two, or three heater bands with one thermocouple controlling them. Assume the heater band closest to the thermocouple burns out; the other two heater bands have to supply all the external energy required, creating the possibility that the area is hotter near the two heater bands that are working. In the event, the band farthest from the thermocouple burns out, the barrel area under the burnt-out heater is anticipated to be cooler than areas where the heaters are functioning properly near the controlling thermocouple. Burnt-out heater bands should be replaced as soon as possible to assure uniform heat input.

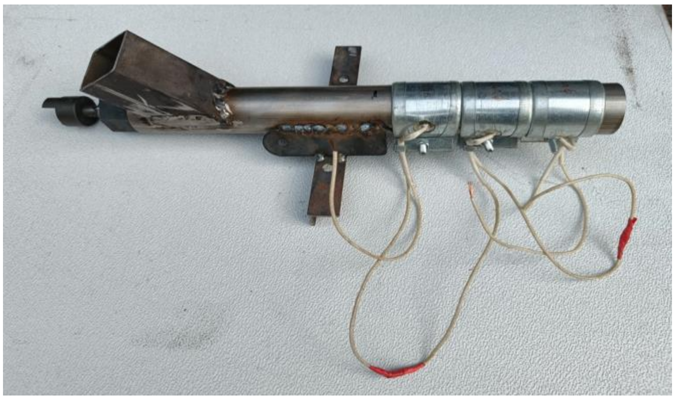


Fig.9: Heater system

TEMPERATURE ZONE CONTROL

Each extruder temperature zone has at least one heater and possibly multiple heaters controlled by a thermocouple. A signal from the thermocouple communicates with the controller, indicating whether the heater is to be turned on or off. For the controller and heaters to function properly, the thermocouple must operate properly. A faulty thermocouple with an open circuit indicates the temperature is low, resulting in the heaters staying on and causing substantial overheating. A closed thermocouple indicates the temperature is high; heaters remain off and the temperature zone cools. If a thermocouple is not responding properly, it must be replaced. The thermocouple well in the barrel should be at least 1.2 inches (30 mm) deep and installed away from the heaters. Never sandwich the thermocouple between the heater and the barrel wall; the thermocouple will be responsive to the heater temperature and not the barrel temperature. We have used 35 x 30 mm, 150 Watt heating band.

3. CAD & ACTUAL SET UP

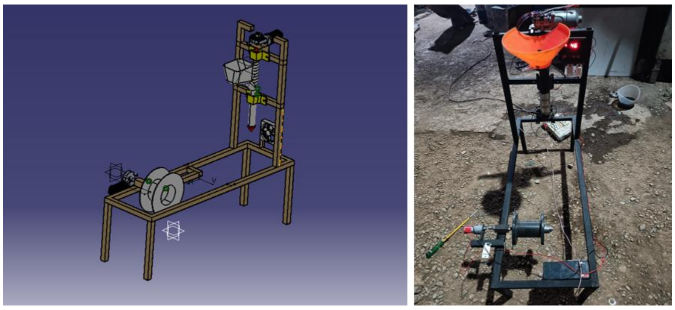
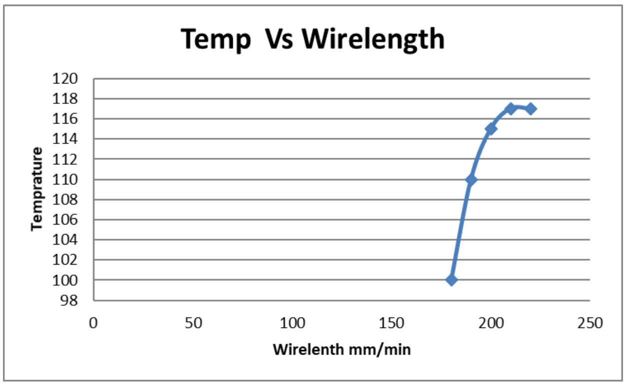


Fig.10: Heater system

4. PRODUCTION RATE WITH DIFFERENT TEMPERATURE

Sr. No	temp	wire length mm/ min
1	180	100
2	190	110
3	200	115
4	210	117
5	220	117



5. COST ESTIMATION

The components purchased are at low cost and the quantity of the components purchased are given in the table

Sr. No	Component name	Quantity	Cost
1	Dc motor	2	3650
2	Extruder screw	1	3500
3	Barrel	1	3000
4	Base Frame	1	2500
5	Square tube	1	1950
6	Temperature controller	2	1850
7	Heaters	2	850
8	PT 100 sensor	2	450
9	Acrylic sheet	1	450
10	Speed Controller	1	450
11	Bearing	1	300
12	Cooling fan	1	175
13	Misc.	1	1000
Total			20125

Table 3: Cost estimation

6. FUTURE SCOPE

1. In the current system, the user must ensure that sufficient quantity of pellets is present in the hopper. A monitoring system can be implemented to monitor and inform the user about the quantity of pellets present in the hopper.
2. Real time implementation of this system may require some changes in design according to the need of the customer

7. CONCLUSION

The prototype for 3D printer filament extruder was successfully developed. The whole setup is miniaturized as possible which is a portable one and can be adopted to small scale industries and also to educational institutions. This developed product reduces maintenance; no trained labors are required and overall reduce the operating cost and investment of the machine. The greater accuracy and control over the process can be achieved. Real time implementation of this system may require some changes in design according to the need of the customer.

REFERENCES

1. Ware.E "Control of plastic extruders with multiple temperature zones using a microprocessor based programmable controller system", IEEE Transactions on industry applications, VOL 1A-20, N0.4,pp.912-917,1984.
2. Mohd Sali Saad, Hishammuddin Jamaluddin and Intanzauih Mat Darus," Implementation of PID controller tuning using differential evolution and Genetic Algorithm", International journal of innovative computing information and control,vol.8,no11,pp.7761-7779,2012.
3. Seema Are, Pooja Khatri and Jatin Garg, "Proportional Integral Derivative controller Tuning Of Temperature Control system", International journal of electronics, Information and systems, Vol.12, No.2,pp.37-42,2010.
4. S. Ravi and P. A. Balakrishnan, "Stable Self Tuning Fuzzy temperature controller for plastic extruder system", International journal of innovative computing information and control,vol.8,no11,pp.7761-7779,2012.
5. A.K.Kochar."Dynamic Modelling and control of plastic extrusion processes", Automatica,vol.13, N0.2,pp.177-183,1977.
6. C.C.Tasi and C.H.Lu, "Fuzzy Supervisory predictive PID control of plastic extruder barrel, J.Chinese Institution Engineering, Vol.21,n0.5, pp 619-624,1988.
7. Ismail Yusuf, Nur Iksan, Nanna Suryana and Herman "A temperature control for plastic extruder used fuzzy genetic algorithms", Proceedings of the International multi-conference of engineers and computer scientist,2010 vol2,17:19.
8. Huailin Shu and Youguo Pi, "Decoupled Temperature Control System based on PID Neural Network", IEEE International Conference on Networking, Sensing and control,2008.
9. Hong Zhou, "Simulation of temperature fuzzy control in the injection mould machine by Simulink", IEEE International conference on networking, sensing and control: ICNSC 2008, Hainan, China, April 6-8,pp.123-128,2008.
10. Jaswinder Singh and Aman Ganesh, "Design and Analysis of GA based Neural/Fuzzy optimum adaptive control", WSEAS Transaction on systems and control,vol.3,no.5,pp.375-382,2008.
11. Leehter Yao and Chin-Chin Lin, "On a Genetic Algorithm based scheduled Fuzzy PID Controllers", International journal of innovative computing information and control, vol.5,no.10,pp.3593-3602,2008.
12. Sheroz Khan Salami Femi Abdul azeez, Lawal Wahab Adetunji, Zahirul alarm.A.H.M, "Design and Implementation of an optimal Fuzzy logic controller using GA", Journal of computer science,vol.4,no.10,pp.799-806,2008.
13. Ali Reza Mehrabian.Y and Morteza Mohammad Zahir "Design of genetic algorithm based steam temperature controller in thermal power plants "ISANG Engineering letters,15:1 EI",2003.
14. Chi Huang Lu and Ching-Chih This, "Adaptive Decoupling predictive temperature control for an extrusion barrel in a plastic injection moulding process", IEEE Transaction on Industrial Electronics,vol.48,no5,pp.968-975,2001.
15. Prabhat Kumar Mahto and Rajendra Mur," Temperature control of plastic extrusion process", International journal of innovative research in science engineering and technology,2015.