International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 12 | Dec - 2021 ISSN: 2582-3930

Design & Development of a Plastic Filament Extrusion Machine

Mr. Nilesh Sangamwar, Mr. Ramankumar Thakre, Mrs. Jayashri Bhojane , Mr. Saddam Patel & Prof. Ninad Patil

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

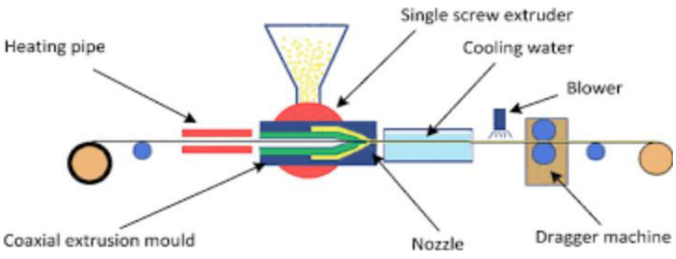

Fig 1: Working Principle

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:

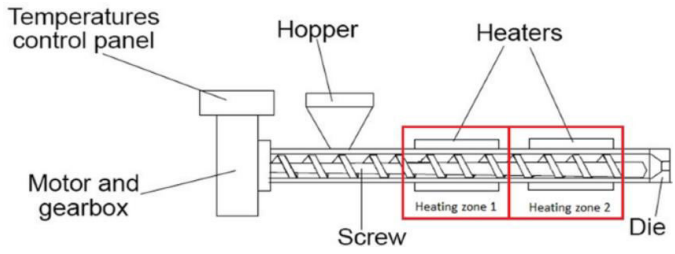

Fig: 2 Block Diagram

LITERATURE REVIEW:

POLYETHYLENE

In its simplest form polyethylene consists of backbone of long chain of covalently linked carbon atoms and hydrogen atoms. Chain atoms are terminated by methyl groups Polyethylene is the most used polymer in the world today. It is proclaimed that it was due to discovery of polyethylene in Britain; they had the best radar network during world war. For material balancing of polyethylene plant, many criteria must be taken under consideration before making any decision. Polyethylene is of various types

HDPE:

It stands for high density polyethylene. Its production is a low-pressure process. Most favorable process considered these days are Ziegler Natta process due to cheaper and abundant availability of catalysts.

∟ **LDPE:** It stands for low density polyethylene. Its production is a high-pressure process. Its production follows high pressure free radical mechanism process.

 LLDPE: It stands for linear low density polyethylene. Its production is also a high-pressure process. Most common process used these days is Phillip's process.

APPLICATIONS

Polyethylene brought a revolution in almost all plastic industry upon discovery. Today polyethylene is widely used for coating of pipelines, wires, etc. it is extensively used for waterproofing applications. It is used in ro to molding and extrusion coating. It finds extensive application in packaging industry as well. It is used for manufacturing of drip laterals. It finds widespread applications in manufacturing of pipes, bulk & rigid packing, h m films, and much more. Low grade polyethylene is used for making carry bags. Toy industry also uses polyethylene extensively.

EXTRUSION

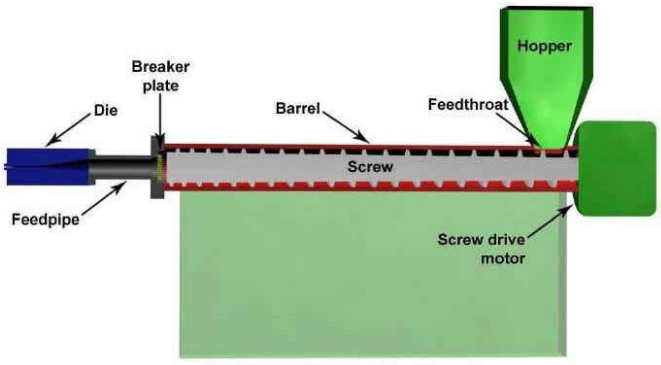

Fig 3: Schematic Diagram Of Extrusion Plant

VITAL PROCESS VARIABLES

In overall process the most important parameters are: -

1. Melt pressure
2. Melt temperature.
3. Motor load

All three parameters are used to measure the pumping efficiency of the extruder. The other important process measure is specific energy consumption which is defined as the power of the motor delivered to the extruder divided by the throughput. It is expressed as Kw hr/Kg. It is calculated by the following formula Polymer specific heat x temperature rise (extrusion process) - increase in the enthalpy Inlet die pressure gives the measure of flow rate of the melt stream through the die thus becoming another crucial process variable. Any variation in die pressure alters the flow rate which results in dimensional variation of the extruded final product. It is advisable to measure the pressure at least two points before and after the breaker plate

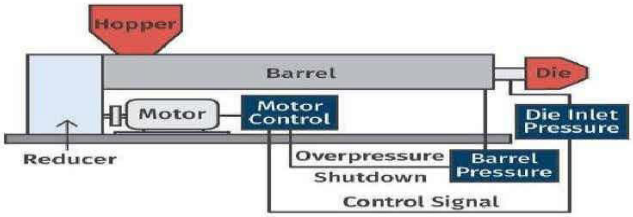

Fig: 4

A Review on Band Heaters for Heating Performance Enhancement, 'Kishor M. Mahajan1. , Dr. Atul A. Patil2. , Prof. V.H. Patil3. (IJSSBT), Vol. 4, No. 2, May 2016

Band heaters are available with elements of different diameters and heights, designed to heat and maintain the temperature of cylindrical parts. Heat transfer is usually achieved by conduction or radiation for high power heaters. They are suitable for solid heating, liquids or gases heating. Applications for band heaters are various they can be fitted to nozzles or extruder barrels, process plastics or today's materials such as resins that requires high temperature or for heating conducts. They can also be used in plastic injection Moulding as process of materials requires high heating power and high temperatures.

Key words: Injection Moulding, Band/Barrel Heater, Watt Density.

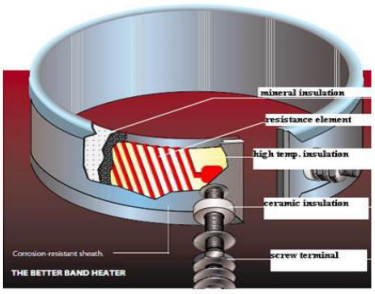

Fig. 5: Construction of MI Band Heater

Comparison Of Mica, Ceramic And Mineral Insulated Band Heaters

	MICA	CERAMIC	MINERAL
Electric Insulation	Mica	Ceramic	Mica
Thermal Insulation	No	Ceramic Fiber	Minerals
Wattage (W/In^2)	10 To 40	20 To 45	45 To 100
Temperature Range (^0c)	150-450	150-650	340-760
Cost	low	high	high
Durability	less	good	better

Table no 1

CONCLUSION After studying in details about three types of band heaters it is seen that, band heaters without thermal insulation causes heat loss to the atmosphere through convection, which increases the cost of energy. Comparative results shows that the mineral insulated band heater gives better watt densities (up to 100 W/in2) and lesser heat loss. Thus mineral insulated band heaters are better band heaters.

Recent Methods for Optimization of Plastic Extrusion Process, ' Geo Raju1, Mohan Lal Sharma2, Makkhan Lal Meena3' ISSN 2250-3234 Volume 4, Number 6 (2014), pp. 583-588

A review of literature on optimization techniques has shown a successful industrial application of DOE-based approaches for optimal settings of process variables. Taguchi method is a robust design technique widely used in industries for making the product/process insensitive to any uncontrollable factors such as environmental variables. Taguchi approach has helped in reducing the experimental time and cost of product or process development and quality improvement.

Design and Development of Plastic Filament Extruder for 3D Printing , "Mamta H. Wankhade1, Satish G. Bahaley2"

3D printing is a form of additive manufacturing technology where a three dimensional object is created by laying down successive layers of material. It is mechanized method whereby 3D objects are quickly made on a reasonably sized machine connected to a computer containing blueprints for the object. As 3D printing is growing fast and giving a boost to product development, the factories doing 3D printing need to continuously meet the printing requirements and maintain an adequate amount of inventory of the filament. As the manufactures have to buy these filaments from various vendors, the cost of 3D printing increases. To overcome the problem faced by the manufacturers, small workshop owners, the need of 3D filament making machine arises. This project focuses on designing and fabricating a portable fused deposition 3D printer filament making machine with cheap and easily available components to draw 1.75 mm diameter ABS filament

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

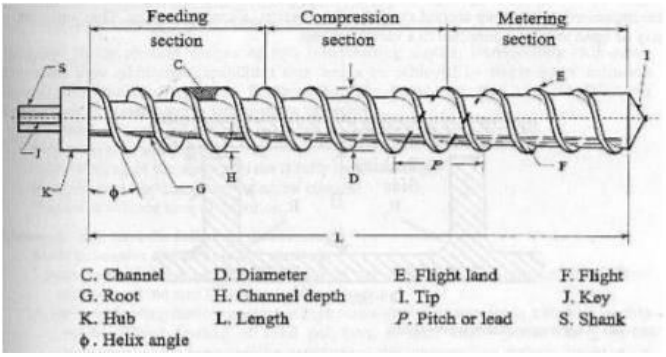

Fig 6 Screw Geometry details

Conclusion : The developments in 3D printing have led to the production of objects made from materials such as plastic, metal, paper and even food. This has given end users the opportunity to explore their creativity.3D printing is being used by universities, manufacturing companies, and everyday users as a quick method of prototyping designs, exploring the capabilities of this technology and seeking ways to improve it. Because of the quick emergence of this technology, leaps have been made towards improving manufacturing.

Mohd Sali Saad[2], investigated the implementation of PID controller tuning using two model heuristic techniques which are Differential Evolution(DE) and Genetic Algorithm(GA).The optimal PID control parameters were applied for high order system, the system with delay and non-minimum phase system. The performance of these techniques is evaluated by setting their objective functions as Mean Square Error(MSE) and Integral Absolute Error(IAE).The reliability between DE and GA in consistently maintaining minimum MSE is studied. The performance of the PID control system tuned using GA and DE method are compared with Zeigler Nicholas method.

Fig. 6

Seema Nara, Pooja Khatri and Jatin Garg[3], said that any temperature control system like an oven, take the certain time to heat up initial. But with the help of genetic algorithm, this time, taken to heat up can be reduced. And the oven can be made to start instantly without wasting time. It was very difficult to achieve an optimal gain like this as up to the present time the gain of the controller has to be manually tuned by hit and trial. Thus, the paper described the Genetic algorithm approach that would certainly reduce manual effort and give an accurate result.

Ware.E [1], explained the extrusion of molten plastic on the wire and other metal shapes requires very close control of numerous variables to ensure consistent product quality at maximum production rates. The advent of the programmable controller afforded the opportunity to accomplish a higher degree of coordination and extruder performance by integrating the variety of individual controls into a single system. A key element of the control integration was the performance of closed loop temperature control by the program of the programmable controller.

Mohd Sali Saad[2], investigated the implementation of PID controller tuning using two model heuristic techniques which are Differential Evolution(DE) and Genetic Algorithm(GA).The optimal PID control parameters were applied for high order system, the system with delay and non-minimum phase system. The performance of these techniques is evaluated by setting their objective functions as Mean Square Error(MSE) and Integral Absolute Error(IAE).The reliability between DE and GA in consistently maintaining minimum MSE is studied.

The performance of the PID control system tuned using GA and DE method are compared with Zeigler Nicholas method.

Seema Nara, Pooja Khatri and Jatin Garg[3], said that any temperature control system like an oven, take the certain time to heat up initial. But with the help of genetic algorithm, this time, taken to heat up can be reduced. And the oven can be made to start instantly without wasting time. It was very difficult to achieve an optimal gain like this as up to the present time the gain of the controller has to be manually tuned by hit and trial. Thus, the paper described the Genetic algorithm approach that would certainly reduce manual effort and give an accurate result.

S.Ravi, P.A.Balakrishnan[4], developed and tested GA-based Fuzzy logic controller for temperature control in a plastic extrusion through simulation. The system was designed with two different control techniques to control a temperature at different set point changes and as well as to control sudden input disturbances. The method was robust against changes in the system parameters and superior to the Fuzzy controller.

A. K. Kochar[5], presented the alternative methods for determining plastics extrusion process models, suitable for high- level control are examined. The importance of time series techniques for feed forward control is demonstrated. The results of extrusion process dynamic model identification experiments, carried out on a single screw extruder used for processing polyethylene are described. Some results of exploratory control strategy simulations were included.

C.C.Tasi and C.H.Lu[6], described the design of single loop fuzzy supervisory predictive PID controllers for a plastic extruder barrel. A fuzzy supervisory shell is proposed to improve the set point tracking performance of the proposed PID method by appropriate adjustment of the weighting term for the control effort.

Ismail Yusuf, Nur Iksan, Nanna Suryana Herman[7], investigated an application of Genetic Algorithm in the design and implementation of Fuzzy logic controllers. This idea was used in a real case application called extrusion of plastic. The comparison of various parameters showed that GA is helpful in improving the performance of FLC. The research developed a system that may help users to determine membership function of FLC using the GA optimization for fastest processing in completing the problems.

Huailin Shu and Hugo Pi[8], analysed the characteristics of the temperature control systems in the industry which have long delayed time, large time constants and strong couple effects. Then introduced a proportional, integral, derivative neural network(PINN) is a multivariable controller. The result proved that the PID neural network has perfect decoupling and self-learning control performances in the coupled temperature system.

Hongfu Zhou[9], introduced a linear control design method for the temperature control in injected mould machine. The temperature control systems was a time delay system, which was described in the first order system on the transfer function. The temperature control fuzzy model had two inputs and one output and using trapezoidal membership function for fuzzification. Simulink in Matlab was used to simulate fuzzy control and best fuzzy parameter.

Jaswinder Singh and Aman Ganesh [10], investigated that the Adaptive Neural Controller(ANC) is used since because it causes flow disturbances and sensor noise is common in chemical and metallurgical industries. In order to maintain optimal performance, the controlling system has to adapt continuously to these changes. Using a neural network controller, ANC modifies network parameters through the genetic algorithm. Along with fuzzy logic controller is also implemented for the online tuning of PID controller even in the presence of noise. The simulation results showed that identified GA-based adaptive neuro-controller along with PID controller was able to adapt the process changes.

Leehter Yao and Chin-Chin Lin [11], presented the adaptive fuzzy PID controller with gain scheduling is proposed in the paper. The structure of the proposed gain scheduled fuzzy PID (GS_FPID) controller consist of both fuzzy PI-like controller and fuzzy PD-like controller. Both of fuzzy PI-like controller and PD-like controller are weighted through adaptive gain scheduling which is determined by fuzzy logic. A modified Genetic Algorithm called accumulated genetic algorithm was designed to learn the parameters of fuzzy inference system.

Sheros Khan, Salami Femi Abdulazeez, Lawal Wahab Adetunji, AHM Zahir Alam[12], investigated all control systems suffer from problems related undesirable overshoot, longer settling times and vibrations while going from one state to another state. This was based on a software approach which was focusing on an algorithmic approach to programming a PIC16F877A microcontroller for eliminating parametric dependence issues while adding the benefits of easier modification to suit a given control system to changing operational conditions.

Ali Riza Mehrabian.Y and Morteza Mohamed Zaheri[13], presented a systematic approach for the design of temperature controller using GA for the thermal power plant subsystems and investigates the robustness of the designed control law. The proposed approach employs GA search for determination of the optimal PI controller parameters for a previously identified non-linear de-super heater of a 4X 325 MW thermal power plant. Results indicate proposed algorithm significantly improves the performance of the thermal power plant subsystem.

Chi Huang Lu and Ching-Chih Tsis[14], presented an adaptive decoupling temperature control for an extrusion barrel in a plastic injection molding process. After establishing a stochastic polynomial matrix model of the system, a corresponding decoupling system representation was then developed. Results proposed that proposed method has been shown to a powerful under set point changes, load disturbances and significant plant uncertainties.

Prabhat Kumar Mahto, Rajendra Murmu[15], developed an ANFIS controller design method for temperature control in plastic extrusion system at different set point changes as well as sudden input disturbances controlled with different

control techniques. The temperature of the plastic extrusion system had a wide range of variation subject to various disturbances. All the PI, PID, FUZZY,ANFIS control method was simulated using Matlab/Simulink. It has been concluded that ANFIS controller gives better performance than three other controllers.

3. CONCLUSIONS (Proposed)

Initial tests employed the silicone heaters to melt the plastic. Though rated to 210°C the heaters only provided enough power to achieve temperatures up to 110°C inside the tube and 150°C outside. The melting point of the PLA plastic being used (3001D from Jamplast) was 200°C. Insulation was added to the outside of the tube but that only increased the temperature to 150°C inside the tube. The heat from silicon heaters caused the plastic to melt somewhat, but not enough to allow extrusion through the die. The plastic would remain in the tube and finally cause the motor to stall when it couldn't provide enough torque.

More power to heat the extrusion tube was provided by switching to Ni Chrome wire as the heating element. With 3.6m of wire, run at 60V, drawing 2.0A the interior of the tube reached 210°C. This provided 120W of power, fully melting the plastic and successfully extruding filament.

The resulting extruded filaments are shown in Figure 6 below alongside a commercially produced PLA filament on the right.

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.