IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

FABRICATION OF 3D PRINTING FILAMENT EXTRUDER FOR THE THERMOPLASTICS

1st Dr. J. NARENDRAN
Assistant Professor – Mechanical
Paavai College of Engineering
(Anna University Affiliated)
Namakkal, India

2nd ARUN C
Mechanical Engineering
Paavai College of Engineering
(Anna University Affiliated)
Namakkal, India

3rd KESHAVAN K
Mechanical Engineering
Paavai College of Engineering
(Anna University Affiliated)
Namakkal, India

4th LOGANATHAN S
Mechanical Engineering
Paavai College of Engineering
(Anna University Affiliated)
Namakkal, India

5th TAMILKUMARAN S
Mechanical Engineering
Paavai College of Engineering
(Anna University Affiliated)
Namakkal, India

Abstract: In recent days, additive manufacturing plays a vital role in industry, such as Automobile, Textile, Robotics, Construction, Aerospace and Medical field etc. To fullfill the industry requirement, one of the technologies in additive manufacturing is 3D printing which is used mainly which increase the demand for 3D printing filament in industry. India generates more than 9.4 million tonnes of plastic waste per year, in these more than 1.4 million tonnes of plastic is PET bottle, over 9400 tonnes of plastic waste in still landfilled or ends up in ground water. Traditional method of recycling PET is the mechanical method which required more energy and cost. The main objective of the project is to fabricate the 3D printing filament extruder to recycle the PET bottles into the 3D printing filament. The extruder can produce the filament from the various thermoplastics such as PLA, ABS, Nylon and PETG. By recycling the plastic, the environmental pollution caused by the plastic may be reduced and tackle the demand of 3D printing filament in industries.

Keywords – 3D Printing, Thermoplastic, Addictive Manufacturing, Filament.

I. INTRODUCTION:

At the heart of your filament extruder lies the drive system. This consists of an electric motor that efficiently pushes plastic through the extruder using a pulley system. The motor's size will depend on the type of filament you plan to produce and the desired output rate. Next comes the barrel and screw assembly. The barrel is a heated metal chamber where the plastic pellets are melted. It needs to be able to withstand high temperatures and be precisely machined to house the screw mechanism. You can find resources online for DIY barrel creation or purchase pre-made options. The screw itself agitates and pushes the plastic pellets forward within the barrel. A single screw design is sufficient for basic filaments, but a double screw design offers superior mixing capabilities for composite filaments containing additional materials.

Once melted, the plastic is forced through the die. This nozzle shapes the molten plastic into a filament with a consistent diameter, typically 1.75mm or 2.85mm depending on your 3D printer's requirements. Pre-made dies are available, or you can create your own using a 3D printed design and a high-temperature resistant material. Feeding the plastic pellets into the barrel is the hopper. This is essentially a funnel that continuously supplies the raw material for filament production.

As the molten plastic exits the die, it needs to solidify quickly to maintain its shape. The cooling system, which can be a simple fan or a more elaborate water cooling setup, plays a crucial role in this process. A rapid cooling process ensures the filament maintains a consistent diameter as it winds onto the spool. Maintaining optimal temperatures within the barrel is essential for proper melting of different thermoplastics. This is achieved through a temperature control unit equipped with sensors that monitor and regulate the heat based on the specific material being used.

II. EXISTING SYSTEM:

Industrial filament extruders are large, high-volume machines designed for commercial filament production. These expensive and complex machines are not suitable for personal use, but offer advantages like high production capacity for supplying filament manufacturers or large-scale 3D printing operations, material versatility for handling a wider range of thermoplastics compared to desktop extruders, and precise control for filament diameter, temperature, and other parameters, resulting in consistent and high-quality filament. Some prominent industrial filament extruder manufacturers include Filabot and Notzon.

Desktop filament extruders are smaller, more affordable machines designed for hobbyists, educational institutions, or small-scale filament production. They are ideal for those who want to experiment with creating their own custom filaments or want to recycle waste plastic into usable filament. These user-friendly machines often come with pre-built components and intuitive controls, and can handle a good range of common thermoplastics like ABS, PLA, and PETG. Some desktop extruders even allow for customization of filament diameter and basic blending of materials for creating unique filaments.

III. PROPOSED SYSTEM:

The current landscape of 3D printing filament extruders offers two main options: industrial machines for large-scale production and less versatile desktop models. This proposal bridges the gap by outlining a desktop filament extruder system that prioritizes affordability, ease of use, and customization. At the heart of this system lies a geared stepper motor. Unlike simpler AC motors used in some extruders, a stepper motor provides precise control over the extrusion rate. This translates to better consistency in the final filament diameter, a crucial factor for successful 3D printing.

Next comes a modular barrel system. Constructed from stainless steel for durability, this barrel features interchangeable heating sections. This innovative design allows for easy replacement of heating elements and future upgrades. By accommodating different heating sections, the extruder can handle a wider range of thermoplastics with varying temperature requirements. Thermoplastic pellets are pushed through the barrel by a screw. For basic filament production, a single screw design is sufficient. However, the system also incorporates an optional mixing nozzle. This nozzle attaches to the end of the screw, enabling the creation of composite filaments. By introducing chopped carbon fiber or other materials into the mix, users can create filaments with unique properties like increased strength.

The molten plastic then exits the barrel through a specially designed die. This die boasts an adjustable diameter mechanism, allowing users to customize the filament size within a specific range, typically between 1.75mm and 2.85mm. This caters to the various filament diameter requirements of different 3D printer models. Solidification is crucial for maintaining the filament's shape. This proposed system employs a dual-stage cooling system. An initial blast of air from a fan rapidly cools the filament as it exits the die. This is followed by a more precise cooling process achieved through a water cooling channel surrounding the die. This two-step approach ensures consistent filament diameter throughout the winding process.

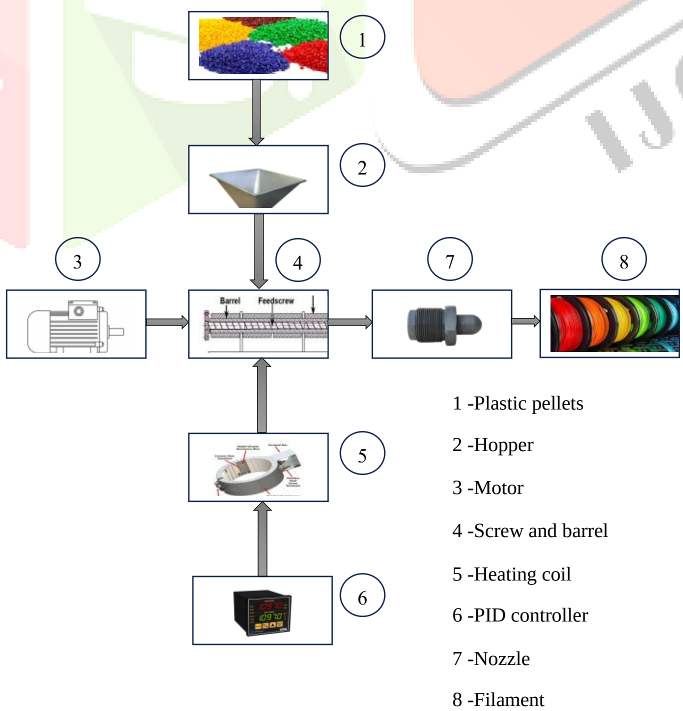

Fig 3.1 Block Diagram

3.1 COMPONENTS REQUIRED:

- SCREW AND BARREL
- BAND HEATING COIL
- PID TEMPERATURE CONTROLLER
- J-TYPE THERMOCOUPLE

- SOLID STATE RELAY
- NOZZLE ASSEMBLY
- AC MOTOR
- GEAR HEAD
- SINGLE-PHASE AC DIGITAL CONTROLLER
- AC COOLING FAN
- TOGGLE SWITCH
- HOPPER

IV. THEORETICAL BACKGROUND:

1. Polymer Physics and Material Science:

Polymer Melting: Thermoplastics used in filament extrusion are polymers with long, chain-like molecules. When heated above their glass transition temperature (Tg) and melting point (Tm), these chains loosen up and gain mobility, allowing them to flow like a liquid. The extruder's screw and barrel work together to generate friction and heat, pushing the plastic pellets to a temperature exceeding Tg and Tm, transforming them into a molten state.

Rheology: This branch of material science deals with the flow behavior of materials. In filament extrusion, the rheological properties of the molten plastic determine its flow characteristics and how easily it can be extruded through the die. The screw design (single or double), extrusion rate, and temperature all play a role in influencing the flow behavior of the plastic.

2. Heat Transfer:

Heat Transfer Mechanisms: The band heating coil wrapped around the barrel transfers heat through conduction to the barrel metal. This heat then conducts to the plastic pellets within the barrel, melting them. The J-type thermocouple measures the barrel temperature, providing feedback to the PID controller. The controller regulates the power delivered to the heating coil based on this feedback, maintaining a consistent temperature for optimal melting.

Heat Loss: Heat loss from the barrel can occur through conduction, convection, and radiation. Proper insulation around the barrel minimizes heat loss and improves efficiency. The cooling fan plays a crucial role by rapidly cooling the extruded filament after it exits the die, solidifying it before spooling.

3. Mechanics of Extrusion:

Screw Design: The screw is a single or multi-flight helical shaft that rotates within the barrel. Its primary function is to convey the plastic pellets forward and generate frictional heat to aid in melting. The screw's channel depth and flight angle influence the material mixing and pressure generation within the barrel. Single screw designs are sufficient for basic filaments, while double screws offer better mixing capabilities for composite filaments.

Pressure Generation: As the screw rotates, it creates pressure within the barrel, pushing the molten plastic towards the die. The die acts as a restriction, and the pressure helps to force the molten plastic through the small opening, shaping it into a filament of the desired diameter.

4. Control Systems:

PID Control: The PID controller is a feedback control system that maintains the desired temperature within the barrel. It continuously monitors the temperature measured by the thermocouple, compares it to the set point temperature, and adjusts the power delivered to the heating coil accordingly. This closed-loop system ensures precise temperature control, crucial for consistent filament quality.

Motor Speed Control: The single-phase AC digital controller regulates the speed of the AC motor. By controlling the motor speed, the controller indirectly influences the extrusion rate of the filament. Some controllers may also offer functionalities like motor direction control for specific operations.

V. HARDWARE DESCRIPTION:

1. Screw and Barrel:

Screw: This rotating metal component pushes plastic pellets through the barrel. A single screw design is sufficient for basic filaments, while a double screw design can improve mixing for composite filaments.
Barrel: This heated metal chamber houses the screw and melts the plastic pellets due to the heat generated by the heating element.

Fig 5.1 Screw and Barrel

2. Heating and Temperature Control:

Band Heating Coil: This coil wraps around the barrel and provides heat for melting the plastic.

Fig 5.2 Band Heating Coil

PID Temperature Controller: This electronic unit monitors temperature using the thermocouple feedback and regulates the power delivered to the heating coil to maintain a consistent temperature within the barrel.

Fig 5.3 PID Temperature Controller

J-Type Thermocouple: This sensor comes in direct contact with the barrel and continuously measures the temperature, providing feedback to the PID controller.

Fig 5.4 J-Type Thermocouple

Solid State Relay (SSR): This electronically controlled switch regulates the power flow to the heating coil based on the signals from the PID controller.

Fig 5.5 Solid State Relay

3. Extrusion and Cooling:

Nozzle Assembly: The molten plastic exits the barrel through the nozzle, which shapes it into a filament of the desired diameter (typically 1.75mm or 2.85mm).

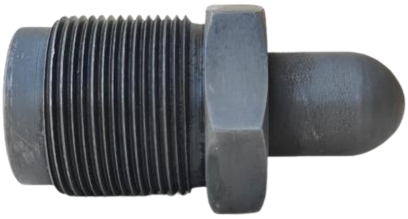

Fig 5.6 Nozzle Assembly

AC Motor: This electric motor provides the driving force for the screw to rotate and extrude the filament.

Fig 5.7 AC Motor

4. Control and User Interface:

Gear Head: This gear reduction unit attached to the motor adjusts the rotation speed of the screw, allowing control over the filament extrusion rate.

Fig 5.8 Gear Head

Single-phase AC Digital Controller: This controls the speed of the AC motor, indirectly influencing the extrusion rate. Some controllers may also incorporate functionalities like direction control for the motor.

Fig 5.9 Single Phase AC Digital Controller

AC Cooling Fan: This fan cools the extruded filament after it exits the nozzle, solidifying it before spooling.

Fig 5.10 AC Colling Fan

VI. WORKING PRINCIPLE:

The unsung hero of 3D printing is the filament extruder. This machine takes raw plastic pellets and transforms them into the essential building block for creating objects layer-by-layer in 3D printers: continuous filament. The process starts by loading plastic pellets into a hopper. From there, a controlled mechanism feeds them into the heart of the extruder – the screw-barrel assembly. Here, the screw pushes the pellets forward while a surrounding band heater melts them at precise temperatures, crucial for optimal extrusion. A PID controller ensures consistent heat by regulating power delivery to the heater based on real-time temperature readings.

Once melted, the plastic travels through the barrel, reaching a nozzle that determines the final filament diameter. This is typically 1.75mm, but can be larger depending on specific printing needs. Exiting the nozzle, the molten plastic undergoes rapid air or water cooling to solidify and maintain its shape. Quality control measures using sensors and gauges ensure consistent filament diameter throughout the process. The solidified filament is then wound onto spools, ready for use in 3D printers. The entire process is automated and controlled for consistent filament production. Different plastics like PLA and ABS can be used, each requiring specific temperature and extrusion settings.

Beyond the basics, filament extruders offer the flexibility to create custom filaments with varying colors, diameters, and even material blends. Advancements in technology have led to faster, more accurate, and material-compatible systems. Dual-extrusion capabilities allow for printing with two colors or materials simultaneously, expanding creative possibilities. Filament extruders also play a role in the circular economy by enabling the recycling of plastic waste into usable filament. Ongoing research aims to further improve efficiency, reliability, and sustainability. This technology also opens doors for new printable materials, pushing the boundaries of 3D printing.

VII. SIMULATION OUTPUT:

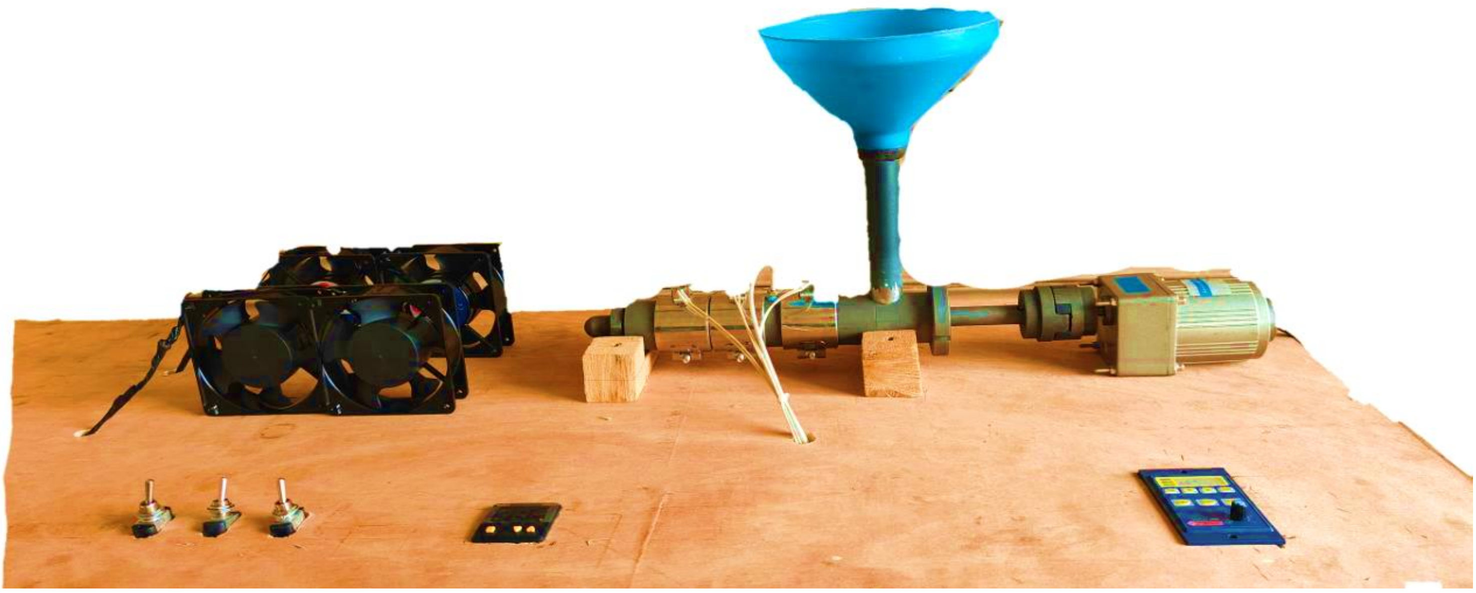

Fig 7.1 Output

VIII. CONCLUSION:

In conclusion, filament extruders are not just machines; they are enablers of innovation. They empower individuals and businesses to bring ideas to life, from prototyping to customized manufacturing. As 3D printing evolves, filament extruders will remain a cornerstone technology, shaping the future of design and creation.

IX. RESULT AND DISCUSSION:

9.1 RESULT:

The unsung hero of the 3D printing world is the filament extruder. This machine takes raw plastic pellets and transforms them into the essential building block for 3D printing: continuous filament. The process starts with loading plastic pellets into a hopper. A controlled mechanism then feeds them into the heart of the extruder, where a screw pushes them forward and a surrounding heater melts them at precise temperatures. A PID controller ensures consistent heat for optimal extrusion. Once melted, the plastic travels through the barrel, reaching a nozzle that determines the final filament diameter. The molten plastic then undergoes rapid cooling to solidify and maintain its shape, before being wound onto spools for use in 3D printers.

Beyond the basics of producing consistent filament, extruders offer flexibility. They can create custom filaments with varying colors, diameters, and even material blends. Advancements in technology have led to faster, more accurate, and material-compatible systems. Dual-extrusion capabilities allow for printing with two colors or materials simultaneously, expanding creative possibilities. Filament extruders also play a role in the circular economy by enabling the recycling of plastic waste. As 3D printing evolves, filament extruders will remain a cornerstone technology, shaping the future of design and creation.

9.2 DISCUSSION:

The growing accessibility of 3D printing hinges on the capabilities of filament extruders. While traditional models prioritize functionality, there's a rising discussion around user-friendly, customizable designs. These new proposals emphasize features like interchangeable heating elements for wider material compatibility, open-source designs for user modifications, and precise control systems for consistent filament quality. This shift reflects a desire to empower individual creativity and experimentation within the 3D printing space, potentially leading to a more innovative and diverse range of printable materials and objects.

X. ACKNOWLEDGEMENT:

Certainly, acknowledging the support and contribution of Paavai College of Engineering, particularly the teaching and non-teaching staff of the Department of Mechanical, is essential. Additionally, expressing gratitude to our parents, friends, and all those who have provided direct or indirect support for this research is imperative.

XI. REFERENCE:

[1] Chen, Wei, et al., Quantitative Analysis of Material Properties in FDM 3D Printing: A Literature Review, 2018.

[2] Garcia, M., Martinez, L., Rodriguez, P.., Thermoplastic Elastomers: A Comprehensive Review, 2019.

[3] Krishna Kumar Nitiyah., Musa Luqman., Mohamad Rasidi Mohamad Syahmie., Ahmad Khairel Rafezi., Abd Rahim Shayfull Zamree., Rozyanty Rahman & Ahmad Azrem Azmi., A Review on the Effect of Extrusion Parameter on 3D Printing Filament Diameter, 2023.

[4] Lim Huat Ng., Shafizal Mat., Syahibudil Ikhwan Abdul Kudus., Faiz Redza Ramli., Abd Rahman Dullah., Mohd Rizal Alkahari., Design and Development of Filament Extruder for 3D Printing Machine, 2022.

[5] Nassar, M. A., Elfarahaty, M., Ibrahim, S., & Hassan, Y. discussed the "Design of 3D Filament Extruder for Fused Deposition Modelling Additive Manufacturing" in volume 9, issue 4, pages 55–62, published in 2019.

[6] Petrakli, Maria, et al., Advances in 3D Printing Filament Extrusion: A Comprehensive Review, 2019.

[7] Rishna Kumar Nitiyah., Musa Luqman, Mohamad Rasidi Mohamad Syahmie., Ahmad Khairel Rafezi., Abd Rahim Shayfull Zamree., Rozyanty Rahman & Ahmad Azrem Azmi., The Assessment of the Filament Extruder Equipment for 3D Printing, 2022.

[8] Samuel H. Huang., Peng Liu., Abhiram Mokasdar., Liang Hou., Comprehensive Literature Review on Additive Manufacturing and Its Societal Impact, 2013.

[9] Sathies, T., Senthil, P., & Anoop, M. S. explored Advancements in Applications of Fused Deposition Modelling Process: A Critical Review in their publication in the Rapid Prototyping Journal, volume 26, issue 4, pages669–87, 2020.

[10] Smith, J., Johnson., A., Brown, K.., Advances in Thermoplastic Materials for Additive Manufacturing ,2020 have concluded an overview of recent.

[11] Smith., John., Jones., Emil., A Systematic Review of 3D Printing Filament Extrusion Processes and Parameters, 2019.

[12] Wang, J., Qiu, J., Xu, S., Li, J., & Shen, L. examined the impact on the mechanical properties and water absorption of Polycaprolactam PA6 and Poly hexamethylene Adipamide PA66 in their 2020 publication in RSC Advances, volume 10, issue 36, pages 21491–86.

[13] Xiao, X. explored the mechanical properties of plastic materials under dynamic tensile conditions in their 2008 publication Dynamic Tensile Testing of Plastic Materials in Polymer Testing, volume 27, issue 2.

[14] Zhong, S., & Pearce, J. M. explored Coupled Distributed Recycling and Manufacturing with Recycle bot and RepRap 3-D Printing in Resources, Conservation and Recycling, volume January, pages 48–58, 2018.