3D PRINTER FILAMENT EXTRUDER

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Abstract- *Thermoplastic polymers find extensive applications across various industrial sectors, including automotive, agricultural, aeronautical, and home accessories. Their versatility is realized through three primary manufacturing processes: Injection molding, extrusion, and additive manufacturing, commonly referred to as a new technology driven by Computer-Aided Design (CAD). This innovative approach involves the use of raw materials in the form of powders or filaments, known as 3D printing, where the filament diameter (ranging from 1.75mm to 2.5mm) is influenced by the size of the 3D printer. Addressing challenges such as the high cost, permanent mechanical properties, and chemical composition of filaments, as well as the generation of wasteful plastics, led to the adoption of a solution. This solution focuses on the creation and production of filaments by utilizing thermoplastics in the forms of pellets, granules, and waste materials. Notably, the proposed solution aims to resolve previous issues and enhance mechanical properties, allowing for the modification of filament behavior through the addition of other polymers, including the combination of two or more.*

Key Words: Extruder, additive manufacturing, thermoplastic, computer-aided design, filament, polymers, mechanical behaviour.

1.INTRODUCTION

3D printing technologies, also known as Additive Manufacturing (AM), have revolutionized the production of physical parts using various materials such as thermoplastics, composites, and metals. This innovation has found applications in diverse industries, including aerospace and automotive, allowing for the creation of intricately designed components without the need for expensive tooling. The technique involves building up successive layers of raw thermoplastic materials, particularly utilizing polyamide (PA), acrylonitrile butadiene styrene (ABS), polylactic acid (PLA), polycarbonate (PC), and polystyrene (PS). Despite the widespread availability of these thermoplastics with favourable mechanical, chemical, and physical properties, they are often expensive and largely imported. To address cost concerns and promote environmental sustainability, waste plastics are incorporated into the process. To further enhance the properties of the 3D-printed parts, modifications to the fused deposition modelling (FDM) printing technique have been undertaken. A crucial aspect of this project involves designing and realizing a testbed for a filament extruder capable of producing filaments at specific diameters of 1.75mm and 2.5mm. The project's objectives include the development of a low-cost filament extruder machine for extracting filament suitable for 3D printing. Subsequently, a comparative study investigates the mechanical properties of the produced filaments compared to those commonly used in the automotive industry. Mechanical tensile tests are conducted using an MTS Tensile Testing Machine with varying crosshead speeds, in line with testing standards. Specimens with diameters of 1.75mm and 2.5mm and a total length of 200mm are examined, employing a crosshead made of PA6 known for its widespread use in various industrial domains despite its limited UV resistance.

1.1 Research problems

- The expensive price of the 3D printing filament
- Permanent mechanical properties
- Importation filament

1.2 Research Objectives and Importance

- Design and manufacturing of new filament extruder design
- Reducing the price of the filament used in 3D printer
- Improving FMD filament materials by conduction modifications.

2. Literature Review

In 2021, Arup Dey, Isnala Nanjin, Roan Eagle, and Nita Yodo authored "A Comprehensive Review on Filament Materials for Fused Filament Fabrication," published in the Journal of Manufacturing and Materials Processing. [A]

T. Sathies, P. Senthil, and M. S. Anoop explored "Advancements in Applications of Fused Deposition Modelling Process: A Critical Review" in their 2020 publication in the Rapid Prototyping Journal, 26(4), 669–87. [B]

Ruben Foresti, Stefano Rossi, and Stefano Selleri presented their work on "Nano-Functionalization of 3D Bio-Engineered Scaffold in Bio-Composite Materials" at the 2019 IEEE International Conference on BioPhotonics (BioPhotonics), pages 100–101. [C]

Mohsen Attaran's 2017 publication in Business Horizons, 60(5), titled "The Rise of 3-D Printing: Advantages of Additive Manufacturing over Traditional Methods," delves into the evolving landscape of additive manufacturing. [D]

Samuel H. Huang, Peng Liu, Abhiram Mokasdar, and Liang Hou conducted a "Comprehensive Literature Review on Additive Manufacturing and Its Societal Impact," published in the International Journal of Advanced Manufacturing Technology, 67(5–8), in 2013. [E]

Mona A Nassar, Mohammed Elfarahaty, Saber Ibrahim, and Youssef Hassan discussed the "Design of 3D Filament Extruder for Fused Deposition Modeling Additive Manufacturing" in Volume 9(4), pages 55–62, published in 2019. [F]

Patrick Holzmann, Robert J. Breitenecker, Aqeel A. Soomro, and Erich J. Schwarz examined "User Entrepreneur Business Models in 3D Printing" in the Journal of Manufacturing Technology Management, 28(1), published in 2017. [G]

Juan Wang, Jianping Qiu, Siyi Xu, Jianxi Li, and Liguo Shen examined the impact on the mechanical properties and water absorption of Polycaprolactam (PA6) and Polyhexamethylene Adipamide (PA66) in their 2020 publication in RSC Advances, 10(36), pages 21491–86. [H]

"3D Printing for Dummies" by KK Hausman and R. Horne, published by Wiley in Somerset in 2014, is a resource available from ProQuest Ebook Central. [I]

Shan Zhong and Joshua M. Pearce explored "Coupled Distributed Recycling and Manufacturing with Recyclebot and RepRap 3-D Printing" in Resources, Conservation and Recycling (January), pages 48–58, published in 2018. [J]

M. Kreiger, G. C. Anzalone, M. L. Mulder, A. Glover, and J. M. Pearce discussed "Distributed Recycling of Post-Consumer Plastic Waste in Rural Areas" in Materials Research Society Symposium Proceedings, 1492, pages 91–96, in 2013. [K]

Xinran Xiao's 2008 publication, "Dynamic Tensile Testing of Plastic Materials," in Polymer Testing, 27(2), explored the mechanical properties of plastic materials under dynamic tensile conditions. [L]

In 2014, T. Letcher and M. Waytashek conducted a study titled "Material Property Testing of 3D-Printed Specimens in PLA on an Entry-Level 3D Printer," and the findings were published in Volume 2A of the Advanced Manufacturing journal. [M]

3. Experimental

3.1 Extruder Design

The extruder is an extended, continuous process for working with polymers, employed in the production of tubing, tire treads, and wire coverings. This apparatus functions by pushing raw material in pellet form into a heated tube. The tube is heated by 2-5 heaters fixed on its external side. During this process, an endless turning screw, driven by a motor, facilitates the pushing of the raw material through the heated tube. The material is then compressed into a shaping die, ultimately resulting in the extraction of the final product – a filament with diameters of 1.75mm and 2.5mm (refer to Fig.1).

Fig -1: Extruder Design

3.2 Extruder Component List

This extruder machine was manufactured using components listed below:

Compents List	
Compents	QTY
Turning screw	1
Steel Tube	1
Hopper	1
Heaters	3
Nozzle	1
Motor	1

3.2.1 Turning screw

The rotating screw utilized measures 32mm in diameter and has a total length of 400mm. This screw is responsible for transferring thermoplastic materials, facilitating their extrusion into various final forms. This is achieved through its rotation around its axis of revolution, coupled with the specific geometry of the flights. Each flight has a width of 20mm, and the pitch is fixed at 43.5mm between every two successive flights, with a channel depth of 17mm.

Fig -2: Turning screw

3.2.2 Steel Tube

I The tube functions as a housing chamber for the screw, facilitating the feed of raw material into the chamber through the screw. The dimensions of the tube include a 34mm internal diameter, 45mm external diameter, and a length of 400mm. Notably, the tube features a hollow area on its lateral surface specifically designated for material feed, as illustrated in Fig. 3.

Fig -3: Steel Tube

3.2.3 Hopper

The suction hopper serves a vital role in this process by retaining the required quantity of material for feeding into the screw.

Fig -4: Hopper

3.2.4 Heater

The heaters are positioned on the lateral surface of the copper tube to ensure the internal thermoplastic material reaches a fusion temperature of 350 degrees Celsius. This facilitates the extrusion process in the final step.

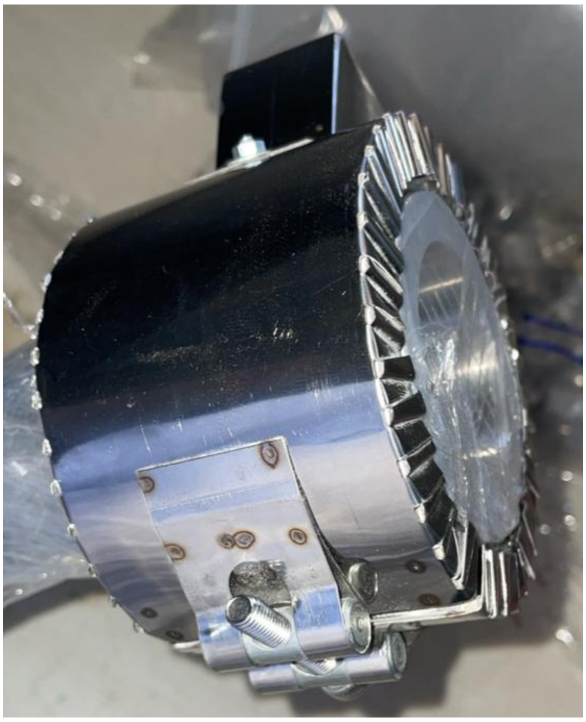

Fig -5: Heater

3.2.5 Nozzle

At the final section of the filament extruder, where the filament is discharged, there is a cylindrical component with an open top and a small hole in the center of its bottom surface. Typically constructed from brass due to its heat-resistant properties, this element is crucial for shaping the extruded filament. For the experimental setup, die will be employed with a diameter of 1.75mm for the small hole. Additionally, it features an inner hex shape to facilitate attachment to the end of the steel tube.

Fig -6: Nozzle

3.2.5 Motor

The system is equipped with a 35 RPM motor, and its speed is regulated by a Pulse Width Modulation (PWM) speed controller. This controller is wired in series with the power source from a 24 V supply and the motor, representing a straightforward control system. Operating as a variable speed control system, the RPM is determined by adjusting the duty cycle. To ensure proper material mixing and melting, the optimal screw speed is targeted at approximately 40 RPM.

Fig -7: Motor

4. CONCLUSIONS

Securing raw materials for 3D printing poses a significant challenge in the utilization of additive manufacturing for production and commercial purposes. This challenge is further compounded by the demand for materials with commendable mechanical properties. To address these issues, we devised a comprehensive plan encompassing the design and production of a filament extruder. The process initiated with conceptualization through software design and culminated in the actualization of the extruder. Throughout this endeavor, various parameters influencing filament extrusion were systematically studied. Additionally, the mechanical properties of the produced filament were subjected to characterization, yielding satisfactory results. The streamlined workflow has not only reduced time and costs but has also contributed to the development of an efficient system for manufacturing filament extrusion.

5. Acknowledgement

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