



DEVELOPMENT AND CHARACTERIZATION OF 3D PRINTING FILAMENT DERIVED FROM RECYCLED PET BOTTLES

Akanksha Santosh Bawadhane

Department of Mechanical Engineering

SKN Sinhgad College of Engineering, Korti, Pandharpur, India

Vaishnavi Ashok Devkar

Department of Mechanical Engineering

SKN Sinhgad College of Engineering, Korti, Pandharpur, India

Janhavi Jitendra Kasegaonkar

Department of Mechanical Engineering

SKN Sinhgad College of Engineering, Korti, Pandharpur, India

Pragati Dilip Kashid

Department of Mechanical Engineering

SKN Sinhgad College of Engineering, Korti, Pandharpur, India

Dr. S. S. Kulkarni (Guide)

Head of Department, Department of Mechanical Engineering

SKN Sinhgad College of Engineering, Korti, Pandharpur, India

Abstract:

The increasing generation of plastic waste has created significant environmental concerns, particularly due to the improper disposal of polyethylene terephthalate (PET) bottles. This study presents the development of a low-cost extrusion system for converting waste PET bottles into material suitable for 3D printing filament production. The proposed system uses manually cut PET bottle strips as feedstock, eliminating the need for a conventional plastic shredding unit. The PET strips are heated and melted within an approximate temperature range of 240–260°C and subsequently extruded through a 4 mm nozzle. A 12 V DC geared motor operating at 10 rpm is employed for pulling and winding the extruded material, while natural air cooling is used for solidification. The influence of processing temperature and pulling speed on filament continuity, surface appearance, and approximate diameter consistency is investigated. Experimental observations indicate that continuous filament can be produced when the heating and pulling conditions are appropriately controlled. Higher pulling speeds generally produce thinner filament, whereas lower speeds tend to produce thicker filament. The developed system demonstrates the feasibility of a simple and economical approach for recycling PET bottle waste into 3D printing filament and provides a foundation for further improvements in automated diameter control, cooling, and material characterization.

Keywords: Polyethylene terephthalate, PET recycling, 3D printing filament, filament extrusion, additive manufacturing, sustainable manufacturing, plastic waste recycling.



1. INTRODUCTION

The rapid growth of plastic consumption has resulted in a substantial increase in plastic waste, creating serious environmental and resource-management challenges. Among the different types of plastic waste, polyethylene terephthalate (PET) bottles constitute a significant portion of post-consumer plastic waste. Although PET is highly recyclable, a considerable quantity of used bottles is still discarded or improperly managed, resulting in environmental pollution.

Additive manufacturing, commonly known as 3D printing, has emerged as an important manufacturing technology because of its ability to produce complex components with reduced material waste. Thermoplastic polymers such as PET and its derivatives can be used as feedstock for fused-filament fabrication (FFF) processes. Commercially available 3D printing filament, however, can be relatively expensive, limiting its accessibility for educational institutions, small-scale users, and researchers.

The conversion of waste PET bottles into 3D printing filament provides an opportunity to combine plastic waste

management with additive manufacturing. Previous studies have investigated the recycling of PET and other waste plastics into filament using extrusion-based systems [1], [2], [4]. These studies indicate that temperature control, material preparation, extrusion conditions, cooling, and pulling speed significantly influence the resulting filament.

In this work, a low-cost PET filament extrusion system is developed using commonly available components. Instead of shredding the bottles into flakes, the bottles are manually cleaned, dried, and cut into strips. The strips are then heated, melted, extruded through a nozzle, cooled, and wound onto a spool. The study focuses on the development of the setup and the effect of major process parameters on the continuity, surface appearance, and diameter consistency of the produced filament.

2. PROBLEM STATEMENT AND OBJECTIVES

A. Problem Statement

The increasing disposal of PET bottles creates environmental problems and represents a loss of potentially reusable polymer material. Conventional filament production systems can involve shredding, pelletizing, drying, extrusion, cooling, and precise diameter-control mechanisms, which increase system complexity and cost.

Therefore, there is a need for a simple and economical system capable of converting waste PET bottles directly into usable filament material with minimum processing stages. The major challenges include achieving sufficient melting of PET, maintaining continuous extrusion, obtaining reasonable filament diameter consistency, and controlling the pulling and cooling conditions.



B. Objectives

The main objectives of the present work are:

- 1) To utilize waste PET bottles as feedstock for the production of 3D printing filament.
- 2) To develop a low-cost extrusion setup using readily available components.
- 3) To investigate the influence of heating temperature on PET melting and extrusion.
- 4) To study the effect of pulling speed on filament diameter and continuity.
- 5) To obtain continuous filament with acceptable surface appearance.
- 6) To demonstrate a simple approach for recycling PET waste through additive manufacturing.

3. LITERATURE REVIEW

Gibson et al. discussed the principles and technologies associated with additive manufacturing and emphasized the importance of material properties and process parameters in polymer-based 3D printing [1]. Wimpenny et al. presented developments in additive manufacturing technologies and highlighted the potential of polymer-based processes for sustainable manufacturing applications [2].

Cruz Sanchez et al. reviewed plastic recycling in additive manufacturing and identified opportunities for integrating recycled plastics into circular manufacturing systems [4]. Chopade et al. investigated the conversion of waste PET bottles into 3D printing filament and demonstrated the potential of PET waste as a feedstock material [5]. Piscan and Nasulea studied filament manufactured through PET material recycling and highlighted the importance of extrusion conditions for filament production [6].

Sanassee and Henrage investigated the production of 3D printing filament from plastic bottle waste using a low-cost extruder, demonstrating the relevance of simple extrusion systems in low-resource environments [7]. Rodiana et al. developed a low-cost device for upcycling PET plastic bottles into 3D printer filament [8]. Leon-Ayala et al. reviewed the reuse of recycled plastics in 3D printing filament production and identified material processing and quality-control requirements as important areas for further research [9].

Olamide et al. provided an overview of converting waste plastics into 3D printing filament and discussed potential industrial applications of recycled plastic materials [10]. The reviewed studies indicate that waste PET can potentially be converted into filament; however, achieving consistent filament diameter and reliable mechanical properties remains a significant challenge. The present work therefore focuses on developing a simple, low-cost extrusion setup and investigating the influence of key processing parameters.

4. MATERIALS AND EXPERIMENTAL SETUP

The developed system uses waste PET bottles as the primary raw material. The bottles are first cleaned thoroughly and allowed to dry. Labels and bottle caps are removed before processing. The cleaned bottles are manually cut into narrow strips suitable for feeding into the heating section.

The major components used in the developed extrusion setup are listed in Table I.

A. Extrusion System

The developed extrusion system consists of a heating section, extrusion nozzle, pulling mechanism, cooling region, and winding mechanism. The PET strips are introduced into the heating region, where they are heated until sufficient softening and melting occur. The molten material is subsequently pushed through the 4 mm nozzle to form a continuous extruded strand.

Fig. 1 shows the complete view of the developed extrusion system.

Table I Components and Specifications of the Developed Extrusion Setup

Component	Type	Specification	Qty.
PET Feedstock	Recycled PET bottle	Waste PET bottles manually cleaned, dried, and cut into strips	–
Heating Element	DC heating coil	Rated voltage: 12 V DC	1
Heating Block	Metallic block	Operating temperature: approximately 240– 260°C	1
Extrusion Nozzle	Metallic nozzle	Outlet diameter: 4 mm	1
DC Gear Motor	Geared DC motor	Rated voltage: 12 V DC; rotational speed: 10 rpm	1
Roller	Cylindrical roller	Diameter: 13 cm	1
Temperature Sensor	Thermistor	Used for monitoring the extrusion temperature	1
Motor Controller	PWM DC speed controller	Used for controlling the DC motor speed	1
Power Supply	DC SMPS	Used to supply power to the heating and motor system	1
Spool	Plastic spool	Used for filament winding and collection	1
Base Frame	Wooden frame	Provides structural support for the extrusion assembly	1
Cooling System	Natural air cooling	Ambient-air cooling for filament solidification	–

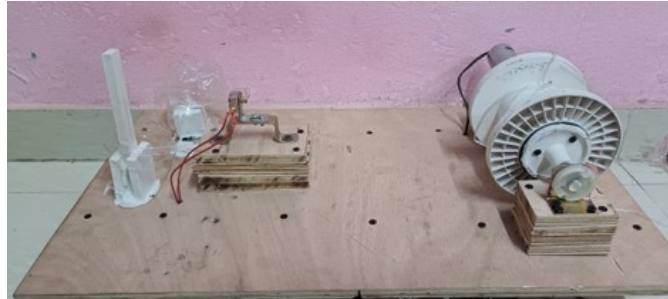


Figure 1 Complete view of the developed low-cost PET filament extrusion setup.

B. Heating System

A 12 V DC heating coil is used as the heating element. The heating block is operated at an approximate temperature range of 240–260°C. A thermistor is used to monitor the temperature of the heating region. Maintaining an appropriate temperature is essential because insufficient heating can result in incomplete melting and unstable extrusion, whereas excessive heating can cause material degradation.

Fig. 2 shows the heating block and heating element.

C. Pulling and Winding Mechanism

After extrusion, the softened PET strand is pulled using a 12 V DC geared motor operating at approximately 10 rpm. The pulling mechanism helps maintain continuous movement



Figure 2 Heating block and heating element.

of the extruded filament and influences the final filament diameter.

A roller of 13 cm diameter is incorporated into the mechanism, and the filament is subsequently collected on a spool.

Fig. 3 shows the DC motor and spool mechanism.

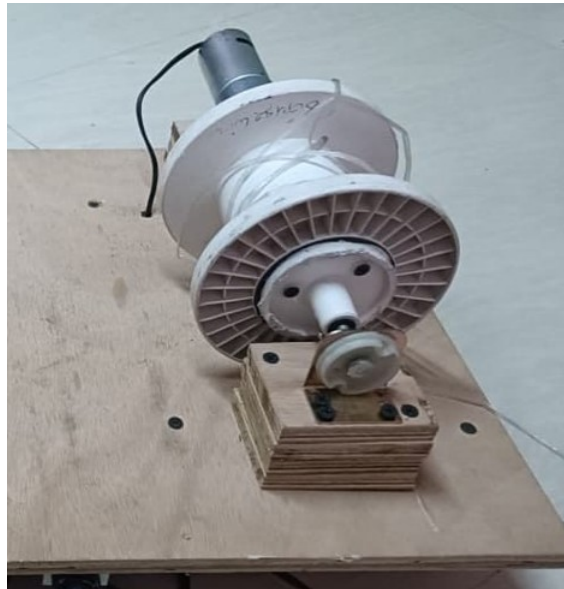


Figure 3 DC motor and spool mechanism.

D. PET Feedstock Preparation

Waste PET bottles are collected and prepared before extrusion. The bottles are cleaned to remove contaminants and moisture. Labels and caps are removed, after which the bottles are manually cut into narrow strips.

The use of strips avoids the requirement for a separate plastic shredding machine and simplifies the overall system. Fig. 4 shows the prepared PET bottle strips.

5. METHODOLOGY

The complete filament-production procedure consists of the following stages.

A. Preparation of PET Bottles

Used PET bottles are collected and cleaned thoroughly. Labels and caps are removed, and the bottles are dried to minimize moisture during heating.

Figure 4 PET bottle strips prepared for extrusion.



B. Cutting of PET Strips

The cleaned PET bottles are manually cut into strips. The strips are prepared with suitable dimensions so that they can be introduced into the heating and extrusion section.

C. Heating and Melting

The PET strips are introduced into the heating region. The heating system is operated within an approximate temperature range of 240–260°C to soften and melt the PET material.

D. Extrusion

The molten PET is extruded through a metallic nozzle having an outlet diameter of 4 mm. The extrusion produces a continuous molten polymer strand.

E. Pulling and Cooling

The extruded strand is pulled using the motor-driven mechanism. Natural air cooling is provided after extrusion so that the molten strand can solidify before winding.

F. Winding

The solidified filament is collected and wound onto a spool. The winding mechanism helps maintain continuous collection and prevents excessive tangling of the produced filament.

Fig. 5 shows the recycled PET filament collected on a spool.

6. DESIGN CONSIDERATIONS AND PROCESS PARAMETERS

Several parameters influence the quality of the produced filament.

A. Temperature

Temperature is one of the most important parameters in PET extrusion. The developed setup operates at approximately 240–260°C. The selected range provides sufficient thermal energy for

PET softening and melting while avoiding unnecessary overheating.



Figure 5 Recycled PET filament collected on a spool.

B. Pulling Speed

The pulling speed affects the cross-sectional size of the extruded filament. For a given material flow rate, increasing the pulling speed generally reduces the filament diameter, whereas decreasing the pulling speed results in a thicker filament.

C. Cooling

Cooling is required to solidify the extruded PET before winding. The developed setup uses natural air cooling. The cooling region is positioned after the nozzle and pulling section so that the filament can solidify progressively.

D. Spool Winding

The spool collects the solidified filament continuously. Controlled winding helps reduce tangling and assists in maintaining a stable pulling condition.

E. Structural Stability

The supporting frame must provide sufficient stability to the heating, pulling, roller, and winding components. A stable frame minimizes unwanted vibration and movement during operation.

B. Effect of Pulling Speed

The pulling speed had a noticeable influence on the resulting filament thickness. At relatively higher pulling speeds, the extruded material was stretched more strongly, resulting in a thinner filament. At lower pulling speeds, more material accumulated per unit length, resulting in a thicker filament.



C. Effect of Temperature

The temperature of the heating region strongly influenced extrusion stability. At insufficient temperature, the PET did not melt uniformly, leading to irregular extrusion. Increasing the temperature within the suitable operating range improved material flow. Excessive heating, however, should be avoided because prolonged overheating can affect polymer quality.

D. Surface Appearance

The produced filament exhibited a generally continuous appearance when suitable heating and pulling conditions were maintained. Variations in filament diameter and surface uniformity were observed due to manual feeding, natural cooling, and the absence of an automatic diameter-control system.

E. Cooling and Winding

Natural air cooling allowed the extruded PET strand to solidify before collection. The motor-driven spool provided continuous winding of the filament. The effectiveness of winding depended on maintaining consistent pulling and avoiding sudden variations in filament movement.

Table II Experimental Observations

Parameter	Observation
Heating temperature	Stable extrusion was obtained within the approximate operating range of 240–260°C.
Pulling speed	Higher pulling speed generally produced thinner filament, while lower speed produced thicker filament.
Filament continuity	Continuous filament formation was possible when heating and pulling conditions were appropriately maintained.
Surface appearance	Surface quality depended on temperature stability, pulling condition, and cooling.
Cooling	Natural air cooling allowed the extruded strand to solidify before winding.
Winding	Motor-driven winding enabled continuous collection of the produced filament.

7. RESULTS AND DISCUSSION

The developed setup was experimentally operated to evaluate the feasibility of producing filament from waste PET bottles.



A. Filament Continuity

Continuous extrusion was obtained when the PET material was sufficiently heated and the pulling mechanism was operated under suitable conditions. Stable heating and consistent pulling were found to be important for maintaining continuity.

8. APPLICATIONS

The developed PET filament extrusion system can be used in several areas:

- **Educational applications:** Demonstration of polymer recycling and additive manufacturing principles.
- **Rapid prototyping:** Production of recycled polymer filament for experimental prototypes.
- **Small-scale plastic recycling:** Conversion of waste PET bottles into reusable polymer material.
- **DIY and hobby applications:** Development of low-cost recycled filament systems.
- **Sustainable manufacturing:** Integration of plastic waste recycling with additive manufacturing.

9. LIMITATIONS AND FUTURE SCOPE

Although the developed system demonstrates the feasibility of converting waste PET bottles into filament, several limitations remain.

The present system does not incorporate an automatic filament-diameter measurement and feedback-control mechanism. Consequently, variations in filament diameter can occur due to changes in feeding, temperature, pulling speed, and cooling conditions.

Future development can include an automatic diameter sensor and closed-loop control system for maintaining a more uniform filament diameter. Improved temperature control, controlled cooling, automated PET feeding, and a more precise pulling mechanism can also enhance the performance of the system.

Further research should investigate the mechanical, thermal, and dimensional properties of the produced filament. The influence of repeated recycling, additives, material blending, and processing conditions can also be investigated. Increasing the extrusion capacity and developing standardized processing conditions would further improve the applicability of the developed system.

10. CONCLUSION

A low-cost extrusion system was successfully developed for converting waste PET bottles into 3D printing filament. The system uses manually cut PET bottle strips, a 12 V DC heating coil, a metallic heating block, a 4 mm extrusion nozzle, a 12 V DC geared motor operating at 10 rpm, a 13 cm diameter roller, natural air cooling, and a motor-driven spool.



The experimental observations demonstrate that waste PET bottles can be processed into continuous filament when suitable heating and pulling conditions are maintained. Temperature and pulling speed were identified as important parameters influencing extrusion stability and filament thickness. Higher pulling speeds generally resulted in thinner filament, while lower pulling speeds produced thicker filament.

The developed system provides a simple and economical approach for integrating PET waste recycling with additive manufacturing. Further improvements in automatic diameter control, cooling, feeding, process monitoring, and material characterization can enhance filament quality and enable broader practical applications.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the Department of Mechanical Engineering, SKN Sinhgad College of Engineering, Korti, Pandharpur, India, for providing the necessary facilities and support to carry out this work.

REFERENCES

- [1]I. Gibson, D. Rosen, and B. Stucker, *Additive Manufacturing Technologies*, 2nd ed. New York, NY, USA: Springer, 2015.
- [2]D. I. Wimpenny, P. M. Pandey, and L. Jyothish Kumar, *Advances in 3D Printing & Additive Manufacturing Technologies*. Singapore: Springer, 2017.
- [3]C. K. Chua and K. F. Leong, *3D Printing and Additive Manufacturing: Principles and Applications*, 4th ed. Singapore: World Scientific, 2017.
- [4]S. M. Cruz Sanchez, A. Boudaoud, M. Camargo, and C. Pearce, “Plastic recycling in additive manufacturing: A systematic literature review and opportunities for the circular economy,” *Journal of Cleaner Production*, vol. 264, 2020.
- [5]S. Chopade, S. Chopade, S. Gawade, K. Shirsat, D. Ajmera, and Y. Bharambe, “Conversion of waste PET bottles into 3D printing filament: A sustainable approach,” *Journal of Neonatal Surgery*, vol. 14, 2025.
- [6]L.-C. Pisan and M.-D. Nasulea, “3D printing filament manufactured by PET material recycling,” *Journal of Neonatal Surgery*, vol. 78, 2025.
- [7]L. Sanassee and K. Henrage, “Production of 3D printing filament from plastic bottles waste using a low-income settings extruder,” *Journal of Material Cycles and Waste Management*, vol. 26, 2024.
- [8]I. M. Rodiana, B. A. Pramudita, N. A. Barokatillah, A. R. Saleh, and A. T. N. Daniswara, “Low-cost device to upcycling PET plastic bottle into 3D printer filament,” Telkom University, 2025.
- [9]W. Leon-Ayala, S. Ramos-Cosi, and C. Marrujo-Ingunza, “A systematic review on the



reuse of recycled plastics in 3D printing filament production,” University of Sciences and Humanities, 2025.

- [10] O. B. Olamide, O. T. Olumide, O. I. Ikeoluwa, and P. K. Farayibi, “Waste plastics to 3D printer filament: An overview on industrial applications,” *Iranian Journal of Health, Safety & Environment*, vol. 10, 2020.