iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: VI Month of publication: June 2025

DOI: https://doi.org/10.22214/ijraset.2025.72549

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

Review on Design & Development of Filament Making Setup for FDM 3D Printer from Waste Plastic Bottle

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Abstract: Deposition Modeling, or FDM, is a popular method for 3D printing technology capable of constructing intricate 3D models purely based on a design. Recently, there has been a shift towards using FDM for mass production purposes due to the evolution of 3D printing materials making it easier to create unique products for personal and commercial purposes. Particularly, conductive thermoplastic composites are used to make sensors and electronic parts for incorporation into the 3D printed structures. Nevertheless, the FDM printed parts can have some issues such as weak interlayer adhesion among the constituent layers, from which the mechanical strength of the printed objects is reduced. In this case, heat treatment procedures aimed at increasing interlaminar shear strength (ILSS) of fiber-reinforced PEEK composites have been proposed. Evidence suggests that controlling heat treatment rates yields robust improvement of the FDM parts performance.
Keywords: FDM 3D Printing, Filament Production, PET Bottle Recycling, Waste Plastic Reuse, Additive Manufacturing, Sustainable Design, Filament Extruder, Recycled Filament, Plastic Waste Management, Circular Economy

I. INTRODUCTION

In recent years, additive manufacturing, particularly Fused Deposition Modelling (FDM), has experienced significant growth in popularity due to its capacity to fabricate intricate geometries, minimize material waste, and reduce prototyping expenses. A critical component in FDM printing is the filament, which is commonly composed of materials such as polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS). The choice of filament directly influences print quality, mechanical properties, and the overall cost associated with 3D printing. However, commercially available filaments are often costly and contribute to the increasing demand, thereby raising Environmental concerns Concurrently, plastic pollution has emerged as a pressing global issue, with polyethylene terephthalate (PET) bottles representing a significant source of non-biodegradable waste. Recycling PET waste into functional products not only mitigates environmental impact but also aligns with the principles of a circular economy. In light of this, the present project seeks to design and develop a filament production system that transforms waste plastic bottles into usable filament for FDM 3D printers. The proposed system incorporates a plastic shredding mechanism, an extrusion unit, a heating and cooling arrangement, and a spooling system, all engineered to produce filament with consistent diameter and quality. This methodology not only reduces the costs associated with filament production but also offers an effective strategy for managing plastic waste. The results of this project hold the potential to benefit educational institutions, makerspaces, and small-scale manufacturing entities by fostering sustainable and cost-effective practices in 3D printing.

II. PROBLEM STATEMENT

The world is drowning in plastic waste, and the booming 3D printing industry is only adding to the problem. While 3D printing has become widely popular for its versatility and accessibility, the filament materials used are mostly derived from virgin plastics - a major environmental concern. This clash between the rise of 3D printing and the global plastic crisis presents a significant challenge that needs to be addressed. But with a little creativity and innovation, we can find sustainable solutions to keep our planet healthy and our 3D printers humming.

III. KEY OBJECTIVES

To establish a comprehensive mechanical framework that encompasses cutting, extrusion, heating, cooling, and spooling components, ensuring uniform filament diameter and seamless extrusion.

- To create a cost-efficient and effective filament extrusion system that transforms waste PET plastic bottles into high-quality filament suitable for FDM 3D printing
- To evaluate the mechanical and thermal properties of recycled PET filament and see how it stacks up against standard commercial filaments like PLA and ABS.
- TO fine-tune process parameters like extrusion temperature, screw speed, and cooling rate, it's essential to maintain the dimensional accuracy of the filament, aiming for a measurement of 1.75 mm ± 0.05 mm.

IV. LITERATURE REVIEW

1) *Filament for a 3D Printer from Pet Bottles- Simple Machine Igor Tylman and Kazimierz Dzierżek Department of Robotics and Mechatronics, Faculty of Mechanical Engineering, Bialystok University of Technology, Bialystok, Poland International Journal of Mechanical Engineering and Robotics Research Vol. 9, No. 10, October 2020*

The study by Tylman and Dzierżek introduces a low-cost method to convert PET bottles into 3D printer filament using a simple machine. However, key research gaps remain, including inconsistent filament quality, lack of testing during actual printing, absence of automation, and no analysis of environmental or economic impact. Further research is needed to improve material performance, ensure quality control, and evaluate large-scale feasibility.

2) *A review on the fused deposition modelling (FDM) 3D printing Ruben Bayu Kristiawan, Fitrian Imaduddin*, Dody Ariawan, Ubaidillah, and Zainal Arifin*

While the review by Kristiawan et al. provides a comprehensive overview of FDM 3D printing processes, materials, and applications, it lacks in-depth analysis of emerging advanced materials, hybrid additive techniques, and multi-material printing. The review does not fully address the limitations in surface quality, interlayer bonding, and dimensional accuracy. Furthermore, there is limited discussion on real-time process monitoring, AI-driven optimization, and sustainability concerns such as energy consumption and recyclability. These gaps suggest the need for future studies focusing on enhancing material performance, automation, and environmentally responsible FDM processes.

3) *3D printing filament as a second life of waste plastics Katarzyna Mikula1 &DawidSkrzypczak1 & Grzegorz Izydorczyk1 & Jolanta Warchoł1 & Konstantinos Moustakas2 & Katarzyna Chojnacka1 & Anna Witek-Krowiak1*

The study by Mikula et al. explores the potential of using waste plastics for producing 3D printing filament, highlighting sustainability benefits. However, it lacks detailed investigation into the mechanical and thermal consistency of filaments made from diverse plastic waste streams. The study does not fully address the challenges of contamination, degradation during recycling, and the impact on 3D print quality. Additionally, real-world application testing, standardization protocols, and economic feasibility analyses are limited. These gaps indicate a need for further research into quality control, process optimization, and scalable implementation of recycled filament in practical additive manufacturing.

4) *Material flow analysis and carbon footprint of water-packaging waste management Vera Amicarelli a, Roberto Leonardo Rana Caterina Tricase a b, Christian Bux*

The study by Amicarelli et al. effectively applies material flow analysis and carbon footprint assessment to water-packaging waste management. However, it lacks integration of circular economy strategies such as reuse and upcycling into the analysis. The study does not explore region-specific behavioural, policy, or technological influences on waste flows and emissions. Additionally, dynamic modelling to predict long-term environmental impacts is absent. These gaps highlight the need for more holistic, scenario-based approaches that incorporate circular practices, stakeholder behavior, and policy-driven interventions in future research.

5) *A Critical Review on of 3D Printing Materials and Details of Materials used in FDM Thirunahary Swetham1, Ketham Madhana Mohan Reddy2, Akhil Huggi3, Mavoori Naveen Kumar4 UG Final Year Students, Department of Mechanical Engineering, Vidya Jyothi Institute o Technology, Hyderabad, India 4Assistant Professor, Department of Mechanical Engineering, Vidya Jyothi Institute of Technology, Hyderabad, India*

The review by Swetham et al. outlines commonly used materials in FDM 3D printing, focusing on their properties and applications. However, it lacks a deeper analysis of recent advancements in composite, biodegradable, and smart materials. The study does not address challenges like moisture sensitivity, warping, and interlayer adhesion in practical printing conditions.

Additionally, performance comparisons under real-world loading or thermal conditions are missing. There is also limited discussion on material recyclability and environmental impact. These gaps suggest the need for further research on advanced material development, sustainability, and application-specific performance evaluation in FDM.

V. METHODOLOGY

Bottle Collection & Cleaning: - Collect waste plastic bottles from Households Schools, Offices, Hotels, Canteens, Cafeterias, local recycling centres or waste pickers, and community cleanup drives, Etc.

A. *Cleaning*

- Step 1: - Label Removal: Remove labels from bottles.
- Step 2: -Internal Washing: Wash bottles by water or detergent.
- Step 3: -Cap Removal: - Remove caps (often made of HDPE or PP, which should not mix with PET)
- Step 4: - Drying: Air dry or sun-dry cleaned bottles for best results, bottles should be completely dry to prevent steam or bubbles during extrusion

Cutting PET Bottles: - Cutting the PET bottles into a long thin strip using Bottle cutter fitted in the setup.
Extrusion (Heating + Nozzle): - To melt cleaned PET plastic and force it through a precisely machined nozzle to produce filamentwith a consistent diameter (1.75 mm) suitable for FDM 3D printing.
Cooling System: - Used 12v cooling fan for filament colling.
Filament Pulling and Spooling: - Used gear motor for filament pulling and spooling.

VI. CAD DESIGN

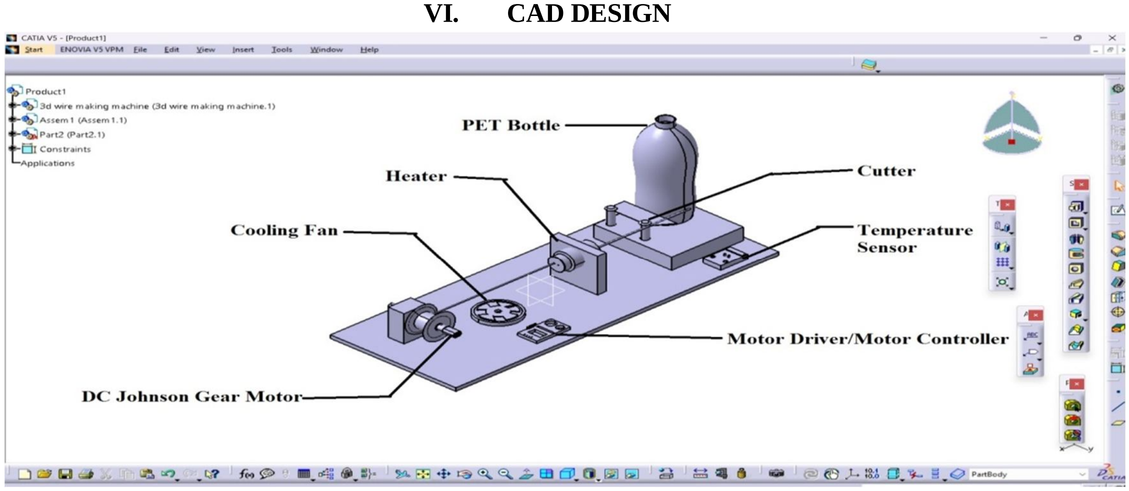

Fig.1 CAD Model

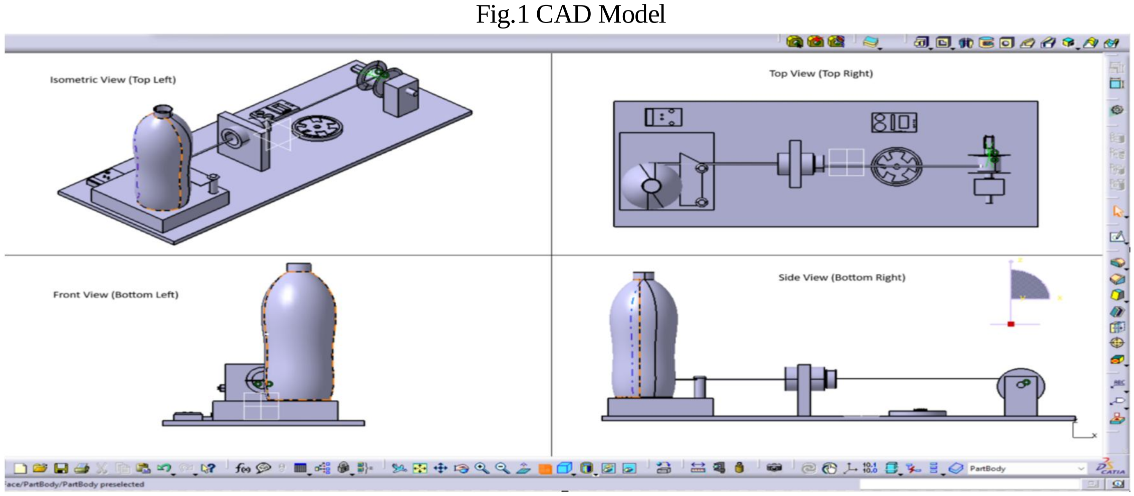

Fig.2 Isometric and Orthographic view

A. *Component Description (Based on Views)*

1. Isometric View (Top Left)
   - Gives a 3D perspective of the machine layout.
   - Shows key components mounted on a base plate:
     - PET bottle holder
     - Cutting and heating section
     - Cooling fan
     - DC gear motor
     - Motor driver/controller

2. Top View (Top Right)
   - Offers a clear layout of internal arrangements.
   - Key visible parts:
     - Power source (likely an electrical socket input)
     - Cutter mechanism
     - Heater and sensor unit
     - Pulley or gear drive system
     - Fan and extrusion motor

3. Front View (Bottom Left)
   - Shows vertical alignment of the PET bottle above the cutter.
   - Indicates the feeding path from the bottle to the cutting unit.
   - Highlights height proportions and space management.

4. Side View (Bottom Right)
   - Displays component alignment along the length of the machine.
   - Clear view of:
     - PET bottle positioning
     - Cutter and heater in series
     - Motor and gear system
     - Cooling fan near filament exit

B. *Functional Overview*

1. Feeding Section:
   - A PET bottle is mounted vertically and manually fed into a cutting mechanism.
2. Cutting Section:
   - The cutter slices the bottle into continuous PET strips.
3. Heating Section:
   - The PET strip passes through a heater with a temperature sensor to melt it.
4. Extrusion and Pulling:
   - A DC Johnson gear motor pulls the molten PET through a die to form filament.
5. Cooling Section:
   - A cooling fan solidifies the hot filament before spooling or collection.
6. Control System:
   - A motor driver/controller regulates motor speed and ensures process stability.

C. *Application*

This system is a sustainable solution for recycling PET plastic waste into FDM 3D printer filament. It is ideal for DIY recycling, small-scale fabrication labs, or educational projects in mechanical and mechatronics engineering.

VII. CONCLUSION

The reviewed literature collectively emphasizes the growing interest and potential of converting waste PET bottles into 3D printer filament as an eco-friendly and cost-effective solution. Tylman and Dzierżek successfully demonstrated a simple, low-cost machine for filament production, showcasing a practical approach to plastic recycling. However, major research gaps persist across studies, including:

1) Inconsistent filament quality and insufficient real-time testing during 3D printing.
2) Lack of standardization, mechanical and thermal performance assessment, and automated quality control mechanisms.
3) Minimal evaluation of economic feasibility, scalability, and long-term sustainability of using recycled materials.
4) Limited focus on advanced materials, hybrid printing techniques, and multi-material FDM capabilities.
5) Inadequate integration of AI-based optimization, real-time monitoring, and circular economy models.
6) Environmental assessments often ignore reuse and upcycling strategies, as well as regional policy impacts.

Thus, while initial findings and prototypes show great promise, future research must focus on material consistency, technological enhancements, real-world application validation, and environmental and economic assessments to enable the scalable, sustainable, and efficient production of 3D printing filament from waste plastics.

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