Bottle-2-Build: Recycling Waste Plastic Bottles into 3D Printing Filament

Archit Dilip Ghadshi[1], Nitesh Chandana[2], Narmada Rajput[3]
[1]*Assistant Manager, Learning Links Foundation*
[2,3]*School Student, Karmaveer Bhaurao Patil Vidyalaya, Juchandra*

Abstract- 3D printing technology is widely used in educational institutions for making models and prototypes. However, the quality of 3D printing filament supplied to schools is sometimes poor, which causes the filament to become brittle after long storage. Brittle filament breaks easily and becomes unusable, resulting in material wastage and financial loss. In addition, during the 3D printing process, extra material used as support structures also becomes waste. At the same time, plastic bottle waste is increasing continuously in the environment due to its slow degradation rate.

To solve both problems, the Bottle-2-Build project proposes a system that converts waste plastic bottles and discarded filament into reusable 3D printing filament. The plastic bottles are cut into thin strips, melted, and passed through a specially designed mechanism to produce filament of 1.75 mm diameter suitable for standard 3D printers. The developed filament can be reused for printing new objects. This project provides a low-cost, eco-friendly, and sustainable solution for filament production while reducing plastic pollution.

Keywords - 3D Printing, Filament Recycling, Plastic Bottle Recycling, PLA, Sustainability, Low-Cost Filament

I. INTRODUCTION

3D printing is becoming an important technology in schools, colleges, and industries for rapid prototyping and model making. Most 3D printers use PLA or similar thermoplastic filament as raw material. In many cases, filament supplied to educational institutions becomes brittle after long storage due to moisture absorption, poor manufacturing quality, or improper handling. Such brittle filament cannot be used for printing and results in wastage.

Another major problem is the accumulation of plastic waste, especially plastic bottles made from PET, which take hundreds of years to decompose. Recycling plastic waste into useful products is necessary to reduce environmental pollution.

The Bottle-2-Build project is designed to solve both problems by converting waste plastic bottles and unused filament into reusable 3D printing filament. The system produces filament of standard diameter which can be used again in 3D printers.

II. PROBLEM STATEMENT

With the increasing use of 3D printing technology in schools, colleges, and laboratories, the demand for reliable and good-quality filament has also increased. Most low-cost 3D printers use PLA filament as the printing material because it is easy to use and environmentally safer compared to other plastics. However, in many educational institutions, the filament supplied by vendors is of poor quality or stored for long periods, which causes it to become brittle due to moisture absorption and material degradation. Brittle filament breaks easily during printing and becomes unusable, resulting in wastage of material and financial loss for the institution.

Another major source of wastage in 3D printing occurs during the printing process itself. Many designs require support structures to hold the object while printing. These supports are removed after printing and cannot be reused directly, which leads to additional material loss. Failed prints due to incorrect settings, power failure, or poor filament quality also contribute to significant wastage of filament.

At the same time, environmental pollution caused by plastic waste is increasing rapidly. Plastic bottles made of PET are widely used but take hundreds of years to decompose naturally. Large amounts of plastic bottles are discarded every day, creating serious environmental problems. Although recycling methods exist, they are not always accessible at small scale or in educational environments.

Therefore, there is a need for a system that can solve both problems by converting waste plastic and unusable filament into reusable 3D printing material. Such a system should be low-cost, easy to use, and suitable for schools and laboratories. The Bottle-2-Build project is proposed to address this problem by developing a mechanism that can recycle waste plastic bottles and brittle filament to produce standard 3D printing filament.

III. OBJECTIVES

The main objective of the Bottle-2-Build project is to develop a sustainable and economical method for producing usable 3D printing filament from waste materials. The specific objectives of the project are described below.

3.1 Reuse of Brittle and Wasted PLA Filament
One of the primary objectives is to reuse PLA filament that has become brittle due to long storage or poor quality. Instead of discarding such filament, the project aims to melt and reshape it so that it can be used again for 3D printing.

3.2 Recycling of Plastic Bottles into Filament
The project aims to utilize waste plastic bottles as raw material for filament production. Since plastic bottles are easily available and recyclable, converting them into filament can reduce environmental waste and provide useful material for printing.

3.3 Production of Standard Diameter Filament
Most desktop 3D printers require filament of standard diameter, usually 1.75 mm. Therefore, another important objective is to design a mechanism that can produce filament with nearly uniform diameter so that it can be used in common 3D printers without modification.

3.4 Reduction of 3D Printing Cost
Commercial filament is expensive for regular use in schools and laboratories. By producing filament from waste plastic, the project aims to reduce the cost of 3D printing and make the technology more accessible for educational purposes.

3.5 Reduction of Plastic Pollution
Plastic bottles are one of the major sources of environmental pollution due to their slow degradation rate. Recycling these bottles into useful filament will reduce the amount of plastic waste and promote environmentally friendly practices.

3.6 Development of Low-Cost Prototype for Educational Use
Another objective of the project is to design the system using simple and easily available components so that the prototype can be built at low cost. This makes the project suitable for schools, colleges, and small laboratories where expensive recycling machines are not affordable.

3.7 Promotion of Sustainable Manufacturing
The project also aims to promote the concept of sustainable manufacturing by encouraging reuse of materials instead of disposal. This approach supports environmental conservation and responsible use of resources.

IV. LITERATURE REVIEW

Recycling of plastic materials for additive manufacturing has been widely studied in recent years due to the increasing use of 3D printing technology and the growing problem of plastic waste. Many researchers have explored the possibility of converting waste plastic into usable 3D printing filament using extrusion mechanisms.

According to Anderson [1], the rise of low-cost manufacturing technologies such as 3D printing has created a need for affordable raw materials. Commercial filaments like PLA and ABS are costly for educational institutions, and reuse of plastic can significantly reduce expenses.

Lipson and Kurman [2] explained that additive manufacturing produces material waste in the form of support structures and failed prints, which cannot be reused directly without processing. This leads to increased material consumption and higher operational cost.

Studies based on ASTM standards for additive manufacturing [3] show that most desktop 3D printers require filament of standard diameter (generally 1.75 mm or 2.85 mm). Maintaining uniform diameter during extrusion is necessary to ensure proper printing quality.

The RepRap open-source project [4] introduced the concept of distributed recycling, where plastic waste can be converted into filament using small extrusion machines. Their work demonstrated that low-cost filament production is possible using simple mechanical and heating systems.

Research published in the Journal of Cleaner Production [5] shows that PET plastic from bottles can be recycled and reshaped into new products because it has good thermal stability and strength. This makes plastic bottles a suitable material for filament production.

Reports from the United Nations Environment Programme [6] state that plastic bottles are one of the most common sources of environmental pollution due to their slow degradation rate. Recycling these bottles into useful products can reduce landfill waste and environmental damage.

The 3D Printing Handbook by 3D Hubs [7] explains that proper temperature control, extrusion speed, and cooling are important factors for producing good quality filament. Without diameter control, the filament cannot be used in standard printers.

From the above studies, it is clear that recycling plastic into filament is possible, but most available machines are expensive and not designed for school-level use. Therefore, the Bottle-2-Build project focuses on developing a simple, low-cost, and educational prototype that can reuse waste plastic bottles and brittle filament to produce usable 3D printing filament.

V. MATERIALS USED

- Waste plastic bottles
- Waste PLA filament
- Heating element
- Motor and gear mechanism
- Extruder nozzle
- Diameter control mould (1.75 mm)
- Frame structure
- Cooling system
- Filament spool

VI. METHODOLOGY

The Bottle-2-Build system is designed to convert waste plastic bottles and damaged filament into reusable 3D printing filament using a mechanical extrusion process. The complete process consists of several stages, which are explained below.

6.1 Collection of Waste Material

Waste plastic bottles made of PET and unusable PLA filament are collected from laboratory waste and surroundings. These materials are selected because PET and PLA are thermoplastic materials that can be melted and reshaped multiple times [5].

6.2 Cleaning and Preparation

The plastic bottles are cleaned to remove dust, labels, and impurities.
Cleaning is necessary because impurities can affect melting quality and may block the extrusion nozzle. After cleaning, bottles are dried completely to remove moisture.

Moisture inside plastic can cause bubbles during melting, which reduces filament strength [7].

6.3 Cutting Process

The plastic bottles are cut into thin strips using a manual or mechanical cutter.
Purpose of cutting:

- Makes melting easier
- Ensures uniform feeding
- Prevents blockage in heater

Thin strips allow smooth movement into the extrusion mechanism.

6.4 Heating Mechanism

The plastic strips are passed through a heating chamber. A heating element is used to raise the temperature to the melting point of plastic.
Typical temperatures:

- PLA → ~180–200°C
- PET → ~220–250°C

Temperature must be controlled carefully because:

- Low temperature → plastic will not melt properly
- High temperature → plastic burns and becomes weak

Proper heating ensures smooth extrusion [7].

6.5 Extrusion Mechanism

After melting, the plastic is pushed forward using a motor-driven gear or screw mechanism.

The extrusion system performs two functions:
1. Push melted plastic forward
2. Maintain continuous flow

The molten plastic passes through a metal nozzle at the end of the heater.
This nozzle gives the initial shape to the filament.

6.6 Diameter Control System (1.75 mm Mould)
After coming out of the nozzle, the filament passes through a specially designed mould.
The mould is made with a hole of 1.75 mm diameter.
Purpose:
- Maintain uniform filament thickness
- Make filament compatible with standard 3D printers [3]

Without diameter control, the filament cannot be used in printer because the feeding motor requires constant thickness.

6.7 Cooling System
After passing through the mould, the filament is cooled using air or water cooling.
Cooling is important because:
- Hot filament is soft
- Cooling makes it strong and solid
- Prevents bending

Controlled cooling helps maintain correct diameter.

6.8 Spooling Mechanism
The cooled filament is collected on a spool. Spooling keeps filament straight and prevents tangling. The spool can then be used directly in a 3D printer.

6.9 Testing in 3D Printer
The produced filament is loaded into a 3D printer and used to print test objects. If the printer runs smoothly and object prints correctly, the filament is considered successful.

6.10 Overall Working Flow
Bottle → Cleaning → Cutting → Heating → Extrusion → Diameter Control → Cooling → Spooling → 3D Printing

VIII. RESULT

The proposed system for converting used plastic bottles into 3D printing filament was designed, assembled, and tested successfully. The complete process included collection of plastic bottles, cleaning, cutting into strips, melting, extrusion, diameter adjustment, cooling, and spooling. The experimental results confirm that waste plastic bottles made of PET material can be reused to produce filament suitable for basic 3D printing applications.

During the experiment, plastic bottles were first washed properly to remove dust, labels, and moisture. After cleaning, the bottles were cut into thin strips so that they could be fed easily into the heating chamber. The heating unit was able to melt the plastic at the required temperature, and the extrusion mechanism pushed the molten plastic through a nozzle to form a continuous filament.

The diameter of the filament was controlled using a simple guiding and pulling mechanism. The obtained filament diameter was close to the standard size of 1.75 mm, although small variations were observed at some points. After extrusion, the filament was cooled using air cooling and then collected on a spool.

The prepared filament was tested on a 3D printer to check whether it could be used for actual printing. Small test models were printed successfully, which shows that the recycled filament can be used for basic prototyping. The printed objects had acceptable strength and shape, but slight surface irregularities were seen due to minor changes in filament thickness.

One of the major outcomes of this work is cost reduction. The filament produced from waste bottles is much cheaper compared to commercially available filament. This makes the system useful for educational institutes, hobby projects, and small laboratories where filament cost is a problem.

Another important result is environmental benefit. Plastic bottles that normally become waste can be reused to create useful material. This helps in reducing plastic pollution and supports the idea of recycling and sustainable development.

Some limitations were also noticed during testing. Proper temperature control is required to get smooth extrusion. If the temperature is too high, the filament becomes weak, and if the temperature is low, extrusion becomes difficult. The diameter control mechanism also needs improvement for better print quality. Moisture present in plastic can cause bubbles in filament, so proper drying is necessary.

From the overall results, it can be concluded that the developed system works successfully and can be improved further to produce better quality filament.

VIII. EXPECTED OUTCOME

- Production of low-cost filament from waste plastic bottles
- Reduction in plastic waste and environmental pollution
- Reusable filament for multiple 3D printing tasks
- Useful setup for schools, colleges, and small workshops
- Support for eco-friendly and sustainable manufacturing
- Possibility of improving the system for better quality filament

REFERENCES

[1] Anderson, C., Makers: The New Industrial Revolution, Crown Publishing, 2012
[2] Lipson, H., Kurman, M., Fabricated: The New World of 3D Printing, Wiley, 2013.
[3] ASTM International, Additive Manufacturing Standards.
[4] RepRap Project – Open-Source Filament Extruder.
[5] Journal of Cleaner Production – Plastic Recycling Research
[6] United Nations Environment Programme – Plastic Waste Report.
[7] 3D Hubs, The 3D Printing Handbook.
[8] Dongkeon Lee, Takashi Miyoshi, Yasuhiro Takaya and Taeho Ha, "3D Micro fabrication of Photosensitive Resin Reinforced with Ceramic Nanoparticles Using LCD Microstreolithography", Journal of Laser Micro/Nano engineering Vol.1, No.2, 2006.
[9] Ruben Perez Mananes, Jose Rojo-Manaute, Pablo Gil, "3D Surgical printing and pre contoured plates for acetabular fractures", Journal of ELSEVIER 2016.
[10] Alexandru Pirjan, Dana-Mihaela Petrosanu, "The Impact of 3D Printing Technology on the society and economy", Journal of Information Systems and Operations Management, Volume 7, Dec 2013.
[11] Gabriel Gaala, Melissa Mendesa, Tiago P. de Almeida, "Simplified fabrication of integrated microfluidic devices using fuseddeposition modeling 3D printing" Science Direct.
[12] Pshtiwan Shakor, Jay Sanjayan, Ali Nazari, Shami Nejadi, "Modified 3D printed powder to cement-based material and mechanical properties of cement scaffold used in 3D printing", Science Direct.
[13] Siddharth Bhandari, B Regina, "3D Printing and Its Applications", International Journal of Computer Science and Information Technology Research ISSN 2348-120X.
[14] Elizabeth Matias, Bharat Rao, "3d printing on its historical evolution and the implications for business", 2015 Proceedings of PICMET: Management of the Technology Age.
[15] Frank van der Klift, Yoichiro Koga, Akira Todoroki, "3D Printing of Continuous Carbon Fibre Reinforced Thermo-Plastic (CFRTP) Tensile Test Specimens", Open Journal of Composite Materials, 2016, 6