International Journal of Advanced Technology in Engineering and Science
Vol. No. 12, Issue No. 03, March 2024
www.ijates.com
ijates
ISSN 2348 - 7550

3D printing Filament Making Using plastic waste

Mr. Vishal Vishnu Jankar[1], Mr. Rushikesh Ramchandra Hake[2], Mr. Ashwin Aannaso Sanadi[3], Mr. Suhas Maruti Bamane[4], Mr.M.N.Potdar[5]

[1,2,3,4,5]Shri Ambabai Talim Sanstha's Sanjay Bhokare Group of Institutes

Department- Electronics and Telecommunication Engneering.

ABSTRACT

The widespread use of plastic is leading to increased plastic waste and environmental concerns globally. This research paper aims to address this issue by investigating the potential of creating a sustainable 3D printing filament using recycled polyethylene terephthalate (PET) bottles. Our experimental setup involved a 1.6 mm diameter nozzle witha heater block to ensure precise temperature control during filament extrusion, resulting in a reliable and repeatable filament diameter of 1. 65 mm. The study focuses on creating a consistent filament with a 1.65 mm diameter using recycled PET bottles. Additionally, finite element analysis (FEA) is conducted using SolidWorks software to compare the mechanical properties of the PET filament to conventional polylactic acid (PLA) material widely used in 3D printing. The FEA simulations analyse stress, strain, and displacement for both PET and PLA materials, and the results are compared to draw conclusions based on the numerical observations. The findings from this research will offer valuable insights into the potential of recycled PET bottles as an environmentally friendly alternative for 3D printing filaments.This work contributes to reducing plastic waste and promotes sustainable practices in additive manufacturing.

1. INTRODUCTION

The 3D printing industry is undoubtedly experiencing rapid growth, with an expected market value of $83.9 billion in 2029, a significant jump from $18.33 million in 2022. However, this growth is accompanied by several challenges. Limited material choices and compatibility issues with different printers pose hurdles for the industry. Furthermore, difficulties in post- processing and recycling, such as nozzle clogging when using recycled plastic for filament, need to be addressed. One promising solution to address these challenges is the fabrication of 3D printing filament from recycled PET plastic. This process involves a series of critical steps that require careful temperature control at various stages to ensure proper melting and extrusion. The Filament Bot Machine, equipped with a heated barrel and a screw-like mechanism, is a valuable tool for melting and pushing the plastic to create the filament. To achieve consistent filament diameter and quality, a diameter control system is employed during the extrusion process. The extruded filament is rapidly cooled to solidify it, and precise spooling ensures the filament is neatly wound without tangles. Prior to extrusion, the recycled plastic is thoroughly cleaned and prepared, enhancing the quality of the end product. To ensurea high-quality end product, regular quality checks are conducted throughout the process.

These checks monitor the filament's diameter, strength, and appearance, thereby ensuring that the recycled PET filament meets the required standards. Despite the emerging potential of this technology, there are challenges to overcome, such as contamination in the plastic waste stream, difficulties in obtaining a consistent filament diameter, and the lack of standardization in filament properties. Nonetheless, the process of creating 3D printing filament from waste plastics has the potential to significantly impact both the 3D printing industry and the environment. Researchers and innovators in the field are actively working to develop filaments that are compatible with existing 3D printers and offer solutions to post- processing and recycling issues. By doing so, they aim to harness the full potential of 3D printing while contributing to a more sustainable and environmentally friendly approach to manufacturing. In conclusion, the fabrication of 3D printing filament from recycled PET plastic holds promises for addressing the challenges faced by the 3D printing industry. With continued research, development, and standardization efforts, this emerging technology could play a crucial role in shaping the future of 3D printing and its environmental impact.

2. Methodology

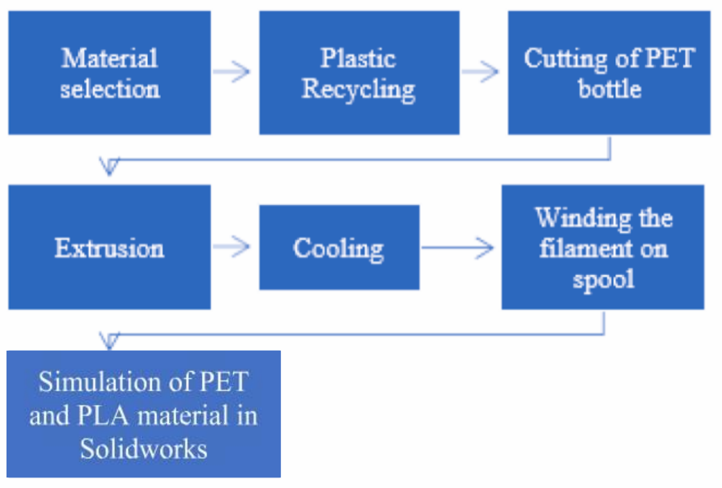


Fig. 1. Design of methodology.

To create a sustainable fabrication of 3D printing filament from recycled PET plastic, a step- by-step methodology is followed, which is illustrated in Fig.1. This methodology is an essential step towards achieving sustainable 3D printing practices by reducing plastic waste and promoting the use of eco-friendly materials. Step by Step methodology that is followed for production of the recycled PET filament is elaborated in detail starting from material selection to extruding the filament.

2.1 Material selection

As demonstrated in that the initial stage of the methodology is material selection. This includesidentifying plastic waste available for 3D printing filament, which necessitates selecting certain types of plastic to serve as a source material for 3D printing. Subsequently, the properties of the plastic waste, such as melting temperature, tensile strength, and elastic limit, were observed. Plastic waste is classified into various types, such as thermoplastics and thermosetting plastics, based on their characteristics For this study, we chose waste plastic bottles made from PET plastic because most of the available waste is made up of PET plastic.

International Journal of Advanced Technology in Engineering and Science
Vol. No. 12, Issue No. 03, March 2024
www.ijates.com
ijates
ISSN 2348 - 7550

2.2 Recycling plastic

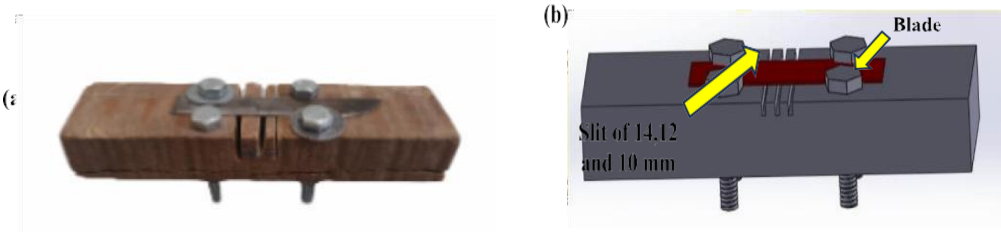
Once the first step of material selection is completed, the next step is to recycle the plastic bottles. As depicted, the first stage of recycling is to wash the bottles thoroughly and dry themto remove any residual impurities. After the bottles are cleaned, they are heated to make them more pliable and remove any irregularities, making it easier to cut them into strips. This step is important because it enables the bottles to be transformed into the desired shape and size forthe next stage of the process. By cutting the bottles into strips, this enables the plastic to be easily fed into the extruder of Flatboat. This step is crucial for the overall success of the process, as it ensures that the recycled plastic can be efficiently used to create 3D printing filament.

2.3 Cutting PET bottles

(a) (b)

Once the plastic bottles are cleaned and heated, they are sorted and cut into continuous strips using the plastic strip cutter. The width of the strip is of different sizes, 12 mm and 10 mm, as illustrated. These strips of plastic are commonly referred to as “Pre- filament.” The purpose ofcutting the plastic bottles into strips is to facilitate the subsequent steps in the process, which are extrusion and winding the filament on a spool.

Fig.2 (a) 12 mm plastic strip; (b) 10 mm Plastic strip.



(a) (b)

Fig.3 (a) PET Strip cutter; (b) 3D design of PET strip cutter.

The plastic strips, as illustrated in, are cut using a specially designed plastic strip cutter that has three different sizes, namely 14 mm, 12 mm, and 10 mm, which ensures that the plastic strips are of a consistent width. This consistency is essential to ensure that the strips can be easily fed into the extruder machine.

2.4 Extrusion

The next steps in the process of recycling plastic bottles into 3D printing filament. Once the plastic strips have been cut to the desired width, they are fed into an extruder machine, as shown in Fig. 4.

The extruder of flatboat heats the plastic strips and melts them into a consistent, molten state. Itis equipped with a heating element, whose temperature ranges from 0 to 400 °C. The molten plastic is then pushed through a die or nozzle opening to form a long, continuous filament. The nozzle is 1.6 mm in diameter.

After extrusion, the filament undergoes a cooling process to ensure that it solidifies and maintains its shape. The filament is passed over a cooling fan, which cools it down quickly andefficiently. It is crucial because it prevents the filament from losing its shape or warping duringthe winding process.

Finally, the filament is wound onto a spool. The spool is rotated at a consistent speed, and the filament is carefully wound onto it, layer by layer. This process ensures that the filament is wound evenly and tightly, preventing tangles or knots that could affect its quality. Once the spool is filled with filament, it is ready to be used for 3D printing. The resulting filament is ofhigh quality, has a consistent diameter, and is suitable for a wide range of 3D printing applications.

3 Experimental setup and FEA analysis

illustrates the experimental setup of the Flatboat machine used to fabricate 3D filament. The machine is fabricated using wood as the base material. The extruder machine plays a crucial role in the fabrication process by melting and shaping plastic strips into the desired 3D filament.

The plastic strips are fed into the extruder, where they undergo a heating process to achieve a temperature range of 225–245 °C, which is regulated using a PID temperature controller. This controlled heating process allows the plastic to melt and become a molten liquid, which canthen be pushed through a nozzle opening to create the 3D filament's desired diameter. Once thefilament has been extruded, it is essential to cool it down to ensure that it retains its desiredshape and size. The cooling is achieved naturally at the ambient room temperature. This cooling process helps to solidify the molten plastic, ensuring that it retains the shape and size created during the extrusion process.

Overall, this process of extruding and cooling the filament is critical to ensuring the qualityand consistency of the 3D printing filament produced. Below are the explanations of the main components and their respective functions.

3.1 Plastic Cutter

In, component number 1, the plastic strip cutter, is being utilized to transform plastic bottles into strips. The plastic strip cutter consists of a frame and a cutting mechanism. The frame provides a stable base for the cutter, while the cutting mechanism consists of a blade that slices the plastic into strips of equal width and length. To ensure uniformity, the cutter has a slit mechanism of a particular width. Once the plastic has been cut into equal-width strips, it can be further processed to create a 3D filament.

3.2 Heating Block

In, component number 2 is a heating block which is made of aluminium block to accommodatethe recycled PET plastic strips, specific modifications are made to the heating block. The inlet threads on

International Journal of Advanced Technology in Engineering and Science
Vol. No. 12, Issue No. 03, March 2024
www.ijates.com
ijates
ISSN 2348 - 7550

the heater block have been removed, and the hole has been widened to facilitate the smooth passage of the plastic strips through the extruder. In addition to removing the threads and widening the hole, a
taper has been added to the heater block. The tapered design helps in guiding the plastic stripseffectively through the extruder, ensuring a smooth and continuous extrusion process.

3.3 Arduino Uno

The nozzle diameter used in the Flatboat extruder is 1.6 mm. This nozzle size is suitable for the extrusion process of PET plastic and ensures consistent extrusion of the material.

3.4 Nema 17 Stepper Motor

A NEMA 17 stepper motor is a type of stepper motor that conforms to the NEMA (National Electrical
Manufacturers Association) standard size 17. This standardizes the mounting dimensions and shaft size of the motor. NEMA 17 stepper motors are widely used in various applications such as 3D printers, CNC machines, robotics, and automation systems. They are known for their relatively compact size, moderate torque output, and compatibility with various driver electronics. The "17" in NEMA 17 refers to the motor's faceplate size, which is approximately
1.7 inches by 1.7 inches (43.2 mm x 43.2 mm). These motors typically have a step angle of 1.8degrees per step, meaning they require 200 steps for a complete revolution.

3.5 TMC 2208 driver

The TMC2208 is a stepper motor driver chip developed by Trinamic, a company specializing in motion control technologies. It is designed to drive stepper motors with advanced features such as smooth, silent operation and high performance. Some key features of the TMC2208 driver include:

StealthChop 1: Trinamic's proprietary technology for ultra-quiet operation at low speeds by dynamically adjusting the motor current.

Spread Cycle 2: Another Trinamic technology that optimizes the motor current waveform for improved torque and smoothness.

StallGuard 3: A feature that allows the driver to detect motor stall conditions without additionalsensors, enhancing reliability and safety in motion control systems.

Cool Step 4: Technology for automatic current adjustment to optimize energy efficiency and reduce motor heat generation.

UART Interface 5: The TMC2208 supports communication via a UART (Universal Asynchronous Receiver-Transmitter) interface, allowing for configuration and monitoring of the driver parameters.

Overall, the TMC2208 motor driver is popular in various applications, including 3D printers, CNC machines, and other motion control systems, due to its advanced features, quiet operation, and ease of use.

Fig.4 Extrusion of PET filament.

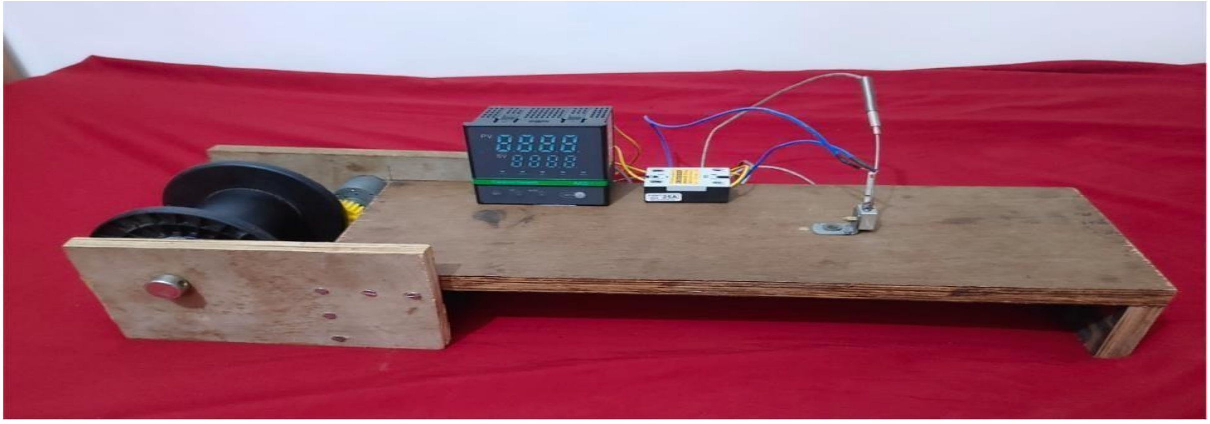


Fig.5 - Experimental model of Flatboat Machine.

consists of two main components: a heating element and a thermocouple. The heating element can produce temperatures ranging from 0 to 400 ˚C, as shown in Fig. 1, component 4, while the thermocouple is a temperature sensor that measures the actual temperature of the heating block. The PID controller employs a feedback loop to maintain the desired temperature range.It continuously measures the temperature of the heating block via the thermocouple and adjusts the heating element accordingly to achieve and maintain the desired temperature. This process is repeated over and over to maintain a stable temperature over time.

CONCLUSION

Based on the experimental results, it is possible to create a sustainable 3D printing filament of 1.65 mm diameter with consistent quality by recycling PET plastic bottles. This outcome highlights the potential for reducing plastic waste and turning it into useful materials for 3D printing.

In addition, simulations conducted in the study allowed us to compare the mechanical properties of PET and PLA materials. The results showed that PET has similar mechanical properties to PLA, which is a commonly used material in 3D printing. This finding indicates that PET can be a viable and cost-effective alternative material for 3D printing filaments.

REFERENCE

1. S. Kim, M.A. Rahman, M. Arifuzzaman, D.B. Gilmer, B. Li, J.K. Wilt, E. Lara- Curzio, T. Saito, Closed-loop additive manufacturing of upcycled commodity plastic through dynamic cross-linking, Sci. Adv. 8 (22) (2022) 1–10.
2. M. Cristea, D. Ionita, M.M. Iftime, Dynamic mechanical analysis investigations of PLA-based renewable materials: how are they useful? Materials (Basel) 13 (22)

(2020) 1–24.

3. M. Attaran, The rise of 3-D printing: the advantages of additive manufacturing over traditional manufacturing, Bus. Horiz. 60 (5) (2017) 677–688.
4. A Charles, E. Harper, Handbook of Plastics, Elastomers, and Composites, 2014.