TRANSFORMING PET BOTTLE INTO THREAD

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ABSTRACT

In India, PET is most commonly used thermoplastic. Nearly 26K tones of plastic waste is generating per day. Although it is recyclable, producing and manufacturing PET has a harmful impact on the environment. It takes upto 1000 years to break down. There are various re-using techniques on PET wastage in various fields. With the advancement in the technologies, we studied and designed an automated device for extracting threads from PET bottles which involves utilizing an ESP32 microcontroller, Stepper Motor, DC Motor and PID based temperature controlling methods. It offers scalable solution for enhancing recycling, manual labor, promoting sustainable waste management practices. The threads extracted from PET bottles can serve various purposes, contributing to both practical and creative applications like Textile Industry, Manufacturing products such as carpets, clothing, upholstery, Packaging Industry, Construction, Automotive, 3D Printing. By incorporating recycled PET threads, there is a reduction in the demand for new raw materials.

Keyword:- *ESP32 Microcontroller, PID temperature controller, DC motor, Stepper motor.*

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1. INTRODUCTION

Plastic pollution poses a significant threat to ecosystems, wildlife, and human health globally. Its widespread use and resistance to degradation make it a persistent environmental problem. Plastic releases toxic pollutants that contaminate land, water, and air, leading to severe pollution. The longevity of plastic exacerbates its environmental impact, with some types taking hundreds to thousands of years to decompose fully. The overuse and improper disposal of plastic are major contributors to pollution. Single-use plastics, such as bottles and packaging, are particularly problematic due to their short lifespan and high production volume. Improper disposal leads to accumulation in landfills and natural habitats, where plastic waste persists for long periods, contributing to environmental degradation. Incineration of plastic waste releases harmful toxins into the air, worsening air pollution and posing health risks. Coastal areas are especially affected, with marine ecosystems suffering from plastic debris. Marine animals are entangled or ingest plastic, leading to injuries, suffocation, and death. Plastic pollution disrupts marine biodiversity and ecosystems, with far-reaching consequences for ocean health. Commercial activities, like fishing, also contribute to plastic pollution through the use of plastic-based equipment. Lost or abandoned fishing gear, known as "ghost gear," continues to trap and kill marine life, exacerbating the degradation of marine ecosystems [1]. Plastic pollution not only harms marine life but also threatens human health. Plastic debris leaches toxic chemicals into soil and water sources, contaminating food supplies and drinking water. Microplastics, tiny particles less than 5 millimeters in size, have been found in various environmental compartments, posing risks to both aquatic and terrestrial organisms, including humans. Efforts to address plastic pollution include legislative measures, public awareness campaigns, and technological innovations. Many countries have implemented bans or restrictions on single-use plastics to reduce consumption and encourage alternative materials. Public education initiatives promote responsible waste management practices and highlight the environmental impacts of plastic pollution. Technological advancements in waste management and recycling offer potential solutions to the plastic pollution crisis. Recycling initiatives aim to divert plastic waste from landfills, repurposing it into new products and materials [2]. However, challenges remain in effectively recycling certain types of plastics, such as polyethylene terephthalate (PET). PET, a commonly used polymer, offers desirable properties for various applications but has low recycling rates due to technical and economic constraints. Mechanical recycling, the most common method, involves shredding used PET products into small pieces, melting them down, and reforming them into new products [3]. Chemical recycling presents an alternative approach, breaking down plastic polymers into monomers for reuse in new production. Efforts to improve PET recycling technologies are underway, driven by growing awareness of environmental impacts and the need for sustainable waste management solutions. Innovations in recycling processes aim to increase efficiency and viability, ultimately reducing the environmental footprint of plastic production and consumption. Promoting circular economy principles, such as extended producer responsibility and product stewardship programs, can also help minimize plastic waste. By incentivizing sustainable product design and responsible consumption practices, we can reduce plastic pollution and create a more sustainable future [2-1].

1.1 CHARACTERISTICS OF PET

Polyethylene terephthalate (PET) is a versatile material widely used in the production of various consumer products, [2] with blow-molded water and soda bottles being its most recognizable application. While PET is relatively new as a packaging resin, it has become indispensable in the production of soft drink bottles, with a growing presence in containers for household items like salad dressing, peanut butter, and jellies. Notably, a significant portion of polyester carpeting in the United States is crafted from recycled PET bottles, highlighting its role in sustainable manufacturing practices. The proliferation of custom bottle designs and the surge in consumption of bottled water and soft drinks outside the home present challenges in effectively recycling PET. However, PET has contributed to waste reduction by replacing heavier steel and glass containers, thereby streamlining the waste management process. Addressing plastic waste concerns necessitates a concerted effort towards recycling, with a focus on enhancing efficiency and minimizing pollution during the recycling process. Plastics recycling strategies are categorized into four types: primary, secondary, tertiary, and quaternary. Primary recycling involves converting waste or scrap into a product with properties akin to the original material. Secondary recycling, on the other hand, transforms waste plastics into materials with different characteristics from the original product. Tertiary recycling focuses on producing basic chemicals and fuels from plastic waste, either within municipal waste streams or as segregated waste. Quaternary recycling involves harnessing the energy content of waste plastics through burning or incineration. In essence, the pursuit of sustainable consumption and production of PET bottles underscores the importance of efficient recycling practices to mitigate environmental impact and conserve energy resources [4].

2. LITERATURE REVIEW

Several studies have delved into the feasibility and benefits of recycling PET bottles into filament for 3D printing.[1] Rajankar et al. (2020) likely delve into the extraction of strips from waste PET bottles, aiming to explore methods for PET plastic recycling.[2] Tylman and Dzierżek (2020) introduce a simple machine for producing 3D printer filament from PET bottles, potentially offering a cost-effective and sustainable solution for filament production.[3] Joseph et al. (2024) provide a comprehensive review of PET recycling processes and technologies, discussing efficiency, challenges, and environmental implications, contributing to the advancement of sustainable waste management practices. [4] Bedawi may focus on managing PET plastic bottle waste through recycling initiatives in Khartoum State, potentially addressing local environmental concerns and promoting circular economy principles.[5] Aboulkas et al. (2010) contribute to the understanding of thermal degradation behaviors of polyethylene and polypropylene, offering insights into the pyrolysis kinetics and mechanisms, which could inform the development of efficient recycling processes. [6] Al-Salem et al. (2009) review recycling and recovery routes for plastic solid waste, including PET, providing valuable insights into the global plastic waste management landscape.[7] Anderson (2017) compare mechanical properties of 3D printed specimens using virgin and recycled polylactic acid, shedding light on the suitability of recycled materials for additive manufacturing applications.[8] Oyinlola et al. explore the potential for converting plastic waste into 3D printed products in Sub-Saharan Africa, highlighting challenges and opportunities for sustainable development in the region.Together, these studies contribute to a comprehensive understanding of the environmental, economic, and quality considerations associated with recycling PET bottles for filament production in 3D printing, highlighting the potential for sustainable practices in additive manufacturing and the importance of circular economy principles in reducing environmental impact.

Finally, Khan and Ali (2021) proposed a quality control framework for ensuring the reliability and consistency of recycled PET filament. Their study outlined testing procedures and criteria to assess filament properties, addressing concerns regarding diameter accuracy, homogeneity, and printability. Together, these studies contribute to a comprehensive understanding of the conversion of PET bottles into filament for 3D printing, covering material properties, process optimization, sustainability assessment, economic viability, and quality control measures.

The paper titled "Extraction of Strip from Waste PET (Plastic) Bottles" by Saurabh A. Rajankar et al. explores the innovative use of waste PET bottles in creating string-like strips that can be repurposed for various applications. This technique addresses the pressing issue of plastic pollution while also offering practical solutions for sustainable development.

The primary objective of the study is to convert waste PET bottles into usable strings for construction purposes. The methodology involves a step-by-step process of transforming plastic bottles into string-like strips using simple tools such as knives or scissors. Additionally, the authors propose the construction of a base cutter assembly using materials like PVC pipes, motors, and cutter blades to automate the process and enhance efficiency.

Key findings from the study indicate significant achievements in several areas. Firstly, by repurposing waste PET bottles into strings, the study contributes to reducing plastic pollution, particularly in urban areas. This approach offers an alternative use for discarded plastic, mitigating its harmful environmental impact. Moreover, the implementation of this technique could potentially create employment opportunities, especially in regions grappling with high levels of plastic waste. By establishing small-scale operations for string production, individuals could be employed in the collection, processing, and manufacturing stages.

Additionally, the study suggests that there is potential for improved air quality through the reduction of plastic waste and associated pollution. Burning of plastic waste, a common disposal method in some areas, releases harmful toxins into the atmosphere. By repurposing plastic bottles, the need for incineration decreases, consequently reducing air pollution. Furthermore, the strings extracted from PET bottles can serve as a viable construction material, offering a sustainable alternative to conventional materials like brick or concrete. This not only reduces the demand for virgin materials but also provides a cost-effective solution for building infrastructure.

Practical application and implementation of the proposed technique are feasible using readily available materials and basic tools, making it accessible to a wide range of communities. By utilizing locally sourced waste PET bottles, communities can initiate small-scale production units for string extraction. Furthermore, the construction of the base cutter assembly, as outlined in the study, enables mechanization and streamlines the process for large-scale operations.

In conclusion, the extraction of strips from waste PET bottles presents a promising solution to the challenge of plastic pollution. By repurposing discarded plastic into usable strings, the study not only addresses environmental concerns but also offers socio-economic benefits such as job creation and infrastructure development. Implementing this technique on a larger scale has the potential to significantly contribute to sustainable development efforts worldwide.

Tylman and Dzierżek (2020) introduce a sustainable approach to 3D printing by recycling PET bottles into filament. Their research centers on a machine primarily constructed from 3D printed parts, featuring modular design and a control panel for precise temperature and speed regulation. The process involves cutting PET bottles into strips, winding them onto bobbins, and extruding the plastic through a heating block to create filament. Experimental analysis includes microscope examination, temperature resistance testing, and tensile strength evaluation, showcasing the viability of the recycled PET filament compared to traditional materials like PET-G, ABS, and PLA. This study underscores the potential for environmentally friendly practices in additive manufacturing, fostering the transition towards circular economy principles in the industry.

The machine's modular structure offers flexibility and ease of assembly, allowing for efficient material preparation and filament creation. By repurposing PET bottles into high-quality filament, the research contributes to reducing plastic waste and promoting sustainability in 3D printing. Experimental testing validates the feasibility of the recycled PET filament, demonstrating comparable properties to commercially available materials. This approach not only addresses environmental concerns but also offers cost-effective solutions for filament production, aligning with the growing demand for eco-friendly practices in manufacturing.

Overall, Tylman and Dzierżek's work presents a promising avenue for recycling plastic waste into valuable resources for 3D printing. Their innovative approach highlights the potential for sustainable practices in additive manufacturing and underscores the importance of circular economy principles in mitigating environmental impact. Further development and optimization of the filament creation process could lead to broader applications and enhanced sustainability across various industries.

3. METHODOLOGY

Using Stepper Motor, dc motor and PID based temperature controlling methodology. We studied and designed an automated device for extracting threads from PET bottles which involves utilizing an Stepper Motor, DC Motor and PID based temperature controlling methods. It offers scalable solution for enhancing recycling, manual labor, promoting sustainable waste management practices. And further we implement by using pulling mechanism and Hotend to extract the thread. Cooling process by using water to cooldown the extracted filament.

4. IMPLEMENTATION

4.1 CUTTING

Cutting is the first step in the process where we cut the plastic pet bottles into the strip form by using blades and stepper motor. Initially we will fix the pole to the wooden block with some inclination and blades accordingly. We are using stepper motor with a pulling gear for Automatic strip cutting. Pole with inclination provides better revolution of bottle and followed by stepper motor with pulling gear makes the process of cutting automatically and continuously.

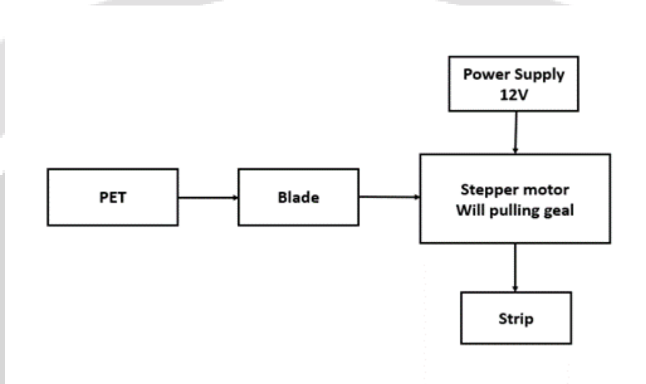

Fig -1: Block Diagram of PET to Strip Cutting

Fig-2: Strip Cutting

4.2 HOTEND

This is the second stage of the process where the PET Strip is converted into a filament. The Conversion takes place with the help of a beating demet heat block, cartridge (heating clement), thermistor Sensor. The heat block will be heated to the required temperature with the help of Cartridge and the temperature is measured with the help of thermistor sensor. This Sensor readings are transmitted to Esp32 micro controller and makes the flexibility to control the temperature and monitor the process through a mobile device. The temperature Controller helps in maintaining the required temperature and it is operated by ESP32. The Current temperature is the hot and will be displayed on a LCD screen.

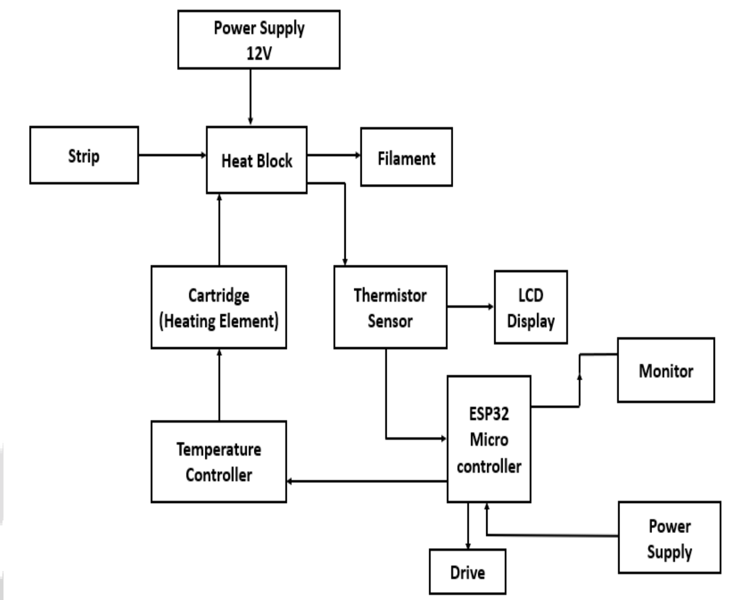

Fig -3: Block Diagram of Hotend Temperature controlling

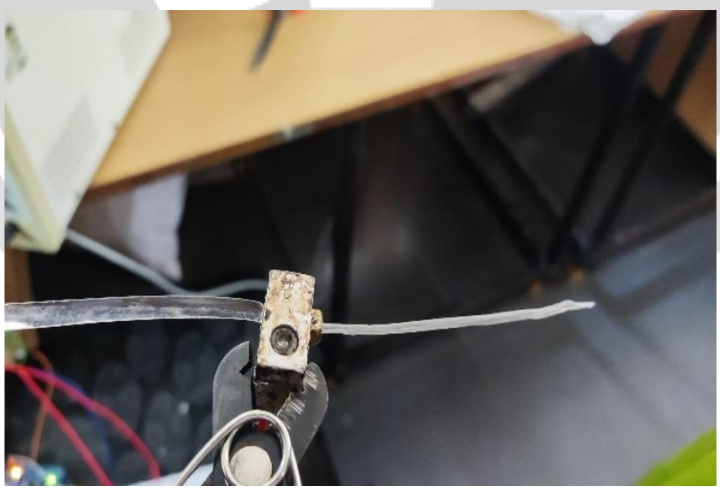

Fig -4: Hotend Temperature Controlling

4.3 Cooling and Spooling

After thread extraction, the cooling and spooling process involves cooling the extracted thread to set its properties and then winding it onto spools. cooling method is used to stabilize its molecular structure and prevent deformation or breakage. Once cooled, the thread is carefully wound onto spools. This spooling process is automated. Overall, the cooling and spooling stages are crucial for preserving the quality and usability of the extracted thread for various applications.

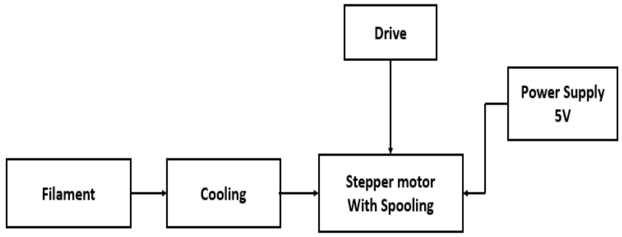

Fig -5: Block diagram of Cooling and Spooling

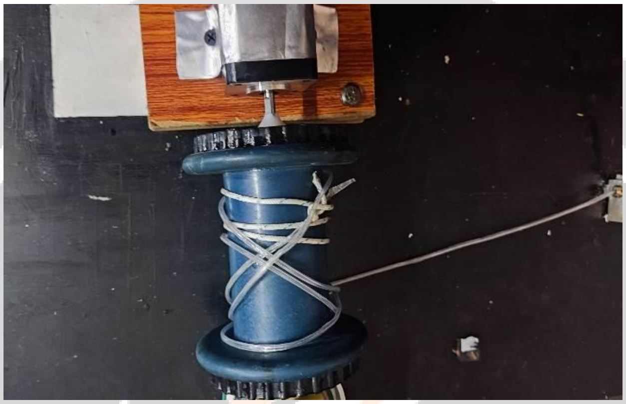

Fig -6: Cooling and Spooling

5. RESULT

Table -1: Results

Parameters	Previous result	Present Result
Speed	5-6 hr	4-5 hr
Efficiency	50/1 kg	48/kg
Quality	1.75mm/2.85	1.75mm

The project showcased an innovative approach to recycling by extracting 3D printing filament from PET bottles. Utilizing an ESP32 microcontroller for automation, coupled with an extruder kit featuring a hotend and thermistor, the process ensured precise temperature control during filament extrusion. This demonstrated a sustainable and efficient method for transforming waste plastic into usable material for additive manufacturing, emphasizing the potential for environmentally conscious innovation in recycling technologies. The microcontroller facilitated automation by regulating the extrusion process, ensuring consistent temperature control for optimal filament production. It monitored and adjusted parameters in real-time, enhancing efficiency and reducing human intervention. This automation streamlined operations, making the filament extraction process more reliable and cost-effective.

The extracted thread will have high quality in terms of thickness, strength, and color. The extrusion process gives us a more quantity of thread filaments within a less and specified time. By the utilization of material which is taken from recycled bottles helps minimizing environmental pollution compared to using virgin materials. Effective waste management ways were executed, taking care on proper disposal of any waste generated during the extraction process.

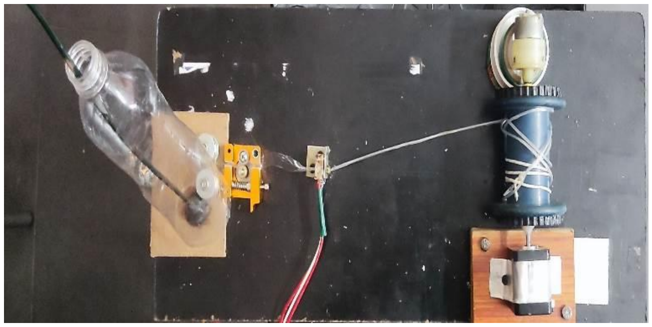

Fig -7: Overall Set Up of Project

6. PERFORMANCE ANALYSIS

6.1 Quality Assurance: The consistent quality of the extracted threads indicates the efficacy of the methodology in maintaining standards throughout the extraction process. This reliability is crucial for ensuring the usability and marketability of the threads for various applications, including textile manufacturing and packaging industries.

6.2 Sustainability Impact: The project contributes to environmental sustainability by reducing waste. Promoting a closed-loop system where materials are reused, reducing the environmental pollution.

6.3 Economic Viability: Thread filaments from PET bottles highlights the economic viability. By using recycled materials, the project offers cost-effective solutions for thread production.

6.4 Temperature analysis:

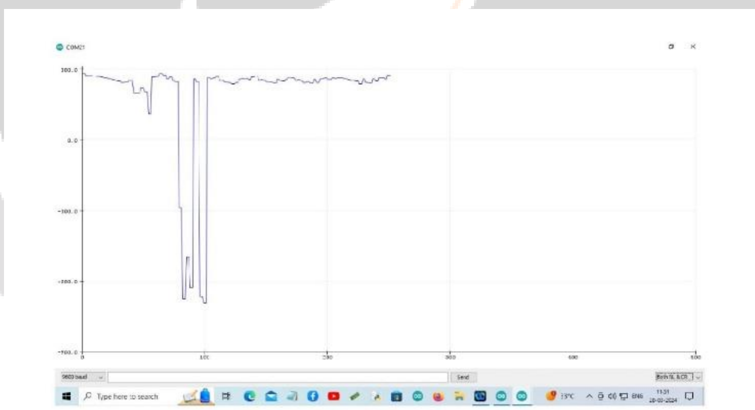

Fig.8: Graph shows temp observation during process

For the extrusion process 9mm width PET strip is converted into filament at a temperature ranging from 240°C to 260°C and the temperature observation during the process is shown in the Fig 4.

Manufactured 3D printing filaments cater to a wide array of applications, each offering unique characteristics and printing parameters. PLA (Polylactic Acid) stands out with its temperature range of 180°C to 220°C, prized for its biodegradability, ease of use, and versatility across hobbyist and professional realms. ABS (Acrylonitrile Butadiene Styrene) require temperatures between 220°C to 250°C, renowned for its exceptional strength and durability, making it a preferred choice for engineering-grade prototypes and functional parts. PETG (Polyethylene Terephthalate Glycol), sharing a similar temperature range with ABS, blends strength with reduced warping tendencies, making it suitable for a broad range of applications, including mechanical components and enclosures. TPU (Thermoplastic Polyurethane) offers remarkable flexibility and impact resistance within the temperature range of 220°C to 250°C, making it ideal for producing items like phone cases, shoe soles, and seals that necessitate elasticity and durability. Nylon, requiring temperatures of 240°C to 260°C, boasts exceptional strength, flexibility, and durability, although its susceptibility to moisture absorption mandates meticulous printing conditions to mitigate warping and ensure optimal layer adhesion. PVA (Polyvinyl Alcohol) serves as a soluble support material for intricate prints, typically necessitating temperatures ranging from 180°C to 210°C. Its ability to dissolve in water eliminates the need for manual support removal, rendering it invaluable in dual-extruder setups for creating complex structures with overhangs and internal cavities. When evaluating filaments derived from PET, such as recycled PET (rPET) and virgin PET (vPET), the manufacturing process plays a critical role. rPET requires a higher recycling temperature range of 240°C to 280°C for proper purification and extrusion, while vPET demands temperatures ranging from 260°C to 300°C due to its higher purity and absence of contaminants. These distinctions underscore the paramount importance of selecting the appropriate filament based on specific project requirements and desired material properties, ensuring optimal outcomes in 3D printing endeavors.

6.5 Time analysis

The conversion of 1 kilogram (kg) of PET bottles into 3D printing filament involves a multi-step process that typically spans between 4 to 6 hours. This timeframe encompasses various essential procedures, including cleaning, cutting into strips, melting, extrusion, cooling, and winding onto spools. The duration of filament manufacturing varies depending on the material and type being processed. For instance, PLA, derived from natural sources such as corn starch, shares a similar timeframe of 4 to 6 hours per kg, aligning with the efficiency of the PET recycling process. ABS, a petroleum-based plastic commonly used in 3D printing, also falls within this range. Similarly, PETG, crafted from polyester-based plastic, maintains a production timeframe of 4 to 6 hours per kg, indicative of its processing similarities to PET. However, materials with distinct properties necessitate different time frames. Nylon, recognized for its durability and flexibility, requires a more extended processing period, ranging from 8 to 12 hours per kg. The additional time accounts for the intricacies involved in manipulating nylon's molecular structure during extrusion. TPU, renowned for its elasticity and resilience, demands a moderate processing duration of 6 to 8 hours per kg. These time estimates serve as approximations, subject to variations influenced by factors such as equipment efficiency, production scale, and specific manufacturing requirements. Such variability underscores the importance of optimizing operational parameters to ensure consistent and efficient filament production across different material types.

6.6 ESP32-Blynk Analysis

The integration of the ESP32 microcontroller with the Blynk platform has revolutionized our approach to converting PET into filament for 3D printing. With this setup, we have achieved comprehensive monitoring and control capabilities across various aspects of the filament manufacturing process. One of the key functionalities enabled by this integration is the precise monitoring and control of stepper motors involved in both the cutting strip process and the spooling process. This ensures that the filament produced maintains accurate dimensions and consistent quality throughout the manufacturing process. Additionally, Blynk facilitates real-time temperature monitoring during the extrusion process, allowing us to maintain optimal temperatures for filament production and prevent any overheating or underheating issues. Moreover, the Blynk mobile application provides remote control over the power supply to the entire system, granting users the flexibility to turn the equipment on or off as needed, regardless of their physical location. This feature enhances convenience and accessibility, particularly for scenarios requiring remote management of the filament production process. Furthermore, the timer functionality offered by Blynk allows for scheduling specific operations within the manufacturing process, such as starting or stopping extrusion at predefined times. This automation optimizes efficiency and productivity by reducing the need for constant manual oversight. Overall, the integration of ESP32 and Blynk into our filament manufacturing system has significantly streamlined operations and enhanced control over critical parameters. This not only improves the quality and consistency of the filament produced but also contributes to greater efficiency and flexibility in 3D printing filament production.

7. FUTURE SCOPE

Further research and development will focus on optimizing the extraction process to improve efficiency and quality while reducing resource utilization and waste generation. Exploring innovations in technology and process optimization could lead to continuous improvements and advancements in sustainable thread production from PET bottles. Automation and Robotics: Investing in automation and robotics technologies could streamline the thread extraction process, making it more efficient and cost-effective. This could involve the development of specialized equipment and machinery tailored to the unique properties of PET bottles.

8. CONCLUSION

In conclusion, the latest iteration of our recycling process showcases significant advancements in efficiency and monitoring capabilities. By integrating automation into the strip cutting phase and leveraging ESP32 for real-time monitoring, we've markedly reduced the need for manual labor compared to previous models. PET bottles are initially cut into strips, a task now seamlessly handled by automated systems. These strips are then processed through an extrusion setup, where they undergo melting and transformation into high-quality filament suitable for 3D printing applications. This process not only transforms waste into a usable product but also highlights the importance of efficiency and quality in sustainable manufacturing practices. Notably, the extrusion process benefits from a moderate level of automation, further streamlining operations. Throughout the entire process, the omnipresence of ESP32 monitoring devices guarantees effortless oversight and precise control, elevating overall efficiency and quality assurance. This combined approach not only optimizes resource utilization but also exemplifies our unwavering dedication to sustainable practices in recycling.

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