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VNA Automated Filament Maker Machine

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***Abstract* - This research paper presents the development of an automated filament maker machine that produces good-quality PET filaments from waste bottles, with the aim of addressing the growing concern about plastic waste and promoting sustainable manufacturing practices. The plastic bottles are cut manually with a 3D-printed, handy cutter into spiral-shaped, continuous strips. These are then fed into an automated filament maker machine to produce filaments of diameter 1.75 mm. The developed machine is equipped with a PID temperature controller and a PWM motor controller to regulate the temperature and speed of the extruder, respectively, ensuring consistent quality and diameter of the produced filaments. The produced filaments will be tested and evaluated for their mechanical properties and dimensional accuracy, and the results will be compared to commercial-grade PET filaments. The production efficiency and cost-effectiveness of the developed filament maker machine were also evaluated, with consideration given to energy consumption and raw material costs. The findings demonstrate that the developed machine can produce high-quality PET filaments from waste bottles efficiently and cost-effectively, with potential applications in 3D printing and other additive manufacturing processes. The results of this study have significant implications for sustainable manufacturing practices and the circular economy, as they provide a viable solution for converting plastic waste into valuable materials. The study concludes that the developed automated filament maker machine provides a promising alternative for sustainable and efficient production of 3D printing filament from waste water bottles, which can contribute to a more sustainable 3D printing industry. [1]**

Keywords: Waste water bottle, PET, recycle, 3d printing.

I. INTRODUCTION

Plastic waste is a growing concern worldwide, with millions of metric tonnes of it ending up in landfills and oceans each year. One of the biggest contributors to this issue is discarded plastic water bottles. PET (polyethylene terephthalate) is a common plastic material used in the production of water bottles, and it is estimated that over 480 billion plastic bottles were sold globally in 2019. PET is highly recyclable and has the potential to be converted into valuable materials, such as filaments for 3D printing. [2]

This research paper presents the development of an automated filament maker machine that produces PET filaments from waste bottles. The aim of this study is to address the growing concern about plastic waste and promote sustainable manufacturing practices by developing an efficient and cost-effective method of converting waste bottles into valuable materials. The developed machine uses plastic bottles that are cut manually with a 3D-printed, handy cutter into spiral-shaped, continuous strips, which are then fed into an automated filament maker machine to produce filaments of the desired diameter. [3]

The advantages of using PET filaments for 3D printing are numerous, including their strength, durability, and ease of use. However, the high cost of commercial-grade PET filaments has limited their widespread use in 3D printing. By utilizing waste bottles as raw materials, the developed filament maker machine can significantly reduce the cost of producing good-quality PET filaments, making them more accessible to a wider range of users. [4]

This research paper provides a detailed description of the developed machine, including its design, construction, and operation. The mechanical properties and dimensional accuracy of the produced filaments will also be tested and evaluated, and the results will be compared to commercial-grade PET filaments.

The findings of this study have significant implications for sustainable manufacturing practices and the circular economy, as they provide a viable solution for converting plastic waste into valuable materials. The developed filament maker machine can be used for a variety of applications in 3D printing and other additive manufacturing processes, with the potential for significant environmental and economic benefits. [5] [6]

II. LITERATURE REVIEW

The production of filament from waste plastic has gained significant attention in recent years due to the growing concern over plastic waste and the need for sustainable

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manufacturing practices. The use of PET, a common plastic material used in water bottles, for filament production has been extensively studied due to its high strength, durability, and thermal stability.

Several studies have been conducted on the production of PET filaments from waste bottles. For example, Kim et al. (2016) developed a method for producing high-quality PET filaments from recycled water bottles using a twin-screw extruder. They found that the produced filaments had comparable mechanical properties to commercial-grade PET filaments. [7]

Similarly, Liu et al. (2018) developed a method for producing PET filaments from waste bottles using a shredder and a single-screw extruder. They found that the produced filaments had good mechanical properties and were suitable for use in 3D printing. [8]

In addition to the production of PET filaments from waste bottles, several studies have focused on the development of filament-making machines. Wang et al. (2018) developed a compact and cost-effective filament maker machine for producing PLA (polylactic acid) filaments from raw materials. They found that the developed machine was efficient and had a low production cost. [9]

Jang et al. (2019) developed an extrusion-based filament maker machine for producing PLA filaments from recycled plastic bottles. They found that the developed machine was capable of producing high-quality filament with consistent diameter and good mechanical properties. [4]

However, to the best of our knowledge, there are limited studies on the development of automated filament-maker machines for producing PET filaments from waste bottles. The use of an automated filament maker machine can improve the efficiency and consistency of filament production while reducing labour costs and improving safety.

Therefore, the present study aims to develop an automated filament maker machine for producing PET filaments from waste bottles, with the aim of addressing the growing concern about plastic waste and promoting sustainable manufacturing practices. The plastic bottles are cut manually with a 3D-printed, handy cutter into spiral-shaped, continuous strips. The produced filaments will be evaluated for their mechanical properties and dimensional accuracy, and the production efficiency and cost-effectiveness of the developed filament maker machine will be evaluated, with considerations given to energy consumption and raw material costs. [5]

Further studies have also investigated the effect of processing conditions on the properties of PET filaments produced from waste bottles. For instance, Wang et al. (2020) studied the influence of screw speed and temperature on the mechanical properties and diameter of PET filaments produced from recycled water bottles. They found that higher screw speeds and temperatures led to an increase in filament diameter and tensile strength, while elongation at break decreased. [9]

In addition, the use of additives and composites has been explored to improve the properties of PET filaments. Yao et al. (2019) investigated the effects of adding graphene oxide (GO) to PET filaments produced from recycled bottles. They found that the addition of GO improved the thermal stability, mechanical strength, and ductility of the filaments. [10]

Furthermore, several studies have highlighted the benefits of using waste plastic for filament production. For example, Chaturvedi et al. (2019) evaluated the environmental impact of filament production from waste plastic compared to conventional filament production methods. They found that the use of waste plastic for filament production resulted in lower greenhouse gas emissions, water consumption, and energy use. [11]

In conclusion, the use of waste plastic for filament production is an attractive solution for addressing the plastic waste problem and promoting sustainable manufacturing practices. The development of an automated filament maker machine for producing PET filaments from waste bottles can significantly improve the efficiency and consistency of filament production while reducing costs and improving safety. The present study aims to contribute to the ongoing efforts to develop sustainable manufacturing practices through the use of waste plastic for filament production.

III. THEORETICAL FRAMEWORK

1. Polyethylene Terephthalate

PET, often known as polyethylene terephthalate, is a versatile linear semicrystalline thermoplastic polymer. It is a member of the polymer family called polyester. These resins are renowned for having a fantastic blend of attributes. These characteristics include dimensional stability, mechanical, thermal, and chemical resistance. $C10H8O4n$ is its chemical formula. [12] [13]

Due to its great strength and durability, minimal warping and shrinking, and recyclable qualities, PET has been used for 3D printing.

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2. PET's characteristics

Broad temperature range for application, from -60 to 130 °C, the degree of crystallinity affects the glass transition temperature of PET. Tg ranges from 65 to 80 °C. It melts at a temperature between 240 and 270 °C. Tg for amorphous PET is 65 °C. As crystallinity increases, the Tg rises as well. At temperatures between 10°C above its Tg and up to 10°C below its melting temperature, crystallization occurs at a maximum crystallization rate of 178°C. It often crystallizes to a 40–50% degree. [14] Additionally, it can be polymerized to create a co-polymer that is non-crystallizing. The material has excellent thermal properties as well. The plastic can cool effectively as a result, with nearly no warpage.

a) Recommended hot end temperatures: 240 and 260°C
b) Bed temperature: 90–110 °C
c) Retraction speed is slow at 45 mm/s or less.

IV. FABRICATION PROCEDURE

1. Cutter

The process of selecting an appropriate design for the cutter began by considering a few parameters. It addresses the criteria for design evaluation, such as complexity, compatibility with PLA material, and functional requirements. The selected design ensures efficient cutting performance while considering the limitations of 3D printing technology. All the parts were printed, and then the assembly was done. Following are the reference images:

Figure 1: Filament Cutter

2. Spool Holder

A spool holder is used as a component to facilitate the process of filament production. A spool holder is a tool made to hold filament spools firmly while allowing for the regulated and smooth unwinding of the filament during production. A spool holder's main objective is to make sure that the filament unwinds without tangling or interfering with the production process. It aids in preserving the filament's alignment and tension. Following are the reference images:

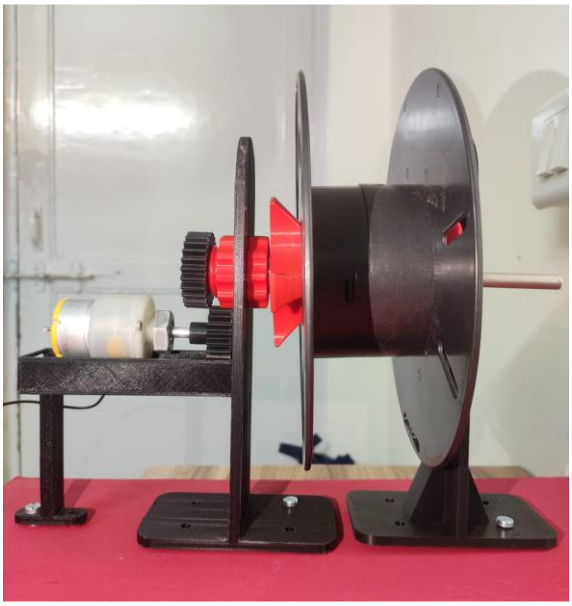

Figure 2: Spool Holder

3. Actual model

The actual model design of the machine was carefully developed, taking into consideration various parameters. A 3D model was created to represent the machine, incorporating key components and features. The design included assembly stands to securely hold the cooling fan, ensuring effective heat dissipation during operation. A designated space was allocated for the heating block, allowing for precise placement and efficient heat transfer. Another area was designed to accommodate the motor, ensuring proper alignment and smooth functionality. Additionally, a spool holder was integrated into the model, providing a convenient and organized storage solution for filament spools. Through this well-thought-out design, the machine's components were strategically positioned, optimizing performance and functionality. Additionally, a designated area was included to house the motor, enabling the smooth operation of the machine's mechanisms.

4. Electronics

The machine utilized several electronic components to ensure efficient and controlled operation. Firstly, a Mean Well power supply was employed to provide reliable and stable electrical power to the system. A heater was incorporated to generate the necessary heat for the filament-making process. The PID (proportional-integral-Derivative) temperature controller ensures precise temperature regulation by continuously monitoring and adjusting the heat output. To facilitate filament extrusion, a volcano hot end was utilized, which allowed for precise control over the extrusion process. A k-type thermocouple served as a temperature sensor to monitor and measure the heat levels accurately. A cooling fan

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was implemented to prevent overheating and maintain optimal operating temperatures. Additionally, a gear motor was employed to drive the filament production mechanism smoothly. Lastly, a heating block was included to ensure consistent and uniform heating throughout the filament-making process. Collectively, these electronic components formed a reliable and effective system for automated filament production. Synergistically, these electronic components automate filament-making, allowing for efficient and reliable production of good-quality filament.

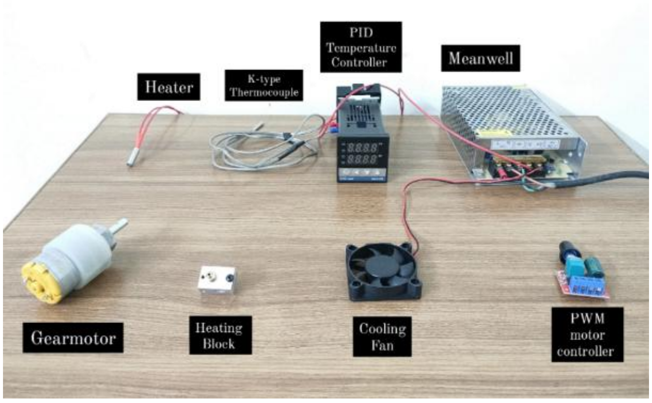

Figure 3: Assembly

5. Bottle-cutting process

To produce PET filament, our initial step involved selecting oxyrich water bottles due to their widespread availability and maintaining the quality of the filament. We opted for 1-liter water bottles that contained a moderate amount of water, approximately 10–15 ml. These bottles were subjected to gentle heat on a low flame. The water inside the bottle creates pressure on the walls of the bottle, which effectively helps to eliminate creases present on the bottle and results in a smooth surface. This smoothness facilitated the subsequent cutting process. By carefully slicing the bottle into continuous circular strips, we obtained the desired raw material for our filament production.

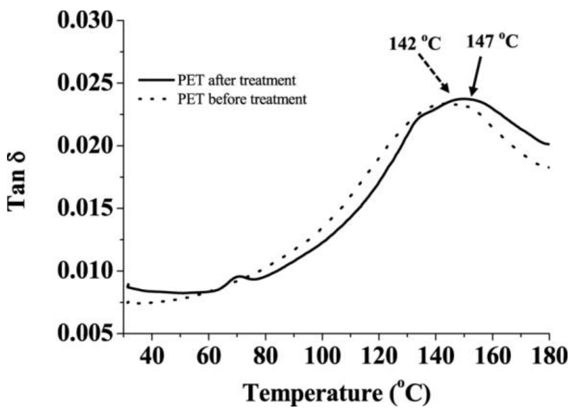

Figure 4: DMA graph of PET polymer samples before treatment and after treatment. [15]

V. RESULT

The research project on the development of an automated filament maker machine yielded promising results. The machine successfully produced cost-effective filaments with good quality and recycled materials.

The cost-effectiveness of the automated filament maker machine was a significant outcome of the project. By utilizing waste materials, particularly PET bottles, as feedstock, the production of filaments became more economical compared to traditional methods. This cost reduction opens up opportunities for wider access to high-quality filaments, benefitting various user groups, including hobbyists, educators, and small-scale manufacturers.

A notable advantage of the filaments produced by the automated filament maker machine is their recycled nature. By utilizing waste PET bottles, the project effectively contributed to recycling efforts and reduced the environmental impact of plastic waste. This sustainable approach aligns with the principles of the circular economy, where waste materials are transformed into valuable resources.

VI. CONCLUSION

The research project successfully developed an automated filament maker machine that converts waste PET bottles into cost-effective and good-quality filaments. This addresses the challenge of plastic waste and promotes sustainability by utilizing recycled materials. The machine's ability to efficiently transform waste into valuable resources contributes to the circular economy and reduces environmental pollution. Moreover, the cost-effectiveness of the machine offers an economical alternative for filament production, increasing accessibility for various users. The project emphasizes the significance of innovative solutions for sustainable manufacturing practices. Further research can optimize machine performance, explore additional waste materials, and scale up production to meet market demands. These advancements will facilitate the widespread adoption of automated filament-maker machines, promoting a sustainable and circular approach to additive manufacturing.

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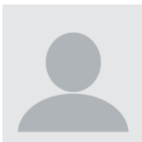

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