Design and Fabrication of a Custom Extruder for Recycling Waste Polymers in a 3D Printer

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Introduction

Sustainable recycling has advanced due to increasing environmental concerns about plastic disposal and harm to the atmosphere. This project involves the design and fabrication of a custom extruder that can recycle waste nylon polymer into filament. The objective is to facilitate green additive manufacturing while promoting circular economy principles in rapid prototyping through the combination of modelling tools and precision manufacturing.

Research aim and objectives

This research main objectives are:

1. To determine the best method to convert polymer waste into a printable feedstock.
2. Design and fabricate a custom extruder for a 3D printer.
3. Print objects from waste polymer.

Literature Review (Summary of recent studies)

1-Design and Manufacturing of a 3D printer filaments extruder.

The design and making of filament extruders have been improved by the process of evolution. Modern extruders now come equipped with advanced heating systems, movable nozzles and precise temperature control. They can use special materials which improve print quality and reduce scrap. The extrusion is made more precise with the help of new innovations such as PID-controlled heating, cooling systems and closed-loop recycling. This project is about designing a special extruder that can create filament from recycled materials. This will aid in sustainable additive manufacturing future(Hachimi et al.., 2021).

2- Recycling of Waste Plastics .

Ineffective recycling of plastic waste is a major environmental threat and plastics do not decompose, causing pollution in the earth. The aims of this project are to use a technology known as 3D printing which can quite easily convert waste polymers into a reusable filament. Plastics are recycled like old or failed 3D prints to create filament, through material recovery and extrusion to close the loop. It cuts down waste in both landfills and oceans while demonstrating the potential of bioplastic as sustainable manufacturing(Bruce et al.., 2020).

3-Effects of nozzle material and its lifespan on the quality of PLA parts manufactured by FFF 3D Printing.

Materials behavior affect their lifespan and heat transfer during 3D printing. In essence, print quality depends on nozzles because they determine how the material gets laid out and formed. The study looked at how PLA plastic parts were printed using brass, steel, and vanadium nozzles. The flavor depended on the thickness, textures and toughness of these prints under various instances. The brass nozzle that was worn out was found to produce a lower quality of prints than steel and vanadium nozzles, thus validating previously suggested heat transfer solutions. While prints in a single direction showed better force distribution, the real star was the vanadium nozzles, especially when printed at 45° /-45° . Likely, this is due to allowing plastic to flow more easily. This gives a clearer idea of how nozzle material can affect the quality of 3D printed parts, particularly with non-abrasive materials like PLA. This information is very helpful to refine the 3D printing procedure to achieve excellent prints (Melo et al.., 2022).

4-The sustainability aspects of 3D printing technology.

3D printing helps the environment in many ways. It can reduce waste, pollution problems, and make everyday items closer to people. This technology reduces the harmful impact on the environment through energy-efficient layer-by-layer production. It does this especially when having the possibility of using biodegradable plastics, like PLA. 3D printing helps make a lot of parts for water treatment and renewable energy but also more than just manufacturing. Ceramics filters, for example, 3D print with photocatalytic devices. Similarly, components for wind turbines and experimental solar cells are other possibilities. To ensure long term sustainability, innovation must continuously focus on recyclability, energy efficiency and responsible scaling of this technology(Nadagouda et al.., 2020).

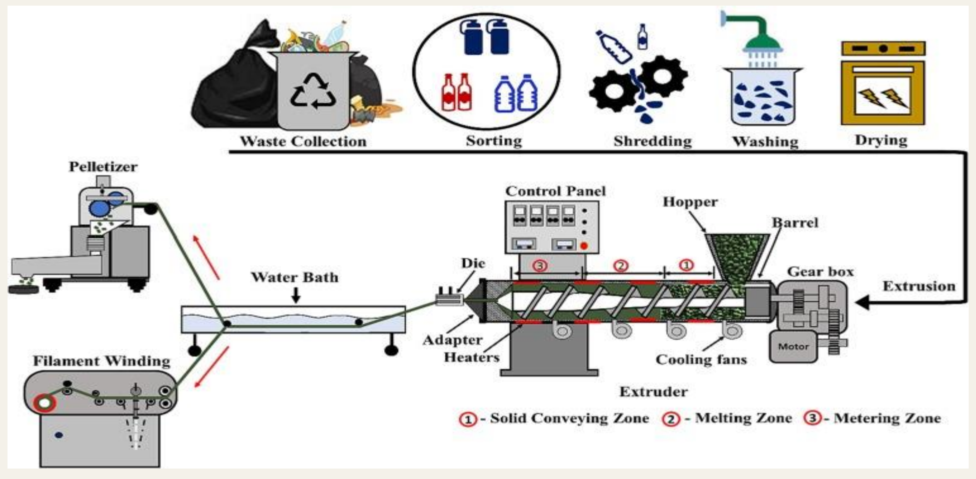

Figure 1: Plastic Waste to Filament Process

Methodology

Nylon was selected as the recycled material due to its durability, flexibility, and suitability for extrusion. The extruder was designed using SolidWorks, incorporating key components such as the motor, barrel, heating system, and a brass nozzle. Brass was chosen to improve heat conductivity and reduce material buildup during extrusion.

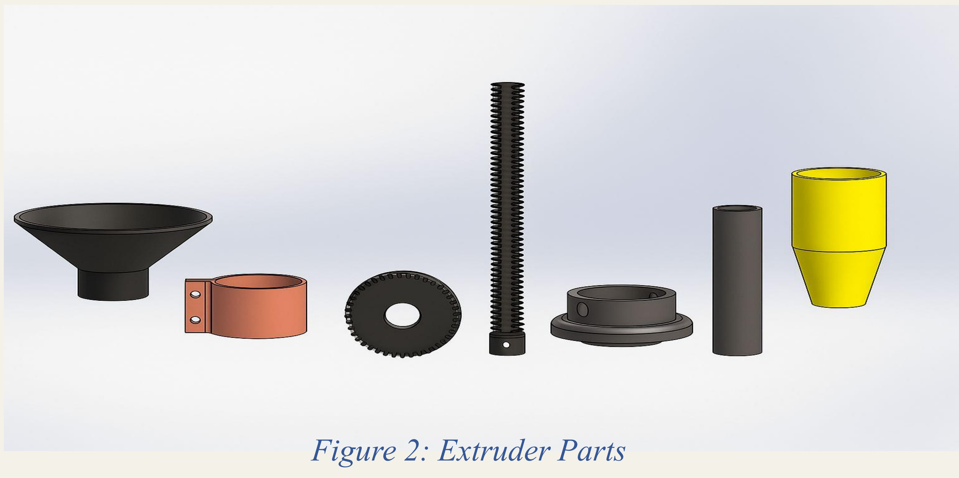

Figure 2: Extruder Parts

Simulations were carried out to evaluate the design. Thermal analysis examined how heat was distributed across the barrel and nozzle, while static simulation checked structural strength under load. Flow simulation was used to analyze the behavior of molten nylon, including its pressure, velocity, and temperature distribution inside the nozzle.

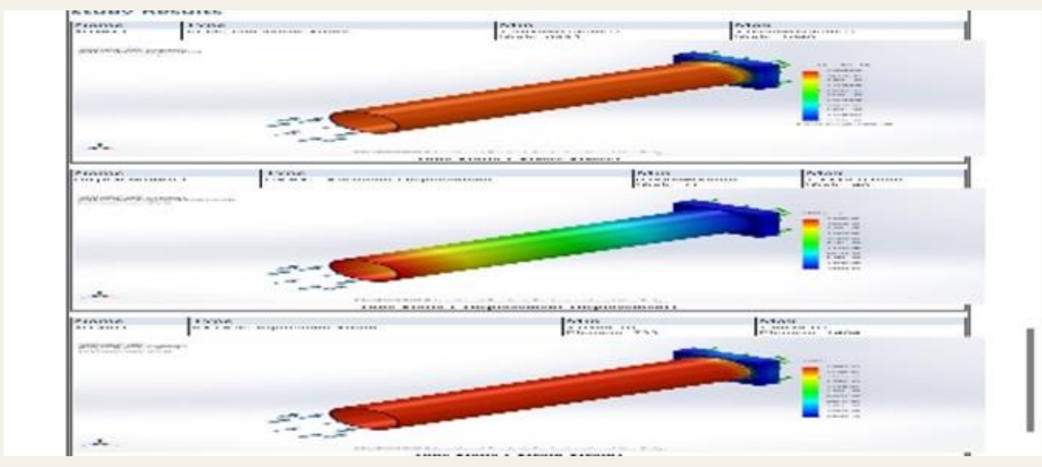

Figure 2: static simulation

After confirming the design through simulations, fabrication of the extruder components was initiated. The parts are currently being machined and prepared for assembly. Once completed, the extruder will be mounted onto a 3D printer frame and tested for its ability to recycle nylon waste into usable filament under controlled conditions.

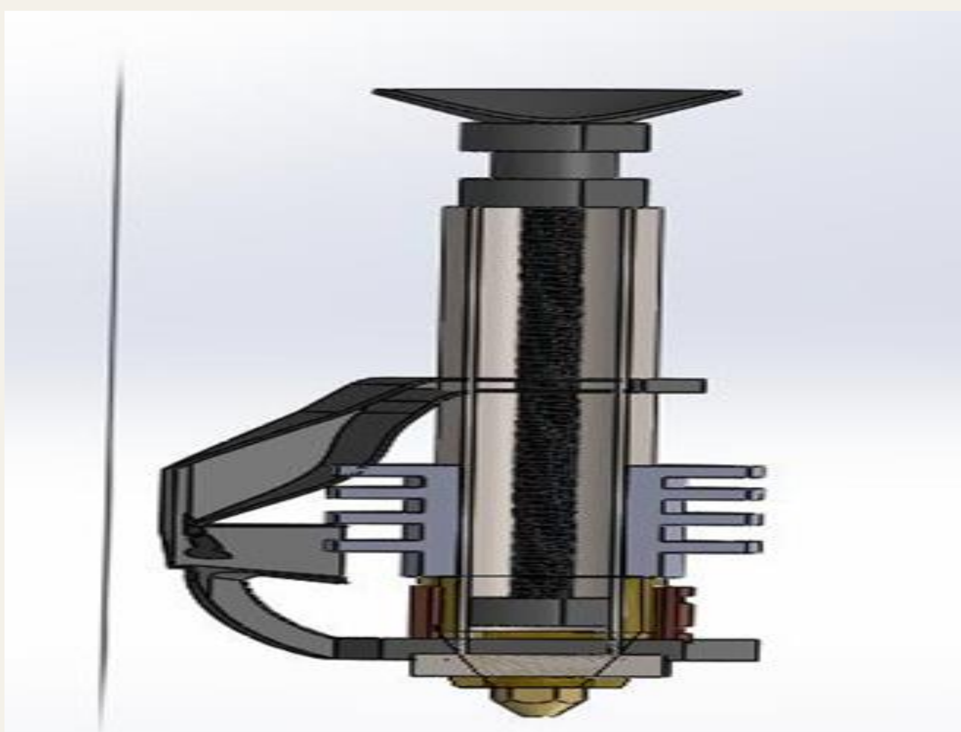

Figure 3: Extruder

RESULTS AND DISCUSSION

The simulations were carried out using SolidWorks software . The figure 4 -6 represents the statis stress, thermal and flow analysis results of various parts in extruder. The figure 7 represents the 3D printer used for the study and the proposed extruder will fit into the existing one for further analysis .

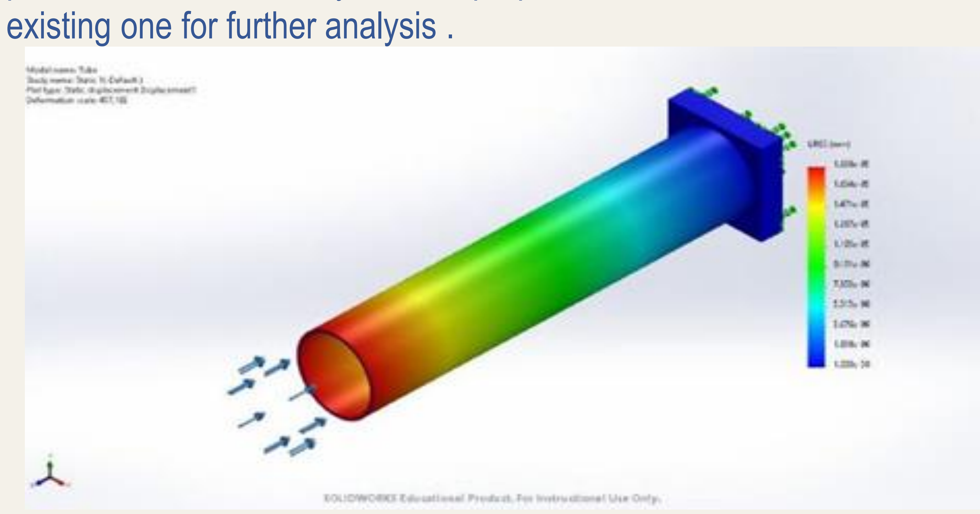

Figure 4: Static Structural Simulation Results – Tube Component.

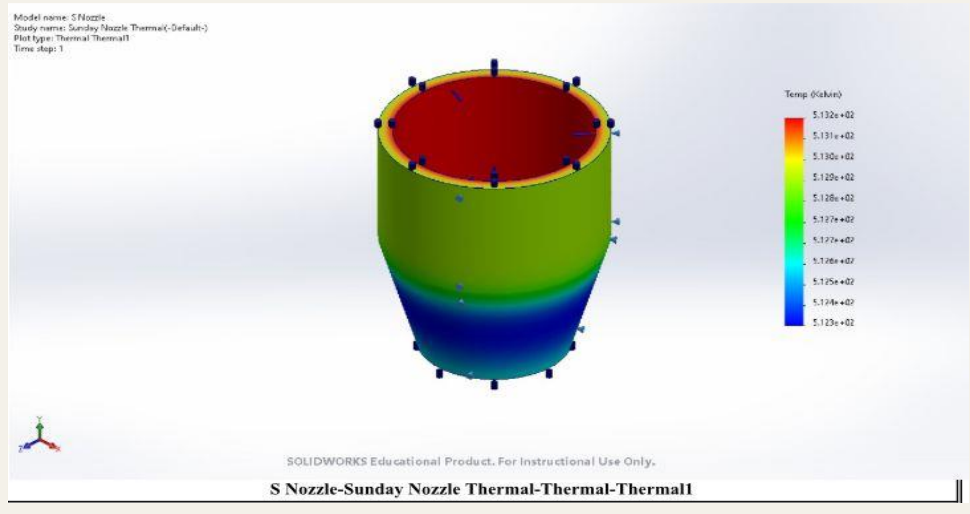

Figure 5: Thermal Simulation Analysis – Sunday Nozzle.

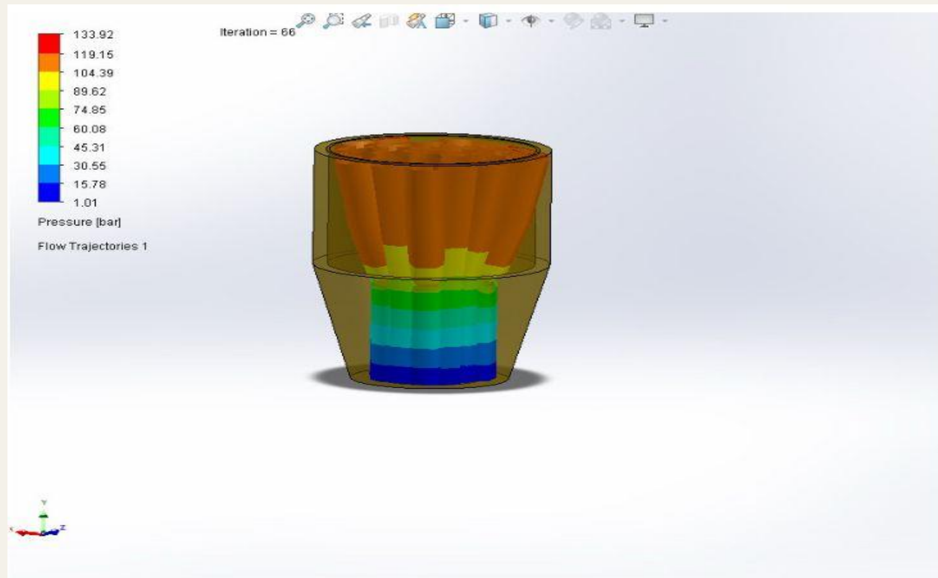

Figure 6: Flow Behavior Analysis – Sunday Nozzle.

Figure 7: 3D Printer with Extruder under testing

Conclusion

Simulations were conducted to verify the design — thermal analysis confirmed effective heat distribution, while structural and flow simulations ensured mechanical reliability and smooth extrusion. This project supports the growing need for sustainable solutions in additive manufacturing, particularly in reducing plastic waste and encouraging material reuse. With further testing and refinement, the extruder has the potential to contribute to more efficient and environmentally friendly 3D

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