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Recycled Materials in Additive Manufacturing: A Sustainable Approach

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Abstract-- **Additive Manufacturing is disrupting the conventional process of producing goods. Additive Manufacturing activities employ modern-day technology that allows them to provide new avenues for how we design products in an effective manner, enable us to quickly produce prototypes, and improve the range of materials used to manufacture goods. Unfortunately, due to the amount of plastic now being produced using Additive Manufacturing, this has led to an overabundance of plastic waste and many concerns regarding the impact of plastics on the environment. This article outlines the sustainable approach of Additive Manufacturing by using recycled plastic materials produced from the post-consumer use of plastic materials for Fusion Deposition Modelling. Examples of post-consumer waste include polylactide (PLA), polyethylene terephthalate (PET) and acrylonitrile butadiene styrene (ABS), which is processed to produce 3D Printer Filament via mechanical recycling methods. We compare the mechanical, thermal and printability properties of the recycled filaments with those of virgin polymers. The results of our experiments indicate that the recycled material retains approximately 75% to 90% of the mechanical strength of the virgin polymer and has lower cost and reduces the environmental impact of traditional virgin plastic. This article demonstrates the feasibility of using recycled plastics as a viable option for manufacturing non-critical engineering applications, which contribute to the development of the Circular Economy and Sustainable Manufacturing Practices.**

Keywords— **Additive manufacturing, recycled materials, sustainable 3D printing, FDM, circular economy.**

I. Introduction

Additive Manufacturing (AM) which is also known as 3D printing has changed the technique things are made by allowing complex parts to be made layer by layer, beginning from digital files. Many different types of AM techniques exist, but most people use Fused Deposition Modeling (FDM) because it is simple, low-cost, and has a wide variety of materials. However, the increasing amount of use and demand for thermoplastic filaments(PLA, ABS and PET) has created concerns about the environment due to plastic waste and carbon emissions. Recycling plastic waste into 3D printing filaments is a viable way to help solve these problems and promote sustainable manufacturing practices.

The purpose of this study is to determine if using recycled plastic materials in additive manufacturing can, in fact, be done. Further, the study compares how well recycled plastics perform (mechanical properties, thermal properties, and economic factors) relative to virgin materials.

II. Literature Review

Numerous studies have examined the utilization of recycled polymers within the additive manufacturing sector. Based on back-tests, it appears that continued thermal processing will eventually degrade polymer chains, thus diminishing the mechanical properties. There are several examples of successfully utilizing recycled materials through optimized extrusion processes and controlled recycling cycles. Recently, advances in the development of additive manufacturing have clearly identified the integration of recycled materials as an important aspect of a circular economy model. Additionally, material location and characterization need to be done correctly in order to ensure reliable engineering performance.

III. Materials And Methodology

A. Material Selection: Post-consumer plastic waste was collected and categorized as:

a) Polylactic Acid (PLA) waste
b) Polyethylene Terephthalate (PET) bottles
c) Acrylonitrile Butadiene Styrene (ABS) scrap

The materials were cleaned, shredded, and dried prior to extrusion.

B. Filament Fabrication: A single-screw extruder was used to fabricate 1.75 mm diameter filament. Extrusion parameters were optimized to ensure dimensional consistency and smooth filament surface.

C. 3D Printing Process: Standard test specimens were printed using an FDM 3D printer following ASTM standards. Printing parameters were kept constant for both recycled and virgin filaments.

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D. Testing and Characterization:

a) Tensile strength (ASTM D638)
b) Flexural strength (ASTM D790)
c) Thermal analysis using DSC
d) Visual inspection for surface quality and layer adhesion

IV. EXPERIMENTAL DATA TEMPLATES

Table I:
Extrusion Parameters

Material	Extrusion Temp (°C)	Screw Speed (RPM)	Filament Diameter (mm)
PLA-R	175-185	25-30	1.75 ± 0.05
PET-R	240–250	30–35	1.75 ± 0.06
ABS-R	210–220	35-40	1.75 ± 0.07

Table II:
3D Printing Parameters

Parameter	Value
Nozzle Diameter	0.4 mm
Layer Height	0.2 mm
Infill Density	100%
Print Speed	50 mm/s

Table III:
Mechanical Properties Comparison

Material	Tensile Strength (MPa)	Flexural Strength (MPa)	Elongation (%)
Virgin PLA	58–62	85-90	5-7
Recycled PLA	45–50	70-75	3-4
Virgin PET	52–56	75-80	12-15
Recycled PET	40–45	60-65	8-10

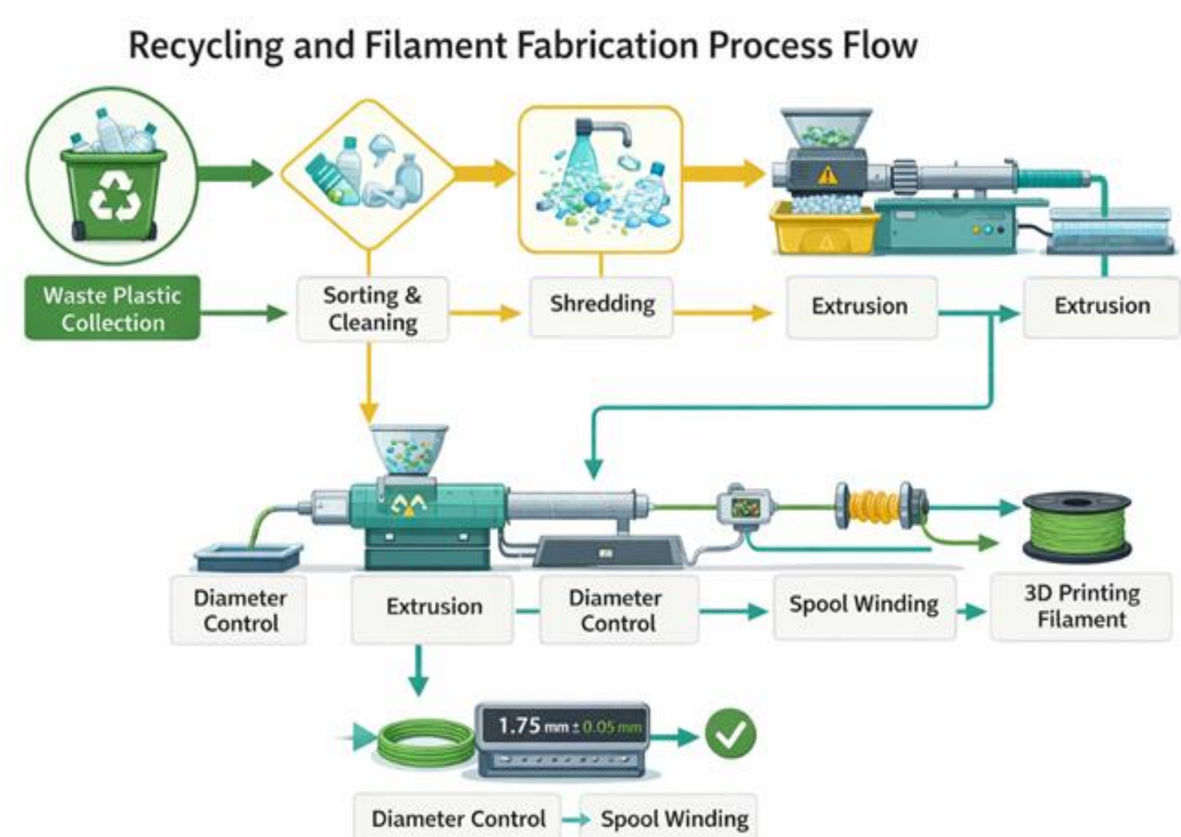

Fig. 1. Recycling and filament fabrication process flow

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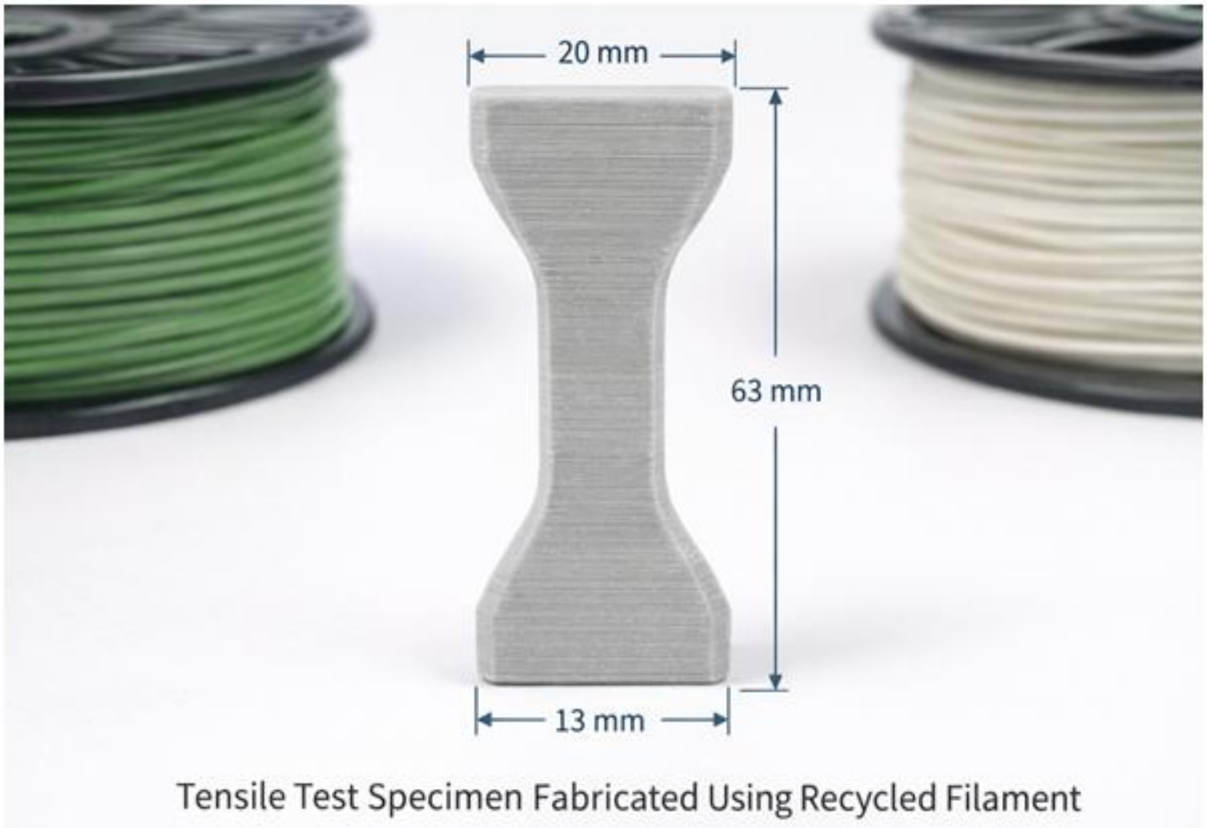

Fig. 2. Tensile test specimen printed using recycled filament

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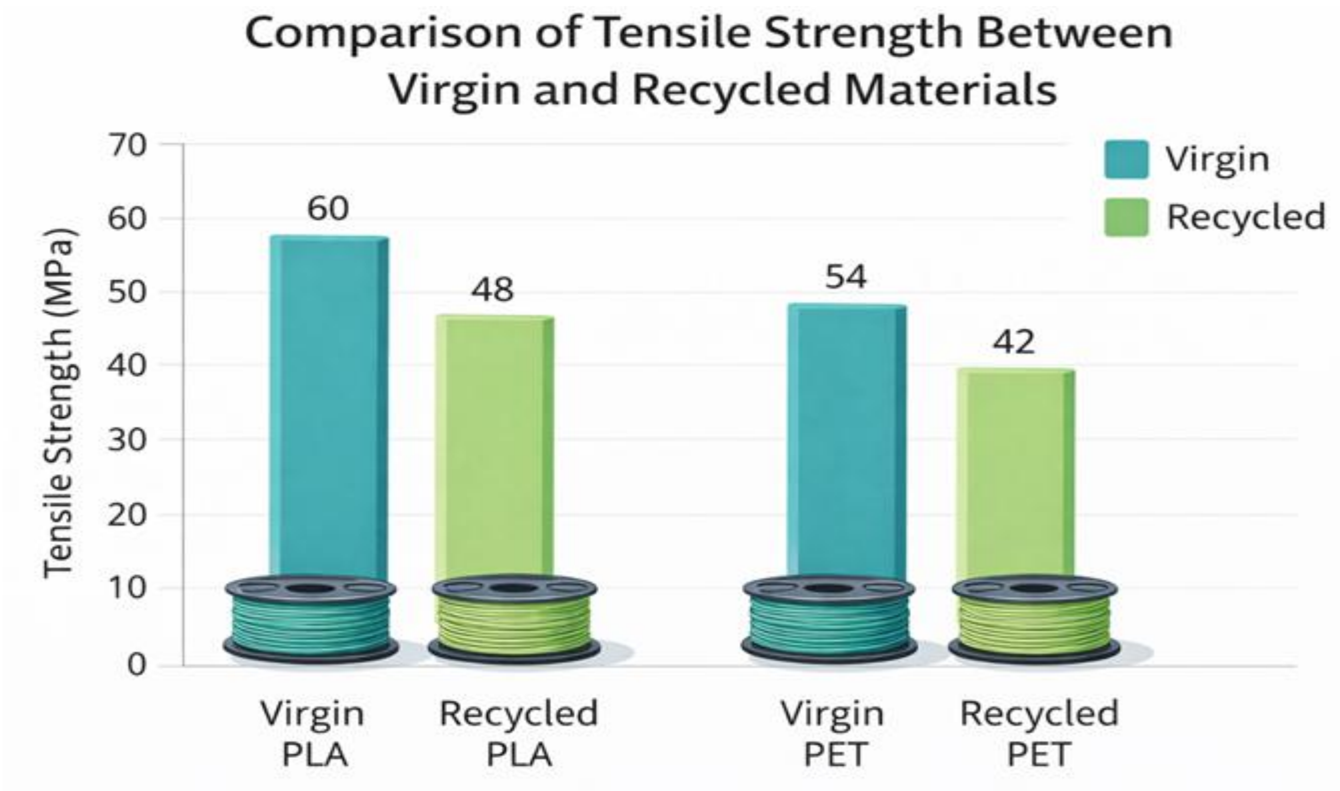

Fig. 3. Comparison of tensile strength between virgin and recycled materials

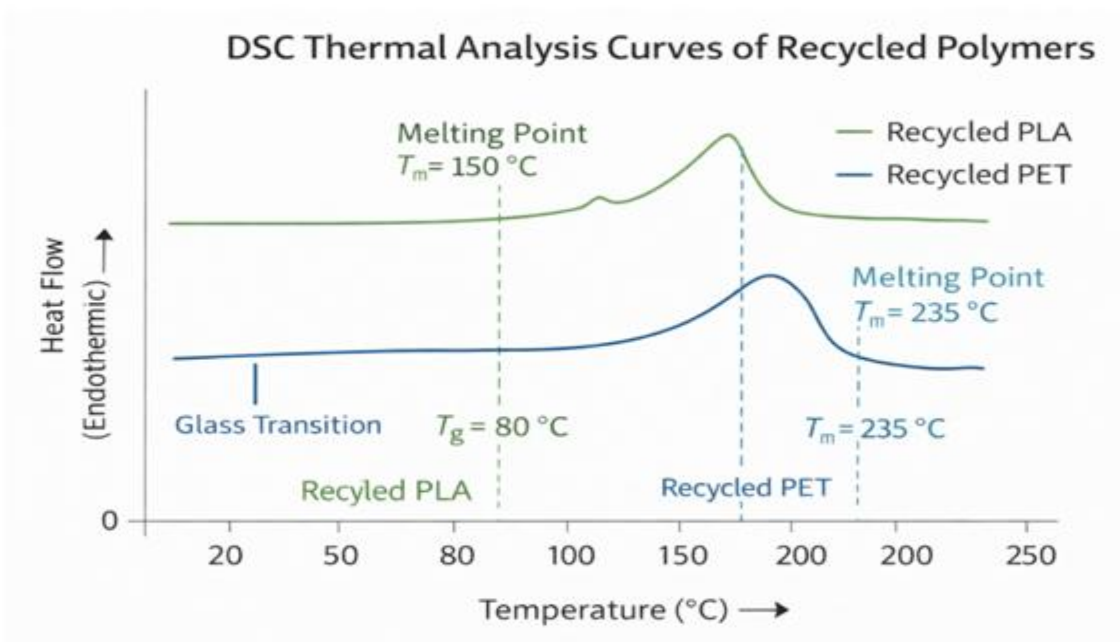

Fig. 4. DSC thermal analysis curves of recycled polymers

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V. Discussion And Results

It demonstrate that at least to some degree the filament mechanical properties of recycled polymers were still maintained. As mentioned earlier, of all recycled filaments produced in the study, the dimensionally stable material was the PLA filament, which is more stable than the upper or lower PET or ABS filament, even after thermal degradation occurred. The surface of the filament samples had some minor defects due to contamination and degradation from exposure to temperature. The glass transition temperature (Tg) for both ABS and PET filament samples were lower than the 200 °C of the virgin counterparts. However, these variations due to contamination and degradation did not limit the material acceptance for using in low-stress print jobs.

VI. Economic/Environmental Impact

An analysis of the impacts of utilizing recycled filament for printing functional parts versus virgin filament has determine that to print with recycled filament results in 35–45% less cost than with virgin filament. This translates to a significant reduction of waste in landfills and reduced energy consumption and a large overall reduction of greenhouse gas (GHG) emissions in printing and manufacturing products.

VII. Summary Of Conclusions

This work has demonstrated that printed components produced from recycled polymer materials can be used in additive manufacturing to create environmentally sustainable products. Even though mechanical properties of recycled printed components are reduced as compared to virgin polymer components, they will perform adequately as both functional products and prototypes.

These findings support advances within the Circular Economy and Green Manufacturing models with recycling techniques and multiple cycles of recycling for polymer products as potential directions for future research.

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