Recycling of plastic waste for additive manufacturing

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Background
The production of complex geometries as available in advanced computer-aided design software has emerged as a research area in three-dimensional (3D) printing. The scientific community is encouraged to continue developing high-performance 3D printable polymer composites that provide benefits such as cost-effectiveness, high precision, reduced polymer waste, minimal chemical usage, and customized complex geometries due to the limitations in 3D printability and mechanical properties of virgin polymers. Data shows that up to 90% of plastics could be reused.

Problem
Due to energy, economic, and logistical difficulties, the poor polymer recycling rate remains a difficulty for humanity today. The usage of thermoplastic materials in the industrial and public open-source additive manufacturing sector is increasing exponentially, resulting in an increase in worldwide polymer consumption and waste generation.

Objectives
• To demonstrate the technical viability of recycling thermoplastic material used as open-source 3D printing filaments.
• Determine effective total blend combination of recycled plastics and virgin plastics.
• Determine the relationship between the extrusion speed and the diameter of the extruded filament.
• Determine surface morphology and mechanical properties of 3D filaments produced.

Methodology

Research phase
• Preparation of raw materials
• Sampling of raw materials
• Chemical characterization
• Mechanical characterization

Manufacturing phase
• Preparation of raw materials
• Extrusion process
• Mechanical characterization

Characterization
• Surface characterization
• Mechanical characterization

Analysis phase
• Research
• Analysis

Key Findings

The blends were created using varying percentages of recycled PLA in a virgin PLA matrix at 175 and 180 degree Celsius.

95&10(%)

90

95

5

10

The effects of melt pressure and forces
• The melt pressure in the extruder chamber directly affects the surface morphology and extrusion diameter of the extruded filament.
• Higher melt pressure is beneficial to reducing surface defects of the extruded filament.

Surface defects are depressed.

The results from the recycling process provide compelling evidence of the feasibility of using recycled PLA for open-source additive manufacturing. However, as the main result, it is highlighted that the recycling process reduces the mechanical properties.

95&90(%)

Future work
• It is recommended that blends be made with the addition of an epoxy-based chain extender (CE)
• Joney's/CE main effect will be to control the Melt Flow Index (MFI) of the bio composites containing recycled PLA.
• The inclusion of CE will improve the impact strength of the filaments produced.

Most notably, this finding is promising, and it could serve as a basis for the study of recyclability of other industrial polymers in order to establish the viability for use in the 3D printing chain.

• Eventually, the viability of an industrial sector focused on polymer waste in 3D printing technology could be a subject of study. Future work should focus on the chemical and thermal degradation of the polymer, as well as the determination of molecular weight reduction and changes in the temperatures of the polymer during the recycling process.

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Conclusion

The effects of the extrusion speed on the stability of the filament

\[ V_s = \frac{d}{V_x} \]

where \(d\) is the diameter of the extruded filament, \(V_s\) is the printing speed (or the nozzle velocity in the \(x/y\) direction), \(V_x\) is the extrusion speed (or the linear velocity pushed by the extrusion motor), \(D\) is the diameter of the rod.

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References


