Recycling of plastic waste for additive manufacturing

Moses Duah, MS Mechanical Engineering
Mentor: Professor Patrick Phelan
Ira .A. Fulton Schools of Engineering
Arizona State University

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 sectors 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.

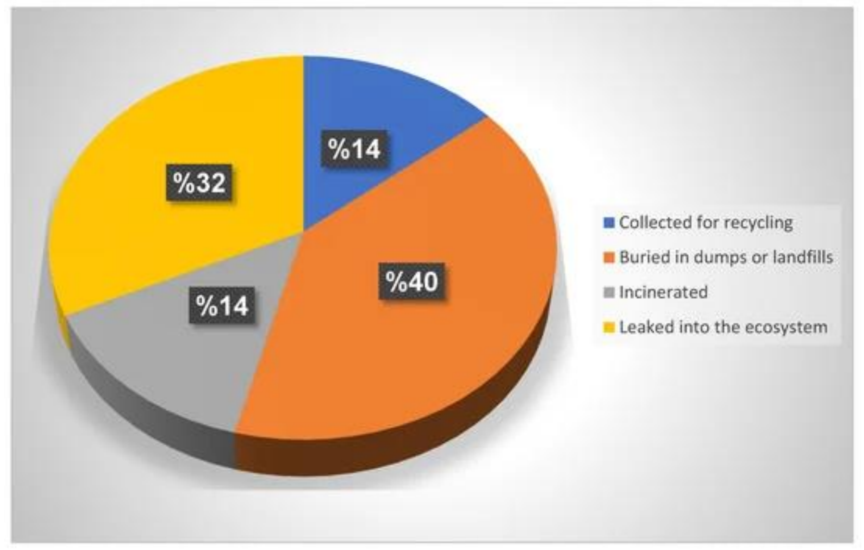
Methodology

Research phase → Literature review → Research methodology → Initial characterization of material

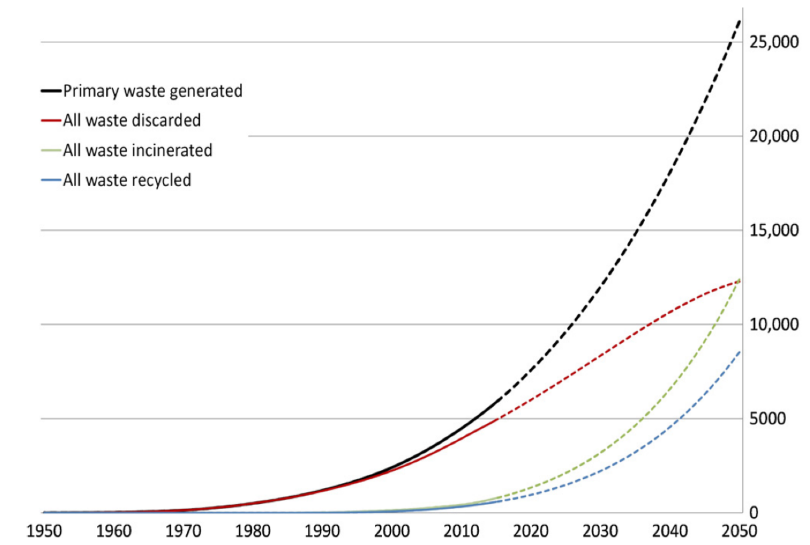
Analysis phase → Preparation of polymer to be recycled → Manufacturing process of 3D printing filaments → Characterization of experimental conditions

- The manufacturing processes were repeated for high accuracy

Key Findings



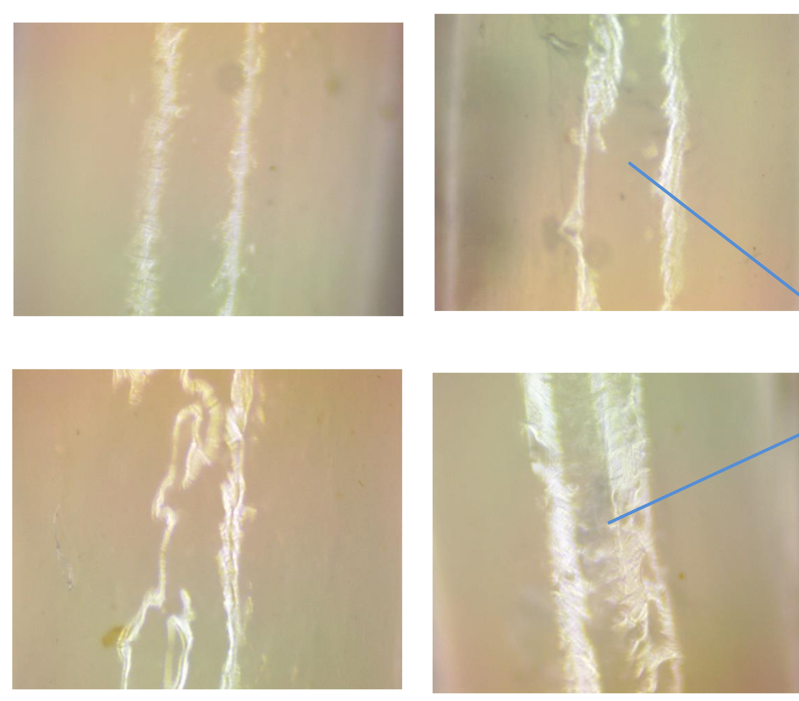
Most plastics are not recycled



•Americans use 2,500,000 plastic bottles every hour! Most of them are thrown away.

•Plastic bags and other plastic garbage thrown into the ocean kill as many as 1,000,000 sea creatures every year.

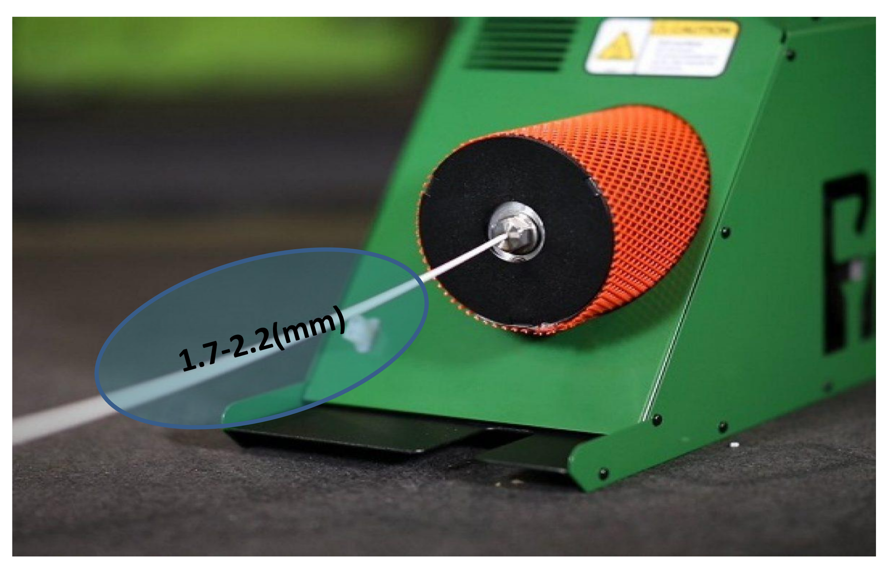
•Recycling plastic saves twice as much energy as burning it in an incinerator.



Results show that recycled plastics were non uniformly distributed in the blend matrix of PLA and RPLA

Recycle plastics

Images from the microscope showed the non-uniform distribution of the recycled plastics in the PLA pellets blend. Plastics must be shredded into very small pieces to allow for uniform blend with PLA pellets. Addition of chain extender will allow for more recycled plastics to be included.



- It is recommended that blends be made with the addition of an epoxy-based chain extender (CE)
- Joncryl'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.

Effects of the extrusion speed on the stability of the filament

$$\frac{V_x}{V_a} = \left(\frac{D}{d}\right)^2$$

where d is the diameter of the extruded filament, Vx is the printing speed (or the nozzle velocity in the x/y direction),

Va is the extrusion speed (or the linear velocity pushed by the extrusion motor), D is the diameter of the rod

Surface defects are depressed.

- The extrusion process is stable under this condition.
- The frequency of the extrusion force oscillation improves.
- The robustness of the extrusion process is improved and stable.

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

PLA %	RPLA %
95	5
90	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
- A fluctuating extrusion force is the main constraint on the stability of extrusion

95&90(%)

5&10(%)

Future work

- 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.

Conclusion

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.

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