Enabling closed-loop additive manufacturing through an on-demand feedstock material customization system

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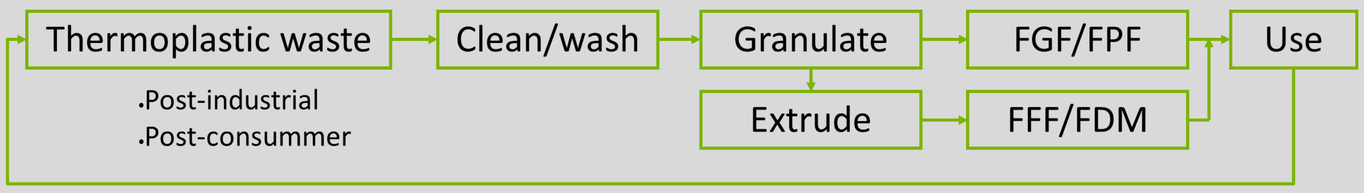
1. Background

The solution for the current plastic waste crisis requires the adoption of circular flows of material. Such a flow has been proposed for material extrusion additive manufacturing technologies: distributed recycling (Image below). In mechanical recycling, thermoplastics suffer degradation processes which affects their properties. To allow the use of the multiple times-recycled polymers in the production of functional parts, there is the need to improve the current distributed recycling model. This work, being developed in a doctoral program, aims to do just that.



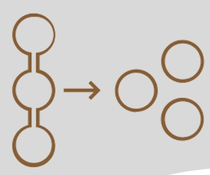
2. Aims

- **Quantify** the effects of multiple FFF reprocessing cycles in PLA;
- **Test** additives for modification of reprocessed PLA, and to **quantify** their influence in properties and microstructure;
- **Adapt** a nondestructive ways for property assessment and prediction;
- **Develop** ways of deciding how to customize PLA and printing parameters to get target properties;
- **Develop** a prototype for the concept.

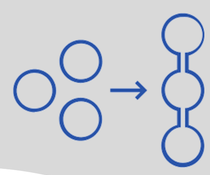
3. Methodology

1 - Study material degradation

- Apply multiple reprocessing cycles to Poly(Lactic Acid) PLA with extrusion of filament and successive FDM;
- Register thermal, mechanical, chemical and theological properties after each cycle;



2 - Study additives for degradation mitigation



- Test the performance of, and select additives for properties recuperation;
- Apply multiple reprocessing cycles to PLA with additive mixing, filament extrusion, and FDM;

3 - Process parameters optimization

- Test multiple combinations of printing parameters with materials with varying number of cycles;
- Register mechanical properties, geometrical accuracy and occurrence of defects.

4 - Development of prediction and control models

- Develop hardware and software to measure and monitor melt behavior in the extrusion process;
- Develop computational models to predict the properties that can be expected from the assessed material;

5 - Development of a demonstration prototype

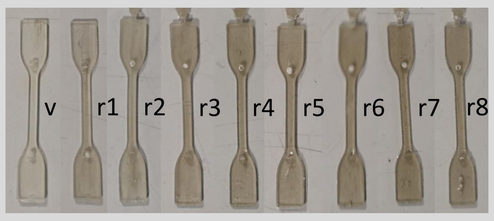
- Develop a prototype system that integrates software and hardware solutions referred in 4, as well as adaptation of existing equipment to allow for a controlled mixture of the additives.

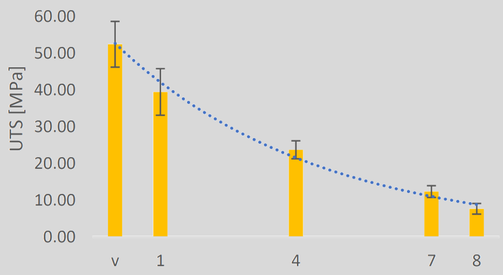
6 - Sustainability validation

- Identification of real world applications;
- Evaluation of environmental, social, and economic sustainability dimensions through a sustainability analysis;

4. Current progress

- Reprocessing PLA through injection moulding (images below): Decline in tensile strength with each cycle;
- Reprocessing PLA through extrusion and FDM: Filament became not viable with one cycle;
- Tests to understand how chain extenders can extend the number of cycles are ongoing.





A monitoring system for acquisition of data from sensors to monitor polymer melt behavior in the extrusion machine, which will be used to assess degradation through the application of prediction models is in development.

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