Air Quality Monitoring in the Environmental Processes

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Abstract: *Classic air quality monitoring technology has reached its technological and cost limits. As spatial monitoring improves, pollution sources, dispersion patterns and health effects can be better addressed while reducing reliance on predictive models. In this context, the work presents a sustainable process of obtaining recycled plastic filament and the environmental conditions and testing of the finished product.*

Keywords: *Plastic recycles, 3D printing process, fused deposition modelling, mechanical recycling*

1. Introduction

The sustainability of the environment is dependent on: the number of the population; rapidity materials development; technological processes and industry-specific activities; all these, more or less, are waste generators [1].

Aspects related to environmental sustainability are in the attention of researchers, but also among legislative priorities at European and global level, thus "Directive (EU) 2018/851/EC amending Directive 2008/98/EC on waste" emphasizes the need for improvement and transformation waste management terminology in sustainable materials management to protect, to conserve and improve the quality of the environment, to protect human health, to ensure the prudent, efficient and rational use of natural resources, to promote the principles circular economy, to increase the use of energy from renewable sources, to grow energy efficiency, to reduce the Union's degree of dependence on imported resources, to create new economic opportunities and boost long-term competitiveness [2].

Over time, waste legislation has evolved from the simple management of them to addressing health problems, protecting the environment and even avoiding them waste and the recovery of resources from generated waste [3].

The concern for the field of waste management is topical worldwide, given the fact that in recent years there has been an intensification and diversification of activities in all economic-social sectors, reaching an upward dynamic of the quantity generated [4,5, 6].

In the current context of the development of the sustainable society, there is the problem of reusing waste, especially plastic waste. The activity of selective collection of waste and its transformation into reusable materials is an important concern at the global level [1,2, 5]. One of these materials is Polyethylene terephthalate (PET), which was patented in 1941 by Dickson and Winfield when they combined phthalic acid with glycol-based substances [7].

PET is a common plastic substance used to make water bottles, carbonated drinks, juices and others. It is a semi-crystalline thermoplastic material created by the condensation of terephthalic acid and ethylene glycol. This material can be found like: semi-crystalline PET, amorphous PET and glycol modified PET with higher impact resistance. PET is durable and easy to transport, but can be difficult to degrade in nature. If not recycled, PET can remain in the environment for hundreds of years, polluting the sea and other environmental areas [6].

The purpose of this study is to analyse the method of transforming PET into filament for use in the 3D printing process. "PET 3D printing is the process of creating a three-dimensional part using PET (polyethylene terephthalate) via additive manufacturing. This type of PET is a stiff, strong material used to make products for waterproofing, bottling, and food packaging. It's one of the most popular materials for Fused Deposition Modelling FDM/FFF-style 3D printing due to its chemical resistance, mechanical properties, and favourable melting temperature of 260°C” [7]. The material for 3D printing is named filament.

2. Material and Methods

2.1 Information about general characteristics of PET filament

PET is a polyester resulting from the esterification reaction of ethylene glycol in terephthalic acid. As the percentage of aromatic units in the polymer chain increases, so does its hardness and strength.
The properties of PET filament are [7]:

- excellent mechanical, thermal and electrical resistance;
- low absorption features;
- good flow characteristics.

The recycled material for PET filament are used PET bottles (virgin resin vPET, recycled material rPET and commercial material PETG) [6].
Another sources for 3D printing filament are:

- corn starch, tapioca roots or sugar cane, a very easy-to-use material for Polylactic Acid (PLA) (Figure 1) [8];
- glycol (G) + PET (Polyethylene terephthalate) for PETG (Figure 1) [8];
- thermoplastic polymer, ABS (acrylonitrile-20%, butadiene-25%, styrene-55%);

For each of these materials the properties are different (Table 1) [7].

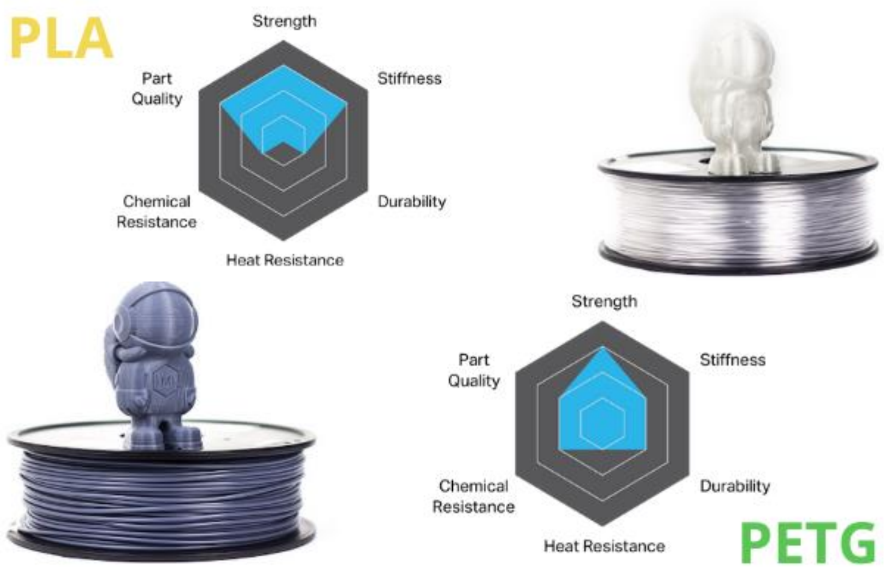

Fig. 1. Types of PET filament [8]

Table 1: The properties of different types of PET [7]

Characteristics of polyester	Polyethylene terephthalate (PET)	Polylactic Acid (PLA)	Acrylonitrile Butadiene Styrene (ABS)	PETG
Tensile strength (MPa)	57	38	44	50.4
E-modulus (MPa)	2300	3120	1900	2020
Elongation at break (%)	70	7	10 50	130
Flexural Strength (MPa)	82.5	106	2400	70

Characteristics of polyester	Polyethylene terephthalate (PET)	Polylactic Acid (PLA)	Acrylonitrile Butadiene Styrene (ABS)	PETG
Glass transition temperature (°C)	70	56.9	105	85
Recycled content	100%	55%	65%	67%
Heat deflection temperature (°C)	71.6-80.0	52	73	71 ... 103

The most common materials for 3D printing filament are PLA (in biomedical field, tissue engineering, in packaging industry, in textile industry) and ABS (in high temperature resistant objects).

2.2 Method

The purpose of this study is to analyse the method of transforming PET into filament for use in the 3D printing process, FDM - Fused Deposition Modelling. This FDM (Fused Deposition Modelling) rapid prototyping technology is the most widely used additive manufacturing technology and due to its simplicity it is also the most accessible. These characteristics recommend it for use in modelling, prototyping, but also in micro-production applications in low-technology, hard-to-reach areas. This method FDM is a process that includes "layer – by - layer deposition material, via a series of cross sectional slices" [9]. A CAD software is used to print 3D objects (Figure 1, Figure 2) [6].

Fig. 2. The design of sample PET filament

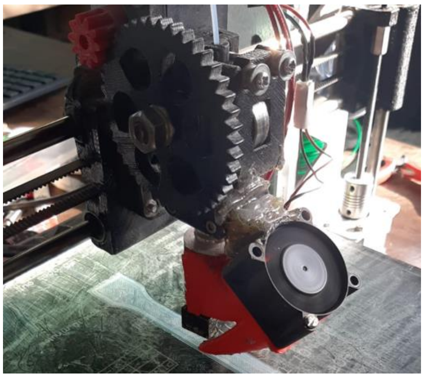

Fig. 3. 3D printing process with sample PET filament [6]

The design of the object is introduced in 3D printer (Figure 4) and after this the object is printed layer –by- layer deposition of raw material.

Fig. 4. CAD software used to print 3D objects

There are many other methods to design the objects [10, 11, 12].

2.3 Mechanical properties of PET filament

After obtaining the 3D printing material, the mechanical properties are analysed. The testing speed is varied from 3.5 to 5 mm/min. The time variation of the extrusion speed has a major influence on the filament thickness (Figure 5, Figure 6).

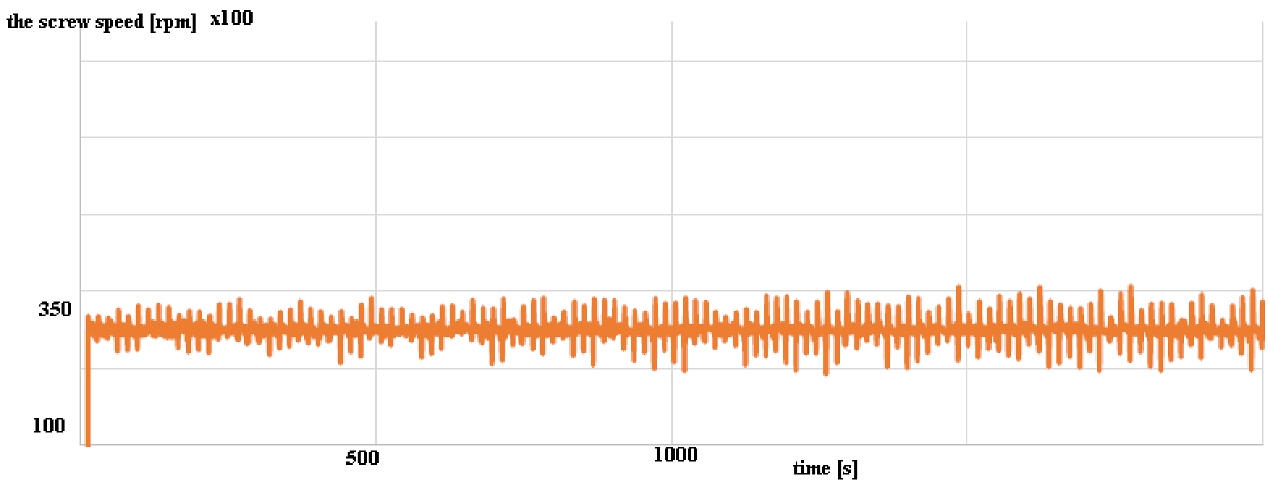

Fig. 5. The variation of screw extruder speed

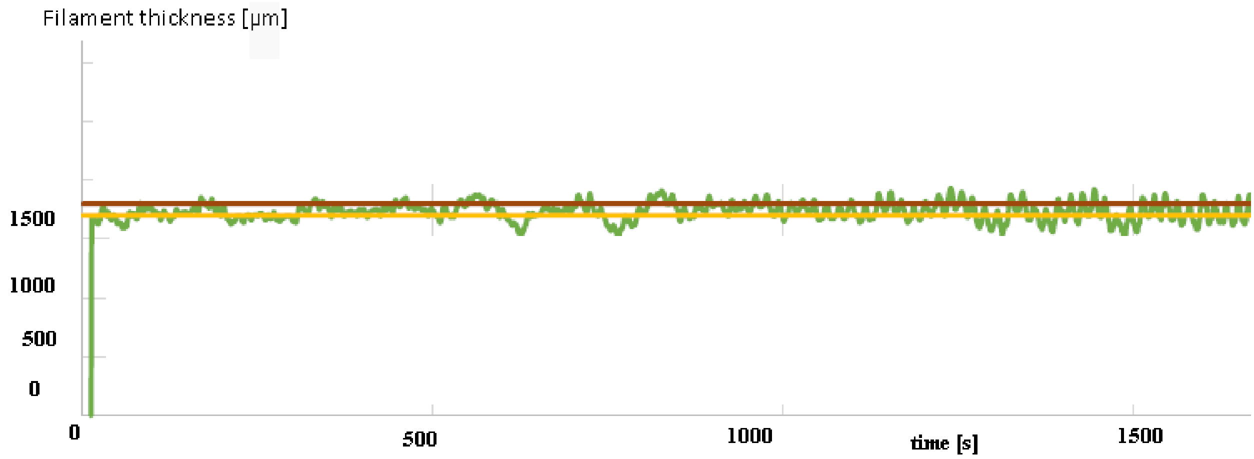

Fig. 6. The variation of filament thickness

It is observed that the variable speed changes the thickness of the filament. Therefore, a stable speed crew extruder is recommended (about 350 ... 380 rpm).

3D printing mostly uses plastic filaments which can be of various types and are made by following

the process of heating, extruding and cooling plastic.
Many industries have adapted re-using waste plastic products for the same purpose [9].
In this work the characteristics of PET filament which will be used for 3D printing process are shown in Table 2.

Table 2: Characteristics of 3D printing PET filament

Characteristics	Polyethylene terephthalate (PET)
Tensile strength (MPa)	42 ... 63
E-modulus (MPa)	3 330
Elongation at break (%)	69
Flexural Strength (MPa)	82.4
Glass transition temperature (°C)	70
Recycled content	100%
Heat deflection temperature (°C)	70 80

After a comparative analysis of the mechanical properties of general PET and PET filament we conclude:

- The minimum value of tensile strength for PET filament is 42 MPa, for industrial PET is 57 MP; the maximum value for PET filament is 63 greater than industrial PET;
- The PET filament has a better elasticity, when heat deflection temperature has a variation in the range 70 ... 800 C;
- During the heating cycles can observed the lamellar thickness distribution of the crystallites (~25% crystallinity);
- some printed objects show structural changes (elongations to tractions, ductile fractures) [13].

2.4 Environmental details of location for air quality monitoring

- **Thermal analysis of plastics**

The heat flux curves of waste PET and PLA are given in Fig. 7.

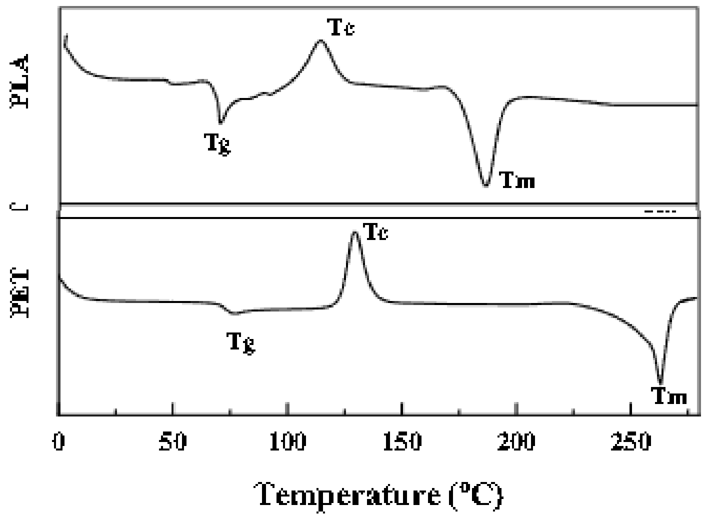

Fig. 7. The variation of heat flux

Where Tc (°C) – the crystallization temperature; Tg (°C) (glass tran-sition temperature; Tm (°C)-melting temperature.
We observe that if compare the heat capacity values of pure PET and pure PLA, the heat capacity value of PET is lower than PLA.

- **Environmental data of air monitoring in location**

The location of process is a workspace for which we have collected daily and weekly data (Table 3, Figure 8, Figure 9) to monitoring air quality in closed space.

Table 3: Daily and weekly variation on temperature and humidity

Day/hour	Air temperature (^{0}C)	Air humidity (%)
5/15/2023 21:21:00	22	39.1
5/15/2023 20:01:00	22	39.1
5/15/2023 18:51:00	22.4	38.6
5/15/2023 18:01:00	22.3	39.1
5/15/2023 14:41:00	22	39
5/15/2023 13:21:00	22	39.1
5/15/2023 12:51:00	21.5	40.6
5/15/2023 12:11:00	21.9	39.6
5/15/2023 9:21:00	21.7	40.1
5/15/2023 3:41:00	21.5	40.6

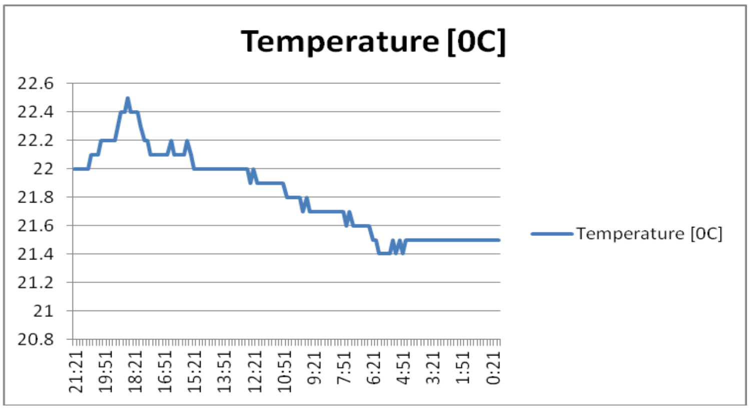

Fig. 8. Daily variation of temperature

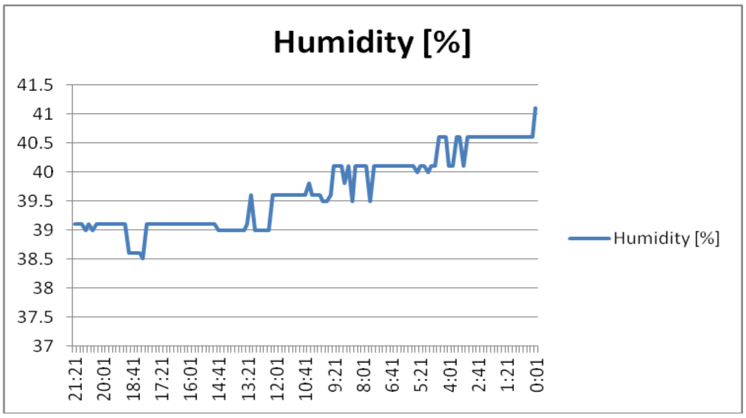

Fig. 9. Daily variation of humidity

The location can be provided with a connection to a photovoltaic system, consisting of a solar panel, buck boost inverter and battery (battery), which provides electricity on sunny days, thus contributing to the application of the concept of environmental sustainability.

3. Conclusions

According to the test standards for tensile (SR EN ISO 527-4:2000), shear (SR EN ISO 14129:2000), bending (SR EN ISO 14125:2000), impact (SR EN ISO 179-2:2002/ SR EN ISO 180:2001) test standards we can conclude that the samples obtained by 3D printing respect the layering of the fibres, their distribution being symmetrical and balanced, framing belong to the group of thermoplastic materials.
After several experiments, it can be concluded that the variation of the screw extrusion speed can influence the thickness of PET filament and its structural qualities. Also, the temperature variation of the heating cycle of the printing material is very important.

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