

Compression testing of samples printed on Delta and Cartesian 3D printer

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Abstract. This paper presents a short part of a larger research and consists in the investigation of the compression behavior of samples printed on two 3D printers, one Delta and one Cartesian, from three types of the commonly used materials, Polylactic acid (PLA), Carbon fiber PLA (CF-PLA), and Polyethylene terephthalate glycol (PETG). After a specific introduction regarding the subject, the printing parameters used for printing the samples are exposed, in a table, followed by a paragraph on the compression testing, both with general and particular information, on this case. The research being under development, the first set of results obtained is presented, further tests and analysis following in order to realize a comprehensive characterization of the 3D printed materials' behavior.

1. Introduction

In the context of using, at a larger and larger scale, of 3D printing in manufacturing processes, mainly, due to its advantages and accessibility, different kind of researches are developed in this area in the last period, in order to find the best solutions for certain situations. From a large range of 3D printing processes, or additive manufacturing technologies (AMT) existing today, the Fused Filament Fabrication (FFF), or Fused Deposition Modeling (FDM) is the most widely used. Many types of materials, increasingly newer and better, are used for 3D printing, the most commonly used today being Polylactic Acid (PLA), Acrylonitrile Butadiene Styrene (ABS), Polycarbonate (PC), Polyethylene Terephthalate (PET), Polyethylene Terephthalate Glycol (PET-G), Polyether Ether Ketone (PEEK) or High-Impact Polystyrene (HIPS), base materials or with various inserts, such as carbon fiber, to improve the properties of the filament. A state-of-the-art guide to modern plastics is represented by [1], which contains a comprehensive approach, an A to Z guide, to the plastics' processes, forms, formulations, design, equipment, testing, and recycling. Many properties and testing methods of the plastic materials are, generally, common to these materials, and the standard testing methods are globally accepted, as presented in [2]. But, despite the increasing use of 3D printed parts, mainly through FDM printing technology, there are no defined standards, specially dedicated to this category of plastic parts. It is generally accepted in this case and is used by the majority of authors, the standard ISO 527 for tensile test [3] and ISO 604 for compression test [4].

A large and consistent analysis of the mechanical properties of parts produced through FDM additive manufacturing technology and the influence of the factors such as material composition, extruding temperature, printing parameters, and environment temperature, on their behavior to tensile and compressive tests, are presented in [5]. A lot of experimental research has been done, and numerous scientific articles have been published, each addressing, in a different manner, the 3D printing and testing of certain standardized test specimens, mainly at tensile and compression. Thus, the experimental characterization of the mechanical properties of the 3D-printed test specimens, by using different printing parameters, are presented, depending on the material used, in: [6], [7] and [8] with PLA; [9] with PLA+ and CF-PLA; [10] and [11] with ABS, [12] with ABS and PC; [13] with PLA, ABS, PETG, and HIPS; [14] with multi-material interfaces. In [15] is presented an extensive state-of-the-art review regarding the optimization of the FDM additive manufacturing process in order to achieve the maximum tensile strength, through a comparative study with PLA, PC, PEEK and ABS.

After studying the few recent and relevant researches in this field, mentioned above, and taking into consideration the available material capacities, we resorted to our own research, by using two 3D printers, and three types of materials, for the printing two models of samples with different printing parameters and working conditions. The experimental procedures and first results obtained at compression testing for one type of the printed samples are further presented in this paper.

2. Printing parameters of the samples

The 3D printers used for printing the samples, available in our laboratory, being part of the medium printing category, are Delta model FLSun QQ-S PRO and Cartesian model Tevo Tornado. Technical specifications of these printers and the software used, as well as an extensive explanation of the printing settings for printing the chosen samples, can be found in [16].

The samples printed for compressive testing are a cube-type model, 20x20x20 mm, with one single piece on the bed, and with the printing settings according to the printing capacity of the printers and filaments used. Three types of the material, PLA, Carbon fiber PLA (CF-PLA), with 20% carbon fiber insertion and PETG were used for printing the samples, with the parameters presented in Table 1.

Table 1. Printing parameters of the samples

3D printer Material	Delta model FLSun QQ-S PRO			Cartesian model Tevo Tornado		
	PLA	PLA-CF	PET-G	PLA	PLA-CF	PET-G
Infill density	100 %	100 %	100 %	100 %	100 %	100 %
Layer thickness	0.2 mm	0.2 mm	0.2 mm	0.2 mm	0.2 mm	0.2 mm
Number of shells	4	4	4	4	4	4
Print speed	85 mm/s	85 mm/s	85 mm/s	65 mm/s	65 mm/s	65 mm/s
Nozzle temperature	225 °C	225 °C	225 °C	225 °C	225 °C	225 °C
Bed tempera-ture	60 °C	60 °C	80 °C	70 °C	70 °C	80 °C

3. Compression testing of samples

The testing of compression is made to determine the material behavior under the compression loading. The test specimens are compressed until a specified value of compression loading, until the cracking, or until the breaking. How there are no defined standards, specially dedicated to the parts printed by using AMT, the compression tests of this type of parts are carried out by using the standard ISO 604:2002 Plastics - determination of compressive properties.

There are a wide variety of machines and equipment available for compression testing, standard or that can be adapted to some specific applications if it is necessary. In this case was used a SCHMIDT Servo Press, with PressControl 5000 HMI, a compact system control for intelligent process control. A sequence during the testing of a PET-G sample, as well as the visualization of the loading diagram, on the display of the control system, are shown in Figure 1.

The types and dimensions of the test specimens from plastic materials, as well as their preparation for testing, are specified in the standard ISO 20753:2018 Plastics-Test specimens. How the enumeration in the standard does not exclude other kinds of test specimens, and there is no special standard for test specimens produced through FDM, other models are sometimes used, cylindrical or prismatic in shape. In Figure 2 are presented three sets of samples, from PLA, PLA-CF and PET-G, after the compression.

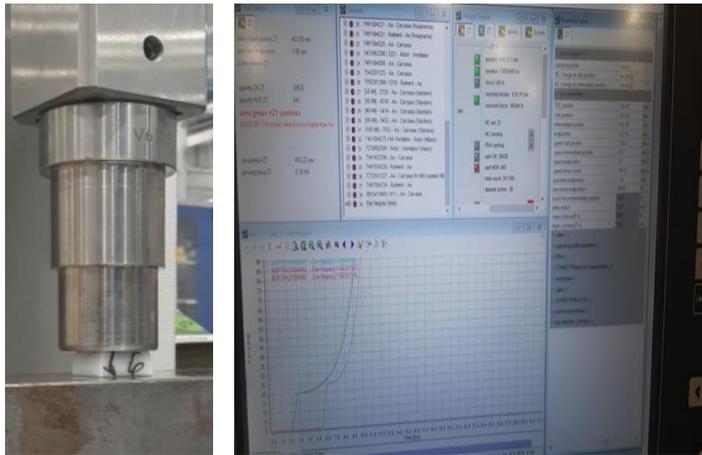


Figure 1. Compression testing of a PET-G sample.

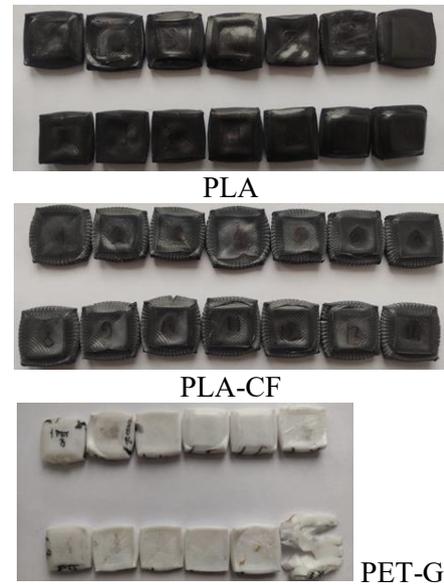


Figure 2. Compressed samples.

4. Results of the compressive testing of samples

By using the control system and software installed on the press, a few parameters can be displayed and analyzed. The first set of them, namely the minimum and maximum forces reached at the ends of the working stroke, previously set, can be seen in Table 2. A detailed analysis and an extensive characterization of the materials' behavior will be conducted in the near future.

Table 2. Compression loading: Reached Force Minim [N] and Reached Force Maxim [N]

Nr. sample	Delta model FLSun QQ-S PRO			Nr. sample	Cartesian model Tevo Tornado		
	PLA	PLA-CF	PET-G		PLA	PLA-CF	PET-G
1	11152	28540	18800	8	35250	23873	22500
	82512	90240	90480		75072	85632	90576
2	12350	22584		9	35810	21848	22600
	84432	61392			74592	83280	90363
3	8706	22872		10	35760	21657	21200
	83232	62832			73584	79104	90384
4	8905	22426	23800	11	31824	22176	23400
	78240	71904	90576		73344	83664	90768
5	35654	22511	21980	12	29587	21908	16800
	84816	72720	90336		82080	83750	90384
6	8950	22850	18900	13	37820	22018	
	69744	72864	90624		71184	82224	
7	21507	23528	20110	14	30257	20154	
	75600	83856	90384		75456	83040	

5. Conclusion

A short part from a larger research under development was presented in this paper. It consists of the compression testing of a type of sample, in a cubic shape, printed on two 3D printers, one parallel and one Cartesian, from three types of the commonly used materials, Polylactic acid (PLA), Carbon fiber PLA (CF-PLA), with 20% carbon fiber insertion, and Polyethylene terephthalate glycol (PETG). In order to realize a comprehensive characterization of the materials' behavior, further tests and analysis will be developed and presented in future work.

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