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**Effective elastic properties of 3D printed specimens,  
in a context of property optimization**

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## **1. INTRODUCTION**

Additive manufacturing by fused filament deposition (FFF) of polymer filament has been widely spread and popularized during the 2010 years. Since then, a wide variety of printers, polymer materials and printing parameters have been investigated [1; 2]. In this context, the specimen design was carried out *via* FreeCAD (<https://www.freecadweb.org/>) then converted for the FFF printing *via* Prusa Slicer (<https://github.com/prusa3d/PrusaSlicer>). The data processing of the tensile tests was performed *via* Scilab (<https://www.scilab.org/>). Thus, a Prusa 3D printer was selected and implemented for the fabrication of standardized PLA specimens [3; 4]. A parametric study on the type of filling allowed to illustrate the variability of the effective mechanical properties obtained *in fine*, through tensile tests measurements.

## **2. MATERIALS AND METHODS**

Although widely used, the optimal use of 3D printers often results from an empirical experience. The work presented here stands in the framework of the tensile characterization of polymer following the ISO 527-1 [3] standard with specimens according to the ISO 527-2 standard [4]. The effective mechanical properties of FFF printed polymers strongly depends on the fabrication process. Each FFF printing parameter has an influence on the actual properties obtained *in fine* [1; 2]. A set of tensile specimens was manufactured according to ISO 527-2 [4], with constant parameters (straight filling pattern, layer thickness of 0.3 mm, extrusion at 215°C, platen at 60°C, printing at 50 mm/s), while two printing parameters are varied, combining the filling rate {60%; 100%} and the printing angles {+45°/-45°; +90°/0°}. Several PLA samples of each configuration have been fabricated and characterized by tensile strength tests according to the ISO 527-1 standard [3].

### 3. MAIN RESULTS

The experimental study lead to compare the effective elastic properties obtained by averaging the results of the two nearest measurements. Thus, the experimental values of the elastic properties are evaluated according to the ISO 527-1 standard, with a quasi-static tensile test in the strain range  $\varepsilon \in [0.05\%; 0.25\%]$  [5]. The four evaluated parameters are the Young's modulus  $E$  (GPa), Poisson's ratio  $\nu$ , maximum stress  $R_m$  (MPa) and porosity ratio  $p$  (%) and are denoted as  $P_{f\alpha} = \{E, \nu, R_m, p\}$ , where the indexes  $\{f, \alpha\} = \{1, 2\}$  correspond to each value of the two studied parameters, *i.e.* the filling rate  $f = \{60\%; 100\%\}$  and printing angle  $\alpha = \{+45^\circ/-45^\circ; +90^\circ/0^\circ\}$ , respectively. As a result, four sets of values are obtained:  $P_{11} = \{1.50 \text{ GPa}, 0.30, 34.0 \text{ MPa}, 14.3\%\}$ ,  $P_{12} = \{1.55 \text{ GPa}, 0.24, 36.5 \text{ MPa}, 14.0\%\}$ ,  $P_{21} = \{2.05 \text{ GPa}, 0.32, 45.0 \text{ MPa}, 0.75\%\}$  and  $P_{22} = \{1.90 \text{ GPa}, 0.30, 44.6 \text{ MPa}, 3.30\%\}$ , constituting reference results to be discussed in terms of specific stiffness  $E/\rho$  and specific tensile strength  $R_m/\rho$  for a future parametric optimization.

### 4. CONCLUSION

As a conclusion, the printing parameters such as the filling rate and the printing angles have been investigated as a way to mitigate the effective elastic properties of the samples, and as an optimization parameter of the raw material printing in view of a targeted application.

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