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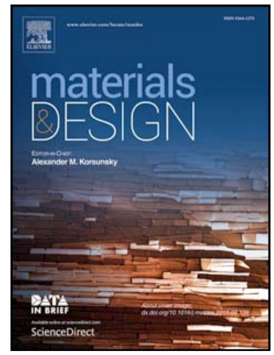

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Additive manufacturing of PLA structures using fused deposition modelling: effect of process parameters on mechanical properties and their optimal selection

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Abstract

Fused deposition modelling is a rapidly growing additive manufacturing technology due to its ability to build functional parts having complex geometries. The mechanical properties of a built part depend on several process parameters. The aim of this study is to characterize the effect of build orientation, layer thickness and feed rate on the mechanical performance of PLA samples manufactured with a low cost 3D printer. Tensile and three-point bending tests are carried out to determine the mechanical response of the printed specimens.

Due to the layer-by-layer process, 3D printed samples exhibit anisotropic behaviour. Upright orientation shows the lowest mechanical properties. On the other hand, on-edge and flat orientation show the highest strength and stiffness. From a layer thickness and feed rate point of view, it is observed that ductility decreases as layer thickness and feed rate increase. In addition, the mechanical properties increase as layer thickness increases and decrease as the feed rate increases for the upright orientation. However, the variations in mechanical properties with layer thickness and feed rate are of slight significance for on-edge and flat orientations, except in the particular case of low layer thickness. Finally, the practicality of the results is assessed by testing an evaluation structure.

Keywords: Fused deposition modelling, Polylactic acid (PLA), Mechanical characterization, Process parameters, Failure analysis

1. Background

Additive manufacturing (AM) technologies are one of the most promising areas in the manufacturing of components [1], [2], [3], [4], [5], [6]. Furthermore, they enable the manufacture of a large range of prototypes or functional components with complex geometries, such as those obtained from a topology optimization process [7], [8], or generated from a fitting process in Computer-Aided Design [9]. AM technology is a very broad term encompassing numerous methods such as Stereolithography (STL) of a photopolymer liquid, Fused Deposition Modeling (FDM) from plastic filaments, Laminated Object Manufacturing from plastic laminations, and Selective Laser Sintering from plastic or metal powders [3], [10]. However, the FDM technique is of particular interest due to its association to desktop 3D printers [11], [12]. FDM forms a 3D geometry by assembling individual layers of extruded thermoplastic filament, such as acrylonitrile butadiene styrene (ABS) or polylactic acid (PLA), which have melting temperatures low enough for use in melt extrusion in outdoor non-dedicated facilities [1].

FDM is a complex process with a large number of parameters that influence product quality and material properties, and the combination of these parameters is often difficult to understand [5], [13]. Printing parameters such as build orientation, layer thickness, raster angle, raster width, air gap, infill density and pattern, and feed rate, among others, have a substantial effect on the quality and performance of FDM printed parts [1], [14], [4], [5], [15], [16], [17], [18], [19], [20]. Since mechanical properties are crucial for functional parts, it is absolutely essential to examine the influence of process parameters on mechanical performance [21], [17], [22], [23], [24]. Thus, further research is required to determine printer parameters such as build orientation, layer thickness and feed rate, particularly since the