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Analysis of Factors Influencing the Mechanical Properties of Flat PolyJet Manufactured Parts

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Abstract

In Additive Manufacturing (AM), parts are manufactured layer-upon-layer. This strategy affects the mechanical properties of AM parts, since they cannot just be assimilated to those of parts manufactured by traditional methods. The PolyJet AM technology uses UV energy to cure layers of photopolymer that are stacked one on top of the following. The amount of energy that reaches each layer is related to several aspects of the manufacturing procedure, such as jetting head displacement strategy or UV irradiation pattern. This work aims to analyse the relative influence of configuration parameters on the relaxation modulus E(t) of flat parts manufactured using PolyJet technology and orientated on the XY plane. Evolution of material properties with respect to time has been used since parts shall present viscoelastic behaviour. Four factors have been evaluated: part spacing along X axis (Δx) and along the Y axis (Δy), orientation of the part within the tray (φ) and surface quality (Q). Influence of Q has been included since material properties could be modified by UV shielding effect. Experimental results have pointed out that Y-spacing and orientation φ both affect E(t).

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1. Introduction

The ASTM F2792-12a standard defines Additive Manufacturing (AM) as “the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing

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methodologies". Consequently, AM processes allow the manufacture of very complex shapes, as well as regular geometries. Nevertheless, this layer-stacking strategy conditions the mechanical properties of AM parts, introducing a certain degree of anisotropy, so they cannot just simply be assimilated to those manufactured by traditional processes. Since AM processes are relatively new, there is still a lack of knowledge on current mechanical behaviour of AM parts [1], which can be a drawback for the industrial adoption of these technologies. This deficit is one of the main challenges that AM processes must face in the future, since achieving reliable industrial-level applications is a prior objective nowadays.

In present work, focus has been put on the PolyJet process. This process uses ultraviolet (UV) radiation for curing layers of jetted acrylic photopolymer. The jetting head is formed by a matrix of jetting orifices disposed along the Y axis, and is mounted on a carriage that allows for X forth-and-back displacements and alternate transverse (Y) relocations. Additionally, the manufacturing tray can move in the vertical (Z) direction, after each layer has been successfully manufactured (Figure 1).

Once the slicing software has split the 3D geometry of a CAD model into a collection of 2D geometries, they shall be manufactured from bottom to top. In a particular layer, the 2D shape is analysed and a CAM code is generated in order to synchronize jetting head displacements with correspondent material deposition. Thus, during forth movement, each orifice in the jetting head coordinates the projection of photopolymer droplets with its instant position, so that an area correspondent to the theoretical shape of the 2D geometry is covered by material. Simultaneously, an UV lamp on the carriage cures the photopolymer, and this curing procedure goes on along back-and-forth movements. Once the layer geometry has been cured, the tray descends a length equal to the layer thickness along the Z axis, and this procedure is repeated until the part is completed.

According to this description, it seems clear that the amount of energy that reaches each layer is related to several aspects of the manufacturing procedure, such as jetting head displacement strategy or UV irradiation pattern. Moreover, some researchers have pointed out that actual parts could have slightly different mechanical properties than those reported by the manufacturer [2]. Thus, factors affecting the degree of curing of the photopolymer layers shall influence the mechanical behavior of the part.

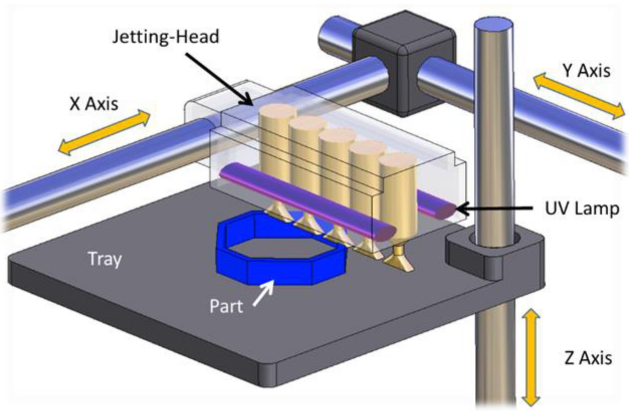

Fig. 1. Schematic representation of the PolyJet system.

The variability on mechanical properties of parts manufactured using PolyJet has been studied by Kesy and Kotlinski [3]. These authors have evaluated several mechanical parameters (such as the tensile strength or elongation at failure) in test bars manufactured with different orientations in the working space. They have found notable differences between orientations, and had related this effect to variations in the amount of UV energy that reaches the different zones in each part. In particular, these authors remark the importance of a comparatively higher density and hardness values (related to a higher degree of curing), found in edges that were built parallel to the X axis.

A research by Barclift [4] have revealed that over-curing caused by parts distribution within the tray could also lead to noticeable differences between mechanical properties of parts sharing common geometries. These authors