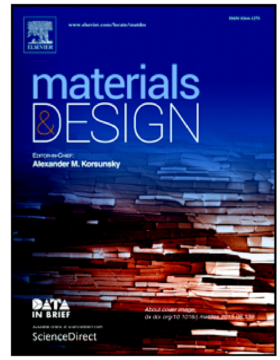
Accepted Manuscript



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PII:	S0264-1275(18)30485-4
DOI:	doi:10.1016/j.matdes.2018.06.018
Reference:	JMADE 3988
To appear in:	*Materials & Design*
Received date:	17 April 2018
Revised date:	8 June 2018
Accepted date:	9 June 2018

Please cite this article as: Josep M. Puigoriol-Forcada, Alex Alsina, Antonio G. Salazar-Martín, Giovanni Gomez-Gras, Marco A. Pérez , Flexural Fatigue Properties of Polycarbonate Fused-deposition Modelling Specimens. Jmade (2018), doi:10.1016/j.matdes.2018.06.018

Flexural Fatigue Properties of Polycarbonate Fused-deposition Modelling Specimens

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Abstract

This report presents an experimental investigation on the influence of part build orientation on the flexural fatigue behaviours of fused-deposition modelling (FDM) processed polycarbonate (PC) parts. Quantification of fatigue behaviour is required to show the feasibility of manufacturing industrial parts with the FDM technique. Therefore, stress-cyclic strain (S-N) curves were experimentally obtained for alternating stress (R-1) and mean stress (R-0.5). Test performances show that the part build orientation significantly affects the dynamic behaviour of FDM parts because of the inner anisotropy. Furthermore, to prove the validity of simulation methods such as finite element analysis (FEA), a case study was conducted. A designed part was simulated with FEA and the obtained von Mises stresses were corrected using the Goodman correction and the S-N curve for R-1. This part was also manufactured and tested to compare the simulated and experimental results. The results show good accuracy between the virtual and physical models.

Keywords: Fatigue, Fused-deposition Modelling, Polycarbonate, Process Parameters

1. Introduction

Additive manufacturing (AM) is a manufacturing process that allows greater design flexibility, enabling companies to produce first and effective design into not only prototypes, but also successful and efficient end-products. The object design is first represented as three-dimensional computer-aided design (CAD) data. By exporting this data to AM software, the faceted model is then mathematically sliced into a series of parallel cross-sections, creating a machine transverse path for each slice. Considering any necessary scaffolding, the software code is imported to the AM machine, building the physical part on site [1].

Numerous AM technologies are presently available commercially and have been studied extensively, including laminated object technology (LOM), selective laser sintering (SLS), stereolithography (SLA), and fused-deposition modelling (FDM). Of these, FDM, also known as fused-filament fabrication (FFF), is among the most popular. FDM has found application in various areas such as the biomedical and tissue engineering fields, from novel scaffold architectures to swellable capsular devices for the oral pulsatile release of drugs [2]. Through this technology, plastics such as polycarbonate (PC), polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), and polyetherimide (PEI) are used as raw materials. In the FDM process, a feedstock filament of the raw material on a spool is fed into the extrusion head with the aid of a tractor wheel arrangement through generating extrusion pressure. The movement of the extruder by a numerical control-based code, coupled with the extrusion of a semi-molten filament above the material's glass transition temperature, enable the production of the desired geometry. Because the semi-molten extruded material is deposited on the previously laid layer, which is still hot, both filaments of material are joined through the local sintering process of neck growth.

Considerable research has been done to optimize the numerous processing parameters that define parts manufactured by FDM. Static and dynamic mechanical properties have been studied previously to optimize FDM parameters. Considerable attention to the directional dependence of FDM components properties for ABS, PLA, PC, and PEI, e.g. tensile, compressive, and impact strengths, has been given in the literature [3–13]. However, fewer studies have addressed time-dependent mechanical properties [14–18], residual stresses [19], or cyclical fatigue performances [20–27]. For instance, the latter has been only analysed for some materials such as ABS, PEI, or PLA.

Lee and Huang [20] studied the tension fatigue behaviour for different part-build orientations of ABS and ABS plus, analysing the total strain energy absorbed. However, although their work provides important baseline data, no analysis of statistical significance is given, because only one specimen was tested at each stress. Ziemian et al. [21, 22] also performed two investigations regarding ABS material and uniaxial fatigue behaviour of FDM components. In the former, they determined the dependence of several mesostructures, i.e. the raster orientation and layering pattern. The results showed superior tension fatigue performance from bidirectional specimens with cross-linked rasters arranged at 45° from the direction of applied tension [21]. In the latter, following their previous research, a fatigue damage analysis and an empirical model of effective elastic modulus were presented. Experience showed that the FDM

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