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NONLINEAR FINITE ELEMENT ANALYSIS OF THE CRACK PROPAGATION IN FDM SAMPLES

Abstract

Nowadays polymer based Additive layer manufacturing (ALM) is widely used both for prototyping and for functional parts. One of the main obstacles towards a wider use of polymeric ALM can be traced back to fact that the numerical tools for design analysis and simulation currently available do not grant users the possibility of designing components by means of a multi-scale approach. Such design philosophy takes into account holistically the effects of the microscale (e.g. the properties of a certain material), the mesoscale (e.g. the effect of the manufacturing technology choices on the final product) and the macroscale (e.g. the actual design choices in correlation with the applied loads and the boundary conditions). The aim of this work is the analysis of the correlation between printing parameters in the Fused Deposition Modeling (FDM) of thermoplastic polymers and their structural response, both in terms of constitutive behavior of the material and fracture mechanics. The experimental campaign has been conducted using two different polymers: Polylactic acid (PLA) and Polyether ether ketone (PEEK). The former has been chosen for its wide use in the field of 3D printing usually for prototyping and hobbyist, the latter for its superior performance in terms of thermal and mechanical properties that allows for 3D printing of functional parts. The effect of the manufacturing choices on the properties of the constitutive behavior of the material was analyzed by means of a Design of Experiment (DOE) statistical approach applied to opportunely chosen test samples. The parameters chosen as control variables were: infill, raster and number of layers. For the numerical simulation, the behavior of the single ply was assumed as orthotropic, homogeneus and linearly elastic and it was calibrated by printing dogbone samples to fully define the elastic tensor of the material and the parameters for the continuum-based failure criterion. At the end of the experimental campaign, different fracture mechanics numerical approaches proved to be the most suitable for either the modeling of the in-ply fracture behavior or the modeling of the delamination, regardless of the printing direction. The numerical parameters necessary for the modeling of the crack propagation were evaluated by means of a data-matching algorithm. The results for the proposed modeling approaches were validated and the virtual tests showed good agreement with their experimental counterpart. Finally, different case studies showing possible applications of the proposed numerical approach are shown.