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Global and Local Buckling Phenomena in FFF Printed Polymeric Elements

Abstract

In recent years, many works discussed if, and to what extent, Fused Filament Fabrication (FFF) could shift from prototyping to manufacturing small productions or individual components. Several authors investigated some mechanical properties of FFF 3D-printed elements under specific printing parameters; others identified the influence of some processing parameters on those properties. Finally, still others tried to trace back their mechanical response with micro or macromechanical approaches. However, the compressive response received little attention.

In this work, the authors studied how Polylactic Acid (PLA) 3D printed specimens behaved under compression, focusing on the buckling problem. The anisotropy of FFF printed components is well-known; the study is limited to the normal direction to the build plate. The global and the local buckling problems have been considered; an extensive experimental campaign studied the critical load trends over a wide range of slenderness ratios. This has been coupled with a preliminary campaign devoted to tensile and compressive properties determination, which demonstrated a strong asymmetric behavior in tensile-compressive mechanical properties of FFF PLA, which suggests that such phenomena cannot be predicted without a dedicated approach. A single-camera Digital Image Correlation (DIC) system monitored the coupons all the test long; this allowed to evaluate the occurrence of buckling by observing the transverse displacements to the load application direction. To this end, the authors choose the specimen geometries to induce buckling in a specific plane. The global buckling phenomenon has been studied through specimens with a constant and squared cross-section. The local buckling investigation considered T-shaped coupons with such geometry to induce the web phenomenon. The analysis revealed that a linear relation well describes the transverse displacement vs. applied load in the pre and post-buckling: their intersection reported the buckling load of each specimen. The authors observed the critical loads decreasing with an increase in the slenderness ratio and evaluated the capability of established analytical models for buckling critical load estimation in isotropic materials to predict the failures. Regarding the global buckling, reference has been made to the Linear Euler model, the Tangent Modulus theory, and Johnson's formula. As to the local, the plate buckling equation has been considered to predict web buckling. In the first scenario, the Tangent Modulus theory well predicted the plastic field phenomenon and the Linear Euler model in the linear field. In the second scenario, the plate buckling equation slightly underestimated web buckling, still providing excellent indications. However, those estimations relied on the compressive mechanical properties: with the tensile ones, the estimates were poor.

Keywords

additive manufacturing, fused filament fabrication, buckling, digital image correlation, experimental analysis