WORCESTER POLYTECHNIC INSTITUTE

DEPARTMENT OF MECHANICAL ENGINEERING

Ph.D. Dissertation entitled: Multifunctional Testing Artifacts for Evaluation Of 3D Printed Components By Fused Deposition Modeling

by

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Abstract

The need for reliable and cost-effective testing procedures for Additive Manufacturing (AM) is growing. In this Dissertation, the development of a new computational-experimental method based on the realization of specific testing artifacts to address this need is presented. This research is focused on one of the widely utilized AM technologies, Fused Deposition Modeling (FDM), and can be extended to other AM technologies as well. In this method, testing artifacts are designed with simplified boundary conditions and computational domains that minimize uncertainties in the analyses. Testing artifacts are a combination of thin and thick cantilever structures, which allow measurement of natural frequencies, mode shapes, and dimensions as well as distortions and deformations along multiple axes and in-time. We apply Optical Non-Destructive Testing (ONDT) together with computational methods on the testing artifacts to predict their natural frequencies, thermal flow, mechanical properties, and distortions as a function of 3D printing parameters. The complementary application of experiments and simulations on 3D printed testing artifacts allows to systematically investigate the density, porosity, moduli of elasticity, and Poisson's ratios for both isotropic and orthotropic material properties to better understand the interrelationship between these characteristics and the selected printing parameters. The method can also be adapted for distortions and residual stresses analyses. We optimally collect data using a design of experiments technique that is based on regression models, which yields statistically significant data with a reduced number of iterations. Analyses of variance of these data highlight the complexity and multifaceted effects of different process parameters and their influences on 3D printed part performance. We learned that the layer thickness is the most significant parameter that drives both density and elastic moduli. We also observed and defined the interactions among density, elastic moduli, and Poisson's ratios with printing speed, extruder temperature, fan speed, bed temperature, and layer thickness quantitatively. This Dissertation also shows that by effectively combining ONDT and computational methods, it is possible to achieve greater understanding of the multiphysics that governs FDM. Such understanding can be used to estimate the physical and mechanical properties of 3D printed components, deliver part with improved quality, and minimize distortions and/or residual stresses to help realize functional components.

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Location: Higgins Laboratories, HL 102, WPI's campus

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ALL ARE INVITED TO ATTEND