Methods to Evaluate Residual Stress in 3D Printed Parts

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Residual stresses are generated during a 3D printing process due to the layer-by-layer sequential solidification of printed materials and are one of the major concerns in additive manufacturing. Determining residual stresses can provide better understanding of 3D printing process and guide the selection of printing parameters to improve print quality, such as the mechanical properties and dimensional accuracy of the finished parts. In this work an experimentally validated finite element analysis (FEA) based model to simulate the printing process is developed for the fused filament fabrication (FFF) 3D printed parts. Commonly used FFF materials, such as ABS and PC, are employed in this study. The hole-drilling method is used in combination with two-dimensional subset-based digital image correlation method to quantify the residual strains and stresses in the 3D printed samples. An FEA-based model is developed to simulate the filament deposition process coupled as well as the temperature change during printing. The material property evolution during the transition from melt to solid is measured experimentally and modeled as by nonlinear temperature-dependent viscoelasticity where viscous properties are functions of temperature. This simulation model is validated by comparing the shape warping of some simple geometries from simulation results and experiments. Finally, hole punching experiments are simulated and compared with experimentally measured residual stress. The developed simulation model for the FFF printing method can be used to optimize the printing parameters, such as printing speed, printing temperature, printing bed temperature, etc.

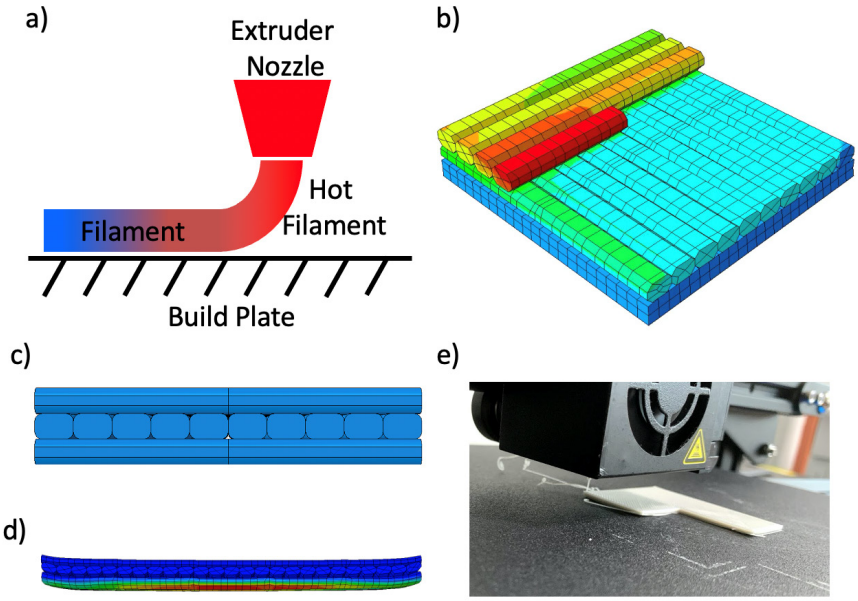

Figure 1: A finite element analysis (FEA) model for simulating the fused filament fabrication (FFF) 3D printing. a) A schematic of the model where heat transfer is considered to capture the dramatic temperature change in the filament. b) A snapshot of the FEA simulation of the filament deposition during printing. c) A side view of the FEA model. d) FEA simulation of the printed sample showing warping after detached from the build plate. e) The sample warp is observed in the FFF printing of ABS.