

PhD Dissertation Defense Announcement
Mechanical and Aerospace Engineering Department
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**IMPROVING STRENGTH AND FRACTURE RESISTANCE IN FUSED FILAMENT
FABRICATION THROUGH PRINthead-INTEGRATED IN-SITU ANNEALING**

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3.00 pm, 14th August, WH 413

Abstract

Fused filament fabrication (FFF) offers substantial design freedom for thermoplastic and fiber-reinforced components, yet its layer-by-layer deposition leaves parts with anisotropic mechanical behavior governed by incomplete polymer healing at inter-bead and interlayer weld lines. Conventional bulk post-process annealing can strengthen these interfaces but at the cost of dimensional distortion and warping. This dissertation develops and evaluates printhead-integrated adaptive in-situ annealing, a localized thermal treatment applied at the point of deposition to promote polymer chain interdiffusion and neck growth without compromising part geometry, for acrylonitrile butadiene styrene (ABS) and short-carbon-fiber-reinforced ABS (ABS-CF).

The research combines analytical, experimental, and numerical work. The analytical part applies established polymer-healing theory to this process, using concepts such as bonding potential, the welding window, and a critical bonding temperature to connect the printhead's thermal history to how completely the weld forms; neck-growth and reptation models then link that history to weld-line strength.

The work is organized around a non-isothermal polymer-healing framework in which a bonding-potential formulation, welding window, and critical bonding temperature relate the thermal history imposed by the printhead to the degree of interfacial weld development, with neck-growth and reptation-based scaling arguments connecting that thermal history to the evolution of weld-line strength. The experimental part measures the resulting mechanical behavior, pairing tensile and toughness testing with fracture tests on compact tension, double cantilever beam, and single-edge-notched bend specimens, and examining the interface through micro-computed tomography void analysis and dynamic mechanical analysis. The numerical part builds a finite-element model of the interface: representative-volume-element homogenization upscales the behavior of the individual constituents to effective properties, and cohesive-zone models calibrated against the fracture tests simulate how cracks start and grow along the weld line. Design of Experiments methods are applied to quantify process-parameter effects and to relate deposition and annealing conditions to interlayer performance.

Together, this work connects theory, experiment, and simulation into a mechanistically grounded and experimentally supported basis for improving weld-line integrity in FFF, and offers a foundation for adaptive in-situ thermal treatment to improve the strength, toughness, and fracture resistance of thermoplastic polymer and polymer composite parts.