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Mechanical and Aerospace Engineering Department
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**Characterization and Enhancement of Fatigue and Fracture properties in
Thermoplastic FFF Parts using In-Situ Annealing**

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Abstract

Fused filament fabrication (FFF) show high anisotropy and reduced mechanical properties as compared to conventional manufacturing techniques. This happens due to the poor interlaminar bonding between the layers, as a result of premature halt of bond healing process. Previous research works show multiple approaches to improve the bond quality to enhance the mechanical properties of FFF parts, however these are complex and expensive techniques. In this work a novel print head assembly is presented to offer a simple and effective solution by applying a thermal field to the part as it is being printed to preheat the previously deposited layer, thus improving the interlaminar bonds and eventually the mechanical properties of the parts. This assembly is compatible with most of the commercial FFF printers with no major modification, unlike other existing technologies. An optimized print head assembly was developed to improve the Fatigue and Fracture properties of FFF parts while minimizing the mass of the block to provide maximum enhancement of the properties while reducing geometric distortions. A design of experiments approach has been used to identify the main effects and interaction effects between the two factors (Plate Thickness and Nozzle Height) with three levels each for three response variables (Increase in Number of Cycles to Failure, Increase in Fracture Toughness, Change in Geometric Distortion). The DOE shows that the nozzle height and plate thickness main effects are present for all three response variables. A localized cooling mechanism has been provided to cool the upper sections of the print head to prevent filament softening and save from clogging and print failure. Parts printed with the optimized print head shows good correlation with the DOE analysis with major improvements in fatigue life, fracture toughness and less geometric distortion of the FFF parts. In conjunction, mesostructured analysis of these parts showed a transformation in the void shape from diamond to circular indicating that these voids would behave more as stress concentration zones rather than failure initiation points, supporting the experimental data.