PhD Dissertation Defense Announcement
Mechanical and Aerospace Engineering Department
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MODELING THE EFFECT OF IN SITU NOZZLE-INTEGRATED COMPRESSION ROLLING ON THE MECHANICAL AND FRACTURE BEHAVIOR OF FUSED FILAMENT FABRICATION (FFF) 3D PRINTED PARTS

By

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2:00 PM, Wednesday, 07/28/2021

Microsoft Teams Link

Abstract

Fused filament fabrication (FFF) is one of the most common additive manufacturing/3D printing techniques where continuously extruded semi-molten filaments are deposited in a layer-by-layer manner. The quality of the manufactured part depends on some major factors such as filament-filament contact and adhesion as well as the void fraction. Filament to filament adhesion affects the part strength under transverse load. In our earlier work, we studied the effect of in situ ball rolling on the thermal and mechanical properties of the printed parts. It was found that when printing/rolling parameters are correctly tuned and in situ compression rolling is appropriately applied over the depositing filaments, a significant increase in material toughness and tensile strength are realized. Here, we have developed an integrated model that includes the in situ compression rolling and filament-filament contact during deposition. The rolling parameters such as ball weight, ball temperature, filament temperature is explicitly included in the model. The effect of these parameters on the part height, void fraction, and filament adhesion are studied. Based on JKR contact theory and the theory of elasticity, our mathematical model predicts the evolution of filament-to-filament contact width and corresponding void fraction and part height in the representative volume element of the simulated printed part. Our prediction matches fairly well with the previous experimental results. We have also optimized the filament temperature during the rolling process. We find that the maximum adhesion between filaments occurs when the two filaments are brought close to isothermal contact. We have concluded that parts fabricated from a system integrated with an in-situ preheating and in situ post-rolling would yield the most effective part.

The next step to fulfill this research's scope is to study the fracture behavior of printed filaments in contact. We consider the effect of the contact half-width and the impact of the shape of the filament cross-section (filaments mesostructured). We believe that studying the fracture behavior of the printed filaments under different temperatures will add significant knowledge to industrial applications like 3d printed electronic devices or 3d printed heat exchangers. The results show that the rolled filaments have a longer contact half-width and larger notch angle at the interface between the filaments, which means higher singularity order and better fracture properties. A mathematical model has been formed to predict the fracture behavior, and experimental validation and investigation has been conducted.