Technical University of Denmark

Popular science summary of the PhD thesis

PhD student: Hao-Ping Yeh

Title of the PhD thesis: Multiphysics Modelling of Polymer-based Additive Manufacturing Technologies

PhD school/Department: Department of Civil and Mechanical Engineering

Science summary

Polymer-based additive manufacturing (AM), or 3D printing, is a cutting-edge manufacturing process that creates three-dimensional objects by layering material precisely based on a digital model. Its flexibility in creating intricate designs, cost-effectiveness for low-volume productions, and ability to fabricate complex geometries that are challenging through traditional means have revolutionized healthcare, aerospace, automotive, and consumer product sectors.

AM of polymer-based products, while highly advantageous, can also present several inherent limitations and defects. Common issues include poor surface quality due to layer-by-layer printing, resulting in visible layer lines or rough surfaces. Moreover, residual stresses within the printed components can be a concern, potentially affecting the final products' mechanical properties and structural strength. This complexity highlights the multifaceted nature of polymer AM, governed by various physical phenomena. These include heat conduction, convection, radiation, dynamics of the melt region, capillarity, the Marangoni effect, elastic and plastic deformation, yielding, creep, and laser-material interaction.

Accordingly, these challenges require careful consideration and mitigation strategies to enhance the quality and reliability of polymer AM-produced parts. Addressing these defects often involves adjusting printer settings, optimizing design, employing proper material handling techniques, and utilizing suitable post-processing methods. Numerical simulations integrating the various complex physical phenomena can serve as a valuable tool for this endeavor. These enable an investigation into how input process parameters impact the final part quality, offering a deeper comprehension of the intricate relationships between various factors in AM.

This PhD project focuses on two polymer AM technologies, i.e., selective thermoplastic electrophotographic process (STEP) and selective laser sintering (SLS). As the first contribution at all working on a simulation model in STEP, we propose a part-scale thermomechanical model to analyze and mitigate dimensional inaccuracies, deformations, and distortions observed in printed products. Integrating with sensorics, data-driven models and in-situ measurement, our comprehensive approach leads to the proposal of optimized parametric settings and refined geometry designs, effectively minimizing defects in the manufacturing process. For the other considered AM technology, SLS of polymers, a CFD model describing the thermal fluid dynamics is proposed to study the melt pool morphologies, surface roughness, and porosity as a function of particle size distribution and laser settings. This model is then combined with machine learning model in which a Physics Informed Neural Network (PINN) is trained to solve the underlying differential equation and the resulting hybrid model is then used as a swift and precise surrogate model to optimize the manufacturing process for SLS.

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Please email the summary to the PhD secretary at the department