Ph.D. DISSERTATION DEFENSE

Candidate: Nan Wu
Degree: Doctor of Philosophy
School/Department: Charles V. Schaefer, Jr. School of Engineering and Science/ Department of Mechanical Engineering
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Title: *Filler Patterning in Stereolithography Vats with Acoustic Waves*
Chairperson: Prof. Kishore Pochiraju, Department of Mechanical Engineering Department of Systems and Enterprises, SES

Committee Members: Prof. Frank Fisher, Department of Mechanical Engineering
Prof. Robert Chang, Department of Mechanical Engineering
Prof. Jacqueline Libby, Department of Mechanical Engineering (formerly with SSE).

ABSTRACT

Stereolithography is a popular additive manufacturing method used broadly in producing complex and geometrically designed objects. This technique has also become the preferred method for creating functional composites due to the choice of available reinforcement materials and the potential to distribute, concentrate, or align reinforcement phases by design. External factors such as electric, magnetic, and acoustic fields can control the arrangement of fillers, allowing the synthesis of composites with unique and anisotropic mechanical or thermal properties. The main challenges for producing lightweight components are optimal placement and alignment of reinforcing fibers.

Among the various methods for controlling the fiber placement within the resin, using acoustic fields during printing has proven to be the most effective. Using ultrasonic waves during printing, reinforcement particles and fibers can be aligned in a specific direction or concentrated at a desired location as determined by the performance requirements. In this effort, numerical methods and experimental validation are used to demonstrate the feasibility of this approach in producing desired particle alignments in a liquid media. Two-dimensional (2D) acoustic wave fields are simulated and analyzed in the time domain using a pseudo-spectral approach combined with the k-space correction technique. The results obtained from this analysis reveal the critical role of frequency, phase, location, and number of transducers in manipulating the fibers using acoustic wave interactions. A multi-physics finite element method is used to solve precise and detailed boundary value problems including the effect of reflective walls. The analysis builds a relationship between acoustic pressure and the distribution of particle volume fraction in the fluid domain.

The simulated filler patterns have been experimentally validated using a laboratory setup with one and two ultrasonic transducers. The filler patterns observed in experiments matched that predicted by the multi-physics analysis and validated the hypothesis that reinforcement fillers can be placed within additive manufacturing using acoustic steering. The effort demonstrates that the acoustic fields can be controlled to produce desired heterogeneity and orthotropy in material properties at each layer during layer-to-layer manufacturing. With this experimental validation, we can expect the emergence of smarter stereolithography vats that can produce lightweight products with optimized internal fiber morphologies fabricated by stereolithography.