Graduate Student Research Seminar

Spring 2023

Deep neural operator for learning transient response of interpenetrating phase composites subject to dynamic loading

Minglei Lu (PhD student)

Advisor: Dr. Zhen Li

Monday, February 13th

3:00 pm (EST) – 132 Fluor Daniel Building

Abstract

Additive manufacturing has been recognized as an industrial technological revolution for manufacturing, which allows the fabrication of materials with complex three-dimensional (3D) structures directly from computer-aided design models. Using two or more constituent materials with different physical and mechanical properties, it becomes possible to construct interpenetrating phase composites (IPCs) with 3D interconnected structures to provide superior mechanical properties as compared to conventional reinforced composites with discrete particles or fibers. The mechanical properties of IPCs, especially response to dynamic loading, highly depend on their 3D structures. In general, for each specified structural design, it could take hours or days to perform either finite element analysis (FEA) or experiments to test the mechanical response of IPCs to a given dynamic load. To accelerate the physics-based prediction of mechanical properties of IPCs for various structural designs, we employ a deep neural operator (DNO) to learn the transient response of IPCs under dynamic loading as a surrogate of physics-based FEA models. We consider a 3D IPC beam formed by two metals with a ratio of Young's modulus of 2.7, wherein random blocks of constituent materials are used to demonstrate the generality and robustness of the DNO model. To obtain FEA results of IPC properties, 5000 random time-dependent strain loads generated by a Gaussian process kennel are applied to the 3D IPC beam, and the reaction forces and stress fields inside the IPC beam under various loading are collected. Subsequently, the DNO model is trained using an incremental learning method, leading to a 100X speedup compared to widely used vanilla deep operator network models. After offline training, the DNO model can act as a surrogate of physics-based FEA to predict the transient mechanical response in terms of reaction force and stress distribution of the IPCs to various strain loads in one second at an accuracy of 98\%. Also, the learned operator is able to provide an extended prediction of the IPC beam subject to longer random strain loads at a reasonably well accuracy. Such superfast and accurate prediction of the mechanical properties of IPCs could significantly accelerate the IPC structural design and related composite designs for desired mechanical properties.

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