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Strategies to Incorporate Mechanics and Manufacturability in Topology Optimization

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Abstract: Recent decades have seen rapid development in all manufacturing technologies, including additive manufacturing (AM). This has raised the need for design methods to leverage the new, increasingly complex fabrication possibilities. Topology optimization has the potential to generate new high-performing design solutions since it is a free-form design method that does not require a preconceived notion of the final layout. It uses computational mechanics and optimization tools to generate improved designs. For operating designs to perform as predicted, the used model must capture the material behavior. Additionally, the planned manufacturing process might induce material characteristics and design limitations that should be considered as the design is generated. This talk focuses on identifying and incorporating behavioral and manufacturing aspects within the design process. Different strategies for integration within topology optimization will be discussed. This includes consideration of manufacturing-induced material characteristics, which is illustrated through tailoring design to material extrusion-based AM. In material extrusion, a nozzle moves across a build plate and deposits a material bead on a 2D slice of the design. These processes typically induce some degree of anisotropy through weak(er) bonding between adjacent beads. To improve the manufacturability of large-scale designs, the application of a Mixed Integer Linear Programming formulation is discussed for highly restricted volume scenarios. Finally, a new design framework is introduced in which the interactive participation of the design engineer is enabled to resolve more complex mechanic phenomena.

Biographical Sketch: Josephine Carstensen is the Gilbert W. Winslow Career Development (Assistant) Professor in the Department of Civil and Environment Engineering (CEE) at MIT. She leads the Carstensen Group, conducting research that revolves around the engineering question of "how we design the structures of the future?" Her work spans from the development of computational design frameworks for various structural types and design scenarios to experimental investigations that are used to inform necessary algorithmic considerations.

Dr. Carstensen has received awards for both research and teaching, including the National Science Foundation CAREER award and CEE Maseeh Award for Excellence in Teaching. She joined the MIT CEE faculty in 2019 after two years as a lecturer at MIT, jointly appointed in CEE and Architecture. She received her PhD from Johns Hopkins University in 2017 and holds a B.Sc. and a M.Sc. from the Technical University of Denmark.

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