ME - PhD Thesis Defense

Topological derivative-based optimization of Fiber-reinforced Structures, Coupled Thermoelastic Structures, and Compliant Mechanisms

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ABSTRACT

The topological derivative of a functional quantifies the sensitivity with respect to an infinitesimal domain perturbations such as a hole, an inclusion, a source term, a crack, etc. In this thesis, topological derivatives are used in conjunction with level-set methods to optimize stiff structures and compliant mechanisms. In the first part of the thesis, we use topological derivatives in polar form to obtain fiber-reinforced structural designs with non-periodic continuous fibers that are optimally arranged in specific patterns. The distribution of anisotropic fiber material within isotropic matrix material is determined for given volume fractions of void and material as well as fiber and matrix simultaneously, for maximum stiffness. In this three-phase material distribution approach, we generate a Pareto surface of stiffness and two volume fractions by adjusting the level-set plane in the topological sensitivity field. The next part of the thesis deals with the topology optimization of thermally coupled elastic structures. In this, we present two design examples: (i) a battery pack for heat dissipation; and (ii) thermomechanical actuators. In addition to the design of stiff structures, we perform topology optimization of compliant mechanisms using topological derivatives. In such elastically deformable structures, we adopt a multicriteria formulation that aims to simultaneously attain desired displacement with adequate overall stiffness. The resulting compliant topologies reduce the occurrence of undesirable discrete compliance, particularly at low volume fraction of material. Finally, we derive topological derivative for a homogeneous Dirichlet condition prescribed on the boundary of a hole. Here, we address the rationale behind the proposed ansätz in the asymptotic analysis of the solution using a second-order Green's tensor. In summary, the analytically derived topological derivative-based optimization approach makes it unique in terms of its computational efficiency and wide applicability for a variety of problems.

ABOUT THE SPEAKER

Akshay Desai is a PhD candidate in the Department of Mechanical Engineering at Indian Institute of Science, Bengaluru, working with Prof. G.K. Ananthasuresh in the field of design and optimization. He graduated with a bachelor's degree in Mechanical Engineering from the Institute of Technology and Management, Gwalior, in 2013. He obtained his master's degree in Mechanical Engineering Department from the Indian Institute of Science, Bengaluru, in 2015. His research primarily focuses on topological derivatives and their applications in topology optimization.