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Topology Optimization under Fabrication Uncertainties

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Abstract

Topology optimization is a systematic and general purpose computational tool for designing high performance structures. The technique is different from shape optimization methods in that it allows for the introduction and removal of structural features by changing the layout of material within the design through variations in both its boundary and its connectivity. While the power of topology optimization has been demonstrated in literature, deterministic conditions are often assumed, meaning various sources of uncertainty that exist either in the design variables or in the parameters that define the system are neglected. These uncertainties, if not incorporated in the design process in a systematic way, may lead to final designs that are suboptimal under real-world engineering conditions. One way to include these uncertainties in the optimization process is to replace the uncertain quantities (e.g. uncertain objective function) by their statistical averages. A better alternative, however, is to include higher order statistics. Robust Design Optimization (RDO) for example seeks to minimize the influence of stochastic variability on the mean design.

From a variety of uncertainty quantification (UQ) algorithms that might be used in the context of design optimization under uncertainty we explore two: stochastic perturbation and stochastic Galerkin projection [1]. We combine these algorithms with powerful topology optimization techniques for discrete and continuum structures (e.g., Heaviside Projection Method [2]) and build an uncertainty-oriented topology optimization framework capable of addressing geometric and material property uncertainties that represent, for example, errors that may arise during the fabrication process. Topologies optimized for mean and variability of mechanical stiffness are presented and the solution quality is verified against results obtained via computationally intensive Monte Carlo simulation based topology optimization.

References

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