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Stress-based topology optimization of frame structures under geometric uncertainty

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Abstract

Probabilistic topology optimization has gained significant research attention recently. This interest stems from the realization that the achieved high-performance designs resulted from deterministic topology optimization algorithms may become suboptimal under real-world conditions that are often accompanied with uncertainties. Among sources of these uncertainties, the ones that define structural characteristics, such as geometry, are numerically challenging to treat as they lead to stochastic structural stiffness. To date, research on developing efficient probabilistic topology optimization under stochastic stiffness is mainly focused on displacement-based objectives. However, in the design of structures, stress is also a primary design criterion that needs to be directly controlled for. A robust stress-based topology optimization methodology for frame structures under geometric uncertainty is proposed in this work. Assuming that such uncertainties are small relative to frame member lengths, the proposed methodology uses stochastic perturbation method to propagate these uncertainties up to the response level, which is expressed by the maximum of expected values of von Mises stresses throughout the domain. Sensitivities of the response with respect to design variables are derived analytically, which allows using efficient gradient-based optimizers. The proposed algorithm is examined with stress-based design of three frame structures under geometric uncertainty. Changes in the topology of these new designs are discussed, and they are shown to outperform deterministic designs when subjected to geometric uncertainties. Moreover, predictions and the resulting designs from the proposed methodology are found to be in excellent agreement with Monte Carlo simulation results.

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