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Topology Optimization of Structures under Random Excitations

Yang Yang[1], Mu Zhu[1], Michael D. Shield[1], and James K. Guest[1]

[1]Johns Hopkins University, Baltimore, MD, USA

Abstract

Topology optimization is a systematic approach to optimizing the distribution of material across a design domain. It is gaining significant traction as an engineering design tool, including for problems governed by dynamic behavior. Such problems include topology optimization for free vibration and forced vibration. In the former, natural frequencies are optimized for a deterministic structure without any loads. In the latter, the optimal response quantities are sought for structures subject to deterministic dynamic loads. However, many applied dynamic loads or excitations are random in nature, such as wind and seismic loads on civil structures, lift and drag forces on aircraft wings, road roughness induced vibrations on automobile components, or any number of other vibratory excitations on mechanical components. Due to the need for a large number of stochastic samples, it is often intractable to obtain their probabilistic characteristics by statistical methods. In this work, direct mathematical models from random vibration theory are used to model the excitations and linear finite elements are utilized to predict the behavior of structures. Depending on the application, we look to either maximize or minimize the stochastic response of structures subjected to stationary stochastic excitations using a variety of different stochastic dynamics formulations and consider their extensions to non-stationary excitations. Discrete element domains are considered, as well as continuum structures using the well-known Solid Isotropic Material with Penalization (SIMP) with Heaviside Project Method (HPM). The gradient-based Method of Moving Asymptotes (MMA) is used as the optimizer in all cases, and, as is to be expected, results are shown to offer enhanced performance when compared to solutions optimized under static load cases.