Keynote Paper

Topology Optimization of Structures subjected to Stochastic Dynamic Loading

Fernando Gomez[1] and *Billie F. Spencer, Jr.[2]

[1], [2] *Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, 205 North Mathews Avenue, MC-250, Urbana, IL 61801, USA*
[2] *bfs@illinois.edu*

ABSTRACT

Topology optimization provides a general approach to obtain optimal material layout in a prescribed domain according to some cost function and subjected to given design constraints. Numerous papers have been written in this field, with more and more results making their way into structural designs. However, the literature on topology optimization for structures subject to stochastic dynamic loads is limited. Most current approaches use deterministic loads either static or dynamic, or samples of a stochastic process through Monte Carlo simulation. In contrast, this study accounts directly for the stochastic nature of the excitation, modeling it as a zero-mean filtered white noise; when combined with the equations of motion for the structure, an augmented state space representation is formed, whose only input is an uncorrelated white noise. The covariance of the stationary response of a system subjected to a filtered noise can be obtained by solving a Lyapunov equation in terms of the state matrices of the augmented system. The optimization problem is formulated with a general objective function defined in terms of the covariances of the structural responses, a volumetric constraint, and design variables as the relative densities of the elements. A gradient-based method is used for the update of the design variables, and the sensitivities are computed using an efficient adjoint method that requires the solution of an adjoint Lyapunov equation. Focusing on the stationary structural responses, the stochastic optimization problem is converted into its deterministic counterpart; and the solution of the Lyapunov equations are obtained using a fast large-scale solver for sparse matrices. To illustrate the framework, topology optimization of a rectangular domain with boundary columns and additional lumped floor masses, representing a mid-rise building under lateral seismic excitation, is explored for a multi-objective performance function. The interstory drift and absolute floor acceleration performance functions yield conflicting designs, and a Pareto combination of them is used to provide a trade-off in the design. The results are consistent with previous results of stochastic parametric optimization; and they are a first step toward efficient topology optimization of stochastically excited structures with multi-objective performance functions.

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[1] Doctoral Candidate
[2] Nathan M. and Anne M. Newmark Endowed Chair in Civil Engineering