Robust probabilistic optimization of engineering systems under uncertainty

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Abstract

Optimization of engineering structures has the objective of identifying the best possible structural design with one or more objective functions under a set of constraints. The optimization techniques used to obtain point-estimates of the optimal design point do not guarantee a robust performance of the structure in the neighborhood of the optimal point. Moreover, the real-life operation of engineering systems has inherent uncertainty associated with them stemming from various sources such as in forcing functions, lack or imperfect knowledge of elastic/geometric parameters, measurement noise and even the lack of an appropriate physical model of the system. The objective of this work is to establish a comprehensive framework for robust optimization of structural dynamic systems under operational and parameter uncertainty modeled with probabilistic descriptors.

The present study is concerned with the robust optimization of corrugated panels which are of particular interest in aerospace applications due to their highly anisotropic property of compliance and high load bearing capacity along orthogonal other. Probabilistic uncertainty descriptors are used here to represent the input uncertainty. Stochastic reduced order modeling has been used for uncertainty propagation to approximate the response surface in a high-dimensional input parameter space with a set of polynomial chaos basis functions. This makes the response surface amenable to fast sampling techniques required for Monte-Carlo model fitting. Global sensitivity indices are used to establish the relative importance of the uncertain parameters which forms the important parameter space for the robust optimization.

This work proposes a novel optimization strategy founded on the Bayesian inference framework which aims to provide a probabilistic estimation of optimization parameters. The objective function is one that is derived from a user-prescribed problem-specific probability distribution associated with the system's quantity of interest. The theoretical challenge associated with the evaluation of the appropriate likelihood functions as well as the associated computational cost will be investigated and discussed in detail. It has to be emphasized that the optimal design point is obtained as posterior joint probability distributions of the optimization parameters as opposed to deterministic point estimates as the optimization outputs which ensures robust performance of the structural system under uncertainty.

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