Assessing Appropriateness of Robust Design Optimization Solutions via Probability of Dominance

J. C. Medina[1], and A. A. Taflanidis[1,2]

[1]Department of Aerospace & Mechanical Engineering, University of Notre Dame, Notre Dame IN - 46556, USA, jmedina4@nd.edu

[2]Department of Civil & Environmental Engineering, University of Notre Dame, Notre Dame IN - 46556, USA, a.taflanidis@nd.edu

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Abstract

Robust Design Optimization (RDO) is a powerful framework for addressing uncertainties in the design of engineering systems. The method adopts a probabilistic characterization of the uncertainty in model parameters of the system under consideration, and then formulates a design problem by considering the minimization of different statistical measures of the response (typically mean and standard deviation) as objectives. These objectives normally conflict with each other, and establishing a compromise between them can lead to a wide range of optimum candidate designs (within a multi-objective optimization setting).

Assessing the appropriateness of these designs and selecting a preferred one are open research questions. A novel robustness measure, termed probability of dominance, is introduced in this work for such purpose. This probability is defined as the likelihood (under the assumed probabilistic characterization) that a particular design will outperform the rival designs within a set of candidate designs. Furthermore, a multi-stage implementation is proposed to provide increased robustness in design selection by considering the comparison among smaller subsets within the initial larger set of candidate designs. These comparisons rely on the degree of dominance, which is estimated for each design by evaluating the probability of dominance over all subsets that include it, and it is shown to be a versatile measure for assessing the appropriateness of each design. The impact of prediction errors between the assumed numerical model and the real system is investigated as well. Relevant questions such as how to select a probability model for the prediction error and its impact on the probability of dominance and on the RDO formulation itself are answered. Two different error cases are considered: either additive or multiplicative influence of the prediction error and comparisons are drawn between them.

Two illustrative examples are presented; the first one considers the robust design of a Tuned Mass Damper (TMD) for vibration mitigation of harmonic excitations, while the second one considers the topology optimization problem for minimum compliance. Relevant comparisons are presented for these two examples and the discussion demonstrates the power of the proposed approach for assessing the designs' robustness.