NON-PROBABILISTIC DESIGN OPTIMIZATION WITH INSUFFICIENT DATA

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Early in the engineering design cycle, it is difficult to quantify product reliability or compliance to performance targets due to insufficient data or information for modeling the uncertainties. Design decisions are therefore, based on fuzzy information that is vague, imprecise qualitative, linguistic or incomplete. The uncertain information is usually available as intervals with lower and upper limits. In this paper, the possibility and evidence theories are used to account for uncertainty in design with incomplete information. The formal theories to handle uncertainty are first introduced using the theoretical fundamentals of fuzzy measures. The first part of the paper highlights how the possibility theory can be used in design. A computationally efficient and accurate hybrid (global-local) optimization approach is used to calculate the confidence level of "fuzzy" response combining the advantages of the commonly used vertex and discretization methods. A possibility-based design optimization method is proposed where all design constraints are expressed possibilistically. It is shown that the method gives a conservative solution compared with all conventional reliability-based designs obtained with different probability distributions. Also, a general possibility-based design optimization method is presented which handles a combination of random and possibilistic design variables. The second part of the paper describes a design optimization method using evidence theory. The method can be used when limited and often conflicting, information is available from "expert" opinions. A computationally efficient design optimization formulation is presented, which can handle a mixture of epistemic and random uncertainties. It quickly identifies the vicinity of the optimal point and the active constraints by moving a hyper-ellipse in the original design space, using a reliability-based design optimization (RBDO) algorithm. Subsequently, a derivative-free optimizer calculates the evidence-based optimum, starting from the close-by RBDO optimum, considering only the identified active constraints. The computational cost is kept low by first moving to the vicinity of the optimum quickly and subsequently using local surrogate models of the active constraints only. Numerical examples demonstrate the application of possibility and evidence theories in design and highlight the trade-offs among reliability-based, possibility-based and evidence-based designs.