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ROBUST RELIABILITY-BASED DESIGN OPTIMIZATION OF STRUCTURAL SYSTEMS UNDER STOCHASTIC EXCITATION

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ABSTRACT

Optimization via general nonlinear mathematical programming techniques has been widely accepted as a viable methodology for engineering design. Standard structural optimization techniques are based on deterministic formulations. However, a structure during its lifetime exhibits substantial variability compared to the prediction made during the design phase. This is due to the lack of information about the value of the model parameters which can be external to the structure such as environmental loads, or internal like material properties. Uncertainties in both loading and structural characteristics can adversely affect the reliability of the structure. Under general uncertain conditions robust reliability-based optimization provides a realistic and rational framework of structural optimization which account for the uncertainties. In this context, the concept of robust reliability is defined to take into account uncertainties from structural modeling in addition to the uncertain excitation.

In the course of the optimization process reliability measures such as failure probabilities must be estimated several times before a near optimum design can be obtained. As previously pointed out, the reliability measures account for the uncertainties in the structural parameters as well as the uncertainties in the loads. For systems of practical interest the repeated evaluation of these quantities can be very costly in terms of computational resources. The computational cost problem is addressed in this work by the use of approximate reliability analyses during portions of the optimization process. The reliability analysis block is first used to analyze a feasible initial design and then generate information that allows the construction of reliability approximations. Following an optimization based on approximate analyses, an exact reliability analysis is performed in the design point obtained by the approximate optimization so that new reliability approximations can be constructed. The process is repeated until convergence is achieved. The proposed sequential approximate optimization scheme generates a series of explicit convex optimization problems. The characterization of such problems requires a single reliability analysis which is performed by an efficient simulation technique.

Numerical examples, including a non-linear multiple-degree-of-freedom system and a finite element model under stochastic ground acceleration, are presented to demonstrate the efficiency and effectiveness of the approach. The effects of uncertain structural parameters on the performance of the final designs are investigated. Numerical results show that the uncertainty in the structural characteristics

may cause significant changes in the reliability of structural systems subject to stochastic loading. For example, final designs obtained by deterministic structural models may become infeasible when the uncertainty in the system parameters is considered. Validation calculations show that the efficiency of the proposed method, in terms of the number of exact reliability analyses to be performed during the entire optimization process, is remarkable. Thus, the proposed implementation is expected to be useful in the reliability-based design optimization of realistic structural systems.