Reliability-Based Optimization and Application of Fuzzy Theory for Robust Structural Design

Chien-Jong Shih, Woe-Chun Liu and R.A.S. Wangsawidjaja

Department of Mechanical Engineering
Tamkang University, Tamsui, Taiwan 25137, R.O.C.

Key words : Structural optimization, Robust design, Multiobjective fuzzy optimization, Goal reliability.

ABSTRACT

This paper present two robust design strategies in structural system that simultaneously optimize the design goal-performance and minimize its performance variability. As a result, the maximization of a predefined goal-reliability indicator is equivalent to the optimization of the goal-performance and the performance variation concurrently. Fuzzy set theory is applied to formulate another way of dealing with such robust designs. Both single and multiple goal problems are investigated with random design variables and probabilistic constraints. This optimization approach can produce the highest goal-reliability, which is higher than that of a fixed goal-performance.

Ⅰ. INTRODUCTION

For modern and complex structural analysis, there is a growing necessity for the analysis of uncertainties and the computation of probabilities. In reality most of design variables and parameters in engineering design problems contain variation and errors. Stochastic programming [6] deals with this situation where some or all of the parameters of an optimization problem are characterized by stochastic variables. A stochastic nonlinear problem can be converted into an equivalent deterministic nonlinear programming problem by the chance constrained programming technique [3]. Consequently, a new goal function of the mean value and variation is constructed by multiplying a weighting factor on each mean and variation individually. Usually a variation analysis or a sensitivity analysis is executed after the engineering design is completed. However, if the variation is considered during the synthesis process, the final design can be enabled to gain a better performance.

Although the variation in the design goal is very often unavoidable, one still can improve this characteristic by decreasing the effect of performance variance. Such methodology is known as the robust design [5]. The simplest way of achieving such a goal to have a small performance variation is to directly reduce the uncertainty of each design variable. However, this strategy can either increase the total cost or be infeasible or even be impossible. Another strategy is to find the design variables with a fixed target value of goal for the design performance and a minimization of tolerance variation without the increase of the cost [2,12].

Traditional approaches [2,4] can calculate and reduce the goal performance variation except goal reliability information. Such a final design may have a too high or an unacceptable low level of reliability. To tackle a robust design problem, Torng and Yang [12] proposed another reliability-based design optimization process to prove that the reduction of a performance variation can be replaced with a functional reliability index under a prescribed target performance value. In the real world problem, not only does the goal-performance variation need to be minimized, but the goal-performance expectation also requires optimization.

In this paper, we use a simple way to define the reliability indicator (or index) as the reference of describing the degree of design robustness and maximize this goal reliability indicator. When the reliability indicator is directly maximized, we actually achieve two aims: optimizing (minimizing or maximizing) the mean performance of the goal and minimizing the performance variation. Applying the fuzzy set theory [14] to this idea, we can get an