

Application of Orthogonal Experimental Design on Reliability and Sensitivity Analysis

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Keywords: Orthogonal experimental design, Reliability, Sensitivity, FORM, Monte Carlo simulation.

Abstract. In the present paper, the effects of four structural parameters at three levels on the reliability and sensitivity of structure are investigated. Sensitivity of parameters is achieved by the range analysis and the significance of parameters is achieved by the variance analysis. A response surface based on orthogonal experimental design and finite element calculations is elaborated so that the relation between the random input variables and structural responses could be established. The First-Order Reliability Method (FORM) as an approximated method is used here to assess the reliability. Comparing with the results of Monte Carlo simulations by ANSYS for a numerical example, the effect of sensitivity analysis has been proved, while the precision of the reliability and sensitivity should be improved in the future.

Introduction

Although the reliability analysis and sensitivity analysis serve different aims, in practice, the implementation of the reliability analysis and that of the sensitivity analysis are very closely connected on both a conceptual and a computational level [1]. All of the methods used in reliability and sensitivity analysis can be divided into three: analysis methods, such as FORM, which depend on the explicit limit state function; stochastic FE methods, such as Monte Carlo simulations (MCs) [2], which is good precision but time-consuming; Response Surface (RS) method based on quick response model, such as Neural Network (NN)-based RS method, which has good generalization ability and time-saving.

Orthogonal experimental design is formulated in a way that minimizes the number of experiments so that the experimental cost can be saved [3]. Each experiment is conducted with the predefined combination of different levels of variables, and the performance of each individual variable can be calculated separately providing it is independent of the other variables. Because of its advantages, it has been widely used in design optimization [4], sensitivity [5,6] and reliability analysis [7].

In the present paper, Orthogonal Experimental Design (OED), Finite Element Simulations, RS and FORM compose the successive stage of the reliability and sensitivity assessment methodology. Sensitivity of parameters is achieved by the range analysis and the significance of parameters is achieved by the variance analysis. RS function of second order polynomial is obtained using least squares regression method. FORM is used here for the reliability index and the reliability probability. Finally, the feasibility and validity of this methodology are checked by the Monte Carlo simulations (MCs) by ANSYS.

Sensitivity Analysis

Sample Preparation for OED. As shown in Fig. 1, the model consists of two different materials, which is fixed at the bottom and applied the uniform pressure on the upper surface. The elastic modulus and Poisson's ratios of structure E_1, E_2, μ_1, μ_2 are input stochastic variables as Gaussian distribution with $E_1 = (200, 30)$ GPa, $E_2 = (242, 37.5)$ GPa, $\mu_1 = (0.3, 0.03)$, $\mu_2 = (0.35, 0.035)$. The input samples are designed as four factors with each at three levels, i.e. parameters are sampled only with μ and

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