PAPER REF: 3955

RELIABILITY ASSESSMENT OF STRUCTURES WITH MIXED UNCERTAINTIES

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ABSTRACT

This paper presents an efficient uncertainty analysis to assess the reliability of structural systems in the presence of mixed uncertain variables. The proposed method involves high dimensional model representation for the limit state function approximation, transformation technique to obtain the contribution of the fuzzy variables to the convolution integral and fast Fourier transform for solving the convolution integral. In the proposed method, efforts are required in evaluating conditional responses at a selected input determined by sample points, as compared to full scale simulation methods. Therefore, the proposed technique assesses the reliability of systems accurately with significantly less computational effort compared to the direct Monte Carlo simulation.

Keywords: random variable, fuzzy variable, structural reliability, high dimensional model representation.

INTRODUCTION

A deterministic approach to engineering analyses may result in inconsistent design owing to uncertainties present in the input. Probabilistic analysis offers the required realism needed in engineering systems and provides the opportunity for improvement in design. Many probabilistic analysis techniques have been developed to facilitate the use of probability theory and to allow the knowledge of uncertainty to be applied more effectively. For example, the most common approach to predict the failure probability involves first-order and second-order reliability methods, which are not adequate for highly nonlinear problems (Liu and Der Kiureghian, 1991). Similarly the simulation methods are not computationally efficient, and are not suitable in optimization processes. If the source of uncertainties accounted is from the variation due to lack of knowledge in the system then the uncertainties are to be treated as epistemic. These variables can be modelled as interval or fuzzy variables using fuzzy theory to represent non-random variables by membership functions (Balu and Rao, 2012; Penmetsa and Grandhi, 2003).

In real engineering problems, some uncertainty variables are random in nature while some are non-random. In such situations, the reliability analysis of structures in presence of mixed uncertain variables demands more computation as every configuration of fuzzy variable needs one probability analysis. Therefore in this paper an efficient computational procedure is presented based on the high dimensional model representation (Rabitz and Alis, 1999; Rao and Chowdhury, 2008) and fast Fourier transform (Sakamoto et al., 1997) to estimate the reliability of structure in presence of mixed uncertain variables.

RESULTS AND CONCLUSIONS

A cantilever beam subjected to a tip load is considered. The limit state function for failure is defined as tip displacement greater than 3.8 mm. The geometrical dimensions are considered to be random variables while the tip load is a fuzzy variable. Therefore, for every possible value of this load, there would be a corresponding failure probability and using the proposed method the bounds of this failure probability is estimated. The limit state function is approximated using first-order HDMR, and then the function is divided into two parts, one with only the random variables along with the value of the constant part, and the other with the fuzzy variable. The joint membership function of the fuzzy part of approximated limit state function is obtained using suitable transformation of the fuzzy variables. Figure 1 shows the membership function of reliability estimated by the proposed methods, as well as that obtained using traditional MCS.

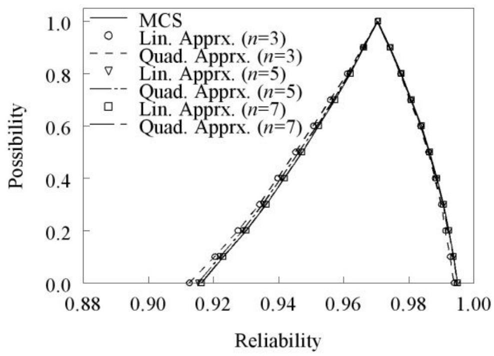

Fig. 1 - Membership function of reliability for cantilever beam

The computational effort in terms of number of function evaluations for linear and quadratic approximations is 25. However, the combinatorial approach to explore the entire domain with a sampling size of one million for direct MCS, results in 21 million exact function evaluations to obtain the membership function of reliability. This clearly shows the efficiency of the proposed method.

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