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Uncertainty quantification and propagation analysis of structures based on measurement data

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ABSTRACT

Considering that excessive sample data points are needed in the probabilistic method, in this paper, two non-probabilistic methods are proposed for uncertainty quantification and propagation analysis based on the Gray mathematical theory and the information entropy theory. These two methods can give the interval estimation of true value from the framework of non-probabilistic theory under the condition of few sample points for the uncertain parameters. The uncertainty propagation analysis for the structural responses is implemented based on the quantification results of the uncertain structural parameters. Research on the comparisons of these two methods is performed by a plane truss structure with ten bars, and the numerical results show the feasibility and validity of the proposed methods.

1. Introduction

In practical engineering, because of the effect of multifarious factors such as measurement errors, dispersivity of parameters, modeling errors and so forth, uncertainty exists in many problems. We cannot use traditionally determined analysis methods to deal with the modeling and the solution any longer, but should seek help from the uncertainty analysis method. In recent years, the non-probabilistic convex method of set theory has demonstrated great superiority in processing the uncertainty problems arising from lack of data. Ben-Haim et al. [1] proposed and advocated initially to utilize the convex method of set theory when dealing with the uncertainty issue. Qiu et al. [2–4] applied the above set theory convex method to the analysis of structural response, and obtained respectable results.

At present, however, with reference to the research of uncertain structural problems, most of the work is focused on the analysis of propagation. These methods are always based on the assumed interval or ellipsoid of structural uncertain parameters, and the estimation of structural response will be obtained by the uncertainty propagation analysis with the quantification of initial input parameters, namely, according to the known data point to obtain a reasonable interval estimation. So far, research on these aspects is scarce, so that the uncertain analytic method based on non-probabilistic convex set theory is limited to practical applications. In the aspect of uncertainty data processing, Halme et al. [5] proposed using the data envelopment analysis to quantify uncertainty. Wang et al. [6] obtained a systematic summary of uncertainty quantitative assessment. Qin et al. [7] have studied the method of confidence interval estimation in view of the difference in structures and the missing data. Zhilin et al. [8] proposed a new point on fitting empirical data under interval error. Wang et al. [9] have made some explorative research concerning the uncertainty structural analysis proceeding from primitive data, and a comparison of different situations between the convex modeling method and the interval analysis method based on various simulation data has been performed. Afterward, with the real elastic measurements of material T300/QY8911, the measurements of elastic moduli are quantified by either the smallest ellipsoid or the smallest four-dimensional uncertainty

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