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RELIABILITY ANALYSIS OF STRUCTURAL DYNAMIC CHARACTERISTICS BASED ON A REDUCED PHYSICAL MODEL

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Engineering structures are becoming large and complex. The establishment of an elaborate Finite Element (FE) model requires a lot of computational time and storage requirements, which makes effective dynamic analysis very difficult. Therefore, great progress has been made in the theory and application of dynamic model reduction techniques during recent years[1].

Most of the large-scale eigenvalue problems can be solved using existing reduction methods. However, in engineering structures, uncertainty is unavoidable and reliability analysis is considered to be necessary. Because reliability analysis is in essence an iterative process in need of many times of structural analysis, the reliability analysis of dynamic characteristics of complicated structures would become almost impossible because of prohibitive computational burden if using elaborate FE model. If using traditional model reduction techniques, the implementation of reliability analysis would face difficulty. The key of the reduction process focuses on searching an optimal coordinate transformation in most reduction methods, resulting in a transformed reduction coordinate space, which generally has no explicit physical meaning. Thus, it is difficult to transform the physical properties of the original structure to the reduced coordinate space. However, in reliability analysis, uncertain physical properties should be decomposed and appear in the reduced coordinate space. To achieve this objective, the design variable decomposition method[2][3] is combined to construct a reduced physical model in this paper.

This model reduction method based on the assumption of block-wise rigid body motion is first proposed by Zhang and Ding[4] and extended to three-dimensional space by Wang et al[5]. In this paper, based on the physical insight of structural dynamic behaviour, the elaborate FE model built by ANSYS software is divided into several sub-domains. Each sub-domain is assumed to move in a synchronized pattern and the nodal displacement field in each sub-domain is approximated by a block-wise rigid body motion. By minimizing the displacement errors measured in strain energy, a modified pseudo-rigid movement pattern is obtained as a set of base vectors. A final system equation with a reduced number of DoFs is obtained by projection of the fine FE model onto the base vectors, which remain nearly constant as the uncertain physical properties change. The obtained stiffness and mass matrices of the reduced model explicitly depend on the uncertain physical variables by combining with the design variable decomposition method. Then a rocket launcher is analyzed to obtain the reliability of the fundamental frequency and a wing structure is analyzed to obtain the reliability of the gap between the first two consecutive vibration frequencies. The results are compared with that of the response surface method-based reliability approach and Monte Carlo Simulation. The results demonstrate the feasibility and effectiveness of the proposed method.

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