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This paper is devoted to the construction of stochastic reduced-order computational model for dynamical structures having a high modal density in the low-frequency range. We are particularly interested in automotive vehicles which are made up of stiff parts and f exible components. This type of structure is characterized by the fact that it exhibits, in the low-frequency range, not only the classical global elastic modes but also numerous local elastic modes which cannot easily be separated from the global elastic modes. To solve this diff cult problem, a new approach has recently been proposed for constructing a reduced-order computational dynamical model adapted to the low-frequency range. The proposed method requires to decompose the domain of the structure into subdomains. Such a decomposition is carried out using the Fast Marching Method. An adapted generalized eigenvalue problem is constructed using such a decomposition and allows an adapted vector basis to be computed. This basis is then used to construct the reduced-order computational model. Model uncertainties induced by modeling errors in the computational model are taken into account using the nonparametric probabilistic approach which is implemented in the reduced-order computational model. The methodology is applied on a complex computational model of an automotive vehicle.

1 Construction of the reduced-order computational model

First, the domain is decomposed into subdomains. For a computational model of a complex structure such as an automotive vehicle, the decomposition of the domain is not easy to be carried out because the geometry is very complex and curved. The method we propose for this decomposition is based on the Fast Marching Methods (FMM) introduced in [2] which gives a way to propagate a front on connected parts from a starting point. The construction of the reduced-order computational model is based on the introduction of a projection operator on a subspace of the admissible space. Then, the kinetic energy is reduced on each subdomain using this projection operator. The elastic energy is not reduced and therefore remains exact. We then introduce respectively the following global eigenvalue problem and the local eigenvalue problem

$$-\lambda^g[M^r]\phi^g + [K]\phi^g = 0 \quad \text{and} \quad -\lambda^l[M^c]\phi^l + [K]\phi^l = 0 \quad , \tag{1}$$

where $[M^r]$ is the reduced mass matrix, $[\mathbb{K}]$ is the stiffness matrix, $[M^c] = [\mathbb{M}] - [M^r]$ is the complementary mass matrix and $[\mathbb{M}]$ is the mass matrix. The solutions of these eigenvalue problems give respectively a basis of the admissible space of the global displacements and a basis of the admissible space of the local displacements. It can be shown that the family made up of the union of these two basis constitutes a basis of the admissible space. The aim of this work is to construct a reduced-order computational model adapted to the low-frequency range in which the synthesis of the frequency responses can be obtained using only the global displacements eigenvectors. Since a part of the mechanical energy is transferred from the global eigenvectors to the local eigenvectors which induces an apparent damping on the global generalized coordinates, an adapted correction of the damping reduced matrix is proposed.

2 Construction of the probabilistic model of uncertainties

The last step is to construct a probabilistic model of uncertainties in the reduced-order computational model in order to take into account the system-parameter uncertainties and the model uncertainties induced by modeling errors in the reference model from which the reduced-order computational model has been deduced. We also have to take into account uncertainties induced by the irreducible errors introduced by neglecting the contribution of the local displacements in the constructed reduced-order computational model. To take into account all these sources of uncertainties, we use the nonparametric probabilistic approach (see [3]) which consists in replacing, in the reduced-order computational model, the deterministic generalized mass, damping and stiffness matrices by random matrices. Finally, the random responses of the stochastic reduced-order computational model are calculated using the Monte Carlo simulation method.

3 Results

We have applied this new methodology to a complex computational model of an automotive vehicle in which there are simultaneously global and local elastic modes which cannot easily be separated using usual methods. For the frequency band of analysis the stochastic ROM is obtained with only 36 global eigenvectors. The random responses show a good agreement with respect to the stochastic reference responses calculated using a classical modal analysis (using 240 elastic modes).

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