Global reduced-order model adapted to the low- and medium-frequency analysis of complex dynamical structures

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ABSTRACT

In this work, we present a novel approach for constructing a reduced-order model (ROM) in the framework of structural dynamics. In general, the low-frequency range is characterized [1] by the presence of a few isolated resonance peaks associated with large-wavelength elastic modes, while in the high-frequency range there are numerous small-wavelength elastic modes. In the medium-frequency range, the resonance peaks are not isolated and the modal density is increasing rapidly. The classical modal analysis method, which uses the elastic modes as a projection basis, is then particularly effective and efficient in constructing a small-dimension ROM for the low-frequency range. For higher frequencies, the number of modes increases and consequently other methods may be preferred (such as statistical energy analysis for the high-frequency range). This work deals with the case of complex industrial structures for which the modal density is high in the low-frequency range, due to the presence of numerous local (thus small-wavelength) modes. This feature is related to (1) a complex configuration that consists in the presence of small substructures attached to the stiff master frame of the structure as well as (2) the high complexity of the computational models required for such structures. Consequently, the use of the classical elastic modes yields a high-dimension ROM and is thus not suitable to the addressed problem. We thus propose a general methodology for constructing a small-dimension basis constituted of global displacements, which are driven, in the low-frequency range, by the large-wavelength displacements of the master frame (see [2]). The converged small-dimension ROM obtained using the global displacements contains an error that is related to the neglected contributions of the discarded local displacements. The methodology for calculating the global-displacements basis consists in solving the generalized eigenvalue problem associated with the conservative linear dynamical system, in which the kinetic energy is approximated while the elastic energy is kept exact. The choice of vector subspace used for the approximation is responsible for the separation between the global and the local displacements. The resulting approximated mass matrix is constructed upon the use of the reduced kinematics corresponding to the approximation vector subspace in which the approximated displacements (or shapes) are such that the local displacements are filtered. The error induced by neglecting the local displacements can thus be controlled in adjusting the kinematics reduction used for the mass matrix in the eigenvalue problem. In this contribution, the theoretical developments are presented, followed by a numerical illustration and validation related to the complex computational model of an automotive vehicle.

REFERENCES

[1] Ohayon, R. and Soize, C., 1998, *Structural acoustics and vibration*, Academic Press.

[2] Soize, C. and Batou, A., 2011, *Stochastic reduced-order model in low-frequency dynamics in presence of numerous local elastic modes*, Journal of Applied Mechanics - Transactions of the ASME 78(6) 061003