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On a Treatment of High-frequency Issues in Numerical Simulation for Transient Systems by Model Order Reduction via the Proper Orthogonal Decomposition

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Abstract

A new numerical strategy to remedy high-frequency issues caused by finite element discretization in structural dynamic problems has been proposed. A noteworthy characteristic of this advocated approach is that it is based upon the use of the proper orthogonal decomposition (POD) incorporated in conjunction with implicit or explicit numerically non-dissipative time integration schemes to substantially improve or eliminate undesirable effects due to high-frequency instabilities. Original systems with high-frequency issues are reduced via POD based on an adequate choice of a numerically dissipative scheme so that the resulting reduced systems contain no high-frequency participation. This approach confers the inherent advantages that numerically non-dissipative mechanical integrators, e.g., energy-momentum conserving or variational integrators, can be used to solve the reduced systems, fulfilling the requisite conservation laws in the projected basis and therefore provides a robust simulation. Linear and nonlinear numerical applications are shown to demonstrate the benefits and feasibility of this technique.

Keywords: Computational dynamics, Proper orthogonal decomposition, Time integration

1 Introduction

Structural dynamical systems can be categorized briefly as the class of inertial problems (vibrations) and the class of wave propagation problems. This paper primarily focuses upon the class of inertial problems and also extends to wave propagation problems to a limited extent. In vibration problems where high frequency participation of modes influences the analysis, most often numerically non-dissipative schemes are preferred but may fail to complete the analysis due to failure in nonlinear iterations; consequently controllable numerical dissipative schemes are chosen but may lose some energy and/or may extend the time duration of interest. Having to face this dilemma of what to choose, this paper provides an optimal resolution. That is, we not only reduce the overall model by choice of a numerical dissipative scheme to first obtain such a reduced model, therein, we employ a numerically non-dissipative scheme to preserve the energy via the reduced model. Although we mostly recommend such an approach for vibration applications, we also illustrate to wave propagation but we exercise caution that these latter may be more challenging.

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