VIBRATION OF COMPLEX AEROSPACE AND AUTOMOTIVE STRUCTURES: RESEARCH MILESTONES AND CHALLENGES

Abstract:
Recent developments are presented for the efficient analysis of vibration in large-scale complex structures. The key issues considered are the generation of reduced-order models (ROM) for the fast and accurate prediction of vibratory response in the low- to mid-frequency range, the development of physical substructuring approaches for capturing critical power flow paths, and the prediction of the effects of parameter uncertainties and design changes. The new methods developed and the attendant results are presented for two classes of engineering structures, namely jet engine bladed disks and ground vehicles. For large-scale finite element models of bladed disks, a component mode mistuning approach is proposed to generate a ROM whose size is on the order of the number of blades. The component mode mistuning ROM incorporates as parameters the blade-to-blade differences that are known as blade mistuning. While a simplified ROM is developed for the common case of small mistuning, the general model successfully handles large mistuning situations, including intentionally mistuned bladed disks, damaged and fractured blades, geometric blade mistuning, and disk design changes. The component mode mistuning model is also especially well suited to the identification of blade mistuning from response measurements, and experimental results are presented for a NASA compressor stage prototype. For vehicle structures, an efficient component mode synthesis with a new interface modal reduction method is proposed, which employs modes characterizing the vibration of the interface between components and relies on the filtration of the interface matrices and constraint modes. By selecting component and interface modes for the frequency range of interest, highly reduced models are obtained: for example, a 2100-degree of freedom (DOF) ROM is generated in the 0-200 Hz range from a 1.5-million-DOF finite element model of a sport utility vehicle. A novel representation is adopted to display power flow through the vehicle structure as a two-dimensional “map,” which can be used to illustrate the structural paths through which the vibration energy is transmitted from the source to the key response points. Furthermore, recent progress in predicting the effects of parameter uncertainties is highlighted. The presentation concludes with a discussion of the challenges for ongoing and future research in complex structure vibration.