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A SUBSTRUCTURAL ANALYTICAL METHOD FOR MICRO-VIBRATION RELATED ANALYSES

Abstract

The Finite Element Analysis (FEA) has become the most utilized method to carry out structural analysis and it is implemented in various software packages which are commonly used in Industry. FEA gives accurate predictions up until the first few structural modes of vibration, where the behaviour of real structures is quite deterministic. In the high frequency range statistical approaches are more suitable, and here Statistical Energy Analysis (SEA) has been applied quite successfully. In the mid-frequency range FEM predictions start to become unreliable, and SEA is not applicable as some of its basic assumptions are not verified. This paper has been developed in the context of a project concerning analyses of transmission of micro-vibrations in satellite structures. In addition to the ones related to the mid-frequency range, micro-vibrations introduce other issues: due to the very small amplitude of these disturbances, the related uncertainties are more substantial (e.g. cables might become paths for vibration transmissions). Because of the large bandwidth of the frequency range related to micro-vibrations, their modelling and analysis pose a challenge, in particular in the mid-frequency range, where many of the micro-vibration sources on board a spacecraft (e.g. reaction wheels) tend to act. Monte Carlo Simulations (MCS) give the best (most realistic) results in the mid-frequency range, but they are still too computationally expensive, especially for large models of structures as complex as spacecrafts. Spacecraft are often built-up structures made of various components which are produced by different companies and whose models are delivered as mass and stiffness reduced matrices. The unavailability of the geometric details of each component at disposal, along with the necessity for consistently reducing the time needed to perform the analysis, forms the basis of the new method developed in this paper, which can be classified as a Stochastic FEM. We propose to merge the efficiency of CB reduction with the simplicity and reliability of MCS for the various subsystems to produce an overall analysis algorithm. The method (Craig-Bampton Stochastic Method, CBSM) will be described in this article; with a benchmark example shown. A proof of the validity of the method in a real industrial application will also be presented, which will be performed by comparing the results obtained in applying the CBSM and the MCS to results obtained during an experimental campaign. This campaign has been carried out on the spacecraft SSTL 300 (made available by the company SSTL in Guildford, UK).