Frequency Response of Complex Systems with Localized Nonlinearities

Authors : E. Menga, S. Hernandez

Abstract : Finite Element Models (FEMs) are widely used in order to study and predict the dynamic properties of structures and usually, the prediction can be obtained with much more accuracy in the case of a single component than in the case of assemblies. Especially for structural dynamics studies, in the low and middle frequency range, most complex FEMs can be seen as assemblies made by linear components joined together at interfaces. From a modelling and computational point of view, these types of joints can be seen as localized sources of stiffness and damping and can be modelled as lumped spring/damper elements, most of time, characterized by nonlinear constitutive laws. On the other side, most of FE programs are able to run nonlinear analysis in time-domain. They treat the whole structure as nonlinear, even if there is one nonlinear degree of freedom (DOF) out of thousands of linear ones, making the analysis unnecessarily expensive from a computational point of view. In this work, a methodology in order to obtain the nonlinear frequency response of structures, whose nonlinearities can be considered as localized sources, is presented. The work extends the well-known Structural Dynamic Modification Method (SDMM) to a nonlinear set of modifications, and allows getting the Nonlinear Frequency Response Functions (NLFRFs), through an ‘updating’ process of the Linear Frequency Response Functions (LFRFs). A brief summary of the analytical concepts is given, starting from the linear formulation and understanding what the implications of the nonlinear one, are. The response of the system is formulated in both: time and frequency domain. First the Modal Database is extracted and the linear response is calculated. Secondly the nonlinear response is obtained thru the NL SDMM, by updating the underlying linear behavior of the system. The methodology, implemented in MATLAB, has been successfully applied to estimate the nonlinear frequency response of two systems. The first one is a two DOFs spring-mass-damper system, and the second example takes into account a full aircraft FE Model. In spite of the different levels of complexity, both examples show the reliability and effectiveness of the method. The results highlight a feasible and robust procedure, which allows a quick estimation of the effect of localized nonlinearities on the dynamic behavior. The method is particularly powerful when most of the FE Model can be considered as acting linearly and the nonlinear behavior is restricted to few degrees of freedom. The procedure is very attractive from a computational point of view because the FEM needs to be run just once, which allows faster nonlinear sensitivity analysis and easier implementation of optimization procedures for the calibration of nonlinear models.

Keywords : frequency response, nonlinear dynamics, structural dynamic modification, softening effect, rubber
Conference Title : ICSDEE 2016 : International Conference on Structural Dynamics and Earthquake Engineering
Conference Location : New York, United States
Conference Dates : October 10-11, 2016