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Spectral element-based prediction of active power flow in Timoshenko beams

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Abstract

The analysis of standing waves, which correspond to the reactive part of the power in structures, is not a sufficient tool for studying structural vibration problems. Indeed, the active power component (structural intensity) has shown to be of great importance in studying damped structural vibration problems. One of the most common numerical discretization methods used in structural mechanics is the finite element method. Although this procedure has its advantages in solving dynamic problems, it also has disadvantages mainly when dealing with high frequency problems and large complex spatial structures due to the prohibitive computational cost. On the other hand, the spectral element method has the potential to overcome this kind of problem. In this paper, the formulation of the Timoshenko beam spectral element is reviewed and applied to the prediction of the structural intensity in beams. A structure of two connected beams is used. One of the beams has a higher internal dissipation factor. This factor is used to indicate damping effect and therefore causes structural power to flow through the structure. The total power flow through a cross-section of the beam is calculated and compared to the input power. The spectral element method is shown to be more suitable to model higher frequency propagation problems when compared to the finite element method.

Keywords: Structural power flow; Structural intensity; Timoshenko beam; Spectral element method; Finite element method

1. Introduction

One of the well-known ways to efficiently analyze vibrations of frame structures with complicated boundaries and different discontinuities is the use of matrix formulations such as the finite element method (FEM). However, a large number of finite elements must be used to adequately model the distribution of the inertia of the structure. Furthermore, the higher the frequency, the larger the number of elements that must be used. The FEM can also show some computational difficulties when analyzing large frame structures, where members are usually long and too many finite elements need to be used in the discretization process. Recently, one of the potential alternative techniques being used to analyze the dynamical

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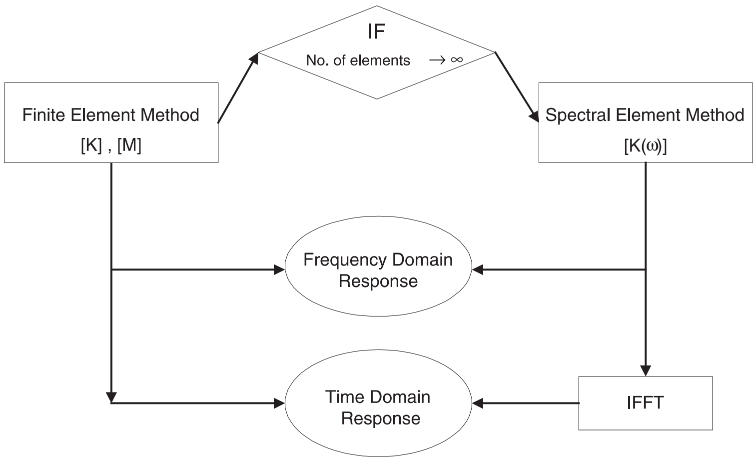

Fig. 1. Relations between FEM and SEM models.

behavior of structures is the power flow (or structural intensity) approach. The term power flow denotes the energy per unit time flowing across a surface defined within the structure by its normal. The use of power flow techniques in this kind of problem may be very useful because power flow calculation combines both force and velocity in one concept.

The measurement of structural power flow was first introduced by Noiseux (1970). In his work, bending vibrational waves obtained as a vector at a measurement point were described in terms of transverse vibrations, and then, the combined rotational and linear accelerations were used for power flow estimation considering far field conditions. The near field conditions were then included in the generalized approach. Experimental results were also used to illustrate the measurement technique. Experimental methods for measuring flexural power flow have been extensively investigated by Pavic (1976) and Verheij (1980). Power flow is usually computed experimentally from measured vibrations using finite difference approximations of the spatial derivatives that appear in the analytical formulations. The number of accelerometers used varies from two to five along each direction, depending on the assumptions made. Other methods have also been used in predicting power flow from measured vibration data: a wave component approach by Halkyard and Mace (1993), a regressive discrete fourier series (RDFS) by Arruda et al. (1996b), and a modified Prony method by Arruda et al. (1996a). Hambric and Taylor (1994) have presented a general approach that allows the application of the FEM power flow analysis to real structures by incorporating experimentally measured termination impedance as boundary conditions. This approach has been investigated on a straight beam.

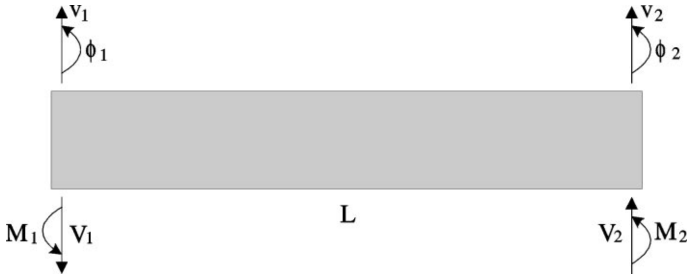

Fig. 2. Timoshenko beam with end loads and DOF.