Wave propagation analysis of functionally graded plates based on a frequency domain SFEM

Namita Nanda

Department of Applied Mechanics, Indian Institute of Technology,
New Delhi, 110 016, India

1. INTRODUCTION & OBJECTIVE

Functionally graded materials (FGMs) are a new class of materials with more than one constituent material. Usually, the materials that constitute FGMs are metal and ceramic. The properties of the materials vary spatially so that there is no sudden change in the elastic properties across the interface. Ceramic in an FGM provides heat resistance, whereas the metal constituent provides mechanical strength and toughness. Because of this, FGMs are widely used in applications such as turbine blades, nuclear reactors, and aerospace components. Due to such vast applications, these structural components are expected to be subjected to high frequency loading, and wave propagation through them becomes an interesting part of the investigation. In recent years, wave propagation studies in FGM structures have attracted the interest of the research community because of their applications in structural health monitoring, damage detection, and assessment.

In the wave propagation problems, the incident pulses have shorter duration, and at higher frequencies, the wavelengths are small, and the conventional finite element methods require very fine mesh. Therefore, finite element methods become computationally expensive for solving wave propagation problems at higher frequencies. Generally, the element size should match with the wavelengths and to overcome meshing difficulties, spectral finite element methods (SFEM) are used. In the present work, a frequency domain SFEM is developed for an FGM plate.

2. RESULTS & HIGHLIGHTS OF IMPOINTANT POINTS

The efficiency and accuracy of the present spectral element are established by comparing the natural frequencies with the published analytical results as shown in Table 1. The spectral element developed is then used to study free vibration response and wave dispersion characteristics of FGM plates (Fig. 1). It is found that the volume fraction index very much influences the wavenumber-frequency dispersion relations of the FGM plate. The volume fraction index also significantly affects the phase velocity and group velocity.

Table 1. Natural frequencies of simply supported Al/Al_2O_3 FGM plate (a/b = 1, $\bar{\omega} = \omega h\sqrt{\rho_c/E_c}$)

h/a	Method	*n*					
		0	0.5	1	4	10	∞
0.05	Present SFEM	0.01496	0.01265	0.01150	0.00997	0.00959	0.00767
	Hashemi et al. (2010)	0.01480	0.01281	0.01150	0.01013	0.00963	-
	Zhao et al. (2009)	0.01464	0.01241	0.01118	0.00970	0.00931	-
0.1	Present SFEM	0.05752	0.04947	0.04486	0.03912	0.03720	0.02953
	Hashemi et al. (2010)	0.05769	0.04920	0.04454	0.03825	0.03627	0.02936
	Zhao et al. (2009)	0.05673	0.04818	0.04346	0.03757	0.03591	-
0.2	Present SFEM	0.21131	0.18139	0.16567	0.14304	0.13384	0.10738
	Hashemi et al. (2010)	0.21120	0.18060	0.16500	0.13710	0.13040	0.10750
	Zhao et al. (2009)	0.20550	0.17570	0.15870	0.13560	0.12840	-

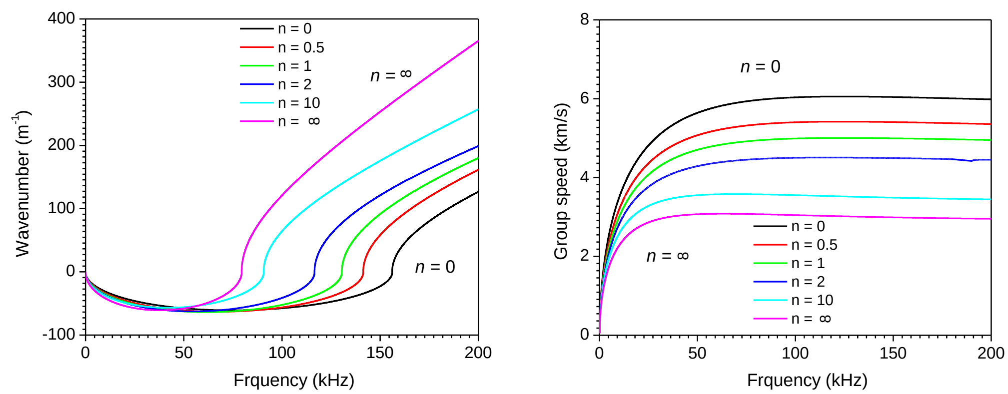

Figure 1. (a) Wavenumber-frequency plot corresponding to q_x mode and (b) Group speed -frequency plot of w mode, for different values of volume fraction index of an Al/Al_2O_3 plate of length a = 1 m and a/h = 50.

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