Composite Structures 187 (2018) 439–453

Contents lists available at ScienceDirect

Composite Structures

journal homepage: www.elsevier.com/locate/compstruct

Scattering of an acoustic wave by composite cylindrical shells: Influence of inner and outer layer thicknesses on the circumferential waves

Said Agounad[a,*], El Houcein Aassif[a], Younes Khandouch[a], Dominique Décultot[b], Gérard Maze[b]

[a] Laboratory of Metrology and Information Processing, Physics Department, Ibn Zohr University, B.P. 8106, 80000 Agadir, Morocco
[b] Laboratoire d'Ondes et Milieux Complexes, UMR CNRS 6294, Université du Havre 75, rue Bellot, 76600 Le Havre, France

A R T I C L E I N F O

Keywords:
Acoustic scattering
Composite structures
Vibration modes
Surface waves
Time-frequency analysis

A B S T R A C T

Acoustic scattering of a plane progressive wave from the composite cylindrical shell is investigated through the solution of the wave equation and boundary conditions of stresses and displacements. The investigated range of reduced frequency extends over $0.1 < k_1a_1 < 200$ (k_1 is the wave number in a fluid medium surrounding the composite cylindrical shell and a_1 is the outer radius of the shell). The far field form function for two-layered stainless steel/polymer cylindrical shell is evaluated and examined. The achieved results are compared with those obtained in the case of one-layered cylindrical shells made of stainless steel or polymer. The investigation is carried out into the influence of the inner layer thickness (polymer) on the circumferential waves of the stainless steel/polymer composite cylindrical shell on the one hand and of the outer layer thickness (stainless steel) on the other hand. This influence is studied based on the evolution of the cutoff frequencies of the circumferential waves. A comparative analysis of the evolution of the cutoff frequencies of the one-layered and composite cylindrical shells is conducted. The estimation of the cutoff frequencies is done from plane of modal identification and two time-frequency planes, the spectrogram and the reassignment spectrogram. The results show that these planes are very useful to estimate the cutoff frequencies of the circumferential waves of the composite cylindrical shell. They can therefore be suggested as an alternative of the proper modes theory which is applicable in the case of homogeneous structures.

1. Introduction

The scattering of a plane acoustic wave has drawn immense attentions from research activities because of the growing interests in various fields. Many authors have dealt with the acoustic scattering from cylindrical components (e.g., tubes, fibers, cylinders, pressure vessels, wires, etc.). The first investigation into the scattering of a normal incident plane acoustic wave upon an immersed cylinder was done by Faran [1]. The acoustic scattering of an oblique incident wave on a cylinder was considered by numerous researchers [2–8]. Thereafter, the similar investigation for the elastic cylindrical shell was carried out [9–16]. Recently, the research activities in this field were focused on acoustic scattering from the composite cylinder and cylindrical shell due to their growing use in engineering applications. Dai et al. [17] applied an exact solution to study the thermoelectroelastic behavior of a fluid-filled cylindrical thin-shell made of functionally graded piezoelectric material (FGPM). Rajabi and Behzad [18] introduced an exact analysis based on the wave function expansion to examine the acoustic scattering of a plane wave incident at an arbitrary angle on an arbitrary fluid-filled thick helically filament-wound cylindrical shell immersed in water. Yin and Yue [19] used the expansion of transient wave function in a series of eigenfunctions to investigate the transient plane-strain response of multilayered elastic cylinders subjected to uniformly distributed dynamic pressures at the boundaries. Kaduchak and Loeffler [20] employed an exact three dimensional elasticity theory to analyze the acoustic scattering of an oblique incident plane wave upon a multilayered transversely isotropic cylindrical shell. Kim and Ih [21] utilized the normal mode expansion method and resonance scattering theory to isolate the resonance behavior of a transversely isotropic cylindrical shell submerged in water and air-filled cavity, excited by an oblique incident plane wave. Chati et al. [22] investigated the scattering of a normal incident plane acoustic wave from an aluminum tube with a concentric Lucite cylinder coupled by a thin water layer. Hasheminejad and Rajabi [14] employed the laminate approximate approach in the context of state space model to analyze the scattering of a plane acoustic wave by an immersed orthotropic cylindrical shell. Dai et al. [23] studied the static bending of a finite length two-layered structure subjected to radially symmetric mechanic and thermal

* Corresponding author.
E-mail address: said.agounad@edu.uiz.ac.ma (S. Agounad).

https://doi.org/10.1016/j.compstruct.2017.12.015
Received 26 July 2017; Received in revised form 30 October 2017; Accepted 11 December 2017
Available online 13 December 2017
0263-8223/ © 2017 Elsevier Ltd. All rights reserved.

loadings. Wang et al. [24] investigated the transient responses in a double-layered elasto-piezoelectric cylindrical shell in the state of axisymmetric plane strain. Li and Hua [25] developed an approximate solution to the problem of the transient vibration of an infinite-length elastic laminated cylindrical shell subjected to an underwater shock wave. Xi et al. [26] used a layer element method, formulated as part of the elasticity theory, for investigating frequency and group velocity dispersive behaviors of waves in submerged laminated composite cylindrical shell. Jin et al. [27] proposed an exact solution for the free vibration analysis of composite laminated cylindrical shells with general elastic boundary conditions and arbitrary lamination schemes. Rajabi et al. [28] studied the scattering of an oblique plane acoustic wave upon a laminated composite cylindrical shell using the three-dimensional exact equations of anisotropic elasticity. Dai et al. [29] carried out a review of latest research findings on functionally graded material cylindrical components under coupled physical interactions. Xie et al. [30] applied a simple and accurate solution procedure based on the Haar wavelet method to the free vibration analysis of composite laminated cylindrical shells under various boundary conditions.

The excitation of an elastic cylindrical shell by a plane acoustic wave perpendicularly to its revolution axis leads to the formation of circumferential waves in and around the shell [11,31,32]. For some frequencies, these waves create standing waves on the circumference of the shell constituting resonances. The Resonance Scattering Theory (RST) [2] shows that the backscattered acoustic field is the superposition of the non-resonant field which is related to the geometric reflection of the incident wave on the shell and resonant field which is related to the resonant frequencies of the cylindrical shell. Each resonant frequency is corresponding to an integer ‘n’ called vibration mode or mode n [4]. The mode n is the number of wavelengths around the circumference of the shell to observe a given resonance. The resonance frequencies are related to the physical and geometrical properties of the considered structure. The characterization and the non-destructive testing of the structure can therefore be carried out from these frequencies [15,16,33,34].

The present paper focuses on the investigation of the acoustic scattering from two-layered stainless steel/polymer cylindrical shell excited by an incident plane wave perpendicularly to its axis. This structure is immersed in water and filled with air. The investigation is done based on the solution of the wave equation in different media and boundary conditions at interfaces. The time analysis is used to study the chronological evolution of the acoustic scattering. The main drawbacks of this analysis are the overlapping of echoes and lack of information about the frequency content of the circumferential waves. The frequency analysis is useful to study the frequency content of the acoustic scattering, but does not enable us to check up the temporal evolution. In order to overcome the limitations of these analyses, the time-frequency representation is used [35,36]. Numerous time-frequency methods have been proposed [37–40]. To improve the readability of the time-frequency representation, many authors have proposed to use the reassignment method [41–44]. In the case of the one-layered cylindrical shell, several authors showed that the time-frequency representation is very useful for estimating the properties of the circumferential waves [16,45]. In this work, the spectrogram, the reassignment spectrogram, and the plane of modal identification are used to estimate the cutoff frequencies of the circumferential waves of the composite cylindrical shell. The influence of the outer layer thickness on the waves propagating in and around the composite cylindrical shell is investigated on the one side. In this case, the outer radius ratio is varied from 0.32 to 0.99 with steps of 0.01. However, the inner layer thickness is still constant. On the other side, the influence of the inner layer thickness is investigated. In this case, the inner radius ratio is varied from 0.32 to 0.99 with steps of 0.01 and the outer layer thickness remained constant. This influence is studied based on the evolution of the cutoff frequencies of the circumferential waves. The achieved results are compared with those obtained in the case of the one-layered cylindrical shells made of the polymer or stainless steel. The identification of the cutoff frequencies is useful for characterization purposes. Indeed, these frequencies are dependent on physical properties of the cylindrical shell.

The theoretical model developed in this paper can be applied to study the acoustic scattering by bi-layered cylindrical shells. In the case where one of the layers is made from the polymer as in this paper, the studied range of reduced frequency shall be selected carefully. Indeed, the absorption in polymer material increases with frequency. Because of the loss of acoustic energy by absorption, the magnitude of resonances is decreased.

The remaining part of this paper is structured as follows. Section 2 describes the acoustic scattering by the composite cylindrical shell. The numerical results and their analysis are carried out in Section 3. Section 4 devotes to study the influence of inner and outer layer thicknesses on surface waves of the composite cylindrical shell. Finally, conclusions are given in Section 5.

2. Formulation of the acoustic scattering from bilayered cylindrical shell

The acoustic scattering of a normal incident plane wave, with angular frequency ω, on an immersed and fluid-filled bilayered cylindrical shell is dealt with through the solution of the wave equation and boundary conditions. The problem geometry and cylindrical coordinate systems (r,θ,z) are shown in Fig. 1. The z-axis is coincident with the revolution axis of the cylindrical shell. The radius ratio of the inner layer and that of the outer layer of the composite cylindrical shell are defined as $r_{21} = a_2/a_1$ and $r_{32} = a_3/a_2$, respectively. The global radius ratio is given by $r_{31} = a_3/a_1$.

2.1. Wave equation

Wave equation of an acoustic wave propagating in an isotropic elastic medium is obtained from fundamental principle of dynamics applied to a volume V of this medium. Applying of the Green's theorem and after some manipulations, the wave equation may be expressed as [11,46]

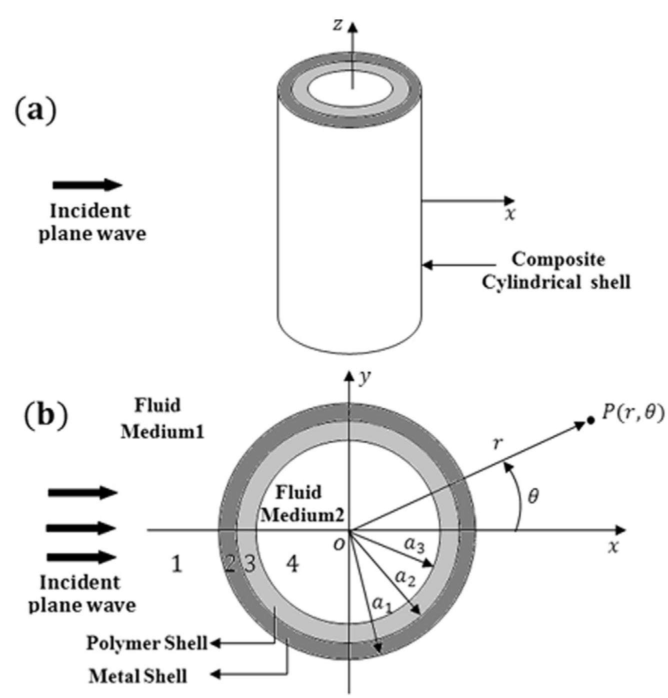

Fig. 1. Configuration of problem: (a) interaction of a plane acoustic wave with composite cylindrical shell, (b) polar coordinate system and different fields.

Download English Version:

https://daneshyari.com/en/article/6704360

Download Persian Version:

https://daneshyari.com/article/6704360

Daneshyari.com