Advances in Applied Mathematics and Mechanics
Adv. Appl. Math. Mech., Vol. **15**, No. 6, pp. 1655-1698

DOI: 10.4208/aamm.OA-2022-0176
December 2023

Vibration Behavior of a Sandwich Porous Elliptical Micro-Shell with a Magneto-Rheological Core Based on the Modified Couple Stress Theory

A. Mohammadpour, S. Jafari Mehrabadi*, P. Yousefi
and H. Mohseni Monfared

Department of Mechanical Engineering, Islamic Azad University, Arak Branch. Arak, Iran

Received 1 July 2022; Accepted (in revised version) 7 December 2022

Abstract. Recently, the use of porous materials has grown widely in many structures, such as beams, plates, and shells. The characteristics of porous materials change in the thickness direction by different functions. This study has investigated the free vibration analysis of a sandwich porous elliptical micro-shell with a magneto-rheological fluid (MRF) core for the first time. Initially, we examined the displacement of the middle layer's macro- and micro-components, using Love's shell theory. Next, we used the modified couple stress theory (MCST) to obtain the strain and symmetrical curvature tensors for the three layers. The Hamilton's principle was implemented to derive the equations of motion. We also used the Galerkin's method to solve the equations of motion, resulting in a system of equations in the form of a linear eigenvalue problem. By solving the governing equations, we obtained the various natural frequencies and loss factors of the elliptical micro-shell, and compared them with the results in earlier studies. Lastly, we investigated the effects of thickness, porosity distribution pattern, aspect ratio, length scale parameter, and magnetic field intensity on the natural frequency and loss factor of the micro-shell. The data accuracy was validated by comparing them with those of reputable previous articles.

AMS subject classifications: 74-11

Key words: Elliptical micro shell, free vibration, magneto-rheological core, modified couple stress theory, sandwich porous material.

1 Introduction

Elliptical cylindrical shells are a particular type of structural element in engineering. The vibration of elliptical cylindrical shells is more critical than many other cylindrical structures. These structures are commonly used in acoustic transducers, submarine vehicles,

*Corresponding author.
Email: sjmamir@gmail.com (S. Jafari Mehrabadi)

aircraft wings, fuselages, acoustic mufflers, and other similar structures. An extensive review, which has been published by Liessa [1], addresses the vibration of shells, including circular cylindrical shells. In recent years, Quato [2] published a review of more recent articles on similar shells. However, few studies have been conducted to date on the vibrational behavior of elliptical, cylindrical shells.

The vibration equations of elliptical, cylindrical shells are partial differential equations (PDEs) with variable coefficients of radius and circumferential curvature, making it more challenging to solve the analytical vibration problems of elliptical cylindrical shells than circular cylindrical shells. To overcome the difficulty of analysis, numerical methods have been applied to the analysis of the vibration behavior of elliptical, cylindrical shells. Shirakawa and Morita [3] considered the cross-section of the ellipse as two interconnected pieces of one circular arc. In their study, they employed the equations of circular, cylindrical shells to analyze vibration behavior of elliptical cylindrical shells. Further, the natural frequency of elliptical cylindrical shell are determined by assuming the continuous conditions of two pieces of the circular arcs. However, this method is very complicated due to the high-order partial derivatives. Hence the reason for undertaking the current study. After presenting the aim of the study, this article provides a careful review of the pertinent literature to familiarize the readers with the state-of-the-art studies on the subject.

1.1 Aim of the study

Considering the growing use of the functionally graded (FG) porous materials and their significant impact on controlling the free vibration behavior of FG porous elliptical microshells and the scarcity of research findings on this subject, we aimed to investigate a novel structural model as a porous elliptical micro-shell with a magneto-rheological core. The innovative objectives of this study were the impact of shell thickness, porosity distribution pattern, aspect ratios, length scale parameter, and magnetic field intensity on the natural frequencies and the loss factors, based on the modified couple stress theory (MCST), Hamilton's principle and Galerkin's method. Briefly, our promising results provide first-hand evidence that the material length scale and porosity parameters, geometry, wave number, cross-sectional, elliptical ratios, and magnetic field intensity all impact the structure's natural frequency and loss factor. These will be presented and discussed following a review of the literature.

1.2 Literature review

Klosner and Pohle [4, 5] used a perturbation method to examine the vibration behavior of elliptical, cylindrical shells. However, this method can only be applicable for shells with a small elliptical parameter. Yamada, et al. [6] derived the equations for elliptical, cylindrical shells, using Sanders' shell theory and the principle of energy change, implementing the Ritz method to derive the natural frequency of their elliptical shell. Based