Free Vibration analysis of a rotating cylindrical shell made of FG-GPLR porous core and MEE face with uncertain parameters in thermal environment

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ABSTRACT

In this study, free vibration analysis of a rotating composite double-layer cylindrical shell has been carried out using first-order shear deformation theory. The shell is made of a thin magneto-electroelastic (MEE) top layer bonded to the functionally graded graphene platelet reinforced (FG-GPLR) porous layer and is subjected to the thermal environment. The two ends of the shell can be considered as pinned boundary conditions due to the presence of bearings that prevent transverse movement. At first, natural frequencies of the forward and backward modes for the rotating composite shell were obtained and verified by the literature results. Then the effect of rotational speed, mode numbers, temperature change, porosity and GPLs mass fraction on the frequencies were investigated. This study then seeks to investigate the effect of uncertainties in the MEE layer properties on the free vibration of a rotating composite shell exposed to electric and magnetic potentials. In this case, the uncertainties in the elastic modulus, piezoelectric and piezomagnetic coefficient of the smart layer, are introduced using a symmetric Gaussian fuzzy number. The governing equations for the uncertain system are obtained by combining Hamilton's principle and the dual parametric form of fuzzy numbers; Then the natural frequencies of the uncertain model are calculated using Navier's approach. Free vibration is also investigated by obtaining the natural frequency borders with respect to the various uncertain parameters**. The results have shown that the porosity increased the frequencies. In the case of uncertain properties, with increasing of the electric potential, the frequency bounds decreased slightly, but they increased intensely with increasing of the magnetic potential.**

KEYWORDS

Rotating composite cylindrical shell, Magneto-Electro-Elastic layer, FG-GPLR porous material, Natural Frequency, Uncertain parameters.

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1. Introduction

Natural Frequency evaluation of rotating composite shells has been a major concern for scientists, to avoid the resonance phenomena. Vibration analysis of the shells considered by many researchers. Malekzadeh and Heydarpour [1] studied the vibration behavior of rotating FG shells in the thermal environment using FSDT. Free vibration analysis of rotating FG-CNTRC shells reported by Qin et al. [2] with FSDT. Utilizing the Donell model, Liu et al [3] obtained vibration characteristics of a rotating multi-layered shell under thermal load. Tornabene [4] investigated the natural frequencies of rotating panels by means of HSDT.

Piezoelectric and piezomagnetic materials are combined to make the composite material called magneto-electro-elastic (MEE) composites. These composites can convert one form of energy to another, among magnetic, electric, and mechanical energies. The vibrational properties of MEE structures have been discussed in the literature. Applying GDQM Rostami et al. [5] examined the natural frequencies of rotating cylindrical shells with FG-MEE coating with FSDT. Vinyas [6] considered the vibration behavior of MEE annular plates with the aid of TSDT.

In order to better investigate the behavior of composites, it is necessary to quantify the impact of uncertainty in the investigations. So far, little research has been done in this field. Piovan et al. [7] investigated the dynamic behavior of thin-walled beams by means of parameter uncertainties. Karkon et al. [8] studied the effects of uncertain elastic modules on the buckling and vibration of plates, using FEM and Gaussian random field scheme. Considering parameter uncertainties, the dynamic response of the rotating cylindrical shell is reported by Zhao et al. [9]. In this study, vibration analysis of the rotating shell including the MEE composite layer with uncertain parameters is presented. In addition, for the first time, the effect of porous GPLRC in the shell, which increases its strength and reduces its weight, is investigated on the frequency results.

2. Methodology

In Figure 1, the model is presented in the form of a rotating two-layer cylindrical shell, where R is the average radius and L is its length. This shell consists of a core made of porous FG-GPLR material with a thickness of h and an outer layer made of a hybrid smart MEE layer with a thickness of h_p. Cylindrical coordinates x,θ, and z are used for the model and the rotation speed of the shell around the x-axis is equal to **Ω.** The mechanical properties of the porous FG-GPLR layer are calculated by considering the improved Halpin-Tsi micromechanical model [10], the mixture law, and also the relationships specific to the FG porous closed-cell material.

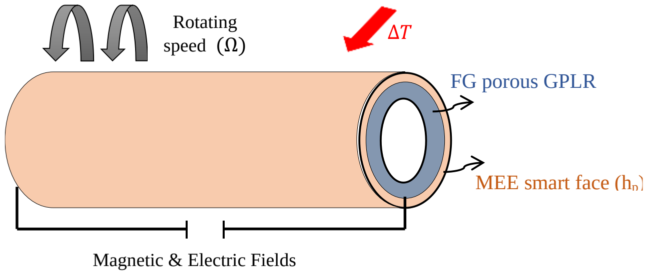

Figure 1. Schematic of double layer rotating cylindrical shell in thermal environment

Hamilton's principle is used to obtain the coupled equations of the cylindrical shell. By assuming the simply supported boundary conditions, Navier's method is used to solve the equations. For the elastic modulus and piezoelectric and piezomagnetic constants of the smart layer, the predicted uncertainty is assumed as a symmetric Gaussian fuzzy number (SGFN) [11].

3. Results and Discussion

Figure 2 presents the dimensionless frequency changes of the reinforced shell in terms of velocity in two half-wave numbers for both cases with and without porosity.

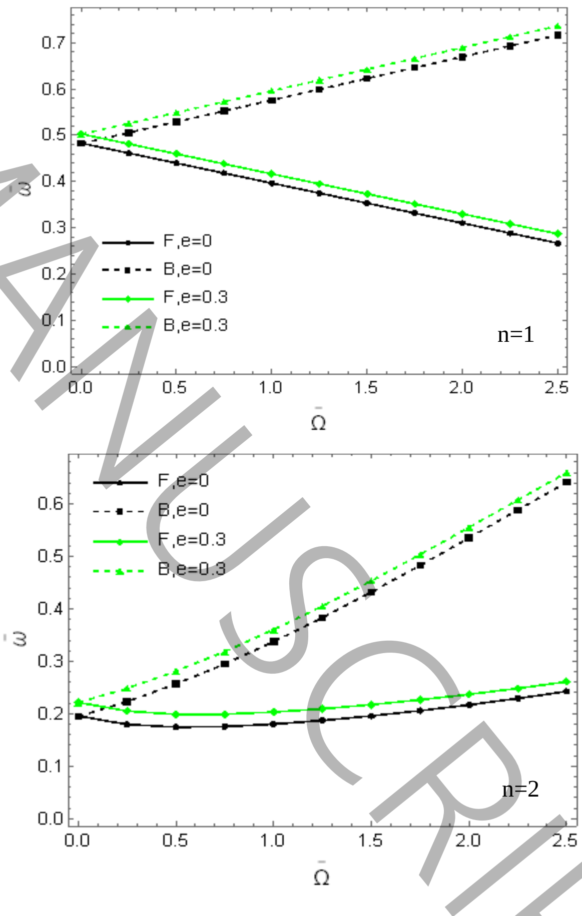

Figure 2. Effect of porosity on the frequencies for the rotating composite shell versus the rotation speed

According to the results, in all three diagrams and for both B and F modes, the presence of porosity has led to an increase in frequency. Porosity was expected to reduce the hardness and density of the shell. But because the mass change is greater than its hardness, it has finally led to an increase in frequency.

According to Figure 3, it is evident that the upper and lower limits of the natural frequency both decrease with the increase of the electric potential value, while with the increase of the magnetic potential value, the opposite of this behavior is observed, and the reason is that the positive changes of the electric potential It can reduce the stiffness of the shell, while the positive sign of the magnetic potential increases the stiffness of the shell.

4. Conclusions

In this research, the free vibration of the rotating composite cylindrical shell made of porous FG-GPLR and smart magneto-electroelastic layer in the temperature environment has been investigated, considering the uncertainty in the properties of the smart layer. In the first part, the calculation of the natural frequency of the two-layer composite rotating shell with fully defined properties is considered, while in the second part of this study, the effect of the uncertainties of the properties of the outer intelligent layer on the vibration is considered. The most important research results are:

In both Backward and Forward modes, the increase in the mass fraction of graphene in the inner layer has led to an increase in bending stiffness and subsequently to an increase in frequency, on the other hand, the presence of porosity has led to an increase in frequency. The increase in the temperature on the external surface has led to the creation of compressive stresses and reduced the frequency. In the case of indeterminate properties, the upper and lower edges of the natural frequency both decrease to a small amount with the increase of the electric potential value, while they increase dramatically with the increase of the magnetic potential value.

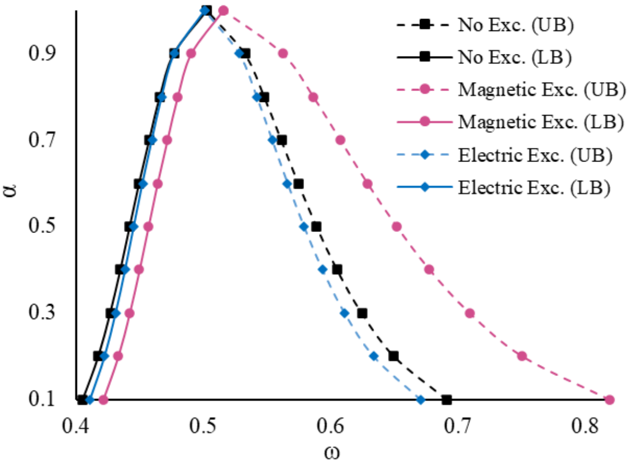

Figure 3: Gaussian fuzzy output for natural frequencies of smart sandwich shell, when Ω=0

5. References

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