Advances in Computational Design, *Vol. 7, No. 3 (2022) 211-227*
https://doi.org/10.12989/acd.2022.7.3.211

Computational electromechanical approach for stability/ instability of smart system actuated with piezoelectric NEMS

Zhonghua Luo*, Xiaoling Cheng and Yuhan Yang

School of Electronics and Information, Nanchang Institute of Technology, Nanchang 330044, Jiangxi, China

(Received August 21, 2021, Revised January 27, 2022, Accepted March 8, 2022)

Abstract. In this research, the size-dependent impact of an embedded piezoelectric nanoplate subjected to in-plane loading on free vibration characteristic is studied. The foundation is two-parameter viscoelastic. The nonlocal elasticity is employed in order to capture the influence of size of the plate. By utilizing Hamilton's principle as well as the first- order shear deformation theory, the governing equation and boundary conditions are achieved. Then, using Navier method the equations associated with the free vibration of a plate constructed piezoelectric material under in-plane loads are solved analytically. The presented formulation and solution procedure are validated using other papers. Also, the impacts of nonlocal parameter, mode number, constant of spring, electric potential, and geometry of the nanoplate on the vibrational frequency are examined. As this paper is the first research in which the vibration associated with piezoelectric nanoplate on the basis of FSDT and nonlocal elasticity is investigated analytically, this results can be used in future investigation in this area.

Keywords: first order shear deformation theory; nanoplate; nonlocal theory; piezoelectric materials; vibration

1. Introduction

Due to vast application of structures in small scales—nano and micro—these structures have been topics of many papers in the past few years. In this regard, the fact that should be considered is that the behavior of structures in these scales cannot be predicted using common elasticity (Habibi *et al.* 2016, 2018a, b, 2019a, b, c, Ebrahimi *et al.* 2019a, Esmailpoor Hajilak *et al.* 2019, Pourjabari *et al.* 2019, Safarpour *et al.* 2019a). Therefore, researcher has devoted quite effort to capture the impacts of small size on the characteristics of micro- and nano-structures. Given this, many different elasticities, such as modified couple stress (Habibi *et al.* 2017, 2019a, b, c, d, e, Safarpour *et al.* 2018, Chen *et al.* 2022) and the nonlocal theory (Eringen 2002), has been employed to do so.

There has been a large number of articles and research whose main focus is nonlocal or nonlocal strain gradient theory. For example, Safarpour *et al.* (2018), using a nonlocal strain gradient elasticity, carried out the wave propagation associated with a nanoshell which is constructed from composite materials and placed in a thermal environment. They presented analytic solution in order to extract the results. Also, the buckling in addition to vibration of a shell

---

*Corresponding author, E-mail: fc@nut.edu.cn

http://www.techno-press.org/?journal=acd&subpage=7 ISSN: 2383-8477 (Print), 2466-0523 (Online)

which is modeled by nonlocal strain gradient theory which is made of reinforced composites with the aid of graphene was investigated (Mohammadgholiha *et al.* 2019). In this paper, GDQM is employed as the numerical solution procedure. By utilizing nonlocal strain gradient elasticity along with the first shear order theory, the formulation for frequency behavior of a composite microtube is extracted and solved by GDQM (Oyarhossein *et al.* 2020). Additionally, Al-Furjan *et al.* (2021a) investigated the vibrational behavior related to a rotation nanodisk which is constructed by piezoelectric materials. In the mentioned article, the nonlocal strain gradient as the size-dependent theory and higher shear deformable plate theory are incorporated in order to obtain the equations. Next, the vibration as well as buckling analysis associated with a cylindrical shell which is made of composite material is analyzed by utilizing generalized differential quadrature element method, as the numerical solution (Moayedi *et al.* 2021). Also, the stability analysis and vibrational characteristic of nanobeams constructed with axially FG materials was probed, utilizing the nonlocal elasticity as the size-dependent theory (Shariati *et al.* 2020a).

Piezoelectric materials have been employed in various devises such as sensors, controller, and actuators, as by means of which strain energy can be altered to electrical energy and vice versa (Ebrahimi *et al.* 2019b, 2020a, Hashemi *et al.* 2019, Moayedi *et al.* 2019, 2020a,b, Mohammadgholiha *et al.* 2019, Mohammadi *et al.* 2019, Habibi *et al.* 2020, Oyarhossein *et al.* 2020, Shariati *et al.* 2020b, c, Shokrgozar *et al.* 2020). Accordingly, scholars have utilized this type of material in various structures. For instance, Habibi *et al.* (2019e) explored the wave propagation in a nanostructure which is made of composite material and coupled with a piezoelectric layer. The size effects have been considered through nonlocal strain gradient theory. Also, the buckling along with vibration of a rotating thick shell in a cylindrical shape which is covered by a piezoelectric layer and having a attached mass-spring was studied (Safarpour *et al.* 2019b). In this paper, the impacts of various thermal distribution on the system was investigated. Additionally, the vibrational behavior of rotating nanoshells constructed with reinforced composites with nanoplatelets and a layer of piezoelectric was probed by Habibi *et al.* (2019b). They incorporated GDQM in order to extract the results. By utilizing moderately cylindrical thick shell theory, Shokrgozar *et al.* (2020) formulated the vibration of a rotating cylindrical shell coupled with a piezoelectric layer and attached mass-spring system. Next, the frequency characteristics associated with a microdisk made of reinforced composite with the aid of graphene nanoplatelets and a piezoelectric layer was conducted (Ebrahimi *et al.* 2020b). In this article, in order to attain the mechanical properties of the reinforced composite, the rule of mixture in addition to Halpin–Tsai was used. Some researchers (Hashemi *et al.* 2019, Al-Furjan *et al.* 2020a, b, c, d, e, f, 2021a, Bai *et al.* 2020, Cheshmeh *et al.* 2020, Li *et al.* 2020a, Lori *et al.* 2020, Najaafi *et al.* 2020, Shariati *et al.* 2020d, Zhang *et al.* 2020, Guo *et al.* 2021, Liu *et al.* 2021a) carried out a research on the vibration as well as buckling of a two-layered micro disk containing a piezoelectric layer along with a reinforced composite layer which is subjected to thermal loads. By employing Hertz contact theory together with first-order shear deformation theory, Guo *et al.* (2021) conducted the vibration as well as electrical response corresponded with a curved piezoelectric panel placed on a viscoelastic substrate and under low velocity impact. With the aid of GDQM numerical solution, the electrical behavior of a microdisk containing a piezoelectric layer in addition to a reinforced composited layer with nanoplatelets was investigated (Shamsaddini Lori *et al.* 2021). By employing nonlocal strain gradient theory, the wave propagation associated with a cylindrical shell including a piezoelectric layer as well as a reinforced composite layer embedded in a viscoelastic medium was solved analytically (Habibi *et al.* 2019c). Al-Furjan *et al.* (2020a) managed to conducted a research on the vibration response as well as critical voltage of a cylindrical shell with tow layer whose outer layer is piezoelectric and the inner is made of reinforced porous composite with nanoplatelets. Ebrahimi *et al.* (2019b), by utilizing the nonlocal strain gradient theory, studied the wave propagation related to nanoshells constructed with a piezoelectric layer along with a nanoplatelet-reinforced composite. The dynamic control of a nanoshell made of graphene nanoplatelets reinforced composite which is coupled with a piezoelectric layer was studied (Al-Furjan *et al.* 2020d). The formulations are obtained through first-order shear deformable theory, and also solved by GDQM. In addition, the two-layered cylindrical shells, whose outer layer is piezoelectric and inner one is made of reinforced composite material was studied (Hashemi *et al.* 2019). Al-Furjan *et al.* (2020f) explored the buckling along with the post buckling behavior of an annular plate made of two layers one of which was reinforced composite and the other was piezoelectric. By utilizing the first shear deformable theory, the vibration related to a shell which is covered by piezoelectric layer and having a core made of reinforced composites was investigated. (Al-Furjan *et al.* 2021b)

Vibration behavior of structures has been the subject of a great number of papers, due to the vast usage of this area in various devices. In this regard, the impacts of porosity on the forced along with free vibration of reinforced-composite nanoshells was examined (Pourjabari *et al.* 2019). In this paper, three different types for porosity distribution are considered. Also, Ebrahimi *et al.* (2019c) carried out the vibration together with buckling related to a rotating reinforced composite shell used as a conveying viscous fluid systems. Additionally, buckling as well as the free and forced vibration for nanoshells made of reinforced composites surrounded by Pasternak medium were probed (Moayedi *et al.* 2019). Ghabussi *et al.* (2019) analyzed the vibration reinforced-composited nanoshell in cylindrical shape which is coupled with a piezoelectric layer and embedded in a viscoelastic material. The reinforced composite is considered to be functionally graded in the thickness direction. With the aid of higher shear deformable theory and GDQM, the buckling and vibration characteristic of a microdisk made of reinforced composited with graphene nanoplatelets was formulated and solved by Moayedi *et al.* (2019). In this paper, the rule of mixture is employed in order to obtain the mechanical features related to reinforced composite. By incorporating modified couple stress theory, the forced vibration and buckling related to a reinforced composited nanoshell which is subjected to thermal load was investigated (Ebrahimi *et al.* 2020c). The formulation of vibration as well as buckling associated with a rectangular plate made of reinforced composites with carbon nanotubes was attained by means of higher order shear deformation theory by Cheshmeh *et al.* (2020). Liu *et al.* (2020a) explored the vibration of disk whose material is reinforced composited with the aid of carbon fibers along with carbon nanotubes. The disk is modeled with third order shear deformable theory and is under thermal load. Additionally, the free vibration alongside buckling of a conveying-fluid shell with two layers, the core of which is made of reinforced composites with nanoplatelets, and the outer layer is piezoelectric was analyzed (Shi *et al.* 2020). With the help of higher order shear deformation plate theory, Habibi *et al.* (2020) studied the vibration behavior of a viscoelastic circular plate which is made of composites reinforced by FG distributed graphene platelets. The vibrational characteristic of a reinforced composite disk which placed on a viscoelastic Pasternak foundation and subjected to mechanical as well as nonlinear thermal loads was examined (Shahgholian *et al.* 2020). Shariati *et al.* (2020c) investigated the nonlinear vibration of a disk, whose material is reinforced composite with carbon fiber and carbon nanotube, placed on nonlinear foundation and in a thermal environment. By utilizing the third-order SDT, the nonlinear vibration behavior related to a reinforced composite disk which is placed in hygro-thermal surrounding was carried out (Liu *et al.* 2020b). Also, the vibration behavior for a rotating disk made of composite material and placed on

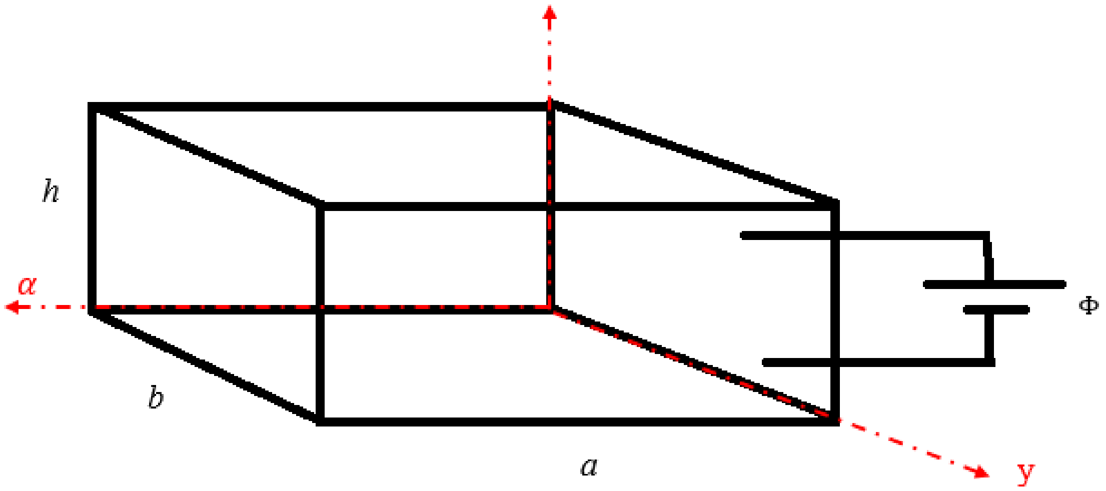

Fig. 1 A schematic of the piezoelectric nanoplate

a two-parameter substrate was examined (Wang *et al.* 2020).

In this study, the fee vibration and critical voltage associated with a piezoelectric nanoplate resting on a viscoelastic foundation and modeled by first order shear deformable plate theory is investigated. The effect related to the size is taken into account using nonlocal elasticity. Also, with the aid of Hamilton's principle, energy method, the corresponding governing equation and end conditions are extracted. Then, using Navier method the equations are solved analytically. The presented formulation and solution procedure are validated using other papers. Additionally, the impact of various parameter which affects the vibration of the nanostructure are studied in detail.

2. Mathematical modeling

Here, the piezoelectric nano late is exhibited in Figure 1. The geometry of the plate is shown in the Fig. 1.

2.1 Kinematic relations

The displacement in three directions can be presented as (Karimiasl *et al.* 2019):

$$\begin{aligned} u(\alpha,y,z,t) &= u_0(\alpha,y,t) + zu_1(\alpha,y,t) \\ v(\alpha,y,z,t) &= v_0(\alpha,y,t) + zv_1(\alpha,y,t) \\ w(\alpha,y,z,t) &= w_0(\alpha,y,z,t) \end{aligned} \tag{1}$$

in which u, w, and v represent the value for the total displacements. In addition, u_0, v_0, and w_0 denotes the value of displacements related to the midplane of the plate. Also, u_1 and v_1 represent rotations of transverse normal on the mid-plane. Also, the associated nonzero strain are written as (Karimiasl *et al.* 2019):

The relation between stress and strain along with the electric displacement associated with the piezoelectric nanostructure can be written as (Eringen 2002, Ke *et al.* 2014):

$$\begin{aligned} \sigma_{ij} &= c_{ijkl}\varepsilon_{kl} - q_{nij}H_n - e_{mij}E_m - \beta_{ij}\Delta T \\ D_i &= e_{ikl}\varepsilon_{kl} + d_{in}H_n + s_{im}E_m + p_i\Delta T \end{aligned} \tag{3}$$

in which e_{mij}, s_{im}, and c_{ijkl}, represent the piezo-electric, dielectric, as well as elasticity matrix constants, respectively. Additionally, in Eq. (3), electric fields strength along with electric displacements are denoted by D_i, and E_m. In addition, the field strength of electric (E_α, E_y, E_z) can be written as follow.

$$E_\alpha = -\frac{\partial \Phi}{\partial \alpha}, E_y = -\frac{\partial \Phi}{\partial y}, E_z = -\frac{\partial \Phi}{\partial z} \tag{4}$$

The electric field can be obtained through the following equation

$$\Phi(\alpha, y, z, t) = \frac{2z\phi_0}{h} - cos(\pi z/h)\phi(\alpha, \beta, t) \tag{5}$$

The parameters which is utilized in Eq. (5) are presented in Ref. (Ghadiri and Safarpour 2016) in detail.

2.2 Hamilton's principle

Hamilton's principle (Adamian *et al.* 2020, Al-Furjan *et al.* 2020a, 2021a, Li *et al.* 2020b, Liu *et al.* 2020b, 2021b, Zare *et al.* 2020, Dai *et al.* 2021, Habibi *et al.* 2021, He *et al.* 2021, Huang *et al.* 2021, Zhang *et al.* 2021) is employed to achieve the governing equation in addition to the boundary conditions as follow

$$\int_{t_1}^{t_2} (\delta U + \delta U^p + \delta U_1 - \delta K + \delta \Pi_{w1} + \delta \Pi_{w2}) dt = 0 \tag{6}$$

where, the kinetic energy associated with the piezoelectric NEMS can be given as:

$$\delta K = \int_Z \iint_A \rho \left\{ (\frac{\partial u}{\partial t}\frac{\partial \delta u}{\partial t}) + \frac{\partial v}{\partial t}\frac{\partial \delta v}{\partial t} + \frac{\partial w}{\partial t}\frac{\partial \delta w}{\partial t} \right\} dA \tag{7}$$

Additionally, the first variation corresponded to potential energy can be written as:

$$\begin{aligned} \delta U &= \frac{1}{2}\iiint_V \sigma_{ij}\delta\varepsilon_{ij} dV = \\ &= \iint_A \begin{bmatrix} N_{\alpha\alpha}\frac{\partial \delta u_0}{\partial \alpha} + M_{\alpha\alpha}\frac{\partial \delta u_1}{\partial \alpha} + N_{yy}\frac{\partial \delta v_0}{\partial y} + M_{yy}\frac{\partial \delta v_1}{\partial y} \\ +N_{yz}(\delta v_1 + \frac{\partial \delta w_0}{\partial y}) + N_{\alpha z}(\delta u_1 + \frac{\partial \delta w_0}{\partial \alpha}) \\ +N_{\alpha y}\left(\frac{\partial \delta u_0}{\partial y} + \frac{\partial \delta v_0}{\partial \alpha}\right) + M_{\alpha y}\left(\frac{\partial \delta u_1}{\partial y} + \frac{\partial \delta v_1}{\partial \alpha}\right) \end{bmatrix} dA \end{aligned} \tag{8}$$

in which

$$\left\{N_{ij}, M_{ij_{ij}}\right\} = \int_z \left\{\sigma_{ij}, z\sigma_{ij}\right\} dz \tag{9}$$

Also, the strain energy related to the piezo patch, Eq. (8), should be as follow

$$\delta U^P = \iint_A (D_\alpha \delta E_\alpha + D_y \delta E_y + D_z \delta E_z) d\alpha^P dy^P \tag{10}$$

core and the face sheet is reduced to 7.

2.2.1 Nonlocal theory

To consider the impact of the nonlocal parameter in governing equation of the system, it can be take into account through the following relation:

$$\sigma_{ij} = (1 - \nabla^2 \mu^2) t_{ij} \tag{11}$$

where in Eq. (15), ∇^2 denotes the Laplacian operator. As the current structure rotates, initial hoop tension occurs. The work done because of to this phenomenon can be given as:

$$\delta \Pi_{w1} = \int_A \left[(N^P) \left(\frac{\partial w_0}{\partial \alpha} \frac{\partial \delta w_0}{\partial \alpha} + \frac{\partial w_0}{\partial y} \frac{\partial \delta w_0}{\partial y} \right) \right] d\alpha d y \tag{12}$$

where

$$N^P = -2(e_{31} - \frac{c_{13} e_{33}}{c_{33}}) \phi_0 \tag{13}$$

Now, the relation associated to the viscoelastic foundation is presented, using Kelvin-Voight model. Where K$_w$, and K$_p$, shows the Winkler coefficient as well as Pasternak coefficient related to the elastic substrate, respectively. Consequently, by substituting strain energy of the size-dependent nanoplate, and with the aid of Eqs. (13), (12), (11), (10), (8) and (7) into Eq. (6), the governing equations correspond to a nanoplate constructed with piezoelectric material and resting on viscoelastic foundation can be attained.

3. Solution procedure

Here, Navier method, as the best analytical solution procedure is utilized. For solving the governing equation of the current simply-supported composite structure the Navier procedure is employed by considering the below equations:

$$\begin{Bmatrix} u \\ v \\ w \\ u_1 \\ v_1 \end{Bmatrix} = \begin{Bmatrix} U \cos(\frac{m\pi}{a} x) \sin(\frac{m\pi}{b} y) \\ V \sin(\frac{m\pi}{a} x) \cos(\frac{m\pi}{b} y) \\ W \sin(\frac{m\pi}{a} x) \sin(\frac{m\pi}{b} y) \\ U_1 \cos(\frac{m\pi}{a} x) \sin(\frac{m\pi}{b} y) \\ V \sin(\frac{m\pi}{a} x) \cos(\frac{m\pi}{b} y)_1 \end{Bmatrix} e^{i\omega t} \tag{14}$$

in which, n and *m* represent transvers as well as axial mode numbers, respectively. Here, by using Eq. (14) into the governing equations, it can be arranged in a matrix form as follow.

Table 1 The first nondimensional vibration frequency of SSSS cross-ply laminated square plate with G_{12}/E_2=0.6, G_{13}/E_2=0.6, G_{23}/E_2=0.5, a=b=1, υ=0.25

E_1/E_2	Ref (Khdeir 1988)	Ref (Thinh *et al.* 2014)	Presented study
10	8.2982	8.2981	8.2485
20	9.5671	9.5671	9.5428
30	10.326	10.326	10.3018
40	10.824	10.854	10.8345

$$K^* + M^*\omega_{m,n}^2 = 0 \tag{15}$$

Lastly, the vibration frequency in addition to the displacement of the structure can be attained analytically by solving the below equation. Also, it is notable that K^* in Eq. (15) can be presented as:

$$K^* = [K] + \phi_0[K^P] \tag{16}$$

where K^P and K, denotes the stiffness matrix related to the system with and without considering applied voltage change, respectively. Here, the critical voltage can be obtained through setting the polynomial zero. Also, the non-dimensional format for critical voltage as well as vibration frequency can be presented as follow.

$$\text{Dimensionless critical voltage}=\sqrt{A_{11}/X_{33}}$$
$$X_{33} = \int_{-h/2}^{h/2} s_{33e}\big(\beta sin(\beta z)\big)^2\,dz \tag{17}$$
$$\text{Dimensionless frequency}=\omega_{n,m}h\sqrt{\rho/_E}$$

4. Numerical results

4.1 Verification

Tables 1 present the compassion between the result related to this paper and those extracted from other articles. In the table, the non-dimensional vibration frequency for different E_1/E_2 are presented. It is observable that the presented results possess such a close agreement with results of other references. Further, the results of this table show that by increasing the E_1/E_2 parameter results in increase in the dimensionless frequency of the structure.

4.2 Parametric results

Here, in the following figures the influence of multiple parameters on the Ω-paramater is clarified. It is seen in Fig. 2 that increasing the aspect ratio diminishes the Ω-paramater to a certain level in which the Ω-paramater does not decrease anymore. Besides, increase in the thickness to

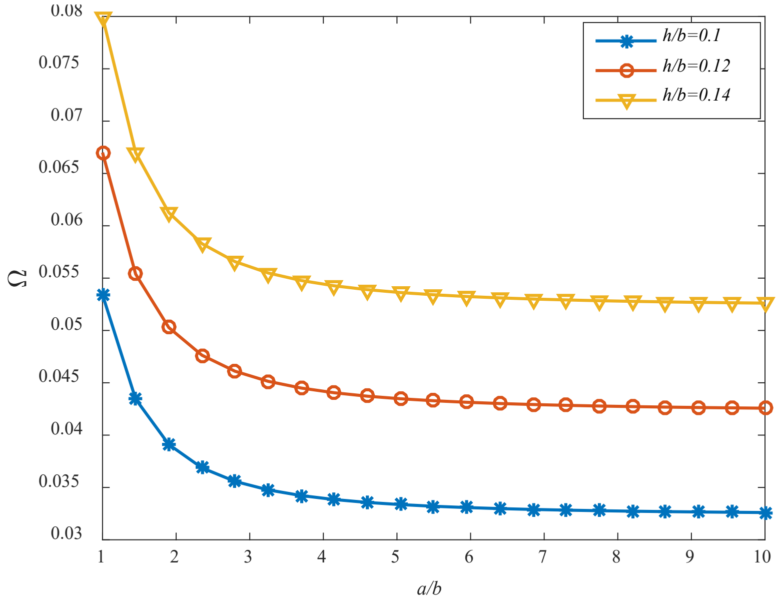

Fig. 2 Effects of plate aspect ratios on the Ω-paramater

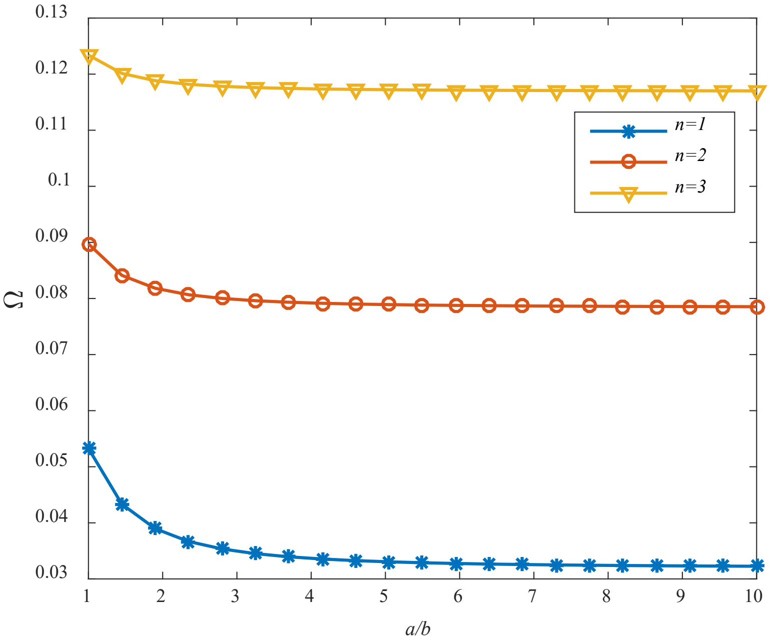

Fig. 3 Effect of transverse mode number on the Ω-paramater versus aspect ratio curves

width of the nano-plate also increases the Ω-paramater. The rate of reduction in Ω-paramater is more severe in low values of the aspect ratio.

Transverse mode number also affects the Ω-paramater. As can be observed in Fig. 3 that increase in parameter n results in Ω-paramater as expected. It seems that this impact is

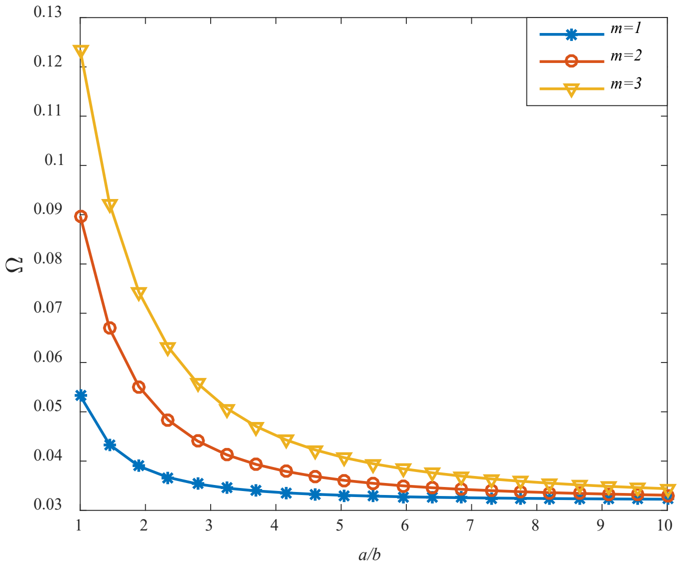

Fig. 4 Effect of axial mode number on the Ω-paramater versus aspect ratio curves

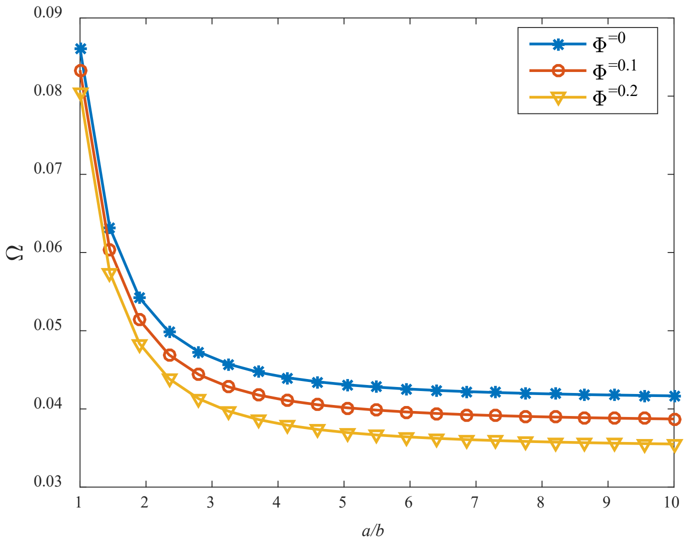

Fig. 5 Effect of external applied voltage on the Ω-paramater versus aspect ration curves

unchanged through all the aspect ratio values. In higher values of aspect ratio, no matter how much is the aspect ratio value, the Ω-paramater approaches a constant value which is depend only on the transverse mode number keeping all other values unchanged.

A similar figure can be drawn to see the effect of axial mode number on the Ω-paramater. As depicted in Fig. 4, in higher axial mode numbers the Ω-paramater curves are upper specifically in low values of aspect ratio. In higher aspect ratios, as the Ω-paramater approaches a constant

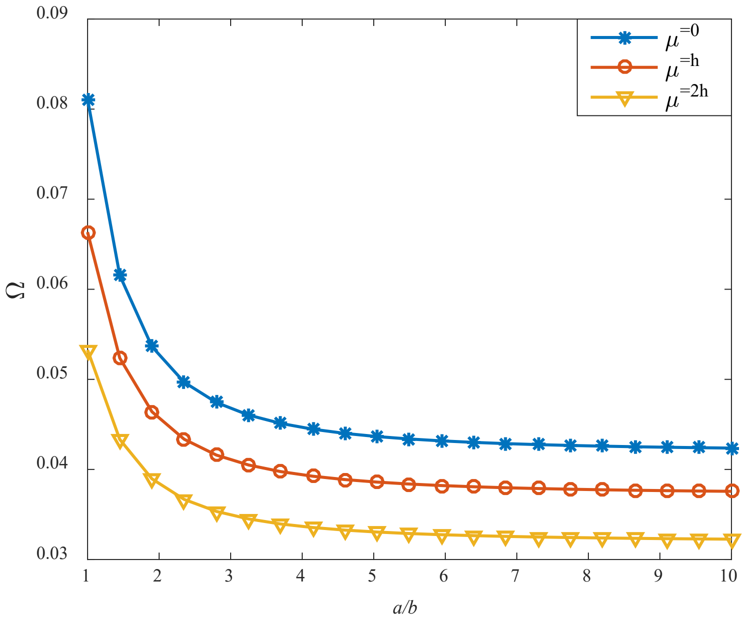

Fig. 6 Effect of the nonlocal parameter on the Ω-paramater versus aspect ratio curves

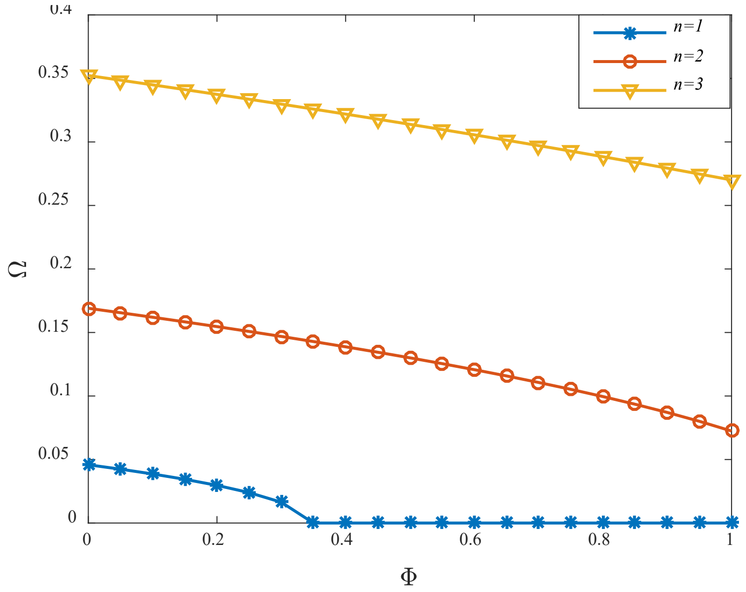

Fig. 7 Transverse mode number and external applied voltage effects on the Ω-paramater

value, the impact of the axial mode number is decreased and it is observed that Ω-paramater has slight dependency on axial mode number.

The external applied voltage alters Ω-paramater behavior. In Fig. 5, the change in values of Ω-paramateris seen as function of both aspect ratio and external applied voltage. Increasing applied voltage causes decrease in Ω-paramater. The impact of applied voltage seems to be unaffected by

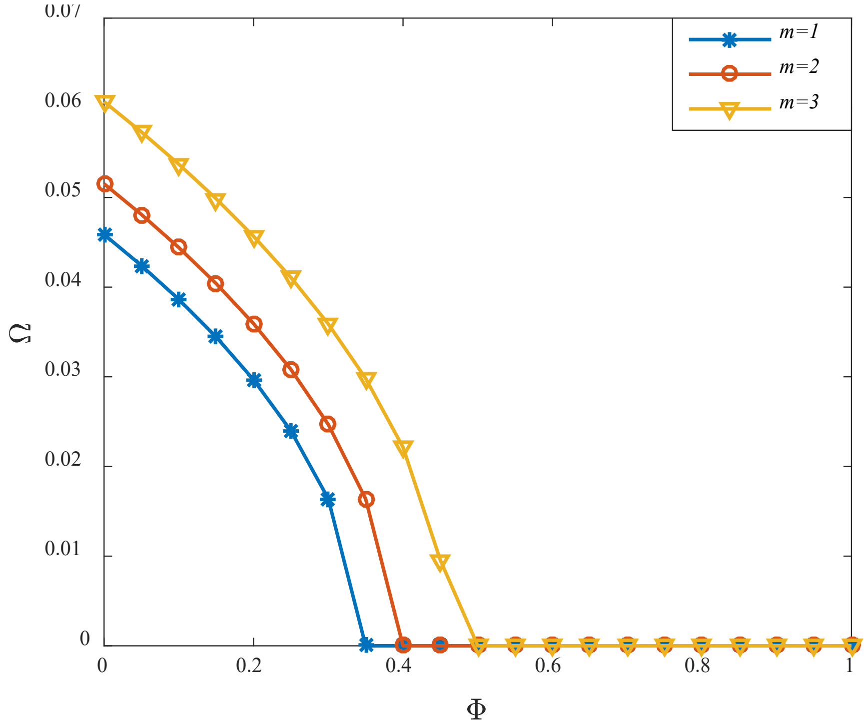

Fig. 8 Axial mode number and external applied voltage effects on the Ω-paramater

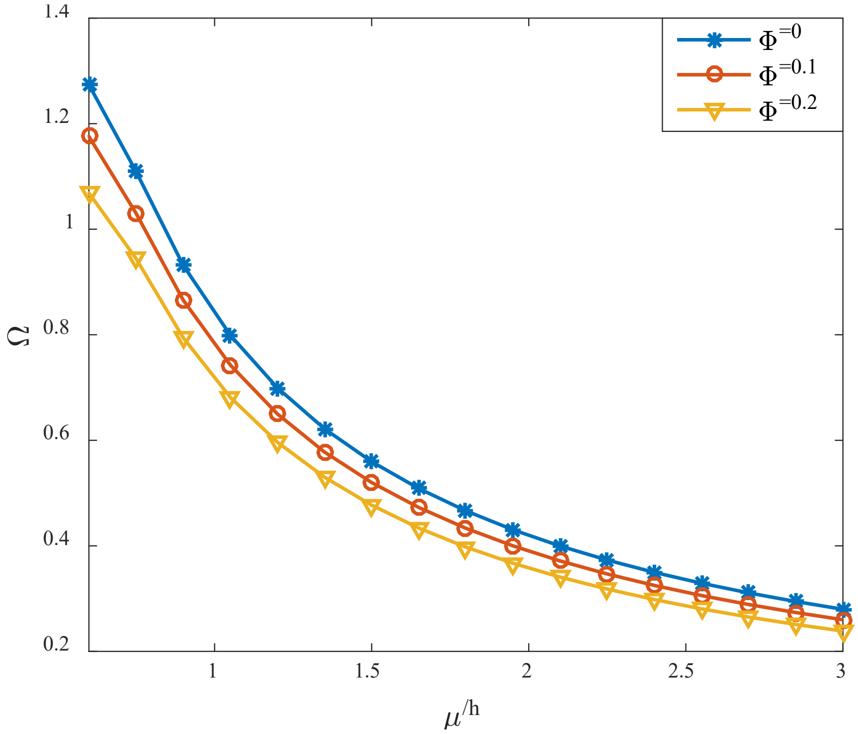

Fig. 9 Effect of nonlocal parameter on the Ω-paramater behvior with change in external applied voltage

the values of aspect ratio. In all aspect ratios the change in Ω-paramater is a constant amount. In addition, the flattening behavior of the Ω-paramater curve at high values of aspect ratio is also observed here.

In Fig. 6, effect of nonlocal parameter μ is shown for Ω-paramater depicted against aspect ratio a/b. The increase in the nonlocal parameter obviously decreases the Ω-paramater values in all aspect ratio. Effect of this parameter is harsher at lower values of aspect ratio as increase from $\mu = 0$ to $\mu = 2h$ results in 52% reduction in Ω-paramater value in $\frac{a}{b} = 1$ while the same amount of increase in nonlocal parameter results in 30% reduction in Ω-paramater.

It is observed before that at high value of external parameter there is no vibration in the nanoplate since the natural frequency is zero is this condition. Same behavior is seen in Fig. 7 for Ω-paramater at high values of external applied voltage for only first transverse mode number. As the transverse mode number increase the Ω-paramater increases. The overall behavior of the Ω-paramater is also detected to be decreasing against increase in applied voltage.

The $\Omega = 0$ condition which was seen in the first transverse mode number is seen for all first three axial mode numbers in Fig. 8. As the axial mode number increase the Ω-paramater increases. The overall behavior of the Ω-paramater is also detected to be decreasing against increase in applied voltage as discussed also in Fig. 7.

Fig. 9 shows that increase in nonlocal parameter μ/h decreases the Ω-paramater values for all applied voltages. However, the reduction percent gradually decreases at high values of nonlocal parameter. The decrease behavior seems to be continued in all ranges of nonlocal parameter.

5. Conclusions

In the current paper, the free vibration characteristic associated with a piezoelectric nanoplate with simply-supported end conditions resting on a viscoelastic substrate under in-plane loading is studied.

- Nonlocal elasticity as the size-dependent theory is utilized.
- According to FSDT as well as Hamilton's principle the equations of motions are obtained.
- The presented formulation and solution procedure are validated using other papers.
- Also, the impacts related to nonlocal parameter, applied voltage, axial mode number, geometry of the nanoplate, as well as stiffness of the elastic foundation on the vibration frequencies are presented.
- It was seen that the vibration frequency diminishes when the applied voltage and nonlocal parameter intensifies and is increased when the mode number increases.
- As this paper is the first research in which the vibration associated with piezoelectric nanoplate on the basis of FSDT and nonlocal elasticity is investigated analytically, this results can be used in future investigation in this area.

6. Fundings

1. Science and technology research project of Jiangxi Provincial Department of education, China, GJJ212104

2. Science and technology research project of Jiangxi Provincial Department of education, China, GJJ212105

References

Adamian, A., Safari, K.H., Sheikholeslami, M., Habibi, M., Al-Furjan, M. and Chen, G. (2020), “Critical temperature and frequency characteristics of gpls-reinforced composite doubly curved panel”, *Appl. Sci.*, **10**(9), 3251. https://doi.org/10.3390/app10093251.

Al-Furjan, M., Fereidouni, M., Habibi, M., Abd Ali, R., Ni, J. and Safarpour, M. (2020a), “Influence of in-plane loading on the vibrations of the fully symmetric mechanical systems via dynamic simulation and generalized differential quadrature framework”, *Eng. Comput.*, 1-23. https://doi.org/10.1007/s00366-020-01177-7.

Al-Furjan, M., Fereidouni, M., Sedghiyan, D., Habibi, M. and won Jung, D. (2020b), “Three-dimensional frequency response of the CNT-Carbon-Fiber reinforced laminated circular/annular plates under initially stresses”, *Compos. Struct.*,113146. https://doi.org/10.1016/j.compstruct.2020.113146.

Al-Furjan, M., Habibi, M., Ebrahimi, F., Chen, G., Safarpour, M. and Safarpour, H. (2020c), “A coupled thermomechanics approach for frequency information of electrically composite microshell using heat-transfer continuum problem”, *Euro. Phys. J. Plus*, **135**(10), 1-45. https://doi.org/10.1140/epjp/s13360-020-00764-3.

Al-Furjan, M., Habibi, M. and Safarpour, H. (2020d), “Vibration control of a smart shell reinforced by graphene nanoplatelets”, *Int. J. Appl. Mech.*, **12**(06), 2050066. https://doi.org/ 10.1140/epjp/s13360-020-00764-3.

Al-Furjan, M., Habibi, M., won Jung, D. and Safarpour, H. (2020e), “Vibrational characteristics of a higher-order laminated composite viscoelastic annular microplate via modified couple stress theory”, *Compos. Struct.*,113152. https://doi.org/10.1016/j.compstruct.2020.113152.

Al-Furjan, M., Moghadam, S.A., Dehini, R., Shan, L., Habibi, M. and Safarpour, H. (2020f), “Vibration control of a smart shell reinforced by graphene nanoplatelets under external load: Semi-numerical and finite element modeling”, *Thin. Wall. Struct.*, 107242. https://doi.org/10.1016/j.tws.2020.107242.

Al-Furjan, M., Oyarhossein, M.A., Habibi, M., Safarpour, H. and Jung, D.W. (2020g), “Frequency and critical angular velocity characteristics of rotary laminated cantilever microdisk via two-dimensional analysis”, *Thin. Wall. Struct.*, **157**, 107111. https://doi.org/10.1016/j.tws.2020.107111.

Al-Furjan, M., Safarpour, H., Habibi, M., Safarpour, M. and Tounsi, A. (2020h), “A comprehensive computational approach for nonlinear thermal instability of the electrically FG-GPLRC disk based on GDQ method”, *Eng. Comput.*, 1-18. https://doi.org/ 10.1007/s00366-020-01088-7.

Al-Furjan, M., Dehini, R., Khorami, M., Habibi, M. and won Jung, D. (2021a), “On the dynamics of the ultra-fast rotating cantilever orthotropic piezoelectric nanodisk based on nonlocal strain gradient theory”, *Compos. Struct.*, **255** 112990. https://doi.org/10.1016/j.compstruct.2020.112990.

Al-Furjan, M., Moghadam, S.A., Dehini, R., Shan, L., Habibi, M. and Safarpour, H. (2021b), “Vibration control of a smart shell reinforced by graphene nanoplatelets under external load: Semi-numerical and finite element modeling”, *Thin. Wall. Struct.*, **159**, 107242. https://doi.org/10.1016/j.tws.2020.107242.

Alipour, M., Torabi, M.A., Sareban, M., Lashini, H., Sadeghi, E., Fazaeli, A., Habibi, M. and Hashemi, R. (2020), “Finite element and experimental method for analyzing the effects of martensite morphologies on the formability of DP steels”, *Mech. Design. Struct. Mach.*, **48**(5), 525-541. https://doi.org/10.1080/15397734.2019.1633343.

Bai, Y., Alzahrani, B., Baharom, S. and Habibi, M. (2020), “Semi-numerical simulation for vibrational responses of the viscoelastic imperfect annular system with honeycomb core under residual pressure”, *Eng. Comput.*, 1-26. https://doi.org/10.1007/s00366-020-01191-9.

Chen, F., Chen, J., Duan, R., Habibi, M. and Khadimallah, M.A. (2022), “Investigation on dynamic stability and aeroelastic characteristics of composite curved pipes with any yawed angle”, *Compos. Struct.*,115195. https://doi.org/10.1016/j.compstruct.2022.115195.

Cheshmeh, E., Karbon, M., Eyvazian, A., Jung, D.W., Habibi, M. and Safarpour, M. (2020), “Buckling and vibration analysis of FG-CNTRC plate subjected to thermo-mechanical load based on higher order shear deformation theory”, *Mech. Design. Struct. Mach.*, 1-24.

https://doi.org/ 10.1080/15397734.2020.1744005.

Dai, Z., Zhang, L., Bolandi, S.Y. and Habibi, M. (2021), "On the vibrations of the non-polynomial viscoelastic composite open-type shell under residual stresses", *Compos. Struct.*, 113599. https://doi.org/10.1016/j.compstruct.2021.113599.

Ebrahimi, F., Habibi, M. and Safarpour, H. (2019a), "On modeling of wave propagation in a thermally affected GNP-reinforced imperfect nanocomposite shell", *Eng. Comput.*, **35**(4), 1375-1389. https://doi.org/10.1007/s00366-018-0669-4.

Ebrahimi, F., Hajilak, Z.E., Habibi, M. and Safarpour, H. (2019b), "Buckling and vibration characteristics of a carbon nanotube-reinforced spinning cantilever cylindrical 3D shell conveying viscous fluid flow and carrying spring-mass systems under various temperature distributions", *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science.*, **233**(13), 4590-4605. https://doi.org/10.1177/0954406219832323.

Ebrahimi, F., Mohammadi, K., Barouti, M.M. and Habibi, M. (2019c), "Wave propagation analysis of a spinning porous graphene nanoplatelet-reinforced nanoshell", *Wave. Random. Complex.*, 1-27. https://doi.org/ 10.1080/17455030.2019.1694729.

Ebrahimi, F., Hashemabadi, D., Habibi, M. and Safarpour, H. (2020a), "Thermal buckling and forced vibration characteristics of a porous GNP reinforced nanocomposite cylindrical shell", *Microsyst. Technol.*, **26**(2), 461-473. https://doi.org/ 10.1007/s00542-019-04542-9.

Ebrahimi, F., Supeni, E.E.B., Habibi, M. and Safarpour, H. (2020b), "Frequency characteristics of a GPL-reinforced composite microdisk coupled with a piezoelectric layer", *Euro. Phys. J. Plus*, **135**(2), 144. https://doi.org/10.1140/epjp/s13360-020-00217-x.

Ebrahimi, F., Supeni, E.E.B., Habibi, M. and Safarpour, H. (2020c), "Frequency characteristics of a GPL-reinforced composite microdisk coupled with a piezoelectric layer", *Euro. Phys. J. Plus*, **135**(2), 1-32. https://doi.org/ 10.1140/epjp/s13360-020-00217-x.

Eringen, A.C. (2002), *Nonlocal Continuum Field Theories*, Springer Science & Business Media, Berline/Heidelberg, Germany.

Esmailpoor Hajilak, Z., Pourghader, J., Hashemabadi, D., Sharifi Bagh, F., Habibi, M. and Safarpour, H. (2019), "Multilayer GPLRC composite cylindrical nanoshell using modified strain gradient theory", *Mech. Design. Struct. Mach.*, **47**(5), 521-545. https://doi/10.1080/15397734.2019.1566743.

Ghabussi, A., Ashrafi, N., Shavalipour, A., Hosseinpour, A., Habibi, M., Moayedi, H., Babaei, B. and Safarpour, H. (2019), "Free vibration analysis of an electro-elastic GPLRC cylindrical shell surrounded by viscoelastic foundation using modified length-couple stress parameter", *Mech. Design. Struct. Mach.*, 1-25. https://doi.org/ 10.1080/15397734.2019.1705166.

Ghadiri, M. and Safarpour, H. (2016), "Free vibration analysis of embedded magneto-electro-thermo-elastic cylindrical nanoshell based on the modified couple stress theory", *Appl. Phys. A.*, **122**(9), 1-11. https://doi.org/ 10.1007/s00339-016-0365-4.

Ghazanfari, A., Soleimani, S.S., Keshavarzzadeh, M., Habibi, M., Assempuor, A. and Hashemi, R. (2020), "Prediction of FLD for sheet metal by considering through-thickness shear stresses", *Mech. Design. Struct. Mach.*, **48**(6), 755-772. https://doi.org/10.1080/15397734.2019.1662310.

Guo, Y., Mi, H. and Habibi, M. (2021), "Electromechanical energy absorption, resonance frequency, and low-velocity impact analysis of the piezoelectric doubly curved system", *Mech. Syst. Signal Pr.*, **157**, 107723. https://doi.org/ 10.1016/j.ymssp.2021.107723.

Habibi, M., Hashemi, R., Sadeghi, E., Fazaeli, A., Ghazanfari, A. and Lashini, H. (2016), "Enhancing the mechanical properties and formability of low carbon steel with dual-phase microstructures", *J. Mater. Eng. Perform.*, **25**(2), 382-389. https://doi.org/ 10.1007/s11665-016-1882-1.

Habibi, M., Ghazanfari, A., Assempour, A., Naghdabadi, R. and Hashemi, R. (2017), "Determination of forming limit diagram using two modified finite element models", *Mech. Eng.*, **48**(4), 141-144. https://doi.org/ 10.22060/MEJ.2016.664.

Habibi, M., Hashemi, R., Ghazanfari, A., Naghdabadi, R. and Assempour, A. (2018a), "Forming limit diagrams by including the M–K model in finite element simulation considering the effect of bending", *Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and*

Applications., **232**(8), 625-636. https://doi.org/10.1177/1464420716642258.

Habibi, M., Hashemi, R., Tafti, M.F. and Assempour, A. (2018b), "Experimental investigation of mechanical properties, formability and forming limit diagrams for tailor-welded blanks produced by friction stir welding", *J. Manuf. Process*., **31**, 310-323. https://doi.org/ 10.1016/j.jmapro.2017.11.009.

Habibi, M., Hashemabadi, D. and Safarpour, H. (2019a), "Vibration analysis of a high-speed rotating GPLRC nanostructure coupled with a piezoelectric actuator", *Euro. Phys. J. Plus*, **134**(6), 1-23. https://doi.org/10.1140/epjp/i2019-12742-7.

Habibi, M., Mohammadgholiha, M. and Safarpour, H. (2019b), "Wave propagation characteristics of the electrically GNP-reinforced nanocomposite cylindrical shell", *J. Braz. Mech. Sci. Eng. Soc*., **41**(5), 1-15. https://doi.org/10.1007/s40430-019-1715-x.

Habibi, M., Mohammadi, A., Safarpour, H. and Ghadiri, M. (2019c), "Effect of porosity on buckling and vibrational characteristics of the imperfect GPLRC composite nanoshell", *Mech. Design. Struct. Mach*., 1-30. https://doi.org/ 10.1080/15397734.2019.1701490.

Habibi, M., Mohammadi, A., Safarpour, H., Shavalipour, A. and Ghadiri, M. (2019d), "Wave propagation analysis of the laminated cylindrical nanoshell coupled with a piezoelectric actuator", *Mech. Design. Struct. Mach*., 1-19. https://doi.org/10.1080/15397734.2019.1697932.

Habibi, M., Taghdir, A. and Safarpour, H. (2019e), "Stability analysis of an electrically cylindrical nanoshell reinforced with graphene nanoplatelets", *Compos. Part B Eng*., **175**, 107125. https://doi.org/10.1016/j.compositesb.2019.107125.

Habibi, M., Safarpour, M. and Safarpour, H. (2020), "Vibrational characteristics of a FG-GPLRC viscoelastic thick annular plate using fourth-order Runge-Kutta and GDQ methods", *Mech. Design. Struct. Mach*., 1-22. https://doi.org/10.1080/15397734.2020.1779086.

Habibi, M., Darabi, R., Sa, J.C.D. and Reis, A. (2021), "An innovation in finite element simulation via crystal plasticity assessment of grain morphology effect on sheet metal formability", *Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications*., **235**(8), 1937-1951. https://doi.org/10.1177/14644207211024686.

Hashemi, H.R., Alizadeh, A.A., Oyarhossein, M.A., Shavalipour, A., Makkiabadi, M. and Habibi, M. (2019), "Influence of imperfection on amplitude and resonance frequency of a reinforcement compositionally graded nanostructure", *Wave. Random. Complex*., 1-27. https://doi.org/10.1080/17455030.2019.1662968.

He, X., Ding, J., Habibi, M., Safarpour, H. and Safarpour, M. (2021), "Non-polynomial framework for bending responses of the multi-scale hybrid laminated nanocomposite reinforced circular/annular plate", *Thin. Wall. Struct*., **166**, 108019. https://doi.org/10.1016/j.tws.2021.108019.

Huang, X., Hao, H., Oslub, K., Habibi, M. and Tounsi, A. (2021), "Dynamic stability/instability simulation of the rotary size-dependent functionally graded microsystem", *Eng. Comput*., 1-17. https://doi.org/10.1007/s00366-021-01399-3.

Karimiasl, M., Ebrahimi, F. and Vinyas, M. (2019), "Nonlinear vibration analysis of multiscale doubly curved piezoelectric composite shell in hygrothermal environment", *J. Intell. Mater. Syst. Struct*., **30**(10), 1594-1609. https://doi.org/10.1177/1045389X19835956.

Ke, L., Wang, Y. and Reddy, J. (2014), "Thermo-electro-mechanical vibration of size-dependent piezoelectric cylindrical nanoshells under various boundary conditions", *Compos. Struct*.,**116**, 626-636. https://doi.org/10.1016/j.compstruct.2014.05.048.

Khdeir, A. (1988), "Free vibration and buckling of symmetric cross-ply laminated plates by an exact method", *J. Sound. Vib*., **126**(3), 447-461. https://doi.org/10.1016/0022-460X(88)90223-4.

Li, J., Tang, F. and Habibi, M. (2020a), "Bi-directional thermal buckling and resonance frequency characteristics of a GNP-reinforced composite nanostructure", *Eng. Comput*., 1-22. https://doi.org/10.1007/s00366-020-01110-y.

Li, Y., Li, S., Guo, K., Fang, X. and Habibi, M. (2020b), "On the modeling of bending responses of graphene-reinforced higher order annular plate via two-dimensional continuum mechanics approach", *Eng. Comput*., 1-22. https://doi.org/10.1007/s00366-020-01166-w.

Liu, Z., Su, S., Xi, D. and Habibi, M. (2020a), "Vibrational responses of a MHC viscoelastic thick annular plate in thermal environment using GDQ method", *Mech. Design. Struct. Mach.*, 1-26. https://doi.org/ 10.1080/15397734.2020.1784201.

Liu, Z., Wu, X., Yu, M. and Habibi, M. (2020b), "Large-amplitude dynamical behavior of multilayer graphene platelets reinforced nanocomposite annular plate under thermo-mechanical loadings", *Mech. Design. Struct. Mach.*, 1-25. https://doi.org/ 10.1080/15397734.2020.1815544.

Liu, H., Shen, S., Oslub, K., Habibi, M. and Safarpour, H. (2021a), "Amplitude motion and frequency simulation of a composite viscoelastic microsystem within modified couple stress elasticity", *Eng. Comput.*, 1-15. https://doi.org/10.1007/s00366-021-01316-8.

Liu, H., Zhao, Y., Pishbin, M., Habibi, M., Bashir, M. and Issakhov, A. (2021b), "A comprehensive mathematical simulation of the composite size-dependent rotary 3D microsystem via two-dimensional generalized differential quadrature method", *Eng. Comput.*, 1-16. https://doi.org/10.1007/s00366-021-01419-2.

Lori, E.S., Ebrahimi, F., Supeni, E.E.B., Habibi, M. and Safarpour, H. (2020), "The critical voltage of a GPL-reinforced composite microdisk covered with piezoelectric layer", *Eng. Comput.*, 1-20. https://doi.org/10.1007/s00366-020-01004-z.

Moayedi, H., Habibi, M., Safarpour, H., Safarpour, M. and Foong, L. (2019), "Buckling and frequency responses of a graphene nanoplatelet reinforced composite microdisk", *Int. J. Appl. Mech.*, **11**(10), 1950102. https://doi.org/ 10.1142/S1758825119501023.

Moayedi, H., Aliakbarlou, H., Jebeli, M., Noormohammadiarani, O., Habibi, M., Safarpour, H. and Foong, L. (2020a), "Thermal buckling responses of a graphene reinforced composite micropanel structure", *Int. J. Appl. Mech.*, **12**(01), 2050010. https://doi.org/10.1142/S1758825120500106.

Moayedi, H., Ebrahimi, F., Habibi, M., Safarpour, H. and Foong, L.K. (2020b), "Application of nonlocal strain–stress gradient theory and GDQEM for thermo-vibration responses of a laminated composite nanoshell", *Eng. Comput.*, 1-16. https://doi.org/10.1007/s00366-020-01002-1.

Moayedi, H., Ebrahimi, F., Habibi, M., Safarpour, H. and Foong, L.K. (2021), "Application of nonlocal strain–stress gradient theory and GDQEM for thermo-vibration responses of a laminated composite nanoshell", *Eng. Comput.*, **37**(4), 3359-3374. https://doi.org/ 10.1007/s00366-020-01002-1.

Mohammadgholiha, M., Shokrgozar, A., Habibi, M. and Safarpour, H. (2019), "Buckling and frequency analysis of the nonlocal strain–stress gradient shell reinforced with graphene nanoplatelets", *J. Vib. Control.*, **25**(19-20), 2627-2640. https://doi.org/10.1177/1077546319863251.

Mohammadi, A., Lashini, H., Habibi, M. and Safarpour, H. (2019), "Influence of viscoelastic foundation on dynamic behaviour of the double walled cylindrical inhomogeneous micro shell using MCST and with the aid of GDQM", *J. Solid Mech.*, **11**(2), 440-453. https://doi.org/10.22034/JSM.2019.665264.

Najaafi, N., Jamali, M., Habibi, M., Sadeghi, S., Jung, D.w. and Nabipour, N. (2020), "Dynamic instability responses of the substructure living biological cells in the cytoplasm environment using stress-strain size-dependent theory", *J. Biomol. Struct. Dyn.*, 1-12. https://doi.org/10.1080/07391102.2020.1751297.

Oyarhossein, M.A., Alizadeh, A.a., Habibi, M., Makkiabadi, M., Daman, M., Safarpour, H. and Jung, D.W. (2020), "Dynamic response of the nonlocal strain-stress gradient in laminated polymer composites microtubes", *Sci. Rep.*, **10**(1), 1-19. https://doi.org/10.1038/s41598-020-61855-w.

Pourjabari, A., Hajilak, Z.E., Mohammadi, A., Habibi, M. and Safarpour, H. (2019), "Effect of porosity on free and forced vibration characteristics of the GPL reinforcement composite nanostructures", *Comp. Math. Appl.*, **77**(10), 2608-2626. https://doi.org/ 10.1016/j.camwa.2018.12.041.

Safarpour, H., Ghanizadeh, S.A. and Habibi, M. (2018), "Wave propagation characteristics of a cylindrical laminated composite nanoshell in thermal environment based on the nonlocal strain gradient theory", *Eur. Phys. J. Plus*, **133**(12), 532. https://doi.org/ 10.1140/epjp/i2018-12385-2.

Safarpour, H., Hajilak, Z.E. and Habibi, M. (2019a), "A size-dependent exact theory for thermal buckling, free and forced vibration analysis of temperature dependent FG multilayer GPLRC composite nanostructures restring on elastic foundation", *Int. J. Mech. Mater. Des.*, **15**(3), 569-583. https://doi.org/ 10.1007/s10999-018-9431-8.

Safarpour, H., Pourghader, J. and Habibi, M. (2019b), "Influence of spring-mass systems on frequency behavior and critical voltage of a high-speed rotating cantilever cylindrical three-dimensional shell coupled with piezoelectric actuator", *J. Vib. Control.*, **25**(9), 1543-1557. https://doi.org/ 10.1177/1077546319828465.

Safarpour, M., Ebrahimi, F., Habibi, M. and Safarpour, H. (2020), "On the nonlinear dynamics of a multi-scale hybrid nanocomposite disk", *Eng. Comput.*, 1-20. https://doi.org/10.1007/s00366-020-00949-5.

Shahgholian, D., Safarpour, M., Rahimi, A. and Alibeigloo, A. (2020), "Buckling analyses of functionally graded graphene-reinforced porous cylindrical shell using the Rayleigh–Ritz method", *Acta. Mech.*, 1-16. https://doi.org/ 10.1007/s00707-020-02616-8.

Shamsaddini Lori, E., Ebrahimi, F., Elianddy Bin Supeni, E., Habibi, M. and Safarpour, H. (2021), "The critical voltage of a GPL-reinforced composite microdisk covered with piezoelectric layer", *Eng. Comput.*, **37**(4), 3489-3508. https://doi.org/ 10.1007/s00366-020-01004-z.

Shariati, A., Ghabussi, A., Habibi, M., Safarpour, H., Safarpour, M., Tounsi, A. and Safa, M. (2020a), "Extremely large oscillation and nonlinear frequency of a multi-scale hybrid disk resting on nonlinear elastic foundation", *Thin. Wall. Struct.*, **154**, 106840. https://doi.org/ 10.1016/j.tws.2020.106840.

Shariati, A., Habibi, M., Tounsi, A., Safarpour, H. and Safa, M. (2020b), "Application of exact continuum size-dependent theory for stability and frequency analysis of a curved cantilevered microtubule by considering viscoelastic properties", *Eng. Comput.*, 1-20. https://doi.org/10.1007/s00366-020-01024-9.

Shariati, A., Mohammad-Sedighi, H., Żur, K.K., Habibi, M. and Safa, M. (2020c), "On the vibrations and stability of moving viscoelastic axially functionally graded nanobeams", *Materials*, **13**(7), 1707. https://doi.org/10.3390/ma13071707.

Shariati, A., Mohammad-Sedighi, H., Żur, K.K., Habibi, M. and Safa, M. (2020d), "Stability and dynamics of viscoelastic moving rayleigh beams with an asymmetrical distribution of material parameters", *Symmetry*, **12**(4), 586. https://doi.org/10.3390/sym12040586.

Shi, X., Li, J. and Habibi, M. (2020), "On the statics and dynamics of an electro-thermo-mechanically porous GPLRC nanoshell conveying fluid flow", *Mech. Design. Struct. Mach.*, 1-37. https://doi.org/ 10.1080/15397734.2020.1772088.

Shokrgozar, A., Safarpour, H. and Habibi, M. (2020), "Influence of system parameters on buckling and frequency analysis of a spinning cantilever cylindrical 3D shell coupled with piezoelectric actuator", *Proceedings of the Institution of Mechanical Engineers*, *Part C: Journal of Mechanical Engineering Science*. **234**(2), 512-529. https://doi.org/ 10.1177/0954406219883312.

Thinh, T.I., Nguyen, M.C. and Ninh, D.G. (2014), "Dynamic stiffness formulation for vibration analysis of thick composite plates resting on non-homogenous foundations", *Compos. Struct.*, **108**, 684-695. https://doi.org/10.1016/j.compstruct.2013.10.022.

Wang, Z., Yu, S., Xiao, Z. and Habibi, M. (2020), "Frequency and buckling responses of a high-speed rotating fiber metal laminated cantilevered microdisk", *Mech. Adv. Mater. Struct.*, 1-14. https://doi.org/10.1080/15376494.2020.1824284.

Zare, R., Najaafi, N., Habibi, M., Ebrahimi, F. and Safarpour, H. (2020), "Influence of imperfection on the smart control frequency characteristics of a cylindrical sensor-actuator GPLRC cylindrical shell using a proportional-derivative smart controller", *Smart Struct. Syst.*, **26**(4), 469-480. https://doi.org/10.12989/sss.2020.26.4.469.

Zhang, X., Shamsodin, M., Wang, H., NoormohammadiArani, O., Khan, A.M., Habibi, M. and Al-Furjan, M. (2020), "Dynamic information of the time-dependent tobullian biomolecular structure using a high-accuracy size-dependent theory", *J. Biomol. Struct. Dyn.*, 1-16. https://doi.org/10.1080/07391102.2020.1760939.

Zhang, Y., Wang, Z., Tazeddinova, D., Ebrahimi, F., Habibi, M. and Safarpour, H. (2021), "Enhancing active vibration control performances in a smart rotary sandwich thick nanostructure conveying viscous fluid flow by a PD controller", *Wave. Random. Complex.*, 1-24. https://doi.org/10.1080/17455030.2021.1948627.

WT