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Accuracy improvement in motion tracking of tennis balls using nano-sensors technology

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Abstract. Tracking the motion of tennis balls is a challenging task in using cameras around the tennis court. The most important instance of the tennis trajectory is the time of impact and touch the court which in some cases could not be detected precisely. In the present study, we aim to present a novel design of tennis balls equipped with nano-sensors to detect the touch of the ball to the court. In the impact instance, tennis ball receives significant acceleration and change in the linear momentum. This large acceleration could deform a small-beam structure with piezoelectric layer to produce voltage. The voltage could further be utilized to produce infrared waves which could be easily detected by infrared detection sensors installed on the same video cameras or separately near the tennis court. Therefore, the exact time of the impact could be achieved with higher accuracy than image analyzing method. A detailed dynamical property of such sensors is discussed using nonlinear beam equations. The results show that within the acceleration range of tennis ball during an impact, the piezoelectric patches of the nano-sensors in the tennis ball could produce enough voltages to propagate infrared waves to be detected by infrared detectors.

Keywords: composite beam structure; impact instance; nano-sensors; Tennis ball tracking

1. Introduction

Tennis ball play is an important and luxuries sport in the world which attracts many players and fans around the world. The amount of prize in this game is higher than other sports and this makes the point count during a match very critical (Habibi *et al*. 2016, 2018a, b, 2019a, b, d, e, Esmailpoor Hajilak *et al*. 2019, Pourjabari *et al*. 2019, Safarpour *et al*. 2019a, Zhu *et al*. 2022). Especially because of the tennis ball speed the exact moment of touching the court is barely possible with naked eye (Habibi *et al*. 2017, 2019a, c, Safarpour *et al*. 2018a, 2019b, 2020, Alipour *et al*. 2020, Ebrahimi *et al*. 2020a, Ghazanfari *et al*. 2020, Chen *et al*. 2022a). Therefore, the image processing technology has helped the referees to make fair decisions for challenging points. However, the image processing method has their problems in recognizing exact moment of ball impact on the play court. Several improvements on the image processing technology have been proposed but the exact impact time determination is still suffering from mathematical approximations (Cao *et al*. 2021a, b, Yang *et al*. 2021, Li *et al*. 2022, Zhao and Wang 2022, Zhou *et al*. 2022). On the other hand, improvement is vision technologies are highly expensive. Therefore, other methodologies should be adopted on this matter.

Melo *et al*. (2021) presented a mathematical approximation algorithm to find the position of the ball touching the court. They utilized two cameras in the tennis court to recognize both ball and court. Their main focus was developing simple and low cost embedded system for detecting trajectory which the experimental tests had approved the accuracy and efficacy of the proposed methodology. Archana and Geetha (2015) proposed an image processing approach to detect ball trajectory and players position in broadcast tennis videos. They claimed that their approach improved the accuracy on the ball track detection. Yan *et al*. (2014) developed a methodology based on machine learning method to annotating tennis game using two levels of processing. The audio processing determines the time of the impact of ball to the court and classification method for labelling sequences. They also provided experimental validation of the approach. Yong *et al*. (2011) improved a motion detection algorithm to assist users in tennis play annotation. Four different detectors had been used to evaluate their performance. It was concluded that the presented method is effective in motion detection of tennis ball. To reduce the cost of speed measurement of tennis balls, Zhao *et al*. (2019) utilized sensor technology. Using sensors on the tennis racket they successfully improved the accuracy of speed measurement about 11%. Conaire *et al*. (2009) utilized cameras to track the tennis ball. Further, the metadata obtained used to find about the sequences of events during play and position of the players. They discussed the applicability of these metadata in coaching players. These studies indicate that using cameras and image processing techniques requires improvements to be reliable and expense for improvement are very high. Thus, other technologies from different fields could be beneficial in this regard.

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Nanotechnology has influenced many fields of technology since the superior characteristics of nano-structured materials have been recognized (Li *et al*. 2017, Zhou *et al*. 2020b, Ma *et al*. 2021, Tang *et al*. 2021, Zheng *et al*. 2021, Wang *et al*. 2022b). Nanosensors are one of the widespread usage of mechanical nanostructures (Ebrahimi *et al*. 2019b, Al-Furjan *et al*. 2020g, 2021, Shokrgozar *et al*. 2020a, Wen *et al*. 2020, Habibi *et al*. 2021b, Shariati *et al*. 2021). Nanosensors are employed as motion and vibration sensors. Using single or double layers of piezoelectric materials could convert the motions and small oscillations into electrical voltage whose amount is proportional to the deflection. Nano- and micro-beams with tip mass equipped by piezoelectric layers are prevalent in motion sensors (Kargarnovin *et al*. 2007, Arefi 2018, Shokrgozar *et al*. 2019, Mao *et al*. 2020, Shi *et al*. 2020). Using of piezoelectric layers in sandwich micro-structures is either for induce vibration or to control vibrations in beam structure (Burdess and Fawcett 1992, Bendine *et al*. 2016, Karimiasl *et al*. 2019). Because of small-scale of these sensors and their constituents, the theories of large scale materials which are examined and verified in macro-scales are proven to be insufficient in small scales. Burdess and Fawcett (1992) experimentally explored the performance of piezoelectric materials in controlling forced and free vibrations. Beam structure with cutouts was investigated by Eltaher *et al*. (2020). The nonlocal elasticity theory was employed to observe the responses of small-scale beam under static and dynamic loadings. Effects of cutouts geometry and scale of the beam on the mechanical performance were reported in detail. Bruant and Proslier (2016) reported the effect of subsized piezoelectric location on the vibration control of the functionally graded beams. They demonstrated that it is possible to use smaller piezoelectric patches with high controlling effects maintaining that the location of the piezoelectric patch should be optimized. Nadal and Pigache (2009) formulated electromechanical behavior of piezoelectric materials using Hamilton’s principle. They validated the formulation of homogenous and inhomogeneous piezoelectric structures by comparing finite element results with experimental outcomes (Ebrahimi *et al*. 2019b, c, 2020b, Hashemi *et al*. 2019, Moayedi *et al*. 2019, Mohammadgholiha *et al*. 2019, Mohammadi *et al*. 2019, Habibi *et al*. 2020, Moayedi *et al*. 2020a, b, Oyarhossein *et al*. 2020b, Shariati *et al*. 2020a, b, Shokrgozar *et al*. 2020b).

In most of the sandwich micro-beams one or more layers of carbon nanotube reinforced nanocomposites (CNT-RC) are used. In addition to CNT, graphene platelets are popular reinforcements. She *et al*. (2018) reviewed the reported properties of graphene platelets and their composite. Using Eringen’s nonlocal theory, Barretta *et al*. (2018) the static deflection of a nano-beam was calculated using numerical methods. They used bi-Helmholtz kernel in the integral form of nonlocal theory. There are several elasticity models incorporating small-scale effects namely strain gradient theory (Lam *et al*. 2003), couple stress theory (Hadjesfandiari and Dargush 2011), nonlocal strain gradient theory (Jirásek 2004) and other modified theories on the basis of these models. Utilizing nonlocal strain gradient theory, Li *et al*. (2015) studied wave propagation in small scale functionally graded beams and they reported that the effects of nonlocal and material parameters are more significant in high wane numbers. Influence of temperature in nonlocal structures were examined by Ebrahimi *et al*. (2016). They found that temperature distribution pattern has significant effect on the wave propagation in these structures. Numerical methods has proven to be effective in obtaining materials responses under static and dynamics loads (Nejad *et al*. 2016, Safarpour *et al*. 2018b, Amelirad and Assempour 2019, Al-Furjan *et al*. 2020h, Oyarhossein *et al*. 2020a, Amelirad and Assempour 2021). The complicated form of nonlocal and gradient models’ differential equations necessitates using numerical approaches. One of the most effective numerical method is differential quadrature method (DQM) and its modified developments. This theory has proven to have high performance in solving nonlinear differential equations and it is widely used in solving structural mechanics problems because of presenting accurate results in comparison to analytical solutions.

In the present study, we aim to present a novel design of tennis balls equipped with nano-sensors to detect the touch of the ball to the court. In the impact instance, tennis ball receive significant acceleration and change in the linear momentum. This large acceleration could deform a small-beam structure with piezoelectric layer to produce voltage. The voltage could further be utilized to produce infrared waves which could be easily detected by infrared detection sensors installed on the same video cameras or separately near the tennis court. Therefore, the exact time of the impact could be achieved with higher accuracy than image analyzing method. A detailed dynamical property of such sensors is discussed using nonlinear beam equations. The results show that within the acceleration range of tennis ball during an impact, the piezoelectric patches of the nano-sensors in the tennis ball could produce enough voltages to propagate infrared waves to be detected by infrared detectors.

2. Methodology

The main idea in the present study is to propose a low cost and reliable methodology using nano-beam sensor technology. Micro-beam structures are extremely low weight (~1-10 milligrams) and could be mounted inside tennis balls without significantly change in its weight. Moreover, due to small cross section of the beams it will not change the mechanical properties and responses of the tennis ball. A schematic representation of a new tennis ball equipped with nano-beam sensor is depicted in Fig. 1. The nano-beam sensor is illustrated in this figure. The beam constructed using three layers of one CNT-TC composite layers and two piezoelectric layers. Viscosity effects of the high pressure gas inside the ball is modeled using viscoelastic layer in this structure. At the end of the beam, an infrared transmitter is installed which is fed by piezoelectric voltage. One side of the transmitter faces outward. This mechanism enables the nanosensors to convert deflection into infrared waves. Only transverse displacement of the beam base could induce enough

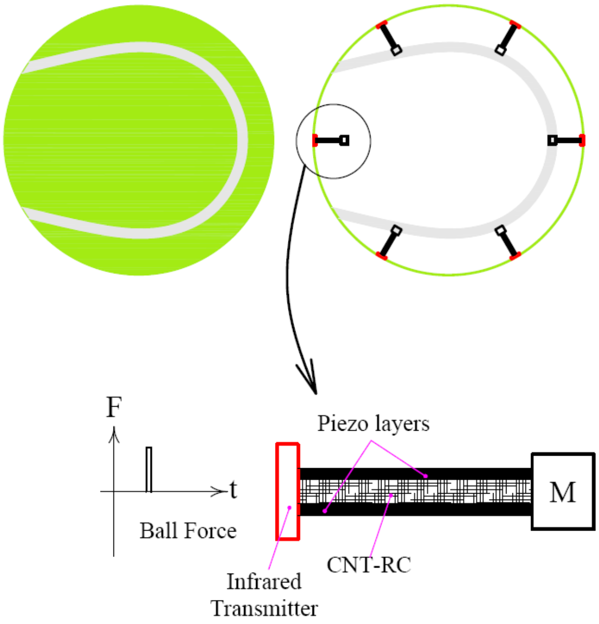

Fig. 1 Structure of cantilever nano-beam sensor and its mount inside tennis ball

deflections in the piezoelectric layers to produce voltage. Since the direction of the impact is not known, several nano-sensors should be used to ensure having enough deflection in some beams to produce infrared waves (Cao *et al*. 2020, Chen *et al*. 2022b, Fang *et al*. 2022, Wang *et al*. 2022c, Zhao *et al*. 2022). The displacement and force on the tennis ball in the case of impacts could be modeled with Kronecker Delta function as below:

$$d_{yl} = d\delta(t - t_0) \tag{1}$$

In this relation, d_{yl} is the displacement of the end of cantilever beam along local y coordinate system which normal to the axis of the beam.

As a moderate to heavy impact loads hits the ball, a sudden change in the linear momentum of the ball is changes abruptly resulting in abrupt displacement in beam base. This base excitation load cause deflection in the beam based on the flexural properties and amount of the tip mass. Therefore, the flexural properties and mass value are two main parameters to be designed for having enough deflection. The deflection should produce instant voltage in piezoelectric layers and the properties of this layer should be such that produces infrared beam in transmitters. The property of the piezoelectric is another parameter have to be determined. In addition, this loading condition should not produce oscillation in nano-beam for a long time (greater than 1 millisecond). If so, the infrared beam will continue to transmit even after the impact. Thus the viscoelastic layer should be designed so that the beam falls into near critical damping condition. This is another parameter to investigate.

Having transmitted infrared waves, it is possible to install infrared receivers around the tennis court as shown in Fig. 2. To avoid extra numbers of transmitter, they are only installed along court lines which are important in annotations. There are total 20 numbers of the sensors all sending signals to a server to be used alongside image processing cameras for detecting exact moment of ball impact.

3. Mathematical formulation

3.1 Kinematic of the nano-beam sensor

As discussed in introduction section, the classical theory is insufficient for model small-scale structures. Therefore, we employ strain gradient theory for modeling the deformable constituent of the structure. The strain tensor $\mathbf{E}$ in small displacement and deflection is expressed as below (Hashemi *et al*. 2019, Al-Furjan *et al*. 2020c, d, e, f, Bai *et al*. 2020, Cheshmeh *et al*. 2020, Li *et al*. 2020a, Lori *et al*. 2020, Najaafi *et al*. 2020, Shariati *et al*. 2020c, Xiong *et al*. 2020, Guo *et al*. 2021b, Liu *et al*. 2021a):

$$\mathbf{E} = \frac{1}{2}(\nabla\mathbf{u} + \nabla^T\mathbf{u}) \tag{2}$$

in which $\mathbf{u}$ is the displacement vector. Assuming Bernoulli-Euler beam theory the components of the displacement in local coordinate system could be described as (Adamian *et al*. 2020, Al-Furjan *et al*. 2020a, b, Li *et al*. 2020b, Liu *et al*. 2020b, Zare *et al*. 2020, Dai *et al*. 2021b, Habibi *et al*. 2021a, He *et al*. 2021, Huang *et al*. 2021a, Liu *et al*. 2021b, Zhang *et al*. 2021):

$$\begin{aligned} u_{xl}(x_l, y_l, z_l, t) &= -y_l\frac{\partial w(x_l, t)}{\partial x} \\ u_{yl}(x_l, y_l, z_l, t) &= w(x_l, t) \\ u_{zl}(x_l, y_l, z_l, t) &= 0 \end{aligned} \tag{3}$$

The subscript l denotes local coordinate system. Variables u_{il} for $i = x_l, y_l, z_l$ are displacement along x, y and z local axes. Transverse deflection of the beam is denoted by $w(x_l, t)$. Using this relations, the nonzero components of strain tensor are:

$$E_{xx} = -y_l\frac{\partial^2 w(x_l, t)}{\partial x^2} \tag{4}$$

The bonding between layers in sandwich beam is assumed to be perfect. Here, we are not seeking details of the formulations as it is presented in several articles comprehensively for an account please refer to (Lam *et al*. 2003, Akgöz and Civalek 2011, Ebrahimi and Barati 2017)

3.2 Kinetics of nano-beam sensor

Hamilton's principle is a powerful method based on the different types of energies in structures which is employed to obtain equations of motion of nano-beam with tip mass. The form of this equation is (Liu *et al*. 2020a, Wang *et al*. 2020, Zhou *et al*. 2020a, Dai *et al*. 2021a, Guo *et al*. 2021a, Shao *et al*. 2021, Wu and Habibi 2021, Kong *et al*. 2022):

$$\int_0^t (\delta U - \delta K - \delta W)dt = 0 \tag{5}$$

In which U is the sum of strain energy in the structure, K is the total kinematic energy and W is the work done by external forces. The δ operator represents the variation of

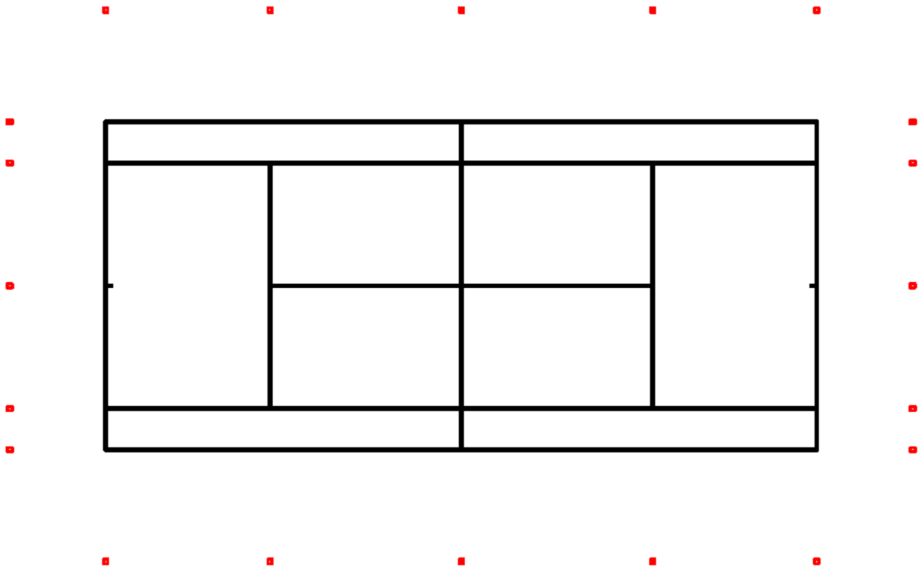

Fig. 2 Location of infrared detectors around tennis court.

the variable. In the following the expression for kinetic is given (Ma *et al.* year, Zhao *et al.* year, Hou *et al.* 2021, Huang *et al.* 2021b, c, Jiao *et al.* 2021, Liu *et al.* 2021c, Moradi *et al.* 2021, Xu *et al.* 2021, Dong *et al.* 2022, Luo *et al.* 2022, Michael *et al.* 2022, Wang *et al.* 2022d, Yang *et al.* 2022, Yu *et al.* 2022):

$$K = \int_0^L \sum_{i=1}^N \frac{1}{2}\rho_i A_i \left[\frac{\partial w(x_l,t)}{\partial t}\right]^2 dx_l + \frac{1}{2}M\left[\frac{\partial w(L,t)}{\partial t}\right]^2 \quad (6)$$

The length of the beam is L and concentrated tip mass is equal to M. Moreover, N shows numbers of different materials used in the sandwich beam structure, ρ is mass density and A is cross section of each layer. The expression for strain energy is as follows:

$$U = b\int_{-c}^{c}\int_0^L T_{xx}E_{xx}\,dx_l dy_l \quad (7)$$

In which, T_{xx} is the normal stress component along local x axis and b is the width of the beam. In addition, c is the half of the beam cross section height. External work on the structure is defined as:

$$W = Fd_{yl} \quad (8)$$

In which the concentrate force F is not known in this case.

3.3 Constitutive equations

In the strain gradient theory, it is assumed that the stress in material point depends on the both strain state and the gradient of strain at that point. The gradient of strain incorporates the effects of strain in neighborhood of the material point into account. The tensorial from of the strain gradient equations is as follows (Fan *et al.* 2022, Wang *et al.* 2022a, Xia *et al.* 2022):

$$\mathbf{T} = \mathbf{E} - l^2\nabla^2\mathbf{E} \quad (9)$$

Table 1 Roots of fifth degree shifted Legendre polynomial

$P_5^* = 252x^5 - 630x^4 + 560x^3 - 210x^2 + 30x - 1$	
x_1	0.9531
x_2	0.7692
x_3	0.5000
x_4	0.2308
x_5	0.0469

in which $\mathbf{T}$ is the stress tensor and l is the length scale parameter. Moreover, the operator ∇^2 in general form is defined as:

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} \quad (10)$$

In the case of the Bernoulli-Euler nanobeam structure the constitutive equation reduces to:

$$T_{xx} = E_{xx} - l^2\frac{\partial^2 E_{xx}}{\partial x^2} \quad (11)$$

3.4 Numerical solution procedure

The partial differential equations appeared in the previous sections are solved using numerical method. An effective and stable numerical method is differential quadrature method (DQM) in which the derivatives of a function is approximates by weighted sum of its value in different points. By this method the differential equation is converted to a system of linear equations. The values of the weight coefficient in the relation could be obtained using several methods depending on the level of accuracy required. Therefore, first derivative of function γ could be estimated by:

$$\gamma'(\beta_i) = \sum_{j=1}^N \alpha_{ij}\gamma(\beta_j) \quad (12)$$

Table 2 Dimensionless natural frequency of cantilever beam in comparison to Ref. (Karkon 2018) results

h/L		Mode of vibration			
		1st	2nd	3rd	4th
0.01	Precent	3.1301	6.2785	9.4047	12.5357
	Ref.	3.1413	6.2811	9.4176	12.5494
0.1	Precent	3.0922	6.0856	8.8364	11.3298
	Ref.	3.1157	6.0907	8.8405	11.3432
0.2	Precent	3.0234	5.6598	7.8251	9.6471
	Ref.	3.0453	5.6716	7.8396	9.6572

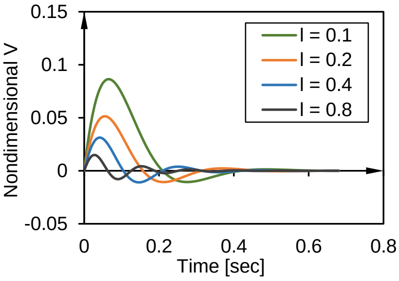

Fig. 3 Effect of length scale parameter on the produced voltage in piezoelectric layers

where, the weights are α_{ij} and N denoted number of grid points in the domain. Here, the shifted Legendre polynomial $P_n^*(x_i)$ is employed to calculate weight coefficients:

$$\alpha_{ij} = \frac{1}{\beta_i - \beta_j}\frac{P_n^*(\beta_i)}{P_n^*(\beta_j)} \tag{13}$$

In addition, roots of the Legendre polynomial are used as the grid points. The roots of fifth order Legendre polynomial is presented in Table 1.

4. Results and discussion

4.1 Validation of the numerical procedure

Numerical procedure employed in this study needs to be validated. In doing so, we solve a benchmark problem in cantilever beam without tip mass as presented by (Karkon 2018). As can be observed, the natural frequency presented by present study is lower in all h/L values and the provided mode of vibrations. One main cause of such difference is using different beam modeling. However, the results are close to each other and thereby the method of this study is validated by comparing with the reference mentioned above.

4.2 Effects of material and geometrical parameters

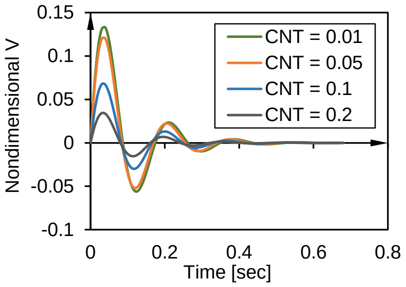

Fig. 4 Effect of CNT weight fraction on the produced voltage in piezoelectric layers

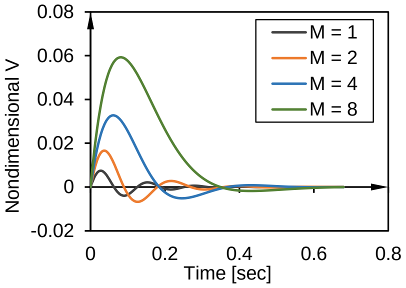

Fig. 5 Effect of nondimensional mass on the produced voltage in piezoelectric layers

In this section effects of different parameters discussed in section 3 are presented. The parameters includes stiffness of the beam which is mainly controlled by CNT reinforcement weight fraction. The other parameter is the tip mass which controls the natural frequency of the beam in and effective way. Also, the damping characteristics of the substrate is influential to discontinue vibration of the nano-beam sensor. In addition characteristics of the piezo electric material is important in inducing voltage for infrared transmitter. To ease in reading mechanical responses the following nondimensional parameters is defined. Nondimensional height of the piezoelectric layer is the ratio of piezoelectric height h_p to the total height of the beam h or h_p/h. Nondimensional mass is defined as $\frac{M}{\rho_p A_p L}$.

In Fig. 3, effect of the length scale parameter is shown. Larger length scale parameter indicate smaller beam structure for same materials. It is seen that increasing length scale parameter cause increase in natural frequency and decrease in voltage amplitude. Both of these effects are not desirable for the purpose of this study. Therefore, smaller length parameter, i.e., larger beam, cause greater induced voltage and lower frequency and is applicable in tennis ball.

Effect of the weight fraction of CNT reinforcement is illustrated in Fig. 4. This figure shows that increasing the amount of CNT slightly increase frequency. However, it decreases the produced voltage. Thus, a compromise should be taken to have better results. One way to change this behavior is explained in the next figure.

The tip mass of the nano-beam probably has the most significant effect on the voltage amplitude and frequency as depicted in Fig. 5. Increasing mass without increase in stiffness of the structure cause larger deflection of beam and consequently induce larger voltage. In addition, larger mass reduces the frequency of vibration. It is seen in this graphs that nondimensional mass equal to 8 leads to considerably good results since large voltage and damped vibration is observed.

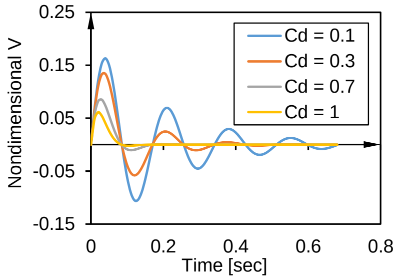

Fig 6 Effect of damping parameter of the substrate on the produced voltage in piezoelectric layers

Damping coefficient of the viscoelastic substrate reduces the voltage amplitude and increase the frequency of the vibration as shown in Fig. 6. Therefore, increase in damping has undesirable consequents in the beam structure. However, some degree of damping must exist in the beam structure to instantly reduce the voltage amplitude. If not, the infrared transmitter continue to blink and the nanosensors become useless in detecting exact moment of the impact. In this regard, it is recommended that damping coefficient be maintained at a midrange level and desired properties set with change in the tip mass.

5. Conclusions

Tracking the motion of tennis balls is a challenging task in using cameras around the tennis court. The most important instance of the tennis trajectory is the time of impact and touch the court which in some cases could not be detected precisely. In the present study, we aim to present a novel design of tennis balls equipped with nano-sensors to detect the touch of the ball to the court. In the impact instance, tennis ball receives significant acceleration and change in the linear momentum. This large acceleration could deform a small-beam structure with piezoelectric layer to produce voltage. The voltage could further be utilized to produce infrared waves which could be easily detected by infrared detection sensors installed on the same video cameras or separately near the tennis court. Therefore, the exact time of the impact could be achieved with higher accuracy than image analyzing method. Detailed dynamical properties of such sensors is discussed using nonlinear beam equations. The results show that:

- Smaller length parameter, i.e., larger beam, cause greater induced voltage and lower frequency and is applicable in tennis ball.
- Nondimensional mass equal to 8 leads to considerably good results since large voltage and damped vibration is observed.
- Some degree of damping must exist in the beam structure to instantly reduce the voltage amplitude.

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

Akgöz, B. and Civalek, Ö. (2011), "Strain gradient elasticity and modified couple stress models for buckling analysis of axially loaded micro-scaled beams", *Int. J. Eng. Sci.*, **49**(11), 1268-1280. https://doi.org/10.1016/j.ijengsci.2010.12.009

Al-Furjan, M., Dehini, R., Khorami, M., Habibi, M. and won Jung, D. (2020a), "On the dynamics of the ultra-fast rotating cantilever orthotropic piezoelectric nanodisk based on nonlocal strain gradient theory", *Compos. Struct.*, 112990. https://doi.org/10.1016/j.compstruct.2020.112990

Al-Furjan, M., Fereidouni, M., Habibi, M., Abd Ali, R., Ni, J. and Safarpour, M. (2020b), "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. (2020c), "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., won Jung, D. and Safarpour, H. (2020d), "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. (2020e), "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. (2020f), "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.S.H., Bolandi, S.Y., Habibi, M., Ebrahimi, F., Chen, G. and Safarpour, H. (2021), "Enhancing vibration performance of a spinning smart nanocomposite reinforced microstructure conveying fluid flow", *Eng. Comput.*, 1-16. https://doi.org/10.1007/s00366-020-01255-w

Al-Furjan, M.S.H., Habibi, M., Ebrahimi, F., Chen, G., Safarpour, M. and Safarpour, H. (2020g), "A coupled thermomechanics approach for frequency information of electrically composite microshell using heat-transfer continuum problem", *Eur. Phys. J. Plus*, **135**(10), 837. https://doi.org/10.1140/epjp/s13360-020-00764-3

Al-Furjan, M.S.H., Oyarhossein, M.A., Habibi, M., Safarpour, H. and Jung, D.W. (2020h), "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

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. Based Des. Struct.*, **48**(5), 525-541. https://doi.org/10.1080/15397734.2019.1633343

Amelirad, O. and Assempour, A. (2019), "Experimental and crystal plasticity evaluation of grain size effect on formability of austenitic stainless steel sheets", *J. Manuf. Pr.*, **47**, 310-323. https://doi.org/10.1016/j.jmapro.2019.09.035

Amelirad, O. and Assempour, A. (2021), "Coupled continuum damage mechanics and crystal plasticity model and its application in damage evolution in polycrystalline aggregates",

Eng. *Comput*., 1-15.
https://doi.org/10.1007/s00366-021-01346-2

Archana, M. and Geetha, M.K. (2015), "Object detection and tracking based on trajectory in broadcast tennis video", *Procedia Comput*. *Sci*., **58**, 225-232.
https://doi.org/10.1016/j.procs.2015.08.060

Arefi, M. (2018), "Nonlocal free vibration analysis of a doubly curved piezoelectric nano shell", *Steel Compos*. *Struct*., **27**(4), 479-493. https://doi.org/10.12989/SCS.2018.27.4.479

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

Barretta, R., Fazelzadeh, S.A., Feo, L., Ghavanloo, E. and Luciano, R. (2018), "Nonlocal inflected nano-beams: A stress-driven approach of bi-Helmholtz type", *Compos*. *Struct*., **200**, 239-245. https://doi.org/10.1016/j.compstruct.2018.04.072

Bendine, K., Boukhoulda, F.B., Nouari, M. and Satla, Z. (2016), "Active vibration control of functionally graded beams with piezoelectric layers based on higher order shear deformation theory", *Earthq*. *Eng*. *Eng*. *Vib*., **15**(4), 611-620.
https://doi.org/10.1007/s11803-016-0352-y

Bruant, I. and Proslier, L. (2016), "Optimal location of piezoelectric actuators for active vibration control of thin axially functionally graded beams", *Int*. *J*. *Mech*. *Mater*. *Des*., **12**(2), 173-192. https://doi.org/10.1007/s10999-015-9297-y

Burdess, J.S. and Fawcett, J.N. (1992), "Experimental Evaluation of a Piezoelectric Actuator for the Control of Vibration in a Cantilever Beam", *Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering*, **206**(2), 99-106.
https://doi.org/10.1243/PIME_PROC_1992_206_315_02

Cao, B., Fan, S., Zhao, J., Tian, S., Zheng, Z., Yan, Y. and Yang, P. (2021a), "Large-scale many-objective deployment optimization of edge servers", *IEEE T*. *Intell*. *Transp*. *Syst*., **22**(6), 3841-3849. https://doi.org/10.1109/TITS.2021.3059455

Cao, B., Li, M., Liu, X., Zhao, J., Cao, W. and Lv, Z. (2021b), "Many-objective deployment optimization for a drone-assisted camera network", *IEEE T*. *Netw*. *Sci*. *Eng*., **8**(4), 2756-2764.
https://doi.org/10.1109/TNSE.2021.3057915

Cao, K., Wang, B., Ding, H., Lv, L., Dong, R., Cheng, T. and Gong, F. (2020), "Improving physical layer security of uplink NOMA via energy harvesting jammers", *IEEE T*. *Inform*. *Forensics Secur*., **16**, 786-799.
https://doi.org/10.1109/TIFS.2020.3023277

Chen, F., Chen, J., Duan, R., Habibi, M. and Khadimallah, M.A. (2022a), "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

Chen, P., Pei, J., Lu, W. and Li, M. (2022b), "A deep reinforcement learning based method for real-time path planning and dynamic obstacle avoidance", *Neurocomputing*, **497** 64-75. https://doi.org/10.1016/j.neucom.2022.05.006

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*. *Based Des*. *Struct*., 1-24. https://doi.org/10.1080/15397734.2020.1744005

Conaire, C.O., Kelly, P., Connaghan, D. and Connor, N.E.O. (2009), "TennisSense: A platform for extracting semantic information from multi-camera tennis data", *Proceedings of the 16th International Conference on Digital Signal Processing*, July.

Dai, Z., Jiang, Z., Zhang, L. and Habibi, M. (2021a), "Frequency characteristics and sensitivity analysis of a size-dependent laminated nanoshell", *Adv*. *Nano Res*., **10**(2), 175.
https://doi.org/10.12989/anr.2021.10.2.175

Dai, Z., Zhang, L., Bolandi, S.Y. and Habibi, M. (2021b), "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

Dong, Y., Gao, Y., Zhu, Q., Moradi, Z. and Safa, M. (2022), "TE-GDQE implementation to investigate the vibration of FG composite conical shells considering a frequency controller solid ring", *Eng*. *Anal*. *Bound*. *Elem*., **138**, 95-107.
https://doi.org/10.1016/j.enganabound.2022.01.017

Ebrahimi, F. and Barati, M.R. (2017), "Flexural wave propagation analysis of embedded S-FGM nanobeams under longitudinal magnetic field based on nonlocal strain gradient theory", *Arab*. *J*. *Sci*. *Eng*., **42**(5), 1715-1726.
https://doi.org/10.1007/s13369-016-2266-4

Ebrahimi, F., Barati, M.R. and Dabbagh, A. (2016), "A nonlocal strain gradient theory for wave propagation analysis in temperature-dependent inhomogeneous nanoplates", *Int*. *J*. *Eng*. *Sci*., **107**, 169-182.
https://doi.org/10.1016/j.ijengsci.2016.07.008

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

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", *Eur*. *Phys*. *J*. *Plus*, **135**(2), 144.
https://doi.org/10.1140/epjp/s13360-020-00217-x

Eltaher Mohamed, A., Omar, F.A., Abdraboh Azza, M., Abdalla Waleed, S. and Alshorbagy Amal, E. (2020), "Mechanical behaviors of piezoelectric nonlocal nanobeam with cutouts", *Smart Struct*. *Syst*., **25**(2), 219-228.
https://doi.org/10.12989/SSS.2020.25.2.219

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*. *Based Des*. *Struct*., **47**(5), 521-545.
https://doi.org/10.1080/15397734.2019.1566743

Fan, L., Huang, Y., Ji, D., Moradi, Z., Safa, M. and Amine Khadimallah, M. (2022), "Interaction of angular velocity and temperature rise in the thermo-inertia bifurcation buckling of FG laminated nanocomposite annular plates", *Eng*. *Struct*., **265**, 114518. https://doi.org/10.1016/j.engstruct.2022.114518

Fang, J., Kong, G. and Yang, Q. (2022), "Group performance of energy piles under cyclic and variable thermal loading", *J*. *Geotech*. *Geoenviron*. *Eng*., **148**(8), 04022060.
https://doi.org/10.1061/(ASCE)GT.1943-5606.0002840

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*. *Based Des*. *Struct*., **48**(6), 755-772. https://doi.org/10.1080/15397734.2019.1662310

Guo, J., Baharvand, A., Tazeddinova, D., Habibi, M., Safarpour, H., Roco-Videla, A. and Selmi, A. (2021a), "An intelligent computer method for vibration responses of the spinning multi-layer symmetric nanosystem using multi-physics modeling", *Eng*. *Comput*., 1-22. https://doi.org/10.1007/s00366-021-01433-4

Guo, Y., Mi, H. and Habibi, M. (2021b), "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., Darabi, R., Sa, J.C.d. and Reis, A. (2021a), "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

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. 10.22060/MEJ.2016.664

Habibi, M., Hashemabadi, D. and Safarpour, H. (2019a), "Vibration analysis of a high-speed rotating GPLRC nanostructure coupled with a piezoelectric actuator", *Eur*. *Phys*. *J*. *Plus*, **134**(6), 307. https://doi.org/10.1140/epjp/i2019-12742-7

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.

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.

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*. *Pr*., **31**, 310-323.

Habibi, M., Mohammadgholiha, M. and Safarpour, H. (2019b), "Wave propagation characteristics of the electrically GNP-reinforced nanocomposite cylindrical shell", *J*. *Brazil*. *Soc*. *Mech*. *Sci*. *Eng*., **41**(5), 221. 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*. *Based Des*. *Struct*., 1-30.

Habibi, M., Mohammadi, A., Safarpour, H. and Ghadiri, M. (2021b), "Effect of porosity on buckling and vibrational characteristics of the imperfect GPLRC composite nanoshell", *Mech*. *Based Des*. *Struct*., **49**(6), 811-840. 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*. *Based Des*. *Struct*., 1-19. https://doi.org/10.1080/15397734.2019.1697932

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*. *Based Des*. *Struct*., 1-22. https://doi.org/10.1080/15397734.2020.1779086

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

Hadjesfandiari, A.R. and Dargush, G.F. (2011), "Couple stress theory for solids", *Int*. *J*. *Solids Struct*., **48**(18), 2496-2510. https://doi.org/10.1016/j.ijsolstr.2011.05.002

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 Med*., 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

Hou, F., Wu, S., Moradi, Z. and Shafiei, N. (2021), "The computational modeling for the static analysis of axially functionally graded micro-cylindrical imperfect beam applying the computer simulation", *Eng*. *Comput*., 1-19.

Huang, X., Hao, H., Oslub, K., Habibi, M. and Tounsi, A. (2021a), "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

Huang, X., Zhang, Y., Moradi, Z. and Shafiei, N. (2021b), "Computer simulation via a couple of homotopy perturbation methods and the generalized differential quadrature method for nonlinear vibration of functionally graded non-uniform micro-tube", *Eng*. *Comput*., 1-18. https://doi.org/10.1007/s00366-021-01395-7

Huang, X., Zhu, Y., Vafaei, P., Moradi, Z. and Davoudi, M. (2021c), "An iterative simulation algorithm for large oscillation of the applicable 2D-electrical system on a complex nonlinear substrate", *Eng*. *Comput*., 1-13. https://doi.org/10.1007/s00366-021-01320-y

Jiao, J., Ghoreishi, S.M., Moradi, Z. and Oslub, K. (2021), "Coupled particle swarm optimization method with genetic algorithm for the static–dynamic performance of the magneto-electro-elastic nanosystem", *Eng*. *Comput*., 1-15. https://doi.org/10.1007/s00366-021-01391-x

Jirásek, M. (2004), "Nonlocal theories in continuum mechanics", *Acta Polytechnica*, **44**(5-6). https://doi.org/10.14311/610

Kargarnovin, M.H., Najafizadeh, M.M. and Viliani, N.S. (2007), "Vibration control of a functionally graded material plate patched with piezoelectric actuators and sensors under a constant electric charge", *Smart Mater*. *Struct*., **16**(4), 1252-1259. https://doi.org/10.1088/0964-1726/16/4/037

Karimiasl, M., Ebrahimi, F. and Mahesh, V. (2019), "Nonlinear forced vibration of smart multiscale sandwich composite doubly curved porous shell", *Thin Wall*. *Struct*., **143**, 106152. https://doi.org/10.1016/j.tws.2019.04.044

Karkon, M. (2018), "An efficient finite element formulation for bending, free vibration and stability analysis of Timoshenko beams", *J*. *Brazil*. *Soc*. *Mech*. *Sci*. *Eng*., **40**(10), 497. https://doi.org/10.1007/s40430-018-1413-0

Kong, F., Dong, F., Duan, M., Habibi, M., Safarpour, H. and Tounsi, A. (2022), "On the vibrations of the Electrorheological sandwich disk with composite face sheets considering pre and post-yield regions", *Thin Wall*. *Struct*., **179**, 109631. https://doi.org/10.1016/j.tws.2022.109631

Lam, D.C.C., Yang, F., Chong, A.C.M., Wang, J. and Tong, P. (2003), "Experiments and theory in strain gradient elasticity", *J*. *Mech*. *Phys*. *Solids*, **51**(8), 1477-1508.

https://doi.org/10.1016/S0022-5096(03)00053-X

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, J., Xu, K., Chaudhuri, S., Yumer, E., Zhang, H. and Guibas, L. (2017), “Grass: Generative recursive autoencoders for shape structures”, *ACM Transact*. *Graphics (TOG)*, **36**(4), 1-14. https://doi.org/10.1145/3072959.3073637

Li, L., Hu, Y. and Ling, L. (2015), “Flexural wave propagation in small-scaled functionally graded beams via a nonlocal strain gradient theory”, *Compos*. *Struct*., **133**, 1079-1092. https://doi.org/10.1016/j.compstruct.2015.08.014

Li, T., Shang, D., Gao, S., Wang, B., Kong, H., Yang, G., Shu, W., Xu, P. and Wei, G. (2022), “Two-dimensional material-based electrochemical sensors/biosensors for food safety and biomolecular detection”, *Biosensors*, **12**(5), 314. https://doi.org/10.3390/bios12050314

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, 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 micro-system via two-dimensional generalized differential quadrature method”, *Eng*. *Comput*., 1-16. https://doi.org/10.1007/s00366-021-01419-2

Liu, Y., Wang, W., He, T., Moradi, Z. and Larco Benítez, M.A. (2021c), “On the modelling of the vibration behaviors via discrete singular convolution method for a high-order sector annular system”, *Eng*. *Comput*., 1-23.

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*. *Based Des*. *Struct*., 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*. *Based Des*. *Struct*., 1-25. https://doi.org/10.1080/15397734.2020.1815544

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

Luo, J., Song, J., Moradi, Z., Safa, M. and Khadimallah, M.A. (2022), “Effect of simultaneous compressive and inertia loads on the bifurcation stability of shear deformable functionally graded annular fabrications reinforced with graphenes”, *Eur*. *J*. *Mech*. *A Solids*. 104581. https://doi.org/10.1016/j.euromechsol.2022.104581

Ma, L., Liu, X. and Moradi, Z. “On the chaotic behavior of graphene-reinforced annular systems under harmonic excitation”, *Eng*. *Comput*., 1-25. https://doi.org/10.1007/s00366-020-01210-9

Ma, Z., Zheng, W., Chen, X. and Yin, L. (2021), “Joint embedding VQA model based on dynamic word vector”, *PeerJ Comput*. *Sci*., **7**, e353. https://doi.org/10.7717/peerj-cs.353

Mao, J.J., Lu, H.M., Zhang, W. and Lai, S.K. (2020), “Vibrations of graphene nanoplatelet reinforced functionally gradient piezoelectric composite microplate based on nonlocal theory”, *Compos*. *Struct*., **236**, 111813. https://doi.org/10.1016/j.compstruct.2019.111813

Melo, A.G., Pinto, M.F., Marcato, A.L.M., Biundini, I.Z. and Rocha, N.M.S. (2021), “Low-cost trajectory-based ball detection for impact indication and recording”, *J*. *Control Automat*. *Electr*. *Syst*., **32**(2), 367-377. https://doi.org/10.1007/s40313-020-00677-7

Michael, M., Meyyazhagan, A., Velayudhannair, K., Pappuswamy, M., Maria, A., Xavier, V., Balasubramanian, B., Baskaran, R., Kamyab, H. and Vasseghian, Y. (2022), “The content of heavy metals in cigarettes and the impact of their leachates on the aquatic ecosystem”, *Sustainability*, **14**(8), 4752. https://doi.org/10.3390/su14084752

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**(1), 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., 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

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. 10.22034/JSM.2019.665264

Moradi, Z., Davoudi, M., Ebrahimi, F. and Ehyaei, A.F. (2021), “Intelligent wave dispersion control of an inhomogeneous micro-shell using a proportional-derivative smart controller”, *Wave*. *Random Complex Med*., 1-24. https://doi.org/10.1080/17455030.2021.1926572

Nadal, C. and Pigache, F. (2009), “Multimodal electromechanical model of piezoelectric transformers by Hamilton's principle”, *IEEE T*. *Ultrasonics Ferroelectr*. *Freq*. *Control*, **56**(11), 2530-2543. https://doi.org/10.1109/TUFFC.2009.1340

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

Nejad, M.Z., Hadi, A. and Rastgoo, A. (2016), “Buckling analysis of arbitrary two-directional functionally graded Euler–Bernoulli nano-beams based on nonlocal elasticity theory”, *Int*. *J*. *Eng*. *Sci*., **103**, 1-10. https://doi.org/10.1016/j.ijengsci.2016.03.001

Oyarhossein, M.A., Alizadeh, A.a., Habibi, M., Makkiabadi, M., Daman, M., Safarpour, H. and Jung, D.W. (2020a), “Dynamic response of the nonlocal strain-stress gradient in laminated polymer composites microtubes”, *Sci*. *Rep*., **10**(1), 5616. https://doi.org/10.1038/s41598-020-61855-w

Oyarhossein, M.A., Alizadeh, A.a., Habibi, M., Makkiabadi, M., Daman, M., Safarpour, H. and Jung, D.W. (2020b), “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", *Comput. Math. Appl.*, **77**(10), 2608-2626. https://doi.org/10.1016/j.camwa.2018.12.041.

Safarpour, H., Ghanizadeh, S.A. and Habibi, M. (2018a), "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., Mohammadi, K., Ghadiri, M. and Barooti, M.M. (2018b), "Effect of porosity on flexural vibration of CNT-reinforced cylindrical shells in thermal environment using GDQM", *Int. J. Struct. Stabil. Dyn.*, **18**(10), 1850123. https://doi.org/10.1142/s0219455418501237

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

Shao, Y., Zhao, Y., Gao, J. and Habibi, M. (2021), "Energy absorption of the strengthened viscoelastic multi-curved composite panel under friction force", *Arch. Civil Mech. Eng.*, **21**(4), 1-29. https://doi.org/10.1007/s43452-021-00279-3

Shariati, A., Habibi, M., Tounsi, A., Safarpour, H. and Safa, M. (2020a), "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., Habibi, M., Tounsi, A., Safarpour, H. and Safa, M. (2021), "Application of exact continuum size-dependent theory for stability and frequency analysis of a curved cantilevered microtubule by considering viscoelastic properties", *Eng. Comput.*, **37**(4), 3629-3648. https://doi.org/10.1007/s00366-020-01024-9

Shariati, A., Mohammad-Sedighi, H., Żur, K.K., Habibi, M. and Safa, M. (2020b), "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. (2020c), "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, G., Araby, S., Gibson, C.T., Meng, Q., Zhu, S. and Ma, J. (2018), "Graphene platelets and their polymer composites: Fabrication, structure, properties, and applications", *Adv. Funct. Mater.*, **28**(19), 1706705. https://doi.org/10.1002/adfm.201706705

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. Based Des. Struct.*, 1-37. https://doi.org/10.1080/15397734.2020.1772088

Shokrgozar, A., Ghabussi, A., Ebrahimi, F., Habibi, M. and Safarpour, H. (2020a), "Viscoelastic dynamics and static responses of a graphene nanoplatelets-reinforced composite cylindrical microshell", *Mech. Based Des. Struct.*, 1-28. https://doi.org/10.1080/15397734.2020.1719509

Shokrgozar, A., Safarpour, H. and Habibi, M. (2019), "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

Shokrgozar, A., Safarpour, H. and Habibi, M. (2020b), "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

Tang, Y., Liu, S., Deng, Y., Zhang, Y., Yin, L. and Zheng, W. (2021), "An improved method for soft tissue modeling", *Biomed. Signal Pr. Control*, **65**, 102367. https://doi.org/10.1016/j.bspc.2020.102367

Wang, H., Habibi, M., Marzouki, R., Majdi, A., Shariati, M., Denic, N., Zakić, A., Khorami, M., Khadimallah, M.A. and Ebid, A.A.K. (2022a), "Improving the self-healing of cementitious materials with a hydrogel system", *Gels*, **8**(5), 278. https://doi.org/10.3390/gels8050278

Wang, Q., Zhou, G., Song, R., Xie, Y., Luo, M. and Yue, T. (2022b), "Continuous space ant colony algorithm for automatic selection of orthophoto mosaic seamline network", *ISPRS J. Photogram. Remote Sens.*, **186**, 201-217. https://doi.org/10.1016/j.isprsjprs.2022.02.011

Wang, W., Chen, Z. and Yuan, X. (2022c), "Simple low-light image enhancement based on Weber-Fechner law in logarithmic space", *Signal Pr. Image Commun.*, 116742. https://doi.org/10.1016/j.image.2022.116742

Wang, Y., Yang, J., Moradi, Z., Safa, M. and Khadimallah, M.A. (2022d), "Nonlinear dynamic analysis of thermally deformed beams subjected to uniform loading resting on nonlinear viscoelastic foundation", *Eur. J. Mech. A Solids*, **95**, 104638. https://doi.org/10.1016/j.euromechsol.2022.104638

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

Wen, F., He, T., Liu, H., Chen, H.Y., Zhang, T. and Lee, C. (2020), "Advances in chemical sensing technology for enabling the next-generation self-sustainable integrated wearable system in the IoT era", *Nano Energy*, **78**, 105155. https://doi.org/10.1016/j.nanoen.2020.105155

Wu, J. and Habibi, M. (2021), "Dynamic simulation of the ultra-fast-rotating sandwich cantilever disk via finite element and semi-numerical methods", *Eng. Comput.*, 1-17. https://doi.org/10.1007/s00366-021-01396-6

Xia, W., Du, J., Habibi, M., Shariati, M. and Khadimallah, M.A. (2022), "Application of Chebyshev-based GDQ and Newmark methods to viscothermoelasticity responses of FG composite annular systems", *Eng. Anal. Bound. Elem.*, **143**, 28-42. https://doi.org/10.1016/j.enganabound.2022.06.003

Xiong, Q.M., Chen, Z., Huang, J.T., Zhang, M., Song, H., Hou, X.F., Li, X.B. and Feng, Z.J. (2020), "Preparation, structure and mechanical properties of Sialon ceramics by transition metal-catalyzed nitriding reaction", *Rare Metals*, **39**(5), 589-596.

Xu, W., Pan, G., Moradi, Z. and Shafiei, N. (2021), "Nonlinear forced vibration analysis of functionally graded non-uniform cylindrical microbeams applying the semi-analytical solution", *Compos. Struct.*, 114395. https://doi.org/10.1016/j.compstruct.2021.114395

Yan, F., Kittler, J., Windridge, D., Christmas, W., Mikolajczyk, K., Cox, S. and Huang, Q. (2014), “Automatic annotation of tennis games: An integration of audio, vision, and learning”, *Image Vision Comput*., **32**(11), 896-903. https://doi.org/10.1016/j.imavis.2014.08.004

Yang, N., Moradi, Z., Khadimallah, M.A. and Arvin, H. (2022), “Application of the Chebyshev–Ritz route in determination of the dynamic instability region boundary for rotating nanocomposite beams reinforced with graphene platelet subjected to a temperature increment”, *Eng. Anal. Bound. Elem*., **139**, 169-179. https://doi.org/10.1016/j.enganabound.2022.03.013

Yang, W., Chen, X., Xiong, Z., Xu, Z., Liu, G. and Zhang, X. (2021), “A privacy-preserving aggregation scheme based on negative survey for vehicle fuel consumption data”, *Inform. Sci*., **570**, 526-544. https://doi.org/10.1016/j.ins.2021.05.009

Yong, C.Y., Sudirman, R. and Chew, K.M. (2011). “Motion detection and analysis with four different detectors”, *Proceedomgs of the 2011 Third International Conference on Computational Intelligence, Modelling & Simulation*, September.

Yu, X., Maalla, A. and Moradi, Z. (2022), “Electroelastic high-order computational continuum strategy for critical voltage and frequency of piezoelectric NEMS via modified multi-physical couple stress theory”, *Mech. Syst. Signal Pr*., **165**, 108373. https://doi.org/10.1016/j.ymssp.2021.108373.

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, 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 Med*., 1-24. https://doi.org/10.1080/17455030.2021.1948627

Zhao, H., Wang, S., Zhou, G. and Jung, W. (2019), *TennisEye: Tennis Ball Speed Estimation Using a Racket-Mounted Motion Sensor*, Association for Computing Machinery, Montreal, Quebec, Canada.

Zhao, H., Zhu, C., Xu, X., Huang, H. and Xu, K. (2022), “Learning practically feasible policies for online 3D bin packing”, *Sci. China Inform. Sci*., **65**(1), 1-17. https://doi.org/10.1007/s11432-021-3348-6

Zhao, L. and Wang, L. (2022), “A new lightweight network based on MobileNetV3”, *KSII Transactions on Internet and Information Systems (TIIS)*, **16**(1), 1-15. https://doi.org/10.3837/tiis.2022.01.001

Zhao, Y., Moradi, Z., Davoudi, M. and Zhuang, J. “Bending and stress responses of the hybrid axisymmetric system via state-space method and 3D-elasticity theory”, *Eng. Comput*., 1-23. https://doi.org/10.1007/s00366-020-01242-1

Zheng, W., Liu, X. and Yin, L. (2021), “Research on image classification method based on improved multi-scale relational network”, *PeerJ Comput. Sci*., **7**, e613. https://doi.org/10.7717/peerj-cs.613

Zhou, C., Zhao, Y., Zhang, J., Fang, Y. and Habibi, M. (2020a), “Vibrational characteristics of multi-phase nanocomposite reinforced circular/annular system”, *Adv. Nano Res*., **9**(4), 295-307. https://doi.org/10.12989/anr.2020.9.4.295

Zhou, G., Bao, X., Ye, S., Wang, H. and Yan, H. (2020b), “Selection of optimal building facade texture images from UAV-based multiple oblique image flows”, *IEEE T. Geosci. Remote Sens*., **59**(2), 1534-1552. https://doi.org/10.1109/TGRS.2020.3023135

Zhou, G., Yang, F. and Xiao, J. (2022), “Study on pixel entanglement theory for imagery classification”, *IEEE T. Geosci. Remote Sens*., **60**, 1-18. https://doi.org/10.1109/TGRS.2022.3167569

Zhu, L., Ren, H., Habibi, M., Mohammed, K.J. and Khadimallah, M.A. (2022), “Predicting the environmental economic dispatch problem for reducing waste nonrenewable materials via an innovative constraint multi-objective Chimp Optimization Algorithm”, *J. Clean. Prod*., 132697. https://doi.org/10.1016/j.jclepro.2022.132697

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