International Journal on Emerging Technologies **10**(3): 244-252(2019)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Damping Characteristics of Composite Cylindrical Shells with & without Longitudinal Stiffeners

Sai Prasanna Kumar J. V.

Aeronautical Engineering Department, Vel Tech Rengarajan Dr. Sagunthala R & D Institute of Science & Technology, Chennai, Tamil Nadu, India.

(Corresponding author: Sai Prasanna Kumar J. V.)
(Received 16 June 2019, Revised 29 August 2019 Accepted 05 September 2019)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Composite are a class of materials whose properties can be tailored, they have excellent mechanical properties whose applications are vast ranging from automobile, aerospace, marine and civil engineering industries. Some of these composites can be manufactured with minimum tooling as well as labour. Composites lend themselves to casted into different shapes and complex geometries with simple hand-layup techniques, perhaps the only disadvantage is the material cost.

The proliferation of laminated composite shells of revolution is a common feature dominating every fields and replacing the traditional materials to a great extent because of its superior strength, strength to weight ratios and its load bearing capacity both statically and dynamically, While the shells which are used in the areas where the structures would be subjected to vibration. Vibration of a part or a component is detrimental to the entire structure wherever is the source of vibration is emerging. Hence, it's important to study the parameters causing the vibration and its prevention or at least reduce the detrimental effects. The lay-up sequence, orientation, temperature and volume fraction have a telling effect on the behavior of the laminate against the external stimuli

This paper presents the experimental and numerical analysis of composite cylindrical laminated shells subjected to free vibration with. The numerical analysis is carried out by using higher order shear deformation theory by implementing block Lanczos algorithm. The analysis was carried out for cylindrical shells, while damping characteristics are represented graphically, and the effect of damping characteristics of cylindrical shells with longitudinal stiffeners are also discussed for different end conditions, in addition to strengthening the polymer resin with various percent of Caoutchouc. A comparison was made between the numerical and experimental methods; the results correlate significantly while the damping ratios of the shells with Caoutchouc fared better.

Keywords: Block Lanczos Algorithm, GFRP cylindrical shell, Stiffener, Caoutchouc, Damping ratio

I. INTRODUCTION

Composites have good vibration damping characteristics due to the dampening of fiber-matrix interface and inter-laminar effects along constituent material's damping properties. Composites are the typical materials that contain two or more chemically different constituents combined in a macroscopic level in order obtain a useful product. The primary constituents of composites are the reinforcement and the matrix. The reinforcements are the load carrying members in the composites and it may be continuous fibers or short fibers or particles with various cross sections (preferably circular) as well as in various sizes. The matrix is the load transferring member in the composite, and it holds the fibers in order to provide the structural integrity. The primary advantages of composites are excellent specific modulus, specific strength, impact resistance and vibration damping. Now a days most of the engineering industries are using composite materials, especially the aerospace industry because of its low weight without compromising the properties. Composites have excellent damping characteristics whose range starts where most of the metals range ends. Aircraft fuselage which holds many parts such as wings, horizontal and vertical stabilizers will undergo such vibrations when an aircraft enters turbulence, uneven engine operation and while landing. It is essential to dampen such vibrations for safe and efficient operation with suitable selection of material parameters and design. In composites the material properties and stacking configuration greatly affects the damping properties of the structure. The primary causes of the damping in the composite materials are the internal friction within the constituent materials and the slip between the fiber-matrix interface.

Ferreira *et al.,* [1] tried the mesh-less method for vibration analysis using Reddy shell theory and got good coincidence with the theoretical results. Nanda, & Sahu, [2] analyzed the application of various shell theories to the composites. Lei *et al.,* [3] studied the vibration characteristics of woven structure with different weaving styles. Maheri [4] studied the effect of boundary conditions and fiber orientation in the damping characteristics of composite laminates. Butterworth *et al.,* [5] determined the damping characteristics of an 11storey reinforced concrete experimentally. Mevada, & Patel [6] estimated the natural frequency and damping ratio of cantilever beam composed with different material like aluminum, brass and steel. Farshidianfar & Oliazadeh [7] compared various theories to determine the natural frequencies of cylindrical shells and the influence of length, radius and thickness in the vibration characteristics are also studied. Tu & Loi [8] investigated the effects of various geometrical properties on the natural frequency of rotating functionally graded cylindrical shells with orthogonal stiffeners. Samanta & Mukhopadhyay [9] determined the natural frequencies of a stiffened shell element using finite element method. Bagheri & Jafari [10] analyzed the cylindrical shells with circumferential stiffeners. Edalata *et al.,* [11] determined the free vibration characteristics of stiffened parabolic shell. Obied & Shareef [12] investigated the effect of various stiffeners in the cylindrical shells. Chen *et al.,* [13] developed a semi-numerical method to analyze the vibration characteristics of a ring stiffened cylindrical shell. Bawa [14] presented the study of vibrational modes of (MgO)n at atomic level. Sandeep Jain [15] addressed the effect of additives in the lubricants on stiffness and damping coefficients journal bearings. Jain & Bajpai [16] studied the mechanical properties self-compacting concrete with steel fiber. Praveen & Vikram [17] investigated the effect of burn clay and fly ash on the structural property of masonry work. Hirwani *et al.,* 18] addressed the non-linear frequency response of carbon epoxy curved panels and Mat Daud & Viswanathan [19] extracted the natural frequency of symmetrically layered angle ply shell filled with fluids.

In the present work, a cylindrical shell with and without stiffeners are carried for the study of the dynamic characteristics. In addition, a filler material was dispersed into the matrix with different ratios and its effect on the damping properties was studied.

II. MATERIALS AND METHODS

The shells for the study are fabricated using Unidirectional E-glass fiber as the reinforcement obtained from St.Gobain Chennai and Bisphenol-A as the matrix along with HY951 as the hardener was supplied from Ciba-Gigi and huntsman Ltd. Chennai. Wooden molds are fabricated by considering the dimensions of the shell. A 10mm slot was milled into the mold which is used to fabricate the shell with stiffeners. The length of the slot is maintained up to the length of the shell element. The epoxy was made to lose its viscosity and caoutchouc was gently added to it by volume and then stirred using an ultrasonicator. After this the hardener was added to process the laminate. Molds are prepared with specific tolerances separately for the shells with longitudinal stiffeners and shells without stiffeners. The mold was cleaned, each layer was laid on it and suitable release agent was applied on it to separate the part. For this study caoutchouc is added to the matrix for different proportions of 5%, 7% and 10% by matrix volume. The fabricated specimens are vacuum bagged and cured at elevated temperature specified by the manufacturer. The properties of constituent materials are listed in Table 1. Fig. 1 and 2 shows the fabricated cylindrical shells without and with longitudinal stiffeners respectively.

Table 1: Material properties.

Material	E-glass fiber	Bisphenol-A	Caoutchouc
Specific gravity	2.5	1.2	0.93
Tensile strength (MPa)	1550	72	25
Compressive strength (MPa)	1550	102	47
Shear strength (MPa)	35	34	12
Young's modulus (GPa)	85	3.4	0.002
Shear Modulus (GPa)	35	1.3	0.0003
Poisson's ratio	0.2	0.3	0.5

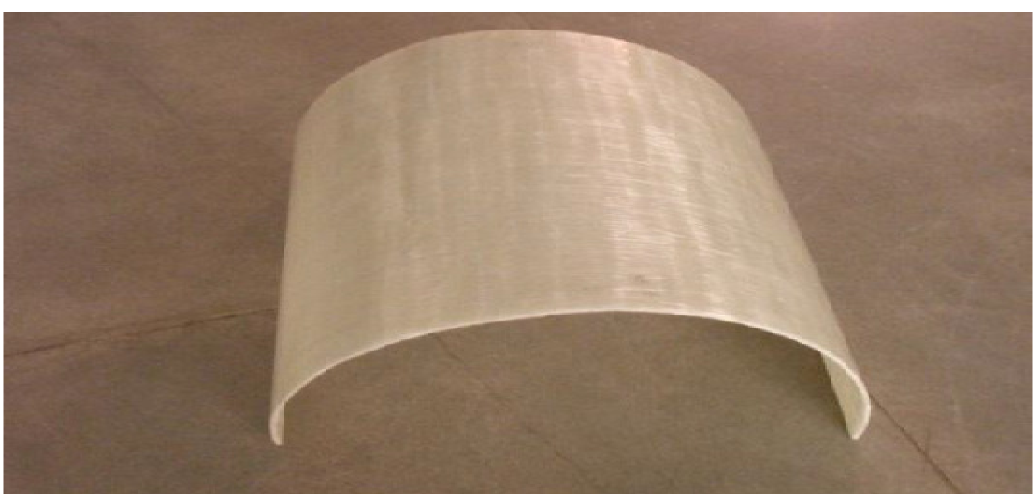


Fig. 1. Fabricated specimen without stiffener.

III. EXPERIMENTAL ANALYSIS

The experimental test to identify the damping characteristics of the shells for the proposed end conditions includes the components Real Time Analyzer (RTA), Accelerometer and impact hammer. RTA is a spectrum analyzer that measures the incoming signal from a microphone or a PA system and displays through software integrated with it. It can measure three measurements per octave at 3 or 6dB increments. The

impact hammer has a force measurement unit within it and show the load transferred through it to the structure. Two accelerometers are fixed diagonally opposite in lengthwise and connected to the RTA along with the load hammer as shown in Fig. 3.
The shells with different material properties through the variation of constituent material proportion and with different design are tested for three different end conditions namely fixed, free and simply supported. In the fixed end condition shown in Fig. 4, the shell is fixed in a support through metal strips over the entire boundary of the shell in the radial as well as the length directions to eliminate the displacements. In the free end condition shown in Fig. 5, the shell can hang on a thread and the end displacements are not restricted. In the simply supported end condition shown in Fig. 6 the shell is placed on a metal block to restrict the vertical displacements.

Fig. 2. Fabricated specimen with longitudinal stiffener.

Fig. 3. Experimental setup.

Fig. 4. Free end condition.

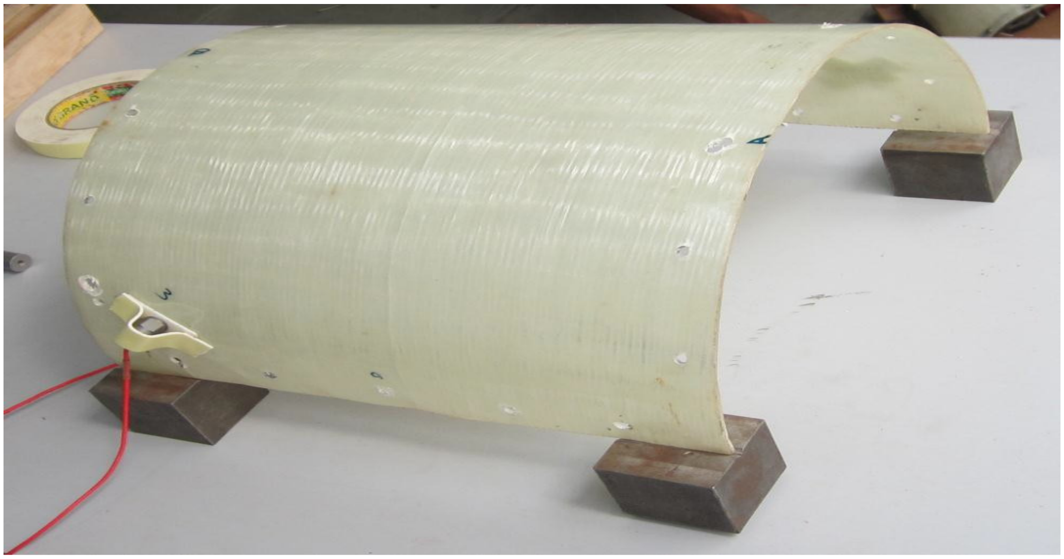


Fig. 5. Simply supported end condition.

Fig. 6. Fixed end condition.

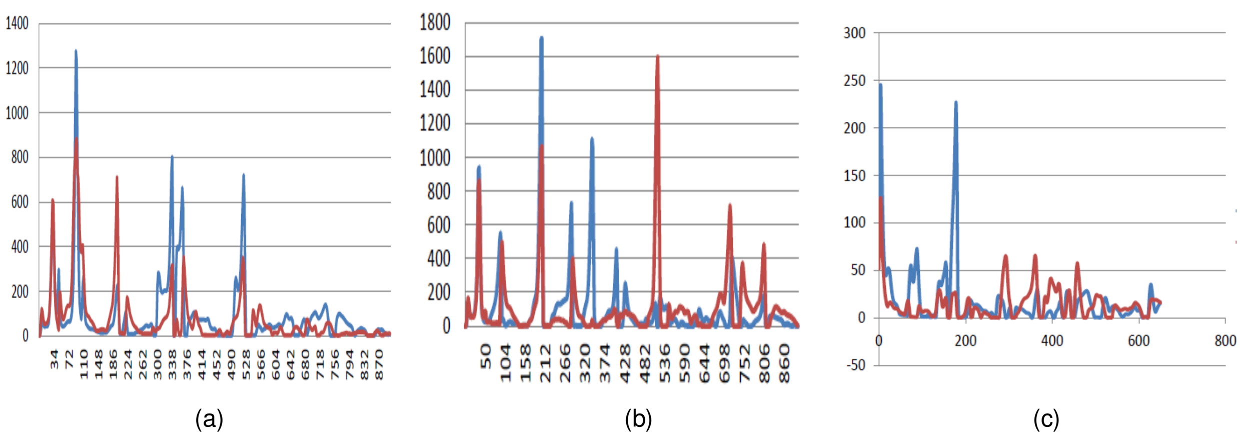
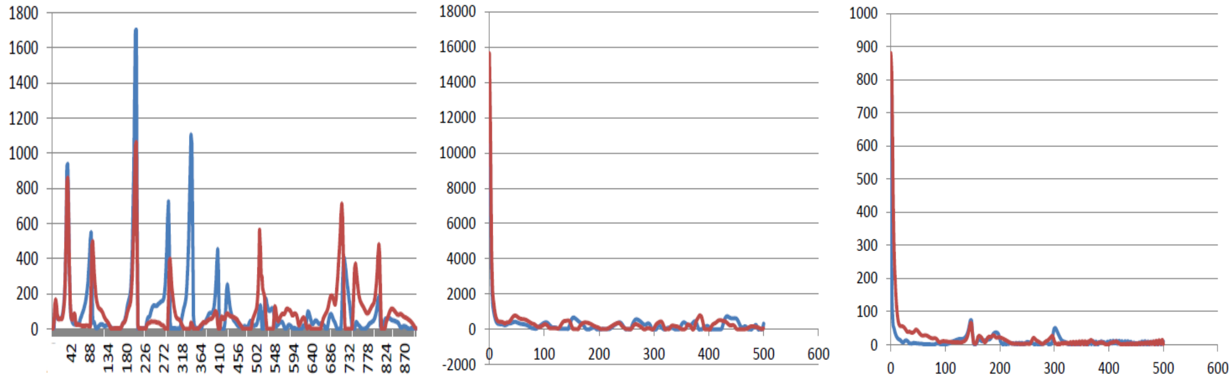
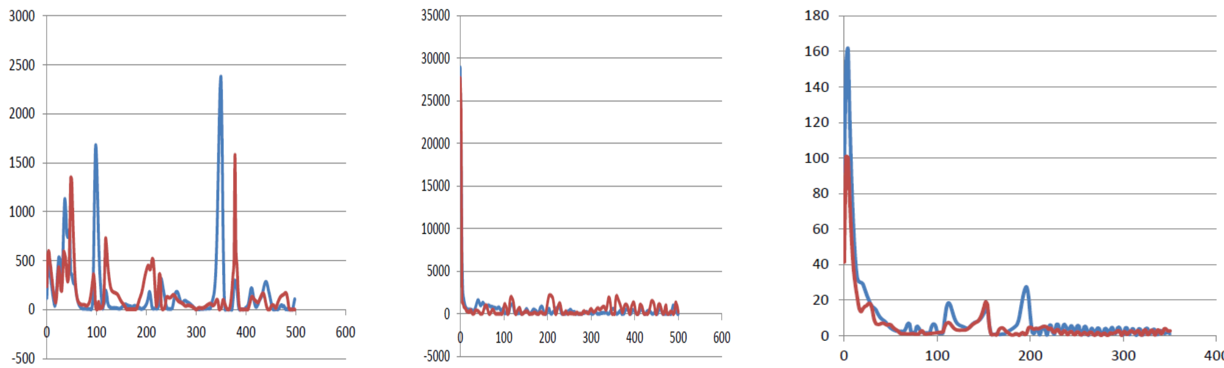


Fig. 7. Response curves of unstiffened (a) free (b) simply supported (c) fixed shells having frequency in Hz as x-axis and amplitude along y-axis.



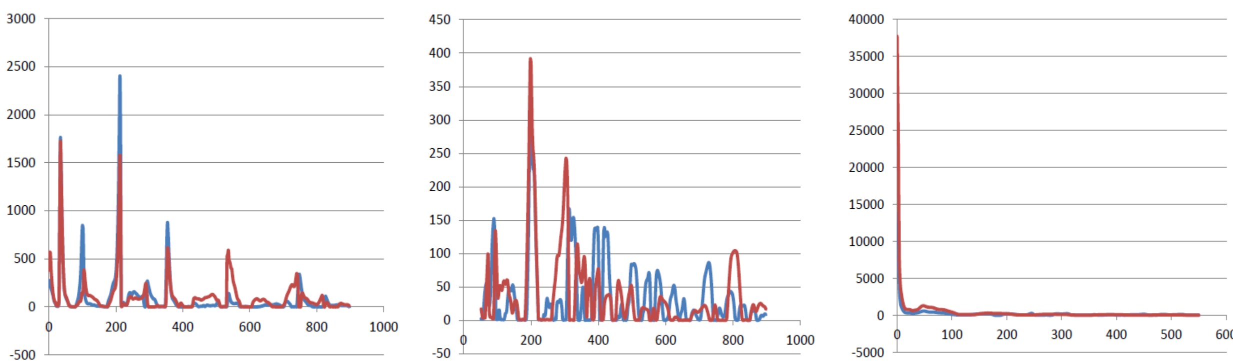
(a) (b) (c)

Fig. 8. Response curves of stiffened (a) free (b) simply supported (c) fixed shells having frequency in Hz as x-axis and amplitude along y-axis.



(a) (b) (c)

Fig. 9. Response curves of unstiffened (a) free (b) simply supported (c) fixed shells with 5% caoutchouc having frequency in Hz as x-axis and amplitude along y-axis.



(a) (b) (c)

Fig. 10. Response curves of stiffened (a) free (b) simply supported (c) fixed shells with 5% caoutchouc having frequency in Hz as x-axis and amplitude y-axis.

From the response curves shown in Figs. 7-10. It can be observed that the oscillations decay faster in the case of fixed shell as compared to the simply supported and free shells. Fixed end condition has better damping because its end condition is also contributing. The stiffened structure vibration decayed rapidly when compared to the un-stiffened panel. Also, it could be noted that the addition of caoutchouc reducing the fluctuations rapidly.

III. FEM ANALYSIS

The shell model is formulated in the FEM with the inner radius of 0.15m, shell thickness of 0.03m and the length of 0.3m. The stiffeners are placed longitudinally in equi-radius for the entire length. The mesh is formulated in such a way that for the un-stiffened shell, the minimum edge length is to be 0.003 m, the total number of elements to be 6624 and the total number of nodes are 47312 also the element load balance ratio is maintained to be 1. The block lanczos algorithm is implemented to solve the eigen values and eigen vectors and for the calculation of 6 eigen vectors totally 136263 equations are considered with the wave front of 99.

The first six modes are considered, and their corresponding natural frequencies are extracted. The damping ratio is calculated from the frequency response of the shell for the remote force.

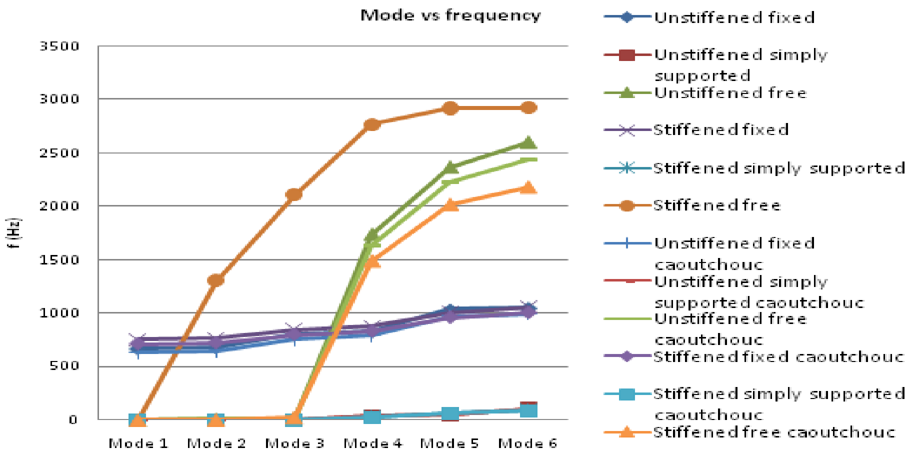


Fig. 11. Representation of natural frequency with respect to modes for various test specimens.

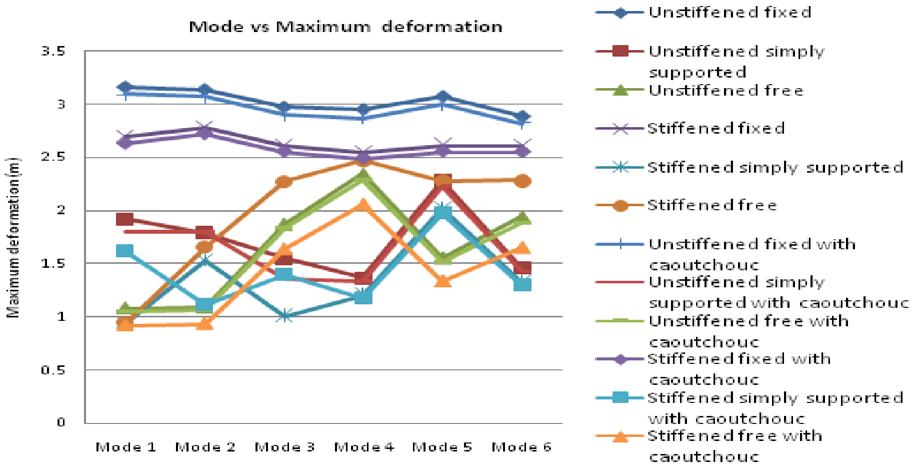


Fig. 12. Representation of maximum deformation with respect to modes for various test specimens.

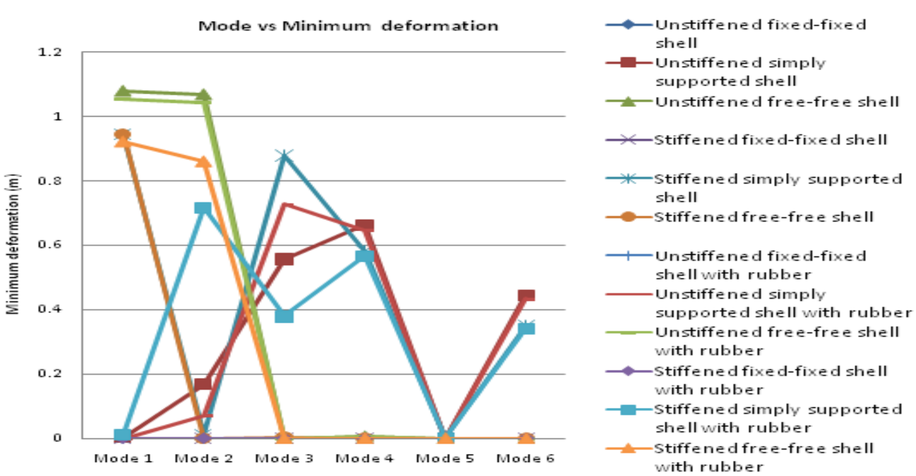
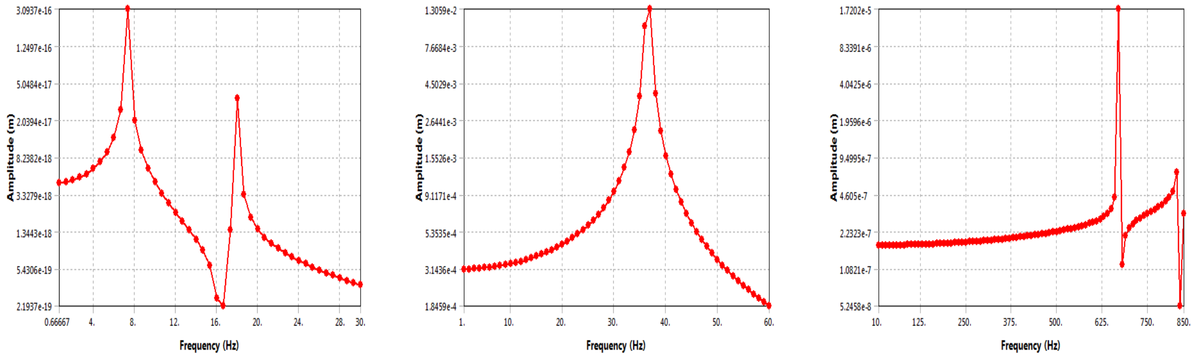


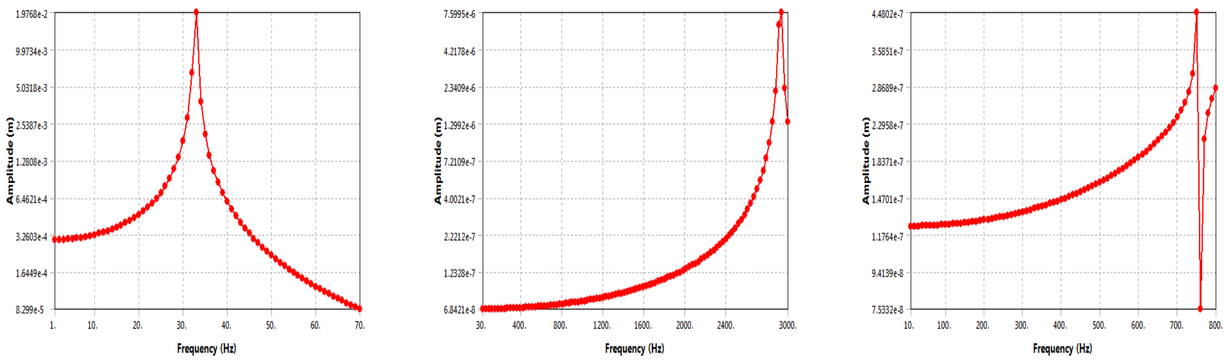
Fig. 13. Representation of minimum deformation with respect to modes for various test specimens.

From Fig. 11, it is evident that the band of natural frequency is wide for the free end condition and narrow for the fixed as well as the simply supported end conditions. Comparably the natural frequencies of the fixed end conditions are very high for the initial modes when compare to the other and the free end condition shells will have higher natural frequencies at the higher modes. The effect of cautchouc tends to increase the natural frequencies irrespective of the mode in the free end condition and at the other end conditions the rate is low when compared to the former one. The deformation of the shell shown in Figs. 12 13, is high for the fixed shell due to the resisting forces of the supports and minimum for the free shells due to the higher energy dissipation. The stiffeners increase the deformation at higher rate in order to dissipate the energy when compared with the un-stiffened shells.



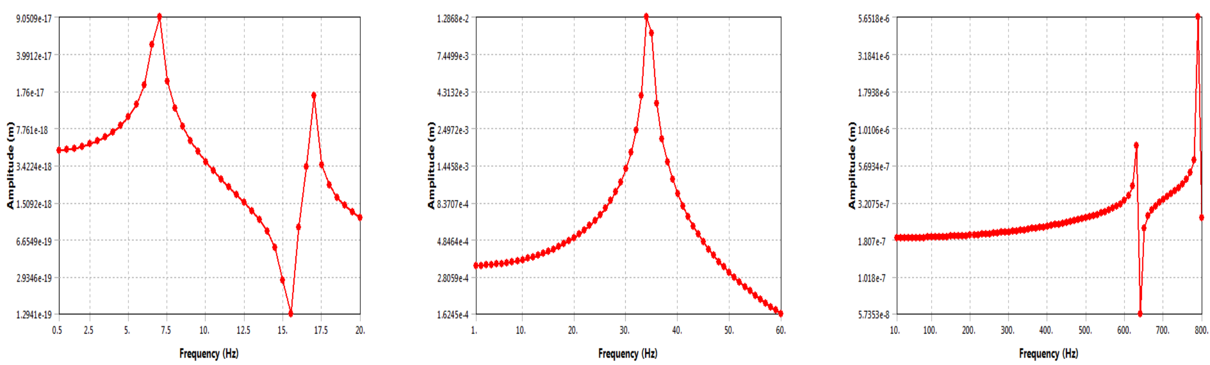
(a) (b) (c)

Fig. 14. Response curves of Unstiffened (a) free (b) simply supported (c) fixed shells having frequency in Hz as x-axis and amplitude along y-axis.



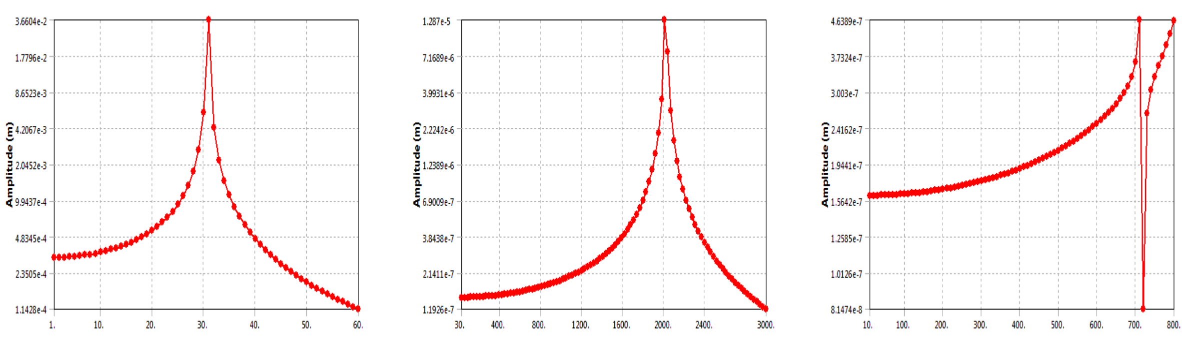
(a) (b) (c)

Fig. 15. Response curves of Stiffened (a) free (b) simply supported (c) fixed shells having frequency in Hz as x-axis and amplitude along y-axis.



(a) (b) (c)

Fig.16. Response curves of unstiffened (a) free (b) simply supported (c) fixed shells with 5% caoutchouc having frequency in Hz as x-axis and amplitude in m as y-axis.



(a) (b) (c)

Fig. 17. Response curves of Stiffened (a) free (b) simply supported (c) fixed shells with 5% caoutchouc having frequency in Hz as x-axis and amplitude along y-axis.

Response curves obtained from the FEM shown Figs. 14-17 depicts that the first peak of the response attained at lower frequencies when the shell is free and higher for the fixed ends. The stiffeners brought the first peak frequency towards right and the effect is high in the simply supported end condition even like the fixed shell without stiffener. The effect of stiffener increases the natural frequency and in turn this postpones the resonance occurring in the lower frequencies range. Addition of caoutchouc doesn't have any effect when compared to the geometry modification but it has helped in decaying the amplitude of vibration irrespective of end condition and geometry.

IV. RESULTS AND DISCUSSION

From the response curves the damping coefficient is obtained using the half power bandwidth method and the very first peak is taken for the consideration. It is observed that from the Fig. 19, the end conditions play a vital role in the value of damping ratio where the fixed supported shell has 45% higher damping ratio than the simply supported shell and 20% higher damping ratio than the free shell. There is effect of stiffeners in the damping characteristics is less when compared to the effect of material properties but there is an average of 5% increment irrespective of the end conditions and material properties. The caoutchouc increases the damping ratio at an average of 30%.

From Figs. 18 and 19 it is observed that the analytical results are significant with respect to the theoretical results. It has been observed that the damping ratio increases at an average of 35% when the end conditions changed from free to simply supported and 18.7% when the end conditions changed from free to fixed. The longitudinal stiffeners increase the damping ratio at an average of 4% irrespective of the material properties. When, the proportion of caoutchouc in the matrix increases at a rate of 5%, the damping ratio increases at an average of 27% irrespective of the end conditions. When the proportion of caoutchouc increases the slope of increment rate of the damping ratio is reduced.

V. CONCLUSION

The vibration characteristics of shells with different design, material properties and end conditions are determined. The effect of material properties, geometry and the end conditions are discussed by considering the parameter like natural frequency, deformation, damping ratio. The numerical and experimental analyses have a high significance. The addition of longitudinal stiffeners and the caoutchoucled to the better damping characteristics.

The effect of hybrid combination of carbon nano tubes on the damping characteristics of the shells with different orientations will be the future work.

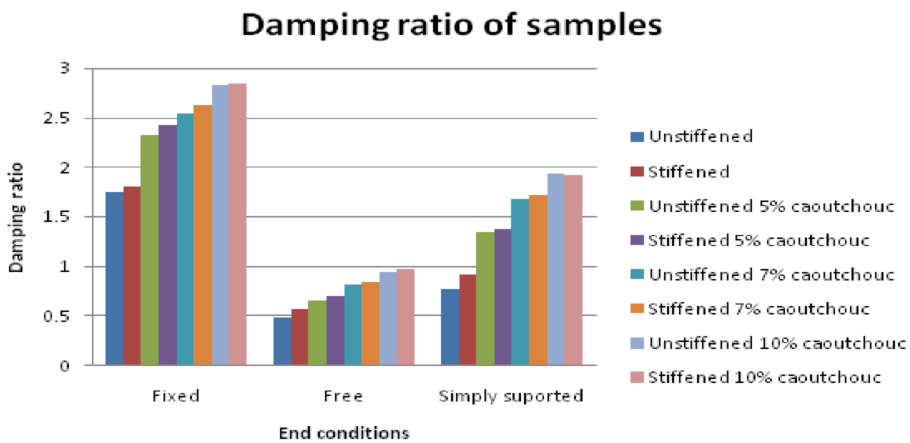


Fig. 18. Comparison of damping ratio (experimental) for various shells with different end conditions.

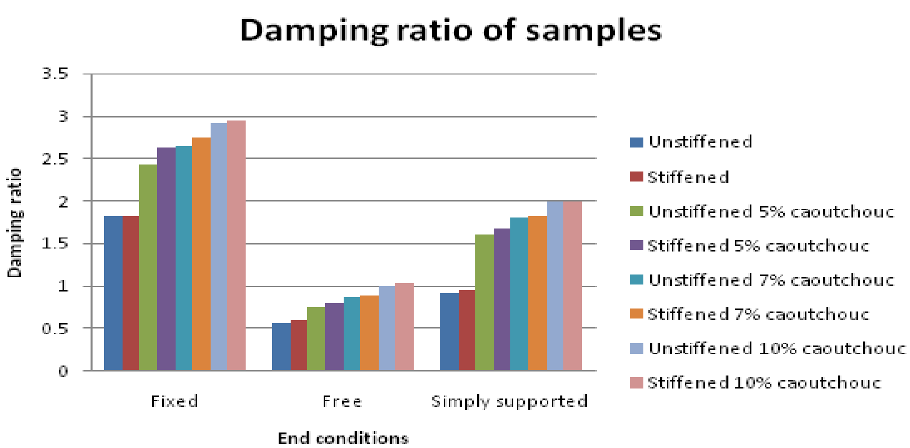


Fig. 19. Comparison of damping ratio (numerical) for various shells with different end conditions.

REFERENCES

[1]. Ferreira, A. J. M., Roque, C. M. C., & Jorge, R. M. N. (2006). Static and free vibration analysis of composite shells by radial basis functions. *Engineering Analysis with Boundary Elements*, *30*(9), 719-733.

[2]. Nanda, N., & Sahu, S. K. (2012). Free vibration analysis of delaminated composite shells using different shell theories. *International Journal of Pressure Vessels and Piping*, *98*, 111-118.

[3]. Lei, X., Rui, W., Shujie, Z., & Yong, L. (2011). Vibration characteristics of glass fabric/epoxy composites with different woven structures. *Journal of Composite Materials*, *45*(10), 1069-1076.

[4]. Maheri, M. R. (2011). The effect of layup and boundary conditions on the modal damping of FRP composite panels. *Journal of Composite Materials*, *45*(13), 1411-1422.

[5]. Butterworth, J., Lee, J. H., & Davidson, B. (2004, August). Experimental determination of modal damping from full scale testing. In *13th world conference on earthquake engineering*, Vol. *310,* pp. 1-15.

[6]. Mevada, H., & Patel, D. (2016). Experimental determination of structural damping of different materials. *Procedia Engineering*, *144*, 110-115.

[7]. Farshidianfar, A., & Oliazadeh, P. (2012). Free vibration analysis of circular cylindrical shells: comparison of different shell theories. *International Journal of Mechanics and Applications*, *2*(5), 74-80.

[8] Tu, T. M., & Loi, N. V. (2016). Vibration analysis of rotating functionally graded cylindrical shells with orthogonal stiffeners. *Latin American Journal of Solids and Structures*, *13*(15), 2952-2969.

[9]. Samanta, A., & Mukhopadhyay, M. (2004). Free vibration analysis of stiffened shells by the finite element technique. *European Journal of Mechanics-A/Solids*, *23*(1), 159-179.

[10]. Bagheri, M., & Jafari, A. A. (2006). Analytical and experimental modal analysis of nonuniformly ring-stiffened cylindrical shells. *Archive of Applied Mechanics*, *75*(2-3), 177-191.

[11]. Edalata, P., Khedmati, M. R., & Soares, C. G. (2013). Free vibration and dynamic response analysis of stiffened parabolic shells using equivalent orthotropic shell parameters. *Latin American Journal of Solids and Structures*, *10*(4), 747-766.

[12]. Obied, H. H., & Shareef, M. M. (2015). Free vibration analysis of stiffened cylinder shell. *International Journal of Energy and Environment*, *6*(3), 273.

[13]. Chen, M., Wei, J., Xie, K., Deng, N., & Hou, G. (2013). Wave based method for free vibration analysis of ring stiffened cylindrical shell with intermediate large frame ribs. *Shock and Vibration*, *20*(3), 459-479.

[14]. Bawa, F. (2014). Classification of vibrational modes of neutral $(MgO)_n$ (n= 3, 4, 6, 8 9 and 12). *International Journal of Theoretical and Applied Sciences, 6*(1), pp 1-8.

[15]. Jain, S., & Bajpai, L. (2014). Analysis of fluid film stiffness and damping coefficient for a circular journal bearing with micropolar fluid. *International Journal on Emerging Technologies*, *5*(1), 206.

[16]. Singh, S., & Anoop. (2015). A study of strength properties of Self Compacting Concrete with the use of Steel Fibers. *International Journal of Emerging Technologies*, *6*(2) pp. 41-52.

[17]. Praveen and Vikram (2017). To Analysis the Structure and properties of burnt clay brick and Fly ash brick. *International Journal of Emerging Technologies*, *8*(1), pp.9-11.

[18]. Hirwani, C. K., Mahapatra, T. R., & Panda, S. K. (2017). Non-Linear frequency response of Laminated carbon -epoxy composite shell Panels. *Defense Science Journals*, pp. 207-211.

[19]. Mat Daud, N. I., & Viswanathan, K. K. (2019). Vibration of symmetrically layered angle-ply cylindrical shells filled with fluid. *PloS one*, *14*(7), e0219089.

How to cite this article: Kumar, Sai Prasanna J.V. (2019). Damping Characteristics of Composite Cylindrical Shells with & without Longitudinal Stiffeners. *International Journal on Emerging Technologies*, **10**(3): 244–252.