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Free Vibration Analysis of Glass/Carbon Hybrid Composite Using Finite Element Method: Effect of Stacking Sequence

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Abstract. Natural frequency is an important property for any structure. In this study, three different polymer based composite (glass fibers, carbon fibers and glass + carbon fibers) considered for numerical free vibration analysis. Composite plates are modeled having eight layer of fibers by varying volume fraction from 0.3-0.6. Aspect ratio kept constant in all the composites. Natural frequencies and mode shapes of all composites are focused. In addition importance is given on the variation across fiber volume fraction. Hybridised composite natural frequencies are compared with the glass and carbon composites.
Keywords: vibration analysis; glass/carbon hybrid composite; finite element method; stacking sequence

INTRODUCTION

As there is increase demand of polymer based composite in aerospace industry because of less weight to strength. Understading of natural frequency is essential to avoid the failure of structure. Numerical analysis is an essential part of design of any new composite. Previously many researchers studied numerical based analysis. A nine-noded isoparametric element used for free vibration by pandit et al. [1]. In their formulation They incorporated shear deformation and mass mass lumping scheme for their analytical study. Numerical approach was adopted to performed various task by considering important paraments; some of them include orientations angles and thickness ratio. Furthermore, aspect ratio was also adopted to get better understanding. Bhar et al. [2] took up work related to shear deformation concepts, there team focused on shear deformation by considering higher order. The area was specific to vibration study with respect to composites. Out of many popular expansions, Taylor series was integrated for stiffner function. With results reported from both HSDT and FSDT, HSDT came up with expectation and led to the accurate results of structural response. Force and free vibration analysis are the important study part in case on cantilevered plates. Pingulkar et al. [3] made study by focusing on free vibration analysis. The area was to focus on cantilevered plates with varying aspect ratio. The ratio was diversified from 0.3 up to 2. Some of the intermediate value of aspect ratio include 0.4, 0.5 and 0.6. One of the key parameters (orientation angle) was having lest influence on the natural frequency of glass fibre. While Sahoo et al. [4] took up experiential approach with respect to free vibration. There team worked with woven glass-based epoxy composite plate. Results was generated from experientially setup and simulation based. Typical parameters considered were geometrical as well as material based. Katariya et al. [5] took up challenge to work with HSDT with skew sandwich composite. The aim was to get results for bending as well as vibration analysis. Next, Mehar et al. [6] worked with free vibration analysis by taking up route of simulations. The composite was made from multi wall carbon nanotube. It was also reinforced polymer. The straight comparison was made between numerical outcomes and experimental data and values where well within acceptable limits. The simulation tool used was ANSYS. Hirwani et al. [7] worked with kinematic models to analyse free vibration. The

shortlisted approach was higher-order shear deformable kinematic models, which was based on the composite. The composite was curved and delaminated. Various popular shape of panels were taken in to account such as cylindrical, elliptical and so on. Sahu et al. [8] studied Glass/Carbon/Kevlar reinforced polymer composite to obtain natural frequency numerically. Also effect of hybridization on natural frequency of composites [9-10].

FINITE ELEMENT ANALYSIS

The 3D model of composite as shown in Figure-1 having dimension of 150 mm × 150 mm × 1.2 mm was constructed in ANSYS environment. For all the composite plates layer thickness were taken as 0.15 mm. Eight noded quadrilateral shell element (SHELL281) were used for composites. The plate were fixed on all edges by assigning all degree of freedom as zero . Modal analysis was conducted to get mode shapes and natural frequencies.

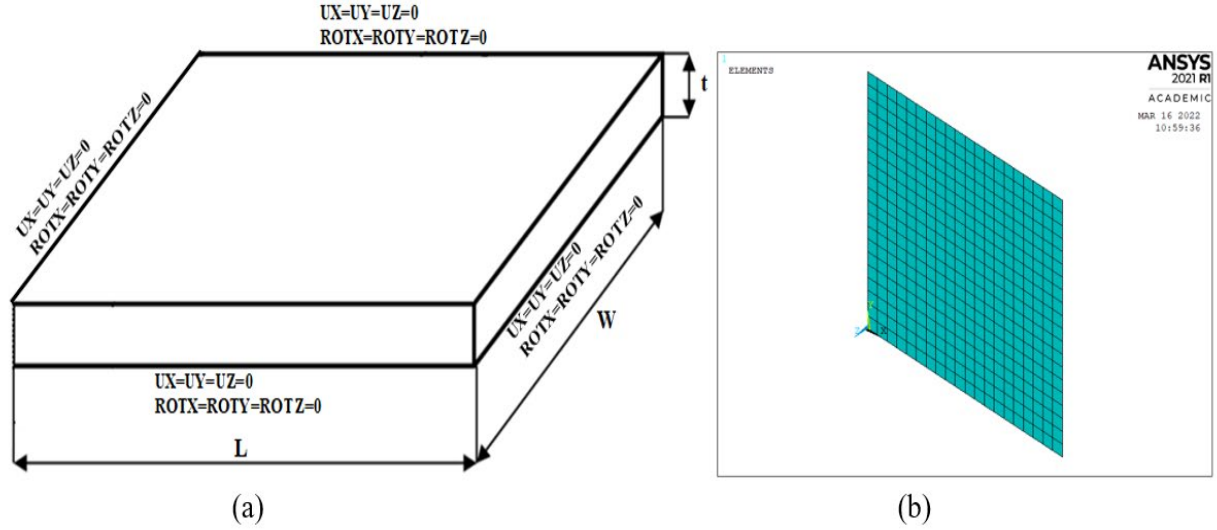

FIGURE 1. (a) Slab with boundary conditions, (b) Overview of mesh showing individual plies

In this simulation glass and carbon fiber reinforced with epoxy was performed by taking symmetric layer pattern of 0°. In addition, right angel was also considered, along with 45° (negative and positive side). Finite Element Analysis conducted for glass fiber, carbon fiber as well as combination of glass and carbon hybrid composite materials. In all the cases fiber directions [0°/45°/-45°/90°]s.

RESULTS AND DISCUSSIONS

Effect of Fiber Volume Fraction in GFRP

Table-1 indicates conisdred two modes along with five modes. Further information about all the natural frequencies of glass fiber composites is also represented in clear way. In case of glass fiber material, an variation of 0.1 was maintained for volume fraction between 0.3 to 0.6. With the help of Figure 2 a better approach can be made between natural frequency with respect to fiber volume fraction. Next, Figure 3 gives the information about considred five modes.

TABLE 1. Data for natural frequencies are indicated from 0.3 to 0.6

Considered Mode	Frequency in Hz			
	0.3	0.4	0.5	0.6
1	305.41	307.812	309.86	311.72
2	542.24	550.3	558.1	566.31
3	659.58	674.58	687.43	699.11
4	844.06	871.05	896.74	923.31

5	873.2	913.7	955.84	984.12

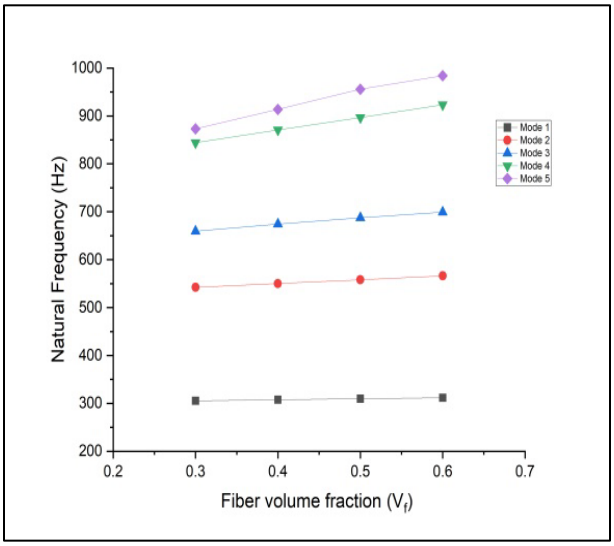

FIGURE 2. Relation between V_f and Natural frequencies

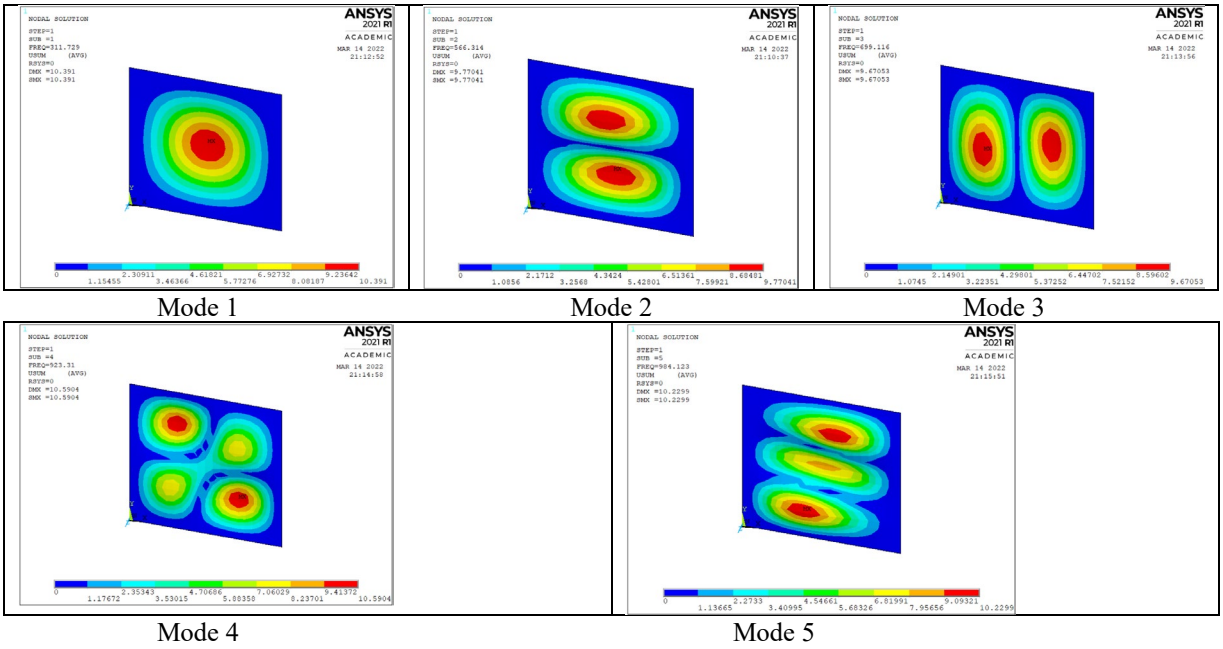

FIGURE 3. ANSYS results for all five modes having aspect ratio = 1

Significance of V_f in CFRP

Table-2 shows the values of natural frequencies of carbon fiber composites for first five modes. Figure-4 shows the plot of natural frequency vs fiber volume fraction of carbon fiber composite.

TABLE 2. Values of natural frequencies from 0.3 to 0.6

Considered Mode	Frequency in Hz			
	0.3	**0.4**	**0.5**	**0.6**
1	496.03	501.46	506.11	510.18
2	1323.54	1339.29	1353.26	1366.04

3	1474.22	1507.83	1536.70	1562
4	2324.91	2377.85	2424.57	2467.09
5	2621.72	2685.88	2743.88	2797.66

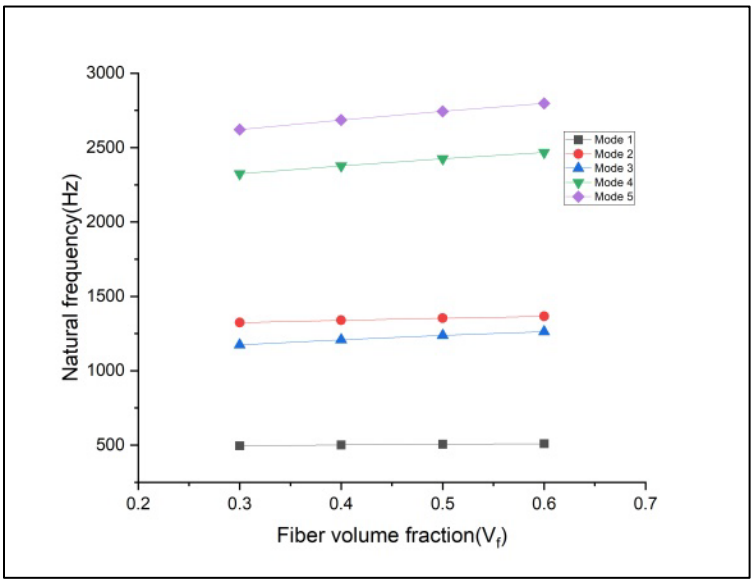

FIGURE 4. Variation of V_f with respect to natural frequencies

Effect of Hybridization

For hybrid composite voulme fraction of 0.6 and layering sequence as [00 glass/450 carbon/-450bglass/900 glass]s considered for analysis and the results are shown in Table-3. Figure-5 shows the relative comparison of all the natural frequencies across considred composites.

TABLE 3. Comparison of natural frequency for 3 mode with hybrid composite (Vf = 0.6)

Considered Mode	Frequency in Hz		
	Glass fiber	Carbon fiber	Glass/carbon fiber hybrid
1	496.03	501.46	506.11
2	1323.54	1339.29	1353.26
3	1474.22	1507.83	1536.70

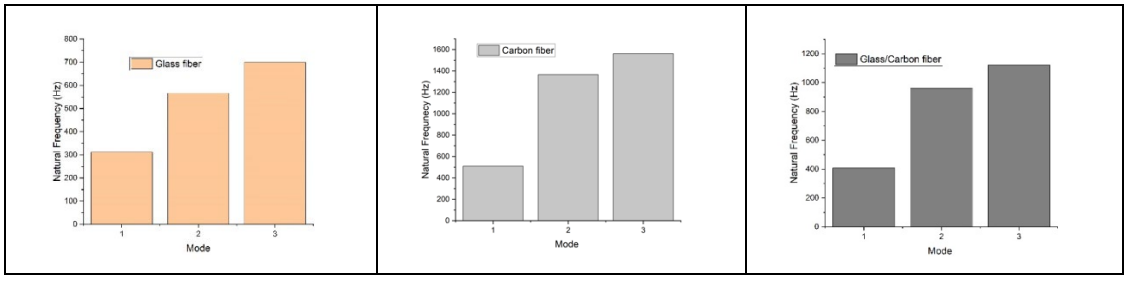

FIGURE 5. Natural frequencies for all the three composites

CONCLUSIONS

Presented work mainly focused to get modal analysis so as to generate nodal frequencies of laminated square composites. Different fiber/matrix combinations investigated by varying the fiber volume. Finally hybridized square plate composites investigated and compared natural frequency with glass fiber and carbon fiber composites. A clear dependent relation was formed between natural frequencies and volume of fiber in composites; both parameters were directly proportional. The natural frequency values are increasing for for higher order modes. Hybrid composite (glass+carbon) natural frequencies values are more than glass fiber composite natural frequencies. On the other hand hybrid composite natural frequencies are lower than carbon fiber composites.

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