Experimental and Numerical Analyse of Laminated Composite Plates

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Abstract— The present research is an experimental and numerical investigation on parametric study of vibration and buckling characteristics of industry driven woven fiber Glail.comss-Carbon/epoxy hybrid composite panels. The effects of lamination sequence on the natural frequencies of vibration and buckling strength of the hybrid panels were studied in this investigation. The panels are cast using hand lay-up technique. The vibration study is carried out using B&K FFT analyzer, accelerometer, and impact hammer excitation. The PULSE Lab software is used to convert the responses from time domain to frequency domain and obtain the Frequency Response Function (FRF). The FRF spectrum and the coherences are studied to obtain a clear understanding of the vibration characteristics of the specimens. Buckling tests are conducted using INSTRON 1195 to obtain the critical buckling load for various lamination sequences. The experimental results are compared with the numerical predictions using the FEM based software package ANSYS 13.0. A very good agreement was observed between the experimental and ANSYS results.

Keywords: Vibration, Buckling, Hybrid Laminates, FFT, FRF Spectrum, FEM

I. INTRODUCTION

Composite materials have extensive applications in various fields including fuselage panels of aero plane, turbine blades, automobile body panels, cryogenic fuel tanks etc. They have various architectural applications such as siding, cladding, roofing, flooring etc. Woven fabric composites are a class of textile composite materials with a fully integrated, continuous spatial fibre network that provide excellent integrity and conformability for advanced structural composite applications. These materials have gained tremendous popularity for possessing excellent durability, corrosion resistance and high strength to weight ratio. Anti-seismic behavior, ease of installation, versatility, excellent fatigue behavior, electromagnetic neutrality, and fire resistance make it a better alternative to steel and other alloys. Thus, the vibration characteristics of the woven fiber laminated composite panels are of tremendous practical importance in prediction of the dynamic behavior of composite panels.

II. ANSYS MODEL

The composite plates were modeled using a commercially available finite element package, ANSYS 13.0 according to ANSYS user's manual [17]. The natural frequencies, mode shapes and buckling loads are obtained by modal analysis. The element type used is SHELL281 which is an 8 noded structural shell, suitable for analyzing thin to moderately thick shell structures. The element was 8 noded with 6 degrees of freedom, three in translations and three in rotation, at each node. The accuracy in modeling the composite shells is governed by the first order shear deformation theory. The whole domain is divided into 8 x 8 meshes for all the cases. Free-free boundary condition was simulated by limiting displacement of the plate in vertical direction along the plane of plate. This closely resembled the experimental set up used in which the plate was hung vertically using strings of negligible stiffness. Similarly, for determination of critical buckling load, C-F-C-F boundary condition was simulated by restricting all degrees of freedom of only two opposite edges.

III. VIBRATION ANALYSIS

The first part of the solution is to obtain the initial stress resultants induced by the moisture and temperature conditions. The element stiffness matrix, the initial stress stiffness matrix due to hydrothermal load, the mass matrix and the load vectors of the element, given by equations (10)-(14), are evaluated by first expressing the integrals in local Natural co-ordinates, ξ and η of the element and then performing numerical integration by using Gaussian quadrature. The initial displacements x, y, z are found the equilibrium condition

IV. COMPUTER PROGRAM

Based on the on top of finite component formulation on thermal analysis with modeling of laminated composite plates, codes square measure developed in MATLAB surroundings to reason the free vibration response of business driven woven fibre Glass/Epoxy composite plates exposed to thermal surroundings. The formulation will handle any pure mathematics, material and general distribution of temperature.

V. EXPERIMENTAL PROGRAMME

The experimental investigation describes in detail of the materials and its fundamental constituents, the fabrication of composite plates, and the test methods according to standards.

A. Fabrication Method

In hand lay-up method, liquid resin was placed along with industry driven woven carbon fiber against finished surface of an open mould. The percentage of fiber and matrix was taken as 50:50 in weight for fabrication of the plates as per ASTM-D5678M-07. Lamination started with the application of a gel coat made up of epoxy resin and 8% hardener (Ciba-Geigy, Araldite HY556 and Hardener HY951) deposited on the mould by brush. Layers of reinforcement consisting of woven roving glass fibers manufactured by Owens Corning, weighing 360 g/m2 and carbon fibers (8H SATIN, T-300) manufactured by TORAY industry, weighing 420 g/m2were placed on the mould at top of the gel coat and gel coat was applied again by brush. Any air which may be entrapped was removed using steel rollers. After completion of all layers, again a plastic sheet was covered the top of last ply by

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applying polyvinyl alcohol inside the sheet as releasing agent. Again one flat ply board and a heavy flat metal rigid platform were kept top of the plate for compressing purpose. The plates were left for a minimum of 48 hours in room temperature before being transported and cut to exact shape for testing. In case of hybrid plates of glass fibre and carbon fibre layers are laid as per the required sequence.

B. Determination of Physical Properties

The physical properties of fabricated composite plates such as density and thickness, represented in Table 1 and 2, were measured up to the required degree of accuracy. The thickness was measured using vernier caliper with a least count of 0.1 mm. The weight of the specimen was measured using digital weighing balance with an accuracy of 0.1 grams.

Sl. No.	No of layers	Length in M	Width in m	Thickness in m	Mass in g	Density in kg/m3
1	4	0.24	0.24	0.0021	174	1438.49
2	8	0.24	0.24	0.0042	345	1426.09
3	12	0.24	0.24	0.0065	519	1386.22
4	8	0.10	0.10	0.0042	60	1428.57

Table 1: Physical properties of the casted carbon fibre specimens

Sl. No.	% of Carbon Fiber	Lamination Sequence	No of layers	Length in m	Width in m	Thickness in m	Density in kg/m3
1	25	[C-G-G-G]s	8	0.20	0.20	0.0033	1608
2	25	[G-C-G-G]s	8	0.20	0.20	0.0031	1596
3	25	[G-G-C-G]s	8	0.20	0.20	0.0034	1621
4	25	[G-G-G-C]s	8	0.20	0.20	0.0033	1685
5	50	[C-C-G-G]s	8	0.20	0.20	0.0036	1549
6	50	[G-G-C-C]s	8	0.20	0.20	0.0035	1536
7	50	[C-G-C-G]s	8	0.20	0.20	0.0036	1549

Table 2: Physical properties of the casted carbon-glass hybrid specimens

C. Tensile Tests of the Specimen

The Young's modulus was obtained experimentally by performing unidirectional tensile tests on specimens cut in longitudinal and transverse directions as described in ASTM-D3039M-08 from the FRP plates fabricated earlier. Strips of specimens having a constant rectangular cross-section, say 250 mm long × 25mm width are prepared from the plates. Three or more sample specimens were prepared from each plate of CFRP in this experiment. The specimen is gradually loaded up to failure, which was abrupt and sudden as the FRP material was brittle in nature. The INSTRON 1195 machine as shown in Figure 5 directly indicated the Young's Modulus, ultimate strength

VI. RESULTS AND DISCUSSIONS

The variation of frequency of vibration of 8 layered carbon/glass hybrid plates with 25 % carbon (C) and 75 % glass (G) reinforcement has been shown in Fig. 2. The sequence of carbon fibre in the composite shown inthe figures below as 1-8, 2-7, 3-6 and 4-5 represent (C-G-G-G)s, (G-C-G-G)s, (G-G-C-G)s, and (G-G-G-C)s respectively. The notations C and G represent the placing of Carbon and Glass fiber in their sequence of stacking. In (C-G-G-G)s the carbon fiber forms the surface layer whereas the inner layers are composed of glass fibre. Similarly, (G-G-G-C)s represents laminate with two layers of carbon core and three layers of glass fiber on the either sides of the core. The natural frequency is lowest for (G-C-G-G)s sequence for all the modes. In case of hybrid composites, the failure was initially observed to be due to delamination between layers of two different fibers. This can be attributed to the weak bonding between the glass and carbon fibers. Since in the case of (C-G-G-G)s carbon fibers form the outermost layer, they provide more strength compared to (G-C-G-G)s and almost equal to (G-G-C-G)s where two glass fibers provide strength equivalent to one layer of carbon fibre. In (G-G-G-C)s, the presence of carbon in the core results in higher strength because of its greater stiffness. The ultimate tensile stresses of the hybrid laminates during the tensile testing showed a similar trend. The experimental and theoretical values obtained by using ANSYS 13.0 are very close to each other.

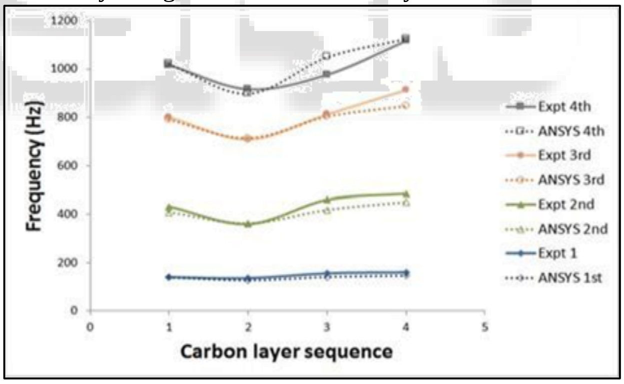

Fig. 1: Variation in natural frequency with the stacking sequence of carbon fibre in carbon/glass hybrid plates with 25 % carbon fibre

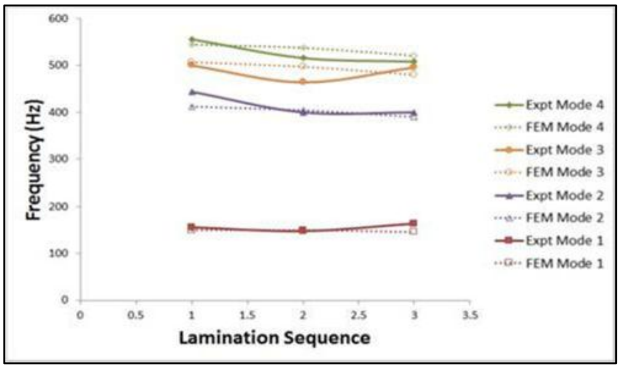

Fig. 2: Variation in natural frequency with the stacking sequence of carbon fibre in carbon/glass hybrid plates with 50 % carbon fiber

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The variation of frequency of vibration of 8 layered carbon/glass hybrid plates with 50% carbon and 50% glass reinforcement for stacking sequence (C-C-G-G)s, (C-G-C-G)2 and (G-G-C-C)s has been shown in Fig. 3 as lamination sequence 1, 2 and 3 respectively. It is observed that the natural frequency for (C-C-G-G)s is highest owing to the greater stiffness of the laminated plates with glass core. The frequency was observed to be the least for plates with alternate layers of carbon/glass fibre stacking. This can be attributed to the lower stiffness due to greater tendency to debond at interface between glass and carbon fibre which is highest in this case.The comparison of natural fundamental frequencies obtained in case of 8 layered carbon fiber plates and the maximum fundamental frequency obtained from various lamination sequence in each case for hybrid plates with 25% and 50% carbon fibers is shown in Fig. 4. It is observed that the highest fundamental frequency is in case of pure carbon plates and thus it has the highest strength. With decreasing carbon content the maximum fundamental frequency decreases. But it doesn’t drastically decrease in hybrids if proper lamination sequence is adapted, as can be seen in the figure the maximum frequencies are not very far apart. The mode shapes for the first four frequencies obtained from ANSYS.

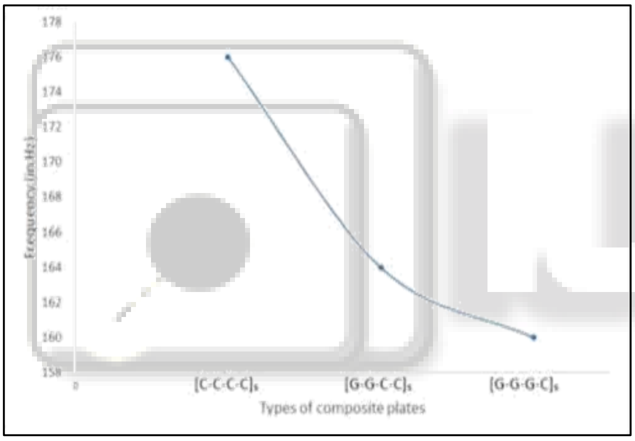
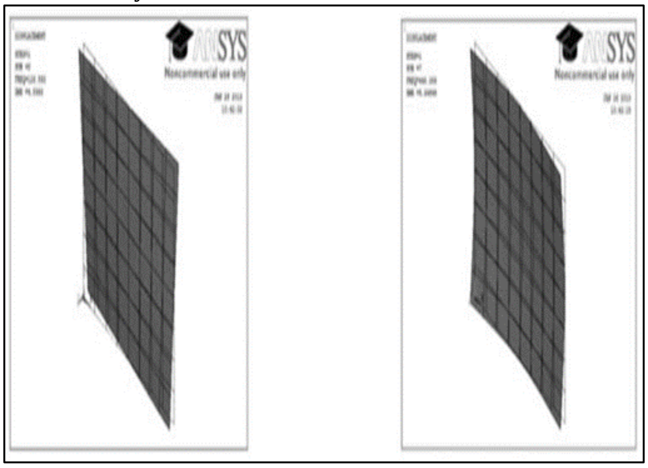


Fig. 3: Comparison of fundamental frequencies obtained for carbon fiber plates with the maximum frequencies obtained for hybrids with 25% and 50% carbon fibers.



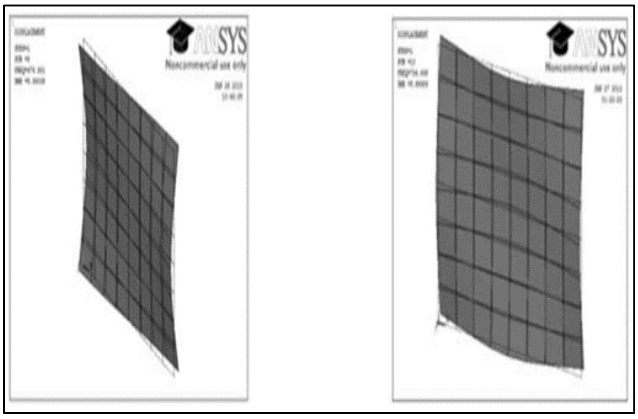


Fig. 5: Mode shapes for first four modes for 8 layered CFRP plate for FFFF boundary condition: (a) 1st lowest frequency, (b) 2nd lowest frequency, (c) 3rd lowest frequency and (d) 4th lowest frequency.

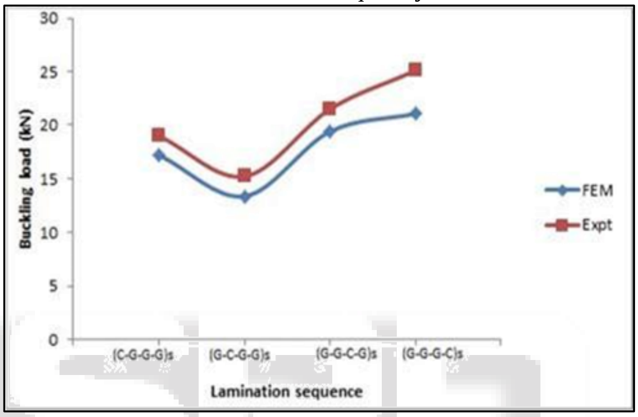


Fig. 6: Variation of buckling load with lamination sequence of CFRP plates in CFCF boundary condition with 25 % carbon fibre.

VII. CONCLUSIONS

The tests for vibration and buckling analysis of glass/carbon epoxy hybrid plates were conducted and the following results were obtained. In case of hybrid plates, the frequencies are observed to change with the stacking sequence. For hybrids with 25% laminate layers of carbon fibre and the rest 75% glass fibre, the minimum frequency is observed in case of (G-C-G-G)s sequence and for hybrids with 50% carbon fibre laminates, the minimum frequency is observed for (C-G-C-G)2 sequence. Plies possessing higher modulus of elasticity when present on the outermost layer, gives maximum buckling load. The effectiveness of hybridization increases if materials with high values of young’s modulus form the outermost layer. The buckling loads of hybrid laminates with same mass and small amount of fibre with high-stiffness are higher than those corresponding to homogeneous laminates. Pure carbon fiber plates possess higher strength in buckling and vibration compared to hybrid plates. In this way, the fabrication of hybrid laminates enables to optimize the structural response to external loads. Thus, composite structures can be designed for optimal structural, technological and economic response for a given geometry and state of stress of structural elements.

References

[1] Bunsell, A.R. and Harris, B., "Hybrid carbon and glass fibre composites," Composites, pp. 157-164, 1974.
[2] Iyengar, N.G.R. and Umaretiya, J.R.,"Transverse vibrations of hybrid laminated plates, Journal of Sound and Vibration," vol. 104(3), pp. 425-435, 1986.
[3] Iyengar, N.G.R. and Umaretiya, J.R., "Deflection Analysis of Hybrid Laminated Composite Plates," Composite Structure, vol. 5, pp. 15-32, 1986.
[4] Barai, A. and Durvasula, S., "Vibration and buckling of hybrid laminated curved panels," Composites, vol. 21, pp. 15-27, 1991.
[5] Badie, M.A., Mahdi, E. and Hamouda, A.M.S, "An investigation into hybrid carbon/glass fiber reinforced epoxy composite automotive drive shaft," Materials and Design, vol. 32, pp. 1485-1500, 2011.
[6] Chen, Chung-Sheng and Fung, Chin-Ping, "Non-linear vibration of initially stressed hybrid composite panels," Journal of Sound and Vibration, vol. 274, pp. 1013-1029, 2004.
[7] Lee, Y.S., and Kim, Y.W., "Analysis of non-linear vibration of hybrid composite plates," Computers and Structures, vol. 61, pp. 573–578, 1996.
[8] Adali S, and Verijenko V.E., "Optimum stacking sequence design of symmetric hybrid laminates undergoing free vibrations," Composite Structures, vol. 54, pp. 131-138, 2001.
[9] Deka, D.J., Sandeep, G. Chakraborty, D. and Dutta, A., "Multiobjective optimization of laminated composites using finite element mthod and genetic algorithm," Journal of Reinforced Plastic and Composites, vol. 24 (3), pp. 273-285, 2005
[10] Chen, Chung-Sheng, "Investigation on the vibration and stability of hybrid composite plates," Journal of Reinforced Plastic and Composites, vol. 24, pp. 1747-1758, 2005.
[11] Benjeddou, A., Deu, J. F. and Letombe, S., "Free Vibrations of Simply-supportedPiezoelectric Adaptive Plates: An Exact Sandwich Formulation," Thin-Walled Structures, vol. 40(7–8), pp. 573–593, 2002.
[12] Harras, B., Benamar, R. and White, R. G., "Experimental and Theoretical Investigation of the Linear and Non-linear Dynamic Behaviour of a Glare 3 Hybrid Composite Panel," Journal of Sound and Vibration, vol. 252(2), pp. 281– 315, 2002.
[13] Shokrieh, M. M. and Najafi, A., "Experimental evaluation of dynamic behavior of metallic plates reinforced by polymer matrix composites," Composite Structures, vol. 75, pp. 472-478, 2005.
[14] ANSYS user's manual, Sawnson Analysis Systems Inc., 2010.
[15] ASTM Standard: D5687/D5687M-07, Standard guide for preparation of flat composite panels with processing guidelines for specimen preparation, 2007.
[16] ASTM Standard: D 3039/D 3039M-08, Standard test method for tensile properties of polymer matrix material.

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