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Parametric Study on Harmonic Behaviour of Sandwich Plates using FEM

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Abstract: Sandwich structures have found numerous applications in making components of aerospace, military, automotive industries etc. Catastrophic vibrations have been occurred when these components subjected to dynamic loads. In this paper, vibration and harmonic behaviours of sandwich plate of two orthotropic composite materials are analyzed using FEM technique. Sandwich plate made of two face sheet and one core sheet in middle has been modelled using an ANSYS APDL FEM tool. Effect of side to depth and aspect ratios are demonstrated on vibration and harmonic response of the plate and the related findings are discussed briefly. The authenticity of the proposed model has been validated by comparing the results with published literature. It can be observed that the results obtained are in good proximity and presently proposed model shows the results with adequate accuracy.

Keywords: Sandwich Plate, Aspect Ratio, Harmonic Behaviour, FEM, ANSYS.

I. INTRODUCTION

Now a days, sandwich plates are increasingly used in weight saving structure in replace of conventional composite materials. Two face sheets of one material are glued above and below on core sheet of different material to manufacture the sandwich plate. Many researchers have paid attention in studying static and vibration characteristics of sandwich structures.

Kulkarni and Kapuria (2008) developed a new improved element to study the vibration behaviour of composite as well as sandwich plates by using third-order zigzag theory.

Icardi and Ferrero (2009) presented impact analysis on sandwich composites using FEM technique based on a refined plate element with strain energy updating process. Xiang Li et al (2011) presented a newly developed optimum design solutions for sandwich structures to satisfy bending as well as torsion requirements using Lagrange multiplier method. Gopichand A. et al. (2012) did static analysis of sandwich panel made of two isotropic materials i.e. stainless steel as face sheet and mild steel as core sheet. compressive strength was compared with experimental value. Arbaoui J. et al. (2014) investigated the effect of intermediate layers and thickness of core on the mechanical properties of sandwich structure made of a honeycomb core three points bending and also developed a theoretical model to calculate the shear properties in multi-cores.

Lashin and Okasha El-Nady (2015) studied the vibrational characteristics of sandwich beam structure at different loading conditions. Bavane et al. (2016) obtained the results for dynamic response for spherical as well as cylindrical shells and plates employing HSDT technique and ABAQUS software. Krzyhak A. et al. (2016) compared the effect of manufacturing method of sandwich structure on mechanical properties such as compressive strength, impact strength and flexural strength. Ijaz H. et al. (2017) presented a simplified methodology for analysis of sandwich structures using the homogenization method based upon the strain energy criterion by the hexagonal core with a simple equivalent volume for FE analysis. Vishnuchaitanya et al. (2017) studied the dynamic behaviour for various laminates with different holes. Narwariya M. et al. (2018) studied the harmonic behaviour of orthotropic plate and examined the effect of number of layers, boundary conditions and thickness to width ratio on natural frequency and resonance amplitude.

Chavan and Kolhe (2018) obtained dynamic characteristics of delaminated Composite Plate using FEM technique. Pagani A. (2018) discussed classical and different finite elements for the analysis of sandwich as well as laminates. Narwariya M. et al. (2019) analyzed the harmonic characteristics of laminated composite skew plates with cut-outs using FEM technique and investigated the effect of different geometries of the cut-out on the resonance point.

Al-Fasih et al. (2020) investigated the fracture behavior of sandwich honeycomb composite beams containing crack at the skin experimentally and numerically under four-point loading.

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II. MODELLING

A. Geometric Modelling

Author Five-layered (0◦/90◦/Core/90◦/0◦) sandwich plate with each ply in the face sheets being of material 1 and core of material 2 are considered to analyze the results with following dimensions:
Ratio of face sheet thickness to depth (Tf/h) is taken as "0.18",
Ratio of length to width (b/a) is varied from "1" to "2.5", Ratio of width to depth (a/h) is varied from "5" to "20",
Geometry of sandwich plate is shown in Fig. 1

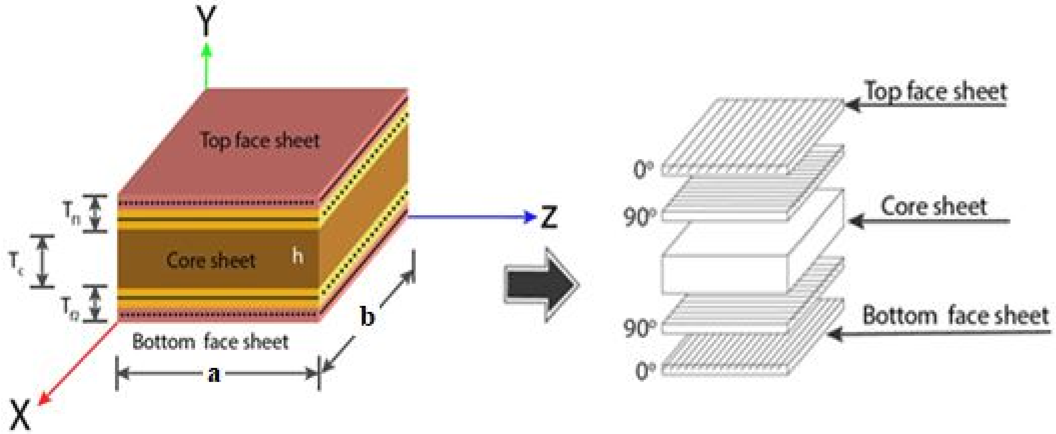


Fig. 1 Geometry of sandwich plate

B. Finite Element Modelling

An 8-node solid 185 and solid-shell 190 elements are taken for core and face materials respectively. SOLID185 Structural Solid as shown in fig. 2, is suitable for modeling general 3-D solid structures. It allows for prism, tetrahedral, and pyramid degenerations when used in irregular regions.

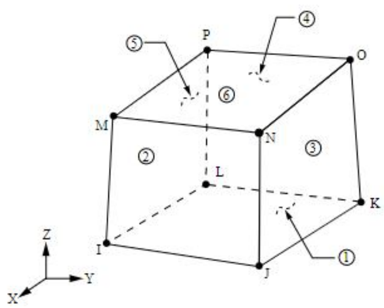
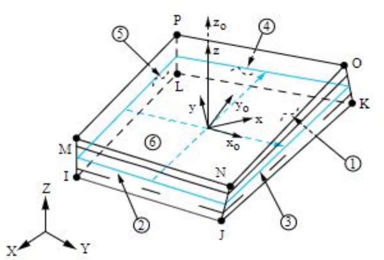


Fig. 2 8-node solid 185

SOLSH190 as shown in fig.3, is used for simulating shell structures with a wide range of thickness (from thin to moderately thick).



x_o = Element x-axis if ESYS is not supplied.

x = Element x-axis if ESYS is supplied.

Fig. 3 SOLSH190

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C. Loading Condition

For vibration analysis, clamped boundary condition (i.e. all the edges of plate are constrained to all the six degrees of freedom) is applied to demonstrate the behaviour of plate. For harmonic analysis, same plate is subjected to a force of 1000 N on every node present on top face sheet as presented in fig. 4.

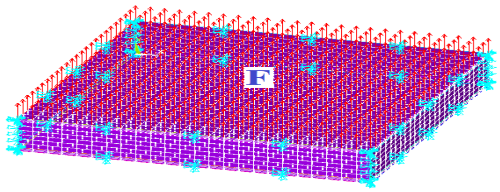

Fig. 4 Sandwich plate with force of 1000 N on every node on top surface under clamped boundary condition

D. Material property

Material property has been taken from published literature of Kulkari et al. (2008) for two sheets of sandwich plate i.e. face sheet and core sheet as listed in Table 1.

Table I. Material property

Property	Face sheet Material (1)	Core sheet Material (2)	Reference
Young's Modulus	Y_{f1} = 276000 MPa Y_{f2} = 6900 MPa Y_{f3} = 6900 MPa	Y_{c1} = 577.6 MPa Y_{c2} = 577.6 MPa Y_{c3} = 577.6 MPa	Kulkarni et al. (2008)
Shear Modulus	G_{f12} = 6900 MPa G_{f23} = 6900 MPa G_{f31} = 6900 MPa	G_{c12} = 107.9 MPa G_{c23} = 222.15 MPa G_{c31} = 107.9 MPa	
Poisson's Ratio	ν_{f12} = 0.25 ν_{f13} = 0.25 ν_{f23} = 0.3	ν_{c12} = 0.0025 ν_{c13} = 0.0025 ν_{c23} = 0.0025	
Density	ρ_f = 681.8 kg/m^3	ρ_c = 1000 kg/m^3	

III. RESULT AND DISCUSSION

In this paper, the effects of width to depth ratio and aspect ratio of the sandwich plate has been demonstrated on vibration and harmonic characteristics. The non-dimensionalized frequency for sandwich plate is taken as [ϖ=100ω_n a√(((ρ_c)/Y_f1))] from published result of Kulkarni et al. (2008).

A. Convergence study

To find the proper mesh size, frequency parameters has been obtained up to six mode with reference to different mesh sizes for five layered (0◦/90◦/Core/90◦/0◦) sandwich plate with clamped boundary condition taking width to depth ratio (a/h) as 10 as shown in fig. 5. It can be clearly observed from the fig. 5 that convergence is achieved at 24 × 24 mesh size.

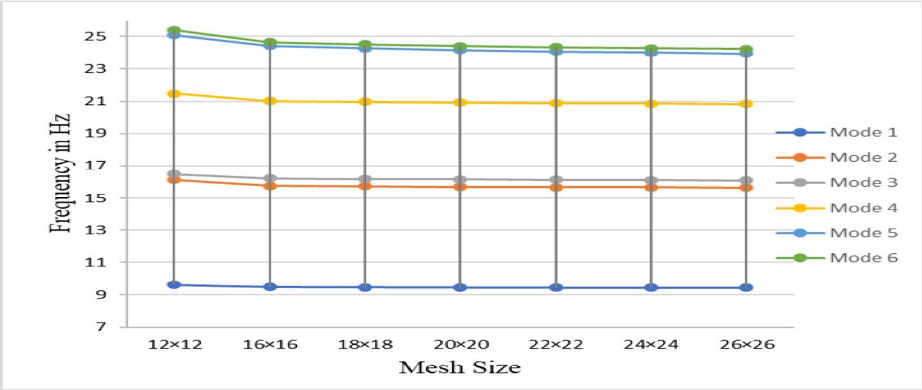

Fig. 5 Non-dimensionalized fundamental frequency for different mesh size

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B. Comparison study

In order to accuracy the present analysis, a comparison study has been done with published result of Kulkarni et al. (2008). Frequency parameters have been obtained for clamped (0◦/90◦/Core/90◦/0◦) sandwich plate for different mesh size taking (a/h) as 10 as presented in fig. 6(a-d). Results observed in good accordance.

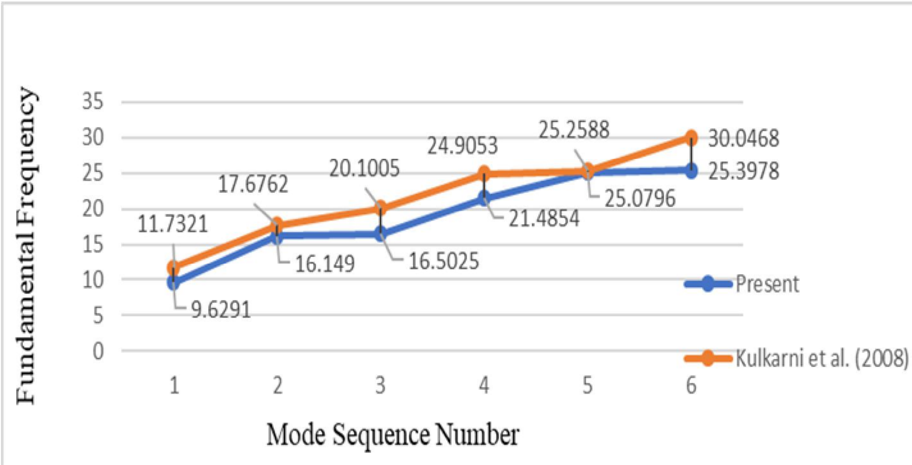

Fig. 6(a) Comparison of non-dimensionalized fundamental frequency at mesh size of 12×12.

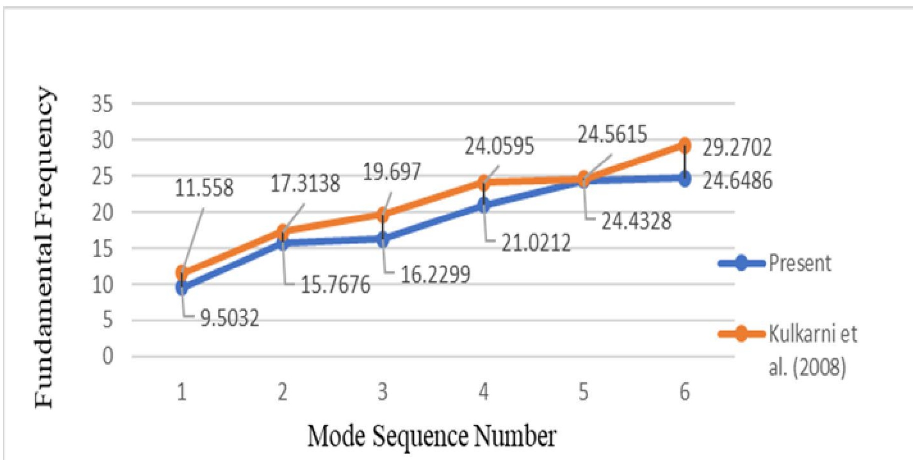

Fig. 6(b) Comparison of non-dimensionalized fundamental frequency at mesh size of 16×16.

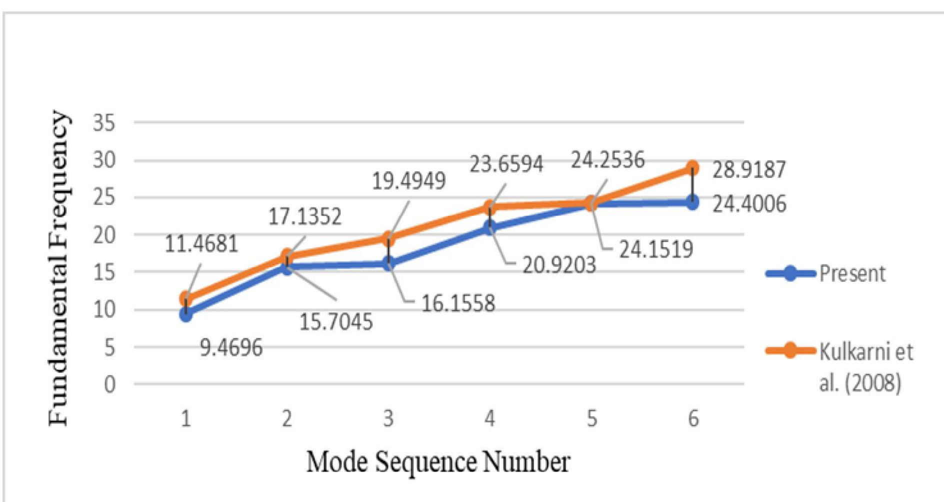

Fig. 6(c) Comparison of non-dimensionalized fundamental frequency at mesh size of 20×20.

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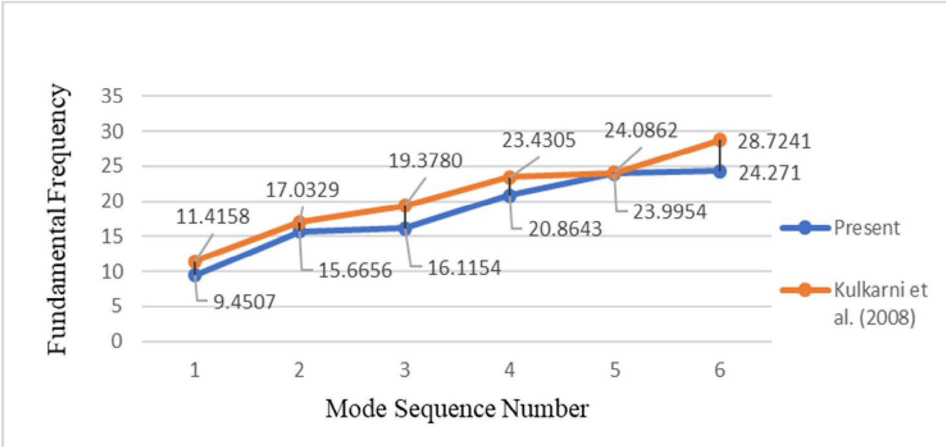

Fig. 6(d) Comparison of non-dimensionalized fundamental frequency at mesh size of 24×24.

C. Vibration Analysis

In this paper, the six modes of frequencies have been studied for sandwich plate to observe the effects of aspect (b/a) ratio and width to depth (a/h) ratio on frequency parameters. The 24 × 24 mesh size and clamped boundary conditions of all edges of the plate has been employed.

1) *Effect of width to depth ratio (a/h):* The non-dimensionalised fundamental frequencies for different a/h ratio are listed in table 2. It has been clear seen from the table that frequency parameters decrease with increasing a/h ratio.

TABLE III

Non-dimensionalised fundamental frequency for different a/h ratio

b/a	a/h	Non-dimensionalised fundamental frequency (ϖ)					
		MSN					
		1	*2*	*3*	*4*	*5*	*6*
1	5	15.350	23.296	30.543	33.987	35.837	41.312
	10	11.517	18.464	21.530	26.506	27.913	34.169
	15	9.800	15.697	18.220	22.550	24.258	29.165
	20	8.751	13.690	16.474	20.138	21.408	26.059

2) *Effect of Aspect Ratio (b/a)*: The non-dimensionalised fundamental frequencies for different aspect ratio are listed in table 3. It has been found from the table that frequency parameters decrease with increasing aspect ratio.

TABLE III

Non-dimensionalised fundamental frequency for different aspect ratio

a/h	b/a	Non-dimensionalised fundamental frequency (ϖ)					
		MSN					
		1	2	3	4	5	6
5	1	15.350	23.296	30.543	33.987	35.837	41.312
	1.5	13.370	17.207	22.951	29.477	29.921	31.804
	2.0	12.710	14.853	18.345	22.845	28.103	29.125
	2.5	12.428	13.750	16.026	19.121	22.873	27.146

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D. Harmonic Analysis

Harmonic analysis is done to compute resonant amplitude at its natural frequency and its responses are drawn on function response function (FRF) graph. In this paper, sandwich plate has been analyzed to examine the response of varying of two ratios i.e. aspect (b/a) ratio and width to depth (a/h) ratio on natural frequency and resonance amplitude under damping ratio as 0.01

1) *Effect of Side to depth (a/h) ratio:* The results are listed in Table 6 for different a/h ratios. It has been found that the natural frequency (NF) decreases with increase in a/h ratio and the resonance amplitude (RA) increases for same case. The percentage reduction in resonance amplitude is increased by 44% when a/h ratio increases from 5 to 10. Further reduction in resonance i.e 59.48% and 67.70% have been occurred with increment of a/h ratio upto 15 and 20 respectively.

TABLE IV

Effect of varying a/h ratio of sandwich plate on the natural frequency and resonance amplitude under damping factor as 0.01.

b/a	a/h	NF *(Hz)*	RA *(m)*	% reduction in RA
1	5	81.219	0.0168606	0.00
	10	30.469	0.0301088	44.00
	15	17.284	0.0416111	59.48
	20	11.575	0.0521942	67.70

Harmonic response for the same plates has been plotted on FRF graph as shown in Figures 7(a-d). These FRF show the graph between frequencies versus amplitude. Peak value represents the resonant amplitude.

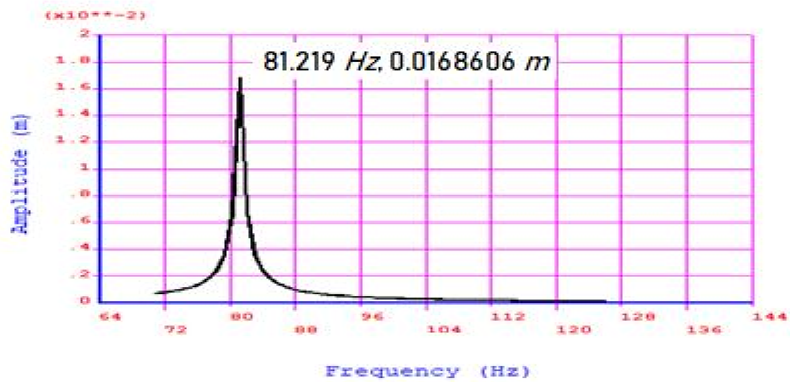

Fig. 7(a) FRF for sandwich plate for a/h ratio as 5.

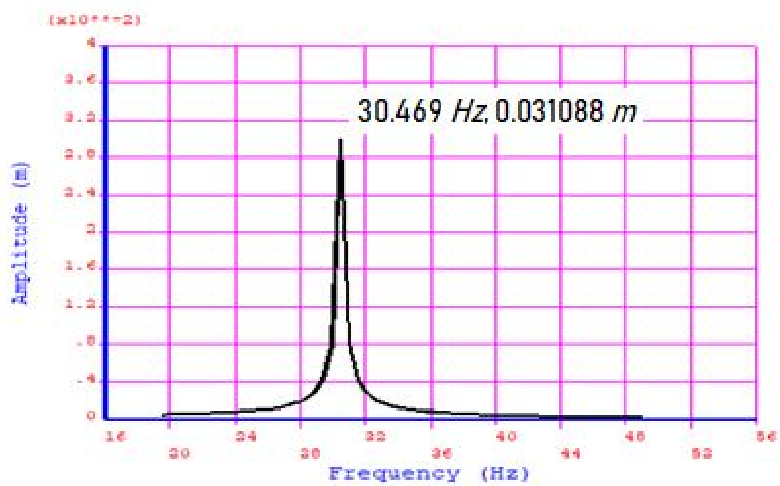

Fig. 7 (b) FRF for sandwich plate for a/h ratio as 10.

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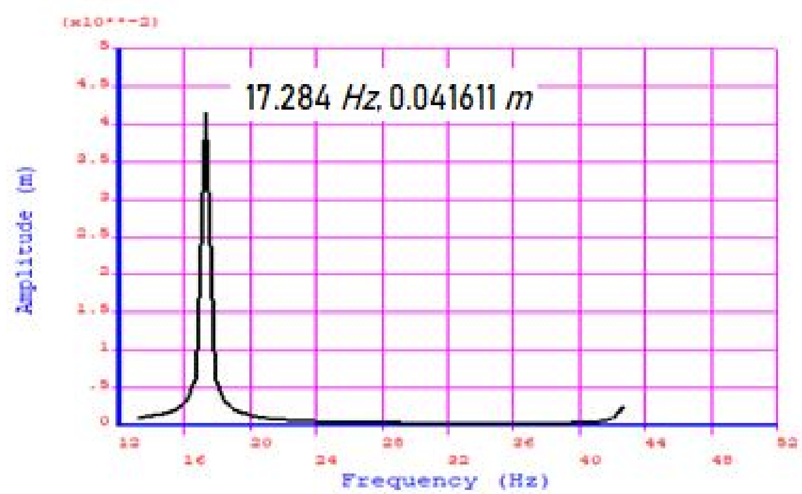

Fig. 7 (c) FRF for sandwich plate for a/h ratio as 15.

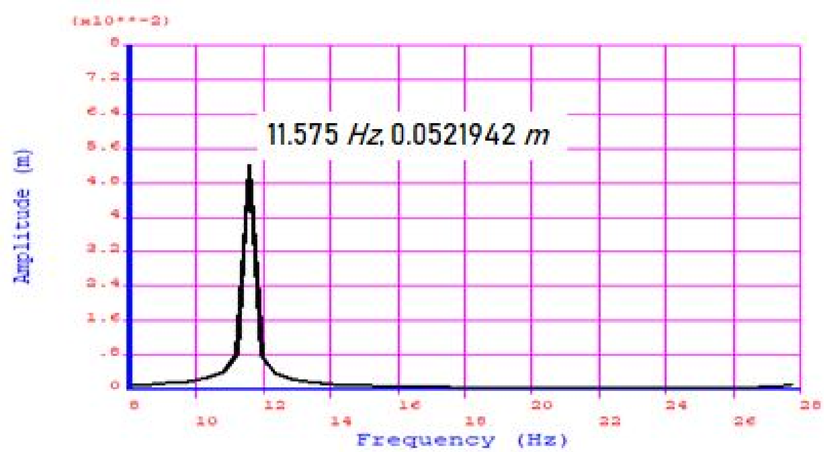

Fig. 7 (d) FRF for sandwich plate for a/h ratio as 20.

2) *Effect of Aspect Ratio (b/a):* Table 5 shows the effect of varying aspect ratio of sandwich plate on the natural frequency and resonance amplitude under damping factor as 0.01. It has been found that the natural frequency (NF) and the resonance amplitude (RA) both decrease with increase in aspect ratio. Resonance amplitude is reduced by 11.81%, 26.69% and 38.65% when aspect ratio increases from 1 to 1.5, 2.0 and 2.5 respectively.

TABLE V

Effect of varying aspect ratio of sandwich plate on the natural frequency and resonance amplitude under damping factor as 0.01.

a/h	b/a	NF *(Hz)*	RA *(m)*	% reduction in RA
5	1	81.219	0.0168606	0.00
	1.5	70.739	0.0148694	11.81
	2.0	67.25	0.0123601	26.69
	2.5	65.759	0.0103440	38.65

Figures 8(a-d) present the FRF for harmonic responses for the same plates.

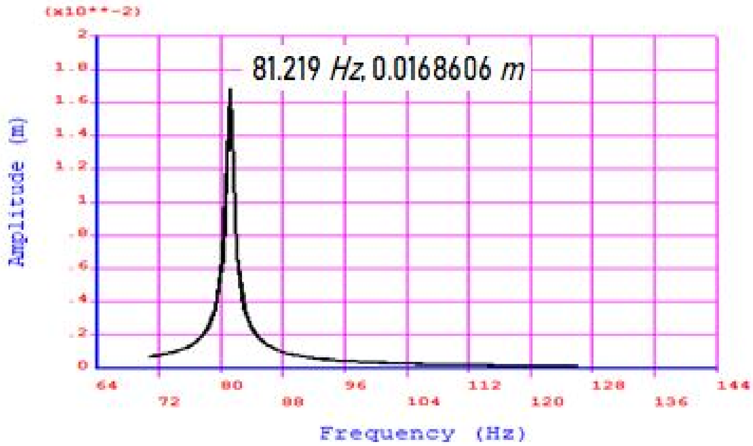

Fig. 8 (a) FRF for sandwich plate for a/h ratio as 20.

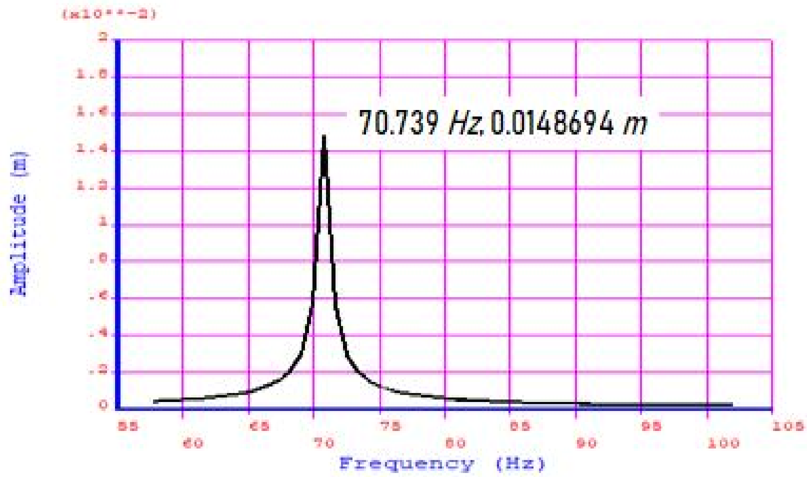

Fig. 8 (b) FRF for sandwich plate for a/h ratio as 20.

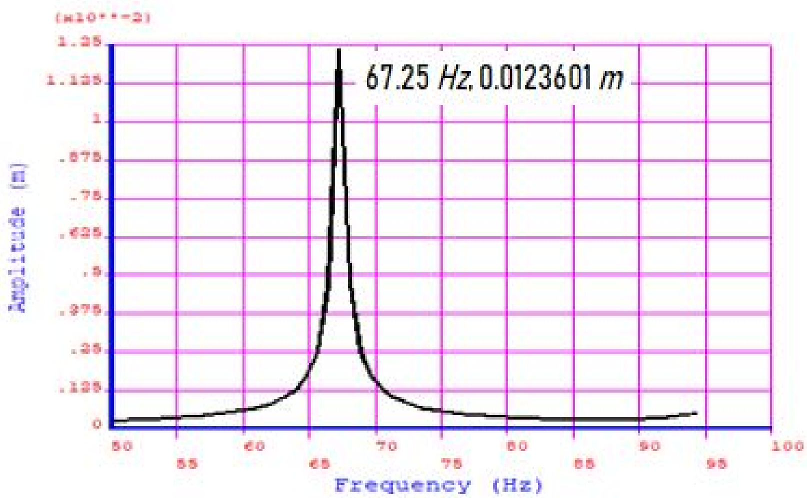

Fig. 8 (c) FRF for sandwich plate for a/h ratio as 20.

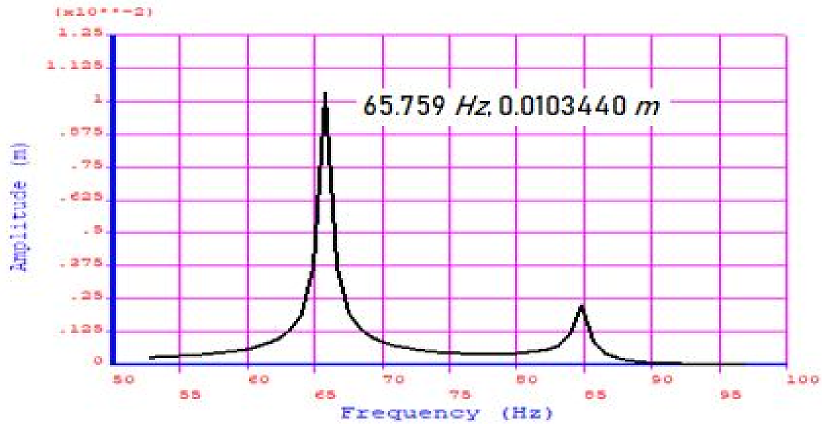

Fig. 8 (d) FRF for sandwich plate for a/h ratio as 20.

IV. CONCLUSIONS

This paper deals with the static, vibration and harmonic response of sandwich plate. The analyses are conducted for various geometries of plate to examine the effect of varying aspect ratio and width to depth ratio on the frequency parameter and resonance amplitude. From the study, following conclusion has been made:

A. The convergence is achieved at a mesh size of (24×24)
B. Results obtained are found in close proximity.
C. Frequency parameters decrease with increasing a/h ratio and aspect ratio
D. The natural frequency decreases with increase in a/h ratio and the resonance amplitude increases for same case.
E. The natural frequency and the resonance amplitude (RA) both decrease with increase in aspect

REFERENCES

[1] S. D. Kulkarni and S. Kapuria, “Free vibration analysis of composite and sandwich plates using an improved discrete Kirchhoff quadrilateral element based on third-order zigzag theory”, Comput Mech, vol.42, pp. 803–824, April 2008
[2] U. Icardi and L. Ferrero, “Impact analysis of sandwich composites based on a refined plate element with strain energy updating”, Composite Structures, vol. 89, issue 1, pp. 35-51, June 2009.
[3] X. Li, G. Li and C. H. Wang, “Optimisation of composite sandwich structures subjected to combined torsion and bending stiffness requirements”, Applied Composite Materials, vol. 19, pp. 689–704, June 2011.
[4] A. Gopichand, G. Krishnaiah, M. Krishna, V. D. Reddy and A.V.N.L. Sharma, “Design and analysis of corrugated steel sandwich structures using ansys workbench”, International Journal of Engineering Research & Technology, vol. 1, issue 8, pp. 1-8, October 2012.
[5] J. Arbaoui, Y. Schmitt, J. L. Pierrot and F. X. Royer, “Effect of core thickness and intermediate layers on mechanical properties of polypropylene honeycomb multi-layer sandwich structures”, Archives of Metallurgy and Materials, vol 59, issue 1, pp. 11-16, 2014.
[6] M. M. A. Lashin and A. El-Nady, “Free vibration analysis of sandwich beam structure using finite element approach”, IOSR Journal of Mechanical and Civil Engineering, vol 12, issue 6, pp. 34-42, Dec 2015.
[7] N. U. Bavane, S. B. Patil, S. S. Shinde, S. B. Kore and R. P. Kamble, “Dynamic analysis of laminated composite plates and shells by using a new higher-order shear deformation theory and ABAQUS software”, IJRASET, vol 4, issue 12, pp. 182-190, 2016.
[8] A. Krzyhak, M. Mazur, M. Gajewski, K. Drozd, A. Komorek and P. Przybylek (2016), “Sandwich Structured Composites for Aeronautics: Methods of Manufacturing Affecting Some Mechanical Properties”, International Journal of Aerospace Engineering, vol 4, pp. 1-10, June 2016.
[9] H. Ijaz, W. Saleem, M. Zain-ul-Abdein, T. Mabrouki, S. Rubaiee and A. S. B. Mahfouz, “Finite element analysis of bend test of sandwich structures using strain energy based homogenization method”, Advances in Materials Science and Engineering, vol 2, pp. 1-10, June 2017.
[10] B. Vishnuchaitanya1, K. V. N. Rao. and P. S. Pradeep, “Dynamic Analysis of Laminated Composite Plates with Holes”. International Journal of Innovative Technology, vol 5, issue 4, pp. 618-625, 2017.
[11] M. Narwariya, A.Choudhury and A. K. Sharma, “Harmonic analysis of moderately thick symmetric cross-ply laminated composite plate using FEM”, Advances in Computational Design, Vol. 3, issue 2, pp. 113-132, April 2018.
[12] D. H. Chavan and S. I. kolhe, Static and Dynamic Analysis of Delaminated Composite Plates. IRJET.vol 5, issue 5, pp. 3490-3496, May 2018..
[13] A. Pagani, S. Valvano and E. Carrera, “Analysis of laminated composites and sandwich structures by variable-kinematic MITC9 plate elements”, Journal of Sandwich Structures and Materials, vol 20, issue 1, pp. 4–41, May 2018.
[14] M. Narwariya, V. Patidar and A. K. Sharma, “Harmonic analysis of laminated skew plate with different geometrical cut-outs”, International Journal of Innovative Technology and Exploring Engineering, Vol. 8 Issue 5, pp. 113-132, March, 2019.
[15] M. Y. Al-Fasih, A. B. H. Kueh and M. H. W. Ibrahim, “Failure behavior of sandwich honeycomb composite beam containing crack at the skin”, PLOS ONE, vol 15, issue 2, pp. 1-19, February2020.