



FREE VIBRATION ANALYSIS OF SANDWICH PLATES WITH CUTOUT

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Abstract. This paper presents the free vibration analysis of sandwich plates with cutouts. Cutouts are inevitable in structural applications and the presence of these cutouts in the structures greatly influences their dynamic characteristics. A finite element model has been developed here using the ANSYS 15.0 software to study the free vibration characteristics of sandwich plates in the presence of cutouts. Shell 281 element, an 8-noded element with six degrees of freedom suited for analyzing thin to moderately thick structures is considered in the development of the model. Block Lanczose method is adopted to extract the mode shapes to obtain the natural frequency corresponding to free vibration of the plate. The effects of parametric variation on the natural frequency of the sandwich plates with cutout are studied and results are presented.

I. INTRODUCTION

These days, sandwich structures are highly acclaimed constructional elements in different fields of engineering application. A Sandwich structure is a special type of laminated structure composed of two thin face sheets along with a thick flexible core. The face sheets are generally unidirectional laminated fiber reinforced composites and the core is a thick layer of low density material [1, 2]. The moment of inertia of the structure considerably increases due to the separation of the face sheets, while the thick layer of low density core makes the structure light [3]. Many often, cutouts are inevitable in the structural applications; For example, for the purpose of facilitating utility services like fuel, hydraulic or electrical lines, for providing accessibility to other parts of the structure, for obtaining reduced weight of the overall structure and the like. The dynamic characteristics of structures in the presence of cutout are influenced greatly and this has attracted researchers for detail analysis of the same. Ju et al. [4] carried out free vibration analysis of square and circular composite plates with delaminations around the cutout and discussed the effects of cutout on the natural frequencies and mode shapes. Boay [5] studied the free vibration of symmetric laminated composite plates containing a circular hole both by finite element investigation and experimental data. Sivakumar et al. [6] presented a finite element analysis to investigate the vibration characteristics of composite plates with cutouts undergoing large amplitude vibrations. The model is based on Ritz finite element method with 9 noded⁰ continuous quadrilateral elements employing a higher order displacement field. The theory accounts for a parabolic variation of transverse shear stress. Results are presented for the dynamic behavior of the plate corresponding to various parameter variations. Nanda and Bandyopadhyay [7] studied the nonlinear free vibration response of a laminated composite cylindrical shell panels with cutout using a finite element method. Liew et al [8] presented a numerical investigation of the free vibration of plates with internal discontinuities due to central cut-outs. The formulation ensures continuity of displacement, slope, moment, and higher derivatives between the adjacent sub-domains. The ridge procedure is adopted to extract the vibration frequency. Breethe [9] studied the natural frequency of laminated composite plate with cutout and the effects of number of layers, angle of fiber orientation, boundary conditions, width to thickness ratio and laminate arrangement with the natural frequencies of plate having cutout at the center are studied. To study the static behavior of a composite plate with central elliptical cutout, Niranjana Kumar et al. [10] presented a finite element model based on three-dimensional elasticity. The transverse deflections, in plane stress and interlaminar stresses are derived corresponding to different parametric

variation. Riyah et al. [11] presented an experimental investigation to study the static behaviour of a laminate plate with cutout. Barut et al [12] presented a semi analytical method for stress and buckling analysis of laminated plates with cutout using a simplified 3-0 plate theory. The theory ensures zero transverse shear stresses at the laminate faces. The formulation is based on cubical variation of the displacement fields. Bhatt et al. [13] carried out an analytical investigation using finite element method for the modal analysis of a laminated composite plate with circular cutout. The finite element analysis was carried out using the commercially available ANSYS software. Bharadwaj et al.[14] predicted the vibration responses of laminated composite plates with cutout. The finite element investigation is carried out using ANSYS parametric design language (APDL) code. Effects of different geometric parameters (aspect ratio, thickness ratio, boundary conditions, number of layers, angle of lamina geometry of cutout, cutout side to plate side ratio and distance between cutouts) and material properties on the free vibration responses are discussed in detail. From the literature review it is found that research has been carried out to study the behaviour of laminated composite plates in presence of cutout are available, but the investigations with respect to the analysis of a sandwich plates in the presence of cutout are limited. Therefore, the analysis of a sandwich plate in the presence of cutout has been intended to be carried out, hence the objective of the present paper. The analysis is aimed to be carried out using the finite element software ANSYS 15.0 and ANSYS parametric design language (APDL) codes have been used to study the behaviour of sandwich plates in the presence of cutouts. The effects of various parameters influencing the free vibration characteristics of the sandwich plates with cutout are studied and numerical results are presented.

II. DEVELOPMENT OF MODEL

Figure 1 illustrates a laminated composite sandwich plate with a central cutout. The top and the bottom faces of the substrate sandwich plate are assumed to be composed of number of unidirectional fiber-reinforced orthotropic layers while the core is of a honeycomb structure. The length, the width and the thickness of the sandwich plate are denoted by a , b and H respectively while the length and width of the cutout are taken to be ca and cb respectively, c being the cutout ratio.

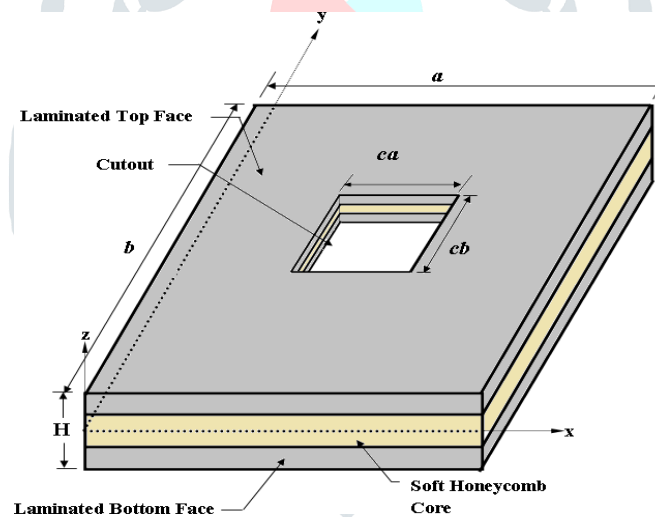
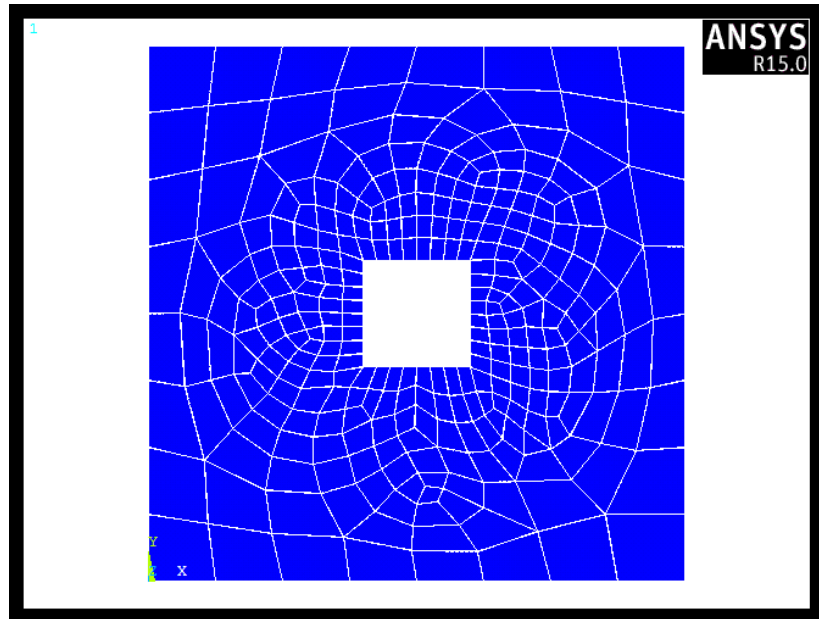


Fig.1 Representation of the Sandwich plate with a cutout

To carry out the dynamic analysis of the sandwich plate with cutout, the plate with cutout is modeled using ANSYS 15.0 software. Shell 281 element is considered to model the structure which is a 8- noded element with six degrees of freedom at each node and is ideally suited for analyzing thin to moderately thick structures and possesses the ability for modeling composite and sandwich structures with layered applications. Block Lanczose method is adopted to extract the mode shapes to obtain the natural frequency corresponding to free vibration of the plate. A typical model of a sandwich plate with a central rectangular cutout is presented in Fig 2.

Fig.2 FE model of the sandwich plate with cutout using ANSYS software



III. RESULTS AND DISCUSSION

To verify the accuracy of the ANSYS model developed here, first, it is validated comparing the results with those available in literature for a similar laminated composite plate with a central circular hole [13] and the results are presented in table 1. The material properties and geometry of the problem considered here are according to those considered by earlier researchers [13].

Table 1. Comparison of results obtained by present model with those of similar model for a laminated plate with cutout [13].

c	Boundary Condition	Natural Frequency	
		Present model	Ref [13]
0	CFFF	14.619	14.631
0.2	CFFF	9.4194	9.5133
0.2	CCCC	111.2	111.87

c =cutout ratio, C – clamped, F - free

The results presented in Table 1 indicates the validation of the present model developed in ANSYS software. Now, for the free vibration analysis of the sandwich plates with cutout, results are obtained and presented. The material properties of the sandwich plate considered here for the analysis are explained in Table 2. The thickness of the sandwich plate is taken as 3 mm and the aspect ratio is considered as 200. The sandwich plate considered

here is square with $a=b$ and the natural frequency for the sandwich plate are expressed in non-dimensional form using the relation.

Table 2. Material properties for the core and the orthotropic faces of the sandwich plate [15].

Facings	$E_1 = 172.5 \text{ GPa}, E_1/E_2 = 25, G_{12} = G_{13} = 0.5 E_2, G_{23} = 0.2 E_2,$ $\nu_{12} = \nu_{13} = \nu_{23} = 0.25, \rho = 1600 \text{ kg/m}^3$
HEREX Core(C70.130)	$E_1 = E_2 = E_3 = 0.10363 \text{ GPa}, G_{12} = G_{13} = G_{23} = 0.05 \text{ GPa},$ $u_{12} = u_{13} = u_{23} = 0.33, \rho = 130 \text{ Kg/m}^3$

First, the results corresponding to the free vibration of the sandwich plate with a central rectangular cutout are obtained for varying sizes of cutout, using the developed ANSYS model for a symmetric sandwich plate (0/Core/0) for simply supported and clamped boundary conditions and are presented in Table 3. The results illustrate that the fundamental frequency of the sandwich plate decreases with small to medium size cutout. However, with the increase in the size of the cutout, the fundamental frequency again goes on increasing. The fundamental frequencies for a sandwich plate with cutout increases with increase in the degree of constraint and are found to be higher for clamped edges as compared to a plate with simply supported edges.

Next, the free vibration response of a clamped sandwich plate with symmetric cross-ply laminated face sheets ($0^0/90^0/0^0/\text{Core}/0^0/90^0/0^0$) is studied for different sizes of cutout and the results are presented in Table 4. It can be observed from Table 4 that the natural frequency follows the same trend as in the case of a ($0^0/\text{Core}/0^0$) plate with the increase in the size of the cutout.

Table 3. Free vibration of sandwich plate ($0^0/\text{Core}/0^0$) with rectangular cutout for clamped and simply supported boundary conditions.

Boundary Condition	c (%)						
	0	10	20	30	40	50	60
Simply supported	17.56	12.07	11.34	10.21	11.32	11.2587	13.70
Clamped	35.772	23.686	23.018	27.80	37.12	50.79	63.54

Table 4. Results of free vibration of sandwich plate ($0^0/90^0/0^0/\text{Core}/0^0/90^0/0^0$) with rectangular cutout clamped on all four sides:

c (%)	0	10	20	30	40	50	60
Natural frequency	36.84	34.07	34.63	40.31	50.57	65.35	88.89

The free vibration response of clamped as well as simply supported sandwich plate with anti-symmetric angle ply laminated face sheets ($-45^0/45^0/\text{Core}/-45^0/45^0$) are studied for different size of cutout. These results are presented in Table-5 and it is observed that the natural frequency of the sandwich plate decreases with small to medium size cutout. However, with the increase in the size of the cutout, the fundamental frequency again goes on increasing. Also, the fundamental frequencies for a sandwich plate with cutout increases with increase in the degree of constraint and are found to be higher for clamped edges compared to a plate with simply supported edges.

Table-5 Results of free vibration of sandwich plate ($-45^0/45^0/\text{Core}/-45^0/45^0$) with rectangular cutout for simply supported and clamped edges.

Boundary conditions	Cutout percentage						
	0	10	20	30	40	50	60
Simply supported	22.267	21.1	20.16	20.4	22.74	25.19	32.423
Clamped	34.587	38.68	33.06	35.72	43.249	58.69	82.55

IV. CONCLUSIONS

A finite element model is developed using the ANSYS Parametric design language (APDL) to study the free vibration characteristics of a sandwich plate in presence of cutout. Sandwich plates with symmetric cross-ply and anti symmetric angle-ply composite facings separated by HEREX core are considered for evaluation of numerical results. The analysis shows the influence of the cutout size on the natural frequency of the sandwich plate. The effect of boundary conditions on the free vibration study of sandwich plates has also been studied.

REFERENCES

- [1] Altenbach, H., Altenbach, J. and Kissing, W., Mechanics of Composite Structural Elements, Springer-Verlag, Berlin, 2004.
- [2] Shivakumar K. N., Argade S. D., Sadler R. L., Sharpe M. M., Dunn L. and Swaminathan G., "Processing and properties of a lightweight fire resistant core material for sandwich structures" Journal of Advanced Materials, Vol. 38, pp.,1-17 2006.
- [3] Saha, G.C., Kalamkarov, A.L. and Georgiades, A.V., "Effective elastic characteristics of honeycomb sandwich composite shells made of generally orthotropic materials", Composites Part A, Vol. 38, pp.1533–1546, 2007.
- [4] Ju F., Lee H.P., Lee K.H. "Free vibration of composite plates with delaminations around cutouts" Composite Structures, Vol.31, pp. 177-183, 1995.
- [5] Boay C. G. "Free vibration of laminated composite plates with a central circular hole" Composite Structures, Vol. 35, pp. 357-368, 1996.
- [6] Sivakumar K., Iyengar N. G. R., Deb K. "free vibration of laminated composite plates with cutout" Journal of Sound and Vibration, Vol. 221, pp. 443-470, 1999.
- [7] Nanda N., Bandyopadhyay J. N., "Nonlinear Free Vibration Analysis of Laminated Composite Cylindrical Shells with Cutouts", Journal Of Reinforced Plastics And Composites, Vol. 26, , pp.1413- 1427,.2007.
- [8] Liew K.M., Kitipornchai S., Leung A.Y.T., Lim C.W. "Analysis of the free vibration of rectangular plates with central cut-outs using the discrete Ritz method" International Journal of Mechanical Sciences, Vol. 45, pp. 941–959, 2003.
- [9] Brethee K. F. "Free vibration analysis of a symmetric and anti-symmetric laminated composite plates with a cutout at the center" Al-Qadisiya Journal For Engineering Sciences, Vol. 2, 2009
- [10] Niranjana Kumar SSR, Sarcar MMM, Balakrishnamoorthy V "static analysis of skew composite laminated plate with cutout" Indian Journal of Engineering and Material Sciences
- [11] Riyah N.K., Ahmed N.E. "Stress Analysis of Composite Plates with Different Types of Cutouts" Anbar Journal of Engineering

Sciences 2 (2009) 11-29

- [12] Barut A., Madenci E. and Nemeth M. P. "Stress and buckling analyses of laminates with a cutout using a 3-0 plate theory" *Journal Of Mechanics Of Materials And Structures* Vol. 6, No. 6, 2011.
- [13] Bhatt D., Mishra Y., Sharma P.K. "Model Analysis of Centre Circular Cutout of Laminated Composite Plate and Square Skew Plate by using FEM" *International Journal Of Engineering Sciences& Research Technology* Vol.3,pp. 8-16, 2014.
- [14] Bhardwaj H. K., Vimal J. and Sharma A. K. "Study of free vibration analysis of laminated composite plates with triangular cutouts" *Engineering Solid Mechanics*, Vol. 3, pp.43-50, 2015.

