SAKARYA ÜNİVERSİTESİ

FEN BİLİMLERİ ENSTİTÜSÜ DERGİSİ

Sakarya University Journal of Science
SAUJS

ISSN 1301-4048 | e-ISSN 2147-835X | Period Bimonthly | Founded: 1997 | Publisher Sakarya University | http://www.saujs.sakarya.edu.tr/

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Recieved: 2022-01-26 00:00:00

Accepted: 2022-05-30 00:00:00

Article Type: Research Article

Volume: 26
Issue: 4
Month: August
Year: 2022
Pages: 687-694

How to cite
Ufuk DEMİRCİOĞLU, Mutlu Tarık ÇAKIR; (2022), An Investigation of the Influence of Various Shaped Cutouts on the Free Vibration Behavior of Sandwich Structures. Sakarya University Journal of Science, 26(4), 687-694, DOI: 10.16984/saufenbilder.1063422
Access link
http://www.saujs.sakarya.edu.tr/en/pub/issue/72361/1063422

Sakarya University Journal of Science 26(4), 687-694, 2022

An Investigation of the Influence of Various Shaped Cutouts on the Free Vibration Behavior of Sandwich Structures

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Abstract

The current study deals with free vibration analysis of a sandwich beam in presence of different cutouts. PVC foam and glass fiber were used for the core and surface layers of the sandwich structures, respectively. First 6 frequencies of the sandwich structures were determined for different cutout shapes to see the effect of cutout shapes on the free vibration behavior of sandwich structures. For this, sandwich beams with different cutout shapes but with the same area were modeled. To see the effect of cutouts-shape only the shape of cutouts was changed and all other parameters were kept unchanged. Analyses were performed by using ANSYS apdl commercially available software. The analysis gives information about the influence of the cutout shape on the first six natural frequencies of the sandwich structures. From the results, it was observed that the changes of cutout shapes caused a significant decrease or increase in natural frequencies of sandwich structures beam depending on the cutout shape.

Keywords: Finite element method, free vibration, sandwich structure, various shaped cutouts

1. INTRODUCTION

These days, development in the industry is paramount. This advancing and ever-developing technology require advanced materials. As a result, researchers are in search of advanced materials. Sandwich structures are the one of the biggest candidate considered as one that can replace conventional materials, when high damping properties, fabrication diversity, good resitance to fatigue, good strength and good stiffness to weight ratio is desired. Sandwich structures can be determined as heterogeneous composite structures in which they are made up of two or more individual materials [1]. Sandwich structures consist of two thin face sheet materials and low-density core materials [2]. In this configuration, face sheet materials bear bending loads while the core carries the transfer shear force and increases stiffness by separating face sheet materials [3, 4].

The cutouts are inevitable because they are used as access locations for electrical and mechanical components. Therefore, the effects of the cutout on the free vibration characteristic of sandwich structure has been studied by several researchers extensively. N. Mishra et al. investigated the influence of the rectangular central cutout on the vibration characteristic of sandwich beam by using the finite element method. From analys the effect of cutout size on the free vibration caharacteristic of sandwich beam is determined [5]. H. K. Bhardwaj et al. studied the influence of triangular cutout on the vibration behavior of composite plates by using ANSYS APDL code.

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The effect of parameters on the free vibration behavior of the sandwich structure was investigated [6]. S. Ramakrishna et al. studied the free vibration of composite plate with circular cutout at the center utilizing the finite element method. The orientation effect of fiber, different ratios (thickness, size), and hole size on the vibration behavior of the sandwich structure is evaluated [7]. S. Chikkol Venkateshappa et al. studied vibration analysis of composite plates with different shaped cutouts experimentally and numerically. The natural frequencies were got by using MSC/NASTRAN. Experimental results was compared to that of finite element results. The influence of ratio of aspect, size of cutout, and cut-out shape on the natural frequencies of sandwich plates were investigated [8]. H. K. Bhardwaj et al. studied the influence of cutouts at a different position on the vibration characteristic of sandwich composite plate experimentally and numerically. The effect of ratios of aspect, ratios of thickness, different material properties, cutouts, number of layers, and boundary conditions, for a cross-ply composite laminate with a skew hole, were evaluated [9]. J. Vimal et al. studied the influence of the circular hole on the vibration behavior of functionally graded composite plates by using the finite element method utilizing ANSYS. The influence of cutout, size of the cutout, index of volume fraction, boundary conditions, and ratio of thickness on the natural frequencies of sandwich structure is evaluated [10]. J. Vimal et al. studied the free vibration of sandwich structure with different cutouts by using the finite element method. Trapezoidal and circular plates that have cutouts are studied and the influence of volume fraction, thickness ratio, and different boundary conditions on the natural frequencies of plates are studied [11]. They presented the influence of cutouts on the vibration behavior of composite plates. Maharudra, B. Arya, and T. Rajanna investigate the effect of central circular cutouts, plyorientation and boundary conditions on the vibration behavior of trapezoidal composite panels using finite element method. Edge conditions, trapezoidal shape ratio, cutout ratio and aspect ratio of the trapezoidal laminated panel are parametrized to investigate the effect of them. From study it was observed that different ply-orientations and boundary condition are more important parameters [12]. S. Dey, T. Mukhopadhyay, S. K. Sahu, and S. Adhikari investigated on stochastic natural frequency analyses of laminated composite curved panels with cetral rectangular cutout using support vector regression model. Vector regression model based on uncertainty quantification algorithm in along with latin hypercube sampling is developed for the study. The developed algorithm is validated by using finite element method. The effect of twist angle and variation in geometry (like cylindrical, spherical, hyperpolic paraboloid and plate) are investigated. From result it was observed that computational time is reduced by using above mentioned algorithm [13]. V. N. Van Do and C. H. Lee investigated free vibration analaysis of fuctionally graded material plate that has complex cutout. Isogeometric analysis method and quasi-3D higher-order shear deformation theory is employed for the vibration analysis. The ingredient fraction, plate geometric parameter and boundary condition are studied to see their effects on free vibration behavior of the plate. From results it was obtained that after a certain length-to-thickness ratio natural frequencies of perforated plate does not increase any more [14].

From the literature review above one can see there are lots of studies about the influence of cutouts on the free vibration characteristic of sandwich beam. Yet, there are no studies that investigate the effect of cutouts shape. The purpose of this study is to investigate the effect of the cutout shape on the free vibration behavior of the sandwich beam.

2. MATERIALS and METHODS

Different shaped cutouts located at the center of sandwich beams were considered to investigate the effect of the shape of cutouts on the first six natural frequency of the sandwich beam. Therefore, six different sandwich structures without cutout and with different cutouts but with the same area (1.1309x10^-4 m2) were modeled by using ANSYS apdl as illustrated in figure 1. The upper and lower skins of sandwich beam are composed of unidirectional glass fiber, while the core is assumed to be Polyvinyl Chloride (PVC) foam. Properties of materials are given in table 1. The length and width of the sandwich beam are 250 mm and 20 mm, respectively. Each layer of the face sheet is 0.2 mm in thickness, whereas the thickness of PCV foam is 10 mm. The sandwich structure has a lay-up sequence (90^0/0^0/core/0^0/90^0).

Figure 1 A schematic model of a sandwich structure. 1) no cutout, 2) circular cutout, 3) triangular cutout, 4) rectangular cutout, 5) pentagonal cutout, 6) hexagonal cutout.

To perform the study of free vibration analysis of the sandwich beam with cutouts, the sandwich structure is designed using ANSYS 20.0 apdl software. Shell 281 element is considered to model the sandwich structure since Shell 281 is suitable for analyzing thin to moderately-thick shell structures. Shell 281 may be used for layered applications for modeling composite shells or sandwich construction. Block Lanczos method is used to get the mode shapes and natural frequency of the sandwich structure under a cantilevered boundary condition. Mesh size is 1 mm as global element size and quadratic mesh is used.

Table 1
Properties of materials considered for analysis

Property	Glass Fiber	PVC Foam
Density (Kg/m^3)	2000	60
Young’s Modulus E_x (pa)	4.5e+10	7e+07
Young’s Modulus E_y (pa)	1e+10	-
Young’s Modulus E_z (pa)	1e+10	-
Poisson’s Ratios v_{xy}	0.3	0.3
Poisson’s Ratios v_{yz}	0.4	0.3
Poisson’s Ratios v_{zx}	0.3	0.3
Modulus of Rigidity G_{xy} (pa)	5e+09	2.6923e +07
Modulus of Rigidity G_{xz} (pa)	3.8462e+0 9	2.6923e +07
Modulus of Rigidity G_{yz} (pa)	5e+09	2.6923e +07

3. RESULTS and DISCUSSIONS

The influence of different cutouts shape on the free vibration characteristic of sandwich structure has been investigated by using Ansys apdl. Different cutouts circular, triangular, rectangular, pentagonal, and hexagonal-shaped holes were considered in this study. To verify the accuracy of the presented finite element method, validation is made by comparing the results with those presented by [15]. The results of the validation study are given in table 2.

Table 2
Comparison of present model with those of a similar model for a laminated plate [15].

Mode	Reference [15]	Present
1.	35.055	35.054
2.	126.4	126.39
3.	218.46	218.45
4.	420.57	420.54
5	606.05	606.00

In this study, the influence of different shaped cutouts on the free vibration characteristic of the sandwich structure is investigated by using ANSYS apdl. Different cutouts but the same area are subtracted from the center of the sandwich plate and the effects of cutout shape on vibration were evaluated. To evaluate the effects of cutouts shape on the free vibration, only the shape of the cutout is changed but the cutout area is held constant regardless of cutouts shape.

Table 3 represents the natural frequency and figure 2 shows the change of natural frequency with cutout shapes of each model. The results indicate that changes in the cutout shapes give a significant influence on the stiffness of the sandwich beam, which leads to decreasing or increasing the natural frequencies of the perforated sandwich beam. Along with stiffness, mass of beam has also effect on the natural frequencis of sandwich structures. However in this study we subtracted the same area from sandwich beams. Same area means the same mass. So, there is no mass effect on the free vibration behavior of sandwich strucres in this study. Through the results, we found out that the cutout shape leads to a change in the natural frequencies of the sandwich beam when compared to the sandwich plate with no cutout. Naturel frequencies increase for all cutout shape except for triangular cutout in mode one, mode two, and mode five. Cutouts cause a decrease in natural frequencies in mode three and mode six, whereas it gives rise an increase in natural frequencies in mode four. To conclude, different cutout shapes changed the natural frequencies of sandwich beam significantly. This situation coincides with experimental and numerical results in the literature. For example, N. Mishra et al. investigated the influence of the rectangular central cutout on the vibration behavior of sandwich structure by using the finite element method. They reported that up to a certain cutout percentage natural frequencies decrease but thereafter they increase [5]. A similar study was verified by researchers using the finite element method [16]. Some studies performed with different cutouts with similar results can be found in ref [17, 18].

Table 3
The natural frequency of sandwich structures with different cutouts.

The shape of the cutouts	Mode 1. Frequency	Mode 2. Frequency	Mode 3. Frequency	Mode 4. Frequency	Mode 5. Frequency	Mode 6. Frequency
No cutouts	571.24	979.99	1200.05	1237.24	1922.18	2483.96
Circular cutouts	580.66	998.25	1188.07	1281.06	1947.58	2423.62
Triangular cutouts	571.12	976.96	1169.18	1279.37	1918.73	2404.57
Rectangular cutouts	581.39	998.05	1185.83	1280.21	1951.30	2372.53
Pentagonal cutouts	577.09	993.16	1184.11	1282.86	1938.51	2423.38
Hexagonal cutouts	577.52	995.20	1183.23	1285.28	1940.74	2422.60

Figure 2 Changes of the natural frequency with cutout shapes

4. CONCLUSION

In this study, free vibration study of the perforated sandwich structure is studied. The finite element method is employed by using the ANSYS apdl to study the free vibration characteristics of a sandwich beam when there are cutouts. The study focus on to reveal the influence of various shaped cutouts on the free vibration behavior of the sandwich structure. Sandwich beams consist of glass fiber face sheet and PVC foam is considered for evaluation of numerical results. The analysis shows the influence of various cutout shapes on the natural frequency of the sandwich beam. From the results, it was observed that the vibration characteristic of sandwich beams changes with cutout shapes without showing any trend. Therefore, it can be concluded that the natural frequencies of the laminated composite sandwich beam are significantly influenced by the cutout shapes.

Acknowledgments

We thank to reviewers and editors for their valuable time they spent evaluating our article.

The Declaration of Conflict of Interest/ Common Interest

"No conflict of interest or common interest has been declared by the authors".

Authors' Contribution

The authors contributed equally to the study.

The Declaration of Ethics Committee Approval

This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

"The authors of the paper declare that they comply with the scientific, ethical, and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science."

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