Free Vibration Analysis of Perforated Laminated Composite Square Plates

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Abstract

This paper presents a study of free vibration of perforated laminate composite plate. The modal characteristics consist of three layers, the material is hard orthotropic composite material, with simply support (SSSS), Clamped boundary (CCCC) and simple clamed conditions (SCSC) are applied at all four edges of the plate.. The natural frequency and mode shape of the plates have been obtained using ANSYS 15. Eight-node isopaprametric layered shell elements (SHELL 281) are employed in the modeling for describing the vibrations of these perforated laminate composite plates. The effect of number of holes, hole area ratio, lamination angles and boundary condition on vibrations are investigated. The convergence study was achieved for numerically and compare with present literature. The results showed that the frequencies of the plate with one hole at the center are different from the perforated plate when maintaining a fixed ratio hole area, as well the lamination angle has a clear effect on the increase and decrease of the fundamental frequency for all the tested cases.

Keywords: laminate composite plate, Free vibration, Perforated plate, Finite element.

1- Introduction

Laminated composite structure is extensively used in many types of engineering fields such as aerospace, automotive, , marine vehicles, where layers of fibrous composite material can be assembled and joining to obtain necessary engineering properties, including strength, bending stiffness, and in-plane stiffness. Cutouts or (opinings) in composite structure are required for passage together the components, fuel lines, access ports and electrical lines. The presence of openings in the structure serves as doors and windows, providing ventilation, to reduce weight and easy access to other parts of the structure. It is also well professed that these structure are subjected to the undesirable vibration or(dynamic loads) and many more during their service life and again these structures having cutouts may change the responses Significantly. Hence, there is a need to study the vibrations behavior of perforate laminate structure precisely. The vibration responses of perforated laminated composite plates have been extensively studied by a number of researchers. Some of the selected studies are discussed in the following lines. [1] Investigated free vibration characteristics of perforated plates with different sizes of perforation holes arranged in oblique array. The ANSYS program was used for carring out Numerical analysis of dynamic characteristics of perforated plates. the curve fitting technique was employed to finding the relation of the effective resonance frequency with the mass remnant ratio. The functions attained from curve fitting were used to predict precisely the effective resonance frequencies of wide range of perforation geometries. [2] Studied the dynamc responses of laminated composite skew plates with and without perforation. The finite element model was based on shear deformation theory by using ANSYS the influence of the Parametric conditions (support conditions, thickness ratio, modular ratio, orientation angle, number of layer, dimension of cutouts, and skew angle) on the free vibration responses were investigated.

[3] The ANSYS13.0 software was used for analyzed free vibration of four layered angle-ply symmetric laminated plates with various ply angles (±0o to ±90o)s of laminas with different holes location .The composite materials Graphite Epoxy. Length to height ratio considered is 40 and 200. The ratio of perforated area to the plate area remains constant during the analysis as 0.05. Result showed that the frequency of composite plates decreases with increase in L/h ratio. [4] The influence of the skew cut-out on the free vibration of composite laminated plate, emplyed finite element method (FEM), by Ansys softwere was studied. Discussed the influence free vibration characteristics by parameters (thickness ratio, aspect ratio, thickness ratio, angle of lamina, number of layers, geometry of cutout and distance between cutouts). The result show that the frequencies are decreased with increasing the size of the plate and thickness ratio, and decrease with increasing the cutout size, the number of laminates of the plate. [5] The finite element model (FEM) by ANSYS (APDL) code, for study the vibrations analysis the composite plate with cutout. The influence of the free vibration characteristics by parameters (thickness ratio, aspect ratio, thickness ratio, angle of lamina, number of layers, geometry of cutout and distance between cutouts). The results show that the frequency increases with the increase in the modulus ratio, number of layers, of plate and angle of lamina. The frequency decreasing with increase in size of cutout, thickness ratio and aspect ratio. [6] The vibration characteristics of laminated composite plate with square cutouts were studied numericelly and experimentally. compareing the experimental with the numerical results obtained from ANSYS code. Indicate that the fundamental frequency is decreasing with increased the cutout ratio (d/D ratio) under CFFF and SFSF boundary conditions. But frequency under CFCF boundary decreasing with increased the cut-out ratio up to 0.2. [7] The Solid Works was employed for carring out The Finite Element Method. Results showed the presence of hole led to decrease the natural frequency value. And the natural frequency is decreasing with increase the hole size.

[8] Presented experimental and numerical study of free vibration of glass fibre epoxy composite plates. Composites plates having circular, rectangular, triangular and mainly elliptical cutouts with same crosssection area were manufactured. Used Finite element analysis to find natural frequencies and mode shapes for each of these plates for various boundary conditions. Results showed that the shape of cutout is more feasible and safe in application point of view. It is found that, cutout area does not make any difference in effect of cutout shape. [9] Studied vibration response of perforated sandwich plate. Employed FEA (finite element analysis) by (ANSYS 15) to determine the frequency.

The aim of this study is to understand the effect of hole area ratio, lamination angles and boundary condition on the free vibration of square plates with hole at center and perforated plate with (carbon /epoxy) materials. The numerical analysis will be carried out using the finite element ANSYS 15.0 (APDL) using the modal analysis to analyze perforated laminate composite plate.

2- Materials and Methods

A square perforated composite plate with the plane dimensions of a×b×h is considered as show in Fig.1 The plates consist of three layers with angle orientation(+α, -α, +α). The material is hard orthotropic composite.

3- Finite Element Modeling

The model analysis has been done using ANSYS 15 software package. The laminated composite plates are modeled using the element SHELL 281 as shown in Fig 2. The element has 8- nodes and 6- Dof (degrees of freedom) at each node, translation and rotation in the x, y and z direction.

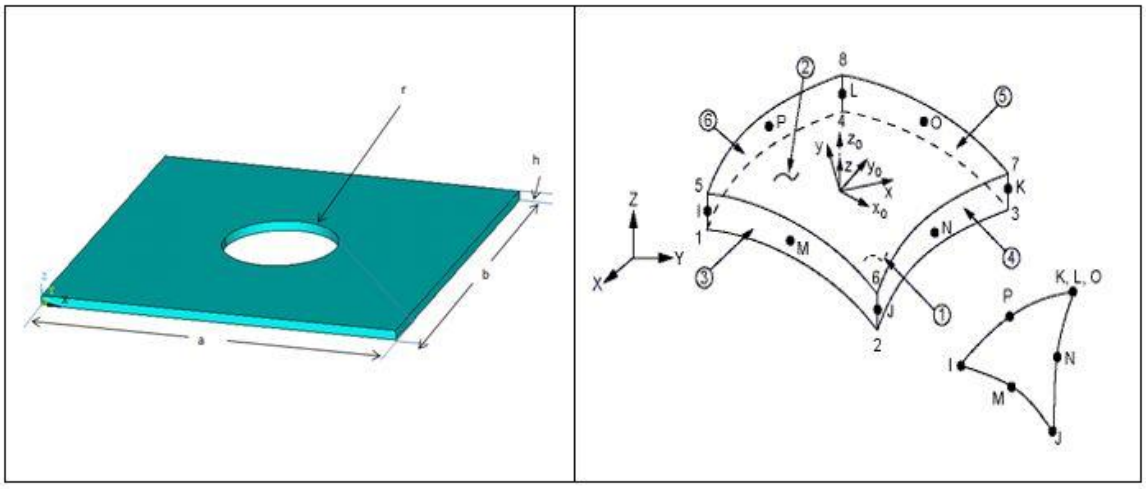

Fig. (1)Representation of the dimensions model and element type

In the present investigation, the models of the angle ply symmetric layered composite plates with various lamination angles (+α, -α, +α) with gradual variation of α from 00~900 in steps of 150 were analyzed. The stacking sequence of the lamina are shown in Fig.3. The observed models have been made up with three equal unidirectional lamina from the material: carbon /epoxy. The material properties of carbon/epoxy composite material is given in Table 1. The plates of same geometry having size 750 X 750mm having (η) hole area ratio (ratio of area of the holes to the area of plate) is maintained constant for all plates and increase as (from 1.4 to 12.6) and b/h thickness ratio (ratio of side to the thickness) considered is 100. In the present study four different models have been considered are shown in Fig.3: Model: 1. Laminated plate with one hole, Model: 2. Laminated plate with four holes, Model: 3. Laminated plate with nine holes and Model: 4. Laminated plate with Sixteen holes. Simply support (SSSS), Clamped boundary (CCCC) and simple clamed conditions (SCSC) are applied at all four edges of the plate. The weights of the plates are exactly the same, because of total holes area are equal in four models which were analyzed under the same loads (self-weights).

Table1. Mechanical Properties of a carbon/epoxy [10]

E_x (MPa)	E_y (MPa)	E_z (MPa)	PRXY	PRYX	PRZX	G_x(MPa)	G_y(MPa)	G_z(MPa)	Dencity (Kg/m^3)
159000	14000	14000	0.32	0.14	0.14	4800	4800	4300	1550

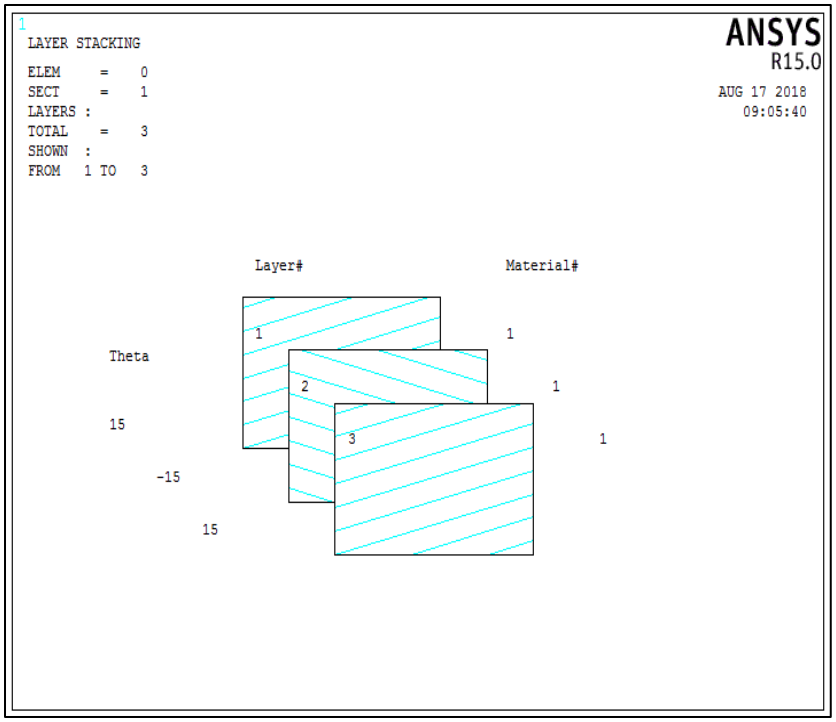

Fig. 2. Representation of the Lamination angles.

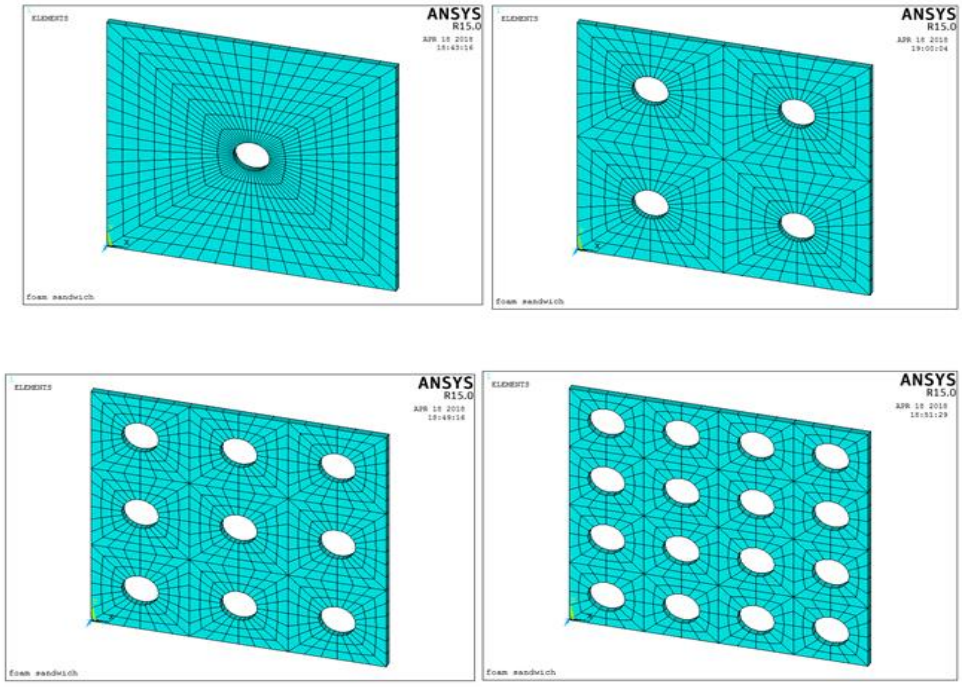

Fig. (3)Representation of the Meshed Models

4- Results and discussion

An attempt was made to study the free vibration characteristics of laminated composite plates with cut-outs. The effect of increasing the number of holes, area holes ratio, fiber orientation and boundary condition on frequency of vibration is studied.

5- Convergence And Validation Study

Convergence study

The mesh convergence study is done for frequency of vibration of laminated composite square plates with simply support (SSSS) and 3-layers symmetric cross ply for different mesh division as shown in Fig.4 As the convergence studies show that a mesh size of 16X16 is sufficient enough to get a reasonable order of accuracy for each model.

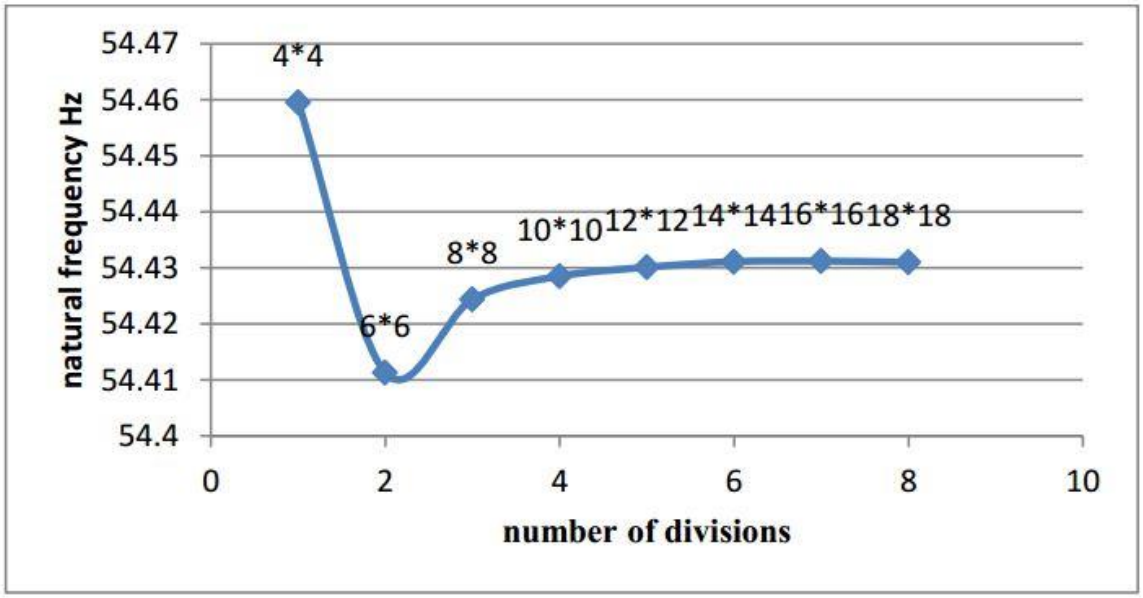

Fig.4 Convergence Results for Various Mesh Divisions.

Validation

A comparison was also made with other researchers [11], [6] for an analysis of laminated composite square plate with central holes by ANSYS15. There are four types boundary conditions such as free free free clamped (FFFC), free clamp free clamped (FCFC), clamped at all edges(CCCC) and simply support at all edge (SSSS) are considered to examine the effect of end conditions on natural frequencies of laminated composite plate with cut-out at centre. Geometry properties and material properties of composite plate: Length=1m, Width=1m, Cutout ratio (diameter/side of square plate) = 0.6, side to thickness ratio=100, Ply orientation= (0/90) s, E11=137.20GPa, E22=E33=14.48Gpa, G12=G13=G23=5.86Gpa, Density=1500kg/m3.

Table 6: Comparison of natural Frequencies (Hz) under different boundary conditions for laminated composite plate with cutout

Boundary condition	No of mode	Cut-out ratio	Ref.[11]	Ref.[6]	Present ANSYS
FFFC	1	0.6	7.21	6.99	7.19
	2		16.103	16.057	16.088
	3		45.34	45.277	45.31
	4		60.251	59.793	58.99
	5		64.197	64.973	64.632
FCFC	1	0.6	68.24	65.066	67.32
	2		69.17	66.344	66.912
	3		171.02	156.30	165.321
	4		171.54	158.44	162.753
	5		176.67	167.58	167.66
CCCC	1	0.6	263.64	232.97	228.923
	2		269.94	240.32	245.985
	3		271.34	244.68	244.95
	4		281.46	253.27	256.098
	5		385.14	345.35	248.981
SSSS	1	0.6	54.293	52.976	52.159
	2		88.57	81.591	84.198
	3		89.481	81.798	83.813
	4		145.29	133.09	138.852
	5		191.81	162.95	176.882

Vibration of composite laminated plate with circular holes

a) Laminated Composite plates subject to SSSS simply supourt boundary condition

Fig. (5). Illustrates the varietion of natural frequency of three layered laminated composite plates with different number of holes with respect to the fiber orientation angle and the three (η) hole area ratio, with Simply support boundary conditions were applied at all the four sides of the plate i.e., u= 0.(where u is deformation in z- direction) considered in this investigation. The results indicate that increasing the number of holes causes decrease in the stiffness of the plates which lead to lowering the natural frequency of laminate plate, so that the behavior of plate with center hole(1 hole) different from perforated plate (4, 9 and 16 holes). At η=1.4% the best fiber orientation angle is 350 for all models.

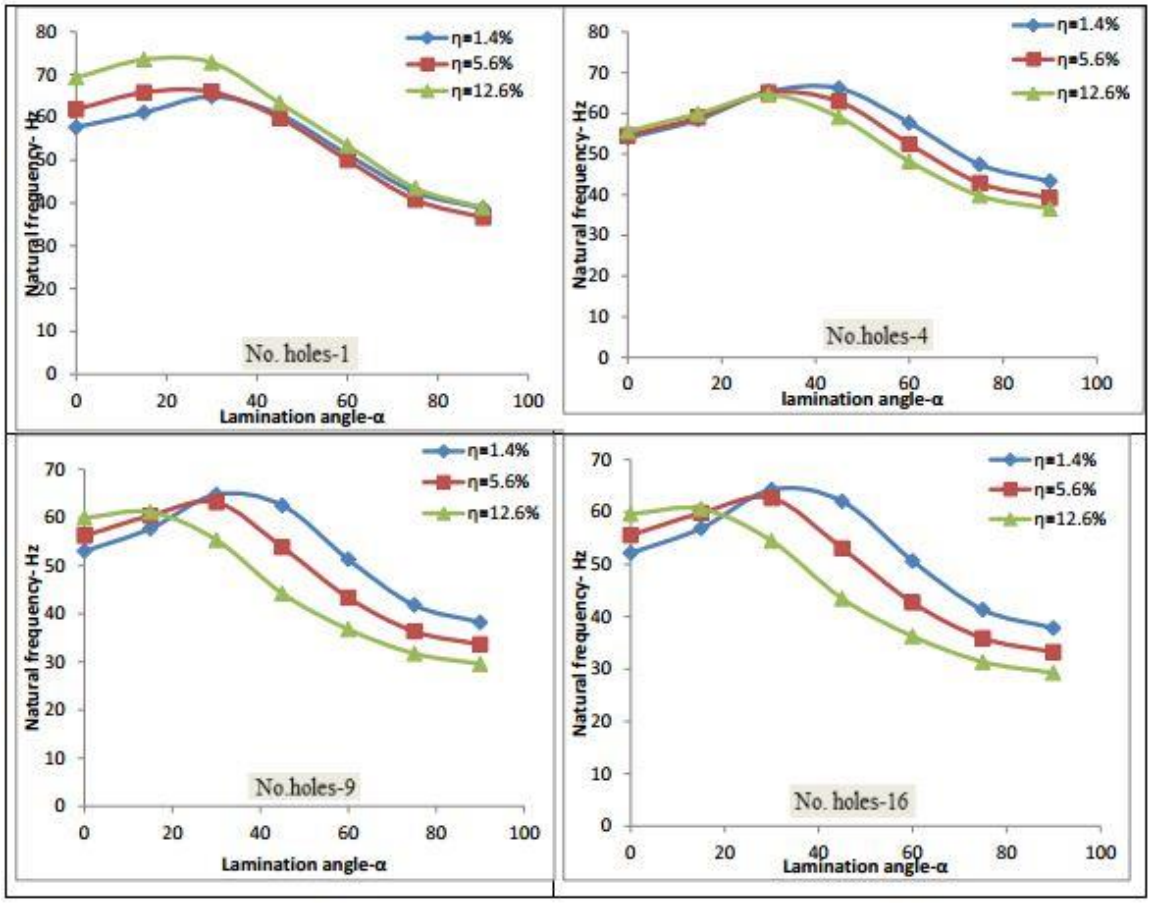

Fig. (5) Variation of frequencies with respect to the lamination angles and holes area ratio for simply support (SSSS) boundary condition.

b) **Laminated Composite plates subject to clamped (CCCC) boundary condition**

Fig. (6). Illustrates the varietion of natural frequency of three layered laminated composite plates with different number of holes with respect to the fiber orientation angle and the three (η) hole area ratio, with clamped boundary conditions were applied at all the four sides of the plate, u=v=w=θx= θy= θz=0. Considered in this investigation. The results indicate that the clamped boundary conditions lead to increase in natural frequency because the increase in stiffness, so that the behavior of plate with center hole(1 hole) and plate four holes in SSSS different from CCCC.

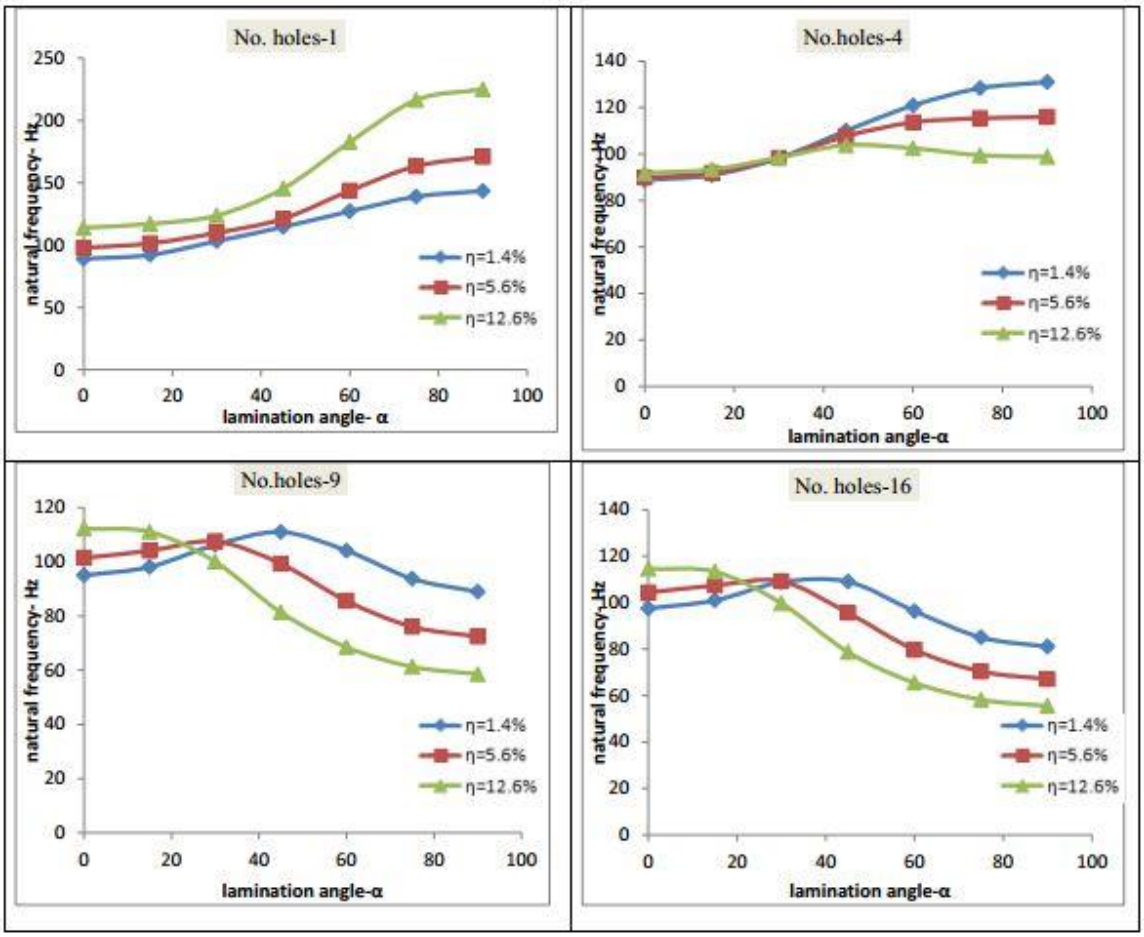

Fig. (6) Variation of frequencies with respect to the lamination angles and holes area ratio for clamped (CCCC) boundary condition.

c) Laminated Composite plates subject to simply clamped (SCSC) boundary condition

Fig. (7). Shows the change of natural frequency of three layered laminated composite plates with different number of holes with respect to the fiber orientation angle and the three (η) hole area ratio, with clamped boundary conditions at two opposite sides and simply support at other two opposite sides applied considered in this investigation. The results show that the increasing hole area ratio (η) of plate with center hole(1 hole) will lead to increase in frequency at any fiber orientation angle because decreasing in mass of plate and increase in stiffness causing due to the edges supports of plate.

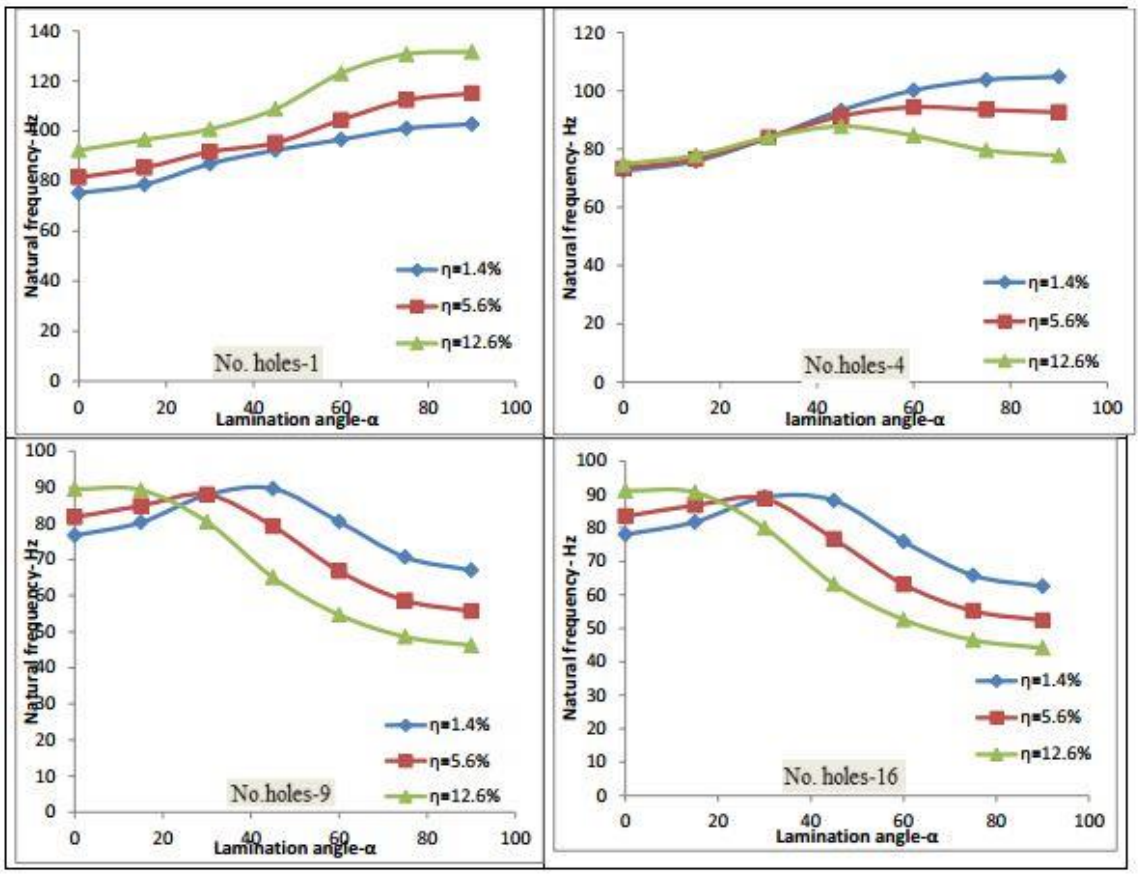

Fig. (7) Variation of frequencies with respect to the lamination angles and holes area ratio for SCSC boundary condition

6- Conclusion

In this study, the free vibration response of a symmetric angle-ply laminated composite perforated plates investigated. The modeling process and solutions were done using finite element analysis software package ANSYS15.0. The conclusions that can be drawn from the present study are summarized as follows.

1. The plate with one hole have higher frequencies than perforated plates and the frequency decrease with increased number of holes because lower in stiffness of the laminate plates..

2. The SSSS boundary condition, the frequencies were found to be higher for angle ply (35°/-35°/35) at η=1.4. The CCCC boundary condition, the frequencies were found to be higher for angle ply (45°/-45°/45) at η=1.4.except plates with one and four holes the frequencies increased with increase the ply angle at all holes area ratio.

3. Clamped CCCC boundary condition yielded greater magnitudes of frequencies rather than simply supported SSSS and SCSC boundary condition for all range of lamination angles and holes area ratio.

4. The frequencies of perforated plates are decreased with increase holes area ratio except the plate with one hole the frequency increase with increase in holes area ratio.

CONFLICT OF INTERESTS.

- There are no conflicts of interest.

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تحليل الاهتزاز الحر للصفائح مربعة طبقية مركبة ومثقبة

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الخلاصة

تقدم هذه الورقة دراسة الاهتزاز الحر للوحة ‘طبقية مركبة ومثقبة. وتتكون خصائص النموذج من ثلاث طبقات، مع الشروط الحدودية (اسناد بسيط، ثابت واسناد ثابت وبسيط) في جميع الحواف. وقد تم الحصول على التردد الطبيعي وشكل التشوه للألواح باستخدام طريقة العناصر المحددة حزمة.(ANSYS 15) تم التحقق من تأثير عدد الثقوب ونسبة المساحة الثقوب، زاوية التصفيح والشروط الحدودية على الاهتزازات. تم دراسة التقارب النماذج وعمل مقارنة مع الباحثين المقدمين. أظهرت النتائج أن ترددات الصفيحة ذات الثقب الواحد في المركز تختلف عن الصفيحة المثقبة عند المحافظة على نسبة مساحة ثقب ثابت، وكذلك لزاوية التصفيح تأثير واضح على زيادة وتقلص التردد الأساسي لجميع الموديلات الحالية، وعند كل الشروط الحدودية.

الكلمات داله: صفيحة الطبقية المركبة، الاهتزاز الحر، الصفيحة المثقبة، العناصر المحددة.