INTERNATIONAL JOURNAL OF
ENERGY AND ENVIRONMENT
ISSUE ON APPLIED MECHANICS RESEARCH
Volume 7, Issue 6, 2016 pp.469-474
Journal homepage: www.IJEE.IEEFoundation.org

Free vibration investigation of isotropic composite skew plate with different shapes holes

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Abstract
The experimental and numerical investigations of free vibration study of composite skew plate are done. The free vibration characteristics are determined numerically using ANSYS package. A comparison between these investigations is done also. The effects of the skew angle, thickness of plate, central hole shape, and a percentage of hole area to the plate area on the free vibrations characteristics of isotropic skew plates were discussed. The rapprochements between results show good agreements between the experimental and numerical results. The natural frequencies generally are increased with an increasing in the skew angle; also the natural frequencies are increased with the increasing of the plate thickness, and are decreased with the increasing of the area of the hole. Three shapes of holes had been studied (circular, square and triangular) holes, the natural frequency reaches the maximum value for the circular hole, and the minimum value for the triangular hole.

Keywords: Skew plate; Composite isotropic plate; Natural frequency ion.

1. Introduction

The plate of skew shape has a vast applications in many engineering fields like mechanical or civil engineering applications. The accurate solution of many problems related to this type of plates ; specially composite plates; are very complicated and may be not available, therefore the researchers used the numerical or semi-analytical investigations to identify these plates. One of these methods is the finite element analysis over and above the experimental techniques.
M. Sathyamoorthy And K. A. V. Pandalait, [1] used governing dynamic equations for the large amplitude flexural vibration of orthotropic skew plates in the Berger formulation, the results obtained were compared with those got without making use of the approximate formulation due to Berger. In all these cases it was found that the nonlinearity was of the hardening type, i.e., the period of nonlinear vibration decreases with increasing amplitude. N.C. Bhandari, B. L. Juneja and K. K. Pujara [2] presented the vibration of the integral stiffened skew plate on the unorganized spaced elastic support. The approximate analyses; in order to get the mode shapes and natural frequencies for various tip conditions; was presented, at which Lagrange's equation was used. A response to an exponentially decaying impact load and the half sine wave transient load of a support skew plate had been determined by the modal analysis, with using of the normalized mode shapes and frequency thus obtained. Maloy K. Singha [3] investigated the large amplitude of the free flexure vibration behavior of the thin laminate composite skew plate used the finite element approaching. The formula including effects of the in-plane and rotary inertia and shear deformation. A variation of the non-linear frequency ratio with the

amplitude was brought out considering various parameters like boundary condition, skew angle, aspect ratio, number of layers and fiber orientation. M.K. Singha [4] studied large amplitude of the free flexural vibration behavior of the symmetrical laminate composite skew plate which used a method of the finite element. The formula includes the effect of the in-plane and rotary inertia shear deformation. Geometry of the non-linearity based on the Von Kármán's assumption was introduced. A nonlinear matrix amplitude equation was obtaining by employ Galerkin's method and solved by the direct iteration technique. A variation of the nonlinear frequency ratio with the amplitude was brought out by considering different parameters like as the fiber orientation, boundary conditions and skew angle. A.K. Upadhyay and K.K. Shukla [5] presented a large deformation flexural response of the composite laminate skew plate which is subjected to a uniform transverse pressure. The von-Karman's nonlinearity and third order shear deformation theory (TSDT) were used for this analysis. Effects of the transverse shear, geometric nonlinearity, aspect ratio, boundary conditions and modular ratio on a behavior of the laminate composite skew plate had been discussed in details. Achache Habib, Boutabout Benali and Ouinas Djamel, [6] studied the numerical method for an evaluation of a stress concentration factor (SCF) in the three dimension laminate composite under the mechanic load. A propose method which used a finite element formul In order to analyze a stress concentration around the geometric notches, many studies like the analytic, numeric and experiment techniques found a stress distribution in a laminate composite plate with the presence of a circle hole using the finite element method. Kode Srividya, V. Balakrishna Murthy and M.R.S. Satyanarayana [7] investigated the free vibration analysis of the thick four-layered skew laminate composite plate with the circle cutout. Three dimension finite element model (FEM) which used the elastic theory for a determination of the stiffness matrices were modeled in the ANSYS software in order to evaluate first five natural frequencies of the laminate. Namita Nanda [8] investigated large amplitude of free flexure vibration of doubly curve shallow shell in a presence of holes. The Finite element model using an eight-nodded, isoperimetric quadrilateral element was employed. The nonlinear strain of the Von Karman type was incorporated into the first-order shear deformation theory. Practical implications are spacecraft, aircraft and several other structures where shell panels were used, undergo the large amplitude nonlinear vibration. Janghorban Maziar, [9] studied cutouts in structures due to practical consideration. In order to investigate the free vibration of functionally graded plates with multiple circular and noncircular cutouts, finite element method was used. The parameters considered were used as follows: cutout size, cutout location, number of cutouts and different boundary conditions.

The laminate composite skew plate is largely used as a chief component in the marine, aerospace, and the other modern industry. That material allows a high-strength structure with the minimum weight; therefore form the thin plate component that is prone to big amplitude oscillation. The Analyses of a large amplitude of the free vibration of plate has been proven practical important in the structure design, and has a recent receive increasing an attention of the researcher. Through the vibration of the plate, by increase the deflection, the tensile membrane stress developing in a thickness of the plate, which makes the plate stiffer, the result in the change of the frequency and the mode shape. Numerous papers and researches are available on the experimental and numerical simulation of free and transient vibration of composite plate, therefore, the references and papers that have direct relationship to the work presented in this paper reported above.

The first aim of this study is to construct a test rig to investigate the isotropic skew plate provided with central hole experimentally using free vibration test technique. The second goal is to build a finite element model of the same plate with skew shape to study the free vibration characteristics numerically in order to confirmation the experimental results.

2. Experimental work

The aim of the experimental work is to study the natural frequency of the skew composite plates with different shapes and size of holes also with different skew angles and thickness using free vibration test. For (0.5) fiber volume fraction the density of composite is ($1800 kg/m^3$).

2.1 Tensile test

The tensile test was done according to ASTM D 638-03 for a specimen that cut from the laminate with dimensions (165mm length, 19mm max. width, and 13mm min. width and 3mm thickness) as shown in Figure 1. The test is achieved at the department of Materials Engineering in the University of Technology. The specimen is put longitudinally in the tensile test machine and pulled hydraulically with large steel strip at a velocity of (2.3 $mm/\min$) as shown in Figure 2 to determine the young modulus which is listed in Table 1.

(a) before test (b) after Test

Figure 1. Tensile test specimen.

Figure 2. Tensile test machine

Table 1. Mechanical properties of chopped composite plate.

properties	value
Elastic modules (E) (Gpa)	22
Shear modulus (G) (Gpa)	8.89
Poission ratio (v)	0.27

2.2 Fabrication of specimens

Chopped fiber glass is used as a reinforcement phase in the form of random fabric and the polyester resin is used as the matrix phase for the composite material of the composite specimen. The mold used in the experimental work consists of two pieces of glass of skew shaped shown in Figure 3. The dimensions of the pieces of glass are (33 x33) cm^2. In order to make the composite plate, amount of resin is spread uniformly over the mold by means of brush, and then the first layer of mat is laid and so on. The casting operation is done at the room temperature for approximately (8) hours, finally it is removed from the mold to get a good surface finished composite plate.

2.3 Vibration test

Vibration test was carried out on a chopped composite plate with dimensions (33cm length and 33cm width) and different thickness (0.3cm, 0.4cm and 0.5cm), with different shapes of holes (circle, square and triangle) and hole areas of (4%, 6% and 8%) from the total area, and without holes also with different skew angle (0º, 15º, 30º and 45º), with two boundary condition (CSSS). In order to find the natural frequency and the response so that the damage can be detected and characterize the material. Impact hammer type (780985-01) is used to excite the plate with impulse signal causing vibration of plate. An accelerometer type (4368) is fixed on the composite plate to pick up the signal to oscilloscope type (DS1102E). The oscilloscope is viewing the response of the specimen that is loaded by the impact hammer which is connected to the oscilloscope and generates the applied load to the plate. The oscilloscope presented the signal as wave with peaks that will give the natural frequency. As shown in Figure 4.

Figure 3. The mold of the composite skew plate.

Figure 4. Cantilever skew plate test rig.

Figure 5 displays the response spectrum obtained from the experimental investigation of a cantilever skew plate made of isotropic material for plates of a skew angle (0º,15º,30º and 45º) respectively. They are inferred from the Fourier Transform of the time history of the transient response of the excited plate. The figure shows the first mode natural frequency and it is of value of 21.05 Hz.

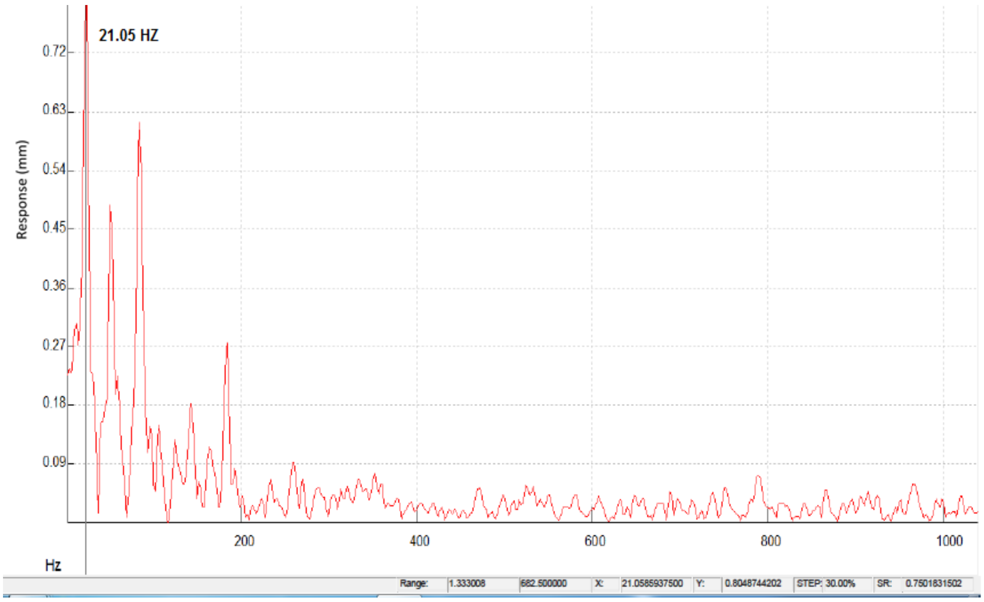

Figure 5. Experimental response (displacement) spectrum of the cantilever skew angle 0º.

3. Numerical work

The numerical analysis is achieved in this work using a FINITE ELEMENT PACKAGE known as ANSYS package for isotropic materials. A modal analysis is performed in the present work. A modal analysis is used in order to calculate the ω_{mn} and w_{mn} of the structural plate. These two values are very important parameters for the designing of the plate dynamically loaded condition. It is also required for the analysis of the spectrum or the superposition mode harmonic and the transient analysis. Shell 281 is selected to solve the present problem**.** It is 8-node linear element through a 6- degree of the freedom in an individual node, which are linear movement in the x, y, z axes and the rotational motions about these axes.

4. Results and discussion

The free vibration analysis is experimentally and numerically achieved for the cantilever skew plate made of isotropic composite materials. The plate is made of different thicknesses (3mm, 4mm, and 5mm), different shape of holes (circle, square, and triangle), different holes areas (4%, 6%, and 8%) and different skew angles (0º, 15º, 30º and 45º). effects of the above parameters on the free vibration characteristics are discussed below.

The numerical and experimental results of the fundamental frequency of a cantilever skew plates of angles (0º, 15º, 30º and 45º) are shown in Figure 6 which show that the fundamental natural frequency increases with the increasing of the skew angles, because of the increasing in the diagonal diameter of the plate the natural frequency increases with a maximum discrepancy of (1.766%), also the natural frequency increases with the increasing of plate thickness Figure 7. The reason of this behavior is due to the increase in the stiffness of the structure with a maximum discrepancy of (3.71%), [10]. Figure 8 shows that when the hole area increases, the fundamental frequency decreases with hole areas (4%, 6% and 8%). The reason of this decreasing is due to the decreasing of surface area of the plate with a maximum discrepancy of (1.76%).

Figure 9 show that when the hole shape changes the fundamental frequency will change too. Three shapes of holes had been studied (circle, square and triangle). The natural frequency show that the circular hole has the larger value of natural frequency from the skew plate with square hole and triangular hole for the same hole area and thickness and skew angle of plate. Because of the increasing of the circumference of the hole the natural frequency will decrease, so the circumference of the triangle is more than the circumference of the square and the circle, then the natural frequency of the triangle has the minimum value, with a maximum discrepancy of (5.631%).

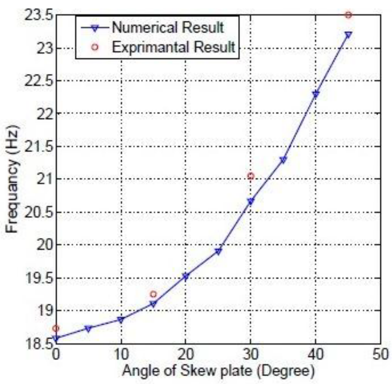

Figure 6. Effect of the skew angle on the natural frequency for a cantilever skew plate.

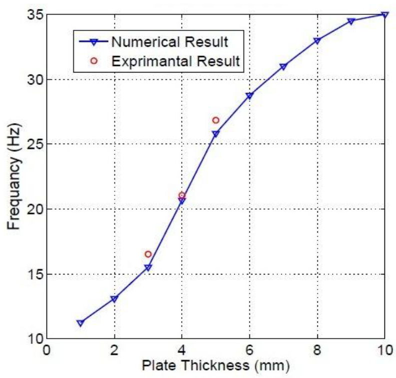

Figure 7. Effect of the plate thickness on the fundamental natural frequency for a cantilever skew plate.

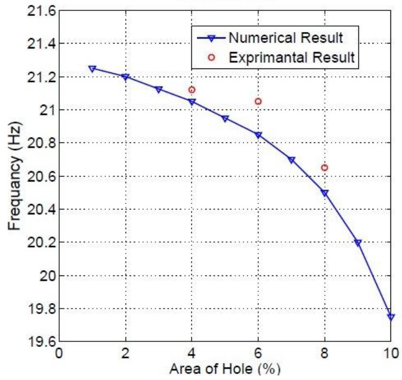

Figure 8. Effect of hole area percentage on the natural frequency for a cantilever skew plate.

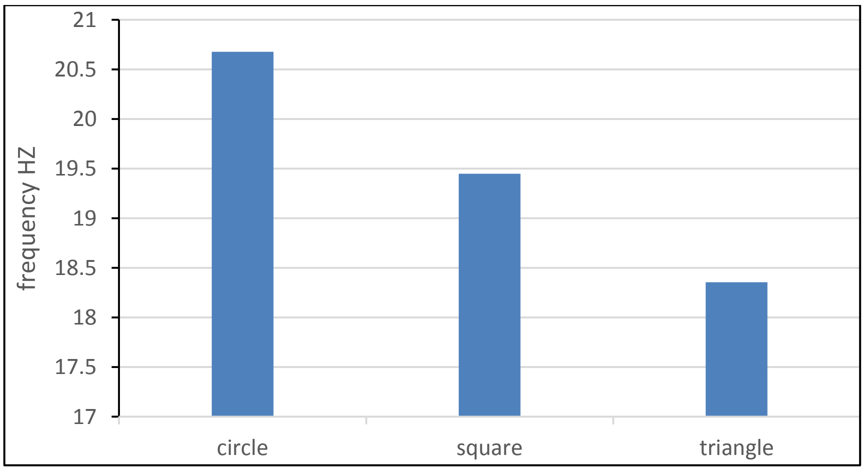

Figure 9. Effect of hole shape on the fundamental frequency for a cantilever skew plate.

5. Conclusions

From the numerical and experimental investigations of the present work, the following concluding remarks are noticed

1. When the skew angle increases, the natural frequency increases too.
2. When the plate thickness increases the natural frequency is increased.
3. When the hole area increases the natural frequency decreases.
4. The natural frequency has the maximum value when the hole shape is circular, and has a value little than the maximum when it's square, the minimum value of the natural frequency when the hole is triangle.
5. The maximum discrepancy between the experimental and numerical results was 6%.

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