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Vibration Analysis of Composite Plate at Different Boundary Conditions

Devidas R. Patil [1], P.G.Damle [2], Dr. D.S.Deshmukh[3]

P.G. Student, Department of Mechanical Engineering, SSBT's C.O.E.T, Jalgaon, Maharashtra, India[1]

Associate Professor, Department of Mechanical Engineering, SSBT's C.O.E.T, Jalgaon, Maharashtra, India[2]

Professor *& Head,* Department of Mechanical Engineering, SSBT's C.O.E.T, Jalgaon, Maharashtra, India[1]

ABSTRACT: In this paper a Vibration Analysis of a composite plate is presented at different boundary condition applied on it. Generally plates are subjected to load conditions that cause deflections transverse to the plate. Vibration directly influences the performance and life of engineering structures, and invariably, damping in the structures influenced its vibration behavior. Various types of damping mechanisms have been developed over time to control the undesired vibration of structures. a plate Finite Element formulation and problem modelled in ANSYS platform, are provided with emphasis on the terms related to the stiffness and mass matrices. Then, a set of results are presented to show the applicability of the present problem to various types of plates under free vibration conditions. Subsequently Three ply laminates has been considered and results are compared with isotropic plate.

KEYWORDS: Boundary conditions, isotropic material, Finite Element method, thickness ratio, etc.

I. INTRODUCTION

Plates are straight, flat and non-curved surface structures whose thickness is slight compared to their other dimensions. Generally plates are subjected to load conditions that cause deflections transverse to the plate. Geometrically they are bound either by straight or curved lines. Plates have free, simply supported or fixed boundary conditions. The static or dynamic loads carried by plates are predominantly perpendicular to the plate surface. The load carrying action of plates resembles that of beams or cables to a certain extent. Hence plates can be approximated by a grid work of beams or by a network of cables, depending on the flexural rigidity of the structures. Plates are of wide use in engineering industry. Many structures such as ships and containers require complete enclosure of plates without use of additional covering which consequently saves the material and labor.

The analysis of plates first started in the 1800s. Euler [1] was responsible for solving free vibrations of a flat plate using a mathematical approach for the first time.Then it was the German physicist Chladni [2] who discovered the various modes of free vibrations. Then later on the theory of elasticity was formulated. Navier [3] can be considered as the originator of the modern theory of elasticity. Navier's numerous scientific activities included the solution of various plate problems. He was also responsible for deriving the exact differential equation for rectangular plates with flexural resistance. For the solution to certain boundary value problems Navier introduced exact methods which transformed differential equations to algebraic equations. Poisson in 1829 [4] extended the use of governing plate equation to lateral vibration of circular plates. Later, the theory of elasticity was extended as there were many researchers working on the plate and the extended plate theory was formulated. Kirchoff [5] is considered as the one who formulated the extended plate theory. In the late 1900s, the theory of finite elements was evolved which is the basis for all the analysis on complex structures. However the analyses using finite elements are now being carried out using comprehensive software which requires high CPU resources to compute the results. Another method for analysis of plates statically and dynamically was later developed for arbitrary shapes using advanced finite elements. Actually there was a method called the weighted residual method which was used in analysis of plate even before the finite element method of analysing the plate was formulated.

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Composite material refers to material that is created by the synthetic assembly of two or more organic or inorganic materials in order to obtain specific material properties such as high strength and high stiffness to weight ratio, corrosion resistance, thermal properties, fatigue life and wear resistance and increased tolerance to damage [7]. Development and design of polymer composite materials and structures is the fastest growing segment of lightweight (durable and sustainable) construction and product engineering. Since fifteen years for each five years period the world market volume of advanced polymer composites was doubled.

II. OBJECTIVE OF PRESENT WORK

The main objectives of the present study are the following to conduct a comprehensive parametric study on the effects of

1. Boundary condition
2. Width-length ratio
3. Thickness ratio

In this paper, a plate Finite Element formulation and problem modeled in ANSYS platform, are provided with emphasis on the terms related to the stiffness and mass matrices. Then, a set of results are presented to show the applicability of the present problem to various types of plates under free vibration conditions.

III. ANALYSIS OF ISOTROPIC & 3 PLY LAMINATED PLATE

In this study, finite element analysis is conducted using ANSYS software. An 8 node shell element, (specified as SHELL 281 in ANSYS) is used throughout the study (Fig.1). The element has eight nodes with six degrees of freedom at each node (Fig.2): translations in the x, y, and z axes, and rotations about the x, y, and z-axes (when using the membrane option, the element has translational degrees of freedom only). Thus each element has 48 degree of freedom in total. SHELL281 is well-suited for linear, large rotation, and large strain nonlinear applications.

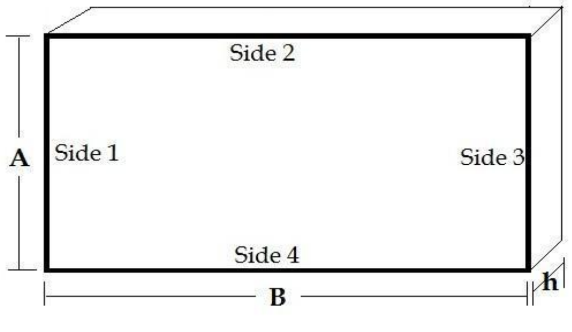

Fig 1: A 3D rectangular plate

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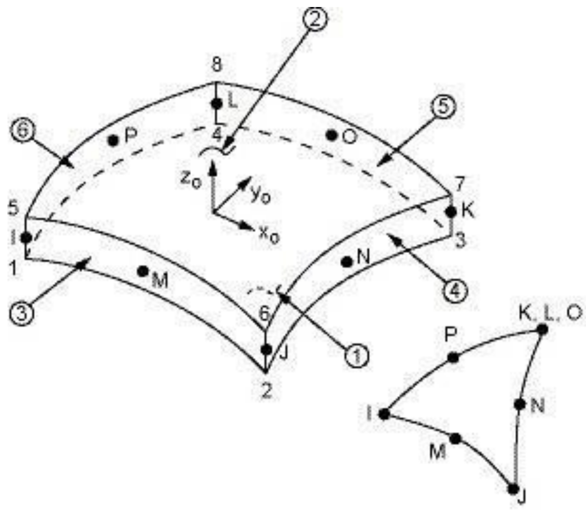

Fig 2: A typical element used in the analysis.

IV. Results

A. ISOTROPIC PLATE

Isotropic rectangular plates have been analysed. The material properties are- E = 10.92 x 10^6 N/m^2, Poisson's ratio = 0.3, Density = 7850 kg/m^3, Thickness = 0.01 m, Aspect ratio = 0.4, 1. 1.5, 2.5. Table 1 shows very good convergence in the values of obtained results by the present study and the open literature. Also fig. 3 shows the variation in frequency with respect to the boundary condition.

Boundary Condition	**Mode Number**				
	1	**2**	**3**	**4**	**5**
SSSS	39.337	85.361	111.23	157.21	162
SSSC	49.892	92.205	134.69	166.73	176.58
SSCC	54.269	105.04	137.18	185.37	188.1
SCCC	67.537	113.31	163.52	193.54	207.2
CCCC	72.587	127.45	166.22	216.48	216.67
CFFF	5.3846	15.643	33.363	54.343	60.891

Table 1: Natural frequencies of rectangular plate with different boundary conditions.

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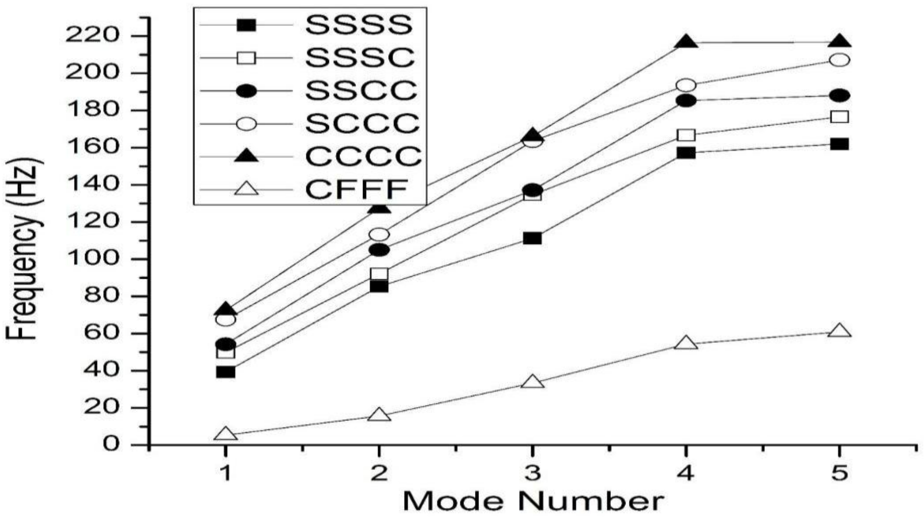

Fig 3: Natural frequency at different boundary conditions for Isotropic plate.

B. 3 PLY COMPOSITE PLATE

3 ply angle laminated composite plate has been considered in the present study. The composite plate is analysed using finite element analysis software for fibre orientation 45/-45/45.
The material properties are: E1 = 280 GPa, E2 = 7 GPa, G12 = G13 =4.2 GPa, G23 = 3.5 GPa and ν12 = ν13 = 0.25.
For the study of effect of boundary condition on the natural frequency of plate a 3 ply composite rectangular plate of h/A = 0.01 and B/A = 1.25 is modeled in ANSYS. The material properties are: E1 = 280 GPa, E2 = 7 GPa, G12 = G13 =4.2 GPa, G23 = 3.5 GPa and ν12 = ν13 = 0.25, ν23 = 0.1. Fiber orientation is 45/-45/45.

Mode Number	**Boundary Condition**					
	SSSS	**SSSC**	**SSCC**	**SCCC**	**CCCC**	**CFFF**
1	71.594	86.789	91.778	112.46	119.83	6.0817
2	126.11	140.16	153.93	168.98	184.61	24.379
3	197.84	213.56	231.64	247.63	266.39	35.783
4	202.84	229.41	233.84	265.27	271.58	63.021
5	284.76	302.42	319.69	340.01	356.84	86.503
6	286.23	305.58	322.59	341.13	360.68	117.83
7	378.94	401.1	417.83	441.22	458.5	144.02
8	389.12	407.64	427.85	445.97	466.27	144.61

Table 2: Natural frequencies of 3 ply composite plate with different boundary conditions.

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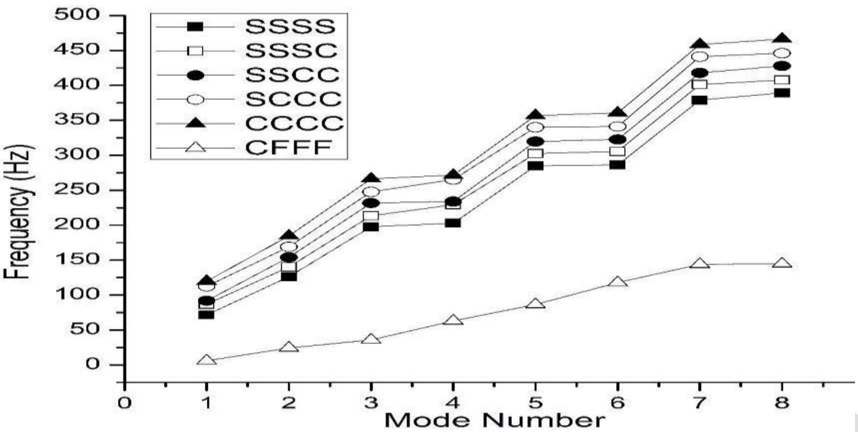

Fig 4: Natural frequency at different boundary conditions for 3 ply composite plate.

Table 2. Shows the natural frequencies of 3 ply composite plate with different boundary conditions and the variations in the frequency with respect to the boundary conditions are shown in the figure 4.

V. CONCLUSION

The problems are related to isotropic uniform thickness rectangular plates having different thickness ratios, different aspect ratios and different boundary conditions. The problem is simulated in ANSYS v14.5. Meshing is done by taking a grid of 40X40 shell 281 elements.

On the basis of present study following conclusions are drawn:

A. ISOTROPIC PLATE:

1. The natural frequency increases with increase in mode number.
2. The natural frequency increases with increase in constraints.
3. Of all the tested boundary conditions natural frequency is lowest for a cantilever plate (CFFF).
4. Of all the tested boundary conditions natural frequency is highest at all sides clamped plate (CCCC).
5. The natural frequency increases with decrease in B/A ratio. It means when by keeping A as constant and B is kept on increasing natural frequency of the plate decreases.
6. The natural frequency increases with increase in h/A ratio. It means when by keeping A as constant and h is kept on increasing natural frequency of the plate increases.
7. Thicker the plate more the natural frequency.
8. The visualizations of Ux, Uy, Uz, ROTx, ROTy, and ROTz provide valuable insight into the deflections of the plate.

B. 3 PLY COMPOSITE PLATE:

1. In the 3 ply composite plate the natural frequency increases with increase in mode number.

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2. In the 3 ply composite plate the natural frequency increases with increase in constraints.
3. In the 3 ply composite plate of all the tested boundary conditions natural frequency is lowest for a cantilever plate (CFFF).
4. In the 3 ply composite plate of all the tested boundary conditions natural frequency is highest at all sides clamped plate (CCCC).
5. In the 3 ply composite plate the natural frequency increases with decrease in B/A ratio. It means when by keeping A as constant and B is kept on increasing natural frequency of the plate decreases.
6. In the 3 ply composite plate the natural frequency increases with increase in h/A ratio. It means when by keeping A as constant and h is kept on increasing natural frequency of the plate increases.
7. In the 3 ply composite plate thicker the plate more the natural frequency.
8. In the 3 ply composite plate the visualizations of Ux, Uy, Uz, ROTx, ROTy, and ROTz provide valuable insight into the deflections of the plate.

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