Volume : 2 | Issue : 3 | March 2013 • ISSN No 2277 - 8160

Research Paper | Engineering

Effect of Angle Stiffeners on the Dynamic Characteristic of Clamped Isotropic Rectangular Plate

Mohammedya Sin. M. Modan	L. D. College of Engineering Mechanical Department, Navrangpura, Ahmedabad-15
Prof. M. Y. Patil	L. D. College of Engineering Mechanical Department, Navrangpura, Ahmedabad-15
Rahul. M. Thakkar	L. D. College of Engineering Mechanical Department, Navrangpura, Ahmedabad-15

ABSTRACT

The work presented here is the study of vibration behavior of thin isotropic rectangular- plate with angle shaped stiffeners. The rectangular thin isotropic plate is considered and its natural frequencies are simulated by normal mode analysis using FEA software. The analysis is performed by clamping all the edges of the plate. The rigid coupling condition is assumed between the plate and stiffeners. The normal mode analysis is performed for different thickness and angles of stiffeners. In this study effect of different angle and thickness of angle stiffener on dynamic characteristics has been found. From the study it is derived that out of the different angle stiffener 90° stiffener gives maximum shift in the natural frequency. Also as thickness of the stiffener increases shift in natural frequency in upward direction has been found.

KEYWORDS: Rectangular plate; Stiffeners; Clamped; Dynamic analysis; Vibration, Normal mode analysis.

I. INTRODUCTION

The structures finds a variety of engineering application in which they are subjected to dynamic loads which are periodic in nature, as a response to such loads the structures vibrate. In the dynamic service conditions if the operating frequency of loading meets the natural frequency of the system the resonance occurs and structure fails irrespective of its strength. This means that though the structure is safe in static design, it fails in the dynamic condition as a result design for vibration becomes necessary to ensure safety of the structure under service. Vibration also creates detrimental effect on relevant structures, human being and creates annoying noise. Natural frequencies cannot be avoided also operating frequency to achieve desired results is necessary it cannot be altered. The only possible solution to avoid the resonance condition and detrimental effect on structure and human being is to shift the natural frequency away from the operating frequency range and minimizing displacement, velocity and acceleration of vibrating structure within permissible limits. One of the ways to achieve the desired dynamic characteristics is the structural modification by tuning the stiffness, mass and damping of the structure.

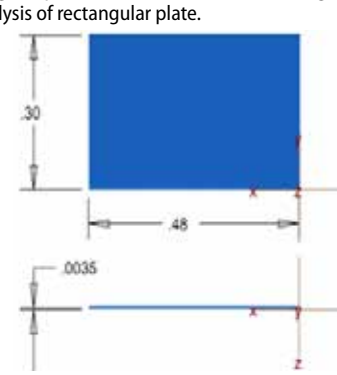
Plates attached by stiffeners represent a class of structural components that are widely used in many engineering applications such as ship decks, bridges, Automobile super structure, Aircraft, industrial structures and buildings etc. Addition of stiffener significantly affects the dynamic characteristics of the plate and shifting of natural frequency away from the operating frequency range hence it is of direct interest in structural designs.

The fundamental research work related to free vibration analysis of the rectangular plate and plates with other geometry is well explained by Leissa W [1]. In his work the effect of plate's various boundary conditions on the modal parameters is studied and equations of natural frequency and mode shapes has been derived. The effect of Poisson's ratio and aspect ratio of the plate on natural frequencies was studied by Rossi et al. [2]. Manzanares B.et al.[3] proposed theoretical and experimental studies on the transverse vibration of rectangular plate with all edges free. They developed experimental technique using electromagnetic-acoustic transducer which is highly reliable for the lower normal modes.

Vibrations of stiffened plate's studies have been extensively expressed by many researchers using various analytical and numerical techniques, as comprehensively reviewed in Refs. [4-5]. Luan Yu et al.[6] developed an improved smearing technique for modeling the vibration of cross stiffened thin rectangular plate. The smearing technique given by Szilard has inadequate accuracy of predicted natural frequencies whereas the improved smearing technique gives considerable accuracy comparatively. Hongan Xu et al. [7] developed an analytical method for the vibration analysis of plates reinforced by beams of arbitrary lengths and placement angles. The effects of various support conditions, general coupling conditions, and reinforcing arrangements with respect to the number, orientations, and lengths of attached beams on dynamic characteristics of combined system has been studied. Dozio L.et al. [8] proposed analytical–numerical method for quick prediction of the dynamic characteristics of rectangular ribbed plates. The approach is suitable for low-frequency free vibration analysis of thin rectangular plates reinforced by a small number of light stiffeners. Zeng H.et al. [9] studied the vibration of rectangular stiffened plate by Differential Quadrature Method. The plate and the stiffeners are treated separately and their compatibility is modeled by their governing differential equations. Chen Z.et al. [10] studied the vibration localization in plates rib-stiffened in two orthogonal directions to see the effect of small misplacements of stiffeners, with various combinations of flexural and torsional rigidities, on both the free vibration and forced vibration responses of the plate. Holopainen T.P.et al.[11] presented a new finite element modelling for free vibration analysis of plates which are eccentrically stiffened using this model the mesh distortion could not any significant effect on the accuracy of the results.

II. METHODOLOGY

A thin rectangular plate is considered as shown in fig. 1(a) for the free vibration analysis of rectangular plate.



The plate is assumed to follow the Classical Thin Plate Theory also known as the Kirchhoff's Plate Theory which is fundamental theory to model thin plates. The plate has length along x direction, width along

y direction and thickness along z direction, hence the plate is assumed to lie in the x-y plane. The plate has three independent displacements i.e. displacement along x, y and z directions. The stiffeners are lying on the plate such that length of the stiffeners is parallel to the width of the plate. The stiffeners and the plates are assumed to have rigid coupling at their connecting interface. The stiffener has an angle A and thickness ts, both Angle of stiffener (A) and thickness of stiffener (ts) are considered as variables.

The plates which are considered for normal mode analysis are tabulated as shown in table 1. It is assumed that the plate and the stiffeners are made of the same material. The bare plate and the stiffened plates have following material characteristics;

- Material: Steel.
- Modulus of Elasticity: $2\times10^{11}N/m^2$.
- Poisson's ratio: 0.3.
- Density: 7860 kg/ m^3.

The finite element models of all the plates are generated in PATRAN software using the QUAD4 element. This element is used for meshing the structure geometry; the element has four nodes and three degree of freedom per each node. The meshed models are then used for FEA in NASTRAN software. The normal mode analysis is performed by keeping all edges

Plate No.	Base dimensions X × Y × Z (mm)	Angle of stiffener A (degree)	Thickness of stiffener ts (mm)	Material
1	480 × 300 × 3.5	Bare plate		Steel
2		70	1.5	
3		70	2	
4		70	3	
5		90	1.5	
6		90	2	
7		90	3	
8		120	1.5	
9		120	2	
10		120	3	

of the plate as clamped; this set of boundary conditions is CCCC.

III. RESULTS AND DISCUSSIONS

The normal mode analysis is performed on the bare plate without any stiffener and on the angle stiffened plates having all edges Table 1: Modelling of Bare and stiffened plates clamped. The results of first ten modes and corresponding natural frequencies of all the ten plates having all edges clamped (CCCC) are compared and shown in table 2. It is observed that with addition of stiffener of any size the natural

Table 2 Normal modes of Bare and stiffened plates

Model	Natural frequency (Hz.)									
	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6	Plate 7	Plate 8	Plate 9	Plate 10
	Bare plate	A= 70 ts=1.5	A= 70 ts=2	A=70 ts=3	A= 90 ts=1.5	A=90 ts=2	A=90 ts=3	A=120 s=1.5	A=120 ts=2	A=120 ts=3
1	310.91	773.41	841.42	902.56	820.14	806.08	955.77	675.68	782.80	864.94
2	547.44	920.75	972.29	1022.3	957.47	938.50	1083.6	816.23	925.09	1064.9
3	919.49	1116.3	1160.7	1215.3	1123.2	1125.1	1269.8	1014.7	1138.0	1410.0
4	956.40	1705.9	1805.7	1898.2	1910.5	1957.2	2174.4	1707.2	1883.9	2151.9
5	1158.4	2083.0	2251.6	2364.8	2220.6	2181.3	2562.1	1743.6	1959.7	2249.6
6	1537.2	2193.4	2292.8	2408	2353.0	2371.5	2622.9	1787.9	1993.5	2251.4
7	1583.5	2277.1	2458.9	2557.5	2408.7	2406.9	2754.0	1805.8	2021.0	2389.4
8	1992.2	2657.2	2804.4	2917.6	2571.5	2590.7	2949.8	2176.2	2323.2	2750.3
9	2128.5	2824.0	2945.0	3035.7	2979.7	3018.1	3236.0	2630.1	2756.0	3317.9
10	2216.6	2864.0	3041.4	3097.2	3179.9	3200.8	3582.7	2756.5	2941.3	3394.2

Frequencies of the plate increases from that of the plate without stiffener.

The comparison of natural frequencies of the stiffened plates with 70°, 90° and 120° angle of stiffener and all edges clamped (CCCC) it can be observed that plate with 90° angle of stiffener gives highest value of natural frequency for all modes.

The natural frequencies of the stiffened plates with 70° angle and 1.5, 2, 3 mm thick stiffeners having all edges clamped (CCCC) comparing the results it can be observed that the stiffened plate with 3 mm thick stiffener gives highest value of natural frequencies.

Similar trend is observed in stiffened plate with 90° angle and 1.5, 2, 3 mm thick stiffeners as well as stiffened plate with 120° angle and 1.5, 2, 3 mm thick stiffeners having all edges clamped.

IV. Conclusion

The vibration analysis of the bare plate and stiffened plates is performed keeping all the edges of the plate as clamped. The results of the analysis give the following noteworthy information on vibration of stiffened plates.

1. Reinforcement of the stiffener to the plate has an effect of shifting natural frequencies of the plate towards higher side.
2. The increasing angle of stiffener does not necessarily increase the value of the natural frequency, out of three angle shaped stiffener 70°, 90°, 120°; the 90° angle shaped stiffener gives the highest value in natural frequency for clamped boundary condition.
3. The increasing thickness of the stiffener increases the natural frequencies of the plate for all the different angled plates for clamped boundary conditions.

REFERENCES

[1] Leissa A. W., "Vibration of plate", NASA, SP- 160(1969). | [2] Rossi R.E., Laura P.A.A., "On the effect of the Poisson's ratio and certain approximation schemes on transverse vibration s of thin rectangular plates with a free edge", Journal of Sound and Vibration, 194(3), 439-444(1996). | [3] Manzanares B., Flores J., Gutie´rrez L., Me´ndez R.A., Monsivais G., Morales A., Ramos F., "Flexural vibrations of a rectangular plate for the lower normal modes", Journal of Sound and Vibration, 329, 5105-5115(2010). | [4] Mukherjee A., Mukhopadhyay M., "A review of dynamic behavior of stiffened plates", The Shock and Vibration Digest, 18 (6), 3–8(1986). | [5] Mukhopadhyay M., Mukherjee A., "Recent advances on the dynamic behavior of stiffened plates", The Shock and Vibration Digest, 21,6–9(1989). | [6] Luan Yu, Ohlrich M., Jacobsen F., "Improvements of the smearing technique for cross-stiffened thin rectangular plates", Journal of Sound and Vibration, 4274-4286(2011). | [7] Hongan Xu, Jingtao Du, Li W.L., "Vibrations of rectangular plates reinforced by any number of beams of arbitrary lengths and placement angles", Journal of Sound and Vibration,329, 3759-3779(2010). | [8] Dozio L., Ricciardi M., "Free vibration analysis of ribbed plates by a combined Analytical-numerical method", Journal of Sound and Vibration, 319, 681-697(2009). | [9] Zeng H., Bert C.W., "A differential quadrature analysis of vibration for rectangular stiffened plates", Journal of Sound and Vibration, 241(2), 247-252(2001). | [10] Chen Z., Xie W.C., "Vibration localization in plates rib-stiffened in two orthogonal directions", Journal of Sound and Vibration, 280, 235-262(2005). | [11] Holopainen T.P., 1995, "Finite element free vibration analysis of eccentrically stiffened plates", Computers & Structures, 56(3), 993-1007(1995). |