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Vibrational Analysis of Aluminum 6061 Plate

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ABSTRACT: Aluminum alloy and Aluminum composite plates have wide range of application like in airplanes, transportation, and construction industries. It has advantages over other materials due to its mechanical properties. It is low on cost and having high strength to mass ratio. It is important to do vibrational analysis because it gives the information about dynamic characteristics like frequencies and mode shapes. The frequencies are important to study. The structures' designers consider the resonant frequencies and modal shapes in designing structures. The structures are generally subjected to vibrations like in the form of external excitation. The modal analysis help to design the structures which resist the effect of vibrations.

This study is conducted to get the dynamic characteristics like natural frequencies and modal shapes of aluminum 6061 plate which is isotropic. The modal analysis is conducted by both simulation and experimental methods. The experiment is performed on aluminum plate with attached inner tire tube sheet covered one third, two third and fully covered of the one side of the plate. These parameters are compared with the plane aluminum plate. Finally results are discussed.

KEYWORDS: Natural Frequency, mode shape, aspect ratio, accelerometer, damping.

I.INTRODUCTION

The studying of vibrations of plate is so important since such kind of components is frequently used in engineering applications. They have different shapes like straight, flat and non-curved surfaces. Plate is defined as geometry element which have the aspect ratio is much less about than one While they are in functioning, they may subject to dynamic excitation may occur. In dynamic analysis, the characteristics like natural frequencies and mode shapes are important to study. These parameters are used to predict the response due to excitation. The natural frequencies have the great importance in the analysis of response of the structures due to various excitations .For calculation of these characteristics, modal analysis is used. Modal analysis is performed by both experimental method and simulation. In this study, the aluminum plate is taken because Aluminum alloy and Aluminum composite plates have wide range of application like in airplanes, transportation, construction industries. It has advantages over other materials due to its mechanical properties. It is low on cost and having high strength to mass ratio.

In this paper, the square plate is aluminum 6061 with Young's Modulus of rigidity of 70 GPa, density 2770 Kg/m³, Poisson's ratio 0.33. The dimension of the side of square plate is 300mm and is thickness of 10 mm. The impact testing method is used with free-free boundary condition.

II. LITERATURE REVIEW

A lot of work has being done by researchers on both dynamic and static characteristics of plates. In 1969, Leissa has presented work on free vibrations of rectangular plates with free boundary condition. In 1970, Monahan at el studied the natural frequencies and mode shapes for plates with cut outs. In 1976, Asku and Ali have done study on dynamic characteristics of mild steel rectangular plates. They have done experimental work and compared the results

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Vol. 6, Issue 7, July 2017

with theoretically obtained results. In 1985, Ganesan and NagarajaRao have presented work on dynamic analysis of isotropic plates. They studied the vibration with changing aspect ratio. In 1989, Liew et al, applied the Raleigh-Ritz method and studied the effect of fiber orientation, plate aspect ratio and different boundary conditions. In 1993, K.H. Low has studied on free vibrations of plate with mounted edges. He observed the variation of frequencies with respect change of weight. In 1993, Reddy proposed theory for analysis of composite plates. In the same year, Kaushal and Bhat used the finited element method and Rayliegh-Ritz method for studying vibrations. In 1994, Mundhkur et al studied the dynamic characteristics of square plate of different boundary conditions. He observed the variation of frequencies with changing boundary conditions. In 1999, Haung and Sakiyama studied on vibrations of rectangular plate with having different shapes of holes like circular, semi-circular, elliptical, triangular etc. In 2001, Singh at el examined the natural frequencies of composite plates with different materials. In 2003, Sakiyama et al have studied the vibrations of orthotropic square plate with a square hole. He used the Green function for obtaining solution and has changed the thickness ratio and observed the results with changing thickness ratio.

III. EXPERIMENTAL METHOD

The specimen used for experimental analysis of Aluminum 6061 is as follows

- Square plate of dimensions 300mm and thickness of 10mm.(see the figure 3.2)
- Data acquisition system:SIRIUSi 8xACC (Dual Core), USB-based 8-channel IEPE/Voltage unit
- Sensors and transducers: Modal hammer Dewesoft IH-400N-1 (scaling: 22,7 mV/N), Acceleration sensor Dewesoft I1T-50g-1 (scaling: 99,3 mV/g)
- Used software: Dewesoft X2, DSA package (including Modal test FRF)

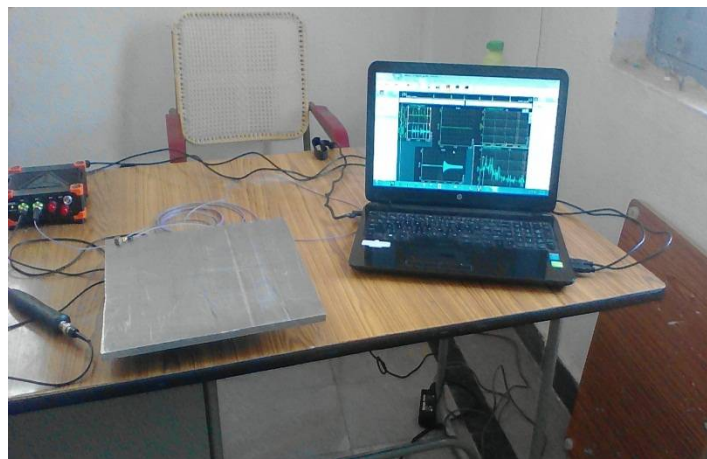


Figure 3.1 Experimental Set up

Experimental Procedure:

Mark the lines on square plate which divides into several blocks. Identify the nodes like node1, node2, node3 up to node16 (see the figure 3.2). Connect the PC to Vibration Analyzer through cables. Attach the Impact hammer and accelerometer through cables to PC. The channel 1 is for impact hammer and channel2 is for accelerometer. Fix the accelerometer at node 13 on the plate. Open the software in PC which analyses the input signals that are received to vibration analyzer. Vibration analyzer will get the signals from Impact Hammer and Accelerometer. The software in PC will give the respond that is FRF which gives the resonant frequencies as shown in the figure3.1. Perform the

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Vol. 6, Issue 7, July 2017

experiment for flat aluminum plate and plate covered with different sizes of inner tire tube sheets as shown in the figure.



Figure 3.2 Flat Aluminum plate



Figure 3.3 Aluminum Plate with damping of one by third proportion of the plate

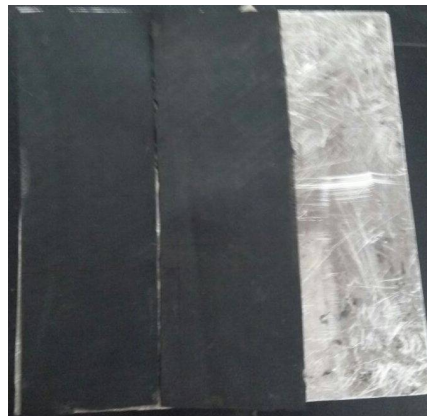


Figure 3.4 Aluminum Plate with damping of two by third proportion of one side of plate



Figure 3.5 Aluminum Plate with full damping of one side of the plate

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

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Vol. 6, Issue 7, July 2017

IV.FEA ANALYSIS using ANSYS 15.0

The FEA Analysis is done in ANSYS15.0 Workbench. The steps like design, meshing, applying load conditions are done in this software. The first thing to be done is selection of material (aluminum) and the parameter shall be fixed automatically. Then, the properties are defined before design the modal. The properties generally defined for modal analysis are Young's Modulus and density of material. The properties of aluminum plate are given as input. Then, the design of model is done using design tools. After the design is completed, the meshing is done. Since the boundary condition applied is Free-Free boundary condition, it is not necessary to define loads. Finally the results are obtained that are natural frequencies and mode shapes.

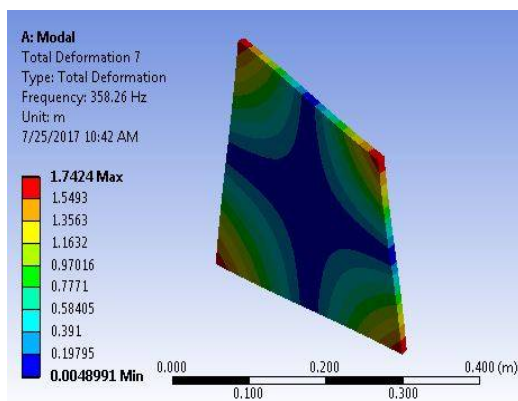


Figure 3.6 Mode Shape 1

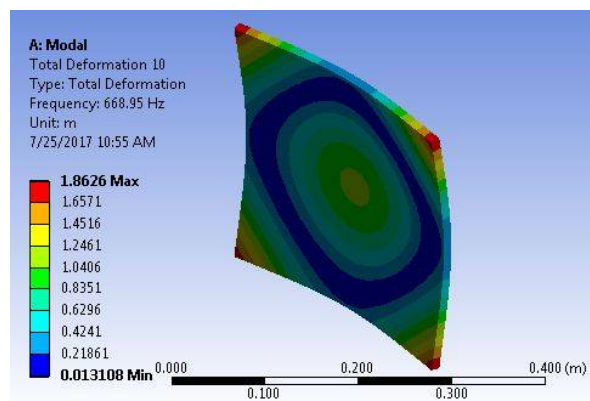


Figure 3.7 Mode Shape 2

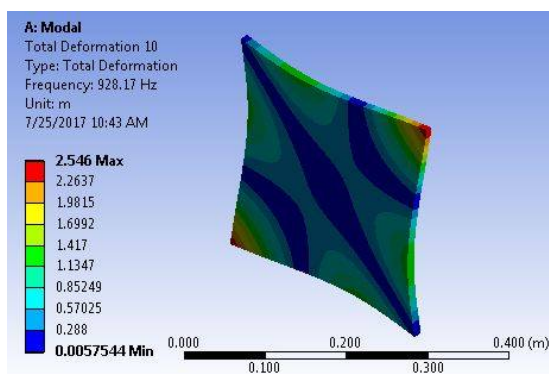


Figure 3.8 Mode Shape 3

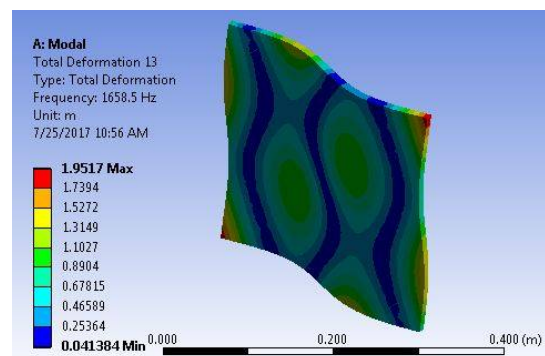


Figure 3.9 Mode Shape 4

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

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Vol. 6, Issue 7, July 2017

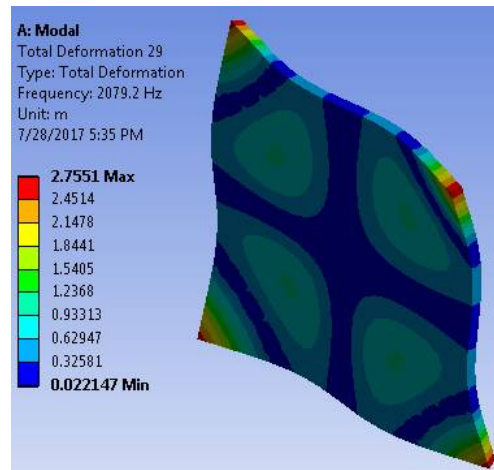


Figure3.10 Mode Shape 5

V. OBSERVATIONS OF EXPERIMENT AND FEA ANALYSIS

The specimen of Square Aluminum 6061 plate is chosen for testing. The properties of material are of Young's Modulus(E)=68.9Gpa, Poisson's ratio=0.33 and density is 2720 kg/m³. The experiment is done on the plate with free-free boundary condition. The Simulation is done for flat Aluminum 6061 plate and aspect ratio is subject to change. The results obtained from Experiment and Simulation are tabulated as follows

Results obtained from the Experimental Test are as follows:

TABLE I
Frequencies of plate with different proportions of damping from Experimental Work

Mode	Frequency in Hz			
	Flat plate	Plate covered with 1/3 of damping (tire tube sheet)	Plate covered with 2/3 of damping (tire tube sheet)	Plate covered fully with damping (tire tube sheet)
1	356.445	346.660	346.680	341
2	664.063	654.297	639.648	634
3	922.882	903.320	893.555	878
4	1684.57	1660.156	1625.977	1606
5	2050.781	2011.719	1992.188	1953

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Vol. 6, Issue 7, July 2017

TABLE II
Frequencies of Flat Aluminum plate from FEA Analysis using ANSYS15.0

Mode	Frequency
1	358.26
2	668.95
3	928.17
4	1658.17
5	2079.20

Comparison in dynamic structure characteristics of modal analysis between simulation and experimental work:

The comparison is generally done by comparing the results obtained both in Simulation and Experimental work. The natural frequencies of aluminum 6061 plate that are obtained from simulation software and experimental work is studied. The difference between resonant frequency for accelerometer and simulation is given as $f_1 - f_2$. The error is calculated as

$$\text{Error} = f_1 - f_2$$

$$\text{Error percentage} = (f_1 - f_2) / f_1$$

Results obtained from the FEA Analysis are as follow

TABLE III

Frequencies of flat aluminum plate for different aspect ratios from FEA Analysis using ANSYS15.0

Mode	Frequency		Difference $ (f_1 - f_2) $	Error percentage $(f_1 - f_2) / f_1 \times 100$
	Experimental (f_1)	Simulation (f_2)		
1	356.445	358.26	1.815	0.51%
2	664.063	668.95	4.887	0.74%
3	922.882	928.17	5.288	0.57%
4	1684.57	1658.17	26.40	1.57%
5	2050.781	2079.20	28.419	1.38%

VI. RESULTS AND DISCUSSION

On the basis of Experimental work and FEA Analysis by using the ANSYS 15.0 software, the vibrational characteristics of the plate with free boundary condition is done.

For Experimental Work: The natural frequencies for plate covered with inner tire tube sheet show the decrement with increase amount of portion covered of the plate with tire tube sheets.

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Vol. 6, Issue 7, July 2017

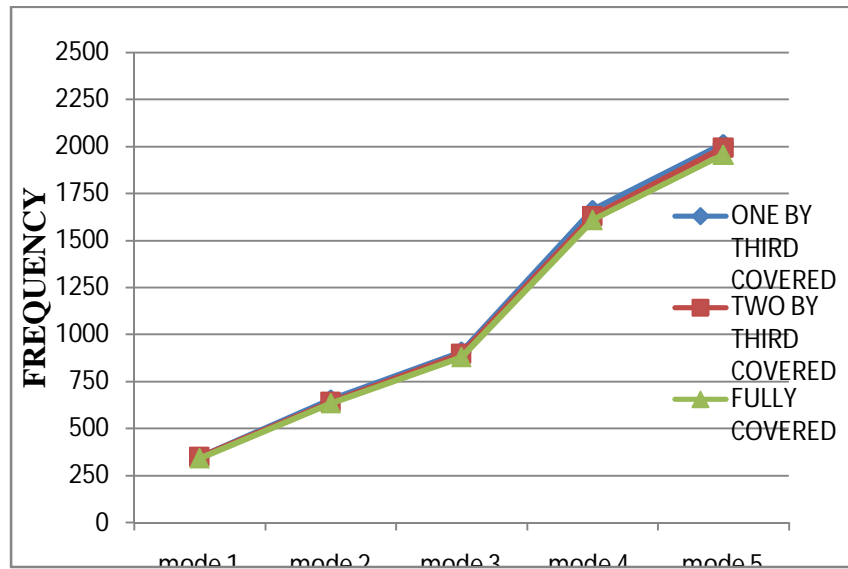


Figure 5.1 Chart for Aluminum plate covered with different proportions of damping (inner tire tube)

A. For FEA Analysis:

From the following graph, it is observed that natural frequencies are increasing with increasing aspect ratios.

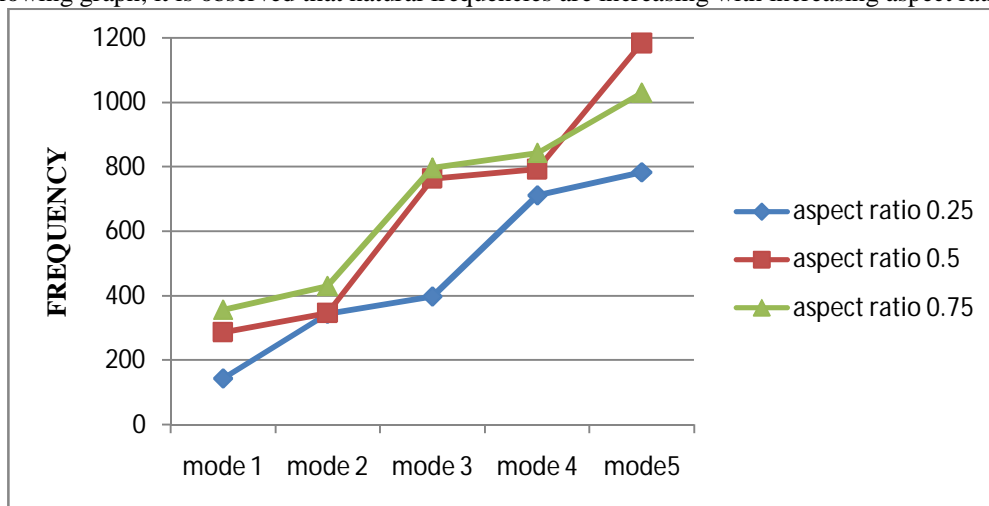


Figure 5.2 Chart for flat Aluminum plate with different aspect ratios

VII.CONCLUSION

In this work , the vibrations of plate are analyzed using both the experimental and theoretical (ANSYS) have been done successfully. The experimental work is done for flat aluminum plate and plate covered with damping using tire tube with proportions one by third, two by third and with fully covered on one side of the plate. The theoretical study using ANSYS has been done for flat plat without damping. The results obtained from experimental work and FEA Analysis for flat aluminum plate is compared and graphs are drawn for the results. The first five natural frequencies are

International Journal of Innovative Research in Science, Engineering and Technology

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Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

derived from both experimental work and simulation for flat aluminum plate. The natural frequencies obtained for flat aluminum plate and plate covered with damping from experimental work. These results are analyzed and the error percentage calculated shows that the values that are obtained from the experimental work are not much deviated from the results obtained from the FEA of the flat Aluminum plate. It is also observed that the values of natural frequencies of flat aluminum plate and aluminum plate with covered tire tube sheets are significantly varied because of change in mass and properties of material.

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