Vibration Analysis of Laminated Triangular Plate by Experimental and Finite Element Analysis

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Abstract— This present paper deals with analysis of triangular plate with free-clamped-free boundary condition for different materials. The analysis performed for isotropic right triangular plate and for symmetrically laminated/composite triangular plates. For symmetrically laminated/composite triangular plate different materials as FRP, rubber, plastic are consider. The work is divided into two parts i.e. FEM analysis and experimental modal analysis. The object of modal analysis is to find out modal parameters as frequency and mode shapes. In experimental work, triangular plates fabricated and by using FFT analyzer, the modal parameters are determined. The results obtained in analysis compared graphically.
Keywords— Triangular Plate, Vibration analysis, modal analysis, laminated plates.

INTRODUCTION

Plates are important structural element in engineering applications, such as ship structure, aero plane structure, pressure vessel, missile liquid container etc.[2] Flat triangular plate with variable thickness are used in aerodynamic lifting and stabilizing surfaces on rocket, guided missile and high speed aircraft. The application of plate theories has recently become very important with the of speed turbo machines. Turbo machines employ rotating plates or blades; these cantilevered plates are most severely stressed element subjected to highly fluctuating forces. The dynamic analysis of these elements is of critical importance for safe operation of these units.

Laminated/composite plates are used in aerospace engineering application because of their many advantages over isotropic plates, for example, composites have higher strength-to-weight and stiffness-to-weight ratios. Maximization of these advantages can lead to better and more spacecraft that are economical design.[1]

STATEMENT OF PROBLEM

In present, case the right angle triangular plates of material Mild Steel and Aluminum as shown in figure. Every plate has thickness of h =3 mm and other sides as 150mm and 100 mm as shown in figure 1.

In the second case, laminated/composite right angle triangular plate having three layers and thickness for every layer as 1 mm and remaining sides same as above is considered. Every layer of composite material bonded together by matrix material. The problem is to determine natural frequencies of the plates in both cases with boundary condition as free-clamped-free.

The objective of the work is to formulate the plates of triangular shape under free-clamped-free boundary condition and with different materials.

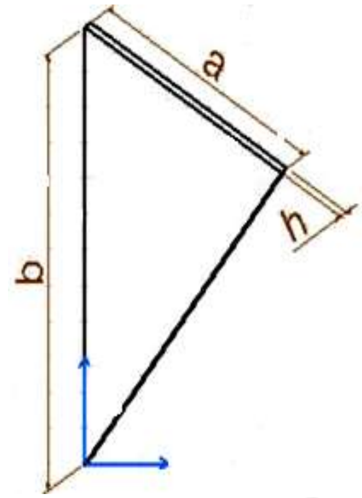

Figure.1 Geometry of triangular plate

FINITE ELEMENT ANALYSIS

Due to development, high speed Finite Element has become a powerful tool for the solution of wide range of engineering problems. The basic idea of FEM is to find the solution of complicated problems to improve the solution by spending more computational efforts. The ANSYS program is a large-scale multipurpose finite element program that may be use for solving several classes of engineering analysis.

The plate model prepared in ANSYS. The plates are in two different structures one is in basic solid plate of M.S. and Aluminum and other is laminated plate of given dimensions having thickness of 3 mm. Below fig 2 shows the mesh model of M.S. plate in ANSYS.

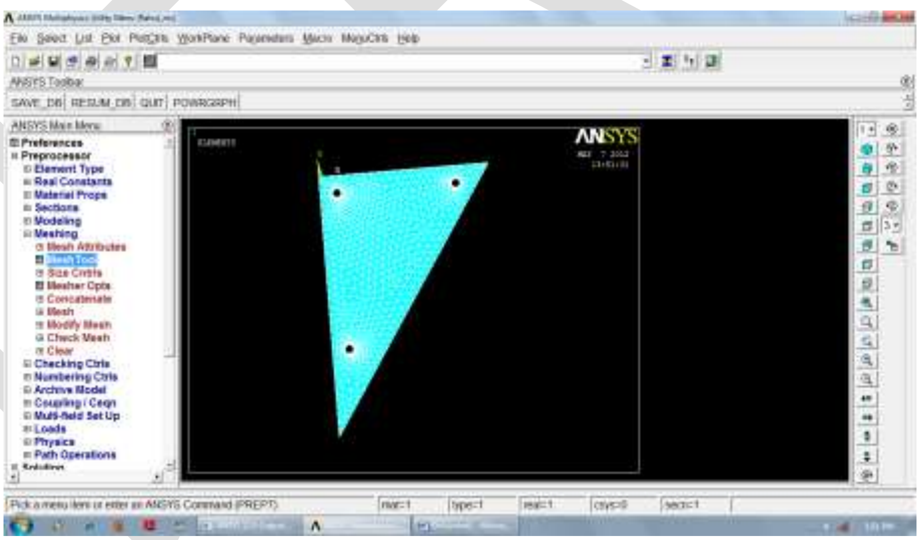

Figure.2 Triangular Plate (M.S.) mesh in ANSYS

EXPERIMENTAL METHOD

The experimental work conducted on FFT (Fast Fourier Transform) Analyzer. Here we use multichannel FFT (4-channel). One channel connected to exciter i.e. to the hammer and other connected to the sensor. During testing, the hammer struck on the plate to get the natural frequency peaks of the plate. The same procedure repeated for other plate. The results of experimentation are shown in Table no.1.

EXPERIMENTAL SETUP

The typical experimental setup is shown in Fig 3 and fixture for clamping of plate and FFT analyzer. The setup consists of hammer, sensor, and FFT analyzer and for display of result laptop. The FFT is multichannel (4 channel) one channel for hammer and one for sensor. The plates excited by hammer and the peak of natural frequency measured by sensor and display the result on laptop screen. The results of measurements are auto generated by FFT software in MS-Word format.

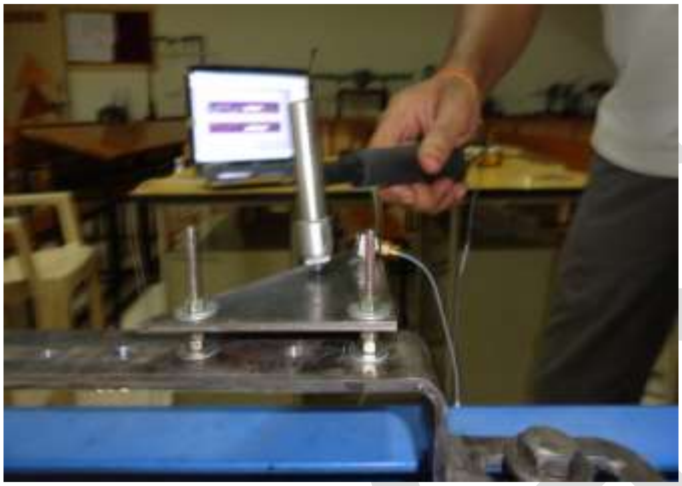

Figure.3 Experimental Setup for M.S. plate

RESULTS

For Mild Steel Plate Young's Modulus E = 2.1*1011 N/m2, Density ρ = 7850 kg/m3, Poisson's ratio γ =0.3, for Aluminum plate Young's Modulus E = 70*109 N/m2, Density ρ= 2710 kg/m3, Poisson's ratio γ = 0.33, for FRP (Fiberglass Reinforced Polymer) Young's Modulus E = 3*106 N/m2, Density ρ= 1799 kg/m3, Poisson's ratio γ = 0.25, for Rubber Young's Modulus E = 0.1*109N/m2, Density ρ= 1200 kg/m3, Poisson's ratio γ = 0.49, for PVC (Polyvinyl chloride) Young's Modulus E = 4.1*105N/m2, Young's Modulus E = 4.1*105N/m2, Poisson's ratio γ = 0.38. It is observed that the natural frequencies for M.S plate is much higher as compared to laminated plates. It is also seen that among laminated plates the frequencies for rubber-laminated plate is lower as compare to PVC and FRP material. Same effect would observe for Aluminium composite plates. The first natural frequency for Al plate is about 202.60 Hz meanwhile the first natural frequency for rubber composite plate is 113.367 Hz which is again much lower as compare to other composite plates of Al.

Factors Responsible for Result Variations

1) Mass Loading Effect

The mass effect of instrumentation can cause an effect on measured vibration spectrum which give deviation in the result.

2) Boundary Conditions

It is very difficult to achieve the exact boundary conditions for testing the model. This is the main cause for variation in the results.

The results of FEM and experimentation tabulated below.

Results of FEM Analysis

Mode No.	Frequency(Hz)							
	MS	MS-Rub-MS	MS-FRP-MS	MS-PVC-MS	Al	Al-Rub-Al	Al-FRP-Al	Al-PVC-Al
1	199.02	141.14	164.18	157.684	202.60	113.367	164.25	155.684
2	847.26	267.68	228.06	227.40	851.22	217.142	222.28	224.55
3	1379.2	327.28	429.26	348.06	1368.9	282.542	435.37	342.76

Table.1 Natural Frequencies Values obtained from FEM Analysis for All Plates for The Condition Free-Clamped-Free Right Triangular Plate.

Results of Experimental Modal Analysis

Mode No.	Frequency (Hz)							
	MS	MS-Rub-MS	MS-FRP-MS	MS-PVC-MS	Al	Al-Rubber - Al	Al- FRP - Al	Al - PVC - Al
1	183.89	146.82	170.43	142.38	188.93	121.17	154.51	146.82
2	844.28	270.19	232.13	230.54	875.06	192.80	193.80	217.23
3	1370.89	314.27	433.94	340.59	1319.12	275.01	440.18	353.91

Table.2 Natural Frequencies Values obtained from FEM Analysis for All Plates for The Condition Free-Clamped-Free Right Triangular Plate.

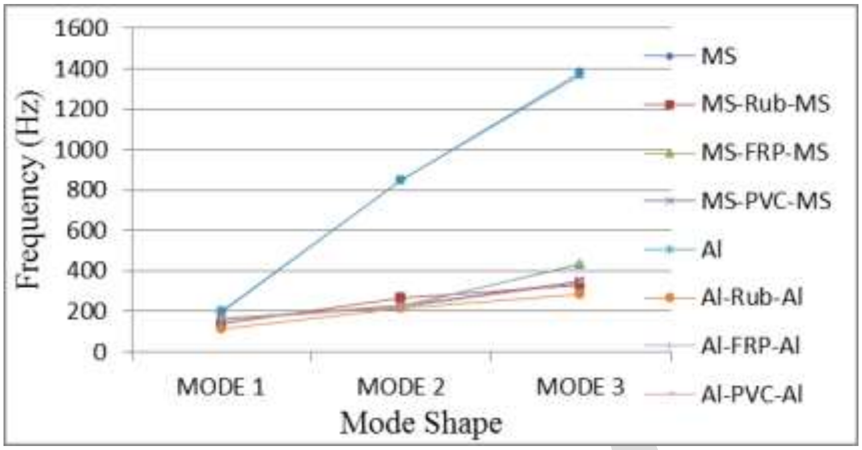

Figure.3 Variation in The Values of Natural Frequencies obtained from FEM Analysis, For All Plates.

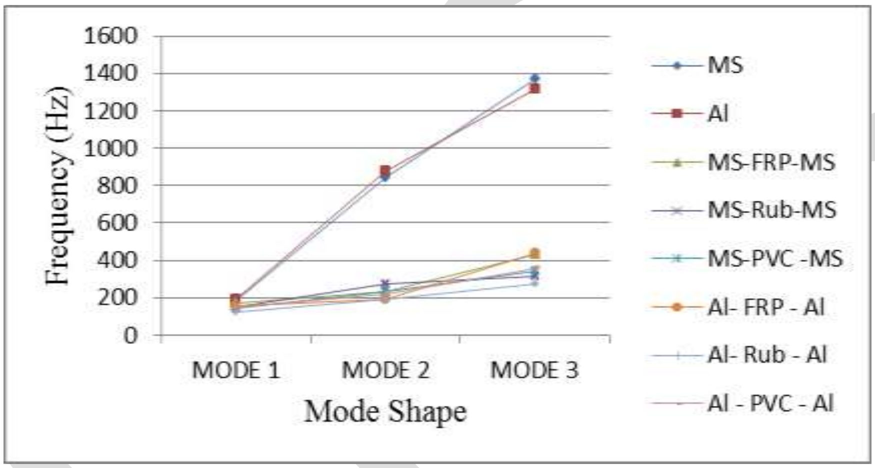

Figure.4 Variation in The Values of Natural Frequencies obtained from FEM Analysis, For All Right Triangular Plate.

CONCLUSIONS

The major objective of this dissertation work is to find the modal parameters i.e. natural frequencies and mode shapes of isotropic triangular plate and for laminated/composite plates. In this work dynamic analysis of triangular plate by using FEM and experimental analysis is carried out. Results from FEM and experimental are compared to verify the practical feasibility.

It is clearly shows that as material for the plate changes from Mild Steel to Aluminum, and for laminated/composite plate Mild Steel to Aluminum-rubber-Aluminum, natural frequencies shifts from upper side to lower side as shown in the figures 3 and 4.

As there is change in material, natural frequency changes, due to changes in material density. The percentage variation in the results obtained from FEM analysis and experimental modal analysis is up to 10%.

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