Effect of Epoxy Glass Fiber Reinforcement on Dynamic Characteristics of Sheet Metal Structure

Sankalp.U. Joshi, Nishant.S.Kulkarni

Abstract: ***Stamped sheets are widely used in automotive and industrial structures. Their stiffness and strength depends on various shapes in which they are stamped (trapezoidal, semi-circular). Epoxy glass fiber is widely used for replacing the actual components or by reinforcement. Reinforcement of this sheet metal structures with epoxy glass fiber will adhere its strength characteristics and also help in stiffing the structure. In order to use same shape of structure with high stiffness reinforcement of epoxy glass fiber can be used on that structure. Vibration of plates greatly depends upon various characteristics like aspect ratio, boundary condition and fiber orientation. The developed shape of structure after sheet metal processing and the thickness of the structure also contributes to its stiffness. Present study involves vibration analysis based on the geometry of the stamped sheets. Fixed – fixed boundary conditions are taking into the consideration, because Stamped sheets generally fails at fastened locations or welded locations. Modal analysis is performed to study dynamic characteristics of reinforced structures. In order to validate the experimental results Comparative analysis is carried out by using finite element analysis. Conclusions are drawn and suitable future scope is suggested.***

Index Terms: Epoxy Glass Fiber, Modal analysis, Finite element analysis,

I. INTRODUCTION

Literature review is based on the different kinds of detailed examination of composite materials. Basically, composite material is a mixture of more than one type of materials having different properties. Composite materials are required to create a product whose all types of characteristics are better than the sum of the combining materials. The variety of application has been increasing because of various aspects such as technical inventions, advanced manufacturing methods which can be used in composite materials. In many industries composite materials used as substitution for metallic products. The external excitation forces or unbalanced forces or couples causes vibrations in machines as well as in mechanisms. Because of these vibrations, excessive stresses are generating in machine parts. It leads to loosening of assembled components. It can also lead to failure of machines or machine components. **S.S.Chavan. [1]** presented experimentally and theoretically that natural frequency increases with increase in aspect ratio as well as changing the fiber orientation also can cause on the natural frequency. **Crawley E.F., J. Compos. Mater. [2]** examined experimentally and theoretically that the natural frequencies and mode shapes of 8 ply graphite/epoxy cantilever plates of various laminates and aspect ratio. **Erkliğ. [3]** investigated the natural frequency and damping properties consisting of various combinations of S-glass, carbon, and Kevlar fibres. They conducted experiments on hybrid composites under the combinations of clamped (C), free (F) and simply supported (SS) boundary conditions. They showed that maximum and minimum frequency values occurred in C-FC-F and C-F-F-F edge conditions respectively. **Pushparaj Pingulkar, Suresha B**. **[4]** worked on the natural frequencies and mode shapes of plate of glass fiber reinforced polymer composites (GFRPCs) and carbon fiber reinforced polymer composites (CFRPCs) are obtained using the commercial finite element analysis software (ANSYS). **S.U.Ratnaparkhi, S.S.Sarnobat.[5]** experimentally and theoretically studied that the natural frequency increases with increase in the fiber orientation. This paper is about effect of vibration analysis of stamped sheets with reinforcement of epoxy glass fiber on it. In this study, analysis plane sheet, circular shape sheet and trapezoidal shape sheet with and without reinforcement of epoxy glass fiber are taken in order to analyse the effect on natural frequency. Present study involves in research in the domain of fixed-fixed boundary condition of composite plate and to check the changes in stiffness and in mode shapes.

A. Scope

The scope of study includes the following:

- Modal analysis of plane, circular, trapezoidal shape sheets as well as glass fiber reinforced sheets using FEA.
- Validation of the obtained results experimentally using FFT analyzer.
- Determining the affecting parameters on natural frequency.

II. MODAL ANALYSIS USING FEA

In present study, fabrication method is essential for making the composite plate in proper manner. Composite plate can be made by using various methods. Matrix material and the fundamental integral are the important factors on which fabrication method depends. In our case Hand lay-up method is used. Simulation is done in ANSYS software.

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A. Experimentation

1. Geometric property

Plane sheet, Circular shape stamped sheet and Trapezoidal shape stamped sheets are taken for the experimentation. By using hand lay-up method reinforcement of epoxy glass fiber added to all these sheets. That means total number of 6 plates are considered for the modal analysis, first three of without reinforcement of epoxy glass fiber on plane sheet, circular shape sheet and trapezoidal shape sheet and next three plates are of with reinforcement of epoxy glass fiber (EGF) 320mm (L)*320mm (W)*3mm (THK**)** is the dimension of sheet with epoxy glass fiber (EGF).

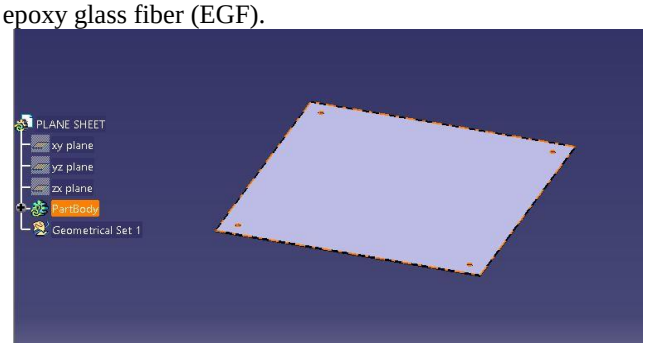


Fig.1.Geometry- Plane shape sheet

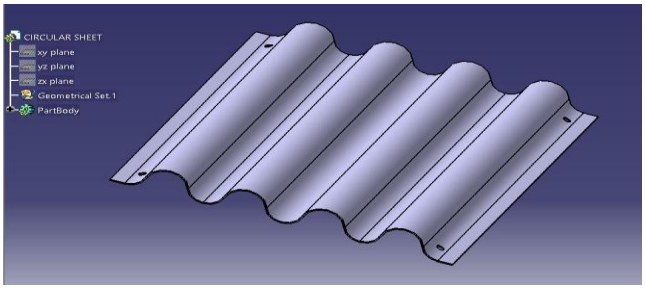


Fig.2.Geometry- Circular shape sheet

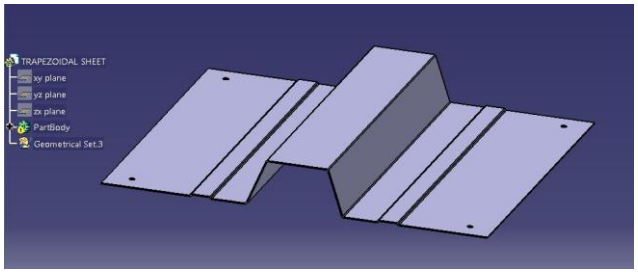


Fig.3.Geometry- Trapezoidal shape sheet

FEA involves three stages of activity:

- The physical problem which will be modelled to solve using finite element method.
- Flexibility method and stiffness method, these two are the approaches which can be used in finite element method as applied to structural mechanics.
- Evolution of the solution is done by sorting, printing and plotting the selected results from finite element method solutions.

B. Meshing

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient Multiphysics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it. The power of parallel processing is automatically used to reduce the time that have to wait for mesh generation.

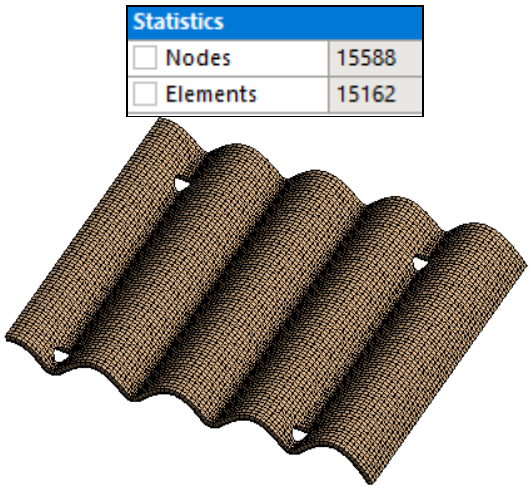


Fig.4. Meshing of Circular shape sheet with E.G.F

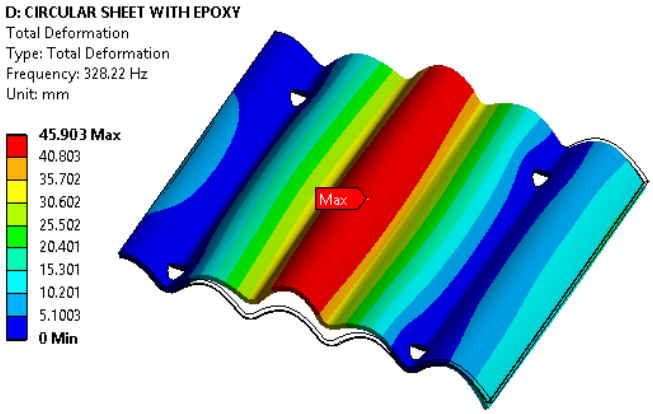


Fig.5. First Mode shape of circular shape sheet with E.G.F

- The results obtained from FEA is given in the Result table.

2. Fabrication Method

Hand lay-up technique is the oldest method of woven composite manufacturing. The samples are prepared by respecting some steps. Stamping of sheet metal is done according to required cross section. Fillets are provided at the sharp bending's. First of all, the sheet metal surface is treated by release of adhesive agent i.e. polyester resin on the surface. The layers of reinforced material i.e. glass fiber are cut to required shapes and placed placed on the surface of the sheet metal. Thus, as previously mentioned, the resin mixed with other ingredients and infused onto the surface of reinforcement already positioned in the fixture using a help brush to uniformly spread it. And then the other mats are placed on the preceding glass fibre layer and pressured using a roller to remove any trapped air bubbles and to achieve required thickness.

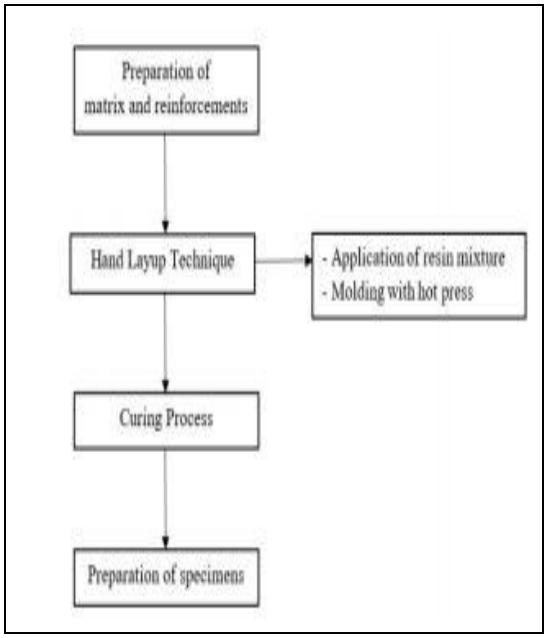


Figure no. 1 Schematic layout of fabrication method

III. TESTING

For experimental testing of sheets having fixed-fixed boundary condition, FFT analyzer is used.

A. Test Setup

Impact test can be accurately done by minimum requirements of following apparatus:

- Tri-axial Accelerometer.
- Impact Hammer with load cell at the tip.
- Multi-channel Vibration Analyzer (At least two-channel).
- A PC or a Laptop loaded with DEWESOFT software (in our case) for modal analysis.
- All types of testing sheets
- Electricity supply for the laptop and analyzer, link cables for the impact hammer and accelerometer, to fix the testing sheets into the fixtures it requires spanner and fasteners, to set the accelerometer it requires wax or adhesive.

Connections are made by using instruction book. Impact hammer is used to excite the sheets. Each corner of sheet is at fixed conditions.

B. Test Procedure

- Mount the testing plates with desired boundary condition. The plate is fixed at each corner using designed fixtures. Then split the plate into the segments by marking equidistant points, it is also required to define the point numbers to use later in the software.
- Attach the required connections.
- After turning on the electricity supply, open the software for modal analysis in the laptop. Provide the needed inputs and confirm the final setting in the software. Confirm that the supply and the communications between devices is very well connected.
- Now hit the impacts by using impact hammer on the nodes marked on the plate or sheet one by one. Impact will be given at each node. Accelerometer is connected at the centre node of the plate.
- The received signals by the vibration analyzer from the accelerometer and the impact hammer for each impact provided one by one will be analyzed and compared by the software (DEWESOFT). The generated frequency response function will be used to find natural frequency of the plate.
- Observe the peaks of the curve which corresponds to their respective natural frequencies.

Figure no. 2 Experimental setup

- Note down the observed frequencies.

IV. DATA ANALYSIS

Table no. 1 Data of plane shape sheet

Shape of the Plate	Mode no.	Experimental frequency (Hz)	Simulation frequency (Hz)	Error (%)
Plane sheet without Epoxy Glass Fiber (EGF)	1	39.06	47.762	17.83
	2	83.008	81.06	2.3467
	3	97.65	89.67	8.172
	4	131.78	124.3	5.6761
	5	141.6	144.47	2.0268
Plane sheet with Epoxy Glass Fiber (EGF)	1	141.529	147.23	4.0281
	2	268.55	273.15	1.7129
	3	302.73	297.12	1.8531
	4	329.14	324.81	1.3155
	5	449.29	475.28	5.7846

Table no. 2 Data of circular shape sheet

Shape of the Plate	Mode no.	Experimental frequency (Hz)	Simulation frequency (Hz)	Error (%)
Circular shape sheet without Epoxy Glass Fiber (EGF)	1	87.89	106.05	18.98
	2	117.18	126.8	8.166
	3	141.6	140.84	0.5367
	4	185.54	180.98	2.4576
	5	253.9	271.39	6.8885
Circular shape sheet with Epoxy Glass Fiber (EGF)	1	302.73	328.22	8.42
	2	336.9	394.98	17.23
	3	419.9	429.63	2.3172
	4	522.46	565.7	8.2762
	5	737.3	750.85	1.8377

Table no. 3 Data of Trapezoidal shape sheet

Shape of the Plate	Mode no.	Experimental frequency (Hz)	Simulation frequency (Hz)	Error (%)
Trapezoidal shape sheet without Epoxy Glass Fiber (EGF)	1	73.24	72.442	1.10
	2	107.42	105.16	2.1038
	3	117.18	109.49	6.5625
	4	122	128.62	5.4262
	5	195.31	196.08	0.4031
Trapezoidal shape sheet with Epoxy Glass Fiber (EGF)	1	214.84	227.02	5.6693
	2	332.03	341.66	2.9034
	3	356.44	344.49	3.3516
	4	429.68	413.23	3.8284
	5	639.64	628.59	1.7275

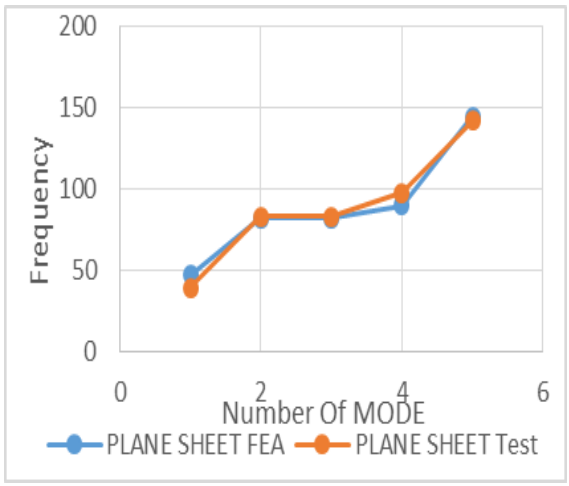
V. RESULTS AND DISCUSSION

The experiment shows that stamped sheets has more natural frequency than plane sheet. In our case, circular shape sheet has more frequency than trapezoidal and plane sheet. Also it can see by adding composite, natural frequency increases. That means sheets gets stiffer than previous. Natural frequency increases with change in shape of the sheet. The error occur between experimental frequencies and simulation frequencies is because of following reasons:

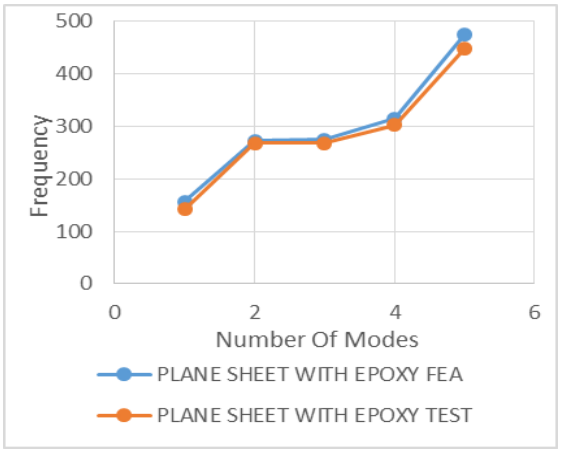
1. Stability of product quality is not enough good since it is made by hand lay-up method.
2. Experimental environment is not same at every instance.

Following graphs shows the comparative analysis between FEA v/s Experimental for every type of shape:

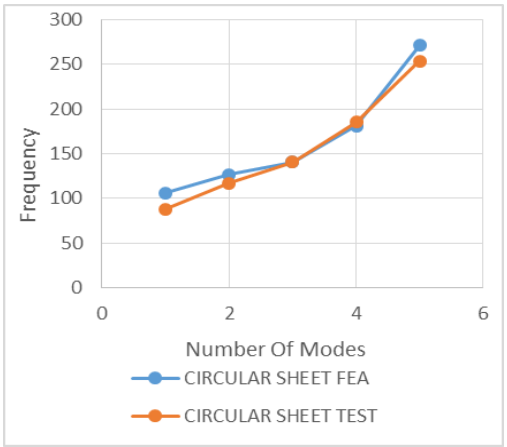
1) Plane sheet without epoxy glass fiber (EGF) -



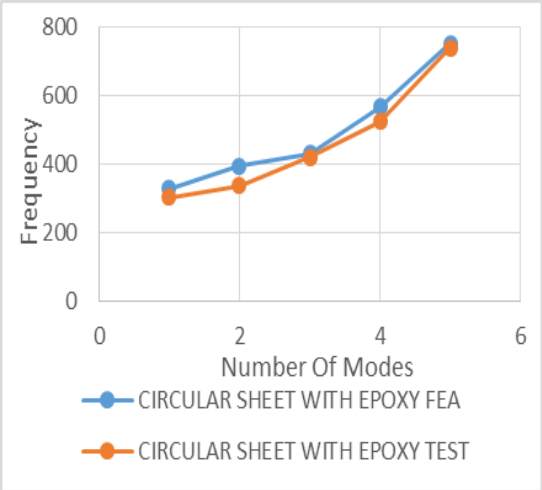
2) Plane sheet with epoxy glass fiber (EGF) –



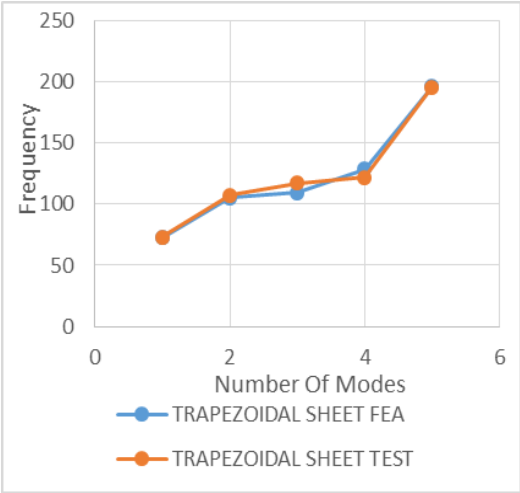
3) Circular sheet without epoxy glass fiber (EGF)-



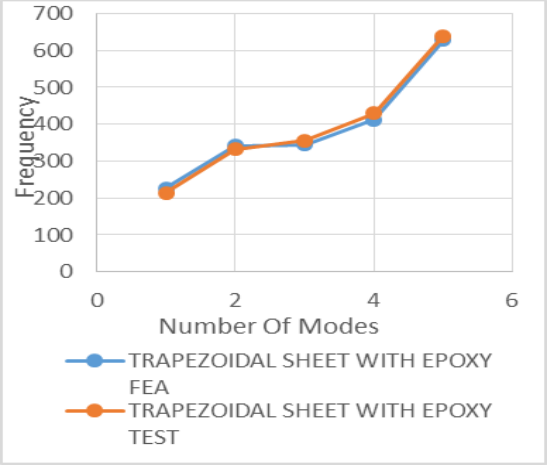
4) Circular sheet with epoxy glass fiber (EGF) -



5) Trapezoidal sheet without epoxy glass fiber (EGF) –



6) Trapezoidal sheet with epoxy glass fiber (EGF)–



VI. CONCLUSION

Composite materials has excellent substantial properties. The values of fundamental natural frequencies of the sheet gained by the composition of fiber glass and epoxy resin on various shapes of the stamped as well as plane sheet. FEA solution and experimental solution shows the same results which is adequate. So far design engineering is concerned, manufacturing process plays the major role.

From above results it is seen that the natural frequency depends upon stiffness. Change in the shape of sheet causes change in the stiffness. This means, stamping of sheets gives more stiffness so that its natural frequency is also get increases.

From the analysis of plane, circular, trapezoidal type sheet and all the sheets with epoxy glass fiber (EGF), it is seen that circular shape sheet with epoxy glass fiber has more stiffness since stiffness is directly proportional to natural frequency.

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