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FEA & Experimental Analysis of Viscoelastic Material with Damping Effect on Sheet Metal Canopy of DG Sets

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Abstract— The sheet metal structures (Canopy) used in DG sets are mostly susceptible subjected to the various static and dynamic loads during their oscillation cycles. Due to this, they encountered resonance condition at various operating frequencies. Resonance leads to harmonic excitation which further introduces the deformation and stresses leading to the failures of sheet metal structures. Reframing of sheet metal structure with the help of elastic material such as rubber, foam, bitumen, NBR latex etc. changes the stiffness of structure. Thus, stiffness alternation leads to change in dynamic characteristics like natural frequency, mode shapes, harmonic response. Modal and Harmonic analysis will be simulated using FEA (Ansys Workbench). In experimentation, Impact hammer test and FFT analyzer was used for the validation purpose. Natural frequencies for sheet metal structure with and without reinforcement calculated. Results and conclusion were drawn by comparing analytical and experimental values. Suitable material will be suggested by analyzing the data along with future scope.

Keywords— Vibrations, Canopy, Sheet Metal Structures, Stamped plates, Viscoelastic material, Damping, DG sets.

INTRODUCTION

Nowadays, addressing vibration and noise issues is essential to the improvement of performance and operational perception in advanced engineering structures and systems. Passive and active structural damping can attenuate a system's vibration and noise through the proper use of materials that possess enhanced damping properties. [1] In recent research, the most popular method to make this attenuation more predictable has been the use of material damping; this typically involves the application of high damping materials like viscoelastic materials. For almost half of a century, researchers have conducted studies on topics including: analytical or numerical modeling techniques of different damping treatments; mathematical representations of damping properties; control strategies by the piezoelectric material and optimization or identification of the damping structure. [2] Among the different viscoelastic damping treatments, constrained-layer damping structures are the most efficient approach when introducing damping to a system.

The issue of deceasing the level of vibration in system arises in various branches of engineering, technology, and industry. During recent years, there has been considerable interest in the practical implementation of these vibration control systems. Many studies focus on the constrained-layered viscoelastic structure. [3] The majority of these studies are based on the three-layer constrained sandwich beam due to its ability to include all of the factors that influence the system damping properties. It turns out that relatively few works have focused on the multiple-layer constrained sandwich beam and its ability to further reduce noise and vibration. Further, the acoustical performance of the damping structure is increasingly focused on the arbitrary type of excitation. Hence, it is of great importance to study the vibration and acoustical performance of the multiple-layer sandwich beam as it relates to the changes of influencing factors. The objective of my research paper is to propose a systematic fibro-acoustical design for the multiple layer constrained damping beam and to establish a quantitative relationship between vibro-acoustical responses and external factors, including ambient temperature, frequency, combinations of different materials, excitation type, etc.

This research began with an in-depth investigation into the damping mechanism using the frequency-domain Biot model. [4] In order to study the vibration characteristics of the damping system, using this Biot damping model, several numerical examples were studied including the lumped-mass system and the multiple-layer sandwich beam modeled by the Finite Element (FE) technique. The semi-coupled acoustical problem was solved by the Boundary Element (BE) technique. These investigations and the resulting calculations are the major contributions of this research in damping. The background is the result of a detailed literature review and provides a concise introduction to recent damping mechanism theory.

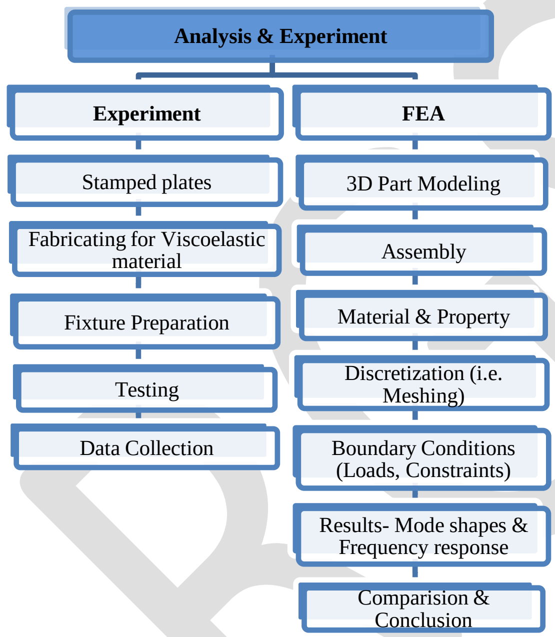
PROBLEM DEFINATION

In DG set, due to high engine rpm and it's connecting sub parts are tends to make vibrations and acoustic noise. The sheet metal structure (canopy) is made up of very thin structural material as compared to other parts of DG sets. The unwanted and unnecessary vibrations pose a potential problem to the designer and other maintenance people. Therefore, it is necessary to reduce those vibrations with the help of damping materials by analyzing it.

OBJECTIVES

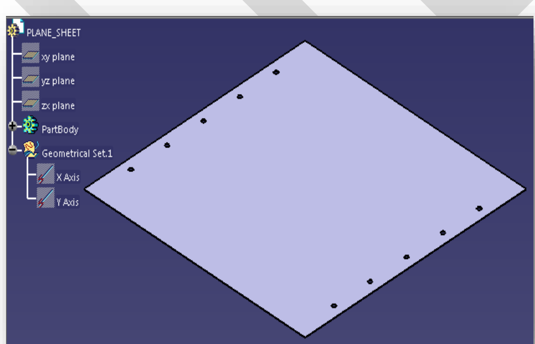
- Modeling stamped plates.
- Analyzing for mode shapes and frequency response.
- Noise optimization by adding viscoelastic material to model.
- Experimental testing and correlating results.

METHODOLOGY



FEA OF SHEET METAL STRUCTURE REINFORCED WITH VISCO-ELASTIC MATERIAL –

Sheet metal is modeled with help of CATIA V5 software –



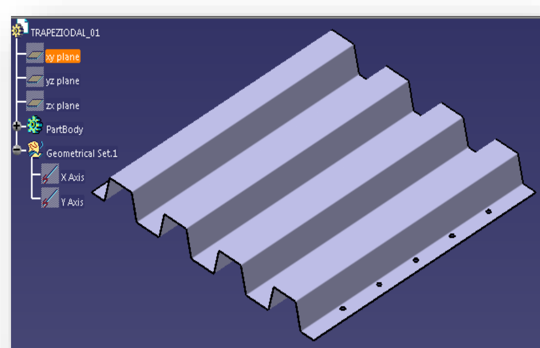


Fig. 1 – Plane sheet metal structure geometry

Fig.2 – Rectangular sheet metal structure geometry

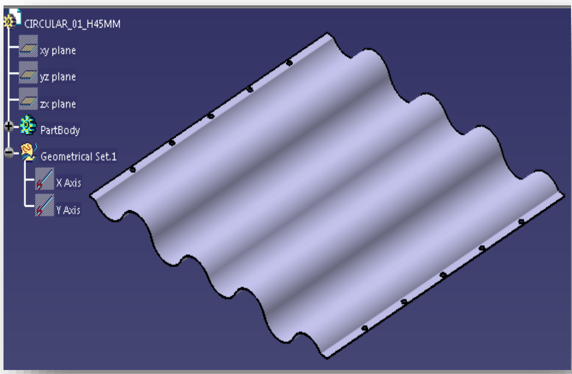


Fig.3 – Circular sheet metal structure geometry

Material properties: Material- Structural Steel

Young's Modulus- 200 GPa, Poisons Ratio- 0.3

Density- 7850 kg/m^3 , Yield Strength- 520 MPa

Meshing: A solid element mesh is required to be generated. The meshing of the side panel is done in Ansys software.

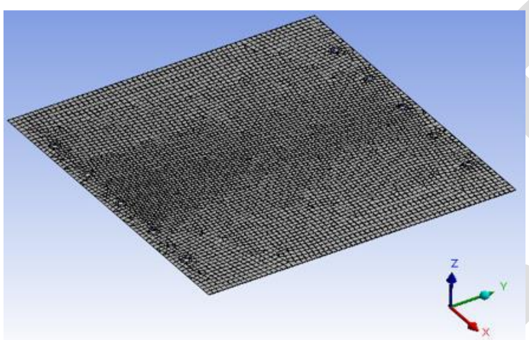


Fig.4 - Plane Sheet Metal Meshing

Element Type: Hexahedron, Tetrahedron
Node: 6047
Element: 5966

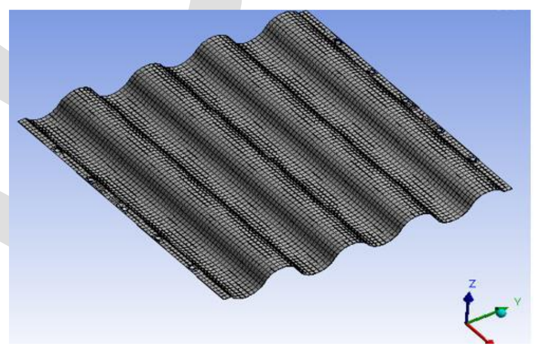
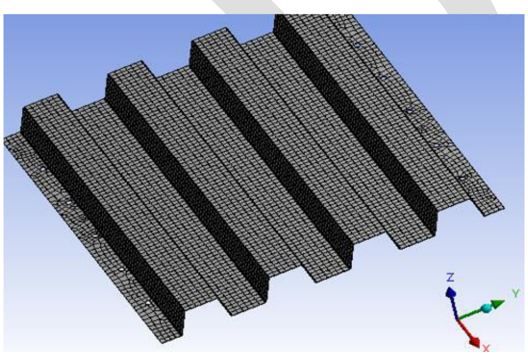


Fig.5 - Circular H-45mm sheet metal structure meshing

Element Type: Hexahedron, Tetrahedron
Node: 42439
Element: 5943



Element Type: Hexahedron, Tetrahedron
Node: 66616, Element: 6396

Fig.6 - Trapezoidal H-55mm sheet metal structure meshing

Free - Free Vibration -

Constraints: The nodes around the side panel holes have a rigid element connecting them to the center of the hole which has of its degree of freedom fixed. The element which is used to fix side panel and vehicle is fixed and used as a rigid element. The minimum and maximum are set, together with other mesh parameters such as element type and material.

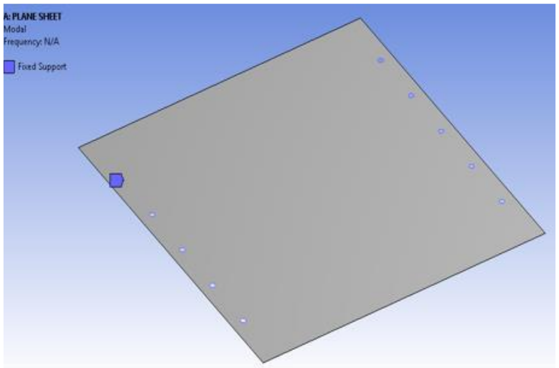


Fig.7 – Boundary Condition for Plane sheet

Post Processing of the Sheet Metal –

The acceptability of the design of the sheet metal needs to be considered from the results of the analysis. The guidance for the modification of the sheet metal need to be available if the design is not considered to be acceptable for the sheet metal is as follows.

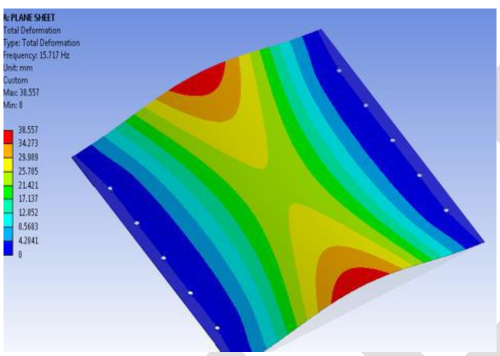


Fig.8 – Mode No. 1

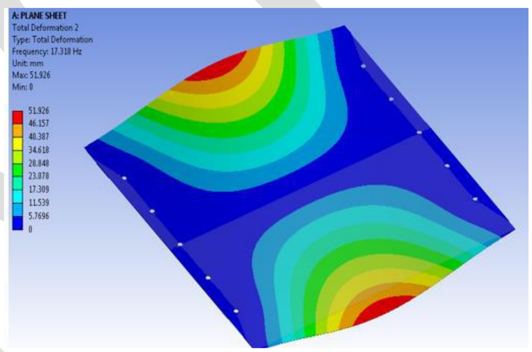


Fig.9 – Mode No. 2

Boundary Condition for Plane Sheet with Visco-Elastic Material –

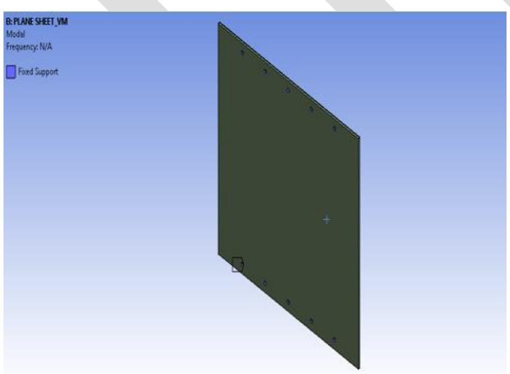


Fig.10 - Boundary condition with VM

Results for Plane Sheet with Visco-Elastic Material –

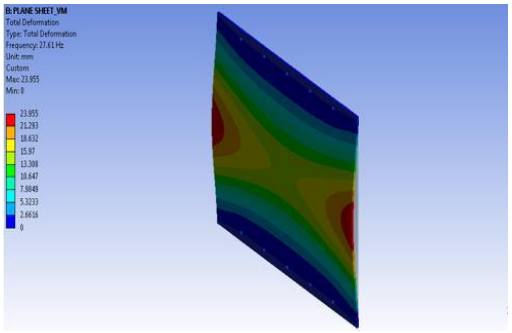


Fig.11 - Mode No. 1

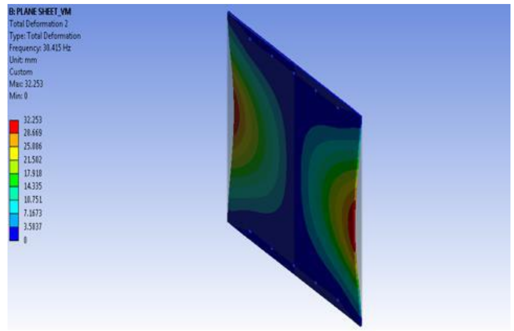


Fig.12 - Mode No. 2

Circular Corrugated sheet with & without VM –

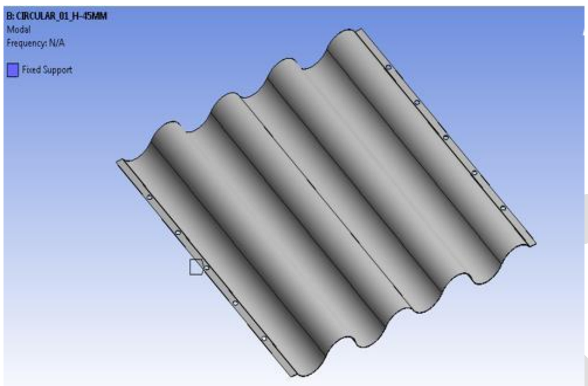


Fig.13– Boundary Condition for Circular Corrugated sheet structure

Post Processing of the Circular Corrugated Sheet structure

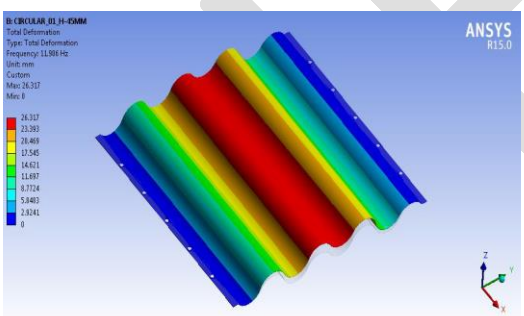


Fig.14 – Mode 1 for Circular Corrugated sheet

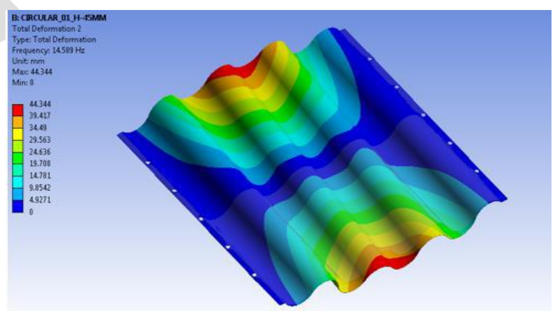


Fig.15 – Mode 2 for Circular Corrugated sheet

Boundary Condition for Circular corrugated sheet with Visco-Elastic Material –

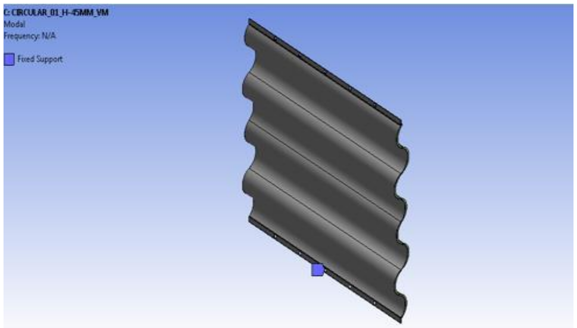


Fig.16 – Boundary Condition for Circular Corrugated sheet with VM

Results for Circular corrugated sheet with Visco-Elastic Material –

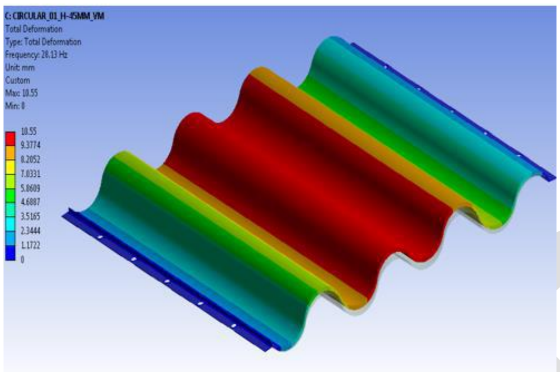


Fig.17 – Mode No. 1 for Circular Corrugated sheet with VM

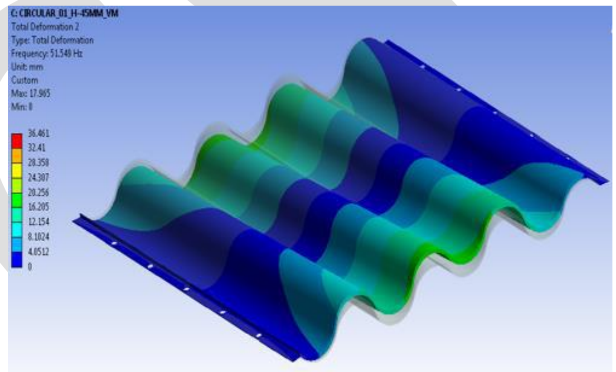


Fig.18 – Mode No. 2 for Circular Corrugated sheet with VM

Trapezoidal Corrugated Sheet structure with & without VM –

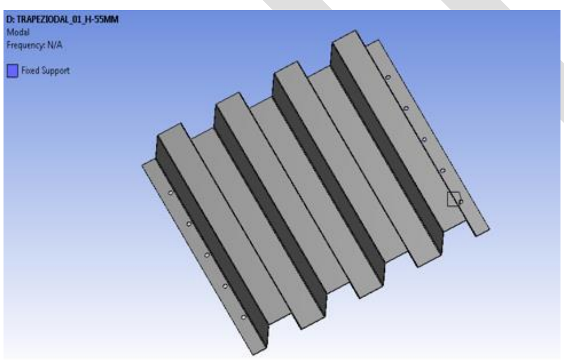


Fig.19 – Boundary Condition for Trapezoidal corrugated sheet

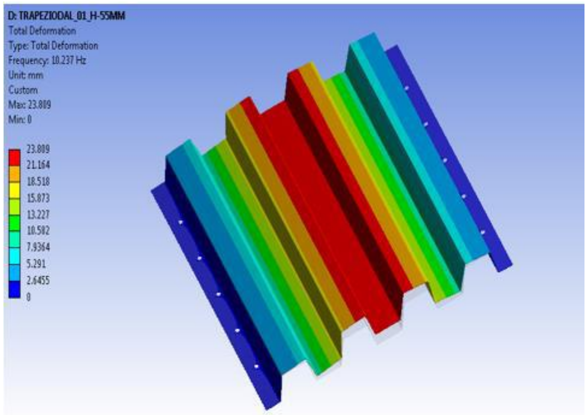


Fig.20 – Mode No. 1 for Trapezoidal corrugated sheet

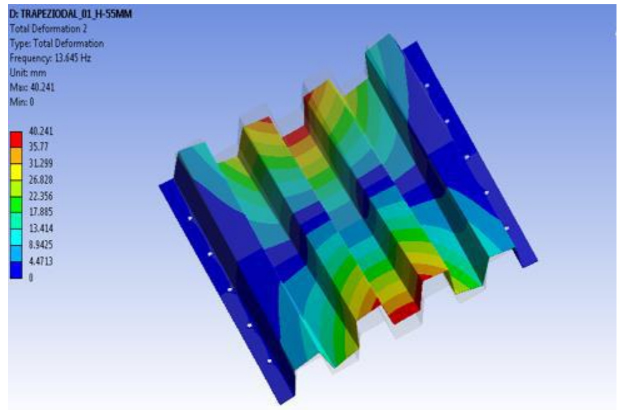


Fig.21 – Mode No. 2 for Trapezoidal corrugated sheet

Boundary Condition for Trapezoidal corrugated sheet with Visco-Elastic Material –

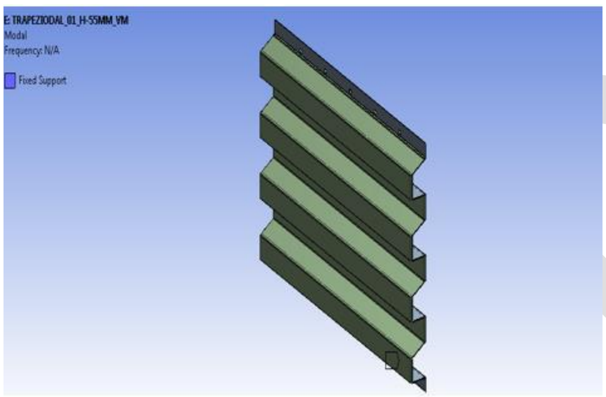


Fig.22– Boundary Conditions for Trapezoidal corrugated sheet with VM

Results for Trapezoidal corrugated sheet with Visco-Elastic Material –

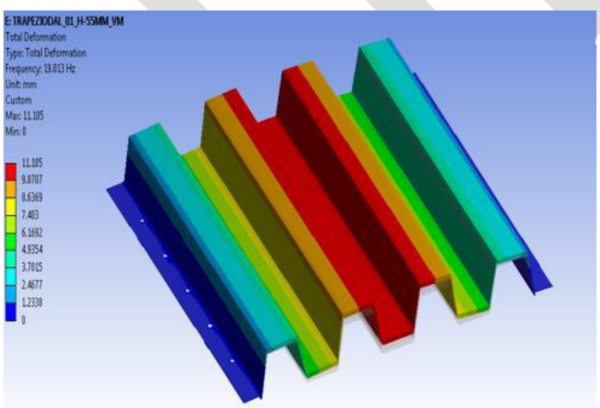


Fig.23 – Mode No.1 for Trapezoidal corrugated sheet with VM

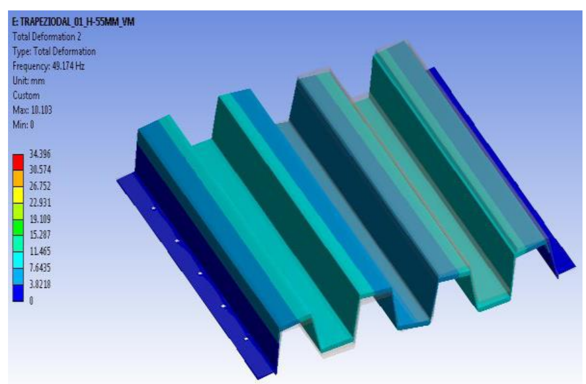


Fig.24 – Mode No.2 for Trapezoidal corrugated sheet with VM

RESULTS ANALYSIS -

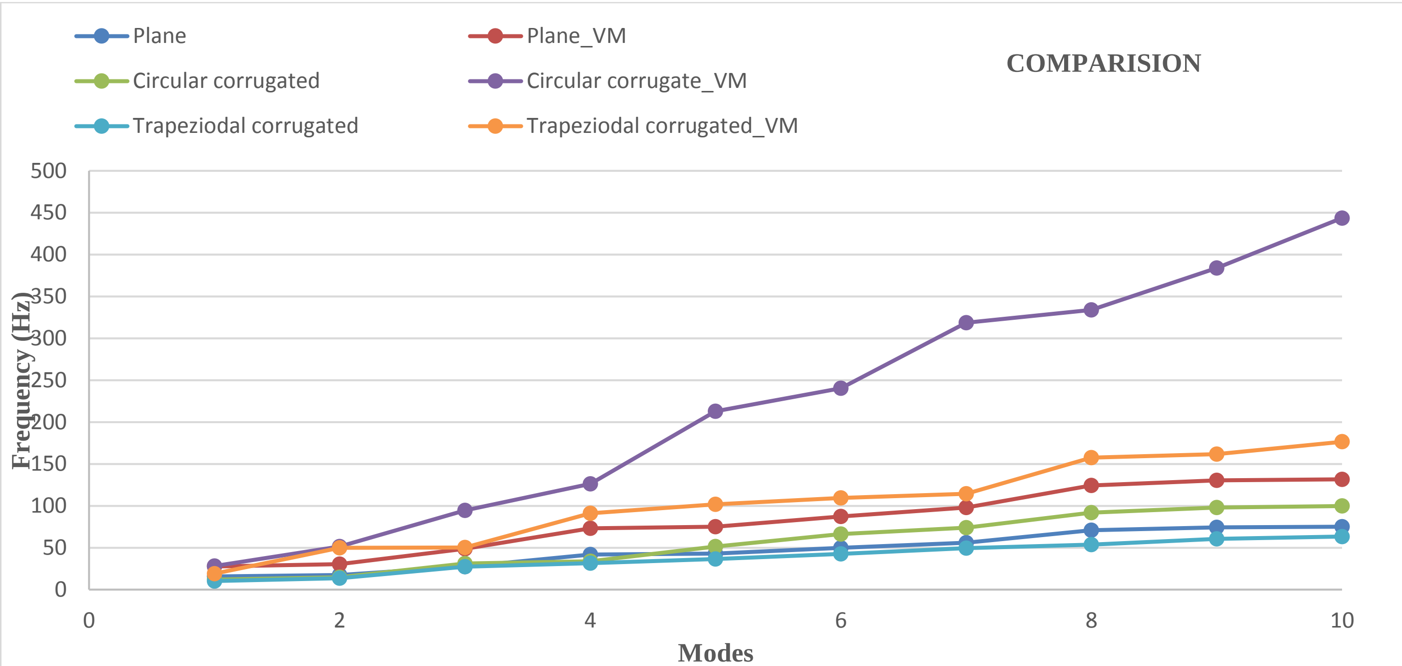
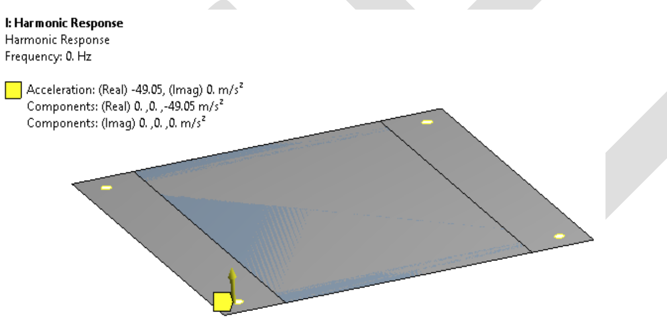


Fig.25 – Comparison between various structures

As by plotting the graph for Frequency vs Modes, the sheet with viscoelastic material is always gives increased frequency range than other sheet without viscoelastic material.

HARMONIC ANALYSIS -

The harmonic analysis is done in ANSYS software in order to find out the frequency response with respect to the amplitude of vibrations.



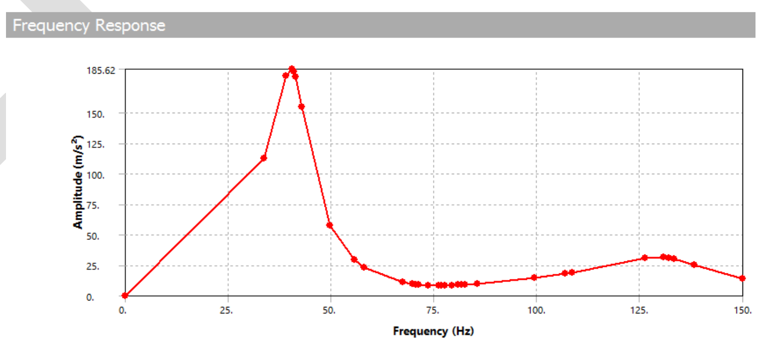


Fig.26 -Harmonic Analysis of plane sheet with damping

Fig.27 - Frequency response for plane sheet

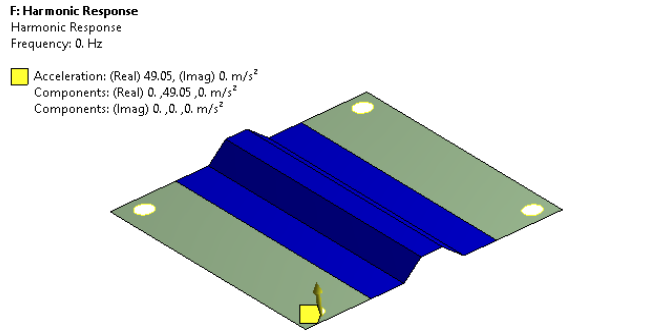


Fig.28- Harmonic Analysis of Trapezoidal sheet with damping

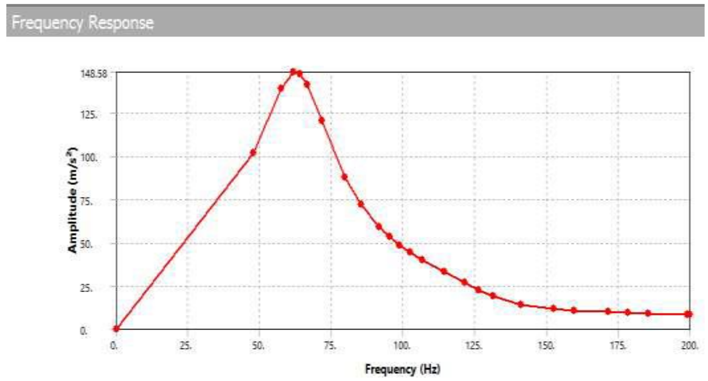


Fig.29- Frequency response for Trapezoidal sheet

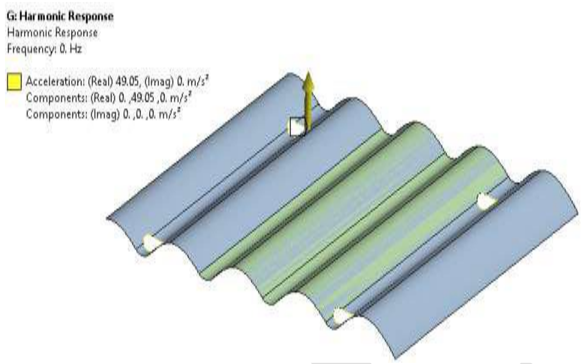


Fig.30- Harmonic Analysis of Circular sheet with damping

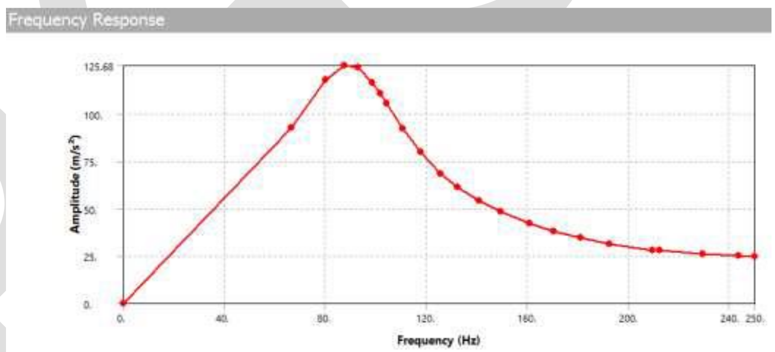


Fig.31- Frequency response for Circular sheet

EXPERIMENTATION –

Experimentation is carried with the help of FFT analyzer and Impact Hammer test. The test set up is as follows -

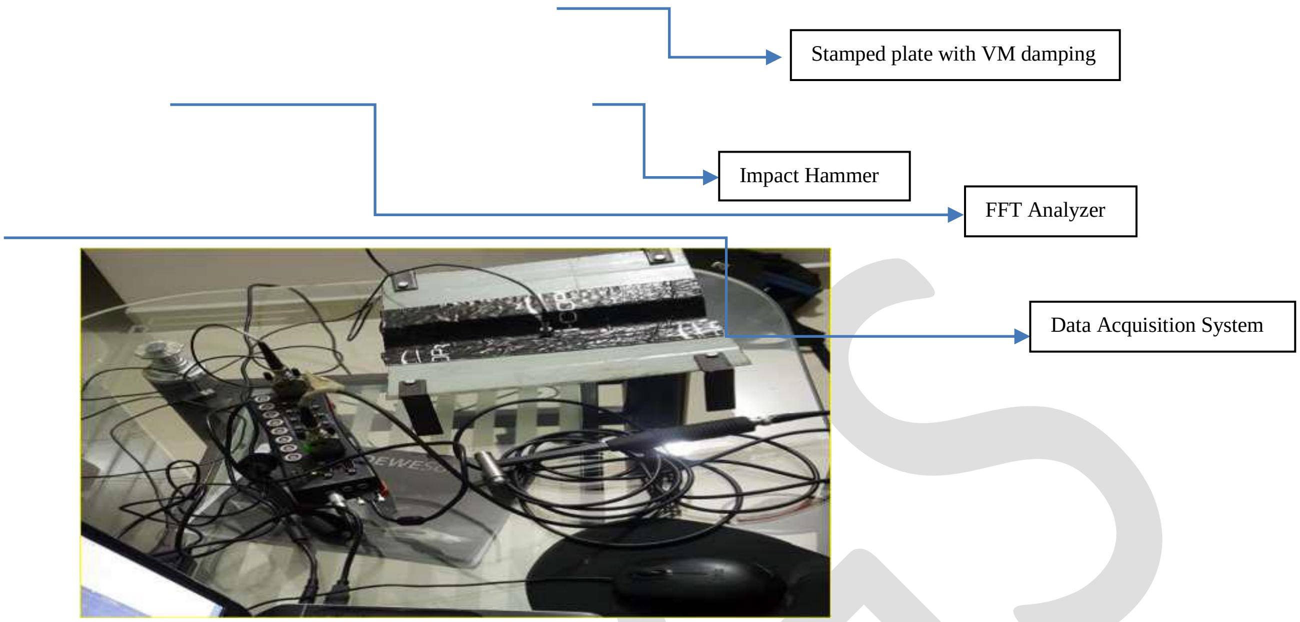


Fig.32 – Experimental test set up.

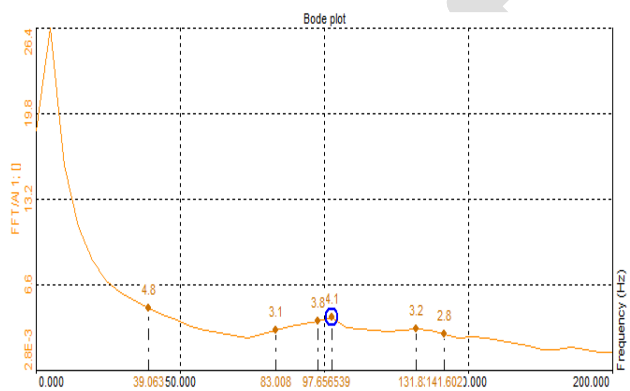


Fig.33- Graph of plane sheet

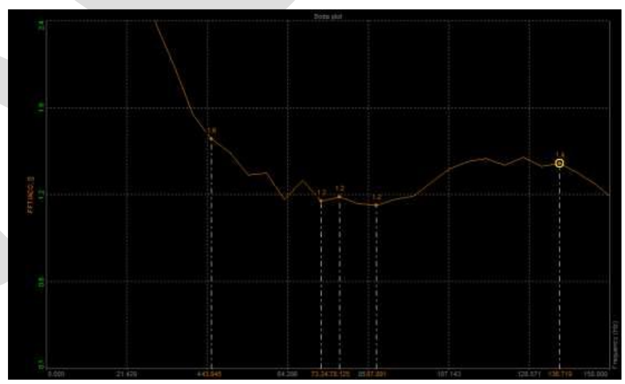


Fig.34- Graph of plane sheet with damper

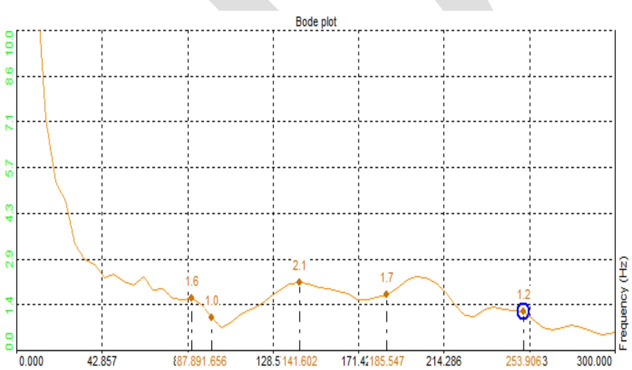


Fig.35- Graph of circular sheet

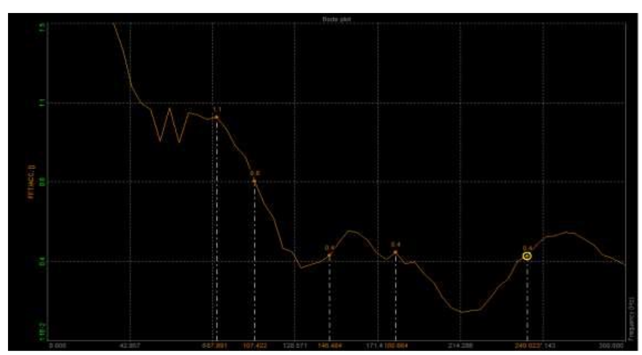


Fig.36- Graph of Circular sheet with damper

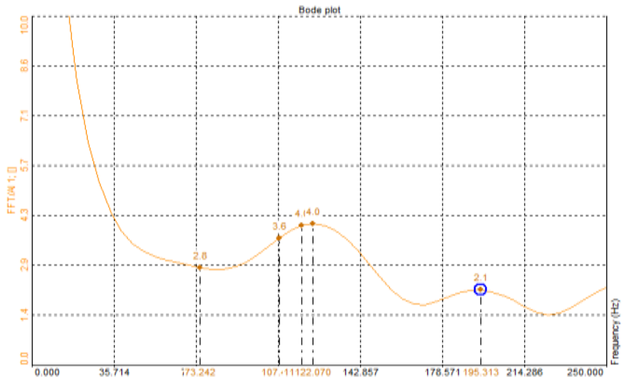


Fig.37- Graph of trapezoidal sheet

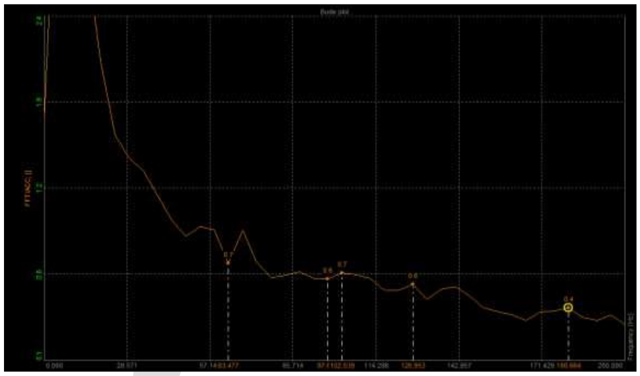


Fig.38- Graph of Trapezoidal sheet with damper

RESULTS -

After the Experimental testing & analysis results, it is seen that the natural frequency of the panel with the damper is less than that of the plane panel. So, it is clear that the vibration of the system will be reduced if the Visco-Elastic Damping material is added to the system. Modal analysis is used to calculate mode shapes and natural frequency of various shapes. Shell element used during analysis helps in achieving good co-relation with reference to experimental results. Results are in good relation with FFT analyzer (Data acquisition system).

Table.1 - Data for comparison of FEA & Experimentation

Mode Number	**Plane sheet with Viscoelastic (FEA)**	**Plane sheet with Viscoelastic (TEST)**
1	40.9	43.94
2	70.557	73.24
3	76.83	78.125
4	81.72	87.89
5	132.1	136.71

Mode Number	**Circular Sheet with Viscoelastic (FEA)**	**Circular Sheet with Viscoelastic (TEST)**
1	92.80	87.89
2	110.77	107.422
3	140.65	146.48
4	180.98	180.66
5	243.77	249.023

Mode Number	Trapezoidal sheet with Viscoelastic (FEA)	Trapezoidal sheet with Viscoelastic (TEST)
1	64.085	63.477
2	95.185	97.6
3	102.49	102.53
4	126.34	126.95
5	178.98	180.66

CONCLUSION

As frequency is related to both sounds (noise) and structural vibrations, stiffness can be controlled by altering shape, size and topology. Viscoelastic material helps in damping vibration that intern results in optimized frequency & dB level can also be included in future scope. The important points are

1. In case of various shapes, the corrugated one considerably shows the increase in frequency than plane sheet. The circular corrugated sheet structure gives higher frequency range than trapezoidal sheet structure. Hence, it is stiffer than other.
2. Natural frequency of FEA results and FFT experimental are in good relationship with each other.

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