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EXPERIMENTAL INVESTIGATION AND VIBRATION ANALYSIS OF COMPOSITE MATERIAL FOR ALLIGNING IT'S CHARACTERISTICS BEHAVIOUR TO ENHANCE IT'S USE IN ENGINEERING APPLICATIONS.

[1]Nilesh S. Navagale , [2]Rahul B. Barjibhe

[1]Research Scholar, [2] Prof. S.S.G.B.C.O.E.T., Z.T.C. Bhusawal. (M.S.)

[1,2] Mechanical Engineering Department,

[1,2] S.S.G.B.C.O.E.T.,Z.T.C. Bhusawal,, K.B.C.N.M.U. Jalgaon (M.S.)

Abstract: Composite material is a material made from two or more constituent materials or Viscoelastic Damping Materials (VDM) with significantly different physical or chemical properties. These materials when combined; produce a material with characteristics different from the individual components. Viscoelastic Damping Materials (VDM) have behaviour which falls between elastic and viscous extremes, therefore some of the energy is recovered upon removal of the load, and some is lost or dissipated in the form of thermal energy. The phenomenon of VEM opens a new horizon for researchers with a tremendous scope to design and investigate a new composite material especially for shock absorbing and vibration damping applications. The use of composites have become more and more important in engineering applications because of their low cost, light weight, high specific strength and good corrosion resistance. This research work aims to evaluate the response of composite material in order to enhance its use for the intended function. The work shall focus on identifying significant control parameters for vibrational characteristics and the effect of altering these parameters. The performance of the composite material in the context of vibration analysis shall be evaluated for offering recommendation of a set of levels for the configuration under study.

***Keywords* – Composite Material, VDM, FFT Analyzer, Damping, Variation in Thickness.**

I. INTRODUCTION

Experimental Modal Analysis is based on the use of experimentally determined data, which is obtained from a test specimen/structure. The modal parameter estimation methods are used to obtain modal parameters of the structure from the measured data. The purpose of experimental modal analysis - with Free - Free boundary condition is easier understand and realize the behavior of the structure and simply to validate the results of the Finite Element Model. Also, in testing ensuring the sure rigidity the fixed support or clamping is also not easy, for that case it is necessary go with Free- Free analysis. Most of the structural components are generally subjected to dynamic loadings in their working life. Usually these components may have to perform in dynamic environment where the maximum damage results from the resonant vibrations. Susceptibility to damage or fracture of materials due to vibration is determined from stress and frequency. Maximum amplitude of the vibration must be in the limited for the safety of the structure. Hence vibration analysis has become very important in designing a structure of component. It is necessary to know in advance its response and to take necessary steps to control the structural vibrations and its amplitudes. Especially in applications such as the Automotive, Aerospace and Machine Tool Industry, the effort of the Design Engineer is to minimize or negate the occurrence of vibrations thereby improving the perception of comfort and or contributing to reduced levels of noise. The challenge in doing this is to minimize the effort and cost of the component.

Though much work has been done on static analysis of an engine components such as connecting rod, crankshaft or Engine Mounting Bracket (EMB), very less has been reported on vibrational characteristics and it's control parameters. A number of research efforts have been devoted to the comparative study of materials such as Aluminum (Al), Magnesium (Mg), Grey Cast Iron (C.I.) etc. used for engineering applications, but very less work has been done on utilization of composite materials for such engineering applications. It is still needed to do the research work to investigate a new class of composite material with different Viscoelastic Damping Materials (VDM) to reduce the vibration characteristics. It is essential to analyze the effect of various factors such as No. of layers, aspect ratio, damping factor, vibration response amplitude, thickness of VDM, mode shapes etc. on the natural frequency.

II. Experimental Method

Sample Preparation:-

For case study of composite specimen/plate, consider three layers of different materials i.e. base layer, constrained layer with VDM (middle layer) and constrained layer. The Viscoelastic Damping Material (VDM) is considered in conjunction with constrained layer. Some of the important Viscoelastic Damping Materials (VDM) are:-1) Polyethylene 2) Poly Methyl Methacrylate 3) Polypropylene 4) Styrene Butadiene Rubber (SBR) 5) Nitrile 6) Butyl Rubber 7) Urethane etc. The base layer as well as the constraining layer is made of same materials such as aluminum alloy, Al 6061 T6. The Viscoelastic Damping Material (VDM) used for this sample is Butyl Rubber which is sandwiched between upper and constrained layer. The size of test specimen/plate is initially considered as the free length (L) as 350 mm and width as 50 mm. The thicknesses of Viscoelastic Damping Material (VDM) varies from 0.8 to 1.5 mm i.e.0.8mm, 1mm and 1.5mm. Accordingly three samples of composite plate are prepared and one sample is of purely Al6061 T6 material having no VDM which are shown in following table.

Table 1 Types of Specimen

Specimen Type	Composed Materials	Thickness (mm)		
		Al	VDM	Al
1	AL –VDM- AL	2	0.8	2
2	AL –VDM- AL	2	1	2
3	AL –VDM- AL	2	1.5	2
4	AL only	2	Not Present	2

The symmetrical composite specimen /plate consists of two layers of same materials such as aluminium alloy Al 6061 T6 & the Viscoelastic Damping Materials (VDM) Butyl Rubber in the core composed of a high strength acrylic double face adhesive as shown in fig.

Fig.1 Sample Preparation

The most suitable techniques for characterizing the material properties of Constrained Layer Damping CLD configuration in the medium frequency range (from 1 Hz up to several KHz) is the `Frequency Response Function Technique' (FRF). This technique offers potential for rapid non-destructive evaluation of material and structures. In this technique the specimen is excited impulsively with a controlled impact hammer with a force transducer attached to its head. The specimen response is sensed by an accelerometer. The signals from the force transducer and the accelerometer are sent to a Fast Fourier Transform (FFT) analyzer which displays the frequency response spectrum.

The experimental program shall consider layers of different Viscoelastic Damping Materials (VDM) whose properties are of interest. By analyzing the resonant peak for a particular mode, a measure of damping, is obtained from the real part of the response spectrum. The performance of constrained layer damping treatment depends to a large extent on the geometry and the type of constraining layer. The maximum amount of shear strain is usually accomplished whenever the constraining layer is of the same type and geometry as that of the structure to be damped. The types of specimen to be used in this test are illustrated in fig.1.

The experimentation will be performed on sandwich test CLD specimen of different viscoelastic materials by using passive damping technique. The dynamic responses of the specimens shall be obtained by means of accelerometer measurements during a free vibration test performed by employing instantaneous hammer impact as excitation. A typically test setup consists of the following equipment for data acquisition –

1. FFT System Hardware-

OR34 FREQ-4M/s. OROS, France make 4 channel FFT analyzer 4 input 24 bits/40kHz, 2 ext. trigger and tach. 6.4 MHz, AC/DC power supply, UPS (15min) 100Mb/s Ethernet interface.

2. Software -

A. ORNV-OCT-8 M/s. OROS, France make Real - time filter based 1/n octave plug-in analyzer (with 100% educational discount)

B. ORNVS-SP M/s OROS, France make sound power software (with 100% educational discount)

C. ORNV-ORD M/s OROS, France make sound power software (with 100% educational discount)

3. Uni-axial Accelerometer -

41A161032 M/s. Meggitt sensing system, USA make Uni-axial accelerometer with 3 m microdot to BNC cable

4. Impact Hammer -

2302-100 M/s. Meggitt sensing systems, USA make Impact Hammer, 100 gm head with 3m BNC-BNC cable

5. Microphone -

46AE M/s. GRAS, Denmark 1/2" CCP Free - field standard microphone.

Experimental setup:

The experimental set up used for the vibration of cantilever sandwich specimen is shown in fig.2. The specimen test scheme consists of CLD specimen clamped rigidly in a fixture to simulate cantilever beam condition. The test CLD specimen consists of a layer of the soft VDM layer whose properties are of interest.

Calculation of experimental natural frequency

To observe the natural frequencies of the composite specimen subjected to small initial disturbance experimentally up to third mode, the experiment was conducted with the specified cantilever composite specimen. The data history and FFT plot was recorded. The natural frequencies of the system can be obtained directly by observing the FFT plot.

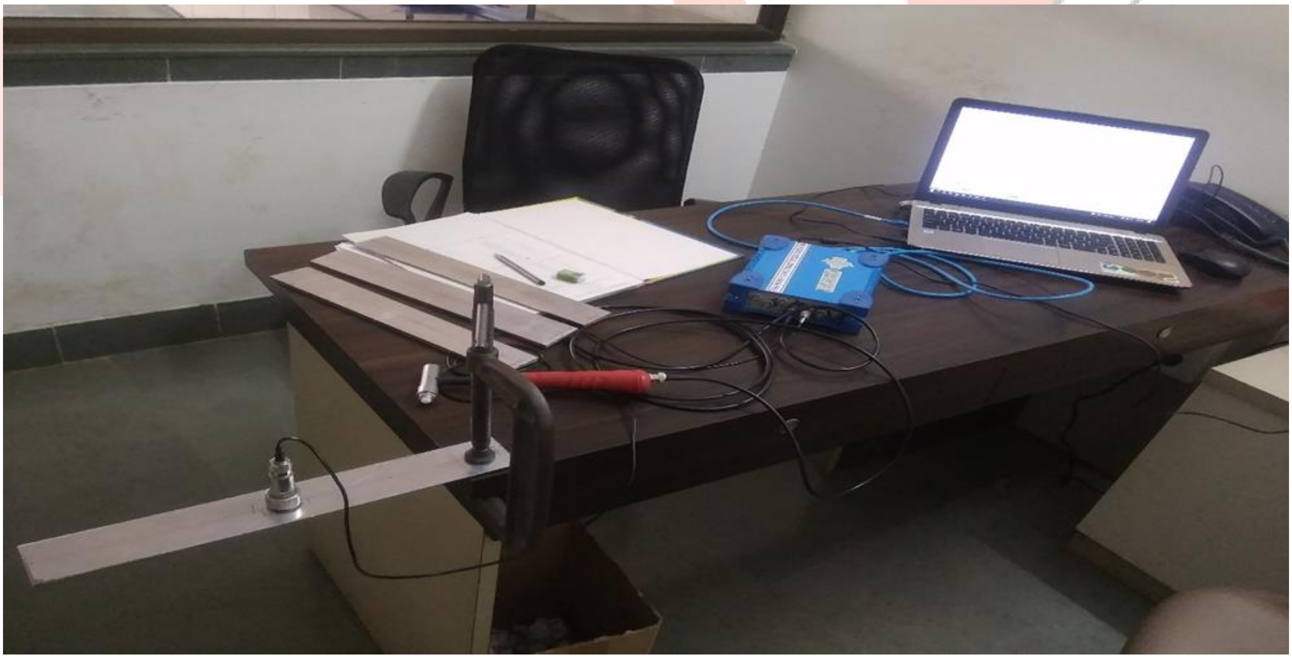
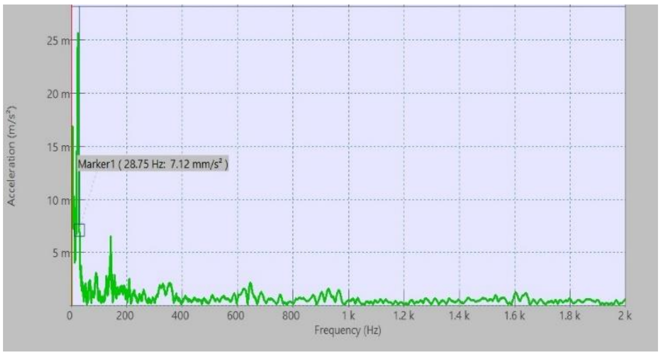


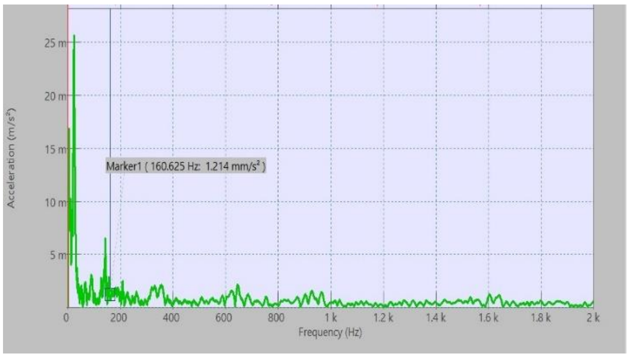
Fig.2 Experimental Set up (Constrained Condition)

III .FREQUENCY RESPONSE FUNCTIONS

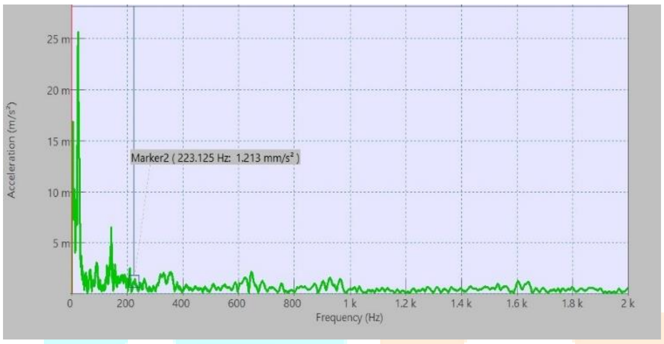
FRF FOR SPECIMEN 1:-



FRF for Frequency 1

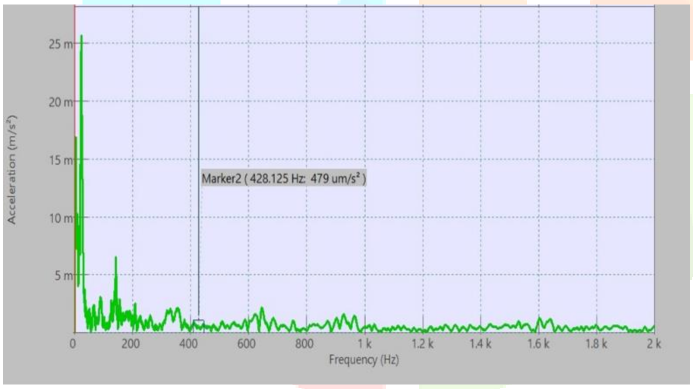


FRF for Frequency 2

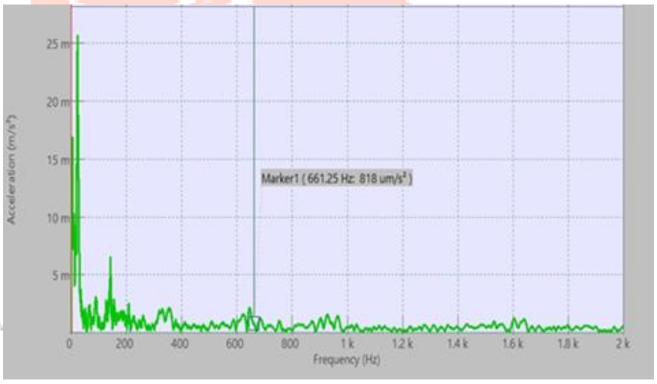


FRF for Frequency 3

FRF for Frequency 4

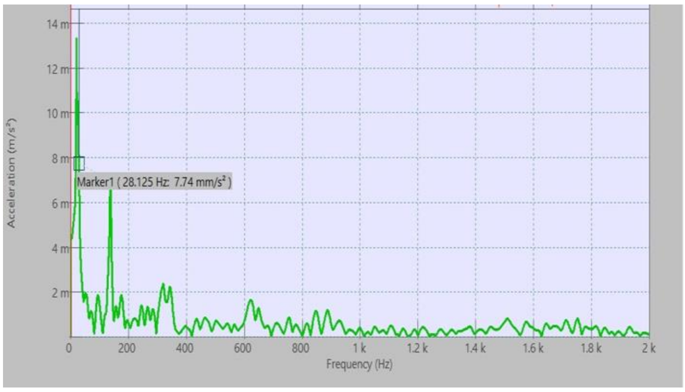


FRF for Frequency 5

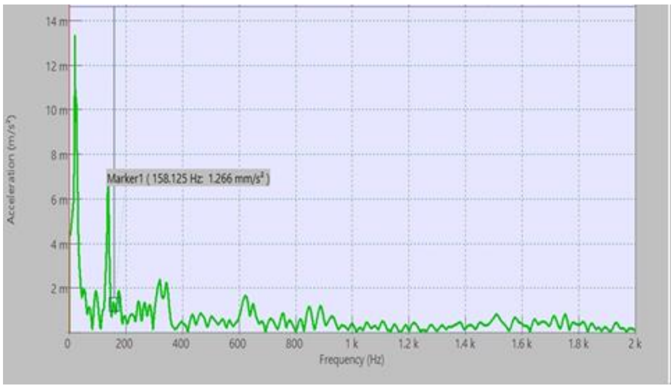


FRF for Frequency 6

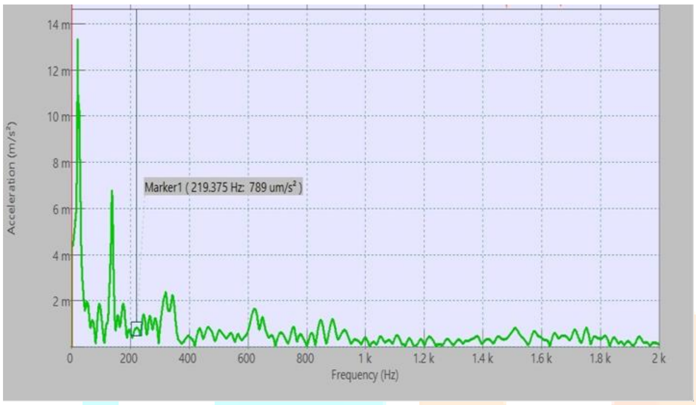
FRF FOR SPECIMEN 2:-

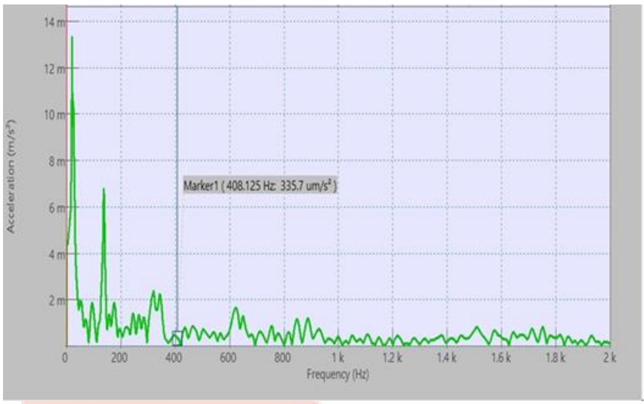


FRF for Frequency 1



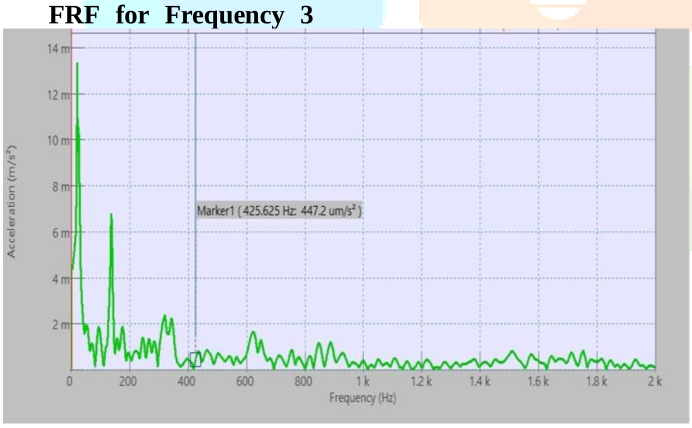
FRF for Frequency 2

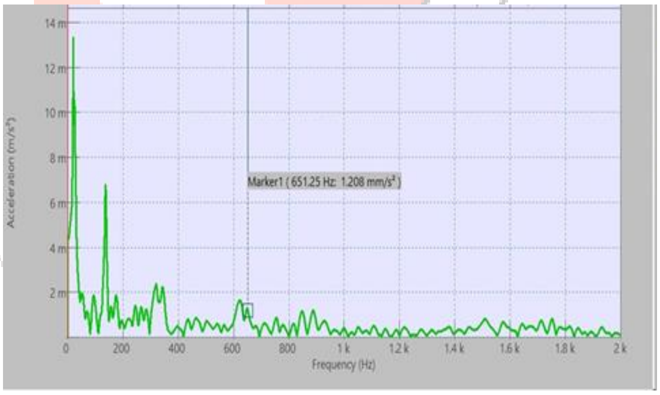




FRF for Frequency 3

FRF for Frequency 4

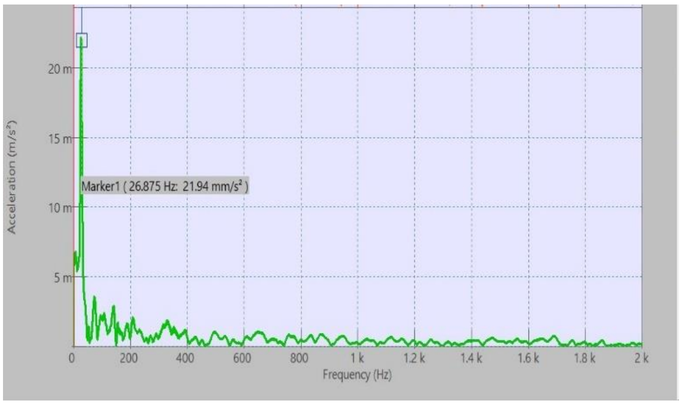




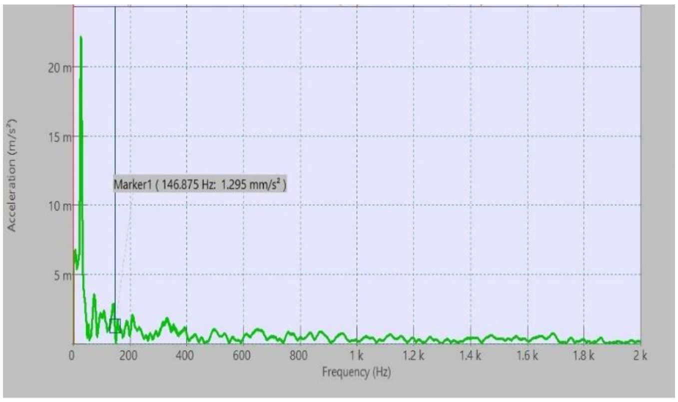
FRF for Frequency 5

FRF for Frequency 6

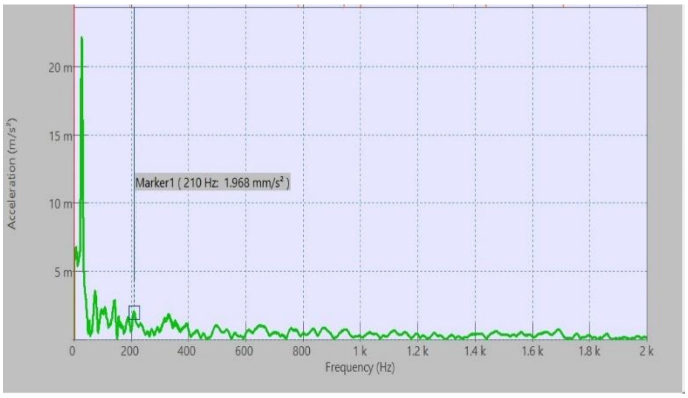
FRF FOR SPECIMEN 3:-



FRF for Frequency 1



FRF for Frequency 2



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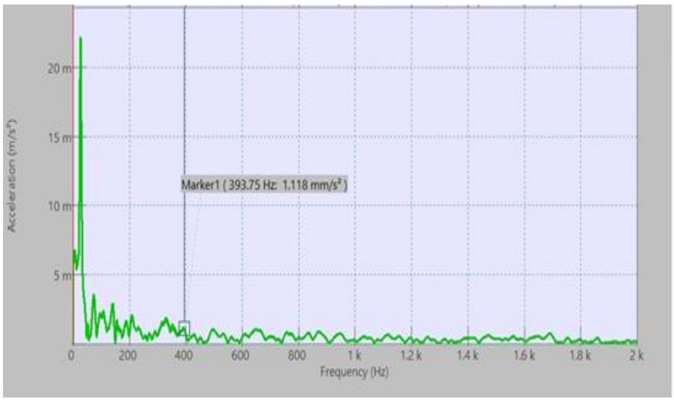
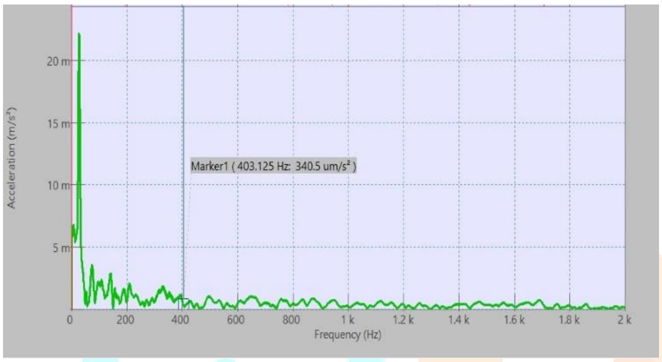
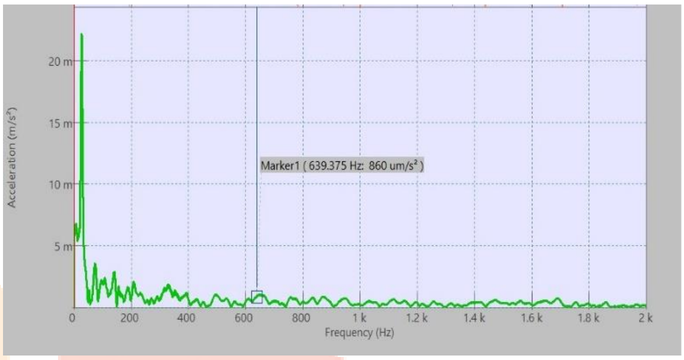


FRF for Frequency 4

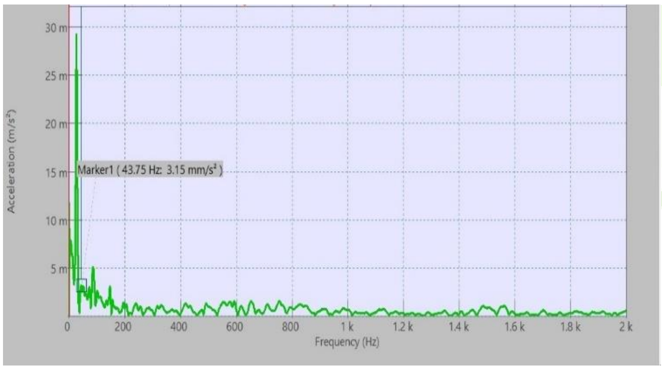


FRF for Frequency 5

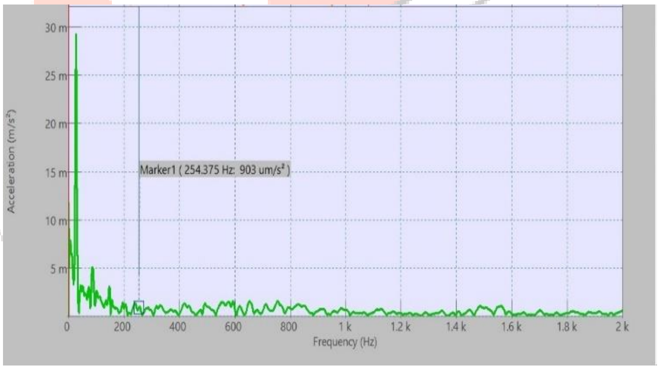


FRF for Frequency 6

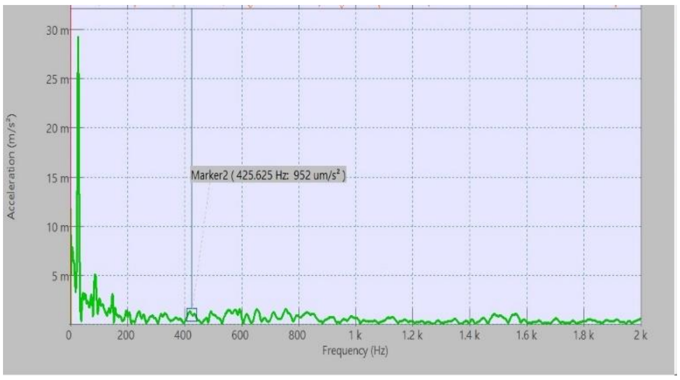
FRF FOR SPECIMEN 4:-



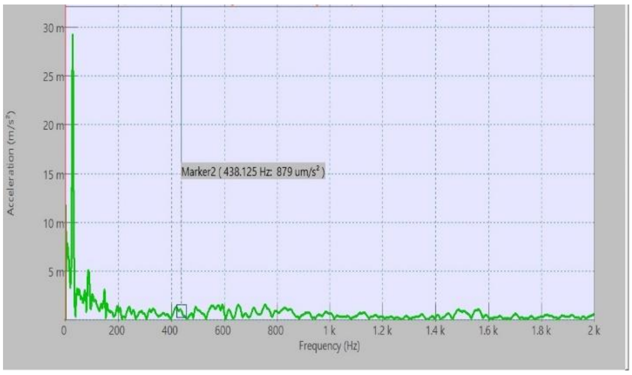
FRF for Frequency 1



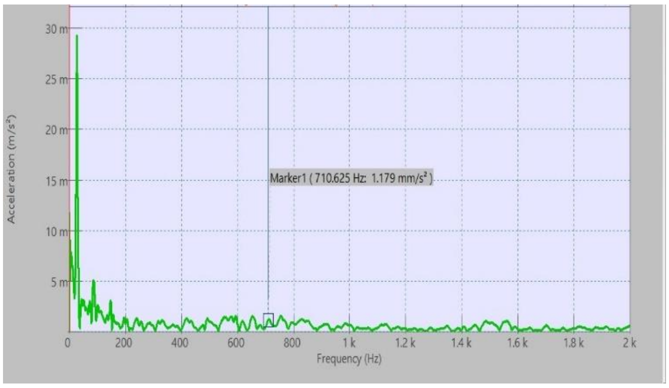
FRF for Frequency 2



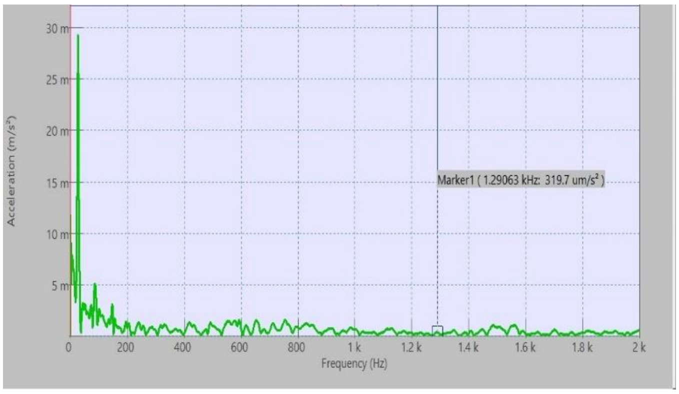
FRF for Frequency 3



FRF for Frequency 4



FRF for Frequency 5

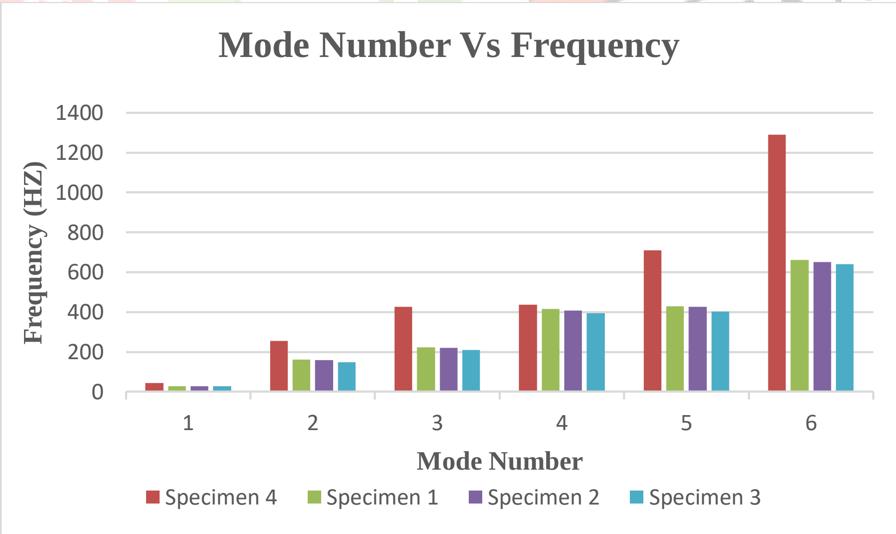


FRF for Frequency 6

IV. RESULTS AND DISCUSSION

Table 2 Expt. Result for Constrained Modal Frequency Analysis

Frequency no.	Frequency (HZ)			
	Specimen 4	Specimen 1	Specimen 2	Specimen 3
1	43.75	28.75	28.125	26.875
2	254.375	160.625	158.125	146.875
3	425.625	223.125	219.375	210
4	438.125	415.625	408.125	393.75
5	710.625	428.125	425.625	403.125
6	1290.63	661.25	651.25	639.375



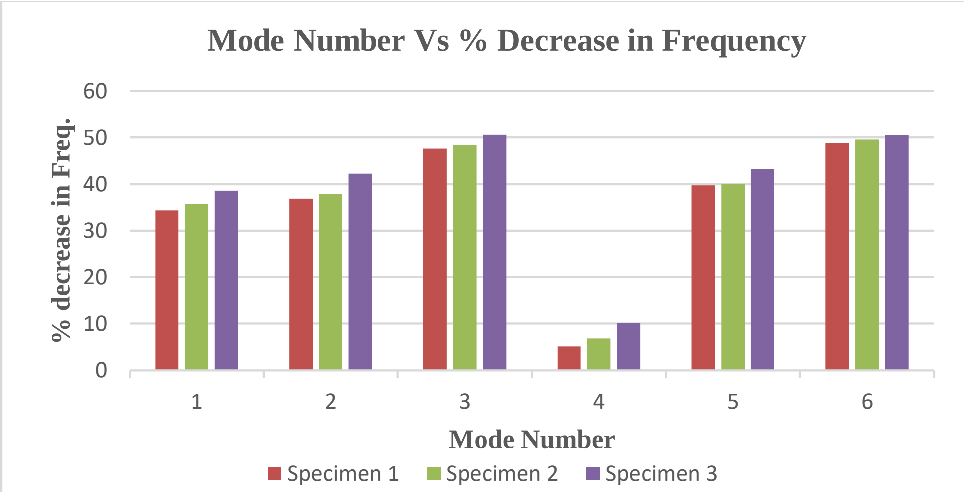
Graph 1: Mode Number Vs Frequency For All 4 Specimens

Effect of Damping (VDM) on Natural Frequency:-

In this research work the specimen 4 is of purly aluminium 6061 T6 material of 4mm thick while the other specimens are of composite specimen containing VDM in between two aluminium plates of 2 mm each. The thickness of VDM is varying from 0.8 to 1.5 mm for the specimen 1,2 and 3 respectively.In this part of the analysis the effect of introduction of viscoelastic damping material (VDM) on natural frequency is analysed.The specimen 4 is compared with the remainning 3 specimens one by one to study the % decrease in frequency for each mode.

Table 3 Comparison of % Decrease in Frequency (as compared to specimen 4)

Mode No.	% Decrease in Frequency		
	Specimen 1	Specimen 2	Specimen 3
1	34.29	35.71	38.57
2	36.86	37.84	42.26
3	47.58	48.46	50.66
4	5.14	6.85	10.13
5	39.75	40.11	43.27
6	48.77	49.54	50.46



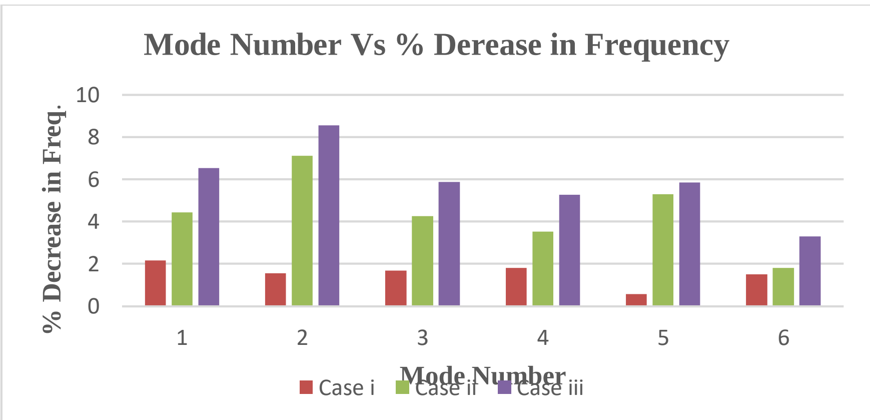
Graph 2: Mode Number Vs % Decrease in Frequency. (Damping Effect)

Effect of Variation in Thickness of VDM on Frequency:-

In this research work, the thickness of VDM is varying from 0.8 to 1.5 mm for the specimen 1,2 and 3 respectively.In this part of the analysis the effect of variation thickness of viscoelastic damping material (VDM) on natural frequency is analysed.The specimens 1,2 and 3 are compared with each other one by one to study the % decrease in frequency for each mode.

Table 4 Comparison of % Decrease in Frequency For Case i, ii and iii

Frequency No.	Mode No.	% Decrease in Frequency		
		Case i (Speci.1 &2)	Case ii(Speci.2&3)	Case iii(Speci.1 &3)
1	1	2.17	4.44	6.52
2	2	1.56	7.11	8.56
3	3	1.68	4.27	5.88
4	4	1.80	3.52	5.26
5	5	0.58	5.29	5.84
6	6	1.51	1.82	3.31



Graph 3 : Mode Number Vs % Decrease in Frequency (Variation in Thickness)

V CONCLUSION

The % decrease in frequency for the specimen 1,2 and 3 are by comparing with specimen 4 is summurised in above table 5.9. This analysis helps us to understand the damping effect of Viscoelastic Damping Material (VDM). From the analysis, it is clear that, as the damping material is intoduced in the composite specimen, the frequency decreases rapidly. The % decrease in frequency is in the approximate range of 5 %to 50%. The % decrease in frequency by comparing the specimen 1with specimen 2,specimen 2 with specimen 3 and specimen 1 with specimen 3 is summurised in above table 5.10. This analysis helps us to understand the effect of thickness variation of Viscoelastic Damping Material (VDM). In this analysis, firstly the thickness variation from 0.8 to 1mm i.e.25 % (case i) then thickness variation from 1 to 1.5 mm i.e 50% (case ii)and lasly thickness variation from 0.8 to 1.5 i.e.87.5%(case iii) are compared and analysed. From the analysis, it is clear that, as the thickness of damping material is increases in the composite specimen, the frequency decreases rapidly. The % decrease in frequency in case ii is more than case i and it is again more in case iii than case i and ii. Hence it is concluded that composite specimen/material with 1 mm VDM thickness is better than the other two specimens. It is suggested as an alternative composite material used in engineering applications such as engine mounting bracket.

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