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Vibrational Analysis of Aluminium Graphite Metal Matrix Composite

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Abstact- **In the present work analytical and experimental solutions of frequency characteristics for the vibration of isotropic metal matrix composite have been obtained. The variations in the fundamental frequency of Aluminium Graphite specimen due to its geometrical structures, percentage of graphite and material properties are going to be studied. The results are validated by the results with those available in the literature. The vibrational study started by determining of its length, thickness, weight and volume to find its density and finding an young's modulus by rule of mixtures. In experimental method is used to evaluate the first three natural frequencies and finding its modal damping from the experimental values, by using FFT analyzer by adopting all varied parameters. In analytical method determination of natural frequencies using ANSYS 11, obtaining its modal and transient analysis for all the specimens and damping ratio by using transient results.**

Keywords— Metal matrix; vibration; modal analysis; natural frequency; FFT analyzer;Damping ; ansys.

I.INTODUCTION

Vibration is the motion of a particle or a body or system of connected bodies displaced from a position of equilibrium, this leads to increase in stresses, energy losses, increase in wear induce fatigue and reduces the life of the component. By calculating vibration behavior statically and dynamically losses pertaining from it can be reduced. For this Modal analysis is used [1].Vibration in composites are varying with different compositions of materials. For better performance qualifying composition can be used based on material property and advantages. MMC's are used in many applications like automotive sectors, aerospace, electronics and communication, and sports market to reach greater extent of profit. With material point of view, polymer matrix composites stay behind with retention of strength, stiffness, and good abrasion and creep resistance properties [2]. Aluminium alloys are better application because their combination gives high strength, low density, durability, machinability, availability and cost compared to other matrix composite materials [3]. The properties of aluminium 6061 and graphite deals that aerospace and many light weight structures have more vibration inputs that can lead to resonance [4], so it is necessary to have sound methodology to control it. To achieve right combination of material properties and serviceability, the important concept to know is dynamic behaviour to understand the dynamic behaviour we must evaluate the density, natural frequencies of the structure, mode shapes and damping factors. Hybrid shafts was manufactured by fibre and aluminium to increase bending natural frequency and damping shafts made of carbon with Al have higher fundamental natural frequency and stacking angle close to zero, which reduces the transmission .A material have more stacking angle than other material is graphite because of its density leads to better transmission[5]. One of the most challenging aspects of modal analysis based damage detection is that damage is usually a local phenomenon and may not significantly influence the lower-frequency response of the structure that is normally measured using FFT analyser tests.

II.LITERATURE SURVEY

Wei-Xin Ren, Tong Zhao and Issam E. Harik, M.ASCE [2004] experimental and analytical modal analysis of a steel-girder arch bridge. The field test is carried out by ambient vibration testing under traffic and wind-induced excitations. Both the peak picking method in the frequency domain and the stochastic subspace identification method in the time domain are used for the output-only modal identification. A good agreement in identified frequencies has been found between the two methods. It is further demonstrated that the stochastic subspace identification method provides better mode shapes. The three-dimensional finite element models are constructed and an analytical modal analysis is then performed to generate natural frequencies and mode shapes in the three-orthogonal directions. The finite element models are validated to match the field natural frequencies and mode shapes.

Roger M Crane, John W.Gillispie [1989] states that Material damping of laminated composites is experimentally determined by the half-power bandwidth method for cantilever beam specimens excited with an impulse excitation. Data acquisition and manipulation are carried out using both an IBM PC-AT and a GenRad 2500 Series FFT Analyzer. Unidirectional continuous fiber 0° and 90° laminates were fabricated from glass/epoxy.(HerculesS2Glass/35016),graphite/epoxy (Hercules AS4/3501-6) and graphite/poly (ether ether ketone) (ICI AS4/PEEK[APC-2]) to investigate the effect offiber and matrix properties as a function of frequency, up to 1000 Hz, on the damping of composites.

Manoj Singla, D. Deepak Dwivedi, Lakhvir Singh, Vikas Chawla[2009] made the modest attempt to develop aluminium based silicon carbide particulate MMCs with an objective to develop a conventional low cost method of producing MMCs and to obtain homogenous dispersion of ceramic material. To achieve these objectives two step-mixing method of stir casting technique has been adopted and subsequent property analysis has been made.

Dunia Abdul Saheb[2011] made the modest attempt to develop aluminium based silicon carbide particulate MMCs and graphite particulate MMCs with an objective to develop a conventional low cost method of producing MMCs and to obtain homogenous dispersion of ceramic material.

J.N.Wei, H.F.Cheng, F.S.Han [2007] this paper illustrates that the effect of macroscopic graphite (Gr) particulates on the damping behaviour of commercial (Al).The damping characterization was conducted on a multifunction internal friction apparatus (MFIFA). The internal friction (IF), as well as the relative dynamic modulus, was measured at frequencies of 0.5, 1.0 and 3.0 Hz over the temperature range of 25–400 °C. The micro structural analysis was performed using transmission electron microscopy (TEM). The damping capacity of the Al/Gr MMCs, with three different volume fractions of macroscopic graphite reinforcements, was compared with that of unreinforced commercially pure aluminium specimens. The damping capacity of the materials is shown to increase with increasing volume fraction of macroscopic graphite particulates

J. Zhang, R.J. Perez, E.J. Lavernia[1989] explains the effect of SiC and graphite (Gr)particulates on the resultant damping behaviour of 6061 A1 metal matrix composites(MMCs) was investigated in an effort to develop a high damping material. The MMCs were processed by a spray atomization and deposition technique and the damping characterization was conducted on a dynamic mechanical thermal analyser. The damping capacity, as well as the dynamic modulus, was measured at frequencies of 0.1, 1, 10 and 30 Hz over a 30 to 250°C temperature range. The micro structural analysis was performed using scanning electron microscopy, optical microscopy and image analysis. The damping capacity of the 6061 Al/SiC and 6061 Al/Gr MMCs, with two different volume fractions of reinforcements, were compared with that of as-received 6061-T6 Al and spray deposited 6061 Al. It was shown that the damping capacity of 6061 Al could be significantly improved by the addition of either SiC or graphite particulates through spray deposition processing.

Gewifel, Zagazig,[2012] this thesis presents the (Al/Gr) composites were fabricated by a proposed technique called “ex-situ and in situ powder metallurgy” to avoid an interfacial reaction between the graphite and the aluminium. In the present study, a cooled compact pressing of material powders followed by hot extrusion techniques were used. Varies weight percentages of graphite flakes were mixed with Al powder using a mechanical mixing stirrer. The effects of graphite content and SiC formation on microstructures and wear properties of composites were investigated. The SiC particles are formed by in-situ reaction at temperatures above 252°C. SiC particles have greatly improved the wear and tensile properties of fabricated composites. The results also showed the SiC particles were refined (<; 1μm) and uniformly distributed in the matrices as a result of hot extrusions and little pores were found in the composites. This improves properties.

III. PROCESSING AND TESTING PROPERTIES OF Al-Gr

A. Processing and calculations

Al-Gr processed with various compositions by stir casting and sand moulding method[3].After processing machining was carried to get specimens in ASTM standard [B211M-03] for analysis by horizontal milling machine. Various compositions are

- 100% Al
- 97% Al + 3% Gr (By weight)
- 94% Al + 6% Gr (By weight)
- 91% Al + 9% Gr (By weight)

Named as 0,1,2,3 models of compositions, with length, width and thickness of 238×12×12 as A and 238×15×15 as D.

The first calculation Density, to calculate density volume is evaluated by (length×width×thickness) and mass by weighing specimen.

Calculation of Young’s modulus by Rule of mixture, which is

$EC_1=EF_1V_F+EM_1V_M$

Where, EC_1, EF_1, EM_1 – Young’s modulus

V_F, V_M – Volume fractions

TABLE 1. SPECIFICATION OF SPECIMENS

Grade	Code	Total length (mm)	Width (m)	Weight (gm)	Density (Kg/m^3)	Young’s Modulus (Gpa)
100% Al	0A	238.04	12.15	90.51	2575	72
	0D	238.05	15.13	141.17	2590.5	70.44
97% Al + 3% Gr	1A	236.06	12.11	86.10	2487.09	68.88
	1D	236.15	15.18	136.66	2511.30	67.32
94% Al + 6% Gr	2A	238.16	12.10	88.50	2537.9	72
	2D	238.05	15.16	138.42	2530.	70.44
91% Al + 9% Gr	3A	238.14	12.11	87.34	2500.87	68.88
	3D	238.18	15.11	137.18	2509.34	67.32

B. EXPERIMENTAL MODAL ANALYSIS

In order to use FEM models with confidence, it has found to be necessary to confirm the accuracy of the model by comparing the modal parameters (frequency, damping and mode shapes) predicted by the FEM model with modal parameters identified by experimental method and estimating the measured frequency response.

Experimental set up has arranged using instrumentation of FFT analyser based upon the measured frequency response function [10].By using these mode shape, modal damping and natural frequencies are observed using graphs.

The resulting vibrations of the specimen in a select point are measured by an accelerometer. The accelerometer is mounted by means of bees wax. The signal was then subsequently input to the second channel of the analyser, where its frequency spectrum was also obtained. The response point was kept fixed at a particular point and the location of excitation was varied throughout the plate. Both input and output signals are investigated by means of FFT and resulting frequency response functions are transmitted to a computer for modal parameter extraction. The output from the analyser was displayed on the analyser screen by using software. Various forms of Frequency Response Functions (FRF) are directly measured are shown below.

Fig I FFT Experimental setup

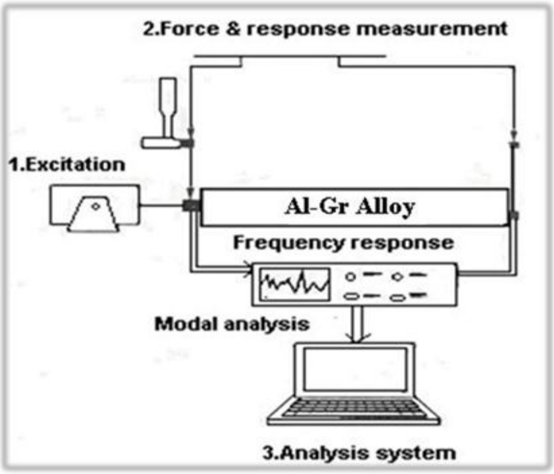


Fig 2. Spectrum showing natural frequencies of 0A

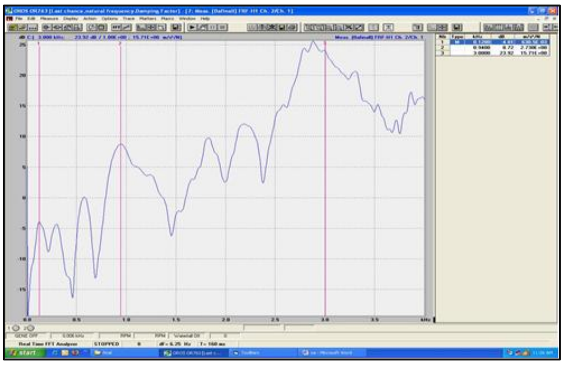


Fig. 3. Spectrum showing natural frequencies of 0D

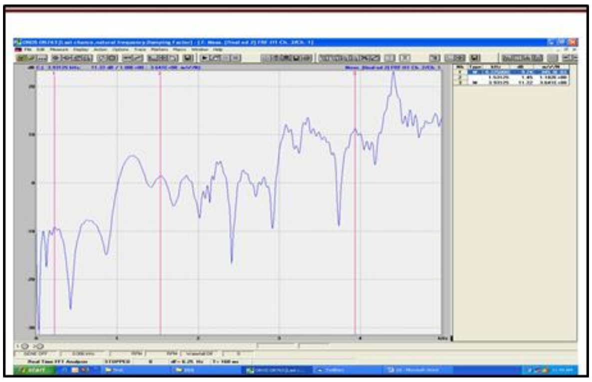


Fig. 4. Spectrum showing natural frequencies of 1A

Fig 5 .Spectrum showing natural frequencies of 1D

Fig 6. Spectrum showing natural frequencies of 2A

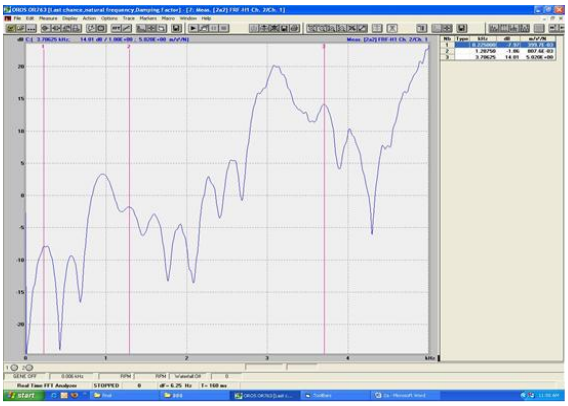


Fig 7. Spectrum showing natural frequencies of 2D

Fig 8. Spectrum showing natural frequencies of 3A

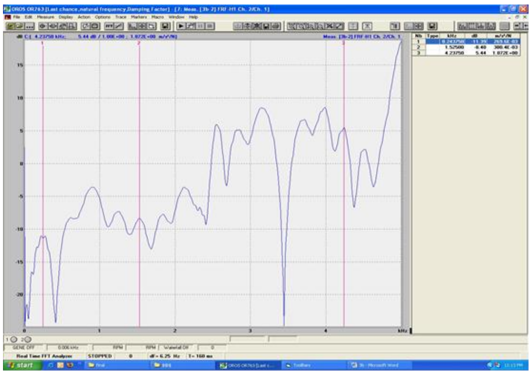


Fig. 9. Spectrum showing natural frequencies of 3D

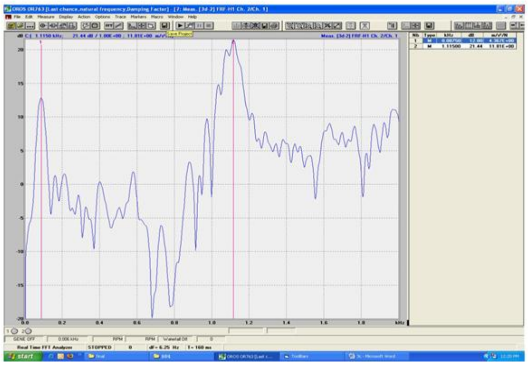


TABLE 2 . EXPERIMENTED GRAPH VALUES OF SPECIMENS

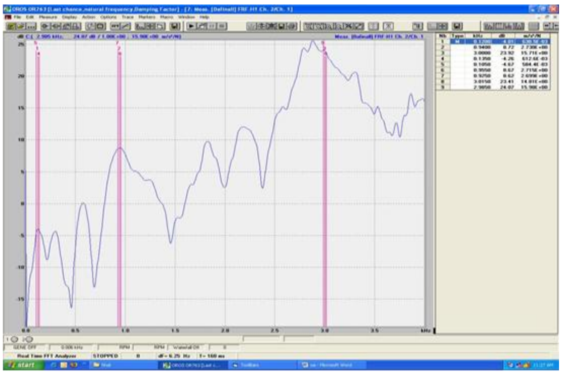
Grade	Specimen code	Natural frequency (Hz)		
		Mode numbers		
		1	2	3
100% Al	0A	120	940	3000
	0D	225	1513.2	3931.2
97% Al + 3% Gr	1A	243.7	1287.5	3643
	1D	262.5	1837.5	4468.7
94% Al + 6% Gr	2A	225	1287.5	3706.2
	2D	226.2	1862.5	4906.2
91% Al + 9% Gr	3A	243.7	1525	4237.5
	3D	875	1115	

Modal Damping is calculated by

$$(\omega_1 - \omega_2) \div 2\omega \qquad (1)$$

Where ω is natural frequency and ω_{1} ,$_{2}$ are -3dB reduced frequencies to the natural frequency. In the fig 10 for each specimen of each natural frequency -3db of spectrum band values are marked and generated the graph. For specimen Al 12mm bar is shown from fig 10 and same has captured and tabulated values.

Fig 10.Spectrum band showing ω, ω_1 and ω_2 0A



The spectrum bands like fig 10.are used to calculate modal damping from equation (1) and are given below in the following tables with particular specimen.

TABLE 3. MODAL DAMPING OF 0A

Mode No	ω(Hz)	ω_1(Hz)	ω_2(Hz)	Modal damping
1	120	105	135	0.125
2	940	925	955	0.0312
3	3000	2985	3015	0.005

TABLE 4. MODAL DAMPING OF 0D

Mode No	ω(Hz)	ω_1(Hz)	ω_2(Hz)	Modal damping
1	225	206	243	0.0822
2	1539	1512	1550	0.0124
3	3931	3912	3950	0.0048

TABLE 5. MODAL DAMPING OF 1A

Mode No	ω(Hz)	ω_1(Hz)	ω_2(Hz)	Modal damping
1	243	225	262	0.0761
2	1287	1268	1306	0.0147
3	3643	3625	3662	0.0057

TABLE 6. MODAL DAMPING OF 1D

Mode No	ω(Hz)	ω_1(Hz)	ω_2(Hz)	Modal damping
1	262	243	281	0.0725
3	4468	4450	4487	0.0041
2	1837	1818	1856	0.0103

TABLE 7. MODAL DAMPING OF 2A

Mode No	ω(Hz)	ω_1(Hz)	ω_2(Hz)	Modal damping
1	225	206	243	0.0822
2	1287	1268	1306	0.0147
3	3706	3687	3725	0.0051

TABLE 8. MODAL DAMPING OF 2D

Mode No	ω(Hz)	ω_1(Hz)	ω_2(Hz)	Modal damping
1	256	237	275	0.0742
2	1862	1843	1881	0.0102
3	4906	4887	4925	0.0038

TABLE 9. MODAL DAMPING OF 3A

Mode No	ω(Hz)	ω_1(Hz)	ω_2(Hz)	Modal damping
1	243	225	262	0.0761
2	1525	1506	1543	0.0121
3	4237	4218	4256	0.0044

TABLE 10. MODAL DAMPING OF 3D

Mode No	ω(Hz)	ω_1(Hz)	ω_2(Hz)	Modal damping
1	875	800	950	0.0857
2	1125	1107	1122	0.0067

Above table values observed and concluded that, damping decreases as natural frequency range increases for entire test specimens. Also modal damping decreases with increase in percentage of graphite.

C. Modal analysis using FEM

FEM involves three stages of activity:

- Preprocessing,
- Processing and
- Post processing.

In this study, finite element analysis is conducted using ANSYS 11 software. To model the composite SOLID 45 element is used. The element is defined by eight nodes having three degrees of freedom at each node. Degrees of freedom are UX, UY, UZ. Material properties are EX, EY, EZ, PRXY,PRYZ, PRXZ.

The FEM model is built and modal analysis is carried out different mode shapes are listed

TABLE 11 .SIMULATED MODAL RESULTS

Grade	Specimen code	Natural frequency (Hz)		
		Mode numbers		
		1	2	3
100% Al	0A	190	1178	3219
	0D	228	1404	3824
97% Al + 3% Gr	1A	205.94	1278	3452
	1D	256.3	1579	4298
94% Al + 6% Gr	2A	222.46	1379	3796
	2D	278.99	1718	4679
91% Al + 9% Gr	3A	241.04	1493	4108
	3D	772.30	1485	5012

Some of mode shapes at natural frequencies are

Fig 11. Mode shape at ω=1178Hz of 0A

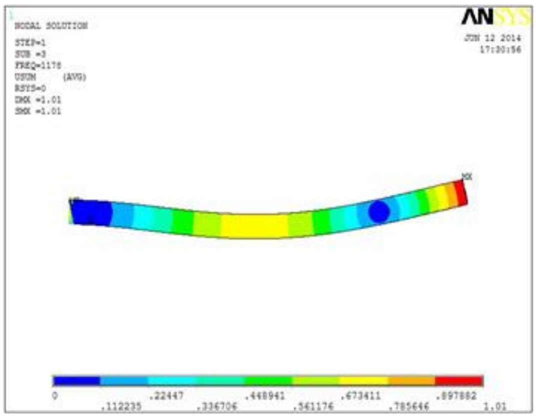
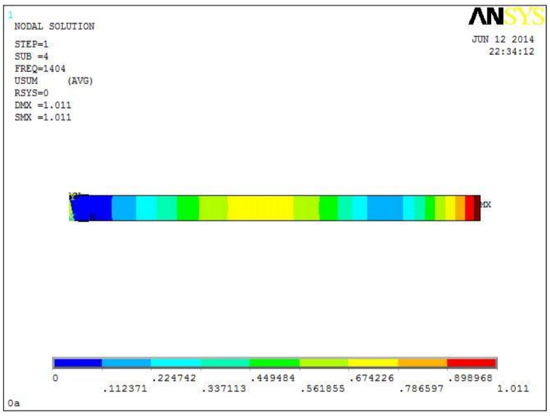


Fig 12. Mode shape at ω=1404Hz of 0D



Determination of damping through logarithmic decrement by determining time step

Time step, T= 1/20f (2)

Where T-Time, f- Frequency of highest mode. Is calculated for each and decrement is natural log of the amplitudes of any two successive peaks given by

$$\delta = \frac{1}{n} \ln \frac{x_0}{x_n}, \tag{3}$$

Where x_0 is the greater of the two amplitudes and x_n is the amplitude of a peak n periods away.

The damping ratio is then found from the logarithmic decrement

$$\zeta = \frac{1}{\sqrt{1 + (\frac{2\pi}{\delta})^2}}. \tag{4}$$

Where ξ is the Damping ratio

1.For Al

X1=600
X4=50 n=4
δ =(1/4) ln(X1/X4) and

The calculated value is $\delta=0.62$, $\xi=0.098$
2. For Al – 3%Gr

$X1=2500$
$X4=1000$ $n=4$
$\delta =(1/4) \ln(X1/X4)$ and
The calculated value is $\delta=0.22$, $\xi=0.036$

3. For Al – 6%Gr

$X1=2750$
$X6=480$ $n=6$
$\delta =(1/6) \ln(X1/X6)$ and
The calculated value is $\delta=0.29$, $\xi =0.046$

4. For Al-9%Gr
$X1=600$
$X4=200$ $n=5$
$\delta =(1/5)1n(X1/X5)$ and
The calculated value is $\delta = 0.21$, $\xi =0.033$

All the three test specimens have $\xi< 1$. Therefore Al, Al – 3%Gr, Al – 6%Gr and Al-9%Gr are said to be underdamped systems.
An underdamped response is one that oscillates within a decaying envelope. The more underdamped the system, the more oscillations and longer it takes to reach steady-state.

IV RESULT

Comparison of Experimental and FEA Results
The data collected from both experimental and FEM analyses are shown in table below.

TABLE 12 COMPARISION B/W EXPERIMENTAL AND FEM RESULTS OF 0A & OD

Specimen name	Mode No	Experimental values	Ansys results	% Deviation
0A	1	120	190	18.28
	2	940	1178	20.20
	3	3000	3219	6.80
0D	1	225	228	1.31
	2	1531.2	1404	8.30
	3	3931.2	3824	2.70

TABLE 13 COMPARISION B/W EXPERIMENTAL AND FEM RESULTS OF 1A & 1D

Specimen name	Mode No	Experimental values	Ansys results	% Deviation
1A	1	243.7	205.94	15.15
	2	1287.5	1278	0.23
	3	3643	3452	5.24
1D	1	262.5	256.3	2.36
	2	1837.5	1579	14.06
	3	4468.7	4298	3.81

TABLE 14 COMPARISION B/W EXPERIMENTAL AND FEM RESULTS OF 2A & 2D

Specimen name	Mode No	Experimental values	Ansys results	% Deviation
2A	1	225	222.46	1.15
	2	1287.5	1379	6.63
	3	3706.2	3796	2.36
2D	1	256.2	278.99	8.13
	2	1862.5	1718	7.7
	3	3706.2	4679	4.63

TABLE 15 COMPARISION B/W EXPERIMENTAL AND FEM RESULTS OF 3A & 3D

Specimen name	Mode No	Experimental values	Ansys results	% Deviation
3A	1	243.7	2441.	1.15
	2	1525	1493	6.63
	3	423705	4108	2.36
3D	1	875	777	8.13
	2	1125	1485	7.7

V. DISCUSSION

The results obtained by experimental and analytical methods agree with each other with a deviation of about an average 4.5% for 0A specimen, 4.10% for 0D. 6.87% for 1A specimen, 6.74% for 1D specimen.3.38% 2A specimen, 6.82% 3A specimen. 2.07% for 3A and 3D specimen 11.3% deviation. There is a good correlation between analytical and experimental values of the modal analysis. Where increase in percentage of graphite leads to increase in natural frequency.

VII.CONCLUSION

- The Analytical and Experimental Modal Analysis of the Al-Gr alloy is done successfully by using ANSYS and FFT Analyzer respectively. Even though the number of modes obtained through Experimental Modal Analysis is less than that in Analytical Modal Analysis, the experimental results backup the analytical results.
- The results obtained by both the methods agree with each other with a deviation of about 1% – 20%. There is a good correlation between analytical and experimental values of the modal analysis
- Density of the Al-Gr alloy decreases with increase in Graphite content.
- From the experiment it is found that, damping decreases as natural frequency range increases of Al – Gr test specimens.
- From the transient analysis it is clear that Al-Gr alloy is underdamped system.
- The damping factor is 0.098, 0.036, 0.046 and 0.033 for Al-6061 Al-3%Gr, Al-6%Gr, and Al-9%Gr respectively.
- The Al-Gr base plates or coolers makes them compatible with ceramic substances, for power applications .The parts stand out due to their low density which is role good standard in weight sensitive applications in traction and transportation.
- Al-gr parts are predestined for heat spreading application as their high lateral thermal conductivity efficiently removes heat from hotspots.

VIII. REFRENCES

[1] Wei-Xin Ren1; Tong Zhao2; and Issam E. Harik, M.ASCE3 Experimental and Analytical Modal Analysis of Steel Arch Bridge [10.1061/~ASCE [0733-9445~2004]130:7~1022]

[2] Roger M. Crane(David Taylor Research Center, Code 2802, Annapolis, Maryland 21402, USA)John W. Gillespie Jr.(Center for Composite Materials, Department ofMechanical Engineering and Materials Science Program, University of Delaware, Newark, Delaware 19716, USA,1989)

[3] Gupta, N., Satyanarayana, K.G. and Materials, C. (2006) Symposium Review: Solidification Processing of MMCs. Journal of Materials Science, 58, 91-93

[4] Sato, A. and Mehrabian, R. (1976) Aluminum Matrix Composites: Fabrication and Properties. Metallurgical Transaction, B, 7, 443-451.

[5] B. Manoj1* , A.G. Kunjomana * Research and Development Centre, Bharathiar University, Coimbatore, 641046 Study of Stacking Structure of Amorphous Carbon by X-Ray Diffraction Technique(Dept.of Physics ,Christ University, Bangalore, Karnataka, Int. J. Electrochem. Sci., 7 (2012) 3127 – 3134)

[6] Manoj Singla, D. Deepak Dwivedi, Lakhvir Singh, Vikas Chawla, "Development of aluminium based silicon carbide particulate metal matrixcomposite", Journalof Minerals & Materials Characterization & Engineering, Vol. 8, No.6, pp 455-467, 2009.

[7] Dunia Abdul Saheb, "Aluminum silicon carbide and aluminum graphite particulate composites", ARPN Journal of Engineering and Applied Sciences,(VOL. 6, NO. 10, OCTOBER 2011)

[8] J.N. Wei, H.F. Cheng, Y.F. Zhang, F.S. Han ,Z.C. Zhou, J.P. Shui (Laboratory of Internal Friction and Defects in Solids, Institute of Solid State Physics, Chinese Academy of Sciences, Hefei, 230031 Anhui, People's Republic of China,2007)

[9] Jerzy W. Wekezer (1989). "Vibrational Analysis of Thin-Walled Bars with Open Cross Sections." J. Struct. Eng., 115(12), 2965–2978. Volume 115, Issue 12 (December 1989)

[10] Sharayu U. Ratnaparkhi,,S.S. Sarnobat "Vibration Analysis of Composite Plate" Department of Production Engineering, D.Y. Patil College of Engineering, Pune, India, (Vol.3, Issue.1, Jan-Feb. 2013 pp-377-380 ,ISSN: 2249-6645)