International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 9, September- 2014

Investigation of Damping Behavior of Aluminum Based Hybrid Nanocomposites

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Abstract: **In aerospace, automotive and manufacturing industries Aluminum (Al) components have dynamic role. The objective of this paper is to investigate the damping characteristics of Al based hybrid nanocomposites. Commercial purity Aluminum as a matrix, Multi Walled Nano Carbon Tube (MWCNT) and Graphene (GR) as reinforcement with a weight percentage of 0.5%, 1%, 1.5%, 2% have been fabricated by Casting and Powder Metallurgy (P/M) techniques. According to ASTM E756-05 standards damping specimens were prepared and carried free vibration test to investigate damping ratio and natural frequencies of specimens. The results reveals that, Al/MWCNT/GR of 1.5 wt.% having significant improvement in damping ratio and Natural frequency. Beyond increasing weight percentage (1.5 wt. %) of MWCNT and GR deterioration in damping ratio (ζ) and natural frequency (Hz). In this work an attempt has been made to investigate damping characteristics by different fabrication techniques.**

Keyword: Nanocomposites, MWCNT, Graphene, Casting, Powder Metallurgy

1. INTRODUCTION

In modern engineering design damping plays a major role. High damping capacity materials minimizes the noise and subsonic vibrations released by the machine components which are subject to fatigue stress.Damping in composite materials is an very important property affecting the dynamic behavior of structures near resonant vibration levels.[1,2] In recent years nano particles have been attracting increasingly attention in the composite community as they are capable of improving the mechanical and damping properties. The demand for high performance damping material is rapidly and continuously growing in a variety of aerospace, mechanical and civil system.[3] Viscoelastic polymer based damping treatment are shown to be promising for vibration and noise control[4].

Nanotechnology may considerably enhance damping behavior and reduce noise of engineering structure through the utilization of nanomaterials that dissipate a substantial fraction of the vibration energy that they receive[5]. Thus carbon nanotube can act as a sample nanoscale damping materials and suggested as next generation damping material. It was also reported that CNT reinforced PMC's shows a great improvement in damping capacity without sacrificing the mechanical strength [6]. However the damping behavior of metal matrix composites reinforced by two nano material has been rarely reported. Many researchers have reported the composites preparation by P/M techniques [8] and some have shown with casting technique [9, 10] in nano composites [11,12].

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In the present work, multiwalled carbon nanotube and Graphene as a reinforcement and commercially purity aluminum as a matrix is used to get the hybrid nanocomposites. The composites samples were prepared by using both P/M casting technique to investigate the damping behavior of the hybrid nanocomposites.

2. EXPERIMENTATION

2.1 Materials

Hybrid Nanocomposites of commercial purity aluminum ingot and in a powder form has been used as base material and nano material such as MWCNT and Graphene are used as reinforcements. MWCNT one dimensional element and Graphene is two dimensional element of single atomic layer carbon crystalline material of SP^2 bonded carbon. Nano materials were emerged as an ideal nano reinforcements for composites due to their superior mechanical properties.

2.2 Fabrication of Composite Specimens

Casting and powder metallurgy technique were used for composite fabrication. MWCNTs and Graphene were dispersed in ethanol and sonicated for 20mins, and decanted to obtained pure nano materials.

Casting:

Aluminum ingot was melted and MWCNT and GR were added into melts and mixed with stirring bar. The reinforcement of 0 wt%, 0.5wt%, 1wt%, 1.5wt%, 2wt% was added into melt aluminum to get the components. The aluminum/MWCNT/GR is poured into the die and solidified.

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Powder Metallurgy:

Aluminum/ MWCNT/GR powders were ball milled at 200 RPM for 10mins. The milled powder was compacted in a circular die with a load of 135kN. The billets are of 0 wt%, 0.5wt%, 1wt%, 1.5wt%, 2wt%. The obtained billets were sintered in inert gas nitrogen for 40mins at 570°C and finally extruded.

2.3 Single Degree of Freedom (SDOF) Free Vibration Test Experimental setup

The natural frequency & damping ratio are frequently used to determine the damping characteristics of structures subjected to various types of loading & boundary conditions. To determine damping ratio & natural frequency of hybrid nanocomposites a Single Degree of Freedom (SDOF) free vibration test on cantilever beam were carried.

The Fig.01 Shows, SDOF free vibration test configuration on cantilever beam specimen.

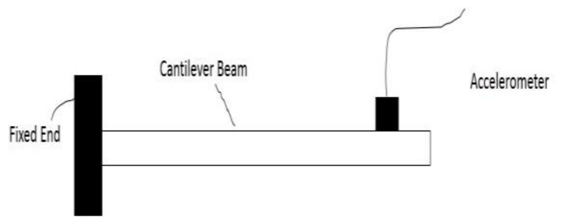

Fig.01. Free Vibration test on Cantilever beam

The testing specimen size of 150 mm X 15 mm X 5 mm were developed in the form of Al, Al/MWCNT & Al/MWCNT/GR. All these specimens are manufactured by casting and powder metallurgy techniques. According to standard test method for measuring vibration- Damping properties of materials ASTM E 756-05. The testing specimens treated as self-supporting with cantilever beam configuration. For fixing the beam as a cantilever, experiment was conducted on specimen with dimensions of 100 mm X 15 mm X 5mm. The experimental setup consists of an accelerometer and FFT analyzer. The accelerometer with sensitivity 9.8m V/g which is used to measure the beam response. PRUFTECHNIK, VIBXpert®II, FFT analyzer was used to extract the damping signals. The accelerometer was fixed by beeswax to the cantilever beam at one of the nodal points. Displace beam tip by impact force, observe the logarithmic decrement of vibratory response, then at a point impact force was struck once and the displacement vs. time plot was obtained from graphical user interface. The FFT analyzer and the accelerometer are the interface to convert the time domain response into frequency domain. Hence the frequency response spectrum was obtained. By moving the cursor to the peaks of the FFT graph, the cursor values and the resonant frequencies were recorded. At the time of the striking with hammer to the singular point precautions were taken whether the striking should have been perpendicular to the beam surface. The above procedure is repeated for all the composite beams. The response signals with respect to amplitude, time period, RMS amplitude and frequency are recorded and stored in the FFT. Five samples specimens were tested and average value was taken to compute damping characteristics. Results are tabulated in table no. 1 to 4 for cast and P/M techniques specimens.

For single degree freedom system, a typical free vibration response is shown in figure 02. The Logarithmic decrement were computed by following equation [6] 2.1.

Logarithmic decrement, $\delta = \left(\frac{X_1}{X_2}\right) = \frac{1}{n}\left(\frac{X_1}{X_{n-1}}\right)$.(2.1)

Where, X1 and X2 are first two successive amplitudes and n is the number of cycles

The damping ratio is computed by using the equation 2.2

$$\zeta = \frac{\delta}{\sqrt{4\pi^2+\delta^2}} \quad ..(2.2)$$

The Fig. 3 (a) and (b) Shows that, FFT analyzer (PRUFTECHNIK, VIBXpert®II) and Accelerometer (A&D 3101) respectively.

3. RESULT AND DISCUSSION

Fig. 4 shows, damping behavior characterstics of commertial purity Aluminium developed by casting technique.

(a) FFT analyzer (b) Accelerometer

Fig. 3: Vibration measuring instruments

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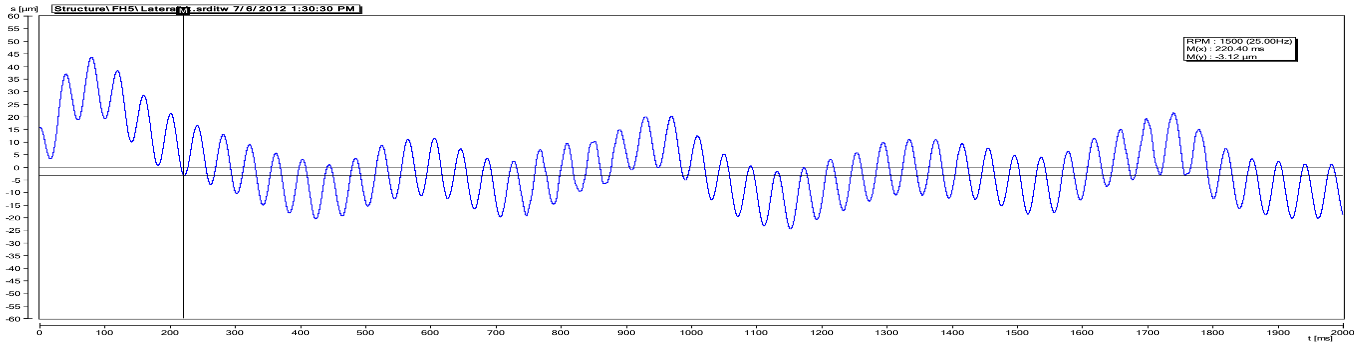

Fig.4: Damping behavior of Cast Al specimen.

With an addition of 0wt.%,0.5wt.%, 1wt.%, 1.5wt.%, 2wt.%. of MWCNT damping ratio & natural frequency are tabulated in table 01 specimens are fabricated by casting technique. It can found that, Al/MWCNT with an 1.5wt.%, shows significat improvement compare to other specimens. A comparabledamping behaviour characterstics observed in fig 5.

Table.01: Damping Characteristics of Al/casted samples

Sl. No.	Material Combination	Natural Frequency (Hz)	Damping Ratio (ζ)
1.	Al	385	0.0027
2.	Al/MWCNT (0.5 wt. %)	398	0.0056
3.	Al/MWCNT (1 wt. %)	386	0.0024
4.	Al/MWCNT (1.5 wt. %)	371	0.0021
5.	Al/MWCNT (2 wt. %)	370	0.0019

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Fig. 6 to Fig. 10 shows the damping behaviour of P/M commertial purityAl, Cast Al/MWCNT (1.5 wt. %), P/M Al/MWCNT (1.5 wt. %), Cast Al/MWCNT (1.5 wt. %),P/M Al/MWCNT/GR (1.5 wt. %) specimens with an beam length of 100mm obtained through Single degree of freedom free vibration test.

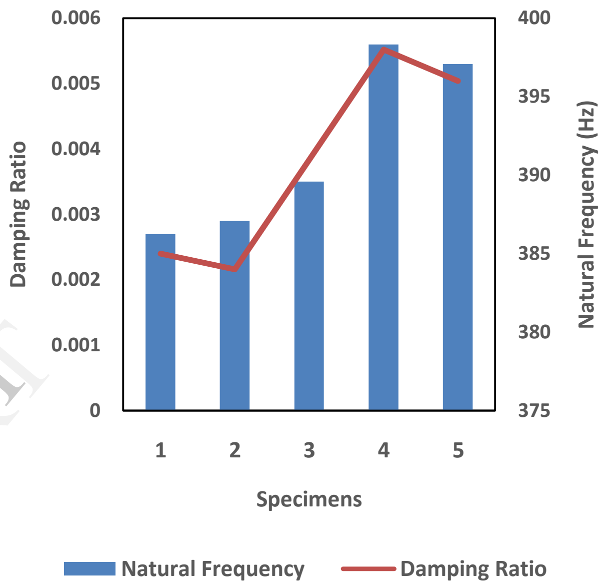

Fig 5: Damping characteristics of Al/MWCNT by casting technique.

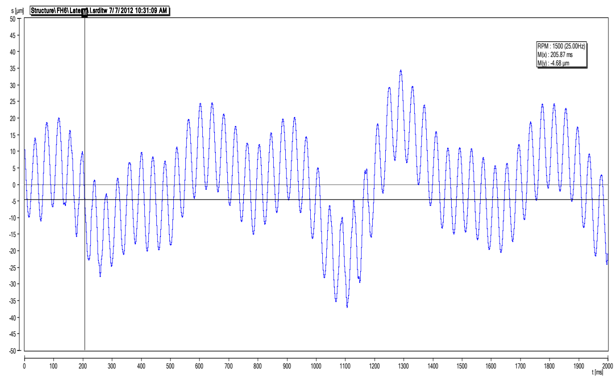

Fig.6: Damping behavior of P/M Al specimen.

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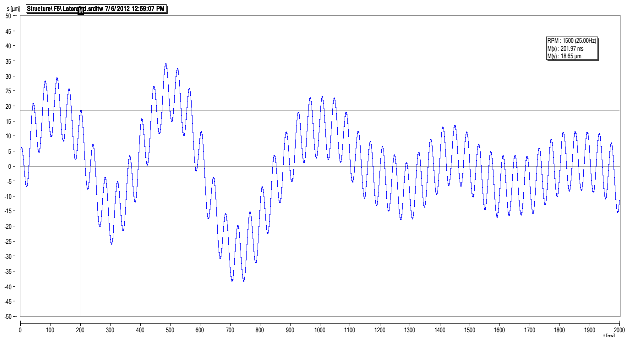

Fig.7: Damping behavior of Cast Al/MWCNT (1.5 wt. %) specimen.

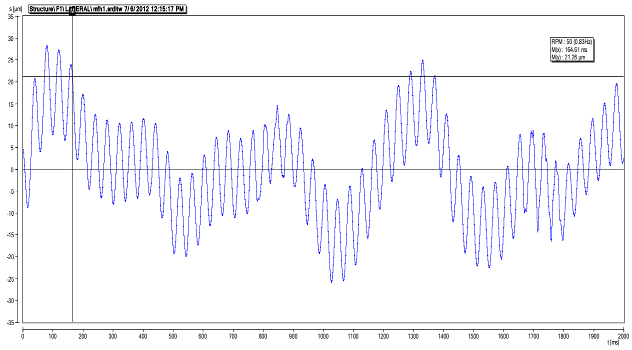

Fig.8: Damping behavior of P/M Al/MWCNT (1.5 wt. %) specimen

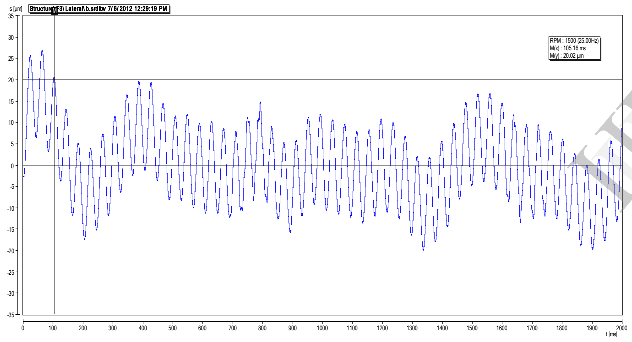

Fig.9: Damping behavior of Cast Al/MWCNT/GR (1.5 wt. %) specimen.

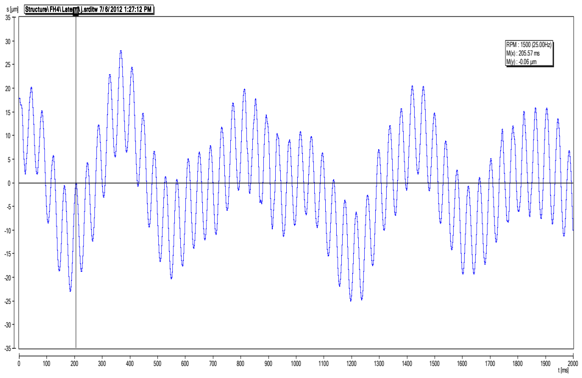

Fig.10: Damping behavior of P/M Al/MWCNT/GR (1.5 wt. %) specimen

From table 2 shows that, damping characteristics of Al/MWCNT by powder metallurgy technique. Al/MWCNT with 1.5 wt. % shows substantial improvement. Fig.11. shows that, damping characteristics of Al/MWCNT by Powder Metallurgy technique. From table 03 shows the damping Characteristics of Al/MWCNT/GR by casting technique, Al/MWCNT/GR with 1.5 wt. % shows extensive improvement. Fig. 12 shows damping characteristics of Al/MWCNT/GR by casting technique. Al/MWCNT/GR with 1.5 wt. % shows considerable improvement. Table.04. damping characteristics of Al/MWCNT/GR for powder metallurgy technique. Al/MWCNT/GR with 1.5 wt. % shows superior improvement. Fig14.Damping Characteristics of Al/MWCNT/GR by Powder Metallurgy technique. Commercial purity aluminum having low frequency and low damping properties, this is due to pores presented in specimen which results in lower stiffness hence it leads to lower elastic modulus as compared to Powder metallurgy specimens.

Table.2: Damping characteristics of Al/MWCNT for P/M samples

Sl. No.	Material Combination	Natural Frequency (Hz)	Damping Ratio (ζ)
1.	Al	406	0.00405
2.	Al/MWCNT (0.5 wt. %)	405	0.00435
3.	Al/MWCNT (1 wt. %)	413	0.00525
4.	Al/MWCNT (1.5 wt. %)	420	0.0084
5.	Al/MWCNT (2 wt. %)	418	0.00795

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Table 3: Damping characteristics of Al/MWCNT/GR for casted samples

Sl. No.	Material Combination	Natural Frequency (Hz)	Damping Ratio (ζ)
1.	Al / MWCNT/GR (0.5 wt. %)	422	0.00493
2.	Al/MWCNT/GR (1 wt. %)	430	0.00595
3.	Al/MWCNT/GR (1.5 wt. %)	438	0.00952
4.	Al/MWCNT/GR (2 wt. %)	436	0.00901

Table.4: Damping characteristics of Al/MWCNT/GR for P/M samples

Sl. No.	Material Combination	Natural Frequency (Hz)	Damping Ratio (ζ)
1.	Al/MWCNT/GR (0.5 wt. %)	461	0.00551
2.	Al/MWCNT/GR (1 wt. %)	469	0.00665
3.	Al/MWCNT/GR (1.5 wt. %)	478	0.01064
4.	Al/MWCNT/GR (2 wt. %)	475	0.01007

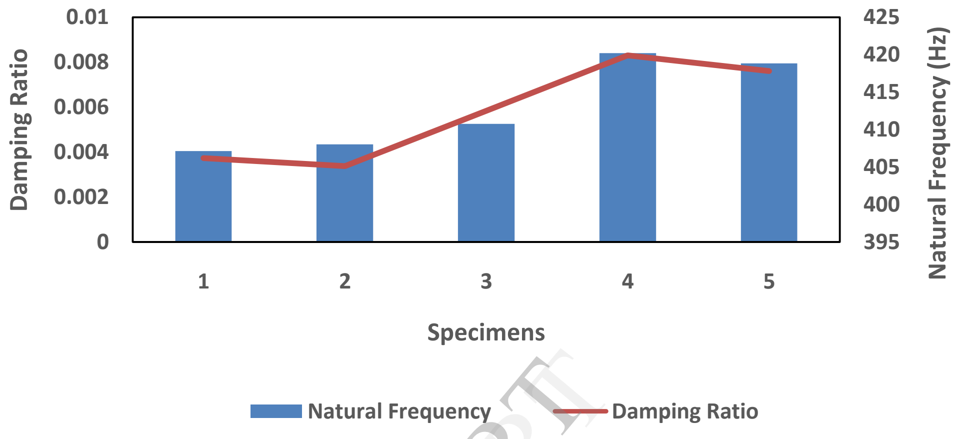

Fig.11: Bar chart of Damping ratio and natural frequencies of Al/MWCNT P/M Samples

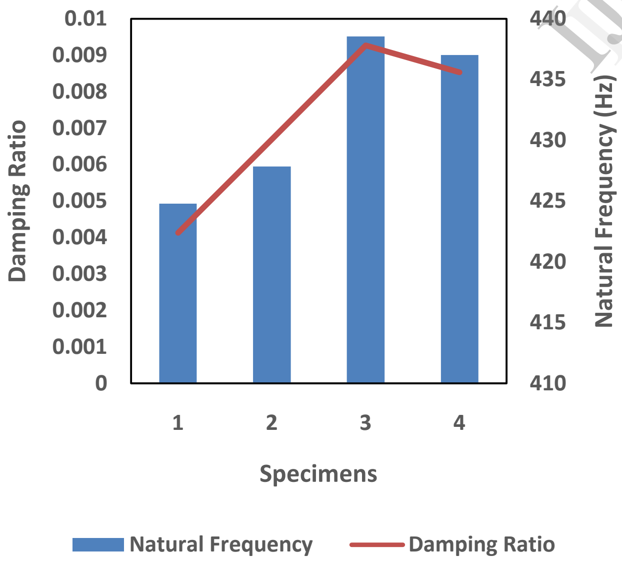

Fig.12: Bar chart of Damping ratio and natural frequencies of Al/MWCNT/GR by Casted samples

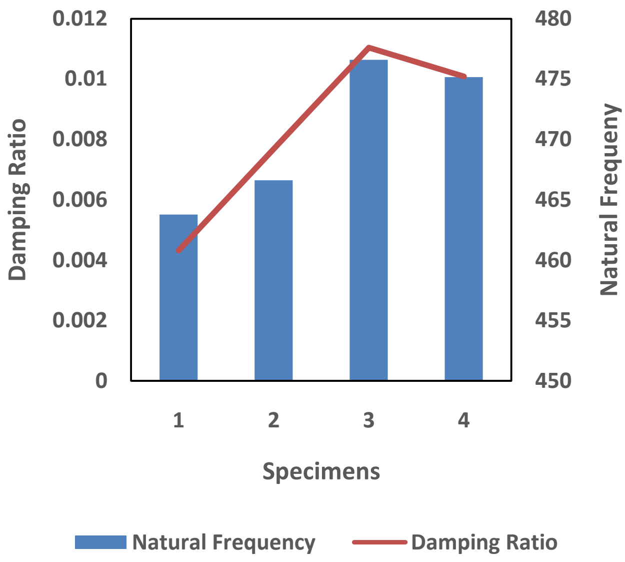

Fig.14: Bar chart of Damping ratio and natural frequencies of Al/MWCNT/GR of P/M samples

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4. CONCLUSION

The main objective of the paper was to investigate the damping behavior characteristics of Al based hybrid nanocomposites. Commercial purity Aluminum as a matrix, Multi Walled Nano Carbon Tube (MWCNT) and Graphene (GR) as reinforcement with a weight percentage of 0.5%, 1%, 1.5%, 2% have been fabricated by Casting and Powder Metallurgy (P/M) techniques. The cast and P/M specimens are extruded into cantilever beams of rectangular cross section. Free vibration test was conducted on the specimens for investigating damping characteristics. The results revels that, Al/MWCNT/Gr (1.5 wt. %) by P/M technique is having better damping properties. Beyond increasing the wt%. Al/MWCNT/GR deterioration in damping and natural frequency and decreasing the wt.% Al/MWCNT/GR reduces damping characteristics. P/M specimen having less voids or pores as compared to Cast specimen, P/M Specimen having significant behavior characteristics of damping.

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