Effect of Carbon Nanotube on Damping Characteristic of Epoxy Polysulfide Blend Composite

Dr. Adnan Neama Abood
Ministry Of Higher Education and Scientific Research/Baghdad.
Dr. Ibtihal.A.Mahmood
Machines & Equipments Engineering Department, University of Technology/ Baghdad.
Ekhlas Edan Kader
Technical College, University of Diyala / Diyala.
Email: eng_ekhlas@yahoo.com

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ABSTRACT

In a Nano-composite structure, it is anticipated that high damping can be achieved by taking advantage of the interfacial friction between the nanotubes and the polymer. The purpose of this paper is to investigate the structural damping characteristics of polymeric composites containing Carbon nanotubes (CNTs) with various amounts with polysulfide rubber (PSR) . The damping characteristics of the specimens with 0 wt% and 0.6 wt% Carbon nanotube contents were computed experimentally. Through comparing with neat resin specimens (epoxy, epoxy +PSR), the study showed that one can enhance damping by adding CNTs fillers into polymeric resins. Similarly experiment showed that the maximum value of damping ratio was obtained at 0.4 wt% CNTs.

Keywords: Epoxy, Carbon Nanotubes, Nano-composite

تاثير انابيب الكربون النانوية على خصائص التخميد لخليط ايبوكسى بولى سلفايد

الخلاصة :

لوحظ انه في المواد المختلطة النانوية يمكن الوصول الى تخميد عالي بالاستفادة من الاحتكاك بين الانابيب النانوية والمادة البوليمرية .الهدف من هذا البحث هو دراسة خواص التخميد في الهياكل للمادة المختلطة المدعمة بالأنابيب النانوية لمختلف نسب المطاط . خاصية التخميد للعينات لنسب الانابيب بين ٠-٠.٦% تم دراستها واختبارها عمليا. ومن خلال المقارنة مع المادة الخام للقاعدة والقاعدة مع المادة المضافة لوحظ ان التخميد تحسن بإضافة الانابيب النانوية للمادة الخليطة. و اظهرت النتائج العملية ان اكبر قيمة لنسبة التخميد (عامل التخميد) هي عند اضافة ٠.٤% من الانابيب النانوية للكربون.

INTRODUCTION

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2412-0758/University of Technology-Iraq, Baghdad, Iraq

Polymeric composites are usually called reinforced plastics. They are composed of reinforcing filler and a polymer matrix. Thermoset resins, such as epoxy resins, have high heat resistance and great structural durability as compared to other polymeric materials. While reinforcing fibers can provide strength and stiffness, epoxy resin can give the desired shape or structure to a composite and distribute the stress between the enforced fillers. The combination of high strength of the reinforcing filler and the epoxy matrix gives composites many desirable chemical and physical properties. They have high strength and can meet specific strength requirements in engineering applications. They have high stiffness and meet the low deformation requirement under high load. Compared to Steel and Aluminum, they have the highest ratio of strength to weight, which is one of the important requirements in the aerospace industry.

Chemically, they are stable and have excellent resistance against corrosion and wearing. Economically, they are cost-effective materials and easy to use [1].

Commonly used nanoparticles in nano-composites include multi-walled carbon nanotubes (MWCNTs)**[2]** . Carbon nanotubes (CNTs), both single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs), have been an active area of research in recent years [3] since they were first identified by Iijima [4]. The high Young's modulus and tensile strength of carbon nanotubes have generated huge interest in the potential development of super-strong, super-stiff composites with carbon nanotubes as reinforcements. SWCNTs have near-perfect lattice structures, which result in predicted elastic moduli greater than 1 TPa and tensile strengths in the order of 100 GPa [5]. SWCNTs are found either in parallel bundles called 'ropes' or in concentric bundles known as MWCNTs [6]. The SWCNTs in the bundle are held together with relatively weak van der Waals forces. When these nanotubes are dispersed in base polymers, significant improvement in mechanical properties of the resulting nano-composites has been demonstrated/ achieved even for very small weight/volume fractions [7].

Most of the research on CNTs-based composites has focused on their elastic properties. Relatively little attention has been given to their damping mechanisms and ability, While Koratkar *et al*.[7][8] recently observed promising damping ability of a densely packed MWCNT thin film (no matrix); however, damping characteristics of MWCNTs filled composites have not been investigated in any detail [2] Jeary [9] discussed the mechanism causing damping and concluded that fracture at both microscopic and macroscopic scale is the dominant mechanism for energy release[10]

The interfacial friction between the nanoparticles and polymer matrix and PS rubber is the primary source of energy dissipation in MWCNTs based nano-composites. In MWCNTs-modified polymer composites, the interfacial friction between the nanoparticles and the polymer resin are also a main source of energy dissipation. This has been found to be the dominant damping mechanism between the two [11,12]. As a uniaxial strain is applied to the matrix of the nano-composite, the nanoparticles de-bond from the matrix in the applied direction. In response to this, the particle remains in contact with the matrix in the transverse direction, while sliding out of plane in the third direction. The friction generated from this interfacial sliding is the primary source of energy dissipation.

This interfacial slip between the surface of the nanoparticle and matrix result in very high mechanical damping. The aspect ratio of the nanoparticles greatly contributes to their damping properties. Higher aspect ratio causes increased interfacial contact. For this reason, long nano-carbon tubes are used rather than shorter nano-fillers. In engineering, the damping ratio is a dimensionless measure describing how oscillations in a system decay after a disturbance many systems exhibit oscillatory behavior when they are disturbed [13]. Introducing CNTs into blend materials is mainly to increase damping due to their high damping properties which is main goal of this research.

Theory

The damping of a structure can be estimated using the Logarithmic decrement A method.

***2.1.* Logarithmic decrement A**

A convenient way of determining the damping in a system is to measure the rate of decay of oscillation. It is usually not satisfactory to measure ω and ωn because unless $\xi > 0.2$, $\omega = \omega n$..The logarithmic decrement, A, is the natural logarithm of the ratio of any two successive amplitudes in the same direction, and so from Fig. (1).

$$A = ln\frac{x1}{x2} \quad \ldots (1)$$

Where

x1 and x2 are successive amplitudes as shown in fig.(1).

Since $\boldsymbol{x} = xe\text{-}\xi\omega t\sin(\omega n+\phi)$ ….(2)

If $x1 = xe\text{-}\xi\omega t$ then **x2,** $= xe\text{-}\xi\omega t(1+\lambda)$ …. (3)

Where

λ is the period of the damped oscillation[14]. Thus:-

$$A = \frac{Xe\wedge -\xi\omega}{= xe\wedge -\xi\omega t(1+\lambda)} = \xi\omega\lambda \quad \text{since} \quad \lambda = \frac{2\pi}{\omega n} = \frac{2\pi}{\omega n\sqrt{1}-\xi\wedge 2} \quad \ldots (4)$$

Experimental work

Materials

MWCNTs with minimum purity of 95%, 3–15 number of walls, average of outer diameter of 2–6 nm, average of inner diameter of 2–6 nm, average of length is 1–10 µm and density of 0.15–0.35 g/cm3 were obtained from Plasma Chem GmbH. Fig.(2) shows SEM of CNTs .

Epoxy resin type (Quickmast 105® (DCP)), containing epoxide group, which is thermoset resin and manufacture by commercially produce from Quick Mast company, the hardener from the same company are used to achieve curing of the epoxy resin and epoxy properties are shown in Table(1). Considering polysulfide resin, one of the most properties that distinguishes this rubber is that it contains sulfur as part of a series of linear polymer whose trademark is (DCP). The polysulfide is supplied in the shape of white dough that changes to elasticity shape by adding PbO_2 (black dough) in the ratio 1:16 with density (1.35) gm/cm3as Table.(2) contain Properties of polysulfide polymers.

Tabel.(1) Epoxy mechanical properties(1).

Test method	Typical results
Compressive strength	70.0 MPa at 20 ◦C
Tensile strength	26.0 MPa at 35 ◦C
Flexural strength	63.0 MPaat 35 ◦C
Young modulus in compression	16 GPa

Pot life	90 minutes at 20 ◦C
Specific gravity	1.04
Mixed viscosity	1.0 poise at 35 ◦C

Tabel.(2) polysulfide mechanical properties.

Property	Typical value or description
General chemical structure	-[R-S]- R=(CH2CL)2or(CH2 (OCH2CH2CL)2
Service temperature (°C)	-50 to 95
Mixng ratio	1: 16
Density (g/cm3)	1.35
Tg (◦C)	292
Hardness (Shore A)	22-39
Ultimate elongation (%)	126-412
Tensile strength (MPa)	0.74 - 0.91

Preparation of MWCNT/Epoxy Polysulfide composite

Three series of composite (Epoxy-2%PSR) were prepared with different content of MWCNTs as 0.2, 0.4 and 0.6 wt%. First MWCNTs were mixed in epoxy resin via ultrasonic (Hielscher UP 400S) for 30 min and then polysulfide resin was added to improve epoxy toughness and mixing was continued for 1 h by (WiseTis) homogenizer with speed of 15000 rpm with ten minute work and ten minute off to keep the device temperature low. Then samples were placed in vacuum for 30 min at 80°C to remove bubbles and after this stage, aliphatic amine hardener and polysulfide hardener were added to composite while were mixed with low speed. After uniform mixing, the mixture was poured into the prepared mold and left for complete curing to be done for 72 hr.

Sample Preparation and Testing Procedure

In this research, Fig.(3) shows the specimens size of 100 mm X 12 mm X 4 mm were prepared from the samples with the percentage indicated in Table(3) .The specimen were subjected to free vibration according the standard test methods for measuring Vibration-Damping properties of materials ASTM E 756-05. The specimens were treated as self-supporting materials with cantilever beam configuration .The experiment was conducted on the specimen this allows sufficient length for fixing the beam as cantilever [14] . The experimental setup consists of an accelerometer KISTLER 8276A5 with sensitivity 9.8mV/g which is used to measure the beam response then there is a condition amplifier Brue&Kjaer which is modify the signal and change the acceleration into displacement information. Data acquisition is through National Instruments eight channel industrial platform sound and vibration measurement module having 24 bit resolution and acquisition rate capability of 1024 kS/s FREECAPTURE. Signal conditioning and analysis is done through SIGVIEW software. The Experiment setup for vibration measurement is shown in Fig.(4) Three sample specimens were subjected to testing in each composite and average value was taken to compute damping ratio and the natural frequency.

Results and Discussions

The regular composite beam without nanotube and the nanocomposite beam with MWCNTs were used as the specimens for damping test. Fig.(5). Shows the SEM images from fracture surfaces of (a) the neat epoxy polysulfide resin and (b)

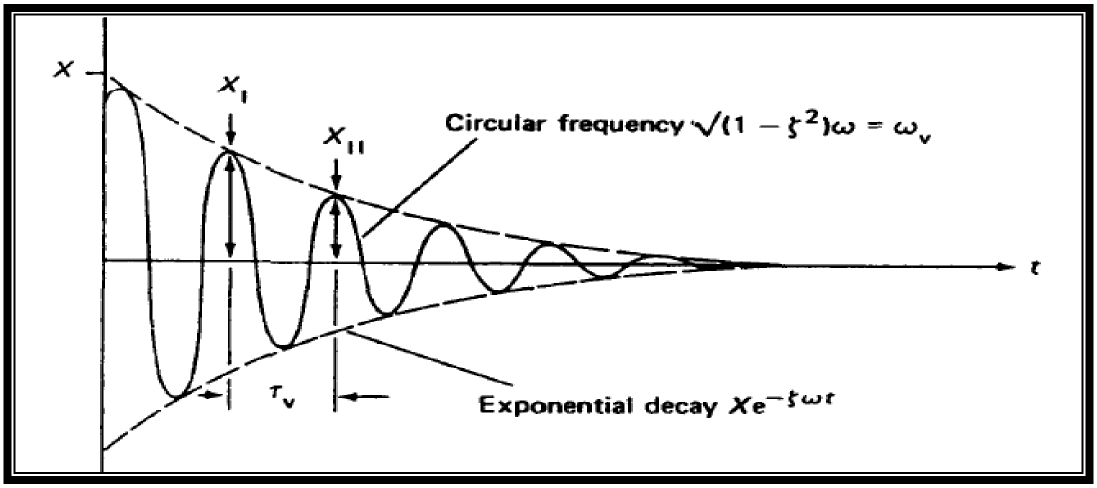
The 0.2 wt% MWNT/epoxy polysulfide nano-composites, MWCNTs were not dispersed well in the matrix. Some smooth outcrops of the MWCNTs indicated that the interfacial bonding between the MWCNTs and the rubber matrix needed to be improved.
Fig.(6) shows that damping ratio increase as MWCNTs% increased, due to energy dissipation ability of MWCNTs and the effect of stick and slip of MWCNTs with absorb energy and reduce the vibration amplitude till decay. Higher damping ratio is preferred in structural damping applications to reduce vibration and its bad effect on structures [15].
Fig.(7) shows that natural frequency decrease as MWCNTs% increase as the amplitude of vibration decrease causing the sample to have less natural frequency.

Fig. (8) to Fig.(12) show amplitude versus frequency for all bends used in this research. From these figures, the logarithmic decrements have been calculated. It can be seen that, the shape of the peak flattens as the weight percentage of MWCNTs increases, resulting in smaller peak amplitudes indicative of increasing damping ratios due to the effect of MWCNTs which dissipate energy in stick and slip of the tubes with matrix upon the applied load and deagglomeration of tubes bundels .PS structure tend to stretch when external tensile load is applied which reduce the amplitude of isolated vibration. Fig.(13) shows the four responses overlayed [16].

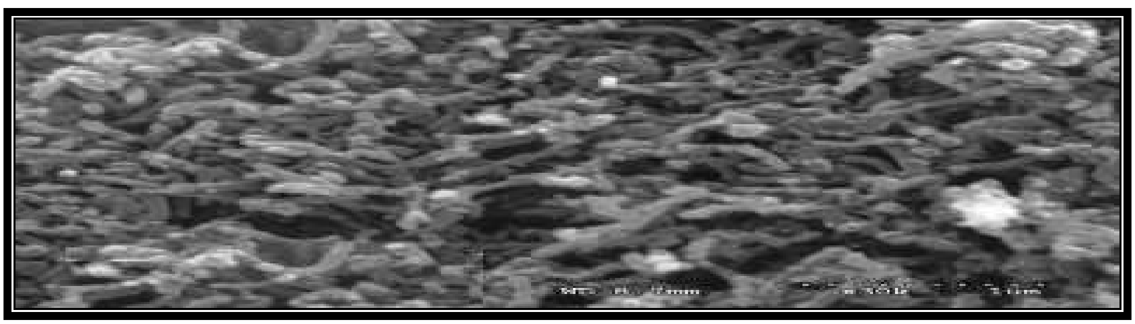
Fig.(14) to Fig.(18) shows the measured FRFs(frequency response function)for specimens with different nanotube material contents (0 wt%, 0.6 wt%). The damping ratios for these specimens were computed according to the theoretical procedure described above. It can be seen that natural frequency decrease as MWCNTs% increase .this behavior can be attributed to the nature of bonding between MWCNTs and the matrix with and the stretching and absorbing of energy of polysulfide which cause the amplitude to reduce and then decay.

CONCLUSIONS

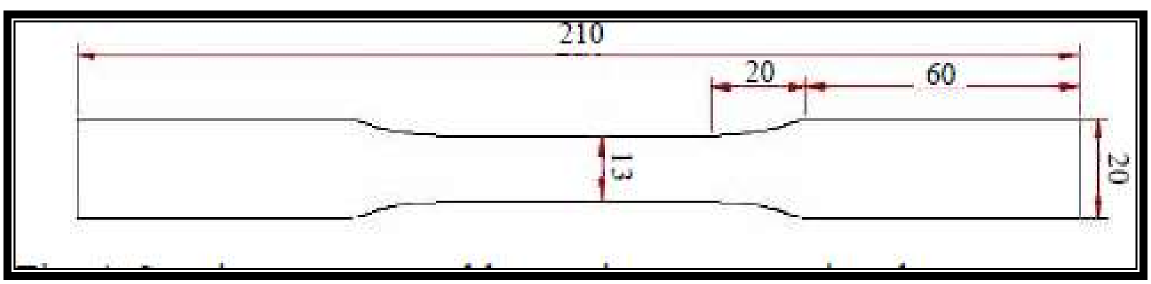
1- Epoxy is compatible with PSR .
2-Dispersion of MWCNTs is very important since it affects the composite mechanical properties
3-Well dispersed MWCNTs led to better damping properties, because of interfacial bonding effect on the blend properties.
4-Damping factor increases as MWCNTs increase up to 0.4% MWCNTs then decreases due to bad dispersion.
5- Natural frequency decreases as MWCNTs increase in the composite blend
6- MWCNTs can effectively reduce vibration problems and maximize the life of the structural members.



Figure(1) vibration decay.



Figure(2) SEM of CNTs

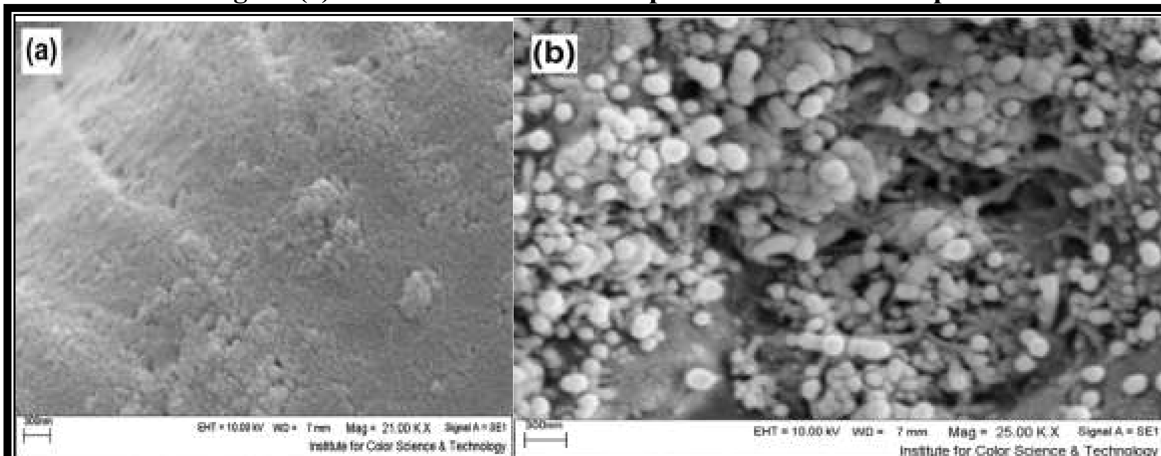


Figure(3) dimensions of damping test sample

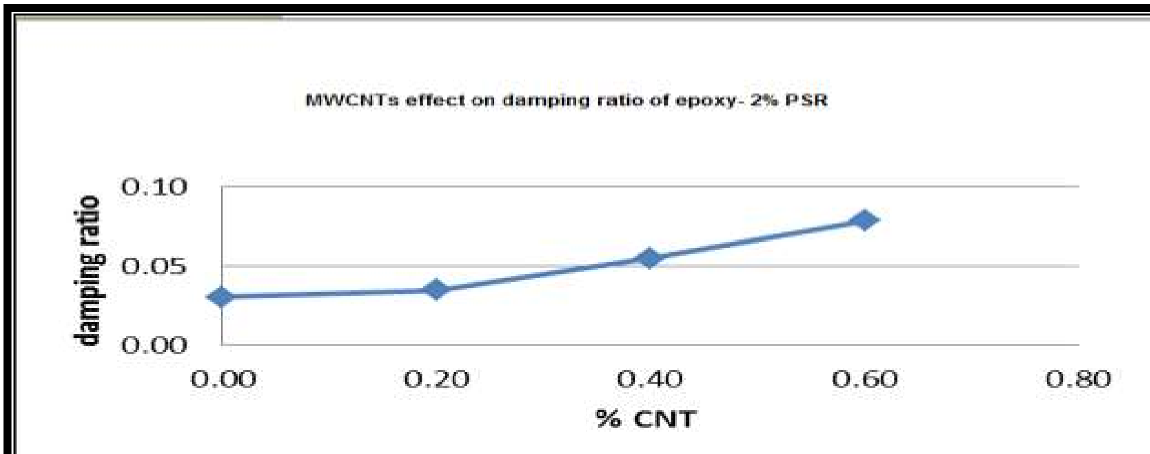
Table.(3) Composite Materials in Experiemental Work .

Sample No.	Epoxy %	PSU %	CNT %
1	98	2	0
2	97.8	2	0.2
3	97.6	2	0.4
4	97.4	2	0.6

Figure (4) Free Vibration Test Setup with Assembled Sample.



Figure(5). SEM images from fracture surfaces of (a) the neat epoxy -PSR resin and (b) the 0.2 wt% MWCNTs/epoxy-PSR.



Figure(6) effect of MWCNTs%on damping ratio.

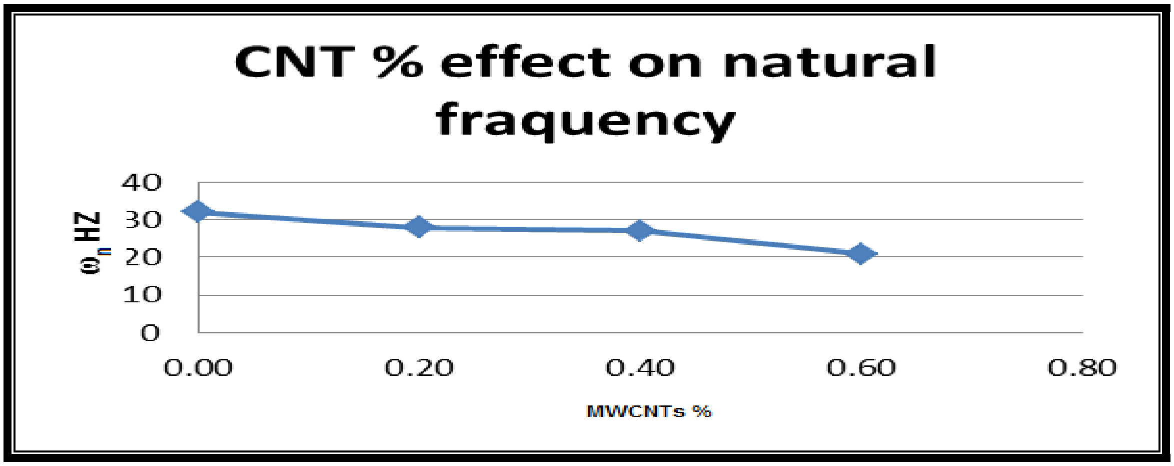
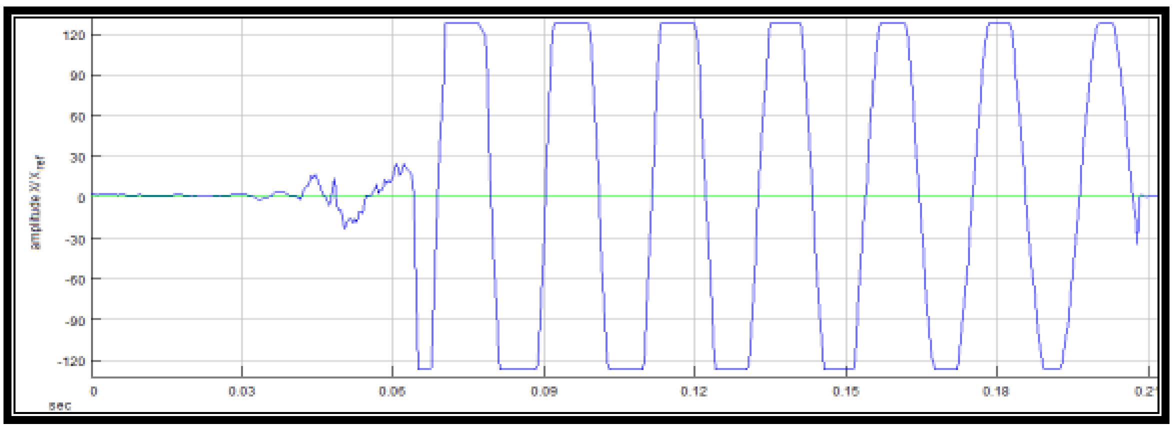
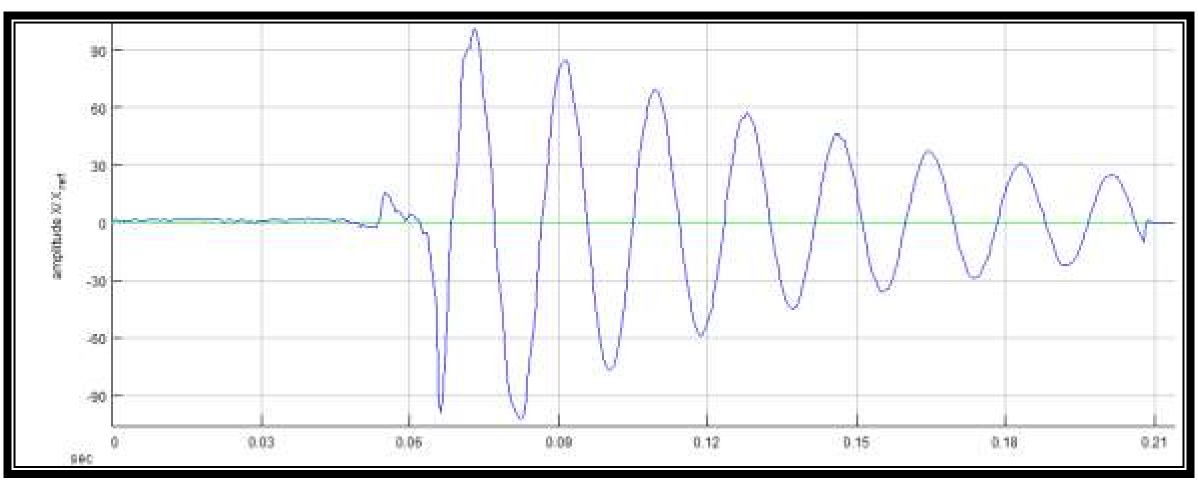


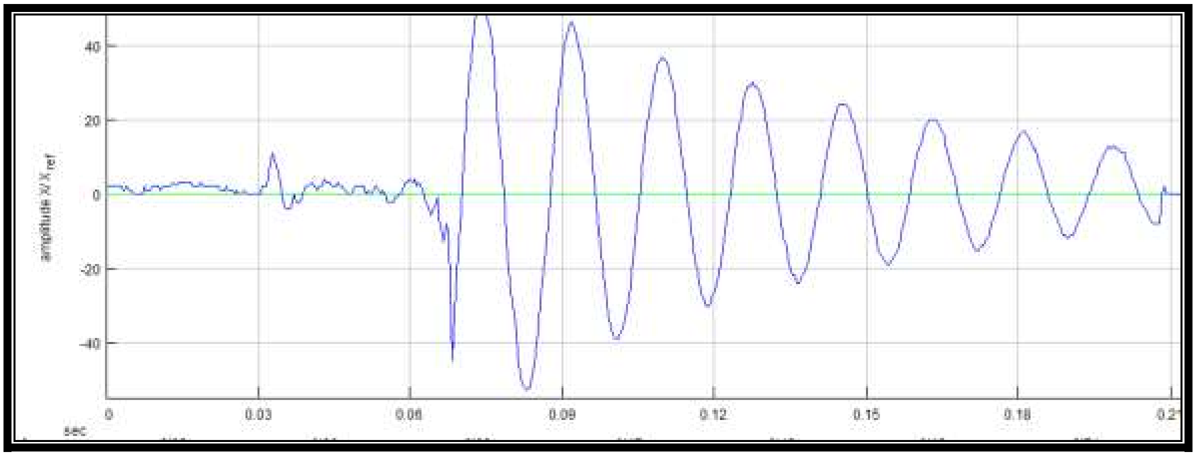
Figure.(7) effect of MWCNTs %on natural frequency.



Figure(8) amplitude decay for epoxy .



Figure(9) amplitude decay for epoxy+2 % PSR.



Figure(10) amplitude decay for epoxy+2 % PSR+0.2% cnt.

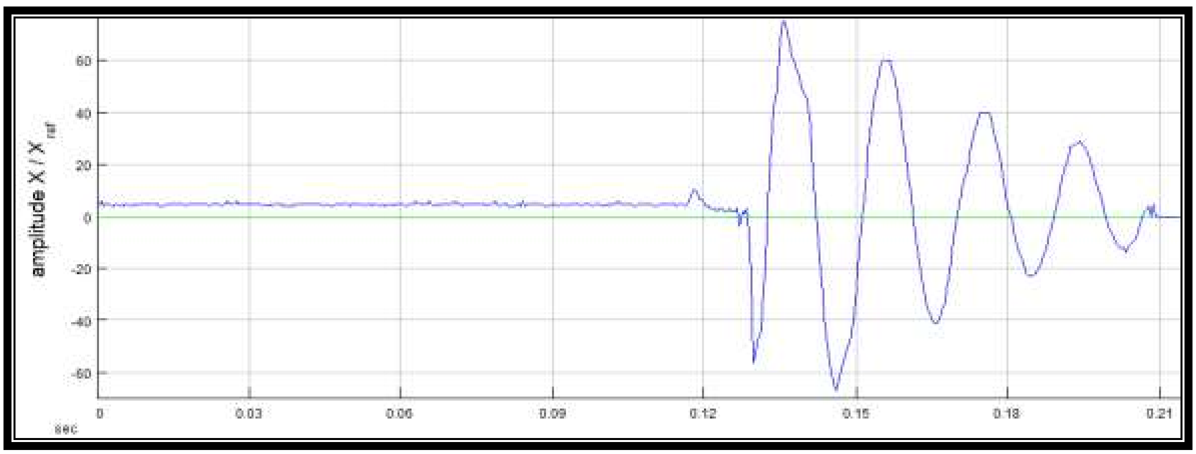
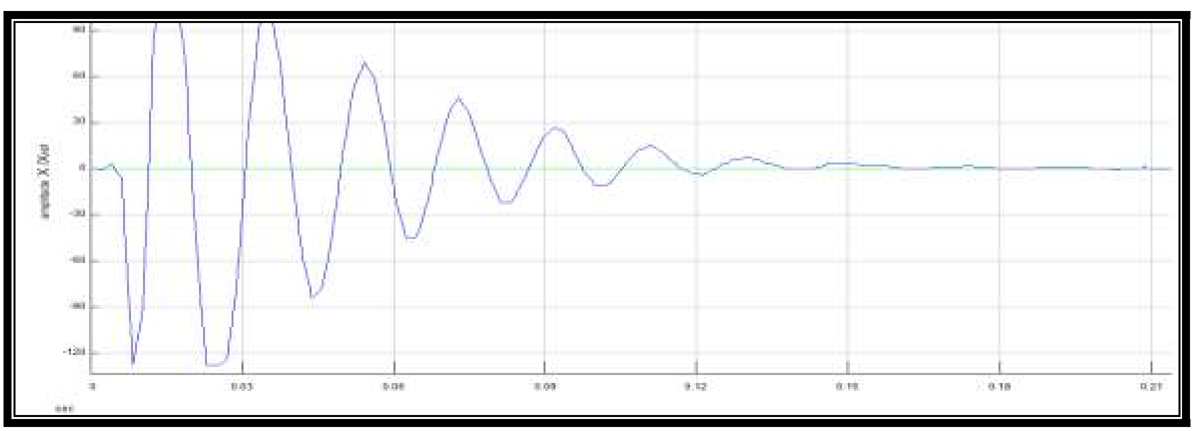
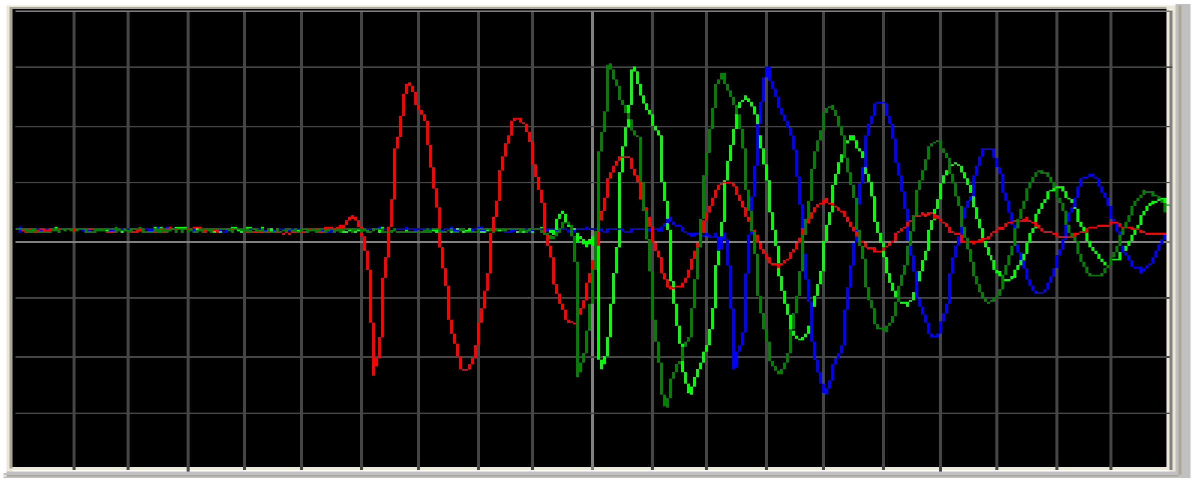


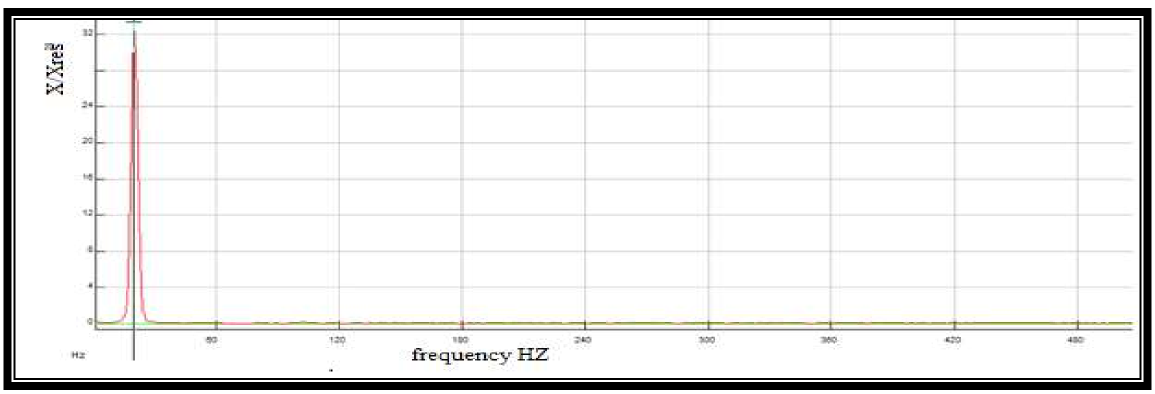
Figure.(11) amplitude decay for epoxy+2 % PS+0.4% MWCNTs.



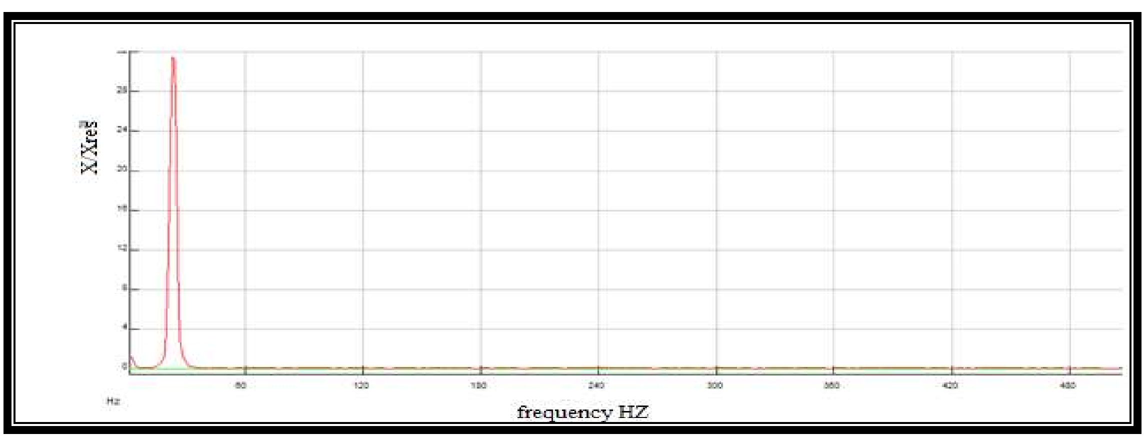
Figure(12) amplitude decay for epoxy+2 % PS+0.6% MWCNTs.



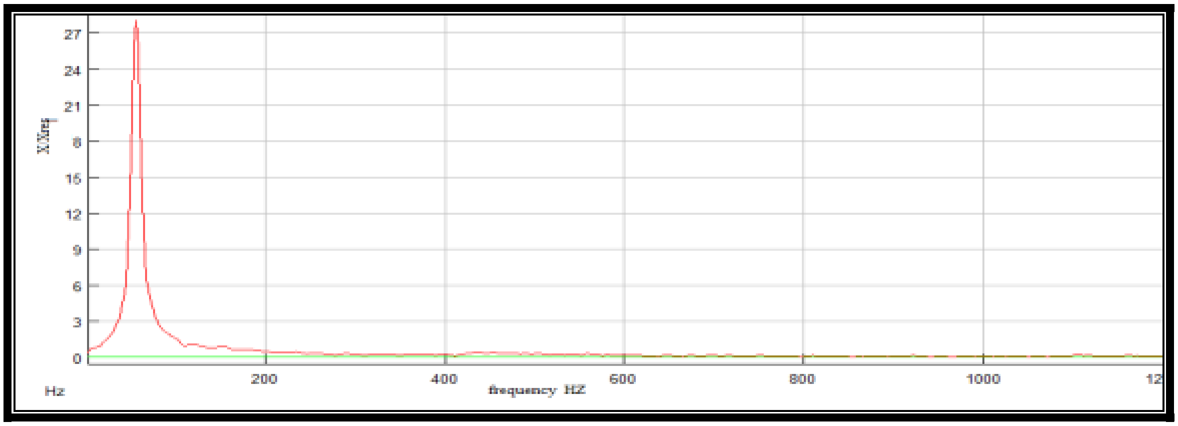
Figure(13) The four responses overlayed in digital Storage Oscilloscope Computer Program.



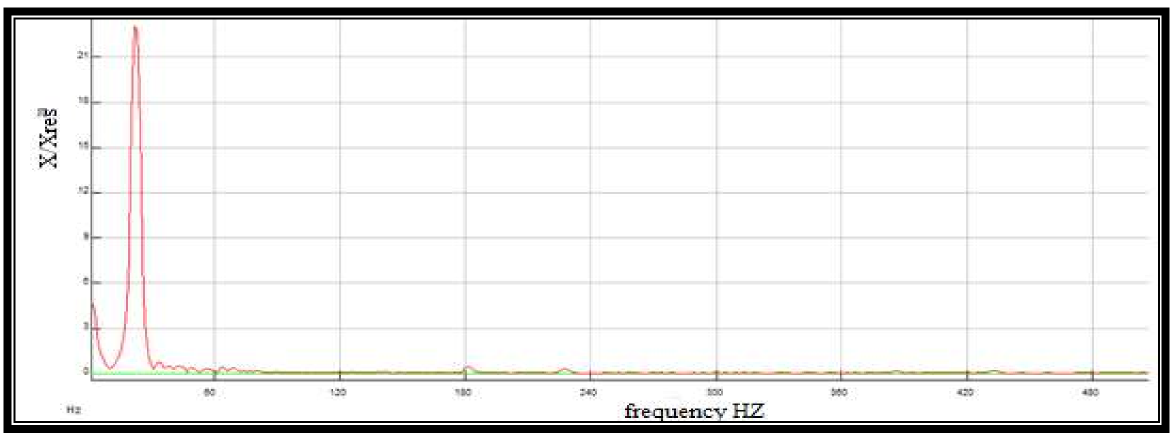
Figure(14) Sig-View Program for FFT Analysis Function of pure epoxy.



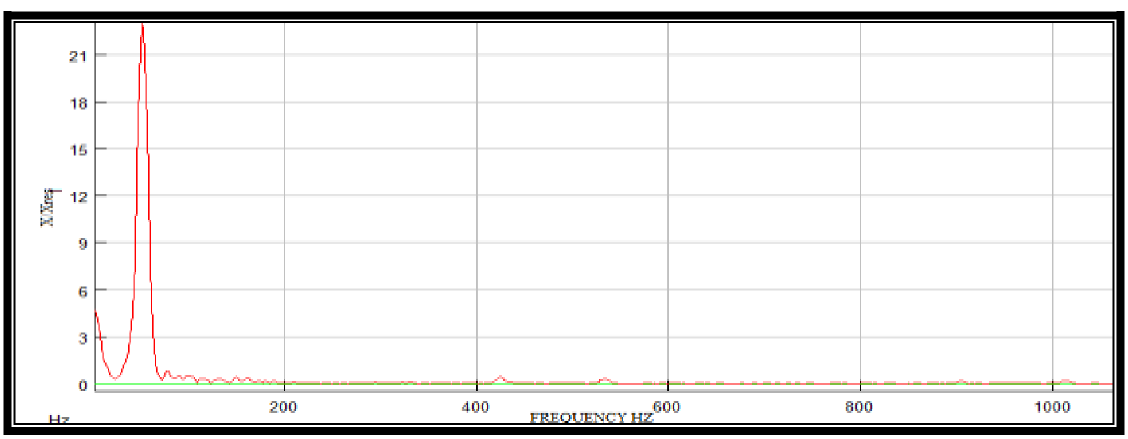
Figure(15) Sig-View Program for FFT Analysis Function of Epoxy -2% PSR .



Figure(16) Sig-View Program for FFT Analysis Function of Epoxy-2% PSR+0.2% MWCNTs+ epoxy.



Figure(17) Sig-View Program for FFT Analysis Function of Epoxy- 2% PSR +0.4% MWCNTs.



Figure(18) frequency response function of Epoxy- 2% PS +0.6% MWCNTs.

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