Advanced Research in Electrical and Electronic Engineering
p-ISSN: 2349-5804; e-ISSN: 2349-5812 Volume 6, Issue 2 April-June, 2019, pp. 65-69

http://www.krishisanskriti.org/Publication.html

Effect of Curing Pressure on Electrical Conductivity and Vibrational Characterization of Carbon Fiber Reinforced Polymer Composites

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Abstract—*The advantages introduced by carbon fiber reinforced polymer (CFRP) composite has created an acceptable alternative in several applications and a perfect replacement for standard materials. The advantages of using CFRP composites are due to their light-weight, high stiffness, as well as corrosion resistance. The replacement of the conventional aerospace-grade metal alloys with CFRP composites results in new challenges. Composites have been widely used in electrical engineering primarily as an insulator. To be used in electrical applications, composites are needed to have acceptable electrical properties, mainly a reasonable electrical conductivity. Hand lay-up method is used for the fabrication of specimens. Two probe method is used for testing the specimens. Vibration Experiment also done for calculating the natural frequencies. All samples are prepared same orientations but different pressure i.e. 100 psi, 200 psi, and 300 psi. Natural frequency and damping ratios of the CFRP samples are calculated for its vibrational behavior. The effect of voltage and time on the resistivity of CFRP analyzed. The effect of curing pressure on electrical conductivity is also analyzed. Resistivity increases along with curing pressure of CFRP, and also increases with time as the more heat is generated in the samples. In vibrational characterization, found that if the curing pressure of the Carbon Fiber Reinforced Polymer is increased then the Elastic Modulus of the CFRP sample also increases.*

1. INTRODUCTION

Composites used on a large scale in the electrical engineering field as an insulator as well as conductor. Composites have acceptable electrical properties and mechanical properties also. Due to their good mechanical properties, the CFRP composites are used in the construction of the aircraft and wind turbines. CFRP composites can be used as a conventional metallic structure in aerospace industries, as well as other industries. For instance, the outer skin of an aircraft should act as a shield against a lightning strike and prevents the penetration of the lightning current, which can lead to catastrophic damages. Lightning-induced damage is mainly thermal damage, and Joule heating is a primary indicator of lightning thermal damage, which is proportional to electrical resistance. Carbon fiber Reinforced Polymers have good vibrational characteristics. Strength of the CFRP can be changed according to need. It depends on fibers direction as well as the stacking sequence of the layers of fiber. CFRP has good electrical conductivity and good dynamic characteristics. Since CFRPs are widely replacing metallic parts and as these materials are not as conductive as metal, there is an increasing need to characterize their electromagnetic properties to understand and anticipate damage caused due to lightning and stress variation.

2. MATERIALS USED

In this present study, unidirectional carbon fiber and unidirectional glass fiber were supplied by Hindoostan Tech, Mumbai, India. Matrix material epoxy resin SY-12(319) was used.

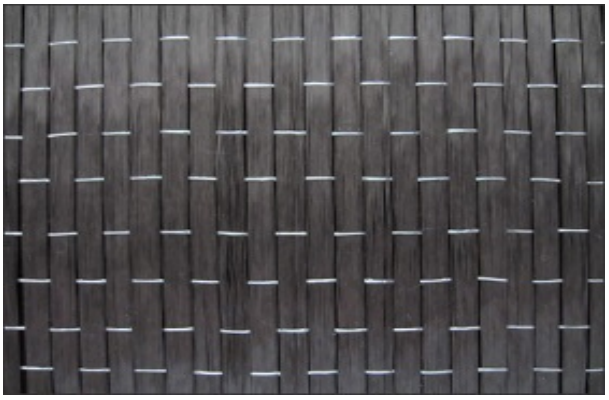


Figure 1. Unidirectional Carbon fiber

Carbon fibers are 5-10 micrometers in diameter. Carbon fibers have good mechanical properties such as high strength, high tensile modulus, and low weight as well as good chemical properties. The epoxy resin is a curing agent. Epoxy resin helps in cross-linking of the materials.

3. DESIGN AND METHODOLOGY

Composite strength depends on fiber directions, stacking sequence, and their dimensions. Therefore before the fabrication design composite according to need.

Table 1. Dimensions of the samples

Parameters	Dimensions
Specimen Length	10 cm
Specimen Width	2 cm
No. of layers	4
Orientation	[0^o/45^o/-45^o/0^o]

Hand-layup technique is used for fabrication of the composite. In this method, cut the carbon fiber layers according to the required dimension. After that prepared the mixture of epoxy and hardener in the ratio 10:1. Mixture applies on each for the stacking in the sequence of required orientation.

The hand layered samples were then placed between the heated plates of curing press at different pressure (100 psi, 200psi, 300 psi).

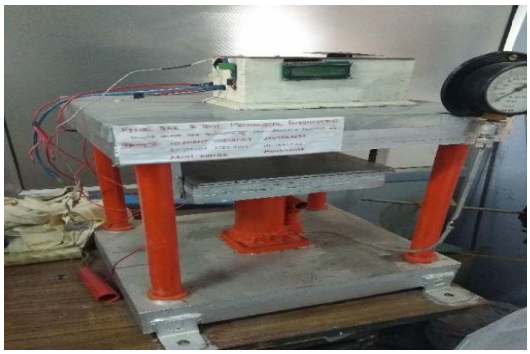


Figure 2: Composite fabrication press

The temperature was set to 40^o C for 1-hour curing of the sample. After 1-hour curing samples were left at room temperature for curing for 24 hours. After curing, the sample was removed from curing press and then GI sheets were detached from the sample carefully.

4. EXPERIMENTATION

In this experiment procedure, two types of experiment are done. First is used for electrical conductivity and the second method is used for its vibrational characteristics. First is the two-probe method, it is a simple interpretation of the measured data is difficult. In this method, two electrodes are connected to the sample to determine its specific resistivity having the resistivity and dimensions of the sample. The two-probe method is based on Ohm's law, i.e., V = IR with V, I and R being voltage, current, and resistance between the two electrodes respectively. When connecting an electrical meter to the two ends of the conductive wires, a circuit is formed, in which a current is produced by the power of the meter. Based on the current and voltage and using Ohm's law, resistance is measured.

Figure 3. Setup of Two probe method

The second method is a vibrational experiment for calculating the natural frequency and damping ratio of the specimen.

Natural frequency shows the dynamic characteristics of the specimen. With the help to this test can be calculated the modulus of the specimen. Vibrational experiment setup based on a USB based data acquisition system. Data recorded by a laser sensor, an acquisition system receives the data and transmit into CPU. With the help of software can analyze the vibrational behavior.

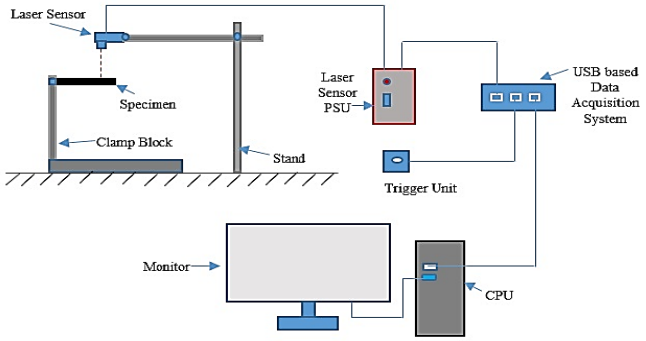


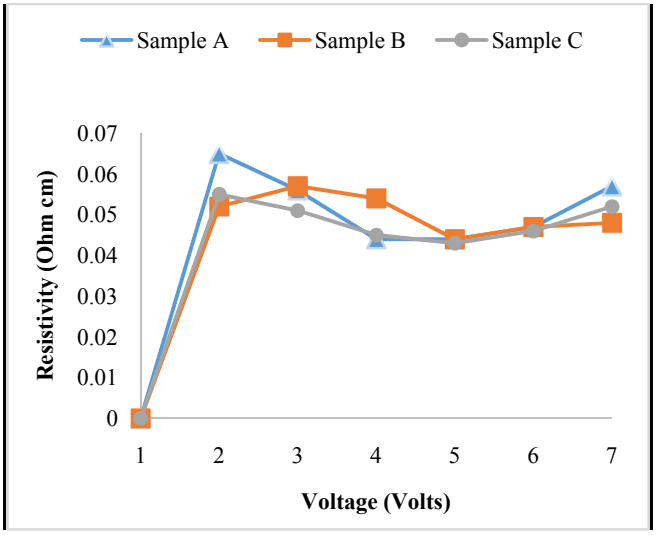
Figure 4. Schematic diagram of Vibration Experimental Setup

5. RESULTS AND DISCUSSION

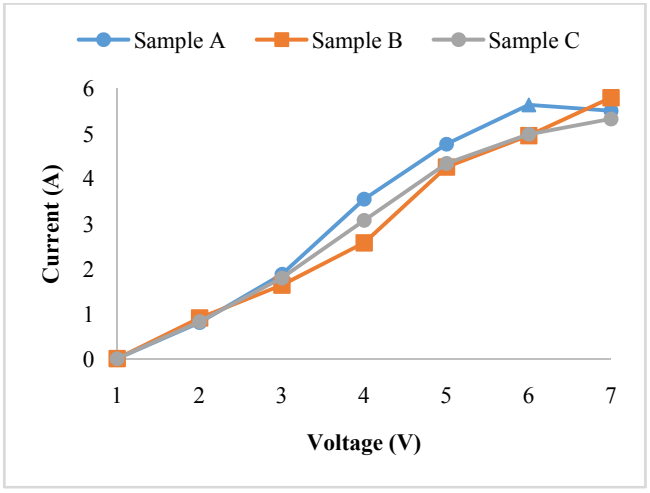
There are results obtained based on electrical analysis and Vibrational analysis. In both cases, calculated the effect of curing pressure. In electrical data analysis, first is the effect of voltage on resistivity another is the effect of time on the resistivity of CFRP specimen. There are Sample A, Sample B,

and Sample C means curing pressure is on these samples at 100 psi, 200 psi, and 300 psi respectively.

5.1 Effect of voltage on resistivity

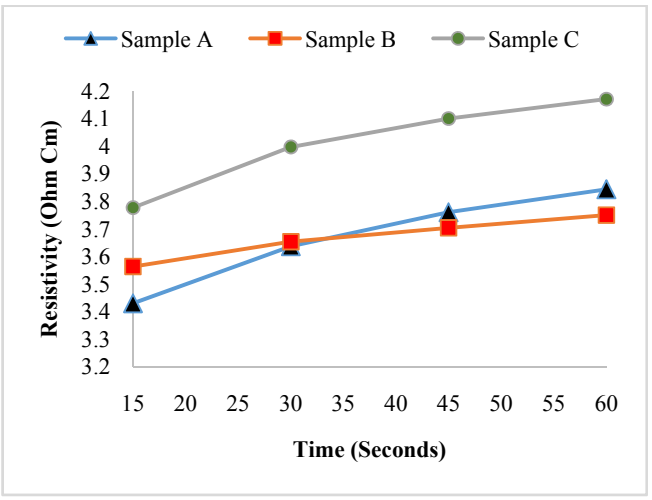


Graph 1. Effect of Voltage on Resistivity

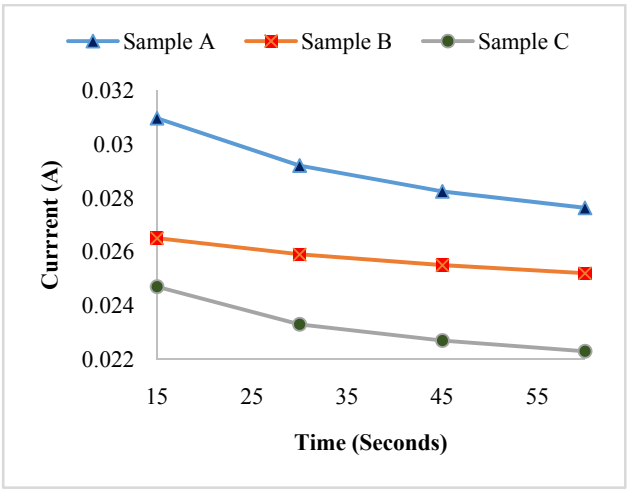


Graph 2. Current vs. Voltage

5.2 Effect of time on resistivity



Graph 3. Time vs. Resistivity

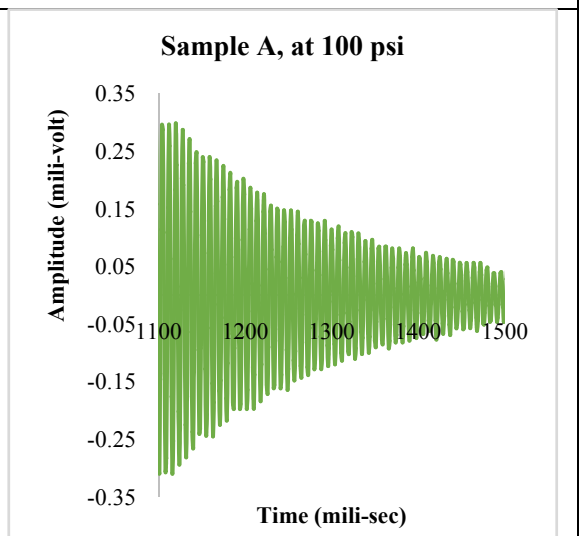
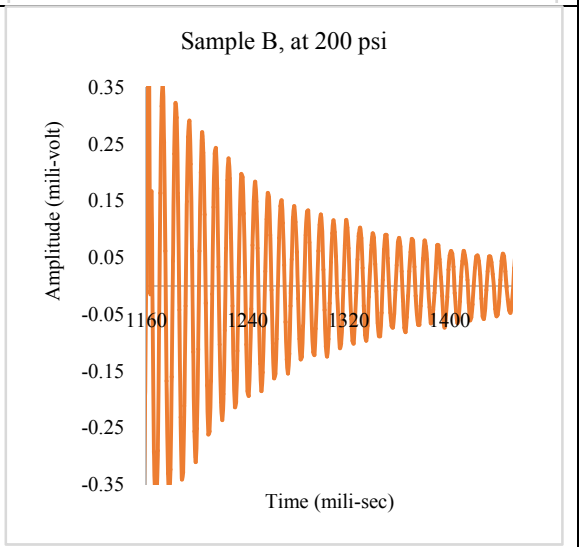


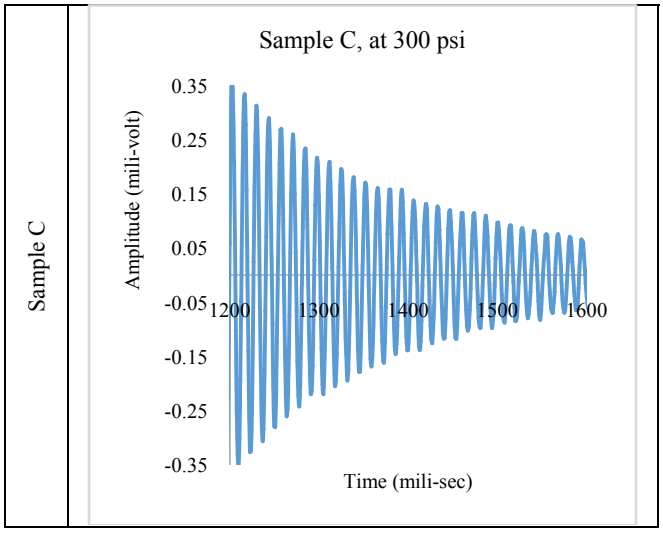
Graph 4. Current vs. Time

5.3 Effect of Curing Pressure in Damping

In the vibrational analysis, the effect of curing pressure in damping, it shows the energy dissipated by samples in respect to time.

Table 2. Logarithmic decrement curves

	Logarithmic decrement curve
Sample A	
Sample B	



5.4 Effect of curing pressure on Natural Frequency and damping ratio

There are data about natural frequencies and damping ratios that how to curing pressure affects the vibrational behavior in CFRPs.

Table 3: Effect of curing pressure on Natural Frequency and damping ratio

S. No.	Sample No.	Natural Frequency (in Hz)	Damping ratio
1	Sample A	127.61	0.00668
2	Sample B	94.468	0.01354
3	Sample C	73.805	0.00916

6. CONCLUSIONS

Analyzed the effect of curing pressure on electrical conductivity in which found that increase the curing pressure of CFRP, then resistivity will increase and also compared resistivity with time in which found that resistivity also increases with time as the more heat is generated in the samples.

In vibrational characterization, we have seen that if the curing pressure of the Carbon Fiber Reinforced Polymer is increased then the Elastic Modulus of the CFRP decreases. Natural frequency is higher at 100 psi and low at 300 psi, but the damping ratio is higher at pressure 200 psi.

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