Xournals

Academic Journal of Material Sciences

ISSN UA | Volume 01 | Issue 01 | January-2019

Carbon Fiber Epoxy Composites and Its Mechanical Properties

Hitesh Pingle[1]

Available online at: www.xournals.com

Received 19th August2018 | Revised 8th October 2018 | Accepted 6th December 2018

Abstract:

Many materials are used in the field of aeronautical such as glass fiber, aluminum and so on. The application of composites materials are growing from customary areas (Aircraft engineering) to various fields (marines, automobile industry, civil engineering) because of the required qualities that can be attained by other constituent materials. In aeronautical industry, Carbon fiber reinforced composites are used for the manufacturing of different components of aircraft with the tight mechanical requirements. This paper discussed about the carbon fiber/epoxy and their strength compared to other composites. To know better understanding of mechanical properties of composites made from the epoxy resin and reinforced carbon fiber, different types of tests such as flexural strength, tensile strength, and compressive asset. The epoxy mastic works to improve the compressive property of composites. And this paper show the effects when carbon nanotube or nano-clay is added to the matrix of carbon fiber and epoxy.

Keywords: *Carbon Fiber, Epoxy, Flexural, Compressive, Tensile Strength*

Authors:

1. *School of Science, Swinburne University of Technology, Melbourne, AUSTRALIA*

Introduction

Polymers are the attractive materials because of the low density compared to others. The demand of this material is increasing continuously because of they have an excellent mechanical properties. It is clear to all that the tension strength is stronger than the compression strength in the most advanced fiber. This property is because of the micro buckling of fibers that are entrenched in the medium governed the compressive forte of unidirectional amalgams with the fiber waviness that being the major factor. In structural application of composites, compressive properties are weak parts. In the manufacturing of high-speed rockets, aircrafts, and other related space and high temperature resins or electronics, are used as composite materials. The major load is shared by the reinforcements when a compound comprises of fiber cavalries that is isolated in a fragile matrix like epoxy/ carbon complex. This fiber bear almost all load. The stiffness and strength of constituent fiber control the stiffness and strength of such complexes **(Banakar and Shivananda, 2012).**

Carbon Fiber Reinforced Polymers (CFRP)

A significant improvement is offered by Carbon Fiber Reinforced Polymers (CFRP) over current conventional materials in aeronautical industry. It is a new class of polymer composites that consist multiple layers of fibrous materials. Because of their advanced properties this new class is used for many purposes like packaging, automotive, electronics, and construction industries. They are used to produce dissimilar physical constituents such as landing-gear doors, flaps, aileron and other structural parts. One of these advanced properties is they have high forte to stiffness and weight to weight ratios. Above the other monolithic constituents, these complexes have exclusive benefits such as high stiffness, high strength, corrosion resistance, long fatigue life, wear resistance, environmental stability and low density.

The complexes of laminates are vulnerable for motorized damage after come in the contact with tension, flexural and impact that results in the failure of materials. Though there is a reason of limiting using this in manufacturing practice. These reason are absence of dependable experimental processes that determine the mechanical characteristics of armored amalgams, complications in the mathematical exhibiting of distortion processes and the assessment of the load-carrying aptitude of protected structure and the prerequisite of new more reasonable manufacturing procedures.

CFRPs' motorized properties can be dogged by constitutes properties, composite's assembles, manufacturing technique and mode of collaboration at interfaces/matrix. By the known properties of constitutes, many mechanical factors of complexes can be determined. Still, the application of arduous mathematical solutions is not possible at all times because of the extreme sensitivity of some factors as strength, to the effects of other features that cannot be accounted completely' **(Rahmani *et al.*, 2015).**

Carbon Sources as a Suitable Material

Carbon and Graphite, both are the high temperature materials that also have a high strength and stiffness properties. These properties are maintained at a constant temperature of up to 2500°K. Composites of carbon fiber have many application such as biomedical, aeronautical, industrial, space and defense applications. The requirement of these supplies is that place where the system is exposed to extreme temperatures. They are used for high performance principles such as solid rocket motors. Now these days, the composites of carbon are used in military and commercial applications. A distinctive combination of chemical, mechanical and physical properties such as high strength and thermal resistance high modulus is contained by carbon fibers.

Formation of Carbon Fiber

The material of carbons fiber is generated by the carbonization of poly acryl nitrite fibers or Pitch resin or Rayon at high temperatures. Then, for enhancing the fiber strength and elasticity, the graphitizing and stretching processes are done. The diameters of carbon fibers is analogous to glass fibers that have a range 9 to 17 µm. Large threads are made from these fibers for the transportation and further production processes. Then, carbon fiber material is processed that includes weaving or braiding and convert into the carbon fabrics, cloths and mats in the same as glass fiber material **(Raja *et al.*, 2015).**

In the development of structure of any aircraft or other, Resin matrix of composites play an important role. Composites resin matrix are based on the carbon fiber and used to determine the chemical and thermal resistance of the complex whereas strength and stiffness are provided by the carbon fibers. An essential role is played by the fiber matrix adhesion strength on the motorized properties of the fibers

reinforced polymer composites. This is because when load is applied to complexes, then the load is transferred and distributed by the fiber matrix interface.

Carbon fibers have poor adhesive and bonding property toward the polymer matrix because of their nature of smoothness and chemical inertness. Various approaches can be applied for improving the bonding properties of carbon fibers. These are categorized into non-oxidative and oxidative treatments.

Composite material are more preferable compared to the steels and different metals because of the high strength at a lower specific weight, excellent resistance to chemicals, environment and corrosion which make it able to use in diverse environments and under various conditions.

Epoxy Resin

The treated end product of epoxy resins is Epoxy. It is used as a colloquial name for the epoxide purposeful group. Another name of epoxy resins is poly epoxides that are the class of reactive pre polymers and polymers that have the epoxide group. Wide range of applications of Epoxy such as use in electrical/electronic compounds, metal coatings, structural adhesives, fiber reinforced plastic materials and high tension electrical insulators. **(Raja *et al.*, 2015)**

It is considered as a combination of properties and a high-performance thermosetting resins. These resins are a versatile polymers that are used across the wide variety of industries. It is a composition of polymers that converts into solid through the chemical reaction. The ability of epoxy resin is: it can be transformed into a tough, hard thermoset from a thermoplastic state or a low-viscosity liquid. This is the most valuable property of epoxy resins.

The system of epoxy consists of two important constituents physically that are resin and curative. Chemical reaction is caused by the curative that convert the epoxy resin into solid. A cross linked complex of molecules is formed. This polymer is known as thermoset polymer structure that has high adhesion properties and cohesive strength because it shows the irreversible rigidness and heat resistance. Epoxy resin thermoplastic and cured state are indicated by the term epoxy. In the application field of industry, Phenolic resin and epoxy resin are very important polymeric materials **(Founda, Guo and Elsharkawy, 2017).**

Combination of Epoxy and Carbon Fibers

The obtained product of epoxy resin and high strength carbon fibers is generally used in many fields such as military, structural, and commercial field. These field require the low weight and high strength. With the low density, they can be molded and designed for having the stack sequences that produce the high stiffness and strength in the direction of high loading.

Wet layup

1. It is one of the kind of fiber reinforcement material manufacturing process.
2. In this method, matrix (Carbon fiber) is located on the forming tool.
3. Then resin 70% of its capacity and remaining part of the matrix 30% are taken in combination.
4. Then, saturation of it is take place with the epoxy resin by pouring the epoxy resin on the reinforced fiber layer.
5. The strengthened fiber layer mould with the wet epoxy resin is permitted to cool at normal room temperature in which vacuum bags are used for compressing the reinforced fiber layer to get the better outcome **(Raja *et al.*, 2015).**

Mechanical Properties

The automated properties of the carbon fiber complexes can be determined by the performance of different tests. These tests are as follows:

Flexural Test: It is the used to test the strength, called flexural strength. The strength that is developed bar shaped sample is considered as a single beam to bending force perpendicular to a bar. The normal length, width and thickness of the composite is measured which depends on the number of layers. Different testing machines are used for performing the tests. Minimum three measurement should be taken. And average is taken of that three measurements.

Compressive Test: For the compressive strength, the measurements of three dimensions are taken with the constant speed of the machine. Same steps are

followed as the Flexural Test, three measurements are taken and then average is find out. Both directions 'Axial and Radial' are used to measure the compression strength.

Tensile Test: In the same manner, three dimensions (Length, Width, and Thickness) are taken as per the number of layers. Then, three measurements are taken and then average is find out **(Founda, Guo and Elsharkawy, 2017).**

The difference between these strength is as: flexural strength is the bent strength means the ability of material that how much it can bent perpendicular to its longitudinal axis. The tensile strength is that strength of bearing the tension before the breakage. While Compressive strength have the same property as the breakage but the principle is different it is broken by the compression effects.

Thermal Conductivity Measurements

This value is used to measure the heat flow across the material. Different types of device are used in determining the thermal conductivity. In this process, specimen is heated at the one side by the metallic steam chamber and another side of specimen is put in the connection with the cylindrical brass calorimeter that is used to measure the amount of the heat. Heat is generated in the form of vapor that flows from high temperature (Steam chamber) to low temperature (toward the calorimeter). The heat flows until the thermometer gives a constant value**.** These tests are very sensitive for the estimation of the strength and conductivity against the many factors such as heat, forces etc. **(Founda, Guo and Elsharkawy, 2017).**

Review of Literature

Karthick and Vetrivel (2016) in their paper, carbon/ glass fiber reinforced hybrid composite was tested based on the experiment. This experiment was conduct to find the mechanical properties like strength. Flexural strength and impact strength were measured as per the ASTM standard. The result was evaluated to know the mechanical properties that made change in carbon/glass in three different laminated. In the experiment, it was noticed that the impact strength, flexural strength and the tensile strength are increased with the increment in the carbon fiber reinforcement present within the matrix. The bonding between fibers and matrix also show the strength of laminate.

Rahmani *et al.*, (2015) studied about the multi-directional laminated carbon fiber/epoxy composites and their tensile strengths by the use of MATLAB software. They gave the different parameters: The fiber orientation is the important enhancing parameters for tensile strengths, the tensile properties were in the parallel direction compared to the perpendicular alignment, and the difference between theoretical and experimental data as the tensile properties of laminated composites shows the hand layup defects.

Liu, Deng and Zhang (2017) proposed that the compressive and flexural qualities of carbon fiber/epoxy complexes by the process of VARIM can be enhanced by reinforcing the matrix with rigid nanoparticles. The incorporation of halloysite nanotubes, the strength of compressive and flexural properties of bulk matrices increased. Compressive and flexural properties of carbon fiber epoxy complexes are very sensitive properties towards the behavior of matrix.

Jagannatha and Harish (2015) analyzed the strength of the hybrid carbon fiber and glass fiber. This analysis was conducted according to the ASTM standards. Different types of automated qualities such as tensile, flexural strength and micro hardness were measured. They concluded that micro hardness of carbon fiber armored composite is greater than compared to other composites.

Banakar and Shivananda (2012) studied the two properties of the composites: tensile and flexural behavior. They gave a conclusion that at 90 degree the tensile and flexural strengths are superior. Specimen can sustain more load at 90 degree than other alignments. Extension and deflection is seen the least in 90 degrees orientation and most in 30 degrees orientation.

Raja *et al.*, (2015) proposed that the hybrid of glass fiber and carbon fiber has very strong motorized properties compared to the glass fiber reinforced plastic material on the basis of young's modulus calculation in both compressive and tensile test. This test was economical compared to other unconventional test. They also gave a suggestion for getting a good result, more number of sample should be used. The combination of plastic fiber and carbon fiber will escalate the stability and strength of the material.

Visal and Deokar (2016) in their paper, they did many experiments and concluded that the addition of carbon nanotube or nano-clay enhance the stability of the properties of CFRP. They also analyzed by NDT testing and gave a result that heating phase is suitable for carbon fiber mapping in early stage while in later stage both cooling and heating phase can be used for impact characterization. The modification have better properties compared to unmodified properties. Tensile strength is one factor that increase and then decreases with the increment in the carbon fiber fraction.

According to Khun *et al.*, (2014), the increased short carbon fiber quantity can increase the young's modulus and the hardness of the epoxy complexes. In the Scanning electron microscope, the observation was noticed that less sensitivity of epoxy composites toward the surface fatigue. In the end of their paper, they established that the assimilation of short carbon fiber is an operative way because of the improvement in the tribiological and mechanical properties.

Fouda, Guo and Elsharkawy (2016) analyzed that resin matrix is one of the most effective and common matrix with carbon fiber. The automated properties of prepared complex is increased by the adhesion bond of resin matrix. They analyzed two resin matrix: carbon fiber epoxy resin matrix and carbon fiber phenol-formaldehyde resin matrix and gave a result in the favor of carbon fiber epoxy resin because of mechanical properties like tensile strength and thermal conductivity is higher in epoxy resin compared to carbon fiber phenol-formaldhyde resin matrix.

Rahmani, Najafi and Ashori (2014) on the basis of their analysis, they gave many conclusions that the mechanical properties of composites is increased with this parameters: fiber orientation> number of laminates> resin type. The five-ply have higher tensile and flexural strength than three-ply composites. For measuring the strength of the composites, different types of machine is used with different standards.

Conclusion

This paper discussed about the strength of Composites made by the carbon fiber and epoxy resin. Carbon fiber reinforced polymer have strong motorized properties such as compressive strength, tensile strength, and high thermal conductivity. Carbon fiber is mixed with epoxy resin considered as best hybrid for many applications like in industrial, structural and in engineering practices. The strength of the composites can be increased by the addition of carbon nanotubes or nano-clay into the matrix. This paper conclude that the carbon fiber epoxy composites are better than other because of their mechanical properties.

References:

Banakar, Prashanth, and H. K. Shivananda. "Preparation and Characterization of The Carbon Fiber Reinforced Epoxy Resin Composites." IOSR Journal of Mechanical and Civil Engineering, vol. 1, no. 3, 2012, pp. 15–18.

Fouda, Hany, et al. "Preparation and Characterizations of Composite Material Based on Carbon Fiber and Two Thermoset Resins." MATEC Web of Conferences, vol. 88, Sept. 2016, p. 02002.

Jagannatha, T D, and G Harish. "Mechanical Properties of Carbon/Glass Fiber Reinforced Epoxy Hybrid Polymer Composites." International Journal of Mechanical Engineering and Robotics Reserach, vol. 4, no. 2, Apr. 2015.

Khun, Nay Win, et al. "Tribological Properties of Short Carbon Fibers Reinforced Epoxy Composites." Friction, vol. 2, no. 3, Jan. 2014, pp. 226–239.

Liu, Fang, et al. "Mechanical Properties of Epoxy and Its Carbon Fiber Composites Modified by Nanoparticles." Journal of Nanomaterials, vol. 2017, 2017, pp. 1–9.

Rahmani, Hossein, et al. "Elastic Properties of Carbon Fibre-Reinforced Epoxy Composites." Polymers & Polymer Composites, vol. 23, no. 7, 2015, pp. 475–482.

Rahmani, Hossein, et al. "Mechanical Performance of Epoxy/Carbon Fiber Laminated Composites." Journal of Reinforced Plastics and Composites, vol. 33, no. 8, Sept. 2014, pp. 733–740.

Raja, D. Bino prince, et al. "Analysis of Mechanical Properties of Glass and Carbon Fiber Reinforced Polymer Material." International Journal of Applied Engineering Research, vol. 10, no. 11, 2015, pp. 10385–10391.

Saravanan, S Karthick, and R Vetrivel. "Experimental Analysis of Carbon/Glass Fiber Reinforced Epoxy Hybrid Composites with Different Carbon/Glass Fiber Ratios." International Journal of Innovative Research in Science, Engineering and Technology, vol. 5, no. 5, 2016, pp. 6769–6780.

Visal, Saleel, and Swapnil U. Deokar. "A Review Paper on Properties of Carbon Fiber Reinforced Polymers." IJIRST - International Journal for Innovative Research in Science & Technology, vol. 2, no. 12, May 2016, pp. 238–243.