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Carbon Fiber Epoxy Composites and Its Mechanical Properties

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Abstract:

Many materials are used in the field of aeronautical such as glass fiber, aluminum and so on. The application of composites materials are increasing from traditional areas (Aircraft engineering) to various fields (automobile industry, marines, civil engineering) because of the required properties 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 tensile strength, flexural strength and compressive strength. The epoxy resin works to improve the compressive property of composites. And this paper show the effects when carbon nanotube or nanoclay is added to the matrix of carbon fiber and epoxy.

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

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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 microbuckling of fibers that are embedded in the matrix governed the compressive strength of unidirectional composites 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 aircrafts, rockets and other related space and electronics, high temperature resins are used as composite materials. The major load is shared by the reinforcements when a composite consists of fiber reinforcements that is dispersed in a weak matrix like carbon/epoxy composite. This fiber carry almost all load. The strength and stiffness of constituent fiber control the strength and stiffness of such composites **(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 manufacture different structural components such as aileron, flaps, landing-gear doors and other structural parts. One of these advanced properties is they have high strength to weight and stiffness to weight ratios. Over the other monolithic materials, these composites have unique advantages such as high strength, high stiffness, low density, long fatigue life, corrosion resistance, wear resistance, and environmental stability.

The composites of laminates are vulnerable for mechanical 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 engineering practice. These reason are lack of reliable experimental procedures that determine the mechanical characteristics of reinforced composites, difficulties in the mathematical modeling of deformation processes and the evaluation of the load-carrying ability of reinforced structure and the need of new more economical manufacturing techniques.

CFRPs' mechanical properties can be determined by constitutes properties, composite's structure, manufacturing technique and mode of interaction at matrix/interfaces. By the known properties of constitutes, many mechanical parameters of composites can be determined. Still, the application of rigorous mathematical solutions is not possible at all times because of the high sensitivity of some factors like strength, to the effects of other factors 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 is maintained at temperature up to 2500°K. Composites of carbon fiber have many application such as aeronautical, biomedical, defense, industrial and space applications. The requirement of these materials is that place where the system is exposed to extreme temperatures. They are used for high performance standards such as solid rocket motors. Now these days, the composites of carbon are used in commercial and military applications. A unique combination of mechanical, physical and chemical properties such as thermal resistance high modulus and high strength 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 thermal and chemical resistance of the composite whereas strength and stiffness are provided by the carbon fibers. An essential role is played by the fiber matrix adhesion strength on the mechanical properties of the fibers reinforced polymer composites. This is because when load is applied to composites, then the load is distributed and transferred by the fiber matrix interface.

Carbon fibers have poor adhesive and bonding property toward the polymer matrix because of their chemical inertness and nature of smoothness. Various

approaches can be applied for improving the bonding properties of carbon fibers. These are classified into oxidative and non-oxidative treatments.

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

Epoxy Resin

The cured end product of epoxy resins is Epoxy. It is used as a colloquial name for the epoxide functional 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 metal coatings, use in electronics / electrical components, high tension electrical insulators; fiber reinforced plastic materials, and structural adhesives. **(Raja *et al.*, 2015)**

It is considered as a high-performance thermosetting resins, a combination of properties. 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 low-viscosity liquid or thermoplastic state. This is most valuable property of epoxy resins.

The system of epoxy comprises two important components physically that are resin and curative. Chemical reaction is caused by the curative that convert the epoxy resin into solid. A cross linked network of molecules is formed. This polymer is known as thermoset polymer structure that has high cohesive strength and adhesion properties 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, Epoxy resin and phenolic 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 used in many fields such as commercial, military and structural field. These field require the low weight and high strength. With the low density, they can be formed and tailored for having the stack sequences that produce the high strength and stiffness in the direction of high loading.

Wet layup

1. It is one of the types of fiber reinforcement material manufacturing process.
2. In this method, matrix (Carbon fiber) is placed on the forming tool.
3. Then resin 70% of its volume 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 reinforced fiber layer mould with the wet epoxy resin is allowed to cool at normal room temperature in which vacuum bags are used for compressing the reinforced fiber layer to get the better result **(Raja *et al.*, 2015).**

Mechanical Properties

The mechanical properties of the carbon fiber composites 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 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 (Width, Length, and Thickness) are taken according to 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 through the material. Different types of apparatus are used in the determination of thermal conductivity. In the process, specimen is heated at the one side by the metallic steam chamber and another side of specimen is put in the contact with the cylindrical brass calorimeter that is used to measure the quantity of the heat. Heat is generated in the form of steam flows from high temperature (Steam chamber) to low temperature (toward the calorimeter). The heat is flow until the thermometer give the 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 tensile strength, flexural strength and the impact strength are increased with the increment in the carbon fiber reinforcement in 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 properties of carbon fiber/epoxy composites 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 composites are very sensitive properties toward 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 mechanical properties such as micro hardness, tensile and flexural strength were measured. They concluded that micro hardness of carbon fiber reinforced composite is higher 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 orientations. Deflection and extension is seen minimum in 90 degree orientation and maximum in 30 degree orientations.

Raja *et al.*, (2015) proposed that the hybrid of glass fiber and carbon fiber has very strong mechanical properties compared to glass fiber reinforced plastic material on the basis of young's modulus calculation in both tensile and compressive 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 mixture of carbon fiber and plastic fiber will increase 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 nanoclay 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 hardness and young's modulus of the epoxy composites. 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 concluded that the incorporation of short carbon fiber is an effective 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 common and effective matrix with carbon fiber. The mechanical properties of prepared composite is increased by the adhesion bond of resin matrix. They analyzed two resin matrix: carbon fiber epoxy resin matrix and carbon fiber phenol-formaldhyde 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 mechanical properties such as tensile strength, compressive 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 nanoclay into the matrix. This paper conclude that the carbon fiber epoxy composites are better than other because of their mechanical properties.

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