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The Effect of Fiber Length on Mechanical Properties of Short Carbon Fiber Composite Material Reinforced with Epoxy Matrix

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Abstract: ***Carbon fiber composites possess the desired and ideal properties which paved way for a speedy development and positive outcome leading to effective use for various applications in last 10 to 15 years. Short carbon fiber possesses good mechanical properties and has been the focus of this experimental work, various parameters affect the performance of the final composite product. In this paper, an attempt has been made to study the effect of fiber length of short carbon fibers on the tensile and compression properties in a 2D random case. Different lengths of short fibers reinforced in epoxy matrix composite plates are manufactured through hand layup technique. Each of the composite plate has a fiber volume fraction of 5% and 95% Epoxy. These composite plates were cut into tensile specimens and compression specimens as per ASTM D3039 as per ASTM D3410 through water jet cutting then subjected to tensile testing and compression testing in accordance with the same standard. Mechanical test i.e. tensile test and compression were performed on UTM and the results are reported. Results of the tests have shown that the Tensile strength and compression strength increases with the increase in the fiber lengths.***

Keywords: Epoxy, Carbon fiber, water jet cutting, UTM, ASTM Test Procedure

1. Introduction

Carbon fiber is greatly employed these days in many aspects because of their exceptional mechanical and thermal properties [3,5]. Because of these properties there has been much research work carried to improve and optimize many parts, structures using the carbon fiber. Carbon fiber composites have shown exceptional performance over other composites fiber material like glass. Most of the fiber composites are reinforced with glass fiber which is relatively inexpensive but attractive mechanical properties of carbon fiber have forced many industries to use carbon fiber to reinforce in the fiber composites thus replacing glass fibers [4, 10]. Carbon is around 70% lighter than steel and round 3 times stiffer than steel. It has got very high stiffness to weight ratio. Short carbon fiber reinforced composites are favorable over long fiber because they can be fabricated with ease and inexpensive way and can be molded to the required shape and dimensions.

Composite material properties are affected by number of factors, some of the factors that can be stated as fiber diameter, fiber length, volume fractions, curing temperature, fiber orientation etc. [1,2]. Based on the evaluation carried out, fiber volume fraction has a significant effect on the mechanical properties [2, 6]. It has been observed as the fiber content in the matrix increases the strength and modulus also increases [7]. But there has been extensive work already carried out to determine the effect of fiber volume content on its mechanical properties and behavior.

Amuthakkannan and et. al. has studied the effect of fiber length and content on mechanical properties in short basalt fiber reinforced polymer matrix composite composites [8]. This paper states fiber length has a very considerable effect on mechanical properties, concludes that the tensile and compression strength increases with the increase in the fiber length. Therefore, studying the effect of fiber length on mechanical properties forms a crucial part of composite analysis [6,8]. Carbon fiber composites usually have polypropylene as the matrix material, with view of ease of manufacturability; Epoxy is also a great material as the matrix material. Epoxy is inexpensive, liquid at room temperature, has good mechanical properties, and blends well with carbon and glass fibers. Besides less work has been done using the carbon fiber-epoxy combination. Therefore, epoxy forms a strong contender to be considered. Carbon fiber reinforced in epoxy matrix has been researched and studied for improving the fracture toughness [9]. This portrays that they can be mixed together for manufacturing a composite.

With the above literature put forward, it can be stated that fiber length has significant effect on mechanical properties. Hence this work is an attempt to study and gain more insights on the effect of fiber length on tensile properties of short carbon fiber reinforced epoxy composites experimentally.

2. Literature Survey

Carbon fiber is greatly employed these days in many aspects because of their exceptional mechanical and thermal properties. Because of these properties there has been much research work carried to improve and optimize many parts, structures using the carbon fiber. Carbon fiber composites usually have polypropylene as the matrix material, with view of ease of manufacturability; Epoxy is also a great material as the matrix material. Epoxy is inexpensive, liquid at room temperature, has good mechanical properties, and blends well with carbon and glass fibers. Besides less work has been done using the carbon fiber-epoxy combination. Therefore, epoxy forms a strong contender to be considered. Carbon fiber reinforced in epoxy matrix has been researched and studied for improving the fracture toughness. This portrays that they can be mixed together for manufacturing a composite.

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3. Details of Experiment

3.1. Materials Used

Figure 3.1.1: Epoxy LY556 & Hardener HY 957

Epoxy is selected as the matrix material for this research work because of its adhesive qualities. In fact, it is more adhesive than other well-known matrix materials like polyurethane or polyester. Also, it has good gap filling properties and compatible with almost all kinds of fiber and fillers, thus making it as the most ideal material for composites. Araldite Epoxy LY556 is the epoxy which is mixed with Hardener HY 957. As per the manufacturer the epoxy & hardener is to be mixed in the ratio 10:1 by weight. The Epoxy-Hardener mixture has a pot life of around 30 minutes.

Chopped Carbon fiber is used as the reinforcement, fibers of lengths 3mm, 6mm and 12mm were reinforced with 5% fiber volume fraction.

Figure 3.1.2: Chopped carbon fibers of 12mm length

Figure 3.1.3: Chopped carbon fibers of 6mm length

Figure 3.1.4: Chopped carbon fibers of 3mm length

3.2. Mold Preparation

Figure 3.2.1: Mold bottom after machining and finishing operations.

The composite is manufactured using hand layup technique because of its ease and cost effectiveness. Firstly, the mold raw material slabs are cut and subjected to machining. Then the following operations are carried out

- Sizing & facing
- Pocket milling
- Drilling

The final dimensions of the mold cavity are 400m x 400mm x 5mm. The mold top & bottom are assembled using 4 bolts are nuts.

The composite has 5% carbon fiber reinforced in the epoxy matrix as per the volume fraction, which gives the corresponding mass of carbon fiber for 5% as 68g. The epoxy matrix fills 95% of the composite which correspondingly as 802g as epoxy and 81g as hardener which accounts for 5:1 ratio by weight as specified by the supplier. Then both are mixed well by stirring followed by the addition of fibers which are mixed in the matrix by stirring. The mixture is then poured in the mold and spread using a roller and scale till the mixture occupies the entire mold cavity. Any trapped bubbles and voids are removed using a needle. Then the mold is closed and bolts & nuts are tightened. This mixture is left for 24hours for curing. The final product is a composite plate of dimensions same as the mold cavity.

The composite plate is now subjected to water jet cutting to cut out tensile specimens and compression specimens as per ASTM standard D3039 and ASTM standard D 3410. As per this standard, the tensile test specimens of size 250mm x 25mm x 5 mm and compression specimens of size 12mm x 8mm x 5mm are cut. Each plate could accommodate 3 such specimens. These specimens are then subjected for tensile testing and compression testing till they fail.

3.3 Testing Procedure as Per ASTM D 3039

The tensile test is carried out as per ASTM D 3039 “Standard Test Method for Tensile Properties of Polymer Matrix Composite Material” [13] measures parameters such as Ultimate tensile load, Ultimate tensile strength & provides a plot of tensile load v/s the displacement.

The test specimen is held in the grippers of the machine and is ensured to have strong and firm grip. The machine loads the specimen at uniform rate about 100mm per minute only in the longitudinal direction. The machine loads the specimen till they break under tensile load. The corresponding values of ultimate tensile load and tensile strength are noted. Simultaneously the displacement in the jaws is noted and the connected computer generates a plot of Load v/s Displacement. The same procedure is repeated for tensile test specimens reinforced with different fiber lengths and the corresponding parameters are recorded. Then this data is printed on a report template including all the specimen dimensions and other details. The compression test specimens were prepared according to ASTM D3410. Dimensions of the specimen are 8mm width, 12mm length and 5mm thickness. The specimen is kept between the two compressive plates in the centre. Load is applied on specimen with the help of moving head. Then load and deflections are noted. From these values compression strength, young’s modulus can be found. The same procedure is repeated for compression test specimens reinforced with different fiber lengths and the corresponding parameters are recorded.

4. Results

A total of 3 specimens are tested for each fiber length and the following results are recorded

Table 4.1: Experimentally determined Values

Length of Fiber	Specimen no.	Tensile Strength (N/mm^2)	Mean Tensile Strength (N/mm^2)	Compressive Strength (N/mm^2)	Mean Compressive Strength (N/mm^2)
3 mm Fiber Length	1	10.54	10.43	51.38	64.37
	2	11.02		72.11	
	3	9.74		69.62	
6 mm Fiber Length	1	9.64	11.86	80.17	71.25
	2	14.07		70.59	
	3	11.89		63.01	
12 mm Fiber Length	1	23.45	18.86	133.50	111.67
	2	16.41		104.88	
	3	16.74		96.65	

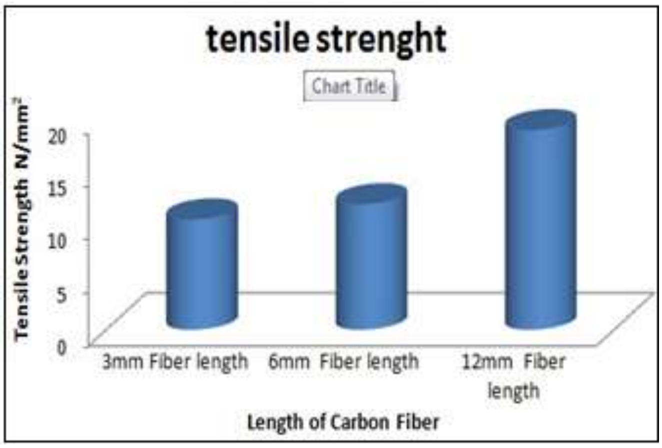

Figure 4.1: Graphical representation of tensile strength v/s Length of Carbon Fiber

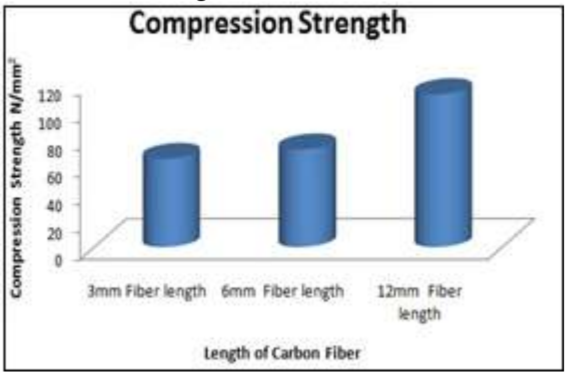

Figure 4.2: Graphical representation of Compression strength v/s Length of carbon Fiber

5. Conclusion

Effect of fiber length on tensile properties and compression of Carbon Fiber reinforced Epoxy composites has been studied. With the increase in fiber length, tensile strength and compression strength also increases. This increase in properties of the composites with fiber length is attributed to the enhancement in contact area of a given fiber with the matrix and better stress transfer due to increased fiber length

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