Research Progress in Mechanical and Manufacturing Engineering Vol. 4 No. 1 (2023) 313-319
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RPMME

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773-4765

Experimental Study in Compressive Strength with Respect to Different Thicknesses of Composite Material

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DOI: https://doi.org/10.30880/rpmme.2023.04.01.035
Received 25 August 2022; Accepted 31 January 2023; Available online 01 June 2023

Abstract: Carbon Fiber is a polymer that is occasionally referred to as graphite fiber. It is a material that is both highly durable and lightweight. Carbon fiber is five times as strong and twice as rigid as steel. Carbon fibers have a low weight-to-strength ratio, excellent chemical resistance, a low temperature of overheating, and limited thermal expansion. Carbon fiber's rigidity, lightness, and stiffness have made it a possible alternative for steel in numerous applications. This study aimed to differentiate the compressive strength result between two-layer and three-layers of carbon fiber tube specimen. A total of six samples of carbon fiber tubes consist of three specimens for two-layer carbon fiber tubes and three specimens for three-layer carbon fiber tubes. The thickness difference between these two samples was only 1.0 mm, which is 1.5 mm for two layers and 2.5 mm for three layers. This study carried out a compression test using a universal testing machine with a maximum load of 10kN to measure the maximum force to break a specimen. The optical microscope was used to identify the failure of the specimen. As a result, it shows that two-layer and three-layer were able to withstand up to a maximum load of 10 kN.

Keywords: Carbon Fiber Tube, Compression Test, Universal Testing Machine, Hand Lay-Up

1. Introduction

A composite material is a mixture of composite materials with physical and chemical characteristics that differ. When mixed, they form a material specifically designed to do a specific task, such as becoming stronger and lighter. They can also help to increase the strength and stiffness of a structure. One of the reasons they are preferred over traditional materials is because they increase the qualities of their base materials while also being useful in a wide range of applications. Thus, one of the composite materials that are widely used is fibers like carbon, glass, and aramid, and they are reinforced into a fiber-reinforced polymer (FRP) composite.

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Numerous modern technologies require materials with unusual qualities that standard metal alloys, ceramics, and polymeric materials cannot provide. This is especially true for materials used underwater, aerospace, and transportation. As a result, the property combinations and ranges of materials have been extended and continue to be expanded through the development of composite materials that are claimed to contain all the answers to the difficulties associated with conventional materials. Composites, a relatively unique class of material, are best defined as those reinforced with fibers or particles embedded in a matrix such as polymers, metals, or ceramics [1].

As with any product, carbon fiber has advantages and disadvantages. Carbon fiber is an excellent material to work with and has various advantages, but it also has specific problems, just like any other product. Once a carbon structure has been dinged or cracked, it cannot be repaired as a steel structure can. Once the framework has been destroyed, the fibers have been broken, and the structure is no longer strong enough to withstand further harm. In most situations, the existing structure had to be demolished and disposed of, and a new one had to be built in its place. All materials have maximum force or limit to withstand before the break. Therefore, it is important to know this limit. So, the different thicknesses of carbon fiber will be used to investigate the maximum amount of compressive force that a material can withstand before it breaks.

2. Material and Methods

The research and experiment focus on the composite material, carbon fiber. The experiment test for this study is to find the maximum force required to break a test specimen and to differentiate the compressive strength result between two-layer and three layers of the specimen. The test that needs to be run is mechanical testing which is a compression test using the universal testing machine with a maximum load of 10 kN. Thus, an optical microscope was used to identify the failure of a specimen after the compression test.

2.1 Material preparation

A total of 6 specimens of carbon fiber tubes were made using the Hand Lay-up technique, which had two types of samples consisting of three specimens for two-layer carbon fiber and three-layer carbon fiber. A carbon fiber tube was prepared by [2].

2.2 Compression test

The compression test was done using a universal testing machine. Generally, the universal testing machine can test two types of tests such as tensile test and compression test. The compression test is one of the tests to identify the characteristic of the material. The compression test was chosen because it can quickly analyse the mode of the deformation process. The standard for the specimen is the ASTM D695-15 standard test method for compressive properties of rigid plastics 1 [3]. The compression testing procedure axially compressed the carbon fiber tube with a maximum load of 10kN. At a steady cross-head displacement of 1.5 mm/min, compression processes will continue until 75 percent of the overall length of the tube has been compressed.

2.3 Optical Microscope Analysis

The specimen illumination provided by UV light is an essential component of a microscope. Condenser lenses and diaphragms are the optical microscope components that contribute to lighting. The illustration makes the specimen visible. Microscopy employs the concept of reflected light, but its techniques are dependent on the manipulation of light, which influences the resolution [4]. Thus, the optical microscope was used to identify the failure after the compression test.

3. Results and Discussion

A compression test was carried out to gain the data and analyze this experiment. The feed rate was 1.5 mm/min, and the displacement ranged from 0 to 50 mm. All the data is plotted on a graph, and an image of the compression behaviour has been captured. Each specimen required nearly ten minutes to complete the compression test, and the Universal Testing Machine automatically transmitted the data to the laboratory computer. The data obtained by the computer were saved in a file, which was then analysed and tabulated according to each type of specimen, which consisted of two types of carbon fiber: two-layer carbon fiber tube (2L-A, 2L-B, 2L-C) and three-layer carbon fiber tube (3L-A, 3L-B, 3L-C). The data was then organized in Microsoft Excel to construct a graph for each specimen collected during the compression test. Thus, there are four types of graphs that have been determined and analyzed for the compression behaviour pattern.

The results for two-layer CFT show that 2L-B has the highest maximum force which is 10.1972 kN and gives the highest value of maximum stress which is 0.11908 MPa. Therefore, for three-layer CFT it shows that 3L-C has the highest maximum force which is 10.1978 kN, and gives the highest value of maximum stress which is 0.11909 MPa. Thus, the percentage difference between 2L-B and 3L-C is 0.006 %. The graph pattern between 2L-B and 3L-C is almost identical as shown in Figure 3.

Next, the results for two-layer CFT show that 2L-C has the lowest maximum force which is 1.8844 kN, and gives the lowest value of maximum stress which is 0.02237 MPa. therefore, for three-layer CFT it shows that 3L-B has the lowest maximum force which is 3.4145 kN, and gives the lowest value of maximum stress which is 0.03584 MPa. Thus, the percentage difference between 2L-C and 3L-B is 57.75 %. The graph pattern between 2L-C and 3L-B is almost identical as shown in Figure 4.

Furthermore, the results for two-layer CFT show that 2L-A has the second-highest maximum force which is 5.5322 kN, and gives the second-highest value of maximum stress which is 0.06425 MPa. Therefore, for three-layer CFT it shows that 3L-A has the second-highest maximum force which is 7.9279 kN, and gives the second-highest value of maximum stress which is 0.08798 MPa. However, the graph pattern between 2L-A and 3L-A is not identical as shown in Figure 1 and Figure 2.

Figure 1: Load vs Displacement for 2L-A

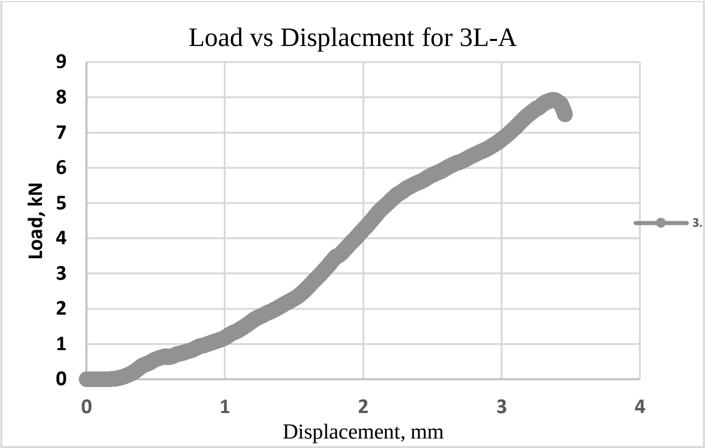


Figure 2: Load vs Displacement for 3L-A

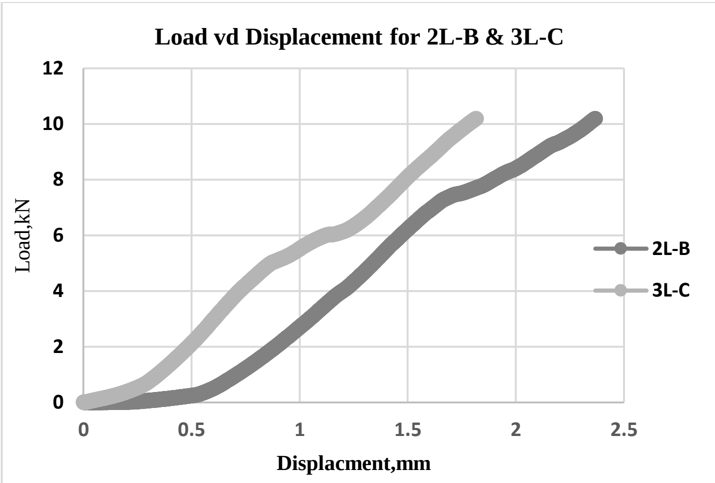


Figure 3: Load vs Displacement for 2L-B & 3L-C

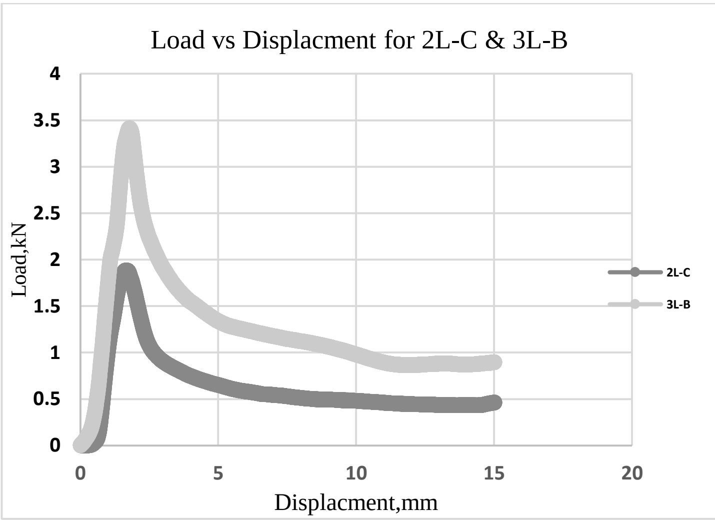
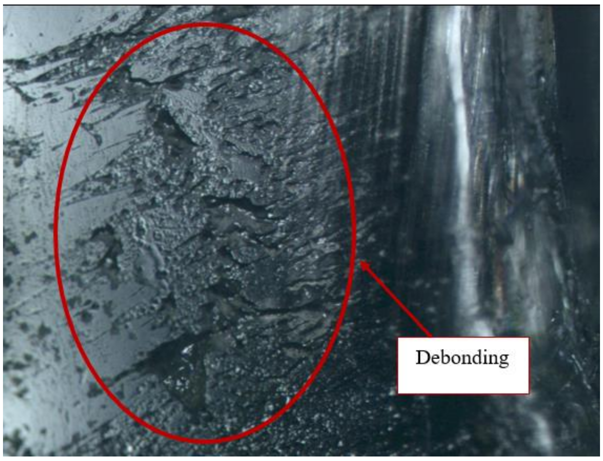
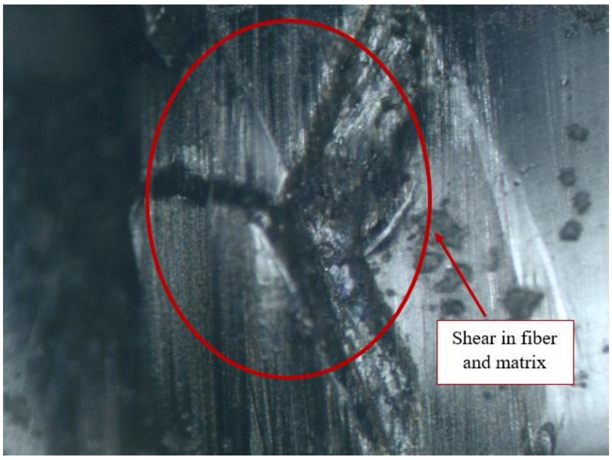


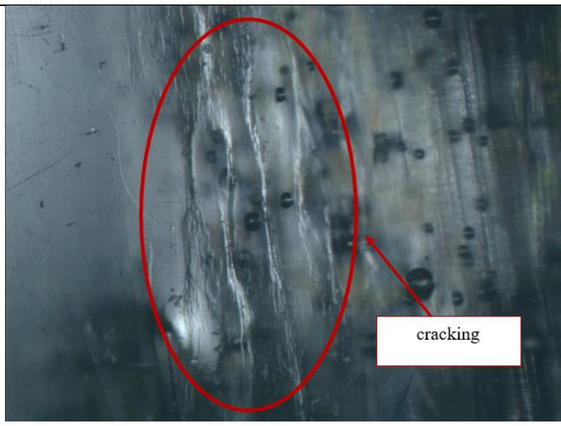
Figure 4: Load vs Displacement for 2L-C & 3L-B

The failure details of these six specimens with two different types of carbon fibre tubes are shown in table 1 in order to investigate the damage modes of CFT using an optical microscope.

Table 1: Failure mode of carbon fiber

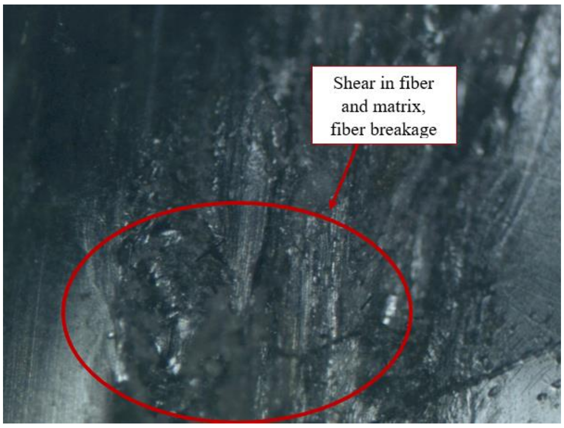
Name of specimen	Modes of damage
2L-A	 5x lens
2L-B	 5x lens
2L-C	 5x lens

3L-A



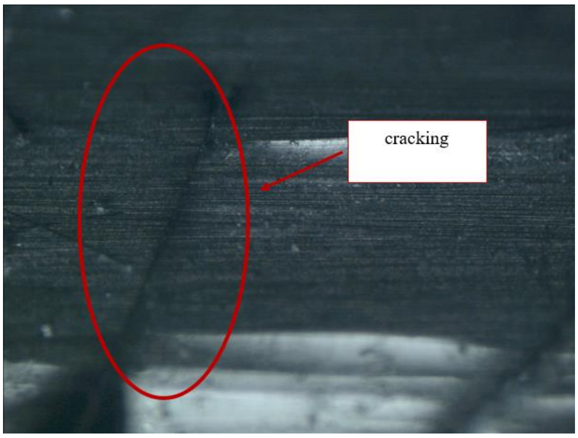
5x lens

3L-B



5x lens

3L-C



5x lens

4. Conclusion

As a result of this experiment, it can be seen that 2L-B and 3L-C have the highest maximum load among other CFT specimens. Furthermore, the pattern of the load-displacement graph between 2L-B and 3L-C indicated an almost identical. The percentage difference between 2L-B and 3L-C is better than 2L-C and 3L-B, which is 0.00 6%. Therefore, it shows that two-layer and three-layer CFT are able to withstand up to a maximum load of 10 kN. An optical microscope was used to identify the failure mode of CFT after the compression test. Thus, the objective of this study was achieved by comparing the compressive strength result between two-layer and three-layer specimens.

Acknowledgement

The authors would like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for their support.

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