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INVESTIGATION OF THE FLEXURAL STRENGTH OF COMPOSITES WITH DIFFERENT RATIOS OF CHOPPED CARBON FIBER REINFORCEMENT

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ABSTRACT

Composite materials are widely used in high-technology applications due to their properties such as high strength and lightweight. Particularly, epoxy matrix materials are employed in structural applications requiring high strength. This creates a need to enhance the mechanical properties of epoxy matrix materials. Additives introduced into the epoxy matrix lead to varying mechanical behaviors in composite materials.

The addition of chopped carbon fiber reinforcement to the epoxy matrix is an effective method. Determining the optimal additive ratios while considering fiber dimensions significantly impacts the flexural strength of the epoxy matrix material.

In this study, chopped carbon fibers were added to an epoxy matrix in weight fractions of 0%, 0.5%, 1.5%, and 3%, and three-point bending tests were conducted. After the tests, microscopic images of the fracture regions were obtained, and damage analysis was performed.

This study aims to investigate the effects of chopped carbon fibers on the flexural behavior of epoxy matrix materials, with the expectation of contributing to the development of composite materials.

Keywords: Chopped Carbon Fiber Composites, Flexural Strength, Epoxy Matrix Reinforcement, Microscope Image

1. INTRODUCTION

Chopped carbon fiber materials are used in many fields, particularly in the automotive and aerospace industries, due to their high strength and lightweight properties[1-6]. The load affecting the composite structure is transferred from one carbon fiber to another[7]. The load on the composite material is distributed across the entire material, enhancing the strength of the composite structure. Additionally, by increasing the fracture resistance of the composite, structural integrity is preserved [8].

Chopped fibers can be either short or long. In composite structures, short fibers are oriented in various directions within the matrix material, whereas long fibers are aligned in the same direction. This results in the irregular distribution of short fibers within the matrix material. Short fiber-reinforced epoxy matrix materials are produced using methods such as extrusion, injection molding, compression molding, and transfer molding [9].

The short beam shear test has become a widely used method for evaluating composite structures. This test method is employed to assess the flexural strength of composite materials. In their study, Sideridis and Papadopoulos conducted three-point bending tests on unidirectional glass fiber-reinforced epoxy composites with fibers oriented in different directions. The flexural tests were performed on samples with fiber orientations of 0°, 15°, 30°, 45°, 60°, 75°, and 90° [10].

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Lin and colleagues produced short carbon fiber-reinforced geopolymer plates with fiber lengths of 2, 7, and 12 mm to enhance the material. The mechanical properties of the prepared composites were examined using three-point bending tests, optical microscopy, and scanning electron microscopy (SEM). The results showed that the short carbon fibers were homogeneously distributed within the geopolymer matrix. The best flexural strength was achieved with composites reinforced with 7 mm long chopped carbon fibers [11].

Singh and colleagues added chopped carbon fibers, ranging in length from 5 mm to 10 mm, to the interfaces of 6-layer GFRP/epoxy plates. The chopped carbon fibers were added at weight fractions of 0%, 1%, 2%, and 5%. The plates were manufactured using hand lay-up and vacuum bagging techniques. According to the experimental results, carbon fiber additions in the range of 5% to 10% resulted in an increase in flexural strength [12].

2. METARIALS and METOD

2.1. Metarials

In this study, chopped fibers were added to an epoxy matrix in weight fractions of 0%, 0.5%, 1.5%, and 3%. The epoxy matrix used was Sicomin, a medium-viscosity matrix material suitable for composite production. The chopped short carbon fibers ranged in length from 1 mm to 10 mm. The chopped fibers are shown in Figure 1.

Figure 1. Chopped Carbon Fibers

2.2. Preparation of Composite Material

Short carbon fiber-reinforced three-point bending test specimens were produced by adding 0%, 0.5%, 1.5%, and 3% fibers by weight to the epoxy matrix. First, a hardener was added to the epoxy matrix material in a proportion of 29% by weight, using a precision scale. The total weight of the matrix and hardener was measured again, and short carbon fibers were added in proportions of 0.5%, 1.5%, and 3% by weight. The mixture was mechanically stirred for approximately 15 minutes.

The resulting liquid composite was poured into three-point bending molds and left to cure at room temperature for about 48 hours. After 48 hours, the specimens were removed from the molds, and excess matrix material around the specimens was carefully cleaned. The specimens were then prepared for three-point bending tests.

2.3. Three-Point Bending Test

Three-point bending tests were conducted on composites reinforced with 0%, 0.5%, 1.5%, and 3% by weight of chopped short carbon fibers. The tests determined the flexural strengths of the composites, allowing the effect of carbon fiber reinforcement on the epoxy matrix to be evaluated.The tests were performed using a SHIMADZU 100 kN testing machine. Figure 2 illustrates the test specimen and the experimental setup.

Figure 2. Three-Point Bending Test Specimen and Test Setup

Composites with 0%, 0.5%, 1.5%, and 3% short carbon fiber reinforcement after the three-point bending test are shown in Figure 3.

Figure 3. Epoxy/Matrix Materials with 0%, 0.5%, 1.5%, and 3% Carbon Fiber Reinforcement After Three-Point Bending Test

3. RESULTS and DISCUSSION

A three-point bending test was conducted on epoxy/matrix composites reinforced with short carbon fibers in weight fractions of 0%, 0.5%, 1.5%, and 3%. Analyzing the flexural force-displacement graph revealed that the highest flexural strength was observed in composites containing 3% short carbon fiber by weight. This was followed, in descending order, by composites with 1.5%, 0.5%, and 0% carbon fiber reinforcement.

Figure 4. shows the three-point bending graphs for composites with 0%, 0.5%, 1.5%, and 3% short carbon fiber reinforcement by weight.

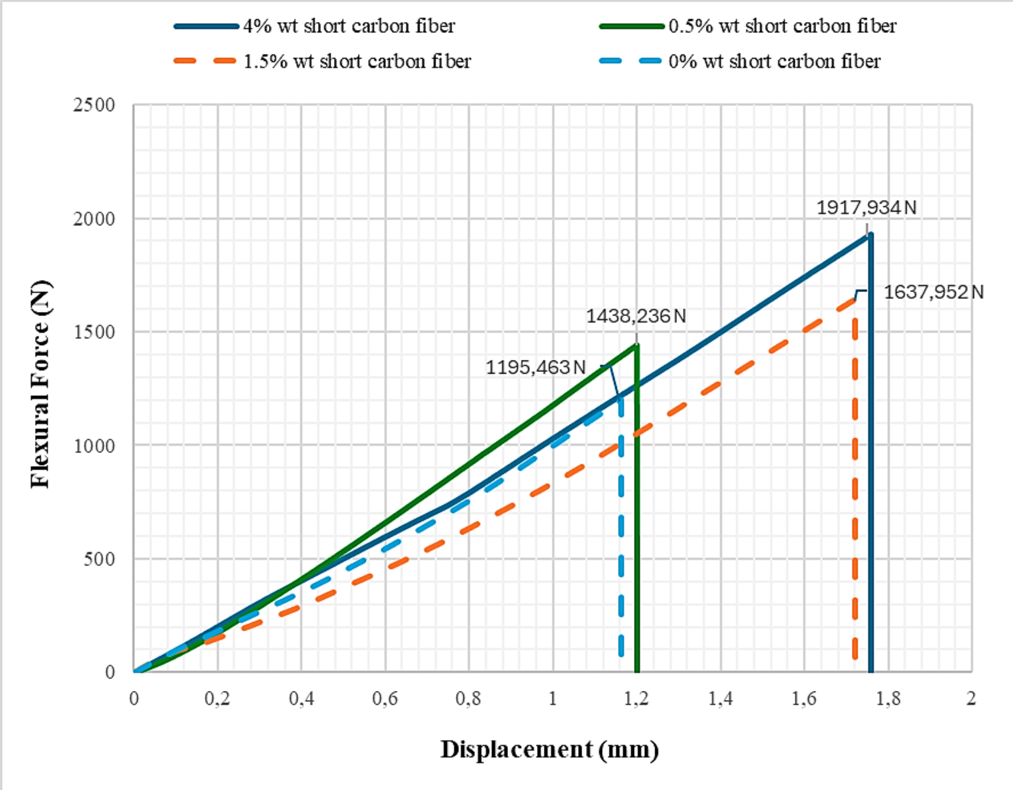

Figure 4. Three-Point Bending Test Graph for Epoxy/Matrix Composites with 0%, 0.5%, 1.5%, and 3% Short Carbon Fiber Reinforcement by Weight

The composites reinforced with 3% short carbon fibers by weight reached a flexural force value of approximately 1917.934 N. The addition of 3% short carbon fibers significantly enhanced the flexural strength of the epoxy/matrix material. In contrast, the neat epoxy composite without carbon fibers exhibited a flexural force value of approximately 1185.463 N, representing a flexural force increase of about 61.7%.

According to the flexural force-displacement graph in Figure 4, the least improvement was observed in the composites with 0.5% short carbon fiber by weight, which exhibited a flexural force value of 1438.236 N. The 0.5% short carbon fiber addition resulted in a flexural force increase of approximately 21.3%.

An important observation from the graph in Figure 4. is that composites with 1.5% short carbon fiber reinforcement by weight displayed a greater displacement increase compared to the previous composite. Short carbon fibers not only contributed to an increase in flexural strength but also improved the elasticity of the epoxy/matrix material. This increase in elasticity in the short carbon fiber composites led to higher displacement values.

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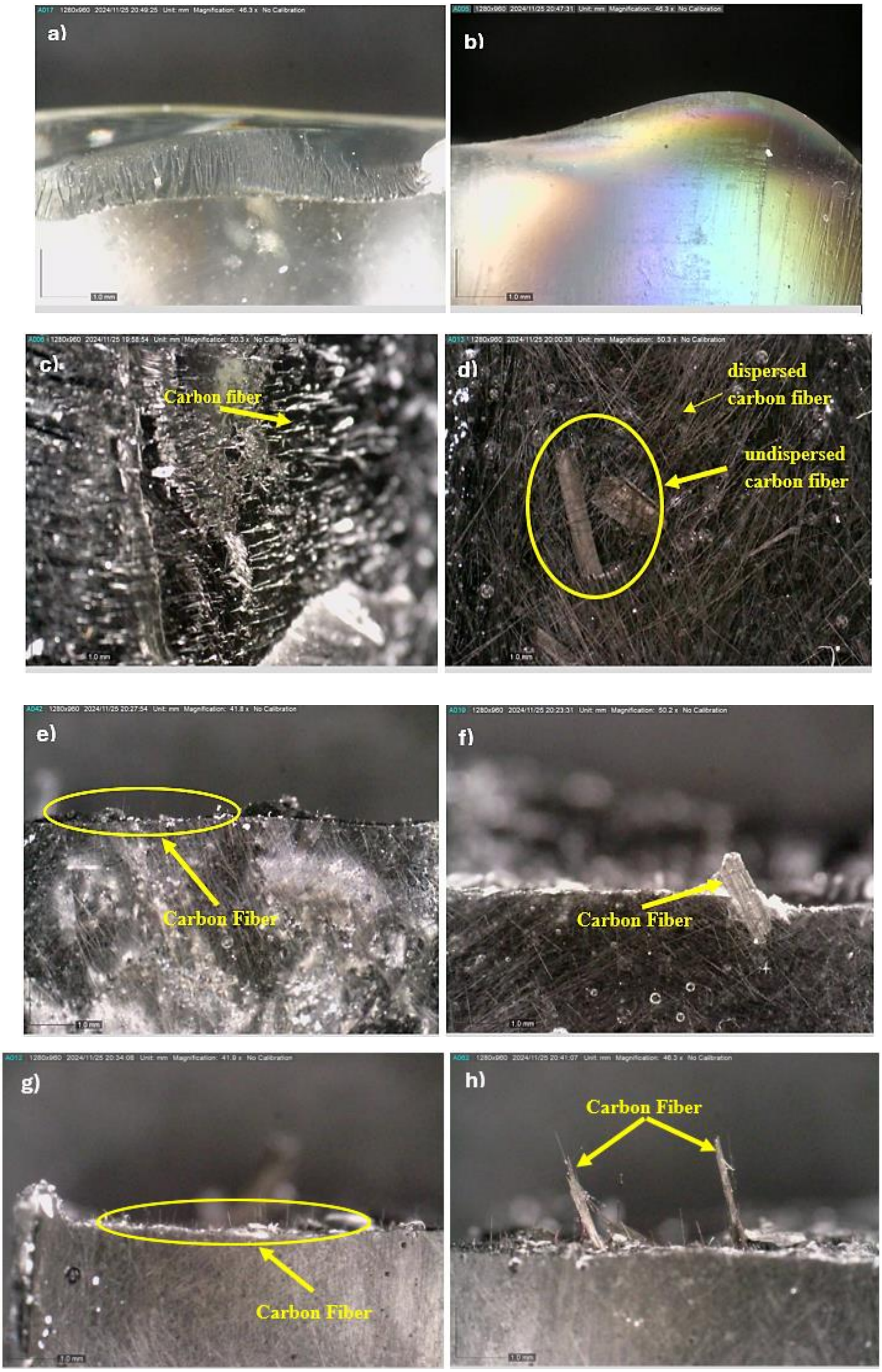

Figure 5. Microscopic Images of Composites with 0%, 0.5%, 1.5%, and 3% Short Carbon Fiber by Weight

Microscopic images were obtained from the fracture regions of epoxy/matrix materials with 0%, 0.5%, 1.5%, and 3% short carbon fiber reinforcement by weight after the three-point bending test. Figures 5a and 5b show the microscopic images of neat epoxy/matrix composites. The fracture surfaces of neat composites appeared relatively less rough. As observed in the flexural force-displacement graph, neat epoxy/matrix composites exhibited lower displacement values compared to other composites, indicating a relatively brittle behavior.

Figures 5c and 5d display the microscopic images of composites with 0.5% short carbon fiber by weight. While the carbon fibers were generally distributed homogeneously, some areas showed a lack of uniform distribution (Figure 5d).

Figures 5e and 5f show the microscopic images of composites with 1.5% short carbon fiber reinforcement. The fracture images revealed a generally homogeneous fiber distribution; however, complete homogenization was not achieved in some areas. In Figure 5e, carbon fiber protrusions on the fracture surface are more evident.

Figures 5g and 5h illustrate the microscopic images of composites with 3% short carbon fiber by weight. In these composites, carbon fiber protrusions on the fracture surfaces are more pronounced.

In general, the composites experienced strength losses due to non-homogeneous distribution. However, the addition of short carbon fibers improved the flexural strength of the epoxy/matrix material. The carbon fibers formed a strong interface with the epoxy matrix, enhancing the flexural strength of the material.

Short carbon fibers increased the load-bearing capacity of the epoxy/matrix, delaying crack formation and improving flexural strength. Additionally, the reinforcement of short carbon fibers enhanced the elasticity of the epoxy/matrix material, providing resistance against crack formation. This is evident in the flexural force-displacement graph, where the displacement values of composites with short carbon fiber reinforcement are higher compared to those of neat epoxy/matrix composites.

4. CONCLUSIONS

In this study, three-point bending tests were conducted on epoxy/matrix composites reinforced with 0%, 0.5%, 1.5%, and 3% short carbon fibers by weight. After the tests, microscopic images of the fracture regions were obtained to analyze the damaged areas.

The addition of short carbon fibers to the epoxy matrix significantly enhanced the three-point bending strength. Increasing the fiber content improved the material's load-bearing capacity and energy absorption ability, resulting in enhanced flexural performance.

Composites containing 3% short carbon fibers by weight exhibited the most optimal performance. At this fiber content, the composites demonstrated improved load-bearing capacity of the epoxy/matrix material.

The highest flexural strength observed in composites with 3% fiber content was attributed to the formation of a strong interface between the carbon fibers and the matrix material, which effectively increased the composite's strength.

Microscopic images revealed that in all fiber content levels, some areas displayed non-uniform distribution of carbon fibers. This inhomogeneity likely had a negative impact on the flexural strength. Achieving complete homogenization is expected to yield even higher flexural strength values.

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