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Fabrication and study on carbon fiber with epoxy and vinyl ester resins

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Abstract. Carbon fibers are fibers of 5 to 10 micrometres in diameter and made of carbon atoms. It is used in various fields like in aerospace, automobile etc because to its high tensile strength, high stiffness and less weight. But it becomes brittle in nature when mixed along with polymer resin, to overcome this carbon fiber is added with resin that gives the composite some ductility. Adding Epoxy and Vinyl ester resins reduces the brittle nature and high resistance towards loaded vibrations will be obtained. This is done by fabricating carbon fiber with epoxy and vinyl ester resins in different compositions by Hand Lapping technique. Different tests were conducted for checking its properties and to know the optimum composition of resins to enhance its properties.

Keywords. Carbon fiber, Epoxy, Vinyl ester, Polymer, Composite

1. Introduction

The new material could be preferred for reasons like material which are lighter, stronger or less expensive when compared to traditional material. The main advantage of modern composite materials is that they are light in weight as well as strong. Choosing a proper combination of reinforcement material and matrix, the new material can meet the requirements [1]. A carbon fiber is a thin strand of material with diameter around 0.005-0.010 mm, made of carbon atoms. These carbon atoms are joined together as microscopic crystals which are aligned parallel to longer axis of fiber. The crystal orientation makes the fiber stronger for its size. Thousands of carbon fibers are twisted together to get a yarn, that could be used to be woven into a fabric. Fabric is combined along with epoxy is moulded into shape to get different composite materials [1-3]. Epoxy adhesives are thermosetting resins that solidify by polymerization and once set it will soften but will not melt under heating. Normally epoxy bonds are rigid that will help to fill small gaps with little shrinkage. It has a variety of cross linking materials that often contain oxirane group. It is reactive to a wide range of curing agents. Curing can take place at ambient temperature or at slightly elevated temperatures [3-5]. In this
paper our aims to study the mechanical properties of carbon fiber epoxy and vinyl ester resin composites.

2. Experimental Work

2.1 Composite specification

Fabrication is done by Hand Lapping technique. Carbon fiber is used as base material and epoxy, vinyl ester resin are employed as reinforcement that are arranged in layer by layer manner. Three different composites are made in same manner by keeping carbon fiber mat as base material and epoxy, vinyl ester resins are added to it in different compositions as follows. Test Piece 1: Carbon Fiber – 50%, Epoxy – 40%, Vinyl Ester – 10%. Test Piece 2: Carbon Fiber – 50%, Epoxy – 35%, Vinyl Ester – 15%. Test Piece 3: Carbon Fiber – 50%, Epoxy – 30%, Vinyl Ester – 20%. The quantity is measured in a precision weighing machine. The catalyst quantity was calculated to be 10% of the epoxy weight. Each composite is made in same way and kept to dry at room temperature for 24 hours under a weight of 15kgs in plastic mould. Table 1 shows the different compositions of test specimens.

| Table 1. Compositions of different test specimens |
|-----------------------------------------------|
| S.No. | Carbon Fiber composition in gms | Epoxy Resin composition in gms | Vinyl Ester Resin composition in gms |
|-------|--------------------------------|-------------------------------|-----------------------------------|
| TEST PIECE 1 | 200 | 180 | 20 |
| TEST PIECE 2 | 200 | 170 | 30 |
| TEST PIECE 3 | 200 | 160 | 40 |

2.2 Hand Lapping

Composites are fabricated in different compositions by hand lapping technique. In this technique a plastic tray is used as mould. Filler chemicals are measured by highly calibrated weighing machine. Epoxy resin is continuously stirred to avoid solidification. OHPC sheet is laid over and bottom of the composite. Poly Vinyl Alcohol is used as insulating material between mould and the composite. Each composite has nine layers which consist of carbon fiber mat, epoxy resin and vinyl ester resin. After completion of layer by layer arrangement, the composites are set free for 24 hours at room temperature under a weight of 15kgs. After 24 hours; the specimens are removed from mould and left for 15 days at room temperature. Once the resting period is completed testing can be performed on test pieces. Figure 1 shows composite specimen dimensions. Using a rotating saw the composites with
different compositions are cut into the required dimensions for different tests. Figure. 1-3 shows the various test specimens.

![Composite specimen dimension](image)

**Figure 1.** Composite specimen dimension

![Test Specimen 1](image)  ![Test Specimen 2](image)  ![Test Specimen 3](image)

**Figure 2 Test Specimen –1  Figure 3 Test Specimen –2  Figure 4 Test Specimen - 3**

2.3 Tensile testing

A tensile test is one of the most fundamental types of mechanical test you can perform on material. This test is simple, inexpensive, and completely standardized. Three test pieces, one from each composition is cut as per ASTM - D638 standard by the help of rotating saw. The tensile test has been conducted in Universal Testing Machine/Electronic of model UTN which is manufactured by Fuel Instruments and Engineers Pvt. Ltd, Maharashtra, India with maximum capacity of 40000 Kgf. Figure. 5 & 6 shows test specimen dimension and after tensile test specimen.
2.4 Compression Testing

In this test, specimen undergoes opposing forces that push inward on the specimen from opposite sides or is otherwise compressed or flattened. This test is the basic type of mechanical test that can be performed on material. Compression tests are simple, inexpensive, and also standardized. Three test pieces, one from each composition is cut as per ASTM – D695 standard by the help of rotating saw. The compression test has been conducted in Universal Testing Machine/Electronic of model UTN 40 with a maximum capacity of 40000 Kgf. Figure 7 & 8 shows test specimen dimension and after compression test specimen.

2.5 Wear Testing

If friction is the dominant factor causing deterioration of the material, abrasion and wear testing will provide the data to compare materials or coatings and can help you predict the lifetime of material or coating. Abrasion testing is employed to check the abrasive resistance of solid materials. For wear testing, Abrasion Resistance Testing Machine is used. It has a 60 grit sheet for creating friction and allows the specimen to travel a 40 m over that sheet. Three test pieces of different compositions are cut according to the requirement. Figure. 9 & 10 shows test specimen dimension and after wear test specimen.
2.6 Water Absorption Test

This test is used to calculate the quantity of water absorbed under specified conditions. Factors affecting water absorption include type of plastic, temperature and length of exposure. The data gives information on the performance of these materials in water or humid environment. Three test specimens one from each composition is used. These test pieces are initially weigh on weighing machine and soaked in water for 24 hours. After test is completed they are again weighed and difference in weight is noted.

3. RESULTS AND DISCUSSION

3.1 Tensile Test

Table 2 shows the tensile test results. The tensile test shows that the test piece 1 with 50% Carbon Fiber Mat, 40% Epoxy resin and 10% Vinyl Ester resin has the highest ultimate tensile strength. The result of this test piece is followed by other two test pieces with low results respectively.

| S.No  | Gauge Thickness (mm) | Gauge Width (mm) | Original Cross Sectional area (mm$^2$) | Ultimate Tensile Load (KN) | Ultimate Tensile Strength (MPa) |
|-------|----------------------|-----------------|----------------------------------------|--------------------------|---------------------------------|
| TEST PIECE 1 | 8 | 13.26 | 106.08 | 4.95 | 49.44 |
| TEST PIECE 2 | 8 | 13.26 | 106.08 | 4.86 | 47.95 |
| TEST PIECE 3 | 8 | 13.26 | 106.08 | 4.87 | 37.48 |
3.2 Compression Test

Table 3 shows the compression test results. The compression test shows that the test piece 1 with 50% Carbon Fiber Mat, 40% Epoxy resin and 10% Vinyl Ester resin has the maximum compressive load capacity. The result of this test piece is followed by other two test pieces with low results respectively. The compression results are shown in table 3.

| S.No | Thickness (mm) | Width (mm) | Original Cross Sectional area (mm²) | Maximum Compressive Load (KN) |
|------|----------------|------------|-----------------------------------|-------------------------------|
| TEST PIECE 1 | 8 | 78.50 | 628 | 16.70 |
| TEST PIECE 2 | 8 | 78.50 | 628 | 11.59 |
| TEST PIECE 3 | 8 | 78.50 | 628 | 8.40 |

3.3 Wear Test

Table 4 shows the wear test results. The wear test shows that the test piece 1 with 50% Carbon Fiber Mat, 40% Epoxy resin and 10% Vinyl Ester resin has the minimum abrasion loss. The result of this test piece is followed by other two test pieces with more abrasion loss respectively.

| S.No | Initial Weight (gms) | Final Weight (gms) | Abrasion Loss (gms) | Percentage % |
|------|----------------------|--------------------|---------------------|--------------|
| TEST PIECE 1 | 2.2213 | 1.9485 | 0.2728 | 12.28 |
| TEST PIECE 2 | 2.1956 | 1.8737 | 0.3219 | 14.66 |
| TEST PIECE 3 | 1.5789 | 1.2638 | 0.3151 | 19.96 |

3.4 Water Absorption Test

Table 5 shows the water absorption test results. The water absorption test shows that specimen 3 with 50% carbon fiber, 30% Epoxy resin, 20% vinyl ester resin has the minimum water absorption. The result of this specimen is followed by specimen 1 and 2 with more water absorption respectively.
Table 5. Water absorption test results

| S.No   | Water Absorption in Percentage (%) |
|--------|------------------------------------|
| TEST PIECE 1 | 3.083                             |
| TEST PIECE 2 | 3.508                             |
| TEST PIECE 3 | 2.540                             |

4. Conclusion

At the end all testing performed on the three test piece with different composition, the test piece with 50% of carbon fiber mat, 40% of epoxy resin, 10% of vinyl ester resin has the maximum tensile, compression, impact strength and minimum wear where as test piece with 50% carbon fiber, 30% epoxy resin, 20% vinyl ester resin has less absorption of water. Hence, on comparing different parameters the test piece 50% of carbon fiber mat, 40% of epoxy resin and 10% of vinyl ester resin excels in almost all the tests. So this composition could be used in various fields like automobiles and aircrafts, where it is used in manufacturing the body of the vehicles which results in high strength to low weight ratio, lower weight of the vehicle puts out higher fuel efficiency.

5. References

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