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Experimental Study on Mechanical Properties of Carbon Fiber/Epoxy Resin in Addition of Reinforcement on Filler Material

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ABSTRACT

In this experimental work, carbon-fiber reinforced polymer composite with an epoxy resin and tri-ethylene tetramine hardener containing the filler composite materials such as SiC, Al2O3 and ZnO2 added and fabricated by hand lay-up technique at ambient temperature, three samples are fabricated and their mechanical properties are studied such as tensile, flexural and impact are studied. All samples are taken for test, carried out according to ASTM standard. To find the significant effect of filler material added in carbon fiber reinforcement composites material mechanical properties are analyzed. The mechanical properties test results shows that sample 3 composites have excellent tensile strength (282MPa) and flexural strength (25.6 MPa) compared to other composites, due to good interfacial bonding between particulates and the epoxy matrix. The test result shows that composites sample 2 is maximum impact strength (7 joules) and the hardness value is highest for Sample 2 filled composite, the reason being filler material uniformly mixed with matrix.

Keywords - Carbon fiber, Epoxy resin, Filler materials and Mechanical Properties.

1. INTRODUCTION

The industrial era has brought the need for new materials to tackle the day to day challenges of current materials for different applications. In the quest for new advanced materials, various material systems. One of the most prominent material systems in the past few decades is composites materials used for many applications for purpose of low cost, lightweight, high specific mechanical performance. Composite material consists of two or more phases combined which are completely insoluble in each other and form a single material known as composite. Composite materials can be classified based on the reinforcement and on the basis of matrix, such as metal matrix composites, polymer composites and ceramic composites. For high performancecarbon fibers reinforcement composites are used by reason of their outstanding mechanical properties, low strength to weight ratio, good stability,and good electrical and thermal conductivity properties. The experimental study [1-5] of particulate reinforced composites materials are modified the mechanical properties of the material. The various filler materials used to modify the properties of the material such as SiC, Al2O3, ZnO, TiO2, CaCO3 etc. The properties of the composites have compared with and without addition of filler materials. The filler material filled hybrid composite improves the physical and mechanical properties like tensile strength, flexural strength and hardness. The filler give more stiffness to the composites. Ranganatha et. al. [6] fabricated carbon fabric reinforced epoxy composites filled with in the range of 2%, 4% and 6% weight proportions of Al_2O_3 by hand layup technique. They compared the mechanical properties of CFRP without any filler with the Al2O3 filled CFRP. The results showed that by increasing filler content the surface hardness Increases but in impact Test, 4% filler addition showed high impact strength. Mentz et. al. [7] prepared SiC filled carbon-fiber composite material was taken under the investigation. The SiC filler gave the better non- brittle fracture behavior and the fiber braking strength is improved that means cracks mechanism is increased. In the research focused [8] on improve the strength of bolted fasteners with TiO_2 and ZnS filled and unfilled Glass Fabric Reinforced Polymer Matrix of Composites material and strength were compared. In comparison with TiO_2 and ZnS filled composites, it was noticed that ZnS filled composites bears more load. Song et. al .[9] formed Graphitic carbon nitride on carbon-epoxy composite is improve the roughness, shear strength and the good interfacial bonding between fiber and matrix increased, it gave the better mechanical properties of the materials. Madhusudhan et. al. [10] investigated the behavior two fibers with tungsten carbide filler material and 3 fibers with SiC carbide as the filler material polymer composites are analyzed. It result shows the shows higher mechanical strength when compared with 3 fiber and SiC carbide as the filler material. Bagci et. al. [11] investigated the effects on SiO_2 filled and fiber orientation, different impact velocities on the solid particles on glass fiber - epoxy composite wear behavior also studied. Its result seems that erosion wear rate decreased in SiO_2 reinforced composites. Prof. Anigol et. al. [12] studied Carbon-Epoxy with various filler materials filled composite and it prepared by hand layup technique and Tensile, Impact and Water Absorption properties were investigated, it result reveled that filler filled composite behavior is same but compared to unfilled composite the properties of the material is improved. Praveenkumara et. al. [13] investigated the effect of Silicon carbide with bamboo/carbon fibers on mechanical and physical properties. The Silicon carbide filled bamboo/carbon fibers has improved tensile, flexural strength and the water absorption behavior were analyzed three different water conditions, namely normal, distilled and salt water. Silicon carbide added bamboo/carbon fibers improved the mechanical properties and water absorption behavior in distilled water is superior to others. In the experimental work aim to find out the effect of filler material filled with carbon-epoxy reinforcement filler such as SiC, Al_2O_3, and ZnO_2 has been investigated. The mechanical properties such as tensile strength, flexural strength, impact strength and hardness were studied.

2. EXPERIMENTAL

2.1. Material

In the present work, carbon fiber is utilized for fabrication of carbon fiber reinforced polymer composites. For this experimental work three samples were selected. The constant basic compositions for the samples are carbon fiber with epoxy resin as the matrix. The various filler materials used are silicon carbide, aluminum oxide, zinc oxide for making hybrid composite materials. The carbon fiber/ epoxy reinforcement composite is fabricated by hand layup method and curing at room temperature. The composite samples made to the standard dimension of 300×300×10mm. (length × breath × thickness). The composites samples are prepared as per ASTM standard.

2.2. Preparation of Sample

Carbon fibers of each layer were fabricated by a hand lay-up method with the filler composite materials under room temperature. Weight percent of chemical powders (silicon carbide, zinc oxide and alumina) was dissolved in epoxy resin and tri-ethylene tetra-amine hardener in ratio of 1:10 added. The carbon fibers were treated by 1.0 mol. concentration dilute acid at ambient temperature for 30 min to take away the impurities from fiber surface. After the acid treatment carbon fibers were applied, sensitization and activation treatments were conducted. The fibers were dispersed in a hydrochloric acid for sensitization. These fibers were then cleaned with distilled water. After rinsing, the surfaces were activated by adding the fibers in the same hydrochloric acid by washing with same distilled water. In this coated- carbon fibers were then added into an HCL solution for 60 min filtered, and dried for 120 min.

2.3. Fabrication Process

The carbon fiber /epoxy resin with filler material is fabricated by hand layup technique at ambient condition and the desired amount of sample (1) were silicon carbide, aluminum oxide and zinc oxide (0.1, 0.2 and 0.1 wt%), sample (2) were silicon carbide, aluminum and zinc oxide (0.15, 0.1 and 0.15 wt%), and sample (3) were (0.2, 0.12 and 0.08 wt%) were added into the epoxy resin with tri-ethylene tetra-amine hardener. In the fabrication processes, wax is applied on the bottom of the mold surface for non stick purpose. Epoxy resin and tri-ethylene tetra-amine hardener were mixed in the ratio of (1:10). Based on volume fraction the chemicals are mixed with epoxy resin and hardener. With the help of mechanical stirrer the additives are well mixed with epoxy resin. Then, the matrix material applied each layer of carbon fiber. Roller is used to remove the air bubbles that are produced during coating. Finally, compressive load applied on composite material. The composite samples were prepared by varying the weight percentage of filler material composites.

3. MECHANICAL TESTING

3.1. Tensile test

In the experimental work, carbon- epoxy reinforcement with filler material composite material was successfully fabricated. The Universal Testing Machine used to tensile tests measurement and test samples was prepared according to ASTM D638 standard. The samples were cut into dog-bone shape. The grip the tensile specimen in the jaw of the universal testing machine and continue loading till the specimen breaking occurs. The tensile strength is observed with the increase in gauge length. The tensile test specimen is shown in Fig.1.

Fig. 1 Tensile test specimen

3.2. Flexural test

Flexural testing is used to determine the bending properties of test specimen. In experimental work, flexural strength of specimen was performed on the universal testing machine. The composite specimens were prepared according to the ASTM D790 standard and three point flexural tests were performed. The cross head position used to measure the deflection of the specimen. The displacement and the flexural strength are measured. The test specimen is shown in Fig.2. The test result of flexural strength of carbon-epoxy reinforcement with filler material filled composited observed and recorded.

Fig. 2 Fluxural test specimen

3.3. Impact test

Impact test was measured for the various filler material filled composite under inspection. The samples were prepared to as per ASTM D256 standard. It's used to measure the impact strength of the material. The test pieces were cut into standard dimension of 64 x 12.7 x 3.2 mm and the depth is 3.33 mm and with 45o notch angle. The specimen is clamped into fixture, the pendulum striking the specimen on notched side. The samples were fractured in Izod impact testing machine and while breaking the specimen the energy (joule) was absorbed by specimen. It was observed and recorded various filler material filled composite material of impact energy. The impact test is used to measure the amount of energy required to break the specimen. The fracture specimen is shown in Fig.3.

3.4. Hardness test

Hardness is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. Shore Hardness Tester was used to measure the hardness of composite specimens under the ASTM D2240 standards. Shore "D" scale is utilized to measure the hardness of carbon-epoxy based materials. The specimen was first placed on a rigid flat surface. The test required force applied in a consistent manner, without shock, and measuring the hardness in few seconds. The shore 'D' hardness value is observed for various filled composites materials. The shore hardness specimen is shown in the Fig.4.

Fig. 3 Izod Impact test specimen

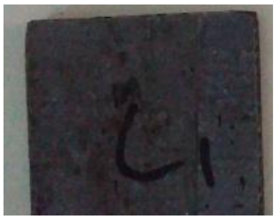

Fig. 4 Shore hardness specimen

4. RESULTS AND DISCUSSION

In the experimental work, carbon- epoxy reinforced with various filler material filled composite materials is used for the investigation. The carbon fiber reinforced composites were successfully fabricated by using tri-ethylene tetra-amine as a hardener for epoxy resin. The test results of the composite materials such as the tensile, flexural, the impact and hardness strength of material are discussed in these sections.

4.1. Effect filler material on tensile strength

Fig.5 shows the effect of fillers in carbon-epoxy reinforced composites. The addition of different fillers (SiC, ZnO_2 and Al_2O_3) influences the tensile strength of composites showed in the graph. From the graph it was observed that the tensile strength of the composites various from 239 to 282 MPa.

The tensile strength variation is reason of various filler material added in the fabrication process. The composite sample 1 and 2 tensile strength is almost same but composite sample 3 exhibited is maximum ultimate strength (282 MPa) compared to other filled composites. From the result it observed that the tensile strength of the sample 3 composites increased compared to other composites. It believes the excellent particle dispersion and strong interfacial bonding between matrix and filler for the effective tensile strength.

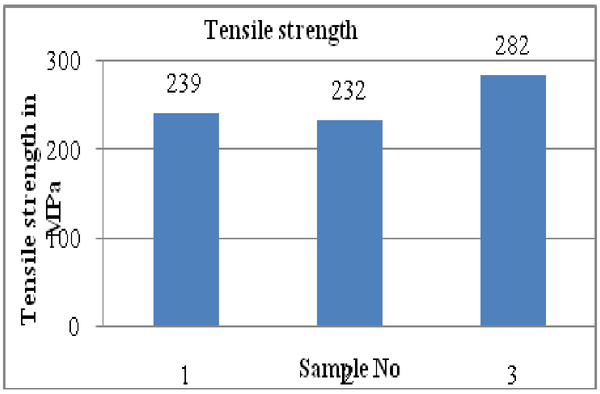

Fig. 5 Effect filler material on tensile strength

4.2. Effect filler material on flexural strength

The Flexural test was carried out and Comparison of the flexural strengths of various filler material filled composite materials is shown in Fig. 6. From the graph composites sample 3 has highest flexural strength (25.6 MPa) when compared with other two samples. The sample 3 has excellent bonding strength between filler and matrix. It was studied that flexural strength of composites increased in sample 3. From the graph it was observed that the increased in the flexural strength of the composites with filler (SiC, ZnO_2 and Al_2O_3) material is probably caused by good interfacial bonding between particulates and the epoxy matrix.

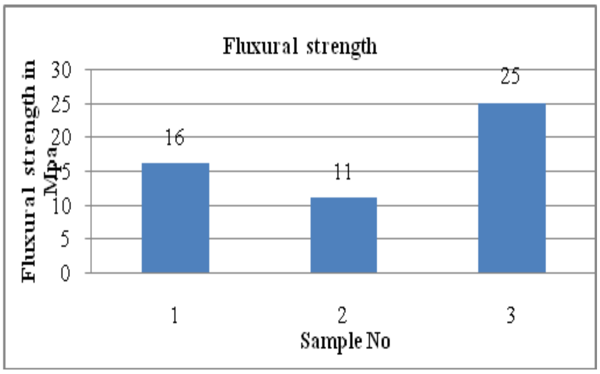

Fig. 6 Effect filler material on flexural strength

4.3. Effect filler material on Impact strength

The Izod test is conducted on test specimen for finding the amount energy absorbed by the composite samples before fracture; the impact strength of various filler material on carbon-epoxy composite material it's shown in Fig. 7. The figure indicated that all three samples of impact energy almost same. The variation obtained is very minimal. The addition of fillers in the matrix is improving impact strength of the composites. The result shows the more energy will be required for the strong fiber matrix bonding; due to high rate energy will be absorbed by the fibers. From the figure, it has seems that sample 2 shows the maximum impact strength (7 joules) when compared to other samples. The flexibility of material is depends upon fillers and matrix strength, it believes that more dispersion energy to avoids the premature cracks formation more effectively.

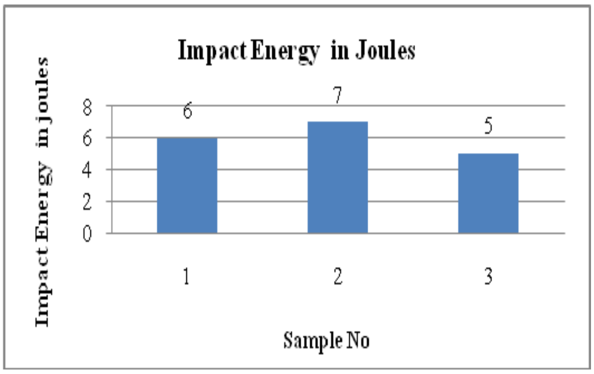

Fig. 7 Effect filler material on impact strength

4.4. Effect filler material on Impact strength

The carbon-epoxy reinforced composites hardness test has been conducted on shore hardness tester. The hardness is measure the according to ASTM standards. Shore "D" scale is utilized to measure the hardness of carbon-epoxy based materials. The fig.8 shows the various filler material filled composite hardness values. The graph indicated that sample 1 has maximum hardness number (50 shore 'D'). This may be due to filler particles uniformly dispersion in the carbon-epoxy matrix which effects in resistance of composites increases against indentation. The filler filled composites increases hardness composites.

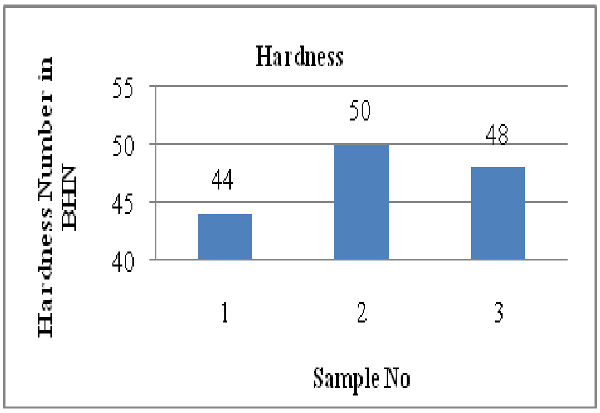

Fig. 8 Effect filler material on hardness

5. CONCLUSION

In this study, the carbon fiber reinforced composites were successfully fabricated by using tri-ethylene tetra-amine as a hardener for epoxy resin. Hand layup has proven to be a good method. The mechanical characteristic of these composites were successfully analyzed by using tensile, flexural, impact and hardness test.

The outcomes of experimental results are summarized as follows,

- In tensile testing, the tensile strength of carbon-epoxy reinforced filler material composites increase strength of the material and also observed that filler added sample 3 gives better tensile strength (282MPa) compared to other samples.

- In flexural testing, the flexural strength of composite material is same as the tensile strength of composites material. The result shows that sample 3 has maximum flexural strength (25.6 MPa) when compared with other two samples. It is found that sample 3 composite is good interfacial bonding between particulates and the epoxy matrix.

- In impact test, the impact strength of composite material was successfully carried as per ASTM standard. It is observed to increase flexibility of the composites. It result has indicated that composites sample 2 exhibited maximum impact strength (7 joules) when compared with other filled composites. It is shows the good bonding strength between fillers and matrix given the good flexibility of material.

- In hardness, Shore tester used to measure the hardness of the material. The hardness is measure the according to ASTM standards. Shore "D" scale is utilized to measure the hardness of carbon-epoxy based materials. The hardness value is highest for Sample 2 filled composite, the reason being filler material uniformly mixed with matrix.

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