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Mechanical Properties of Chopped Carbon Fiber Reinforced Epoxy Composites

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An experimental study has been carried out to investigate tensile, bending, impact and hardness properties of chopped carbon fiber reinforced epoxy composites. Four different weight fractions (0%, 6%, 8%, 10%) were added as reinforcement to composites. The samples were manufactured by using a special designed mold. Tests were carried out according to the ASTM standards. Results of the tests have shown that hardness increases with the increasing amount of carbon fiber in composites. Tensile, bending and impact performances have increased up to 8% of carbon fiber in the composite and then started to decrease.

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1. Introduction

Usage of fiber-reinforced composite structures has increased in such industries as automotive, marine transportation, civil engineering, sporting goods, medical equipment and prosthetic devices. With the increased use of composite materials, there is a need to develop methods to predict the material properties and behavior of composite materials and of structures made of these materials, under a variety of loading and environmental conditions.

Thermosetting polymers are insoluble and infusible after cure because the chains are rigidly joined with strong covalent bonds. Typical examples of thermoset polymers include epoxies, polyesters, phenolics and polyamide. Epoxy is the most popular among the available thermosetting polymers due to its high strength, low viscosity, low volatility and lower shrinkage rates over other thermosetting polymers [1].

Many researchers have made studies in this field. Jacob et al. have investigated the effect of fiber volume fraction, fiber length and fiber tow size on the energy absorption of chopped carbon fiber-polymer composites [2]. Dong et al. have studied improvement of fracture toughness of epoxy resins with short carbon fibers [3].

2. Experimental work

The materials used in this study were chopped carbon fiber (6 mm length), used as reinforcement, and epoxy resin used as matrix. Four different weight fractions (0%, 6%, 8%, 10%) of carbon fiber were used as reinforcement in composites.

A special mold was designed and manufactured for preparation of samples. Epoxy resin (MGS L285) was mixed with hardener (HGS L285) in mass ratio of 100/40, as recommended by supplier. After that the reinforcement was added to the mixture and mixed. Before placing the mixture inside the mold, the mold was polished with a release agent to prevent the composites from sticking onto the mold upon removal. Mixture was poured into mold. The mold was closed under press to avoid occurrence of air bubbles in the composites and heated to 60 °C for one hour. After that composites were left to cure in the mold for 24 hours at room conditions. When the composite was hardened, it was removed from the mold.

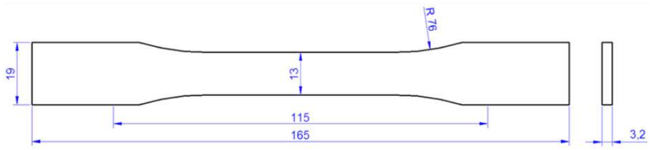

Fig. 1. Tension test sample.

Tension test samples were prepared according to ASTMD 638 (1996) [4]. Tensile tests were conducted on Zwick Roell device at room conditions. Test speed was 2 mm/min. The dimensions of a tension test sample are shown in Fig. 1. Bending test samples were prepared according to the ASTM D790 (2010) [5]. The dimensions of the samples were $12.7 \times 127 \times 3.2$ mm^3.Three point bending tests had stopped automatically when the plastic deformation appeared in the tested composite. Impact tests were conducted according to ASTM D4812-11 standard [6] on samples which had dimensions of $12.7 \times 63.5 \times 3.2$ mm^3. During the tests samples were positioned vertically according to Izod. The impact tests were performed under a hammer that had 5.5 J of energy. Hardness of the samples was measured with a Barcol measurement device, according to ASTM D2583 [7]. All mechanical tests were repeated on five samples and the average values were considered. The tests were conducted at room conditions.

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3. Results and discussion

Tensile test results are shown in Fig. 2. The results show that reinforcement with the chopped carbon was not effective in the increasing of the tensile strength. The epoxy, used as matrix material, had tensile strength of 73.5 MPa. It can be seen that tensile strength was reduced by 7% (to 68.544 MPa) in composites reinforced with 6% of carbon fiber, by 4% (to 70.761 MPa) in 8% reinforced composites and by 22% (to 57.04 MPa) in 10% reinforced composites. Maximum brittleness was found in the composite reinforced with 8% of carbon fiber.

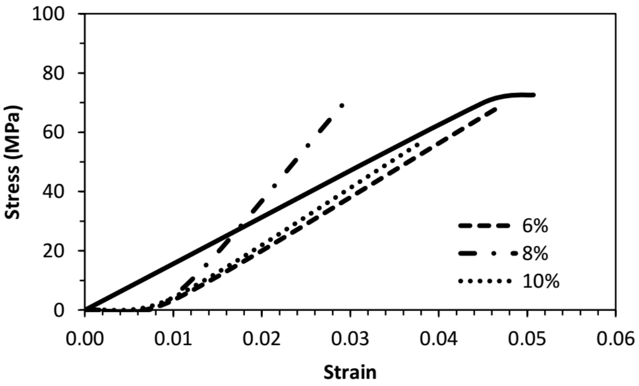

Fig. 2. Tensile test results.

Addition of chopped carbon fiber to the composites has reduced the tensile strength, because the fiber was not continuous and the matrix material was not able to hold composite strongly.

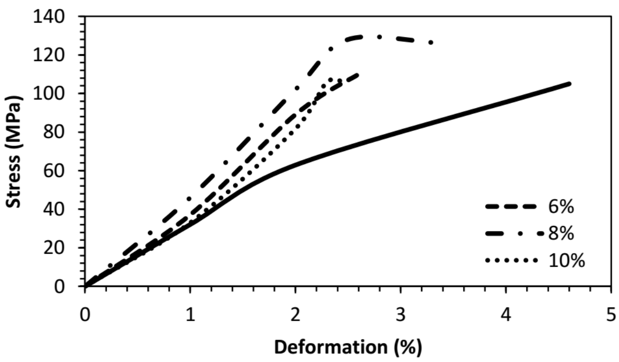

Fig. 3. Bending test results.

Bending test results are shown in Fig. 3. Reinforced composites had higher bending strength compared to the pure epoxy samples. When the amount of fiber became 10%, the epoxy was not strong enough to fix the matrix and the fiber together. As a result, strength started to decrease. Therefore it can be said, that optimum reinforcement amount is about 8%. It can be seen, that bending stress was increased by 8% (to 114 MPa) in 6% reinforced composite, by 22% (to 128 MPa) in 8% reinforced composites and by 1% (to 106 MPa) in 10% reinforced composite.

Impact test results are shown in Fig. 4. It can be seen that impact strength was increased by 142% (to 760.734 J/m) in 6% reinforced composite, by 430% (to 1668 J/m) in 8% reinforced composite and by 3% (326.156 J/m) in 10% reinforced composite.

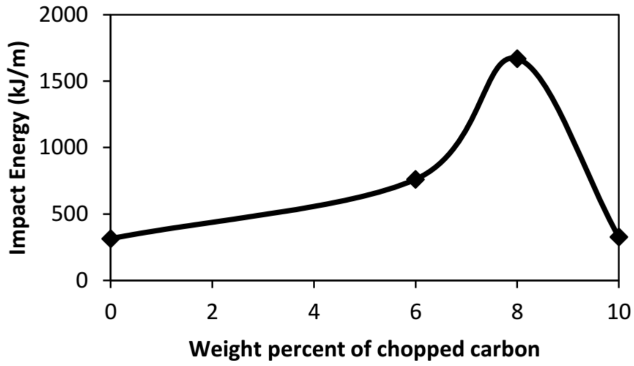

Fig. 4. Impact test results.

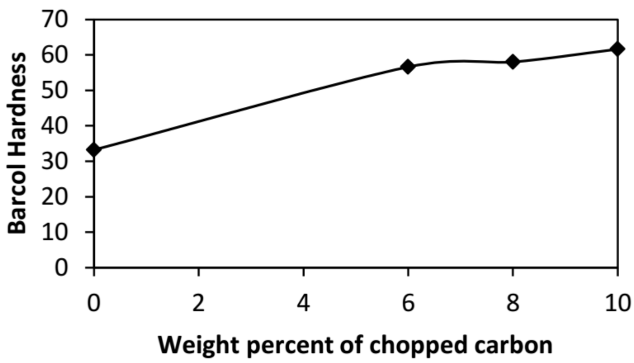

Fig. 5. Hardness test results.

Hardness test results are shown in Fig. 5. As the amount of chopped carbon in the composite increased, the hardness has also increased. The hardness was higher by 70% (56.6 Barcol Hardness) with 6% of reinforcement, by 74% (58 Barcol Hardness) with 8% of reinforcement and by 85% (61.6 Barcol Hardness) with 10% of reinforcement in the composite, compared to hardness of the matrix material.

4. Conclusions

The mechanical performance of the composites was affected by the amount of reinforcement.

The results show that reinforcement of chopped carbon was not effective in increasing the tensile strength. The highest strength was observed in composites reinforced with 8% of carbon fiber.

As the amount of chopped carbon fiber increased up to 8%, bending and impact strength have also increased. With 10% of reinforcement the matrix component was not able to keep together composite. Therefore the strength of the composites has started to decrease.

Hardness of composites increases with the increasing amount of the chopped carbon fiber.

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