

HYBRIDIZATION EFFECT OF GLASS AND CARBON FIBER ON MECHANICAL PROPERTIES OF EPOXY BASED COMPOSITES

By

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Abstract

Hybrid composite fabricated from glass fiber and carbon fiber is made in an epoxy called DGEBA (diglycidylether of bisphenol A). The tensile strength and the impact strength of the hybrid composite were evaluated over a range of glass: carbon ratios. It was found that the mechanical properties increased as the relative proportion of carbon decreased. The carbon fibers and the glass fiber present in the epoxy showed multiple failure modes particularly at lower carbon proportions. It was noted that the overall failure did not occur until a considerable portion of fiber strands were fractured. Failure is thus progressive, and the material is effectively "tougher" than equivalent all-carbon fiber composites. This is precisely the 'Hybrid Effect'.

Keywords: Hybrid composites, Hybrid Effect, Polymer Matrix Compounds, Tensile Strength, Impact strength.

1. Introduction

Carbon fiber composites are becoming widely adopted in the transportation, sporting goods and wind energy sectors, among others [1, 2]. This is because "carbon-fiber composites weigh about one-fifth as much as steel, but can be comparable or better in terms of stiffness and strength, depending on fiber grade and orientation [3-5]. "In addition, carbon fiber show good creep resistance and good compatibility with epoxy matrix. However, the main drawbacks of carbon fiber composites for industrial use are rather susceptible to stress concentration and impact damage due to the brittleness of carbon fiber [4, 6]. The other major factor that is prohibiting the use of carbon fiber in common use is the high price [5-7].

To overcome both of these problems and to make carbon fiber more adaptable, hybridization is done. In the process a more ductile and low priced fiber is introduced in certain proportions to improve the mechanical properties [8-10]. Hybrid composites normally contain a high modulus, high strength and costly fiber such as graphite or carbon fiber. The second fiber is usually a low modulus fiber and cheap fiber like Kevlar, PE or Basalt fibers. The intrinsic mechanical properties of both reinforcement material gives rise to unique structural materials in terms of toughness and strength. Glass fiber may also be a good candidate for the preparation of hybrid composites of this type. It has good toughness properties, low price and relatively good interfacial adhesion to the matrix [11].

In this study hybrid composites have been prepared with glass fiber and carbon fiber as reinforced materials and epoxy resin as matrix. The aim of this study is to find out how the tensile and the impact strength of the hybrid composite varies with varying ratios of component fiber reinforcements. Theoretically, the hybridization of brittle carbon fibers with ductile glass fibers may improve the mechanical properties stated above.

2. Experimental

2.1 Materials

The materials used in this research work were uni-directionally woven carbon fibers and glass fibers and epoxy.

The epoxy system consisted of diglycidyl ether of bisphenol A (DGEBA) which is the prepolymer **A** and a hardener **B** which was a phenolic novolac resin based.

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2.2 Sample Preparation

Five samples were developed varying the relative ratios of carbon and glass fibers. The total volume fraction of fibers in the composite was kept constant at 60%. Two samples were made of pure carbon fibers and glass fibers. The other three samples consisted 1:4; 1:2 and 1:1 carbon: glass fibers ratios respectively. The samples were prepared keeping the fibers unidirectional. The samples were all synthesized as “alternate laminates”. Epoxy **A** and hardener **B** were mixed in 2:1 ratio respectively. The epoxy system was homogeneously mixed first then it was added to the fibers aligned in the mould. The mould was applied firstly with proper layer of mould releasing agent. The mould was then placed in the compression molding machine at 150° C. The composite hardened in 4 hours. The sample was then machined to obtain samples for further testing. A mechanical cutter was used for the purpose.

2.3 Tensile test

Tensile measurements were performed at the Universal Testing Machine. Sample was first prepared according to the standards. The testing conditions were set to epoxy materials. All the samples were tested after 2 days of their curing. It was done to ensure proper curing and so that the entire thermal stresses were minimized.

Tensile strength testing was carried out according to the ASTM D638. The cross head speed was set to 5mm/min.

2.4 Impact test

The impact testing was performed on Tubular Impact Tester. It uses a falling weight (4 lb) to measure the impact strength of a material. This type of impact tester is also called as Universal Impact Tester. The ASTM used in performing the tests is ASTM D-2794.

Tests were performed at ambient conditions and the samples were critically analysed for the initiation of cracks or breakage.

3. Results and discussion

3.1. Tensile and impact test

The graphical results obtained from the tensile tests on the hybrid composite are given in the figures 1-5.

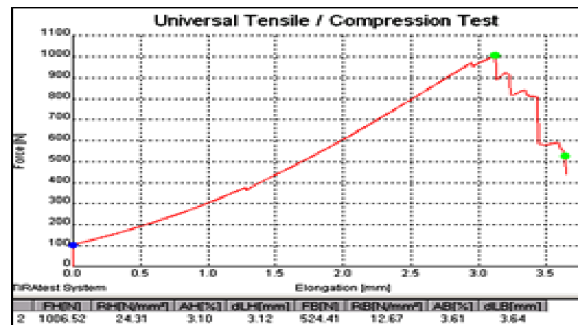


Figure 1. Tensile strength of fiberglass

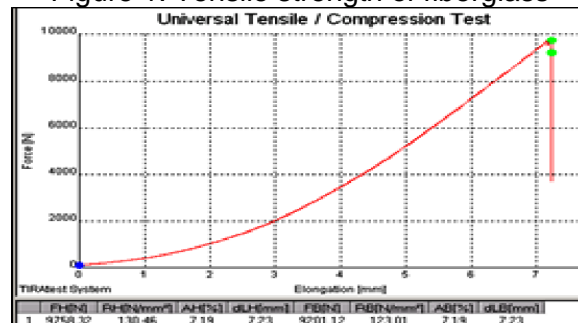


Figure 2. Tensile strength of carbon fiber reinforced epoxy composites

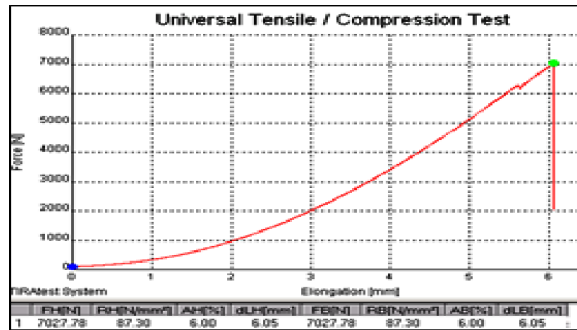


Figure 3. Tensile strength of epoxy composites reinforced with hybrid fibers of carbon and glass in a 1:4 ratio respectively

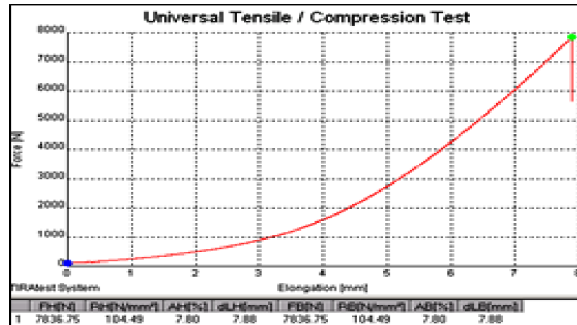


Figure 4. Tensile strength of epoxy composites reinforced with hybrid fibers of carbon and glass in a 1:2 ratio respectively

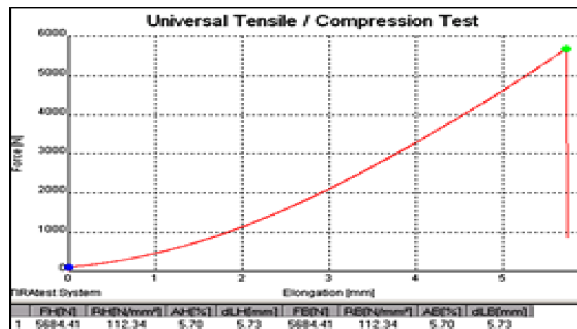


Figure 5. Tensile strength of epoxy composites reinforced with hybrid fibers of carbon and glass in a 1:1 ratio respectively

Tensile strength of epoxy composites increase as glass fiber content increases; shown in figure 3-5. Impact strength is also increased with increasing glass fiber content. Impact strength reduces as carbon fiber fraction increases because carbon fiber is brittle material. Failure initiated by longitudinal splitting which progressed to total disintegration of the test piece at final failure was experienced in all glass fiber samples. In contrast to the behavior of the all-glass laminates the all-carbon composite failed by the propagation of a single transverse crack. As carbon fiber is the stiffer fiber fracture is expected to happen when carbon fiber fails. At low carbon contents the glass fiber will be able to bear the load. In this research work the hybrid effect has been very prominent. The hybrid effect decreased as the carbon fraction in the hybrid increased as shown in the table 1. It is also seen that as glass fiber is an elongational fiber so failure was not sudden but it was due to the load transferring in this type of fiber. It is clear from the Figure 1. This behavior was also seen in the hybrid where the glass fiber ratio was relatively larger. This load transference results in the increased toughness of the hybrid. As a result hybrid effect is more prominent in samples where carbon fiber is less in proportion.

It is very obvious from the Table-1 that as hybridization is increasing, impact strength is increasing, and this is due to the increase in glass fiber content.

Table 1 Results of tensile tests and impact tests

Number of glass Laminate	Number of carbon laminate	Carbon fraction	Impact Strength (KN)	Failure Stress (N/mm ²)	Hybrid effect (%)
1	0	0	3.8	30	-
4	1	0.20	3.6	87	43
2	1	0.33	3.2	104	37
1	1	0.50	2.4	112	28
0	1	1	1.8	130	-

4. Conclusions

The results have clearly shown the existence of hybrid effect and showed that hybridization is dependent upon the ratio of the two fibers present.

It is also noted that part of the hybrid effect is the result of thermal strains induced in the carbon phase. Thermal strains are induced as the composite was heated to an elevated temperatures and the coefficient of expansion for the three materials involved are different.

Therefore, we conclude that properly engineered hybrids provide scope for improvements in the balance of toughness and stiffness in carbon composite laminates.

5. Acknowledgement

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