RESEARCH ARTICLE OPEN ACCESS

Investigation of Effect of Carbon Fibres on the Mechanical Properties of the Hybrid Composite Laminate

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Abstract
In this work Fabric made of woven carbon, glass along with epoxy resins are used to make composite laminate. Average resin fraction on weight basis after curing was 45%. The different types of specimens are prepared with variable percentage of carbon fibres. The mechanical tests such as Tensile test, compression test, flexural test and impact tests are conducted over the specimens and the results are evaluated which indicates that the increase in carbon content increases the mechanical properties of the composite laminate.

I. Introduction

Recent technological breakthroughs and the desire for new functions generate an enormous demand for novel materials. Many of the well-established materials, such as metals, ceramics or plastics cannot fulfill all technological desires for the various new applications. Scientists and engineers realized early on that mixtures of materials can show superior properties compared with their pure counterparts. One of the most successful examples is the group of composites which are formed by the incorporation of a basic structural material into a second substance, the matrix. Usually the systems incorporated are in the form of particles, whiskers, fibers, lamellae, or a mesh. Most of the resulting materials show improved mechanical properties and a well known example is inorganic fiber- reinforced polymers. Nowadays they are regularly used for lightweight materials with advanced mechanical properties, for example in the construction of vehicles of all types or sports equipment.

In the investigation [1], the elastic modulus of hybrid particle/short-fiber/polymer composites was studied using the rule of hybrid mixtures (RoHM) equation and the laminate analogy approach (LAA). In the RoHM, such a hybrid composite was treated as a hybrid system consisting of two separate single systems, namely particle/polymer system and short-fiber/polymer system, the elastic modulus of the hybrid composite was evaluated from that of the two single systems using the RoHM. In the LAA, particle-filled polymer was regarded as an effective-matrix.. It was interestingly observed that the predicted values by the LAA and the experimental results for the elastic modulus of hybrid particle/short-fiber/polymer composites were consistently higher than those predicted by the RoHM, suggesting that the modulus of hybrid particle/short-fiber/polymer composites shows a positive hybrid effect.

Initiation of fatigue damage for a hybrid polymer matrix composite material was studied via 3-Dimensional viscoelastic representative volume element modeling in order to gain further understanding [2]. It was found that carbon fiber reinforced composites perform better in fatigue loading, in comparison to glass fiber reinforced composites, due to the fact that the state of stress within the matrix material was considerably lower for carbon fiber reinforced composites eliminating (or at least prolonging) fatigue damage initiation. The effect of polymer aging was also evaluated through thermal aging of neat resin specimens. Short-term viscoelastic material properties of unaged and aged neat resin specimens were measured using Dynamic Mechanical Analysis. With increasing aging time a corresponding increase in storage modulus was found. Increases in the storage modulus of the epoxy matrix subsequently resulted in a higher state of predicted stress within the matrix material from representative volume element analyses. Various parameters common to unidirectional composites were numerically investigated and found to have varying levels of impact on the prediction of the initiation of fatigue damage.

The effect of thermal exposure in an atmospheric environment for up to 1 year on the flexural performance, under both static and fatigue loading, of a glass fiber/carbon fiber hybrid polymer matrix composite material was evaluated

[3]. It was found that exposure to a temperature near, but below, the glass transition temperature resulted in diminished flexure strength as well as reduced fatigue performance. The magnitude of property reduction was, in general, proportional to the amount of aging time, and was found to be dictated by the dominant aging mechanism. Scanning electron microscopy revealed that the modest reduction in mechanical properties at intermediate aging times was predominantly attributed to thermal oxidation, while for longer aging times thermal aging (dimensional relaxation) was the primary cause for the substantial reduction. Dimensional relaxation of the composite was measured at several isothermal aging temperatures, from which, the activation energy of the aging process was determined. This work provides insight into the evolution of mechanical properties as a function of aging time in an atmospheric environment for a hybrid polymer matrix composite.

A study [4] on the flexural behaviour of hybrid composites reinforced by S-2 glass and T700S carbon fibres in an intra-ply configuration is presented in this paper. The three point bend test in accordance with ASTM D790-07 at various span-to-depth ratios was simulated using finite element analysis (FEA). For the purpose of validation, specimens of selected stacking configurations were manufactured following the hand lay-up process and tested in a three point bend configuration. The validated FEA model was used to study the effects of fibre volume fractions, hybrid ratio and span-to-depth ratio. It is shown that flexural modulus increases when the span-to-depth ratio increases from 16 to 32 but is approximately constant as the span-to-depth ratio further increases. A simple mathematical formula was developed for calculating the flexural modulus of hybrid composites, given the moduli of full carbon and full glass composites, and the hybrid ratio. Flexural strength increases with span-to-depth ratio. Utilisation of hybridisation can improve the flexural strength. A general rule is in order to improve flexural strength, the fibre volume fraction of glass/epoxy plies needs to be higher than that of carbon/epoxy plies. The overall maximum hybrid effect is achieved when the hybrid ratio is 0.125 ($[0_G/0_{7C}]$) when both V_{fc} and V_{fg} are 50%. The strength increases are 43.46% and 85.57% when compared with those of the full carbon and glass configurations respectively. The optimisation shows that the maximum hybrid effect is 56.1% when V_{fc} = 47.48% and V_{fg} = 63.29%.

This study[5] aims at investigating package materials based on polymer matrix for microelectronics. The next generation package materials are expected to possess high heat dissipation capability in addition to low coefficient of thermal expansion (CTE) as the accumulated heat from high performance electronic devices should be removed for proper operation. In this study, various inorganic fillers including aluminum nitride (AlN), wollastonite, silicon carbide whisker (SiC) and boron nitride (BN) with different shape and size were used alone or in combination to prepare thermally conductive polymer composites. In case of AlN, titanate coupling agent was used for the surface treatment of fillers. The use of hybrid filler was found to be effective in increasing thermal conductivity of the composite probably due to the enhanced connectivity offered by structuring filler with high aspect ratio in hybrid filler. For given filler loading, the use of larger particle and surface treated filler resulted in composite materials with enhanced thermal conductivity. The surface treatment of filler also allowed producing the composites with lower CTE

II. Experimental details

2.1 Materials

Fabric made of woven carbon and glass filament of 220gsm and the most common and important class of epoxy resins formed from reacting epichlorohydrin with bisphenol A to form diglycidyl ethers of bisphenol A (DGEBA) are used.

2.2 Fabrication of specimen

The fabric was impregnated by dipping in the resin preform and drying overnight. Then it was taken for compression-molding using conditions: Curing temperature: 70˚C, Curing time: 2 hrs and the average resin fraction on weight basis after curing = 45%. The types of specimens are prepared as per the following details. Totally 30 layers were used in a laminate.

Specimen type	content
Specimen 1	All glass fibres only
Specimen 2	Two glass fibre and one carbon fibre
Specimen 3	One glass fibre and two carbon fibre

2.3 Mechanical testing of composites

The mechanical testing of composite structures to obtain parameters such as strength and stiffness is a time consuming and often difficult process. It is, however, an essential process, and can be somewhat simplified by the testing of simple structures, such as flat coupons. The data obtained from these tests can then be directly related with varying degrees of simplicity and accuracy to any structural shape. The test methods outlined in this section merely represent a small selection available to the composites scientist.

2.3.1 Tensile Testing

Tensile testing utilizes the classical coupon test geometry as shown below and consists of two regions: a central region called the gauge length, within which failure is expected to occur, and the two end regions which are clamped into a grip mechanism connected to a test machine. These ends are usually tabbed with a material such as aluminum, to protect the specimen from being crushed by the grips. This test specimen can be used for longitudinal, transverse, cross-ply and angle- ply testing.

2.3.2 Compressive Testing

This is much more problematical. The results obtained are essentially dependent on the type of compression fixture used. Also, the gauge length is conical, as if it is too long, the specimen will buckle and flex, resulting in premature failure.

2.3.3 Impact Testing

A metal may be very hard (and therefore very strıng and yet be unsuitable for applications in which it is subjected to sudden loads in service. Materials behave quite differently when they are loaded suddenly than when they are loaded more slowly as in tensile testing. Because of this fact, impact test is considered to be one of the basic mechanical tests (especially for ferrous metals).

2.3.4 Flexural Strength

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. The transverse bending test is most frequently employed, in which a rod specimen having either a circular or rectangular cross-section is bent until fracture using a three point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture.

III. Results and discussions

3.1 Tensile Strength Test

Table 3.1 Observations from tensile test

DETAILS	SPECIMEN-1	SPECIMEN-2	SPECIMEN-3
Maximum force(kN)	17.74	20.5	30.04
Max. Displacement (mm)	1.5	5.1	9.3
Elongation(mm)	1.5	5.3	9.9

3.2 Compression Strength Test

Table 3.2 observations from compression test

DETAILS	SPECIMEN-1	SPECIMEN-2	SPECIMEN-3
Maximum force (kN)	39.4	40.84	43.960
Max.Displacement at	1.70	2.1	2.2

3.3 Impact Strength Test

Table 3.3 Observations from impact test

Particulars	Specimen-1	Specimen-2	Specimen-3
Width(mm)	12.9	12.81	11.71
Thickness(mm)	2.21	2.00	1.96
Energy(J-s)	2.6	2.4	3.2

3.4 Flexural Test

Table 3.4 Observations from flexural test

Particulars	**Specimen-1**	**Specimen-2**	**Specimen-3**
Width(mm)	12.17	13.6	11.7
Thickness(mm)	1.29	2.06	1.97
Maximum load(N)	135.221	132.523	145.885

From the above set of reading it can be concluded that specimen-3 i.e., two carbon fibre and one glass fibre possess the superior property than other specimen. We can also come to a conclusion that increases in carbon fibre increases the efficiency of the specimen. It is observed that as the percentage of carbon increases the mechanical properties also increases. In order to maintain uniformity the layers are arranged alternatively.

IV. Conclusion

The mechanical tests such as Tensile test, compression test, flexural test and impact tests are conducted over the specimens with different carbon fibre content and the results are evaluated which indicates that the increase in carbon content increases the mechanical properties of the composite laminate. It can be concluded that the carbon fibres influences a lot over the mechanical properties of the composite laminate.

References

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