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Fabrication and Experimental Evaluation of Mechanical Properties of E-Glass and Aramid Short Fiber Reinforced Composite Material

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Abstract: ***Composite materials play a very important role in the field of engineering. Composites materials are widely used in aeronautical, automotive, space, transport, marine, sports and military industries. In this present study hybrid composite of E-glass/Aramid fiber were prepared by Hand-layup technique. The glass fiber used is E-glass fiber of 6 mm length and aramid fiber used is also of 6mm in length. E-glass and aramid fibers acts as a reinforcement phase and epoxy resin (LY556) acts as a matrix phase. The composite samples were made in the form of plate/sheets. Specimens were cut from the fabricated laminateaccording to the ASTM standard for different experimentsfor tensile test, flexural text, and compression test. The tests were carried as per ASTM standard, D-3039 for tensile test, D-3410 for compression and D-790 for flexural test. Results of the mechanical properties of composites were obtained by tensile, bending and compression tests. From the results obtained from the tensile strength test it has been seen that, addition of aramid fibers improves the tensile strength of the specimen. The reason we know that the tensile strength of the aramid fibers is more compared to the epoxy polymer hence the strength has gone up with the addition of the aramid fibers. From the results obtained from the compression strength test it has been seen that, addition of aramid fibers improved the compression strength of the specimen. The reason we know that the strength of the aramid fibers is more compared to the epoxy polymer hence the strength has gone up with the addition of the aramid fibers. From the results obtained from the flexural test yields that, addition of aramid fibers reduces the flexibility of the composite. Addition of the glass fiber also affected in the same manner.***

Keywords: short E-glass fibers, short Aramid fibers, Epoxy, Hybrid composite

1. Introduction

Hybridization is the process of combining two different fibers with the help of a matrix (resin) in order to obtain the desired properties at a relatively low cost. A hybrid composite is obtained when two or more fiber/matrix systems are combined together to obtain a new composite material. The expense of manufacturing can be decreased by mixing less expensive fibers with more expensive one. Example mixing of glass with aramid fibers or mixing of glass with carbon fibers. Many experimental works are being carried out on the hybrid composite to study the effects of hybridization on the properties of the composite [1]-[2]. Aramid fibers have drawn lot of focus as it is heat resistant and high strength fibers. Functional aramids have found their way into various applications as industrial materials, bulletproof and protective shields, marine fishery parts and civil structures [3]. The fiber volume fraction plays and important role in defining the actual strength obtained by the composite prepared. When fiber volume is increased in the composite the strengths also increased but after certain limit as fiber volume fraction increases the amount of matrix material decreases and it starts weakening interfacial bonding strength between fibers and binder material [4]. In thermoset polymers epoxy have good properties compared to other polymers. Properties such as mechanical, thermal, adhesiveness due to which epoxy is widely used in structural and industrial application. Due to light weight and economic in cost glass fibers are used as a major reinforcement material in fiber reinforced polymer composites. As in glass or carbon fibers when the fibers break they fail due to brittle cracking where as in case of aramid fibers when they break they don't fail by brittle cracking. Failure of aramid fibers takes place due to series failure of small fibrils present. Each aramid fiber is made up of molecular strands of fibrils and fibrils orientation is in the same direction of the fiber itself. Aramid fibers have high toughness compared to glass fibers [5]. An increase in the tensile and flexural properties was observed in hybrid composites when the comparison of hybrid is done with un-hybrid composites and resistance to water absorption is seen in hybrid composites. When the pure glass composite was compared with hybrid glass composite the hybrid glass composite showed good tensile properties [6]. In fiber glass composite material the mechanical properties of the composite depends upon the properties of the glass fiber component and the epoxy component individually as well as the volume ratio of two components. Due to increase in fiber content, the tensile and flexural strength of the glass fiber composite showed a linear increment [7]. On the basis of weight the aramid fibers has better mechanical properties compared to glass fibers and steel. When the aramid fibers are exposed to high temperatures it maintains and retains its mechanical properties due to its excellent resistance to heat and aramid fibers do not melts or get ignited when exposed to oxygen [8]. As a reinforcement material continuous fibers are available in unidirectional mat and woven cloth where as it is available in chopped fibers, milled fibers and random mat in case of discontinuous fibers. Orientation of fibers is random in case of discontinuous fiber composites where as it is preferred orientation in continuous fibre composites. The short fiber reinforced composite consists of a continuous polymer matrix in which fibers of comparatively short in length and fibers are aligned imperfectly/randomly distributed. Short fiber reinforced composite are less strong and less stiff than continuous fiber reinforced composites. In short fiber reinforced composites fiber length plays an important role in defining the mechanical properties and the fibers used are mostly glass even though carbon, graphite are also used and manufacturing of composite is expensive compared to other composites. With the help of injection moulding short fiber reinforced polymer composites are manufactured which helps in achieving better surface finish [9].

2. Materials and Manufacturing Method

2.1 Materials

E-glass fibers are the most widely used reinforcement material for composite. Short E-glass fibers are used as reinforcement in this research work of 6 mm in length.

Aramid fiber is used as a second reinforcing material in the preparation of hybrid composite material. It will increase the mechanical properties such as tensile strength, hardness and flexibility. Epoxy resin is one of the excellent thermosetting polymer resins.

Epoxy resins possess characteristics such as high strength, good adhesion to most of the substrate materials, low shrinkage during curing. Epoxy resin of grade LY556 and hardener of grade HY951 is used.

2.2 Manufacturing methods

The hand lay-up method is the simplest method of all composite material manufacturing methods. Hand lay-up method is chosen for this study because of its low cost of manufacturing and simple fabrication process.

The hybrid polymer composite material is prepared by using short E-glass fibers, short aramid fibers, epoxy and hardener. The materials were taken on weight percentage basis depending upon different volume fraction to be prepared. The mixture of epoxy and hardener was stirred thoroughly and later fibers were added and stirred firmly and later the mixture is poured into the cavity of the mould. The mixture was allowed to cure for 24 hours. After curing the material is safely removed from the cavity. The prepared specimen is cut into required size and shape by using water jet cutting machine required for compression test, tensile test and bending test. Water jet cutting operation provides smooth surface finish compared to other machining process.

According to ASTM D3039 for the tensile test specimens were cut of dimension 250mm×25mm×6mm. As per ASTM D3410 for the compression test specimens were cut of dimension 12mm×8mm×6mm. As per ASTM D790 for the bending test specimens were cut of dimension 125mm×12.5mm×6mm Totally five volume fractions were prepared and three kinds of tests were carried out namely tensile, compression and bending test and 3 specimen were tested for each volume fraction.

3. Mechanical Testing and Characterization

To study the mechanical properties of composites manufactured three tests were carried out namely tensile, compression and bending test.

3.1 Tensile Test

For the tensile test specimens were prepared as per ASTM D3039. The specimen dimensions were 250 mm in length, 25mm wide and 6mm thick. The tensile test was carried out on universal testing machine. A constant loading of 100 mm/min is applied to the specimen. The value of load and corresponding displacement, value of stress and strain and tensile strength were noted. Specimens of different volume fraction were tested and results were noted.

Figure 1: Specimen before tensile test

Figure 2: Specimen after the tensile test

3.2 Compression Test

For the compression test specimens were prepared as per ASTM D3410. The specimen dimensions were 12 mm in length, 8mm wide and 6mm thick. The compression test was carried out on universal testing machine. The test specimen is placed in between the jaws and gradually load is applied and the value of load and corresponding displacement, compressivestrength were noted. Specimens of different volume fraction were tested and results were noted.

Figure 3: specimens before compression test

Figure 4: specimens after compression test

3.3 Bending Test

Bending/Flexural test is carried out to evaluate the bending strength of the composite. The prepared specimen is subjected to three point load in a controlled manner. As per ASTM D 790 specimens for Flexural test were cut from the sheet. Flexural test of composite sample is carried out as perASTM D 790 test standard. . For each volume fraction 3 samples were tested and the value of load and corresponding displacement, value of stress and strain were also noted.

Figure 5: Specimen before bending test

Figure 6: specimen after bending test

4. Results and Discussion

4.1 Tensile Test

From the results obtained from the tensile strength test it has been seen that, addition of aramid fibers improves the tensile strength of the specimen. Initially it was 12Mpa in an average after adding 6% by volume it has gone to 13Mpa.The reason we know that the tensile strength of the aramid fibers is more compared to the epoxy polymer hence the strength has gone up with the addition of the aramid fibers. Addition of glass fiber has taken tensile strength from 14Mpa to 21.37Mpa, indicating the alteration of strength in positive direction with the addition of the glass fibers.

Table 1: Result of tensile test

Volume fraction	Specimen no	Tensile strength (MPa)	Young's modulus (MPa)
E-glass - 2 %	T1	14.23	880.3
Aramid - 2%	T2	12.27	710.11
Epoxy - 96%	T3	10.62	983.5
E-glass - 2%	T1	5.86	915.6
Aramid - 4%	T2	12.82	712
Epoxy - 94%	T3	5.68	507
E-glass - 2%	T1	12.37	644
Aramid - 6%	T2	13.07	726
Epoxy - 92%	T3	13.25	791
E-glass - 4%	T1	19.15	1145
Aramid - 2%	T2	20.94	1072
Epoxy - 94%	T3	24.68	1127
E-glass - 6%	T1	16.92	846
Aramid - 2%	T2	21.37	1151
Epoxy - 92%	T3	14.18	963

4.2 Compression Test

From the results obtained from the compression strength test it has been seen that, addition of aramid fibers improved the compression strength of the specimen from 92Mpa to 97Mpa. Initially it was 92Mpa in an average after adding 6% by volume it has gone to 97Mpa.The reason we know that the strength of the aramid fibers is more compared to the epoxy polymer hence the strength has gone up with the addition of the aramid fibers. Addition of glass fiber has not altered the compression strength after adding 4% by volume, slight change in compression strength is observed after adding glass fiber by 6% by volume.

Table 2: Result of compression test

Volume fraction	Specimen no	Tensile strength (MPa)	Young's modulus (MPa)
E-glass - 2 %	C1	82.866	711
Aramid - 2%	C2	92.25	701
Epoxy - 96%	C3	76.49	605
E-glass - 2%	C1	94.66	1103
Aramid - 4%	C2	79.34	989.25
Epoxy - 94%	C3	62.12	997
E-glass - 2%	C1	97	1317.4
Aramid - 6%	C2	86.91	1255
Epoxy - 92%	C3	84.89	924
E-glass - 4%	C1	83.96	1415
Aramid - 2%	C2	72.56	1311
Epoxy - 94%	C3	72.95	1255
E-glass - 6%	C1	77.05	1159
Aramid - 2%	C2	85.05	1277
Epoxy - 92%	C3	77.49	912

4.3 Bending Test

From the results obtained from the flexural test yields that, addition of aramid fibers reduces the flexibility of the composite. Addition of the glass fiber also affected in the same manner.

Table 3: Result of flexural test

Volume fraction	Specimen no	Bending strength (MPa)	Flexural modulus (MPa)
E-glass - 2 %	B1	3.264	1869
Aramid - 2%	B2	4.574	2359
Epoxy - 96%	B3	2.295	1627
E-glass - 2%	B1	2.020	2103
Aramid - 4%	B2	2.035	1791
Epoxy - 94%	B3	2.487	2224
E-glass - 2%	B1	1.302	1229
Aramid - 6%	B2	2.884	1497
Epoxy - 92%	B3	1.708	1263
E-glass - 4%	B1	2.554	927
Aramid - 2%	B2	2.379	887
Epoxy - 94%	B3	2.491	1082
E-glass - 6%	B1	1.904	1085
Aramid - 2%	B2	2.196	835
Epoxy - 92%	B3	3.749	1169

5. Conclusion

From the results obtained from the different tests conducted to characterize the composite it has been concluded that.

- Polymer matrix materials can be prepared very easily from hand Layup technique.
- It has been noticed that the mechanical properties of hybrid composites such as tensile strength, compression strength Increases with the addition of fibers like aramid and glass fibers.
- And flexibility reduces with the addition of fibers but the bending strength increases with the addition of the fibers.
- By adding one or more types of fibers to prepare a composite would be more beneficial.

- The composition of multiple materials leads to the improvement in mechanical properties compared to that of individual materials.
- Hybrid composite (short E-glass, Aramid fiber reinforced epoxy composites) were successfully prepared by hand lay-up method and successfully tested as per ASTM test standards.

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