PROPERTIES OF GLASS FIBER REINFORCED COMPOSITES BASED ON EPOXY BLENDS

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ABSTRACT

Glass fibre reinforced composites were fabricated from the resin systems diglycidyl ether of bisphenol A and tetraglycidyl-2,2-bis-[4-(p-aminophenoxy)phenyl]-propane using different amine curing agents in presence or absence of fortifier. Mechanical and electrical properties of these composites were found out. Significant improvement in mechanical properties was observed on incorporation of the fortifier.

I. INTRODUCTION

N-glycidyl epoxy resin based on 4, 4'-diaminodiphenyl methane is used extensively as polymeric matrix in high performance composites materials. Because of their high functionality can take more active part during curing, thereby provide very good mechanical properties. Looking to the advantages of multifunctional epoxy resin, a tetra functional N-glycidyl epoxy resin was mixed with the conventional diglycidyl ether of bisphenol-A resin for the fabrication of composites. Different amine curing agents were used as curing agents. The composites prepared using the above resin systems were analyzed for mechanical and electrical resistance properties. The effect of an additive known as fortifier on these properties of composites has been investigated.

II. EXPERIMENTAL

2.1 Resin Systems

Epoxy resin diglycidyl ether of bisphenol A[1] (DGEBA, epoxy equivalent weight 190 g eq^{-1}) was used in 80 parts throughout the study. With this epoxy resin, a tetrafunctional epoxy resin tetraglycidyl-2,2-bis-[4-(p-aminophenoxy) phenyl]- propane[2] (TGBAPP, epoxy equivalent weight 183 g eq^{-1}) was mixed in 20 parts amount. The epoxy fortifier PGEHA was the condensation product of phenyl glycidyl ether (PGE) and 4-hydroxy acetanilide (HA) and was used in 20 parts to the total weight of resin. Various amine curing agents like diaminodipheny ether (DDE), diaminodipheny methane (DDM), diaminodiphenyl sulphone(DDS) were laboratory grade reagents while diamines 2,2-bis-[4-(p-aminophenoxy)phenyl]-propane (BAPP) and 1,1-bis-[4-(p-aminophenoxy) phenyl]-cyclohexane (BAPC) were prepared in the laboratory[3].

2.2 Thermal Properties

To determine the thermal stability of the cured product thermogravimetric analysis was perform using Du-pont 951 thermogravimetric analyzer. Thermal stability of the cured epoxy systems is affected by the structure of the amine used for the curing of the epoxies. Thermal stability of DDS cured epoxy system is highest in the series. Addition of fortifier to the epoxy amine system decrease the thermal stability[2]. Addition of tetrafunctional epoxy resin into DGEBA increase the thermal stability of DGEBA resin [2].

2.3 Fabrication of Composites

Ten pieces of glass cloth 20 cm × 20 cm were impregnated with matrix material composed of DGEBA (used in 80 parts), TGBAPP (used in 20 parts) and different amine curing agents were used in stoichiometric amount. The impregnated pieces were dried at 60˚C. The prepegs were then compressed between flat platens at a pressure of about 150psi at 150˚C for 1.5 hrs. The post curing of the composites were carried out at 180˚C for 1 hour. Another composite (3 plies, 8cm×8cm) of each resin system was prepared under identical condition for dynamic mechanical analysis.

2.4 Testing of Composites

The resin content of the composites was determined from the differences of the weights after heating the preweighed specimen in a furnace at 600˚C for 3 hours. All the mechanical and electrical properties were measured at room temperature(30˚C). Tensile, flexural and interlaminar shear strengths were measured using ASTM methods D 638-76, D 790-71 and D 2344-76 respectively using an universal instron testing machine model 1193. The izod impact strength was measured according to ASTM D 256 with a notch angle of 45˚. During testing the layup of the plies and the test direction of the sample were always kept same with respect to the wrap direction of the glass fabric.

The dielectric properties of the composites, dielectric constant and the loss factor were determined from the measured value of capacitance and dissipation factor on 1615-A capacitance bridge at a frequency of 1KHz. The dielectric strength (break down voltage) was measured with a high voltage tester machine. Resistance to electric current was measured with the help of megohm meter at applied voltage of 500 V.

The glass transition temperature (Tg) was determined on Du pont 980 dynamic mechanical analyzer.

III. RESULTS AND DISCUSSION

For each of the composites mentioned in TABLE 1, various amine curing agents were used in stoichiometric amount. The epoxy fortifier was used in 20 parts to the total weight of the resin system. Resin content of the systems lies in between 30 percent and 34 percent.

3.1 Mechanical Properties

Mechanical properties of the composites are more or less influenced by the nature of the resin –curing agent systems and by use of fortifier. The optimum properties of crosslinked polymer can be decided by a system which is more reactive and the final degree of conversion is more in case of such systems.

TABLE 1 shows the mechanical properties such as interlaminar shear strength, impact strength (izod) and tensile elongation of the composites prepared from DGEBA (80 parts) and TGBAPP resin (20 parts) blend.

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Table 1 : Mechanical Properties of Glass Fiber Reinforced Epoxy Blends

Resin Systems	Proportion	Resin systems	Curing agent	Interlaminar shear strength Kg/cm^2	Impact strength kg.cm/cm of notch	Tensile elongation %
DGEBA-TGBAPP	80:20	RS1	DDS	201	111	1.9
DGEBA-TGBAPP-PGEHA	80:20:20	RS2	DDS	252	137	2.3
DGEBA-TGBAPP	80:20	RS1	DDM	128	48	1.7
DGEBA-TGBAPP-PGEHA	80:20:20	RS2	DDM	173	62	2.3
DGEBA-TGBAPP	80:20	RS1	DDE	141	51	1.9
DGEBA-TGBAPP-PGEHA	80:20:20	RS2	DDE	179	68	2.4
DGEBA-TGBAPP	80:20	RS1	BAPC	169	104	1.8
DGEBA-TGBAPP-PGEHA	80:20:20	RS2	BAPC	207	152	2.2
DGEBA-TGBAPP	80:20	RS1	BAPP	165	75	2.1
DGEBA-TGBAPP-PGEHA	80:20:20	RS2	BAPP	221	105	2.3

The flexural strength of composites prepared by curing epoxy resins with high molecular weight diamines (BAPC and BAPP) [4] are higher than that of the DDS, DDM and DDE cured systems. As the molecular weight of the amines is increases, flexural strength is also increases. The composites cured with BAPC diamine have lower tensile strength. Presence of cyclohexane ring restricts the movement of the molecules resulting in decrease in tensile strength. The comparative data of flexural and tensile strength are shown in Fig.1. The shear strength property of the composites cured with DDS is highest, may be due to the presence of sulphone group as a hinge group in the backbone structure. The composites prepared from amines carrying methylene (DDM) and oxygen (DDE) as a hinge group have the lowest shear strength. The composites based on BAPC and BAPP diamines, where the molecular weight of the amine is significantly higher [5], have shear strength in the intermediate range. The impact strength of the composites cured with BAPC and BAPP fall in the middle range while the composites cured with DDM and DDE have lowest value in the series.

Incorporation of epoxy fortifier to the resin-curing agent systems improves the mechanical properties of the systems[6]. Maximum improvement in flexural strength (61 to 74%), 22 to 33% improvement in interlaminar shear strength, 23 to 46% improvement in impact strength and 10 to 14% improvement in tensile strength are observed by the addition of 20 phr fortifier.

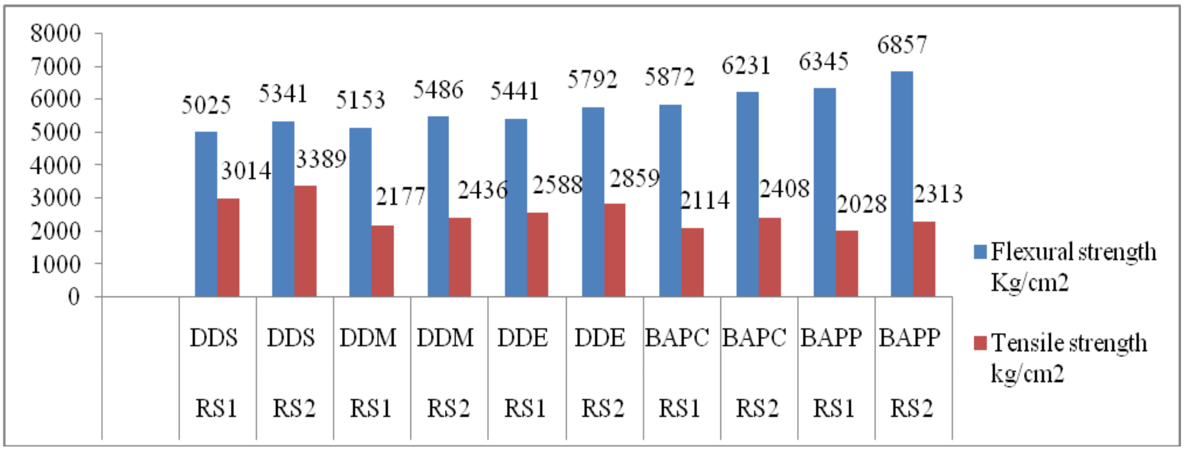

Figure 1: Comparative Data of Flexural Strength and Tensile Strength of Glass Fiber Reinforced Epoxy Blends

3.2 Dielectric Properties

The dielectric data for all the glass epoxy composites are given in TABLE 2. Examination of the data shows that dielectric properties of the composites depend on the chemical constituent of resin structure [7]. The polarity and rigidity of the polymer chain are also the important factors. The resistance column in TABLE 2 reveals that the composites possess good electrical insulation properties. Value of dielectric strength also supports this fact. The value of dielectric constant and tanδ are slightly higher for DDS cured system. The polarity due to SO_2 group in DDS may be responsible for this. Fortifier incorporated composites have higher value of electrical resistance while the value of dissipation factor is low. The lower value of dissipation factors are may be due to the free hydroxyl groups in fortifier [8]. Comparative data of dielectric strength and dielectric constant of the blends are shown in Fig.2.

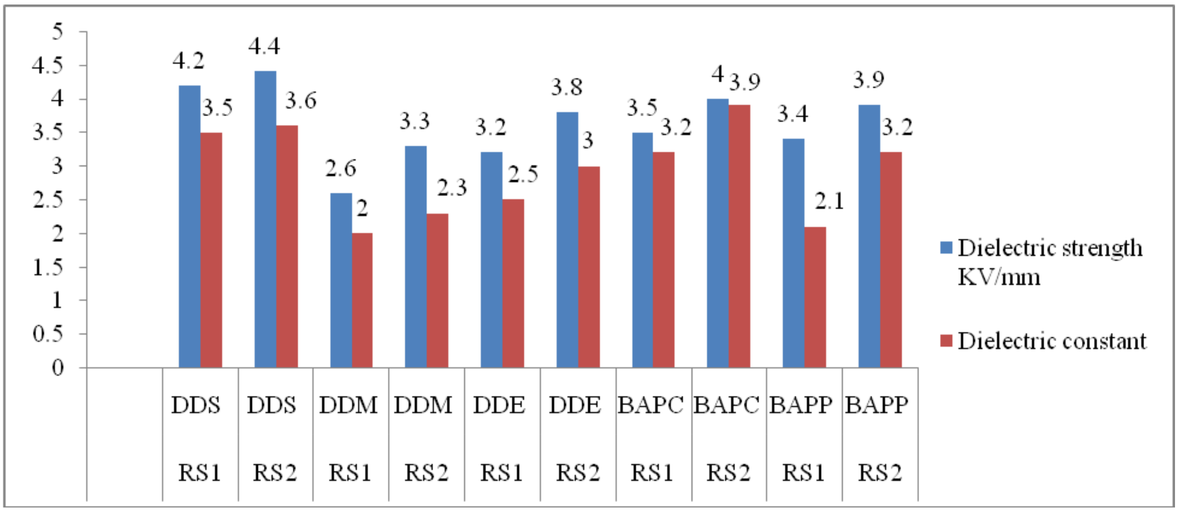

Figure 2: Comparative Data of Dielectric Strength and Dielectric Constant of Glass Fiber Reinforced Epoxy Blends

3.3 Dynamic Mechanical Analysis

The samples were cut from 3 plies composites and were used for DMA analysis at a heating rate 10˚C per min. in the temperature range 25 to 250˚C. The values of glass transition temperature (Tg) are listed in TABLE 2. Tg of the composite prepared using BAPC amine curing agent is highest in the series. Tg values decrease by incorporation of fortifier. Similar type of diminishing of Tg value was observed by McLean et al [9].

Table 2: Dielectric Properties and Glass Transition Temperature of Glass Fiber Reinforced Epoxy Blends

Resin Systems	Proportion	Resin systems	Curing agent	Resistance ohm $\times 10^{10}$	Dissipation factor $\tan\delta$	Glass transition temperature Tg (^{o}C)
DGEBA-TGBAPP	80:20	RS1	DDS	39	0.048	198
DGEBA-TGBAPP-PGEHA	80:20:20	RS2	DDS	48	0.04	182
DGEBA-TGBAPP	80:20	RS1	DDM	25	0.03	168
DGEBA-TGBAPP-PGEHA	80:20:20	RS2	DDM	38	0.023	156
DGEBA-TGBAPP	80:20	RS1	DDE	29	0.031	185
DGEBA-TGBAPP-PGEHA	80:20:20	RS2	DDE	35	0.028	174
DGEBA-TGBAPP	80:20	RS1	BAPC	49	0.041	205
DGEBA-TGBAPP-PGEHA	80:20:20	RS2	BAPC	56	0.038	190
DGEBA-TGBAPP	80:20	RS1	BAPP	44	0.038	200
DGEBA-TGBAPP-PGEHA	80:20:20	RS2	BAPP	59	0.036	190

IV. CONCLUSIONS

Use of multifunctional epoxy resin with DGEBA resin improves the mechanical properties of the composite. Incorporation of fortifier in the epoxy resin systems improves the mechanical properties in the range of 10 to 74%.

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