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Tensile, thermal properties & chemical resistance of epoxy/hybrid fibre composites (Glass/Jute) filled with silica powder

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ABSTRACT

The effect of dispersion, alkali treatment, resistance to chemicals and influence of silica powder on mechanical, thermal properties of hybrid fibre (i.e. jute/glass) composites were investigated as a function of silica loading. NaOH treatment of jute fibres was found to increase the interface between matrix and hybrid fibres. Thus, tensile strength was improved significantly up to 6 wt % silica content, decreases further increase in silica content beyond 6 wt %. Tensile modulus of hybrid composites was tremendously improved up to 15 wt. % silica content. Author proved hybrid composites are resistant to attack of all chemicals except Toluene. (DSC) & (TGA) were improved significantly the glass transition temperature and thermal stability of the treated hybrid fiber at various silica loadings.

KEYWORDS

Chemical resistance;
Hybrid composites;
Silica;
Tensile properties;
Thermal properties.

INTRODUCTION

In every automobile parts manufacturing industry, the glass/jute fibres are used because of their adaptability to different situations and the relative ease of combinations with other materials to serve specific purpose and exhibit desired properties. Ubiquitous plastics usages are inevitable in these days as it is versatile material that lends itself to many uses. The turn around in favor plastic happened not just because of color and durability for household products but also because plastics as an accessory became fashionable and trend setters. Thus this is the day of plastics (composites). As a matter of fact, aircrafts and cars are made of composites to lighten their weight. Glass fibre reinforced composites due to their high specific strength and specific stiffness have become attractive structural materials not only in weight sensitive aerospace industry, but also in marine, armor, automobile, railways, civil engineering structures, sports goods etc. Epoxy resin is the most commonly used polymer matrix with reinforcing fibres for advanced composites applications. They are being used widely as a matrix to hold the high performance fibre reinforcement together in composite materials, as well as a structural adhesive. Among all reinforcing fibres, natural fibres have gained substantial importance as reinforcements in polymer matrix composites. A lot of work has been done by many researchers asperents on these composites based on these fibres[1-4]. Hybrid composites are materials made by combining two or more different types of fibres in a common matrix. They offer a range of properties that cannot be obtained with a single kind of reinforcement. The glass and the jute fibres were combined in the same matrix to produce hybrid composites which impart distinctive properties that cannot be obtained with a single kind of reinforcement[5-12]. Therefore author's main focus is to fabricate advanced composite materials which can compatible with all possible industries. In this present work, tensile strength, tensile modulus, Differential Scanning Calorimetry (DSC) & Thermogavimetric Analysis (TGA) and chemical resistance of epoxy/silica/hybrid fiber (glass/jute) composites are studied to naturally judge the influence of silica powder.

MATERIALS AND METHODS

Materials

Commercially available epoxy resin (LY-556) and hardener (HY-951) are obtained by Huntsman. The weave glass fiber reel & jute fibres are obtained from Saint Gobain Industries Ltd., Bangalore.

Jute fibre treatment

The jute fibers were placed in a glass tray with a 5% NaOH solution and further it was added to the tray and allowed to soak in the solution for about 4 hours. The fibres were washed with water to remove the excess quantity of NaOH sticking to the fibres. Finally the fibers were washed with distilled water and dried in a hot oven at 60ºC for 1 h. The jute fibres were cut into 10mm length with a sharp scissors[3].

Synthesis of sample

The weave glass fibre reel & the jute fibre were taken about 9 vol. %, dismantled and cut with sharp scissors into 20mm and 10mm length respectively. A glass mould with required dimensions was used for making sample on par with ASTM standards and it was coated with mould releasing agent for easy separation of sample. Next the resin and hardener were taken in the ratio of 10:1 parts by weight respectively. First, Silica was mixed with stipulated quantity of resin based on the stoichiometric ratio thoroughly in a beaker for about 1hr at ambient temperature conditions. Pre-calculated amount of hardener is then mixed and stirred for another 30min with mixture prior to pouring in to the mould. Stacking of hybrid fiber was carefully arranged in the direction of perpendicular to the resin flow after pouring some amount of resin into the mould to keep the poor impregnation at bay. Rest of the mixture was poured onto the hybrid fiber glass mould. Brush and roller were used to impregnate fiber. Left it for about

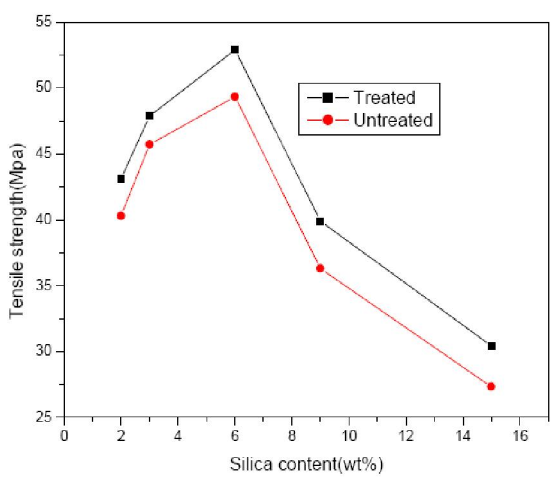

Figure 1 : Tensile strength of untreated and treated epoxy based jute/glass hybrid composites as a function of silica powder

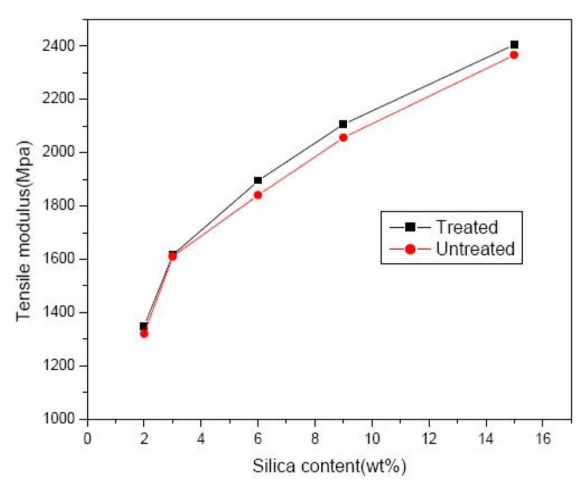

Figure 2 : Tensile modulus of untreated and treated epoxy based jute/glass hybrid composites as a function of silica powder

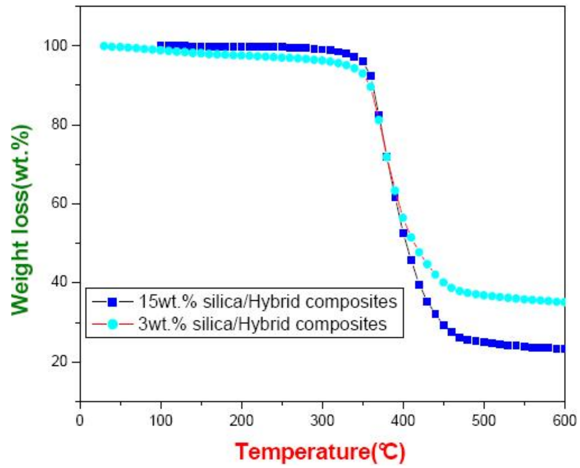

Figure 3 : TGA curves of the samples at different positions in a hybrid composite sheet containing (a) 3wt.% silica + HF(treated) (b) 15wt.% silica + HF(treated)

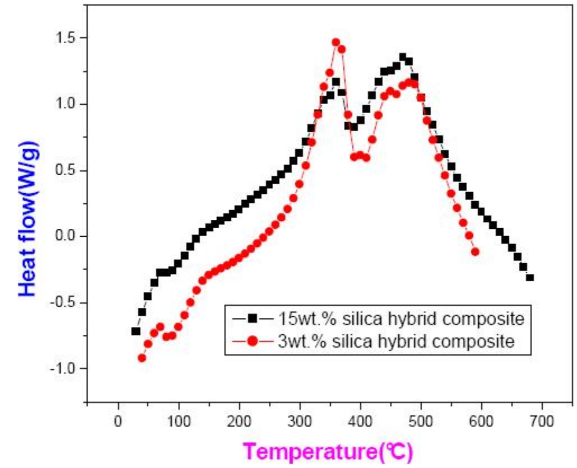

Figure 4 : DSC curves of the samples at different positions in a hybrid composite sheet containing (a) 3wt.% silica + HF (treated) (b) 15wt.% silica + HF (treated)

one day at ambient temperature and later cured in hot oven for 1hr at 80ºC. Last but not the least; removed samples are cut in accordance with ASTM standards.

Tensile load measurement

Tensile strength was studied using Instron Universal Testing Machine supplied by Instron Corporation; series-9 automated testing machine was used with across head speed of 5mm/min. Testing samples were prepared like dumbbell shapes and these dimensions are $(100\times20\times3)$ mm^3 based on the ASTM D 638 standards. Testing was carried out on an average of five samples for each case to meet the accuracy.

Chemical resistance test

ASTM G 543-87[13] was used to study the chemical resistance tests of the composites. The effects of acids, alkalis and solvents, i.e., glacial acetic acid, nitric acid, hydrochloric acid, ammonium hydroxide, aqueous sodium carbonate, aqueous sodium hydroxide, carbon tetrachloride, benzene, and toluene were used on the matrix and hybrid composites were studied. In each case, the samples $(10\times10\times3)$ mm^3 were pre-weighed in a precision electrical balance and dipped in the respective chemical reagents for 24 hrs. They were then removed and immediately washed in distilled water and dried by pressing them on both sides with a filter paper at room temperature[8].

Thermal analysis

The thermal characteristics of the epoxy/clay binary composites were measured using both differential Scanning Calorimetry (DSC-2010 TA Instrument) and thermogravimetric Analyses (TGA) at a rate of 10°C/min under nitrogen flow.

RESULTS AND DISCUSSIONS

Authors were fabricated & tested treated and untreated hybrid composites as a function of silica loading. While testing, a sudden pinging noise was observed when individual filament broke or inter-layer delaminated during the specimen is breaking at maximum load. Fibres breakages, interface debonding, and layer delamination all was observed for silica filled epoxy hybrid composites. As depicted from the TABLE 1, tensile strength increases when silica content increased up to 6 wt %, decreases further increase in silica content up to 15 wt %. Tensile strength was optimally increased at 6 wt %. Tensile strength was increased by 10.55% when compared over 3% silica content for treated hybrid composite. Sudden decrease in tensile strength is due to increased in viscosity of matrix may demobilize the crosslink between the matrix and the hybrid fibres. As a result increase in inertia of matrix will left air bubbles with in the matrix, there by crack initiation come in, will lead ultimately decreased in tensile strength. It was observed that strength was considerably decreased for untreated hybrid composites when compared with treated hybrid composites, as the treatment with alkali leaves out hemicellulose and luster as a

TABLE 1 : Tensile strength & tensile modulus of untreated and treated epoxy based jute/glass hybrid composites as a function of silica powder

Silica	Tensile strength (Mpa)		Tensile modulus (Mpa)	
	Treated	Untreated	Treated	Untreated
Content (wt %)	Composites			
2	43.11	40.30	1347.80	1319.30
3	47.85	45.71	1615.62	1609.23
6	52.90	49.33	1895.00	1840.68
9	39.89	36.29	2106.55	2055.90
15	30.40	27.33	2403.77	2366.20

TABLE 2 : Chemical resistance of epoxy based untreated and treated hybrid fiber composites

Chemical	Treated	Untreated
Hydrochloric acid	+0.873	+0.985
Acetic acid	+0.241	+0.249
Nitric acid	+1.678	+1.879
Sodium hydroxide	+0.568	+0.714
Sodium carbonate	+0.245	+0.557
Ammonium hydroxide	+0.765	+0.321
Benzene	+10.426	+11.235
Toluene	-4.810	-6.879
Carbon tetrachloride	+2.145	+3.458
Distilled water	+1.023	+1.548

result interfacial bond between matrix and the fibre destroys. Linearly increase in tensile strength for treated & untreated hybrid composites were shown in figure 1.

On the other hand, tensile modulus was increased when silica content is increased up to 15 wt %. Tensile modulus was optimally increased at 15 wt % silica content shown in the TABLE 1. Tensile modulus was improved by 48.78% when compared over the 3% silica loadings of treated hybrid composites. This is caused due to poor interface between matrix and the fibres were due to the less quantity of resin present in the sample due to increase quantity of fillers. It was observed that modulus was considerably decreased for untreated hybrid composites when compared with treated hybrid composites. It is observed that, viscosity of composite matrix was proportionally increases with increase in silica content as a result interface between the fiber & matrix was reduced with further addition of silica loadings. Authors were attributed that, micro voids might form due to improper curing. Linearly increase in tensile modulus for treated & untreated hybrid composites were shown in figure 2. Experimental results in the TABLE 2 shows the weight gain (+) of weight loss (-) experimental results of the neat epoxy and hybrid composites as a function of silica when the matrix and hybrid composites were immersed in acids, alkalis, and solvents. From the results it is clearly evident that weight gain is observed almost all the chemical reagents except toluene. The reason is attack of toluene atoms on the cross-linked epoxy. This positive value indicates that the composite materials were swollen with gel formation rather than dissolving in chemical reagents. It is further observed from the results that the composite under the study are also resistant to water. This chemical resistance study clearly indicates that the silica/epoxy hybrid composites are strongly resistance to all most all chemical except toluene. The above results were suggested that these hybrid composites can be used for making water and chemical storage tanks. Based on the experimental results of epoxy modified hybrid composites prepared by loading silica powder by weight is 3, 6, 9, 15 wt. %. TGA analysis was carried out to estimate the amount of resin present in the neat and hybrid composite and their thermal stability. Neat epoxy matrix also fabricated for thermal analysis but absent for tensile testing and chemical resistance. Figure 3 shows the weight loss curves of various hybrid composite materials and the epoxy resin with temperature. It is clear that the decomposition temperature of the composite shifted towards the higher temperature. The derivative weight loss shows only one peak. The decomposition temperature is 352°C for polymer, and 353°C for 3wt. % silica loading treated hybrid composite where as 354°C for treated hybrid composite with 6wt. % silica loading. It is clear that the decomposition temperature of the composite is shifting towards higher temperature indicating higher thermal stability of the polymer with silica loading. The existence of inorganic materials present in the polymer matrix, generally enhance thermal stability of the composite. In the present case also, the thermal stability increases due to presence of inorganic phase and its interaction with the polymer. The weight loss v_s temperature curves shows that the residue left after 450°C is in line with the silica content of each sample. Thermal transition of the pure polymer and the treated hybrid composites were also investigated by DSC. A typical thermogram for neat epoxy with two different silica loadings is shown in the figure 4. The glass transition temperature (T_g) of neat epoxy matrix is observed at a temperature of 357°C in all cases, while the T_g of the epoxy matrix is not so evident. However, with silica loading the T_g values do not shift. An endothermic peak at 450°C is observed for pure epoxy.

CONCLUSIONS

Experimental results of epoxy modified hybrid composites prepared by loading silica powder by weight is 3, 6, 9, 15 wt. % along with neat epoxy matrix. Tensile strength was optimally increased at 6 wt %. Tensile strength was increased by 10.55% when compared over 3% silica content for treated hybrid composite. Tensile modulus was improved by 48.78% when compared over the 3% silica loadings of treated hybrid composites. Thermal stability and glass transition temperature were also increased significantly when compared over the neat epoxy. Chemical resistance was also proved to be significant when subjected to different chemical except Toluene.

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