An Experimental Studies on the Polymer Hybrid Composites—Effect of Fibers on Characterization

M. Ashok Kumar, K. Mallikarjuna, P. V. Sanjeev Kumar and P. Hari Sankar

Abstract The present research focused on the polymer hybrid composite fabrication and its characterization. Kevlar fibers (also called Aramid fibers, KF) are mixed with Sansevieria trifasciata fiber (snake plant leaf fibers, STF) to improve the performance of the epoxy matrix. Former fiber is synthetic fiber and the later is natural fibers are combined proportionately by the rule of mixtures KF and STF treated fiber systems. Wet-hand layup was used to organize systems with weight ratios of KF/STF for treated, viz. 1:0; 0.5:0.5; 0.75:0.25; 0.25:0.75; 0:1 (typically named as A, B, C, D, and E systems from the left). It was found that tensile strength for system-D (treated) was found improvement due to the fact that dust-free, rough, and improved surface area. Impact strength was found significant for the system-D when compared with others. The interface and voids at the fracture surface were improved for the systems C and D which were observed from the SEM images. Chemical resistance found good all the samples except carbon tetrachloride due to the hit of carbon atoms which consequently imparted erosion of the fiber out of the matrix.

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1 Introduction

Polymers are taking their lead in all fields due to their unique properties. The lighter the weight of the product not only save material, but also improves fuel economy. For example, 10% of the vehicle weight shrinks, and then a corresponding ratio of fuel is saved. These materials demand lightweight and strength are the two parameters that are essential. Polymers/fibers are the very light metal ($\rho = 1 - 1.5$ g/cm^3) probably comes out lightweight composite at the end. According to the stress, strain diagram slope of the curve increases strength, stiffness increases on other hand, and toughness decreases due to the decrease in ductile nature. Fiber-reinforced composites have drawn more attention as there are used for weight reduction applications due to their excellent strength and stiffness which comes with less weight.

Natural fibers are used as reinforcing agents over the years and more recently these have used with synthetic fiber in order to improve specific properties that cannot be obtained from the individual fibers. These fibers have renewable, nice appeal, less density, high specific volume, biodegradability less cost, etc., is made them to versatile candidates for specific application. So far flax, hemp, jute, straw, wood fiber, rice husks, wheat, barley, oats, rye, cane (sugar and bamboo), grass reeds, kenaf, ramie, oil palm empty fruit bunch, sisal, coir, water hyacinth, pennywort, kapok, paper-mulberry, raphia, banana fiber, pineapple leaf fiber, and papyrus. Manufacturers are paying attention in incorporating natural fiber composites into both internal as well as external parts of the transportation vehicles. This serves two-fold goal of the companies to lower the overall weight of the vehicle, thus, ever-increasing fuel efficiency in addition to increase the sustainability of the mechanized process. Mercedes Benz, Toyota, and Daimler Chrysler are already started and looking to expand [1–8]. The advantage of these fibers can cost as less as $0.5/kg, whereas synthetic fibers cost $2.50/kg and their densities (1.15 – 1.50 g/cm^3) are coming with even lesser than the synthetic fibers. Strength and stiffness are not high when compared with synthetic fibers. Kevlar fiber is a temperature resistance, high rigidity modulus, high young's modulus, and strong synthetic fiber and it was commercially used as a replacement of steel in racing tires. These fibers are used for a lot of applications, ranging from bicycle tires and racing sails to bulletproof vests; due to their high tensile strength to weight ratio by this way, it is five times stronger than steel [9]. It is also used modern marching drumheads that withstand high impact loads. Having a higher weight of the Kevlar fibers made them to be balanced with the natural fiber which has less weight imparts them more surface area consequently corresponding bonding strength is the indication of the inbuilt mechanical strength in the composites. Therefore, Sansevieria trifasciata is chosen as reinforcement as it is very compatible. Current research is focused on the epoxy as matrix, STF/KF as a reinforcing hybrid fiber is chosen to fabricate the polymer hybrid composites and followed by tensile strength, impact strength, DSC, TGA, and SEM measurements evaluated to assess the material to suit specific applications.

2 Materials and Methods

Epoxy, hardener, Kevlar fibers, and all the chemicals were employed form the Sriram composites from the Hyderabad. STF stuff was received from the formers from Enumuladoddi village, Anantapur district, Andhra Pradesh, India. Glass molds were prepared as per the ASTM standards. Then, finally, composites specimen cut with the help of cutter on par with the standards. Dumbbell shape specimens have been cut to test the tensile strength by using the UTM. Tensile strength test specimens (100 × 20 × 3 mm, ASTM D638) and impact strength test specimens (63.5 × 12.7 × 12.7 mm; ASTM D256) are prepared, respectively, on par with standards. DSC and TGA measurements were observed to check glass transition temperature and thermal stability of the composites. The following chemicals were taken to check the chemical resistance acids: hydrochloric acid (HCl) (10%), acetic acid (CH_3COOH) (5%), nitric acid (HNO_3) (40%); alkalis: sodium hydroxide (NaOH) (10%), sodium carbonate (Na_2CO_3) (20%), ammonium hydroxide (NH_4OH) (10%); solvents: benzene, toluene, carbon tetrachloride (CCl_4), and distilled water (H_2O). Specimens were weighed before and after soaking in the predetermined chemicals. Then, allowed 24 h to soak and removed from the chemical and then weights are measured again. The difference in weights is used to calculate the percentage of weight loss or gain. Fractured surfaces were evaluated by SEM images to evaluate reasons for the decrease or increase in the performance based on the voids, interface, and pull-outs theories observed from the literatures. STF fibers were extracted from the natural retting process in which corresponding plant leaves were soaked in the running water for about 1 month. Then, beated with the help of stick for several numbers of times until all the cellulose and lignin substances come out of the fibers and followed by through washed out with distilled water. This is so-called untreated natural fiber. Untreated fibers are dipped in the NaOH solution to get rid of foreign substances and this is so-called treated fiber.

2.1 Fabrication of Composites

At the outset, the mold surface was coated with mold releasing agent. Continuous fibers of STF (treated) and KF are employed to fabricate the composites. Epoxy and hardener were taken in predetermined quantities such as 10:1 ratio, respectively. Polymers and chemical agents mentioned above are mixed with the help of spatula for about 10 min. Catalyzed resin of 25% spread all over the mold with the help of brush and rollers to ensure wetting at the interstices of the fiber. Then, the layer of KF was stacked and then 25% of the resin is again poured on the KF and makes sure all the fiber ought to be wet and resin has to be spread with roller all over the mold. By doing so, voids could be reduced considerably. Then, another layer of the STF was stacked and followed by remaining resin is poured and spread all over the surface with roller. Then remaining resin poured all over the mold and spread the resin with

Table 1 Different treated polymer composite systems

Composite system	KF (wt%)	STF (wt%)
A	100	0
B	50	50
C	75	25
D	25	75
E	0	100

the help of brush and roller once again. Finally, allow the mold covered with OHP sheet and make sure to pull the roller all over again mold gently. Then the mold is loaded with some weight and make sure without spoiling the uniform thickness of the mold. Then allow the mold to cure for 1 day. In order to remove the composites with ease, post-cured casting is placed in the oven for 45 min at 100 °C. The same procedure was used for the remaining composites (refer Table 1).

3 Results and Discussions

In the present study, ASTM G543-87 is used to prepare samples to measure the chemical resistance of the treated samples. The consequence of some acids such as glacial acetic acid, nitric acid, hydrochloric acid, alkalis are ammonium hydroxide, aqueous sodium carbonate, aqueous sodium ammonium hydroxide, and solvents are carbon tetrachloride, benzene, distilled water, and toluene, respectively, were used (refer Tables 1 and 2).

Table 3 shows the mechanical characterizations that are carried out for different samples and found three reasons. Firstly, tensile strength was found maximum for sample 'D' and it was attributed that high specific volume of STF imparts corresponding improvements in the surface area. Consequently, high surface area means high

Table 2 Measurements of chemical resistance of the treated KF/STF composites

Name of the chemical	wt% gain(+)/loss(−) for composites
Hydrochloric acid	+0.875
Acetic acid	+0.230
Nitric acid	+1.523
Sodium hydroxide	+0.530
Sodium carbonate	+0.234
Benzene	+5.632
Ammonium hydroxide	+0.702
Toluene	+3.253
Carbon tetrachloride	−0.253
Distilled water	+1.036

Table 3 Results of mechanical measurements as a function of specimens

Specimen name	Tensile strength (MPa)	Tensile modulus (GPa)	Impact strength (J/m^2)
A	25.10	0.30	15.20
B	38.44	0.38	13.74
C	39.48	0.39	13.08
D	42.65	0.45	16.43
E	20.63	0.28	9.35

bonding strength. Second reason was treated STF surfaces free from dust, cellulose, and lignin materials which ultimately improves the performance. Lastly, interface between the fiber and matrix was also found significant from the epoxy and KF/STF standpoint (refer Fig. 1). Tensile modulus is also increased for all the samples which is due to the increase in natural fiber content which has paid bonding strength than the other fiber. Impact strength was decreased for specimens B and C when compared to A on the other hand specimen-D has got highest impact strength which is due to the improved STF fiber volume. Tensile modulus and impact strength were found maximum for the sample D when compared with other specimens (refer Table 3). Figures 1 and 2 show the graph which indicates the optimization of tensile strength, tensile modulus, and impact strength as a function of sample.

In Fig. 1, tensile strength and tensile modulus were optimized for except specimen-D and remaining samples have registered less due to the poor interface and voids. Poor interface and voids result in crack initiation at early loadings therefore failure takes place. In Fig. 2, impact strength was improved for the same specimen-D due to the high specific volume of the STF makes more volume of the fiber, furthermore, treated STF sticks well with the matrix due to rough surface might be the reason.

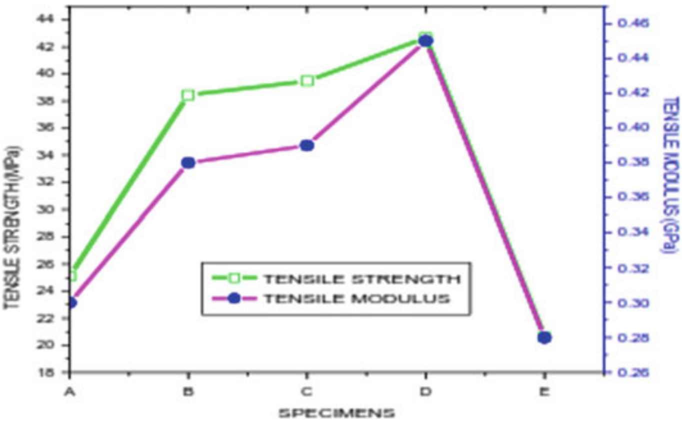

Fig. 1 Tensile strength and tensile modulus measurements of the specimens

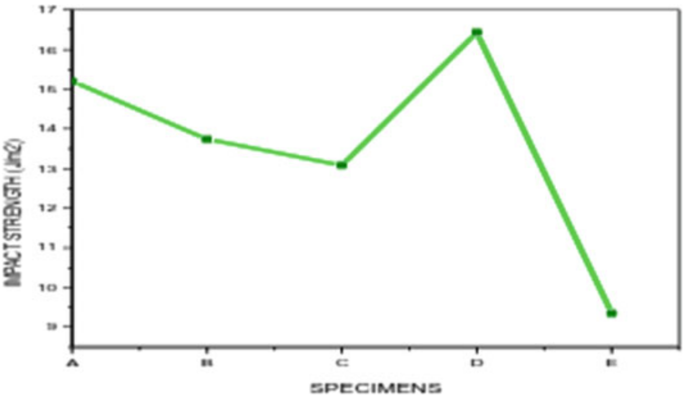

Fig. 2 Impact strength measurements of the polymer hybrid composite specimens

Figure 3 shows the SEM images of the cross-sectional areas of the hybrid composites are discussed as mentioned below. Figure 3a shows the fibers of both natural

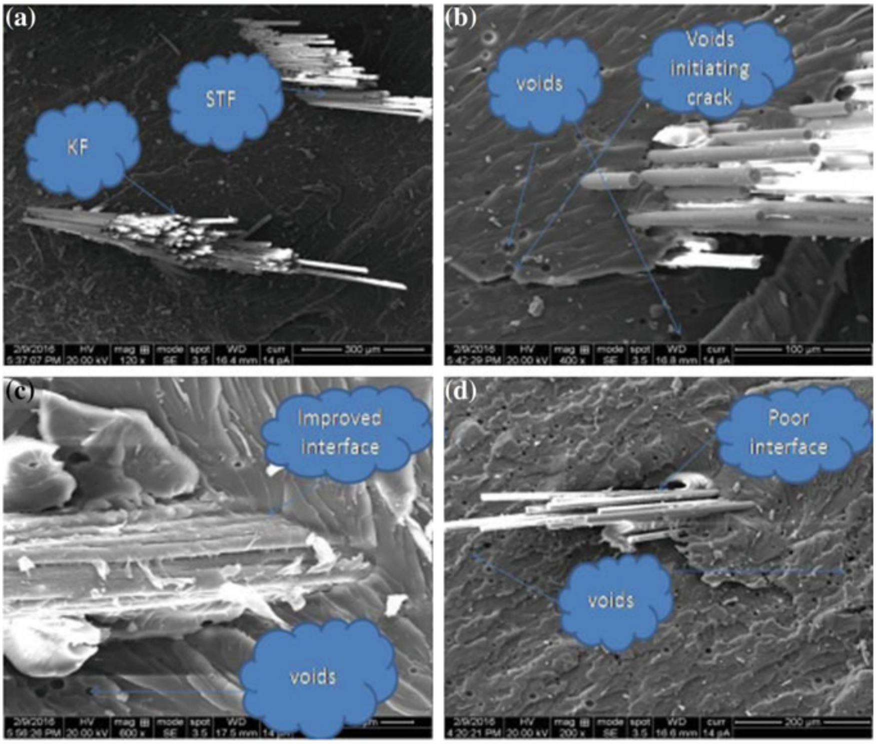

Fig. 3 SEM images for specimens KF/STF **a** 50/50 **b** 75/25 **c**25/75 **d** 0/100, respectively

and synthetic fibers. This image is also depicted some voids that might be the reason for reduced performance. Poor interface might be the one reason for decreased performance, and another reason is pulled outs which are not seen in the image. Natural fiber strand was not coated resin properly due to that fiber pull-out has been observed in the same image [2]. Figure 3b shows that image was not turned to ductile nature due to decrease in natural fiber content. In Fig. 3c, the natural fiber weight ratio has been increased as a result of that brittle nature comes down significantly when compared with the 75/25(KF/STF) composites. Improved interface and void were reduced significantly better when compared with the others. The last image of Fig. 3d shows that the fiber pull-outs and voids observed [5, 6].

4 Conclusion

This paper was dealt with the preparation of polymer hybrid composites and its characterization, viz. chemical resistance, tensile strength, tensile modulus, impact strength, and morphology studies. For specimen-D, tensile strength increased by 70% when compared with specimen-A. Tensile modulus, impact strength was increased up to 50, 8% for the specimen-D, respectively, when compared with specimen-A. In scanning electron microscope analysis, we noticed interface, treatment of the fiber surfaces, pull-outs, and voids were played a significant role in finalizing the performance of the composites. Specimen-D has higher improvement of strengths when compared with the other specimens. Therefore, these composites with specific ratios can be used for the fuel tanks, structural purpose, aero-plane fuselages, and wings.

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