Synthesis and Characterization of Short *Saccharum Cilliare* Fibre Reinforced Polymer Composites

A.S. SINGHA* and VIJAY KUMAR THAKUR

Applied Chemistry Research Laboratory
Department of Chemistry
National Institute of Technology Hamirpur – 177005
Himachal Pradesh, India.
assingha@gmail.com

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Abstract: This paper deals with the synthesis of short *Saccharum Cilliare* fibre (SC) reinforced Urea-Formaldehyde (UF) matrix based polymer composites. Present work reveals that mechanical properties such as: tensile strength, compressive strength, flexural strength and wear resistance of the UF matrix increase up to 30% fibre loading (in terms of weight) and then decreases for higher loading when fibers are incorporated into the matrix polymer. Morphological and Thermal studies of the matrix, fibre and short fibre reinforced (SF-Rnf) green composites have also been carried out. The results obtained emphasize the applications of these fibres, as potential reinforcing materials in bio based composites.

Keywords: Composite materials; Bio fibers, Reinforcement, and Mechanical properties.

Introduction

The increasing environmental perception throughout the sphere has enforced the researchers from a variety of fields to produce new polymeric materials and processes that improve the ecological quality of a number of products¹⁻⁴. These fibers are cheap as they come from renewable natural sources. As a substitute to the use of conventional reinforcing synthetic fibres, raw bio fibrous materials are being inserted in polymer matrices as a strengthening component for inventive products for plenty of applications⁵⁻⁸. Compression molding is one of the suitable techniques to process bio fibre reinforced polymeric material^{3-4,6}. The properties of bio fibres mainly depend on the source, age and separating techniques of the fibre⁹⁻¹². These properties generally vary from plant to plant according to climatic conditions *etc.*

Saccharum Cilliare fibers have high potential as a reinforcing material in polymer composites. Traditionally this fibrous material belonging to Himalayan region is being used by the local people for making low cost articles like socks, boots, mats, ropes, bags *etc.* The literature review has revealed that a very little work has been done on finding the application of this fiber as reinforcing material in the polymer composites¹⁻⁴. Keeping in view the easy availability, abundance and to make the best utilization of this raw natural fibrous material for better end uses we have made an effort to use this fiber as reinforcing material for the synthesis of Urea-formaldehyde (U-F) matrix based Polymer composites.

Experimental Procedure

Materials and Methods

Polymeric *Urea -Formaldehyde* resin was synthesized by the standard method developed in our material science laboratory^{3,4}. *Saccharum Cilliare* fibers of dimension (3mm) after proper purification and drying were thoroughly mixed with UF resin by different fiber loadings (10, 20, 30 and 40%) in terms of weight. Composite sheets of size 150 mm x 150 mm x 5.0 mm were prepared by compression molding technique described somewhere else^{3,4}. Compression molding was performed in a hot press using a mold preheated to 50°C. Composite sheets were prepared by hot pressing the mold at 130°C for 30 min. The pressure applied ranges from 3-4 MPa depending on the loading of reinforcing material. All the specimens were then post cured at 130°C for 12h.

Test methods

Tensile, compressive and flexural strength tests were performed on Computerized Universal Testing Machine (HOUNSFIELD H25KS). Tensile test was conducted in accordance with ASTM D 3039 method. The specimens of dimension 100 × 10 × 5 mm were used for analysis. Compression strength test was conducted in accordance with ASTM D 3410 method. The three point bend flexural test was conducted in accordance with ASTM D 790 method. The wear test of the sample was conducted as per ASTM D 3702 method on Wear & Friction Monitor (DUCOM- TR-20L). Weights of the samples were taken on Shimadzu make electronic balance (LIBROR AEG- 220), curing of samples was done on compression molding machine (SANTECH INDIA Ltd) thermal studies were carried out on Thermal Analyzer (Perkin Elmer) and SEM micrographs were taken on (LEO 435VP).

Results and Discussion

Mechanism and optimization of urea – formaldehyde resin

UF resin was synthesized by the standard method developed in our laboratory, reported somewhere else^{3,4}. Chemical reaction is supposed to take place in two steps³. Suitable conditions of temperature, acidity of the medium and pH are maintained while carrying out the reaction as reported earlier³. At the required level, reaction is arrested by neutralization (pH 7.5-8). The condensation is closely watched and controlled at the stages of production because if the reaction is allowed to continue, cross linking leads to the gelatization of the resin. Optimization of urea – formaldehyde resin has been done by evaluating optimal mechanical properties such as tensile strength, compressive strength and wear resistance *etc* as reported earlier^{3,4}. It has been found that urea-formaldehyde resin in the ratio 1.0: 2.5 exhibits optimum mechanical properties, so this ratio was taken for further preparation of polymer composites.

Mechanical properties of U-F polymer matrix based composites

It has been observed that tensile strength of composites increases on reinforcement with *Saccharum Cilliare* fiber. Composites with 30% wt. loading bear maximum load followed by 40, 20, and 10% loadings (Figure 1 A). It has been observed that polymer composite with 30% loading bear a load of 384.0 N, 40% bear a load of 335.0 N, 20% bear a load of 271.5 N and 10 % bear a load of 221.8 N. In case of compressive strength test it is clear from the figure that composite with 30% loading bear a load of 2675.0 N, 40% bear a load of 2397.0 N, 20% bear a load of 2110.1 N and 10% bear a load of 1745.8 N respectively. Similar trends as obtained in tensile strength and compressive strength tests have been observed for flexural strength results. The flexural properties of samples as a function of force (in terms of load) and deflection are shown in Figure 1 C. It is clear from the figure that composite with 30% loading bear a load of 167.0 N, 40% bear a load of 137.0 N, 20% bear a load of 109.0 N and 10% bear a load of 89.0 N. As evident from (Figure 1D) that wear rate of UF matrix decreases appreciably as reinforcement with *Saccharum Cilliare* fiber. It was observed that particle reinforcement decreases the wear rate to a much more extent. Maximum wear resistance behaviour is shown by composite with 30% loading followed by 40, 20 & 10% loading. From these results it is clear that fiber reinforcement is most effective way for improving the mechanical properties of polymer composites. This may be due to larger surface area and more fiber/matrix interaction in case of natural fiber reinforced also the chemical bonding accounts for the adhesion between amino resin (urea formaldehyde) and the natural fibrous material. The higher bond strength obtained for amino resin matrix is due to the possible reaction between the methylol groups of the resin with the hydroxyl group of cellulose.

Figure 1. Load elongation/deformation/deflection & wear resistance curve of fiber reinforced composites (A, B, C, D).

Thermal and morphological analysis of UF resin and its biocomposites

Thermogravimetric analysis (TGA) of materials such as raw *Saccharum Cilliare* fiber, polymeric UF resin and biocomposites was investigated as a function of % weight loss with

the increase in temperature. The initial decomposition (IDT) temperature, final decomposition temperature (FDT) and differential thermal analysis of fiber, resin and biocomposite are presented in the Table 1. These results are consistent with results reported earlier². Morphological results obtained from SEM micrographs (Figure 2 A-D) clearly show that there is proper intimate mixing of fiber with the resin in the biocomposites synthesized.

Figure 2. SEM images of (A) UF resin (B) *Saccharum Cilliare* fiber (C, D, E& F) composite with 10, 20, 30 & 40% loadings.

Table 1. Thermo-gravimetric analysis of UF, SC and SF-Rnf UF composites

Sr. No.	Sample Code	IDT °C	% wt. loss	FDT °C	% wt. loss	Final Residue, %	Exothermic/Endothermic Peaks °C (μ V)
1	SC	214	13.45	473	66.34	33.56	328.0 (87) ; 432.0 (213)
2	U-F Resin	239	21.48	990	85.31	14.49	181 [6.4]; 255 [5.9]; 274 [28.1]; 547 [9.6] ; 727 [- 23.0]
3	SF-Rnf - UF	223	30.48	771	79.05	20.00	73[2.05] ;262[20]; 243[17]

Conclusions

The mechanical properties of *Saccharum Cilliare* fibers reinforced UF resin based composites have been found to be many times higher as compared to UF resin. These composites can be future materials for the fabrication of eco-friendly materials. These results suggest that these fibers have immense scope in the fabrication of natural fiber reinforced polymer composites having vast number of industrial applications.

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