INFLUENCE OF FIBER PRETREATMENT ON THE MECHANICAL PROPERTIES OF DHARBAI FIBER REINFORCED POLYESTER COMPOSITES

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A new variety of Dharbai fibers (botanical name: *Eragrostis cynosuroides*) used as reinforcement in polyester matrix composites were subjected to surface modifications using sodium hydroxide (NaOH) aqueous solution with a view to enhancing the mechanical properties of Dharbai fiber reinforced polyester composites. The fibers were treated with aqueous sodium hydroxide solution by varying the treatment parameters, namely solution concentration and soaking time of sodium hydroxide solution, and the composites were prepared using the compression moulding process. The mechanical properties of fabricated composites were tested as per ASTM standards. The effects of solution concentration and soaking time on tensile, flexural and impact strength of the Dharbai fiber reinforced polymer composites were studied and the best fiber treatment conditions for better mechanical properties were identified. The investigations confirmed that surface modification by removal of excess cellulose, lignin and alkali soluble particles from the fiber surface improved the fiber–matrix adhesion, which in turn exhibited better mechanical properties compared to those of untreated Dharbai fiber reinforced polyester composites.

Keywords: Dharbai fibers, fiber surface treatment, mechanical properties, scanning electron microscope

INTRODUCTION

Composite products have good mechanical properties per unit weight, are durable and their technologies allow the manufacture of complex and large shapes.[1] It has already been demonstrated that natural fibers, such as flax and sisal, can be successfully used as reinforcement in polymer composites in order to achieve reduction of weight and cost.[2-4] Satyanarayana *et al*. studied the reinforcing effect of coir fiber in the polyester matrix and observed that the composites have low density and high electrical resistance and are likely to be useful as electrical and acoustic insulators.[5] Morphological studies of natural fiber revealed that the outer sheath of lignin develops cellulose ultimates and the presence of excess cellulose and lignin content on the fiber surface results in poor compatibility between fiber and matrix, which restricts the mechanical properties of the composites.[6]

The removal of excess cellulose and lignin from the surface layer of fiber by means of alkali treatment enhances surface roughness and improves the mechanical interlocking at the fiber–matrix interface.[7,8] The use of alkali treated fiber as reinforcement results in significant increases in tensile strength, flexural strength and impact strength of composites.[9,10] This works is focused on improving the mechanical properties of Dharbai fiber reinforced polyester composites by pretreating the Dharbai fibers with sodium hydroxide alkali solutions.

EXPERIMENTAL

Materials and methods

Dharbai fibers (diameter of 0.116-0.145 mm; density of 1150 kg/m^3; mean breaking load of 5.17 N) extracted from Dharbai leaves through the retting process was used as reinforcing material. The unsaturated polyester resin was used as matrix material. The matrix material used in this study was selected based on the availability, cost and mechanical properties.[11,12] Cobalt octoate and methyl ethyl ketone peroxide (MEKP) were employed as accelerator and catalyst, respectively, to enhance the reaction rate and ensure uniform curing of the composite sheets.

The fibers extracted were subjected to chemical treatment using sodium hydroxide (NaOH) aqueous solution. The fibers were soaked in an alkali solution of varying concentration (2, 4, 6, 8, and 10%) for various periods of time (24, 48, 72, 96 and 120 h) as per the full factorial design shown in Table 1. The treated fibers were washed with dilute hydrochloric acid and distilled water to remove excess sodium hydroxide (NaOH) sticking to the fiber surface. The fibers were dried at room temperature for 24 h and used randomly as reinforcement in a polyester matrix system mixed with 2% of cobalt octoate and 3% of methyl ethyl ketone peroxide. The prepared prepregs were compressed by the upper and lower jaws of a compression moulding machine (Make: ACE, Model: 30 HBM) at a pressure and temperature of 2.6 MPa and 60 °C, respectively, for 45 minutes. After curing, the specimens were cut to required dimensions for tensile, flexural and impact testing as per ASTM D638-08, ASTM D790-07 and ASTM D256-06a standards, respectively. SEM study was carried out on the fractured specimen in order to characterize the failure in the composite specimen.

Mechanical testing

The tensile tests were conducted on the prepared composite samples using a computerized universal testing machine at a cross head speed of 5 mm/min at room temperature. The computerized universal testing machine was used to conduct three point flexural tests on the fabricated composite specimens. The specimens were placed on two supports having a span length of 50 mm between the supports. The speed of the jaws was set to 5 mm/min and the test was carried out at room temperature. The impact test was carried out on the fabricated composite specimens using a Pendulum type impact testing machine. The test specimens were supported as a vertical cantilever beam and broken by a single swing of a pendulum, striking the face of the sample. To obtain a statistically significant result for each condition, five specimens were tested to evaluate the average value of tensile, flexural and impact strength of the composites.

RESULTS AND DISCUSSION

Effect of soaking time and NaOH solution concentration on the composites

The influence of NaOH treatment parameters, namely solution concentration and soaking time, on tensile strength, flexural strength and impact strength of Dharbai fiber reinforced composites is shown in Figures 1, 2 and 3, respectively. The tensile and impact strengths of the composites increased when the soaking time was increased gradually form 24 hours to 72 hours, and an adverse effect was observed when the soaking time in NaOH solution was increased beyond 72 hours. The tensile and flexural strengths of the composites were found to increase when the solution concentration was increased gradually form 2% to 6%, and an adverse effect was observed when the solution concentration of NaOH was increased beyond 6%. The best value of impact strength was obtained with the fiber treated in 4% aqueous NaOH solution for 72 hours. Similarly, flexural strength was found to be the highest with the fiber soaked in 6% solution concentration for 48 hours.

Table 1
Selection of parameters and levels

SI No	Levels	Solution concentration (%)	Soaking time (h)
01	Level 1	2	24
02	Level 2	4	48
03	Level 3	6	72
04	Level 4	8	96
05	Level 5	10	120

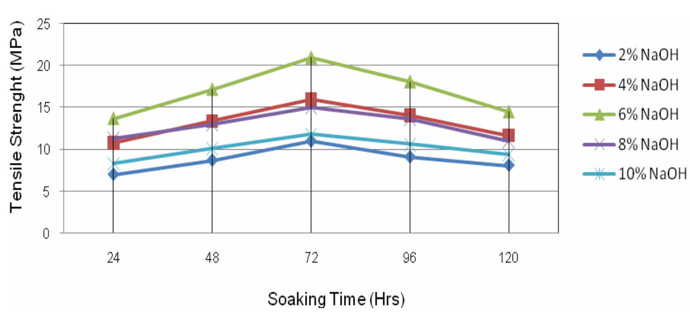

Figure 1: Effect of treatment parameters on the tensile strength of the composites

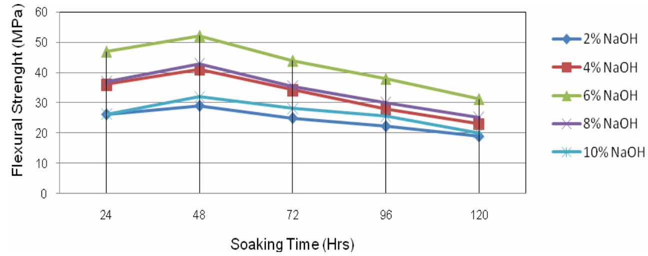

Figure 2: Effect of treatment parameters on the flexural strength of the composites

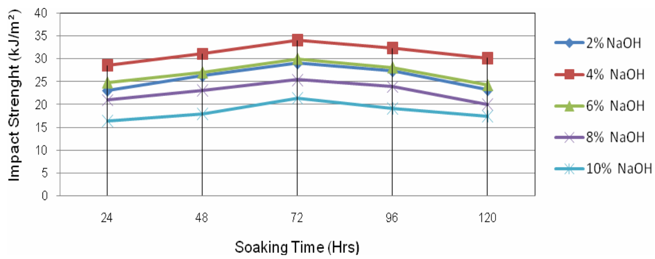

Figure 3: Effect of treatment parameters on the impact strength of the composites

Figure 4: SEM image of tensile fractured specimen

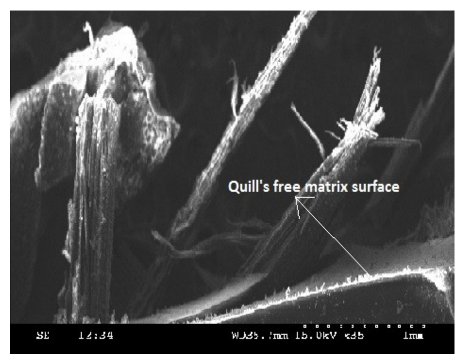

Figure 5: SEM image of flexural fractured specimen

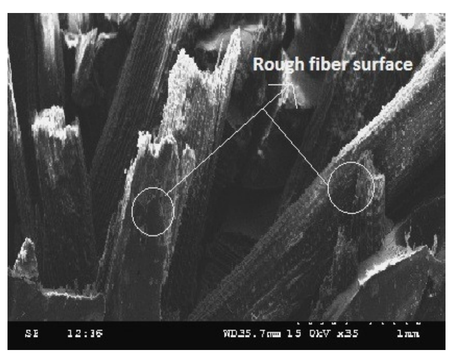

Figure 6: SEM image of impact fractured specimen

SEM study on the fractured composite specimen

Figures 4, 5 and 6 present the SEM images of pretreated Dharbai fiber reinforced composites after tensile, flexural and impact fractures, respectively. The SEM image of tensile fractured surface revealed the adhesion between fiber and matrix. This improved adhesion is due to the removal of the excess cellulose and lignin content present over the hydrophilic fiber surface by means of alkali treatment of Dharbai fibers. The quill's free surface visible in the fractured region of the specimen subjected to the flexural test is due to better inter-laminar bonding between the matrix and reinforcement caused by the removal of the excess wax and ash content present on the fiber surface. The rough surface found around the alkali treated fiber contributed to better stress transformation between the matrix and fiber, which in turn resulted in better absorption of impact energy through uniform fiber breakage.

CONCLUSION

From the experimental results obtained, it can be concluded that the fiber solution concentration and soaking time in aqueous NaOH solution play a significant role in improving the mechanical properties of Dharbai fiber reinforced polyester composites. The removal of lignin, cellulose and alkali soluble impurities from the fiber surface by NaOH treatment made the fibre soft, adhering easily to the polymer matrix. The randomly oriented treated Dharbai fiber reinforced polyester composites exhibited better values of the tensile, flexural and impact strengths, of 21 MPa, 52.2 MPa and 34 kJ/m^2, respectively, which resulted in 23.5%, 21.3% and 17.2% increases in tensile, flexural and impact strengths, respectively, compared to the values obtained for untreated Dharbai fiber reinforced polyester composites.

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