Experimental Investigation of Mechanical and Tribological properties of Bamboo reinforced polymer composites

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Abstract - An investigation was carried out use of light weight bamboo natural fibre. The development and characterization of natural fiber based polymer composites consist of Bamboo fibre reinforced with epoxy resin composites , it was fabricated with different volume fraction (20, 30 and 40%) and different type of orientation like angle (0°, 45°, 90°, 45°, and 0°) to build up the layer. These composites were evaluated for tensile, hardeness, wear and friction properties are compared with those of established different volume fraction composites. It has been observed that the 40% fiber volume with multidirectional composites shows superior strength,higher hardness and good wear resistantanc which has been evaluated by experiment design (L9) taguchi technique was used by this method S/N ratio measurement and a new liner trend equation for composite also developed from test result, which was found that the mean calculated for the test runs shows the less mean specific wear rate..

Keywords – Bamboo, Composites, Epoxy.

I. Introduction

Composite materials consist of two or more constituents with physically separable phases. Composites are materials that comprise strong load carrying material, reinforcement imbedded in weaker material (matrix). Reinforcement provides strength and rigidity to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement.

In our Day to day life fibre reinforced composites instead of many conventional metals such as ferrous and non ferrous, Plastics for automobile and household applications. Extraction and use of these metals will create much environmental damage which in turn to utilize natural fibre composite materials provides improve tensile strength, hardness and wear resistance.

The study on bamboo fiber shows it can with stand high stress abrasive wear, the high stress wear anisotropy of bamboo depends on load and abrasive grit size, the high stress wear behaviour is affected by vascular bundle fiber orientation with respect to the abrading surface and abrasive particles size[1].The sample from higher growth heights was higher, although not to the same extent as has been observed in tests on smaller samples.Suggesting that assembling bamboo into larger structural sections reduces the influence of growth height of the original bamboo. The variation of ultimate strength increases with growth height. The results from this study show that the increase in variability more than counteracts the increase in strength from a design point of view.The elastic modulus is largest for the bamboo laminate sourced from the middle growth section. However, there is not a great deal of variation of elastic modulus with growth height. The steam explosion pre treatment was efficient in the solubilisation of hemi cellulose, but there was also a significant loss of cellulose.The alkaline treatment was harmful to fracture toughness of the bamboo fiber composites because in improving the interfacial adhesion it reduced the main energy absorption mechanisms namely, deboning and fiber pull-out. For the bamboo fiber composites the fracture toughness increased with the alkaline treatment. This behaviour was credited mainly to the fibrillation process, which seems to result from the severe conditions imposed during the treatment and was facilitated by the slow loading rate of the test [2]. It has been observed different fiber volume fraction and different orientation like unidirectional, bidirectional and random providing comparitively not better results.

This research focus onto explore the useful properties, by the development of bamboo fibre composites of ecological purpose (eco-composites) using bamboo fiber and epoxy resin of diffrent volume fraction and multidirection orientation to obtain low wear rate and high strength for the bushes applications for the replacement of plastic materials .

II. EXPERIMENTAL PROCEDURE

A. *Extraction of fiber –*

The bamboo fibre which have been extracted manullay exhibit improved fiber density properties compared to that of chemical treated fibre [3].The fibre which is extracted by thin layer of exodermis (bark) of the bamboo were removed by hand leaving only the hollow cylindrical portion of culm as shown in fig.1(a). The cylindrical culm was peeled in longitudinal direction to make strips of 0.5-1.5mm thick and 1075mm width which is soaked in water for three days at room temprature as ashown in fig.1(b).Then the bamboo fibres were selected under a 10 x NK vison microscope for diameters 30 and 60mm to ensure homogenous dispersion of fibres during fabrication process as depicted in fig.1(c). All extracted fibers had been post-cured in an oven for 5 h at 45˚C and at a humidity level of 80±10% to ensure proper drying of fibers and to enhance surface wettability of the fibers with the epoxy matrix [4]. The diameter of bamboo fiber 0.5-1mm and density of the bamboo fibers was determined to be about 910 kg/m^3.

Fig.1(a) Fig.1 (b)

Fig.1(c) Fig.1 (d)

Figure.1. Process of bamboo fibers - (a) bamboo cylindrical portion of culm,(b) strip soaked in to water , (c)Extract bamboo fibers, (d) bamboo mat

B. *Composite fabrication-*

The resin used for the current work was liquid Epoxy Resin (DER) 331 with density 1120 kg/m^3. The curing agent used was JOINTMINE 905-3S. A steel mould dimensions of 250*250 mm^2 was used for the purpose of fabricating the composite. The inner surface of the steel mould was sprayed with a thin layer of PVA. Prior to this, the resin mixed with hardener (50 wt %) and fiber of length 250 mm (4 wt %) were uniformly mixed with an manual stirrer and poured slowly into the mould. When the mould was completely filled with the mixture, a thin steel plate was placed on top of the mould's opening. A pressure of about 5 kPa was applied on the steel plate to ensure that the trapped air bubbles in the composite were completely forced out. With the pressure still being applied on the mould, the composite block was left to cure for 24 hour at room temperature (28±5 °C). For thoroughness in curing, the hardened composite was removed from the mould and post-cured in an oven at 60°C for an hour. The same procedures were repeated to fabricate the composite block for different multi directional volume fraction. However, compression technique was used for these multi directional orientations, Die size was 250 x 250 mm^2 in which the first layer (0°) of the composite material was obtained by pouring the liquid epoxy mixed with 50 wt% hardener into the mould followed by placement of bamboo fibers in form onto it.

A steel roller was used to even out the epoxy resin on the stacked bamboo fiber while releasing air bubbles from the mixture and ensuring homogenous dispersion of fibers throughout the fabrication process. Next second layer (45°) fiber orientation and liquid epoxy resin mixed with hardener a steel roller was used to even out the epoxy resin on bamboo fiber. Next third layer (90°) fiber orientation and liquid epoxy resin mixed with hardener a steel roller was used to even out the epoxy resin on bamboo fiber. Next forth layer (45°) fiber orientation and liquid epoxy resin mixed with hardener a steel roller was used to even out the epoxy resin on bamboo fiber. Next fifth layer (0°) fiber orientation and liquid epoxy resin mixed with hardener a steel roller was used to even out the epoxy resin on bamboo fiber. This composite maximum thickness of 10 mm was achieved by five layers of fiber with 4 wt% and 7 layers of epoxy resin. After that using compression in hydraulic machine, It was computed based on ASTM D2734 standard.

Composite plates are prepared with mixer of epoxy and Bamboo fiber. The weighted amounts of fiber were taken, and cleaned the dust from fiber. The epoxy resin act as a bonding material of the composite plate. Based on The rule of mixture the fiber and resin were mixed. Previously defined the best volume fraction 0.4 is mainly suites for composite material. The selected volume fraction of fiber and resin were mixing together based on rule of mixer. As like the, same procedure was followed for different length and volume fraction of fiber. The combination of fiber and resin made a composite plate. The fiber and resin mixer pour in to the prepared die with respect to the height of composite plate. The short hammer used for ramming the fiber and resin mixer in the die. The upper plate was placed on the die plate were used applied pressure on the mould. While fabrication of the composite plate high pressure applied on the upper plate After 24 hours, the composite plate was removed from die set.

Figure. 2.Fabricated Bamboo composites

III. RESULT AND DISCUSSION

A. *Tensile Test-*

The prepared composite plate were cut as per ASTM D638 and is tested with a universal testing Machine by clamping the specimens in the fixture of the tensometer. When the machine is switched ON, the stepper motor in the tensometer gradually applied the tensile load on the specimen.The strain gage which is connected in the tensometer, measured the displacement value.The specimen was cut in two pieces, after critical load applied on the specimen.The stress and strain observations are tabel1.

Figure. 3. Tensile Specimen as per ASTM standards

Table I: Tensile test results

S.no	% of Reinforcement	Breaking Stress N/mm^2	Yield Stress N/mm^2	Ultimate Stress N/mm^2	% of Elongation	Young's Modulus N/mm^2
1	**20**	**2.10**	**0.473**	**2.73**	**4.9**	**2.6**
2	**30**	**2.89**	**0.53**	**3.513**	**5.2**	**3.339**
3	**40**	**4.736**	**0.697**	**6.842**	**8.4**	**6.31**

B. Hardness Test -

The specimens were prepared as per ASTM D 785 standards for Rockwell-B hardness test, the specimen is of 25mm diameter and a length of 20mm.Fiber configuration and volume fraction are two important factors that affect the properties of the composite. In this test, the configuration is limited to multi directional fiber sequel to the length of the specimen. The hardness properties of the composites are studied by applying indentation load normal to fibers diameter and normal to fiber length. This is because hardness is a function of the relative fiber volume and modulus.

S.no	% of Reinforcement	Sample-1 RHN	Sample-2 RHN	Average RHN
1	**20**	**42**	**46**	**44**
2	**30**	**70**	**76**	**73**
3	**40**	**84**	**86**	**85**

C. WearTest

Experiments values of wear rate and coefficient of friction were calculated by signal to noise ratio for a given response using appropriate equation. The experimental results and calculated values were obtained based on the plan of experiment and then the results were analyzed with the help of MINITAB 16 software. The influence of controlled factors such as sliding distance, applied load and percentage of reinforcement has been analyzed and it observed that the third level of sliding distance, third level of applied load and third level of percentage of reinforcement are the optimum points for wear rate as shown in Fig.4 and Fig 5.

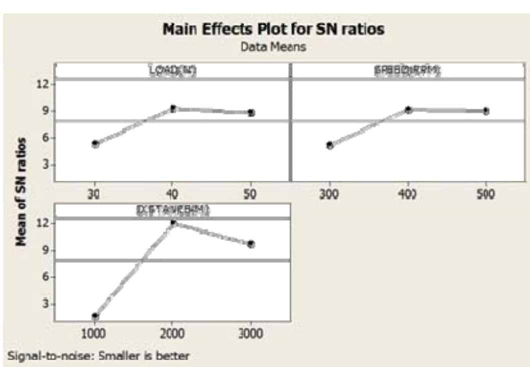

Figure.4. S/N ratio for co efficient of friction

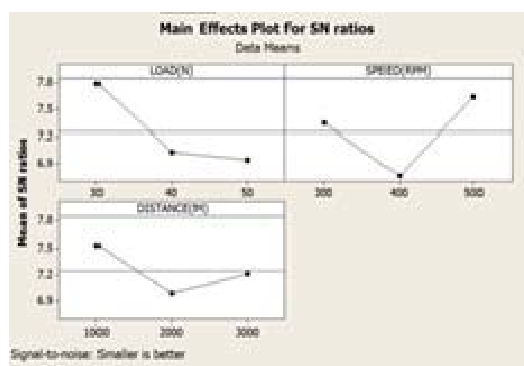

Figure.5. S/N ratio for Specific wear

III. RESULT AND DISCUSSION

Fabrication of natural fiber composite by bamboo fiber reinforced in epoxy composites polymer was prepared successfully. The wear resistance is more in high volume fraction and multi directional orientation like 40% volume fraction is superior than the 30%,20% volume fraction. By using the taguchi the mean also calculated for the test runs the mean specific wear rate is also less bamboo composites.The tensile strength and hardeness are found superior in multi directional 40%volume fraction observed better results.

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