Investigation of Mechanical Properties of Borassus Flabellifer Fibre Reinforced Polymer Composites

Sneha.H.Dhoria[1] **M.Vijaya**[2]

[1,2] Department of Mechanical Engineering, R.V.R& J.C College of Engineering, Chowdavaram, Guntur, Andhra Pradesh, India

Abstract: Most modern technologies coping with ecological aspects have grabbed the sprit of current age. Conservation of raw materials, for instance natural fibres has imposed composite industry to explore and monitor eco-friendly components. A vigorous research in providing the similar performance as their synthetic counter paths are actively in progress where in surrogate reinforcement and resign systems that are environmentally friendly are proposed. The aim of this paper is to study the potential of using borassus flabellifer fibre as reinforcement in polymeric materials. Borassus flabellifer fibre is chemically treated with 5% NaOH solution has been incorporated in a polyester resin matrix at different volume fractions of fibres. Both chemically treated and untreated fibre was utilized and five different fibre volume fractions were used during composite manufacturing. Mechanical tests such as tensile, flexural and impact were conducted. The effect of change in volume fraction on the mechanical properties of the composite is studied for both chemically treated and untreated borassus flabellifer fibre composites. It is found that chemically treated fibre composites have good mechanical properties compared to untreated fibre composites.

Keywords:*Borassus flabellifer fibre, Polyester resin, Mechanical properties, Fibre volume fraction*.

1. Introduction

A great emphasis is obtained in utility of natural plant fibres as reinforcement in fibre reinforced plastics (FRP)to reinstate synthetic fibres such as glass carbon graphite etc.. due to several advantages such as renewability ,low-cost low density high specific strength more over can be extensively surface modified.[A.K. Mohanty et.al- 2005 , P.Wambua et.al -2003]. Plant fibres is an important part of natural fibre, including bast fibres, leaf or hard fibres, seed, fruit, wood, cereal straw, and other grass fibres. The most commonly used natural fibres are blast fibres such as hemp, jute, flax, kenaf, sisal, jute, coconut, bamboo etc., which are used as reinforcement and filler for polymer composites. The principle perception of strengthening the polymer by such fibres is to improve the mechanical properties of the polymer in particular tensile impact and flexural properties [S.V.Joshiet.al-2004, V. Manikandan -2007].

In spite of gradual raise in the application and implementation of natural fibre reinforced compounds, their performance is partial and limited to their enhanced water absorption, thermooxidative de gradation and poor fibre matrix interface and adhesion properties. Cellulose structure caused by the presence of large amount of hydroxyl group in kenaf fibre furnishes hydrophilic nature to the natural fibre, and once they are reinforced in hydrophobic polymers, it results in poormatrix interface. Adhesion properties and amplified moisture. Absorption frequently applied chemical treatments for natural fibres are mercerization, alkali anhydride, resorcinol, amine, silanes, or acrylates based surface treatments.Alkaline treatment is one of the most exercised chemical treatments of natural fibres. The significant alteration proposed by alkaline treatment is the disruption of hydrogen bonding in the network structure, thus increasing surface roughness. This procedure eliminates certain quantity of lignin,wax and oils that cover the external surface of the fibre cell wall, depolymerizes cellulose and exposes the short length crystallites.Several researches reported the addition of alkali-treated fibres can increase the adhesion between the filler and polymer matrix. Many researchers studied the chemical treatments of various natural fibres such as sisal, bagasse, okra,sugar palm, hemp etc. and found that chemical treatment improve thermal, adhesion and mechanical properties [Sreekumar et.al 2009, Mariatti et.al -2008,to M.S Islam -2010]. Recent study reported that 5% treated NaoH fibre reinforced polyester composites having better tensile strength than 10% NaOH treated composites Mishra et.al-2003]. The study was conducted to find out the effects of different conditions of alkaline treatment in terms of the concentration of alkali solution and immersion time on the fibre properties [Reza Mahjoub et.al -2014]. Result from the study found that 5% alkali solution was the best for kenaf fibre treatment because of causing no tension on the fibre texture and structure as compared to 10% and 15% alkali solution.

The main objective of present work is to investigate the tensile, flexural and impact properties of borassus flabellifer fibre polymer composites. Unsaturated polyester resin has been chosen as the matrix material because it is relatively cheap, lower shrinkage and can be moulded at room temperature. The mechanical properties are determined for both chemically treated and untreated borassus flabellifer fibre.

2. Materials

Ecmalon 4411 is purchased from ECMASS resins Pvt. Ltd., Hyderabad, India. It is an unsaturated polyester resin. The resin has Young’s modulus of 0.44 GPa, density of 1360 kg/m^3, tensile strength of 15.4 MPa and elongation at break of 3.6%. The Borassus Flabellifer leaves are collected from nearby local areas of Guntur.

3. Extraction and Treatment of Fibre

Suitable quantity of borassus flabelliber leaves are collected and then dried for 10 days in sun light. Later fibres are separated by removing leaves. After that it is treated with 5% NaOH solution for four hours. Then the fibre is washed with distilled water and it is placed in the oven for half an hour in order to remove any moisture present in the fibre. Then treated fibre is used for fabrication of the composite.

4. Fabrication of Composite Specimens

The mould is arranged on smooth ceramic tile with rubber shoe sole to the required dimension .In order to make sure clean surface on the tile at the outset the ceramic tile is cleansed with shellac,a spirituous product.Then the mould is prepared placing the rubber sole on the tile.The gap between the rubber and the tile is filled with mansion hygienic wax.A thin covering of PVA is applied on the contact surface of the specimen,with a brush.The resulting mould is incurred for 24 hours. The composites were produced using palm and polyester resin. The palm fibre (fig.1) is thoroughly mixed in proper ratio (0, 10, 20 & 30) by weight with polyester resins to get a mixture. When the palm is being taken 10%, the remaining amount is being mixed up by resins and hardener, in which 9% is being occupied by hardener and remaining 81% by the resin. The same process is being continued for different samples. For the % amount of palm taken for total weight, 10% of remaining weight of the resin is being taken by the hardener. Another set of samples were being prepared with a little change in the % weight of the palm being used in the previous samples. For each test five identical specimens of same fibre content are prepared and their dimensions are measured. The five identical specimens are shown in Fig.2.

Fig. 1 Palm Fibre

Fig. 2 Final Specimens

5. Testing of Composites

5.1Tensile Testing

A 2-ton capacity Electronic tensometer is used for testing tensile properties. The Standard test method, ASTM D638M-89 for tensile properties of fibre reinforced composites has been used to test the unidirectional composite specimens. The composite materials used in the current study comprise of natural fibre and unsaturated polyester resin. The specimen is prepared by hand layup process in the form of a rectangular strip of 160 x 12.5 x 3 mm thick and ground to conform to the dimensions. The gauge length, thickness and width are measured with 0.01 mm least count micrometer. The tests are conducted at 28^0C and 50% relative humidity in the lab atmosphere. Five identical specimens are tested for fibre contents in the specimen. The rate of loading is selected such that the testing time of each specimen varied between 2 to 5 minutes.

5.2 Flexural Testing

Standard test method, ASTM D790M-86 for flexural properties of the fibre reinforced composites has been used to test the composite specimens. Thespecimen is prepared by hand layup process in the form of a rectangular strip of 100 x 25x 3 mm thick and ground to conform to the dimensions. The prepared specimens are tested for flexural strength using 3-point bending principle. This test is conducted on the same tensometer which is used for tensile testing.

5.3 Impact Testing

To test the impact properties of fibre reinforced composite specimens, an analog Izod/Charpy impact tester is used. Further more in order to test the composite specimens standard test method,ASTM D256M-97,for impact properties of fibre-resin composites has been used. The specimens are prepared to dimension of 63.5 x 12.7 x 10 mm width. Besides an a V-notch is provided with a sharp file having an integrated angle of 45^0at the centre of the specimen and at $90^0$to the sample axis. Ultimately the depth of the specimen under the notch is 10.16 ± 0.05 mm. The impact testing equipment compiles with ASTM standards. The impact energy is calculated as per the ASTM standards.

6. Problem Formulation

Calculation of volume fraction and density of fibre:

The method involved in measuring the density of the composite of mass m_c at a given mass fraction of resin $m_{r,}$
Volume fraction of resin $V_{r\,=}$ (m_r /m_c) x (ρ_c /ρ_r).
Where ρ_r = density of resin measured to be 1220 Kg/m^3.
Volume fraction of fibre, $V_f = 1- V_r$
Density of fibre $\rho_{f\,=}$ (m_f / m_c) x (ρ_c /V_f)
m_f =mass of Fibre (in grams).
M_c =mass of Composite (in grams).

Tensile Properties:

Tensile strength = Load/Area (MPa)
Young’s Modulus =Stress/strain.

Flexural Properties:
The flexural modulus equation is given by

$$E = \frac{ml^3}{4bt^2}$$

Maximum bending strength equation is given by

$$S = \frac{3PL}{2bt^2}$$

Where, P = maximum applied load
m = slope of load deflection curve (N/mm)
b = width of specimen (mm)
L = span length of specimen (mm)
t = thickness of specimen (mm).

7. Results and Discussion

The results of tensile tests are shown in Figs. 3 and 4 at various fibre volume fractions for both treated and untreated fibre composite

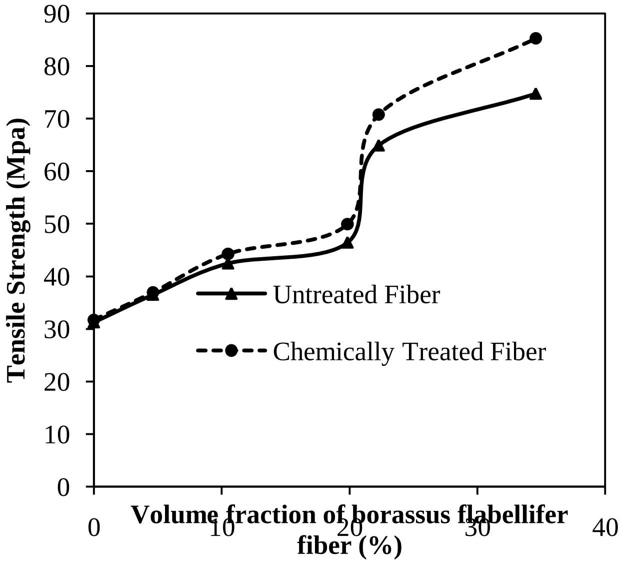

Fig. 3 Effect of Borassus flabellifer fibre volume fraction on tensile strength of composite

Fig. 3demonstrates the comparision of tensile strength between chemically treated and untreated fibre composites at different volume fractions of fibre. Evidently by increasing the fibre content in the polyester matrix, the tensile strength is also increases. Its all because of the polyester resin transmits and distributes the applied stress to the Borassus flabellifer fibres ensuring in higher strength. From the results it is also examined that the tensile strength of chemically treated fibre composites are higher than the untreated fibre composites at all fibre volume fractions. The variation in tensile strength is small upto 10% fibre volume fraction, but beyond 10% there will be significant increase in variation of tensile strength. At 34.5% of fibre the variation in tensile strength is about 13.5%, because when the fibre is treated with 5% NaOH there will be more bonding between the matrix and the fibre.

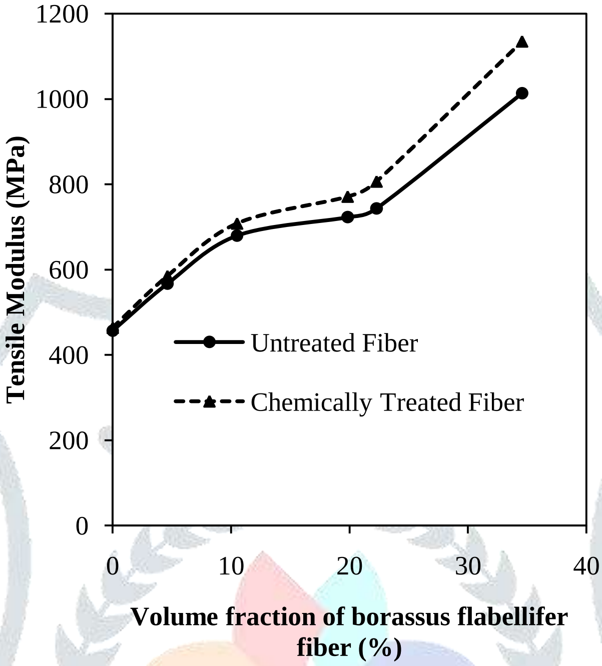

Fig. 4 Effect of Borassus flabellifer fibre volume fraction on tensile modulus of composite

The effect of volume fraction of fibre on tensile modulus for borassus flabellifer fibre composites in comparison to chemically treated Borassus flabellifer fibre composites is presented in Fig. 4. From the results it is evident that the tensile modulus increases as the percentage of fibre volume increases. The variation of tensile modulus of chemically treated borassus flabellifer fibre composites and untreated borassus flabellifer fibre composites is small upto 10% fibre volume fraction. Beyond 10% there will be significant variation and at 34.5% of fibre volume fraction the increase in tensile modulus of chemically treated fibre composites is 12% compared to untreated fibre composite.

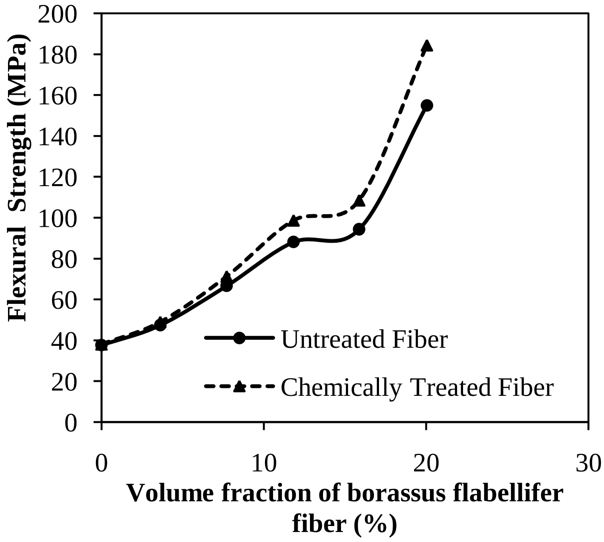

Fig. 5 **V**ariation of flexural strength with Borassus flabellifer fibre volume fraction

The variation of flexural strength between chemically treated and untreated fibre composites is shown in Fig. 5. From the results it is observed that the flexural strength increases as the volume fraction of fibre increases. The variation in flexural strength between the untreated fibre and chemically treated fibre is almost same upto 5% fibre volume fraction. Beyond this value the variation in flexural strength is significant and it is found that 19% increase at 20% fibre volume fraction. This is due to more bonding between the fibre and matrix as the fibre is treated with 5% NaOH solution.

Fig. 6 shows the variation of flexural modulus of borassus flabellifer fibre and chemically treated borassus flabellifer fibre composites at various fibre volume fractions. It was clearly evident that with increase the fibre content in the polyester matrix, the flexural modulus also increases. The variation in flexural modulus of chemically treated Borassus flabellifer fibre composites and untreated Borassus flabellifer fibre composites is small upto 5% fibre volume fraction. Beyond 5% there will be significant variation in flexural modulus and at 20% of fibre volume fraction the increase in flexural modulus of chemically treated fibre composites is 18% compared to untreated fibre composites.

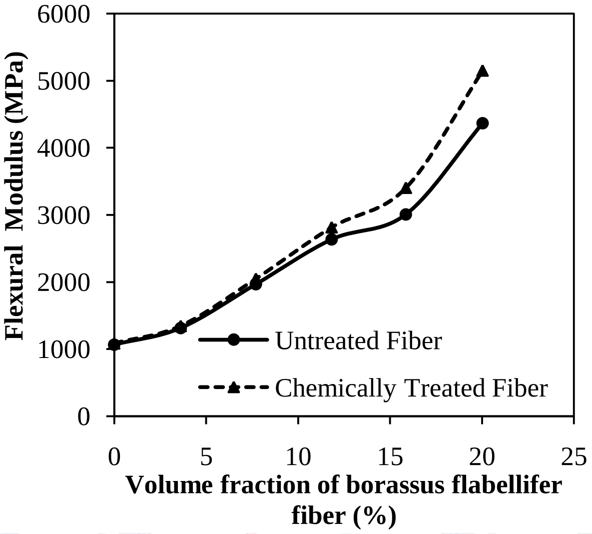

Fig. 6 Variation of flexural modulus with Borassus flabellifer fibre volume fraction

The variation in impact strength with fibre volume fraction is shown in Fig.7 for chemically treated and untreated borassus flabellifer fibre composites. The results show that impact strength increases as the percentage of fibre volume increases. The variation in impact strength between chemically treated borassus flabellifer fibre composites and untreated borassus flabellifer fibre composites is small upto 6.7% fibre volume fraction. Beyond 6.7% there will be much variation and at 16.6% of fibre volume fraction the increase in impact strength of chemically treated fibre composites is 23.3% compared to untreated fibre composites. This is due to the fact that when the fibre is treated with 5% NaOH solution there will be more bonding between fibre and matrix and strength of the fibre increases.

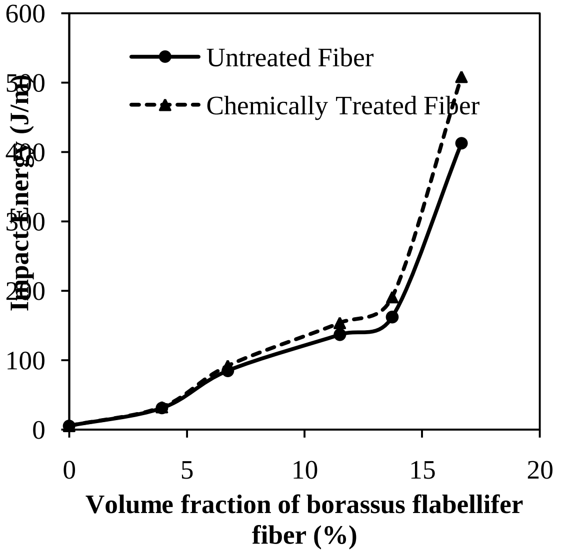

Fig. 7 Effect of Borassus flabellifer fibre volume fraction on impact strength

8. Conclusions

The Borassus flabellifer fibre reinforced composites are prepared according to ASTM standards. The specimens are treated with 5% NaOH solution are also prepared. The mechanical properties such as tensile, flexural and impact properties are determined at various fibre volume fractions. The results of untreated Borassus flabellifer fibre composites are compared with the results obtained by chemically treated Borassus flabellifer fibre composites. The results demonstrated that, the mechanical properties of chemically treated Borassus flabellifer fibre composites increases predominantly when compared to the untreated fibre composites. From the results it is observed that the tensile strength of the treated fibre composites increases by 13.5% than that of untreated fibre composites and flexural strength of the treated fibre composite increases by 19% than that of untreated fibre composite. It is also noted that impact strength of chemically treated fibre composites increases by 23.3% of untreated fibre composite. The results of this study indicate that using Borassus flabellifer fibres as reinforcement in polyester matrix could successfully develop a composite material that can be used as core material for structural board products.

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