

INVESTIGATION OF MECHANICAL PROPERTIES AND TRIBOLOGICAL BEHAVIOUR OF BAGASSE FIBER REINFORCED POLYMER COMPOSITE

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Abstract-Environmental awareness today motivates the researchers, worldwide on the studies of natural fiber reinforced polymer composite and cost effective option to synthetic fiber reinforced composites. With low cost and high specific mechanical properties, natural fiber represents a good renewable and biodegradable alternative to the most common synthetic reinforcement, i.e. glass fiber. Large varieties of sugar cane grow abundantly in many parts of India. Bagasse is considered to be a by-product of the milling process after production of sugar. Bagasse (fibrous residue) is essentially a waste product that causes mills to incur additional disposal costs. These fibers have many advantages over glass fiber or carbon fiber like renewable, environmental friendly, low cost, light weight and high specific mechanical performance. To study the mechanical properties of the composite, different volume fractions of fiber have been taken with in the range of 0-40%. These fibers were randomly distributed in the matrix. Usual hand lay- up technique has been adopted for manufacturing the composite. To have a good compatibility between the fiber and matrix, chemical modification of fibers such as Acetone and Alkali treatments has been carried out and catalyst (Aluminium dioxide) also added to the treated fiber. It was found that alkali treated fiber composite exhibits favourable strength and stiffness in comparison to acetone treatments. Moisture absorption behaviour of both treated and untreated fiber composite was also carried out. For studying mechanical properties of Bagasse fiber in thermosetting matrix composite different test were carried out such as impact test, flexural, tensile, hardness, water absorption and wear test.

Keywords: Acetone and Alkaline, Bagasse Fiber, Catalyst (Al_2O_3), Epoxy, Hardener.

1. Introduction

Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically four combining two or more compatible materials, different in composition and characteristics and sometimes in form.

The natural, bio-degradable features and chemical constituents of the sugarcane bagasse (SCB) have been attracting attention as a highly potential and versatile ingredient in composite materials. Eco-friendly and low cost considerations have set the momentum for material science researchers to identify green materials that give low pollutant indexes. The manifold research that have been carried out on the low cost biodegradable green agriculture waste material. Chemical modifications of SCB wastes are vital and can effectively improve

the matrix-fiber adhesion in the composites thus enhancing those desired mechanical properties and functions on the materials manufactured.

After reviewing the exiting literature available on the natural fiber composite efforts are put to understand the basic needs of the growing composite industry. The conclusions drawn from this is that, the success of combining natural fibers with polymer matrices results in the improvement of mechanical properties of the composite compared with the matrix material.

Thus the priority of this work is to prepare polymer matrix composites (PMCs) using bagasse fiber as reinforcement material. To improve the interfacial strength between the fiber and the matrix, the surface modification of the fiber has to be done by chemical treatment like acetone and alkaline treatment. The composite will then be subjected to different like impact , tensile ,flexural strength and micro hardness. The potential of bagasse fiber for tribological application has to be investigated through performing different tribological test wear test on Pin-on-Disc wear testing machine. All these tests have been carried out as per ASTM standard.

2. Methodology

2.1 Chemical Modification of Fiber

The chemical modification of the fibers alters the surface properties so that better wetting of the fibers with the matrix is possible. This removes the organic residues from the surface of the fibers which enhances the adhesion because natural fibers are coarse in structure, and thus, enable an interlocking mechanism with the matrix. There are various chemical treatments available for the fiber surface modification. Chemical treatment including alkali, acetone, acetylation, benzylation, permanganate treatment are available.

2.1.1 Acetone Treatment

The bagasse fibers were washed in extractor with acetone for approximately 1-1.5hrs. The acetone was evaporated (boiled at 630C) and condensed back into the volume with the fibers. This process was repeated four times for each batch. The used acetone was discarded before the new batch was cleaned in the same manner. The acetone changed from transparent to light yellow after treatment due to the presence of waxes and organic materials after the extraction. All the fibers were washed with pressurized water at a temperature of 900C for 70 minutes before acetone treatment. The fibers were then dried at room temperature for 24 hrs.

2.1.1 Alkaline Treatment

Alkaline treatment or mercerization is one of the most used chemical treatments of natural fibers when used to reinforce thermoplastics and thermosets. The important modification done by alkaline treatment is the disruption of hydrogen bonding in the network structure, thereby increasing surface roughness. This treatment removes a certain amount of lignin, wax and oils covering the external surface of the fiber cell wall, depolymerizes cellulose and exposes the short length crystallites. It increases surface roughness resulting in

better mechanical interlocking. The effect of alkali treatments of bagasse fibers is increase the fiber bonding and strength.

2.2 Composite Fabrication

For preparation of composite the following materials have been used;

- Bagasse fiber
- Epoxy
- Hardener

2.2.1 Fabrication

The type of epoxy resin used in the present investigation was Araldite LY 556, which was used together with hardener HY 951, both are easy available. A wooden mould dimension 120*100*6mm was used for casting the composite sheet. A usual hand lay-up method was used or preparation of the samples. A mould release spray was applied at the inner surface of the mould for quick and easy release of the composite sheet. After keeping the mould on a glass sheet a thin layer (2 mm thickness) of the mixture was poured. Then the required amount of fibers was distributed on the mixture. The remainder of the mixture was then poured into the mould. Pressure was then applied from the top and the mould was allowed to cure at room temperature for 72 hrs. After 72 hours the samples were taken out of the mould. The photograph of the composite and some of the specimen cut for further experimentation. After cutting they were kept in airtight container.

2.2.2 Experimental Design

The composite system outline in table 1 were manufactured to investigate varying properties such as fiber volume fraction and chemical treatment and catalyst (Al_2O_3) of fiber. From the first group of untreated samples 0, 5, 10, 15, 20, 25, 30, 35, 40% volume fraction. From the second group the fiber treated with Acetone. The third group the fiber with alkaline(NaOH).The forth group of samples the fiber treated with acetone and the catalyst (Al_2O_3).The fifth group of sample the fiber treated with alkaline and catalyst (Al_2O_3).Finally all the group of samples were fabricated. We investigated and observed from the five different composition, we concluded that the composite containing 40 % volume fraction of fiber provided the best combination of strength. Therefore for further experimentation, 40% fiber volume fraction has been taken into consideration. Therefore the strength in acetone treated fiber and untreated fiber is somewhat low in comparison to alkali treated fiber and treated alkaline with catalyst(Al_2O_3).However it is established that fiber matrix bonding has improved a lot by chemical modification in comparison with the untreated fiber.

2.3 Material Properties

The main objective is to determine the material properties (Flexural strength, Impact strength, Hardness, Tensile strength, Water absorption and Wear test) of natural fiber reinforced composite material by conducting the following respective tests is carried out.

- Flexural Strength
- Impact Strength
- Hardness Test
- Tensile Strength
- Water Absorption
- Wear Test

3. Results and Discussion

3.1 Flexural Test

The test method for conducting the test usually involves a specified test fixture on a universal testing machine. UTM machine in accordance with ASTM D 790-07 to measure the flexural strength of the composites. Details of the test preparation, conditioning, and conduct affect the test results. The sample is placed on two supporting pins a set distance apart and a third loading pin is lowered from above at a constant rate until sample failure.

3.2 Impact Test

Impact is a very important phenomenon in governing the life of a structure. For example, in the case of an aircraft, impact can take place by a bird hitting a plane while it is cruising, or during takeoff and landing the aircraft may be struck by debris that is present on the runway, and as well as other causes. It must also be calculated for roads if speed breakers are present, in bridge construction where vehicles punch an impact load, etc. Izod impact testing is an ASTM D3039/D3039-00e1 method of determining the impact resistance of materials. An arm held at a specific height (constant potential energy) is released. The arm hits the sample. The specimen either breaks or the weight rests on the specimen. From the energy absorbed by the sample, its impact energy is determined. A notched sample is generally used to determine impact energy and notch sensitivity.

3.3 Tensile Test

Ultimate tensile strength (UTS), often shortened to tensile strength (TS) or ultimate strength, is the capacity of a material or structure to withstand loads tending to elongate, as opposed to compressive strength, which withstands loads tending to reduce size. In other words, tensile strength resists tension (being pulled apart), whereas compressive strength resists compression.

3.4 Micro Hardness

The micro hardness test method as used to determine hardness, is defined in ASTM E10. Most commonly it is used to test materials that have a structure that is too coarse or that have a surface that is too rough to be tested using another test method, e.g., castings and forgings hardness testing often use a very high test load (3000 kgf) and a 10mm wide indenter so that the resulting indentation averages out most surface and sub-surface inconsistencies.



Fig.1 composite laminate



Fig.2 specimen for impact test



Fig.3 Specimen for Tensile test



Fig.4 Specimen for Flexural test

Table 1 Mechanical Properties of Treated and Untreated Bagasse Fiber of 40%

| Fiber vol % | Type of fiber | Flexural Strength (MPa) | Tensile Strength (MPa) | Impact Strength (KJ/m²) |
|--------------------|---|--------------------------------|-------------------------------|---|
| 40 | Untreated | 9.12 | 2.00 | 8.17 |
| 40 | Acetone Treated | 14.26 | 1.00 | 13.48 |
| 40 | Alkali Treated | 14.52 | 4.60 | 34.94 |
| 40 | Catalyst (Alluminium Dioxide) And Acetone | 11.09 | 5.60 | 13.96 |
| 40 | Catalyst (Aluminum Dioxide) Alkaline | 15.75 | 7.00 | 39.01 |

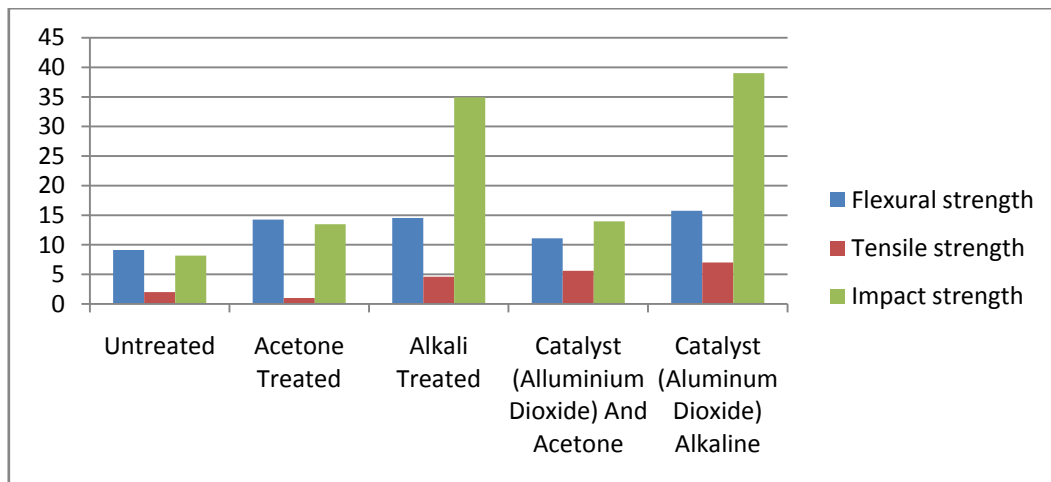


Fig. 5 Comparative graphs of the mechanical properties of 40 % volume fraction of composites after chemical treatment of fibers

- The effect of different chemical modifications of fibers on mechanical properties of the composite have been studied by taking 40 volume % of fiber as an optimum reinforcement as discussed earlier. It is clearly seen from table 1 that, the mechanical properties of the composite enhanced significantly due to chemical modification of fiber surface.
- Figure 5 shows the effect of bagasse fiber content on the tensile and flexural strengths and impact strength of the composites. Fiber content (volume %) varied from 0 to 40 % to investigate its effect on the mechanical properties. From the results it is observed that with increase in fiber content from 40 % the tensile, flexural strength and impact strength increases are gives better results compare to other samples.

Table 2 Micro Hardness test reading of Treated and Untreated Bagasse Fiber of 40%

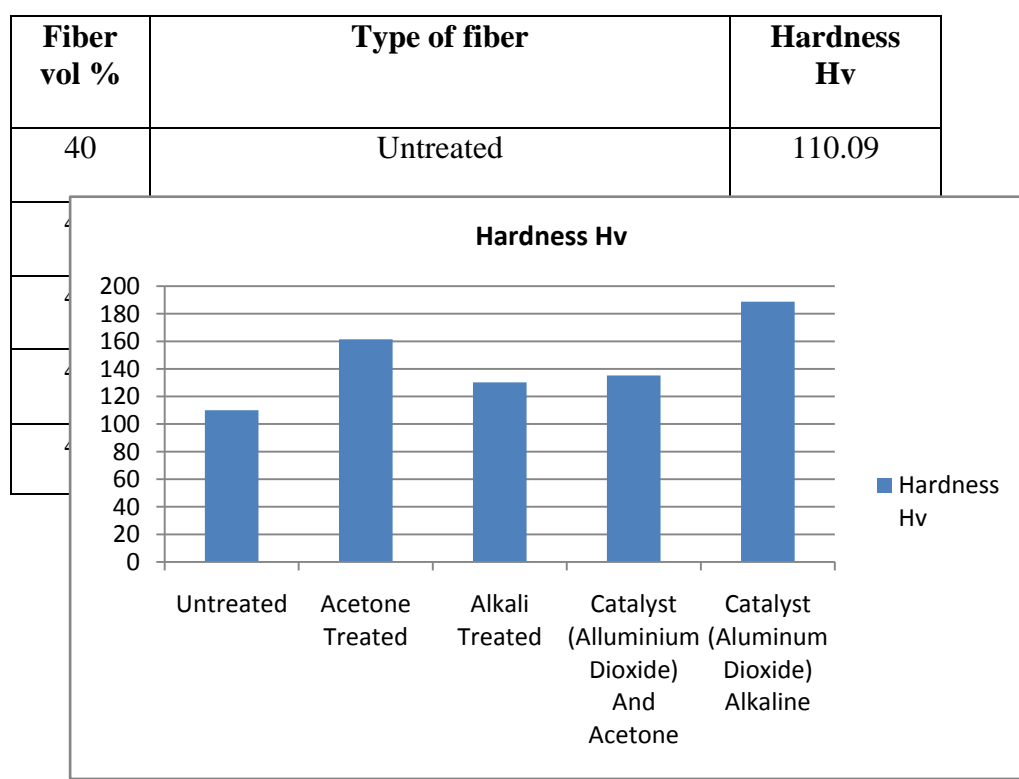


Fig. 6 Comparative graphs of the Micro Hardness test for 40 % volume fraction of composites after chemical treatment of fibers

- Figure 6 shows the micro hardness values for different volume fraction of bagasse fiber composite. It is seen that with the increase in fiber content in the composite, its hardness value improves although the increment is marginal and the hardness is better in treated fiber with catalyst(Al_2O_3).

Table 3 Water Absorption Test For Treated Bagasse Fiber Epoxy Composite for 40% of fiber

| Fiber vol % | Type of fiber | Weight Before Test (G) | Weight After Test (G) | Gain Of Water (G) |
|--------------------|---|-------------------------------|------------------------------|--------------------------|
| 40 | Untreated | 10.74 | 10.96 | 0.20 |
| 40 | Acetone Treated | 10.63 | 10.83 | 0.20 |
| 40 | Alkali Treated | 10.68 | 10.89 | 0.21 |
| 40 | Catalyst (Alluminium Dioxide) And Acetone | 10.68 | 10.90 | 0.22 |
| 40 | Catalyst (Aluminum Dioxide) Alkaline | 10.68 | 10.80 | 0.12 |

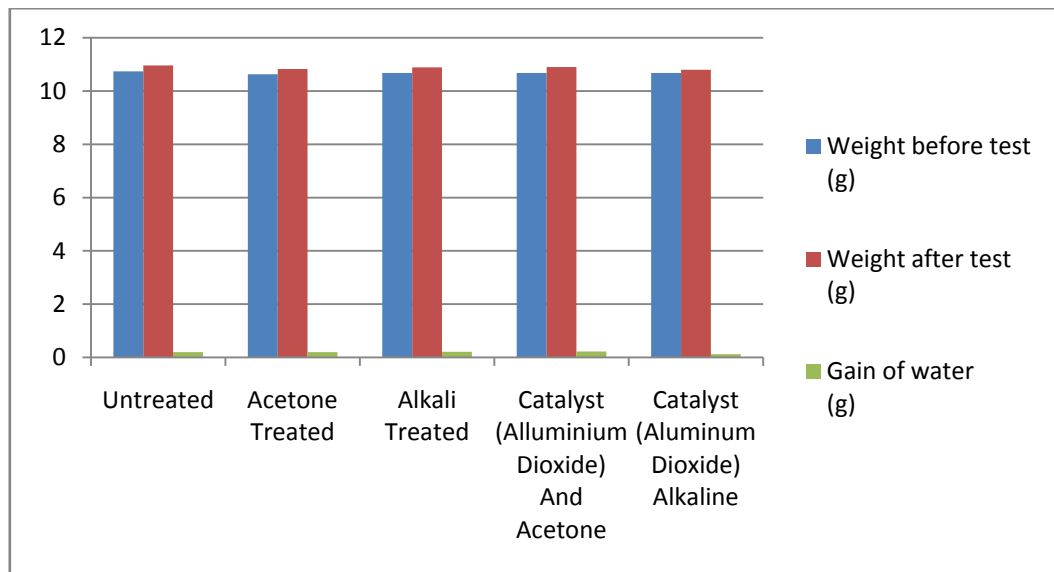


Fig.7 Comparative graphs of the Water Absorption of 40 % volume fraction of composites after chemical treatment of fibers

From the table 3 shows that the water absorption of untreated fiber is high compare to the treated bagasse fiber. From acetone treatment the water absorption is high when compare to the treated fiber with alkaline and catalyst. Therefore the strength in acetone treated fiber is somewhat high in comparison to alkali treated fiber. Finally the fiber treated with catalyst and alkaline (40%) gives the better results on comparison with other fiber combinations.

Table 4 Wear Test For Treated Bagasse Fiber Epoxy Composite for 40% of Fiber

| Fiber vol % | Type of fiber | Wear (mm ³) | Wear resistance (m/mm ³) |
|-------------|---|-------------------------|--------------------------------------|
| 40 | Untreated | 30.24 | 33.06 |
| 40 | Acetone Treated | 28.88 | 34.62 |
| 40 | Alkali Treated | 29.52 | 33.87 |
| 40 | Catalyst (Aluminum Dioxide) And Acetone | 26.64 | 37.53 |
| 40 | Catalyst (Aluminum Dioxide) Alkaline | 20.16 | 49.60 |

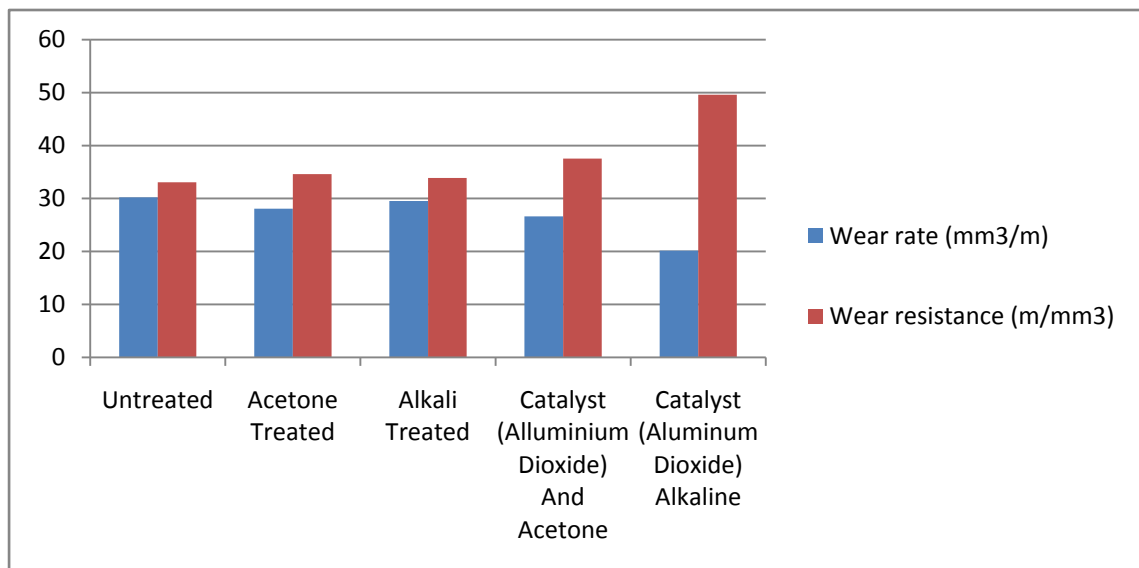


Fig.8 Comparative graphs of the wear rate and wear resistance of 40 % volume fraction of composites after chemical treatment of fibers

- From the figure 8 shown that the treated fiber with alkaline and catalyst (aluminium di-oxide) have high wear resistance and less wear rate compare to other treated fibers. For studying the wear behaviour of Bagasse fiber the wear test is carried out as per the ASTM standard on Pin-on-Disc wear testing machine. finally we observed from the figure 8 the wear rate low in treated bagasse fiber with catalyst(aluminium di-oxide) and alkaline give high when compare to the treated acetone fibers.
- The wear test results shows that the wear rate of pure epoxy reduces significantly with the addition of Bagasse fiber up to 40 vol%. and the wear resistance significantly increase when compared with other treated fibers. So the investigation shows that the combination of fiber treated with catalyst and alkaline 40% is gives the high wear resistance.

4. Conclusion

Bagasse can successfully be utilized to produce composite by suitably bonding with resin for the development of value added products. From the above investigation, it can be concluded that the composite containing 40% volume fraction of fiber provided the best combination of strength. Therefore for further experimentation, 40% fiber volume fraction has been taken into consideration. On increasing the fiber content, the strength, modulus and work of fracture increases and the best combination is found with 40% volume fraction of fiber. The fiber surface modification by chemical treatments significantly improves the fiber matrix adhesion, which in turn improves the mechanical properties of composite. Alkali treatment shows the highest improvement in comparison to acetone treatment. For acetone treatment, the fiber were bonded less. Therefore the strength in acetone treated fiber is somewhat low in comparison to alkali treated fiber. However it is established that fiber

matrix bonding has improved a lot by chemical modification in comparison with the untreated fiber

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