Hybridization of Natural Fiber Composites on Mechanical Properties

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Abstract

Natural fibers are now considered as a suitable alternative to glass fibers due to their advantages like low cost, high strength-to-weight ratio, recyclables, etc. In this investigation, natural fibers like banana, sisal and hybrid (banana/sisal) were fabricated using moulding method. The tensile, flexural and compression strength of the fabricated composites were tested using Universal Testing Machine and analyzed. In addition to that the wear resistances of the fabricated composites are also tested. All the testing was conducted both in as fabricated and under moisture conditions. The hybridization of composites was found to be enhancing the mechanical properties. Tensile and flexural loading conditions, hybrid and banana reinforced fiber performed well. In compression and impact loading, hybrid and sisal fiber reinforced composites found their suitability. Wear resistance of the hybrid composites are found to be good.

Key words:
Natural fiber, hybrid, micrograph, mechanical properties and wear.

1. INTRODUCTION

Natural fibers have received much attention from the research community over the past decade. Natural fibers are now considered as a serious alternative to glass fibers for use in composite materials as reinforcing agents. The advantages of natural fibers over glass fibers are their low cost, low density, high strength-to-weight ratio, resistance to breakage during processing, low energy content and recyclability [1, 2].

The properties of the natural fiber based composites can be affected or modified by number of reasons like fiber combinations, processing of composites, fiber volume fraction, aspect ratio, water absorption etc. The process parameters and their influences on the properties are different with different combinations of fiber and matrix. The fabrication method plays an important role on the properties. There are various fabrication methods for natural fiber composites materials viz. compression molding, injection molding, extrusion molding, hand lay up method, etc. In these methods injection molding will improve the fiber dispersion and hence increase the tensile and flexural properties[3]. On the other hand, extrusion and injection molding damages the properties of the natural fibers[4]. In contrast, Wanjun Liu[5] et al suggested the molding method, which neither damages nor orients the fibers during processing, which preserves the isotropic properties of the composites and reduces the changes in the physical properties.

The type of fiber plays a vital role in the properties of composites. H.Y.Sastra, et.al[6] discussed the flexural properties of Agenta Pinnata fiber reinforced Epoxy composites. The aim of this study is to determine the flexural properties of Arenga pinnata fiber as a natural fiber and epoxy resin as a matrix. Kazuya et.al[7] studied the tensile properties of bamboo based polymer composites and reported that there was an improvement in the tensile strength and modulus by 15% and 30% than that of matrix. The effect of incorporation of sisal fiber content in high impact polystyrene on stiffness was found to be increasing where as the tensile strength decreases [8]. In literature, many natural fibers like jute [9], sisal [10], hemp [11], coir [12] and banana [13] have been tried and showed their suitability to form a composite.

Composites having two or more fillers contained in the same matrix are called as hybrid composites [14]. Sreekala et.al [15] reported the effect of hybridization of glass fiber with oil palm fiber reinforced composites. Nikhil Guptha et al. [16] studied the hybridization of fly ash in glass fiber epoxy on compressive and impact properties. Thomas et al. [17] studied the mechanical properties and cure characteristics of sisal and oil palm hybrid reinforced natural rubber composites. Banana/Sisal as well as PALF/glass hybrid composites enhanced the tensile and flexural properties but which is negative for thermal conductivity [18,19]. The Mechanical properties of glass/palmyra fiber waste sandwitch composites enhance the tensile, flexural and shear strength due to hybridization. Hence, hybridization plays a vital role in improving the properties of composites [20, 21].

However, the hydrophilic nature of natural fibers is a major drawback for their application as reinforcement for composites. The moisture uptake in fiber composites has a deleterious effect on their mechanical properties. Fraga et al [22] discussed the relationship between water absorption and dielectric behavior of natural fiber composite materials. They found that the glass based composite is more resistant to water absorption than jute and washed jute composites, due to the lower hydrophilic character. It was observed the nature of fiber/matrix interface has a considerable influence on the water absorption [23]. An increase in the tensile strength occurs for jute based composites in humidity aging conditions, which is attributed to the improved both polymer and interfacial adhesion strength [13].

From the status of work reviewed, in hybridization of composites, most of the combination, the second fiber is some type of glass fiber. In that aspect, natural fiber cannot replace the glass fibers. So in this investigation, hybridization of different types of natural fibers which is 100 % replacing the role of glass fibers are focused.

2. EXPERIMENTAL DETAILS

2.1 Materials

The matrix material used in this investigation was based on commercially available polyester, Trade name satyan polymer supplied by GV Traders. The matrix was mixed with curing catalyst at a concentration of 0.01 w/w of the matrix for curing. Commercially available sisal, banana and combination of banana /sisal were taken as reinforcement.

2.2 Fabrication of Composites

The natural fiber (banana, sisal and combination of banana / sisal) reinforced polymer matrix composites were fabricated using moulding method. Polyester was used as matrix. For a proper chemical reaction cobalt and methyl ethyl ketone were used as catalyst and accelerator respectively. The banana, and sisal and combination of banana and sisal fibers were prepared as per the aspect ratio and volume fraction. Acrylic sheets were selected as per the following dimension 30x30x0.5 cm. ASTM rubber were cut according to standard thickness of 3 mm. A poly ester resin of 150 ml was mixed with 30 gm of chopped fibers which is 0.5 cm long using fiber cutter. Using a stirrer, stir the mixture for one hour to achieve homogeneous condition. An accelerator of 20 drops was added along with 12 drops of catalyst for curing. The above mixture was poured into the moulding box. Apply poly vinyl over the sheet to prevent rubbing.Finally; the specimen was removed from the molding box after two days.

2.3 Water Absorption

The effect of water absorption on the properties was analyzed. First all the specimens were dried in an air oven at 50^0C and then were allowed them to cool to room temperature in a desiccator before weighing them to the nearest 0.1 mg. This process was repeated until the mass of the specimens were reached constant. Water absorption tests were carried out by immersing the specimens in de-ionized water bath at 25^0C. After immersion for 48 hours, the specimens were taken out from the water and all surface water removed using a clean dry cloth. The specimens were reweighed to the nearest 0.1 mg within 1 minute of removing them from water.

2.4 Tensile, Flexural and Compression Testing

Tensile and flexural testing are static tests that were performed on the fiber reinforced composites. All the tests were performed on a computer controlled 1000 Ton computer controlled Universal Testing Machine. Specimens were prepared according to the ASTM standards. The flexural strength before and after water immersion were determined using three point bending test at room temperature. For flexural testing, the load was placed midway between the supports. In addition to the above tests, the performance of the composites on compression loading was also studied.

2.5 Impact Strength Measurement

The un-notched impact strength was measured using Izod-Impact tester. Experiments were conducted according to ASTM D4812. Five specimens were measured for each case. The specimen for impact test is 9cm X 1.5cm. The specimen is placed horizontally in the test bed. The pendulum is lifted and is made to hit the specimen from height.

2.6 Wear Testing

The rectangular specimen of 45 mm x 35 mm was slid against a rotating abrasive wheel. A constant load of 500 g was applied during the wear test for all the samples. The weight loss was measured for the specified time intervals such as 3, 6 and 9 minutes.

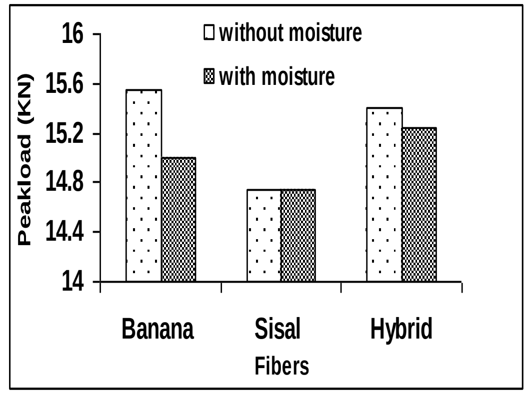

Figure 1 Effect of fibers on Peak Load (With and Without Moisture)

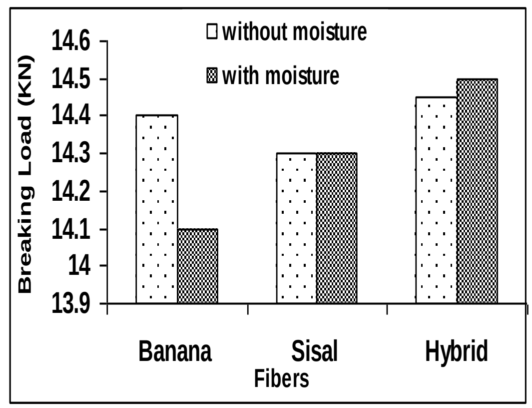

Figure 2 Effect of fibers on Breaking Load (With and Without Moisture)

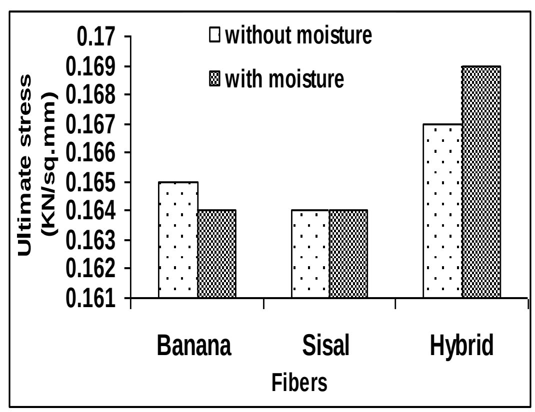

Figure 3 Effect of fibers on Ultimate stress (with and without moisture)

3. RESULTS AND DISCUSSIONS

3.1 Tensile test

The tensile strength of the specimens before and after water immersion were tested using computer controlled Universal Testing Machine. Test specimens were individually cut using a diamond wheel in to rectangular beams according to ASTM standards.

The figure 1, 2 and 3 show the effect of fibers on peak load and breaking load on tensile stress. The specimens produced from banana fiber performed better on tensile loading condition compared to the composites reinforced with sisal fibers.

The hybrid composites showed comparatively better performance. The figures 4, 5 and 6 depict the micrographs taken for the fractured sisal, banana and hybrid composites. Sisal fiber composites, on tensile loading condition, showed a brittle like failure. Elliptical cracks and their fast propagation could be observed from figure 4. Less fibre pull out is observed and this could be reason for the reduction in the tensile strength. Figure 5 represents the tensile fracture micrograph for the banana fiber based composites. Plastic deformation and more fiber pull out could be observed. This nature is justified with the help of figure 7, where more percentage elongation could be observed for the banana fibre composites. Hybrid fibre composites exhibit partial brittle nature of fracture due to the presence of sisal fibres.

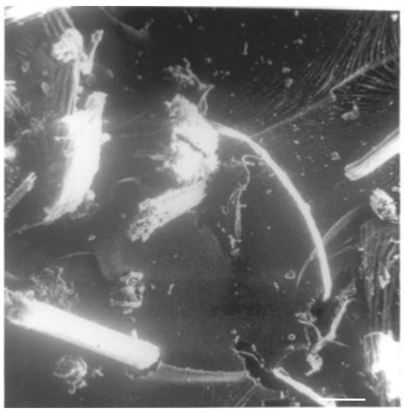

Figure 4 SEM for the fractured sisal fiber composite on tensile loading (70X)

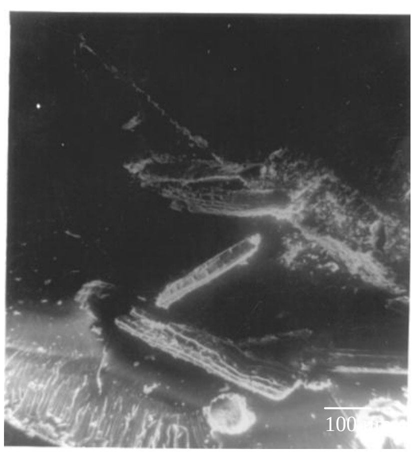

Figure 5 SEM for the fractured banana fiber composite on tensile loading (70X)

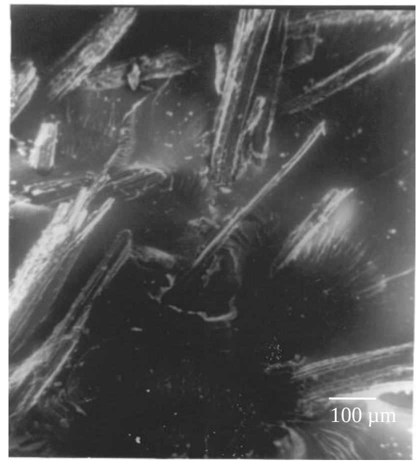

Figure 6 SEM for the fractured hybrid fiber composite on tensile loading (70X)

The specimens tested with the presence of moisture reduce the strength of the composites except hybrid specimen. The reason could be the presence of sisal fiber in the hybrid composites. Because from figure 1 and 2, one can observe the peak load and the breaking load for the sisal fiber composites are not affected much with the presence of moisture. Also the water causes swelling of the fibres which could fill the gaps between the fibre and the polymer matrix and eventually could lead to an increase in mechanical properties [24]. The moisture uptake of the composites reduced the tensile strength of the banana fiber composites (figure 3). The reason could be because of the formation of hydrogen bonding between water molecules and cellulose fibre. Natural fibres are hydrophilic with many hydroxyl groups (-OH) in the fiber structure forming a large number of hydrogen bonds between the macromolecules and polymer. This leads to poor interfacial bonding between the fibre and the matrix, causes a decrease in property [25]. And, in all the cases, specimens with moisture showed improved elongation (Figure 7). The reason could be the water molecules in the composites which are acting as plasticizers which in turn improve the plastic deformation.

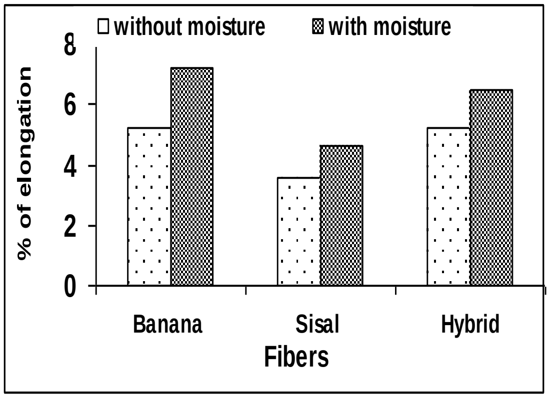

Figure 7 Effect of fibers on % of Elongation (With and Without Moisture)

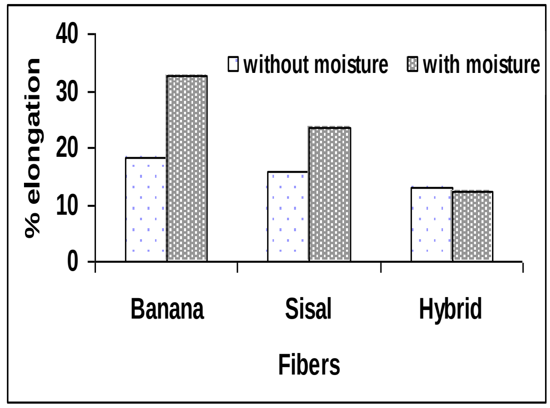

Figure 9 Effect of fibers on the percentage elongation (with and without moisture)

3.2 Flexural Test

The effect of flexural loading on the performance of the fabricated composite materials is shown in figure 8. Three point bending test was employed to investigate this effect. Banana fiber composites are found to be withstanding more loading on flexural testing. In this case also like tensile loading condition, the presence of sisal fiber in the reinforcement reduces the strength. Even in the hybrid composites the slight reduction in the flexural behaviour could be due to the sisal fiber presence.

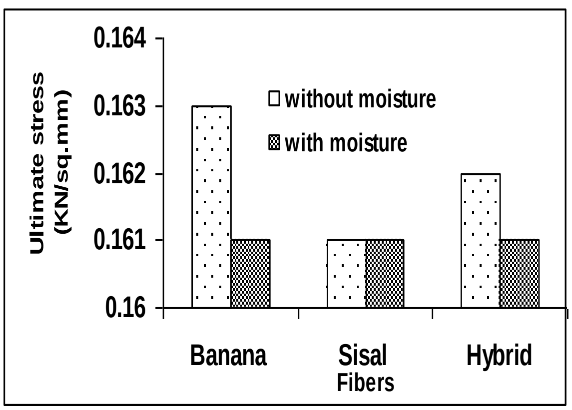

Figure 8 Effect of fibers on Ultimate Stress (with and without moisture)

The presence of moisture in the composites reduces the flexural properties. Since the absorption of moisture leads to the degradation of fibers matrix interface region creating poor stress transfer resulting in a reduction on the flexural strength. Both in the banana and sisal fiber composites the percentage elongation is found to be increasing after immersing the components in to water. The reason could be the presence of water attack on the cellulose structure and allow the cellulose molecules to move smoothly. Hence for the applications where flexural loading conditions are dominating, banana and hybrid fiber composites could be selected.

3.3 Compression Test

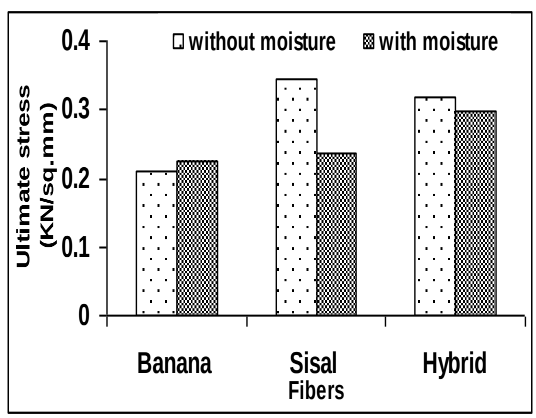

Figure 10 Effect of Fibers on Ultimate Stress (with and without moisture)

The figure 10 shows the effect of fibers and its combination on compression performance. Unlike tensile and flexural, hybrid and sisal fiber composites performed well in this case. Even though the performance of the hybrid and sisal are more or less equal in the dry condition; sisal fiber composites fails to prove the performance under moisture condition. Even under moisture condition the hybrid composites is withstanding more stress compared to sisal fiber composites. Banana fiber composites are found to be less suitable for the applications where compressive stress is dominant. Applications where both dry and moisture environment is present, hybrid composites may be suitable.

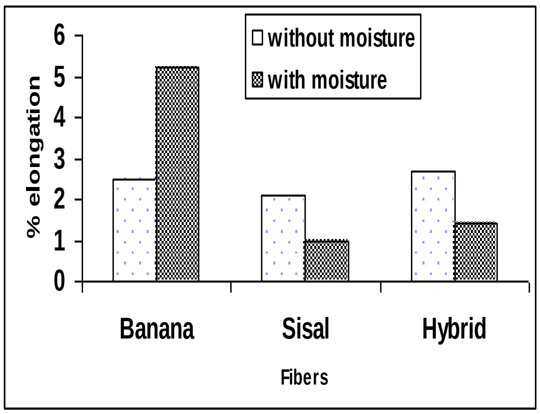

Figure 11 Effect of Fibers on % elongation (with and without moisture)

The effect of fibers on the percentage elongation is shown in figure 11. On compression, the percentage elongation in dry condition is found to be more or less equal in all the cases. But after water absorption, more elongation is observed in the case of banana fiber composites. As explained earlier the reason could be the presence of water which acts as a plasticizer, lead more strain. The presence of sisal fiber plays a vital role in the reduction of elongation in the hybrid composites.

3.4 Impact Test

Un-notched Izod impact test as per ASTM D 256 procedure is followed to find out the energy absorbed by each particle in the composites. The effect of fibers on impact strength for the specimens prepared for both dry and moisture conditions is shown in figure 12. Hybrid and sisal fiber composites absorb more energy on impact loading conditions both in the dry as well as moisture condition.

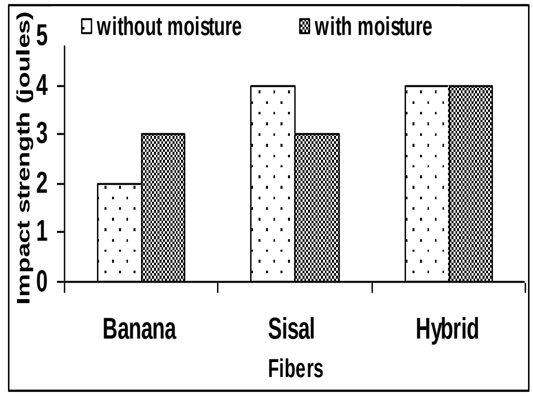

Figure 12 Effect of Fibers on Impact strength (With and without moisture)

The SEM photographs taken for the impact fractured samples of banana, sisal and hybrid composites are shown in figure 13, 14 and 15 respectively. The increase in the impact strength could be observed for hybrid and sisal fiber composites. This could be attributed to fiber bridging through fiber pull out. The greater level of fiber pull out which is observed in the specimen fabricated by sisal and hybrid reinforcement attributes superior impact strength. Banana fiber composite exhibits reduced impact strength. The reason could be the reduced fiber bridging effect resulting lower fiber pull out. The complete breaking of the fiber rather than pull out is observed through SEM analysis.

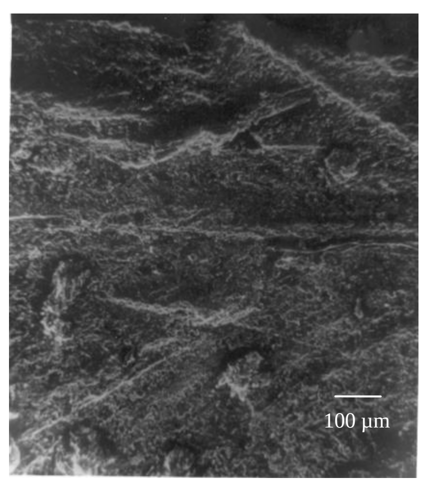

Figure 13 SEM for the fractured banana fiber composite on impact loading (70X)

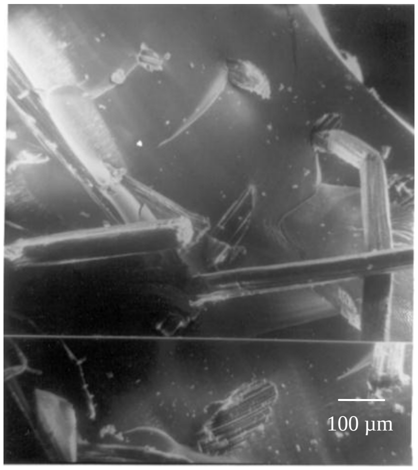

Figure 14 SEM for the fractured sisal fiber composite on impact loading (70X)

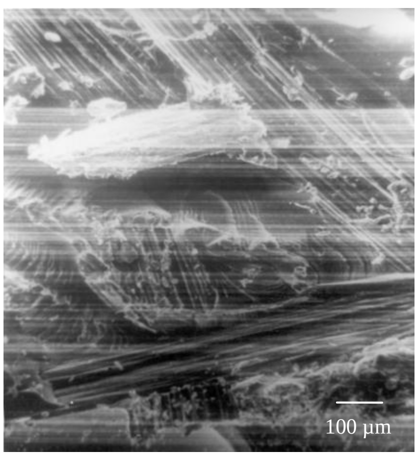

Figure 15 SEM for the fractured hybrid fiber composite on impact loading (70X)

3.5 Wear Test

Wear test is performed by applying a constant load of 0.5N on the specimen against a rotating abrasive wheel. The weight loss of the specimen at three intervals such as 3, 6 and 9 min are observed.

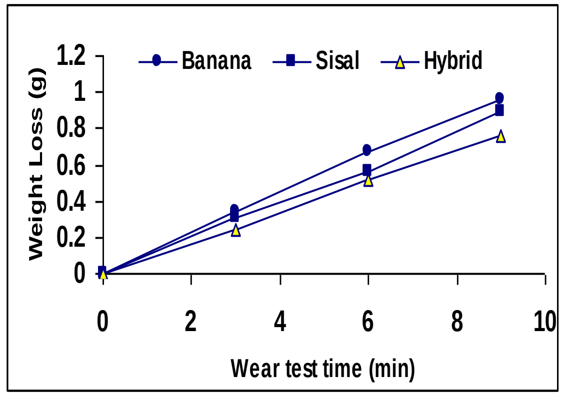

Figure 16 Effect of wear test time on weight loss (Dry specimens)

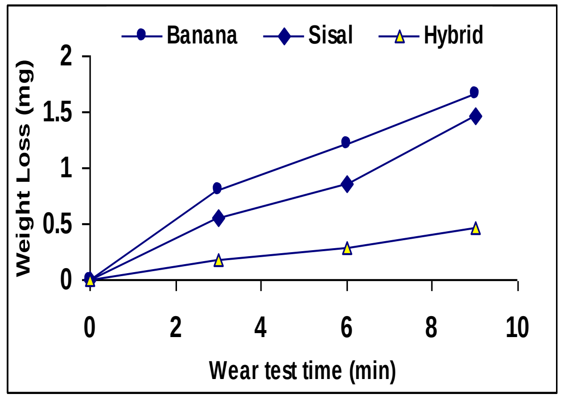

Figure 17 Effect of wear test time on weight loss (with moisture)

Figure 16 depicts the effect of wear test time on the weight loss of the materials. Gradual weight loss is observed in all the cases. Hybrid composites are found to be of better wear resistant. The wear tests conducted for the moisture content samples showed inferior wear performance compared to the dry samples. The wear resistances of banana and sisal fiber composites are found to be decreasing for the samples after immersed in water. Even in this case, hybrid composites showed good wear resistance. The reduction in the wear resistance could be expected due to the damaging of the fiber structure by the presence of water. Uniform weight loss per time could be observed in all the cases.

4. CONCLUSION

From the experiments conducted following conclusions were drawn;

- Hybridization of the composites enhanced the mechanical properties both in the dry and wet conditions.
- Hybrid and banana fiber composites showed better tensile and flexural strength.
- Hybrid and sisal fiber composites are found to be suitable for compression and impact loading conditions.
- Wear resistance of the hybrid composites are good both in the dry and wet conditions.
- The presence of moisture increases the strain in almost all loading conditions.

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