REVIEW ON MECHANICAL & THERMAL PROPERTIES OF HYBRID REINFORCEMENT POLYMER COMPOSITE

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ABSTRACT

Past few years, synthetic fibers are replaced by natural fibres for polymer composite due to their several benefits. Sisal and betel nut fibre is one of the largely used materials in the field of automobile field(brake pad body panels,), aerospace, insulating materials rope, brush, mat, string, cable, welding helmet, chair, table, roof etc. because of its environmental helpful, low cost and high specific mechanical performance. The sisal and betel nut fibre, its low density, lower flexural strength to betel nut and other material. The properties of sisal and betel nut could be improved according to the application-oriented areas. The ash and glass material used in the fabrication process should possess the properties of thermal stability, light weight, excellent bonding. There are so many work deals with the thermal stability, mechanical properties of the randomly oriented sisal and betel nut fibre reinforced polyester and epoxy resin composite. The composites were arranged by compression moulding method with short length fibre or long length fibre but different weight percent of sisal and betel nut fibre content. The Scanning electron microscopy was used to examine the material failure morphology, The sodium hydroxide treatment effect of fibres was verified by FTIR analysis & study of the free radical structure is necessary using Electron spin resonance (ESR) and infrared spectroscopy (FTIR).

Keywords: Sisal; betel nut fibre; polyester and epoxy resin; thermal stability; mechanical properties;

1. INTRODUCTION

Betel nut is the confection of Areca palm tree (Areca catechu), a species of palm, which is native of Malaysia and widely grows across Asia, Taiwan, and India. This research aims to study the physical and morphological properties of betel nut husk agro-decay to determine the suitability of betel nut husk fibre as reinforcement in polymer composites [1]. In this study, we have developed novel composite material using betel nut fibre reinforced with unsaturated polyester. The effect of chemical treatment onto betel nut fibres on mechanical, sound absorption and thermal properties of composites has been examined. The reinforcing property of the alkali treated fibre was also compared with that untreated fibre [2]. Epoxy resin in its restore state has many desirable properties such as high stiffness and strength, excellent chemical and solid

resistance. However, its main drawback is brittleness. One of the most successful methods of improving epoxy toughness is combined with reactive liquid elastomers, e.g. amine-terminated butadiene acrylonitrile (ATBN). In this work, sisal fibre, a renewable natural fibre with a high specific strength and biodegradable properties, was selected. Normally, when the hydrophilic fibre is employed in the hydrophobic polymer, various fibre surface treatments have been done for improving interfacial adhesion and mechanical properties. Therefore, the authors studied the effects of alkalized and silanized woven sisal fibre on the mechanical properties of GDNR/epoxy resin blend[3,2]. Composite materials are known to have high specific modulus, high specific strength, high resistance to corrosion, low weight and can be tailored to meet specific purpose, which give them advantage over universal materials such as metals and ceramics reported that matrix modification led to better mechanical performance than fibre modification in flax fibre/polypropylene composites. Specifically, the modification of unsaturated polyester resin has been reported to raise the impact property [4]. The current work focuses on the response of abrasiveness to processing equipment using natural and synthetic fibre reinforced polyester composites; specifically treated betel nut fibre reinforced polyester (T-BFRP) and chopped strand mat (CSM) glass fibres respectively. For this purpose, it is important to acquire fundamental considerate of different wear mechanisms and this is done through surface smoothness measurement on the counterface and test specimens, followed by SEM examination of the worn surfaces [5]. Natural fibre reinforced polymeric composites have became popular replacement to synthetic fibres due to their added advantage such as high specific stiffness and strength , light in weight, biodegradable and renewable , ease in components fabrication due to its lower fibre density , desirable fibre aspect ratio, easily available from natural sources, higher resistance to equipment abrasion and impact resistance , and lower in cost . Fibres free from impurities produce better surface contact and strength. It was reported that further improvement of fibre interfacial adhesion strength has been achieved through an increase in fibre densities after treating them with a proper chemical solution such as NaOH. From the findings, the densification of the fibre cell wall has contributed to the formation of rougher fibre surfaces [6, 4]. Composites with different contents. The study concludes that the sisal fiber is an ideal substitute of asbestos for brake pads. Observing the tremendous advantages and opportunities associated with natural fibers, there is a need to further investigate the tribological behavior of natural fiber based polymer composites. Hence, the present work aims to explore the possibility of using natural fibers in PLA matrix as a new applicant for tribological applications. The natural fibers used in the study are nettle, grew option and sisal fibers in mat form. The composite laminates were developed using the hot compression method. The dry sliding depreciation test on composite specimen has been carried out against steel counterface using the pin on disc apparatus for different sliding conditions. Friction coefficient and specific wear rate were calculated from the experimental results. The results show that wear execution of PLA, biopolymer has improved significantly due to natural fiber reinforcement. The maximum specific wear rate of developed

composites was more than 70% lower than the maximum wear rate of neat PLA. The scanning electron microscopy (SEM) technique has been occupied to study the worn surface morphology and possible wear mechanism[7]. The intention of this paper is to fabricate a new set of carbon black particulate filled polymer composite using biowaste wood apple shell. The effect of strong particle erosion wear and morphological behavior of the composite was measured. In addition, the wood apple shell particles were also characterized by EDS analyzer to find out the elementary composition present in the wood apple shell particles. Some results, previously published by Adinataetal.(2007), Dandekar et al. (2005) and Abdul Khalil et al. (2007), were very encouraging and point towards the possibilities of structural and thermal applications of these composites[8]. Microstructural studies reveal the even distribution of silicon nitride particles with the excellent bond between the matrix and reinforcement in both as-cast and hot forged condition. They have observed that increased content of reinforcement in both as-cast and hot forged composites do result in significant improvement in fatigue strength. However, when compared with as cast matrix alloy and its Composites, hot forged alloy and its composites exhibit higher fatigue strength. Both as a cast and hot forged composites demonstrate improved fatigue strength when compared with the reinforced alloys under identical test conditions. Fractured surfaces were examined using SEM for the possible fracture mechanisms [9]. There is no difference in the Marshall properties between the dry and wet processes when nylon fibres were used in fibre- reinforced asphalt mixture. Meanwhile, fibres used do not melt in the asphalt which means that there are no apparent special benefits to the wet process. Moreover, the field work done on fibre reinforced asphalt mixtures used the dry process [10]. The author is motivated in the field of natural fibre composite due to their many advantages over the synthetic fibre composite and huge application in the automobile, aerospace, insulating materials etc. This research work deals the mechanical behavior such as tensile, flexural and impact properties of sisal epoxy composite with varying length of sisal fibre [11]. The aims of this work were to produce cellulose from sisal fibers through acid correlated steam treatment and incorporation polypropylene/polystyrene blend (PP/PS blend). It was shown that the use of high aspect ratio cellulose whiskers induces a mechanical percolation phenomenon leading to outstanding and unusual mechanical properties through the formation of a rigid filler network of these nano fibers to study its effect on the properties of [12,8]. In consequence, this work is mainly aimed at evaluating mechanical, thermal, and morphological properties of the blends of polypropylene/filler, under the effects of different doses of gamma radiation. Filters used were wood flour and sisal fibre at 40 and 20 wt.% compositions, respectively. This selection was based on previous works carried out by other researchers and in our own laboratory In order to know the mechanism and the kinetics of the processes taking place in polymers with the participation of free radicals, study of the free radical structure is important using Electron spin resonance (ESR) and infrared spectroscopy (FTIR) [13]. The above review obviously shows that there is small work have been done on the impact of stacking sequence and addition of glass fibers with

two or more natural fibers. Hence, the present study is mainly focused on the influence of various stacking sequences on mechanical properties of the hybrid combination of banana, sisal and glass fibers[14,11]. The composites produced were characterized in terms of thermal and mechanical properties. Even though, a very large quantity of work has been published on various natural fibers based bio-composites, an effort has been made in the present work to introduce a new triglyceride oil-based polyurethane i.e. RSO-based polyurethane as the matrix in the development of new composite materials for lightweight structures. RSO is abundantly available in countries like Nigeria, India, Malaysia, etc. and is currently underutilized. It is hoped that the findings from this study will expand the application of RSO [15]. The current work focuses on the effect of abrasiveness to processing equipment using natural and synthetic fibres reinforced polyester composites; specifically treated betelnut fibre reinforced polyester (T-BFRP) and chopped strand mat (CSM) glass fibres respectively. For this purpose, it is important to acquire the fundamental understanding of different wear mechanisms and this is done through surface roughness measurement on the counterface and test specimens, followed by SEM examination of the worn surfaces [16]. The results show that wear performance of PLA, biopolymer has improved significantly due to natural fiber reinforcement. The maximum specific wear rate of developed composites was more than 70%lower than the maximum wear rate of neat PLA. Scanning electron microscopy (SEM) the technique has been employed to study the worn surface morphology and possible wear mechanism [17,16].).Hence, there will be an adsorption of the surfactant cations on the fiber surface through the ion-pairing mechanism between the cellulose anion and the pyridinium cations, leading eventually to the micelle formation as shown in Fig. 2. After the formation of PMMA film on the fiber surface through ad micellar polymerization, the treated fiber was used to prepare the fiber-reinforced unsaturated polyester composite and the mechanical properties of the composite were investigated [18]. The object of the present study is to use a convenient form of fibre/reinforcement, ie, natural fibres in the form of a mat or fabric, to fabricate composites by the hand lay-up technique. This is the first report by any Single group of researchers wherein the details of fabrication of composites, a number of consumer goods using coir/banana-cotton fabric-reinforced polyester composites and their performance on exposure to weathering are described [19]. The present paper describes the flexural fatigue behaviour under displacement control loading of a cross-ply laminate [0/90] Sisal/polyester biocomposite. A series of fatigue test measurements was performed on samples at different values of loading levels rs, defined as the ratio of dynamic loading level with respect to the static failure load. The use of those cyclic loading characteristics leads to a different and more pronounced hysteresis loops, with a strong dependency over the number of cycles and the loading ratios used [21]. The literature review studies the mechanical and thermal properties of betel nut and sisal fibre reinforced polymer composite and the aim of improving the mechanical and thermal properties which will replace the synthetic fibres.

2. FABRICATION OF SISAL AND BETEL NUT COMPOSITE

2.1 Material preparation

Betelnut is the fruit of Areca palm tree (Areca catechu), a species of palm. The fruits of betelnut are in the form of round or oval in shape, with the color of golden yellow to orange. The betel nut husk is the fibrous part of the fruit, which equals to approximately 60 to 80 % of total volume and weight of betelnut. The properties of betel nut fibre are given in Table.1.

Table 1 Average main chemical constitution of Betelnut fiber[1]

Fiber	Alpha Cellulose (%)	Hemicellulose (%)	Lignin (%)	Pectin (%)	Ash (%)	Other materials (%)
Betelnut	53.20	32.98	7.20	9.2-15.4	1.05	3.12

Table 1 Properties of betel nut

Betel nut fibers and Unsaturated polyerster composites were prepared in the different ratio of 5:95, 10:90, 15:85,20:80 (Betelnut fiber wt%:Unsaturated polyester wt%) using the cold press moulding technique. A circular mould with a diameter of 25 mm and thickness of 2, 4 and 6 mm was used to fabricate the sound absorption specimens. For the tensile test, a mould with a thickness of 5 mm and cross-sectional area of 72.5 mm was used. The inner surfaces of the mould were greased with a thin layer of wax as a release agent. The known weight of unsaturated polyester resin is mixed with 1% of MEKP catalyst to initiate polymerization of polyester resin and stirred properly. The known weights of betelnut fibers were mixed with a solution of catalyst and polyester resin. The mixture is then placed in the mould, making sure that the mould cavity is properly filled. A steel roller was used to distribute the fibers uniformly and to release the air bubbles from the composites. This procedure was repeated until a required thickness was achieved. A pressure of about 50 kPa was applied on the top of the mould to ensure that the bubbles were forced out then the composite is then left to cure for about 24 hours at room temperature. The mould was opened to remove the composites [1]. The materials employed in this investigation were general purpose polyester resin manufactured by ADD resins and chemicals (pty) Ltd., South Africa. The glass fiber was woven roving E-glass fiber of denier 10,820, tightness of weave 7.65 cm2, manufactured by Jiaxing Sunlong Industrial and Trading Co., Ltd., China. The Kevlar s49 fiber was a plain weave mat with denier 1500, tightness of weave 46.24 cm2, manufactured by Carr Reinforcement Limited,UK. The nylon fiber was plain weave with denier 1320, tightness of weave 183.40 cm2, manufactured by Tar Erh, Co., Ltd., China. The hand woven nylon fiber had denier 2360, tightness of weave 117.81 cm2. Dioctyl phthalate (DOP) was manufactured by Zhenzhoup and b Chemical Co., Ltd., China. Hand lay-up

method followed by compression was used to produce the composites in a metallic mold using 1 in. pure bristles brush to apply the polyester mix as prepared. Nine layers of the fibers each was used to produce the plain composites (monolithic) glass fiber reinforced polyester (GFRP), Kevlar composite (KFRP),nylon composite (NFRP) and locally woven nylon composite(LNFRP). Similarly, the asymmetric stacking sequence was used to produce hybrid samples of Kevlar and glass composite (KGFRP), glass and nylon composite (GNFRP) and glass and local nylon composite (GLNFRP) using 5 layers of glass with 4 layers of the other fiber respectively. Also, ter hybrid composites of the fibers were produced using asymmetric stacking sequence with 3layers each of the fibers[2]. Sisal fibre were cut in the length of 5 mm, 10 mm, 15 mm and 20mm. Fabrication of different composite sheets manufactured by hand lay-up method. Epoxy resin & hardener were mixed in ratio of 10:1 by weight as recommended. An aluminium mould with size dimension 400mm×200mm×3mm was used to prepare the composites. The properties of sisal fibre are given in Table.2.

Table 2.Mechanical, physical and chemical properties of sisal fibre [4].

Properties	Diameter (μm)	Density (g/cm3)	Cellulose (%)	Hemicellulose(%)	Pectin (%)	Lignin (%)	Wax (%)	Elongation at break (%)	Tensile strength (MPa)	Young's modulus (GPa
Sisal fibre	100-300	1.45	65-78	10-14	10	9.9	2	4-9	365	12.25

Table 2 Properties of sisal fibre

Four different type of composite has been fabricated with four different fibre lengths. Each composite has constant fibre content 30% by weight. Release agent wax was used to facilitate the easy removal of the composite from the mould. In the composite preparation, curing was done under the 30 kg weight for 24 hours. After 24 hours, the composite was cut according to the ASTM standard for tensile, flexural and impact test[4]. Jute and sisal fibres were reinforced in epoxy resin to prepare the hybrid composites. The epoxy resin (AY105) and corresponding hardener (HY 951) was mixed in a ratio of 10:1 by weight as recommended. The mix was stirred manually to disperse the resin and the hardener in the matrix. The composite slabs were made by conventional hand lay-up technique followed by light compression moulding technique. A stainless steel moulds having dimensions of 500 × 300 × 50 mm3 was used. A releasing agent was used to facilitate easy removal of the composite from the mould after curing.

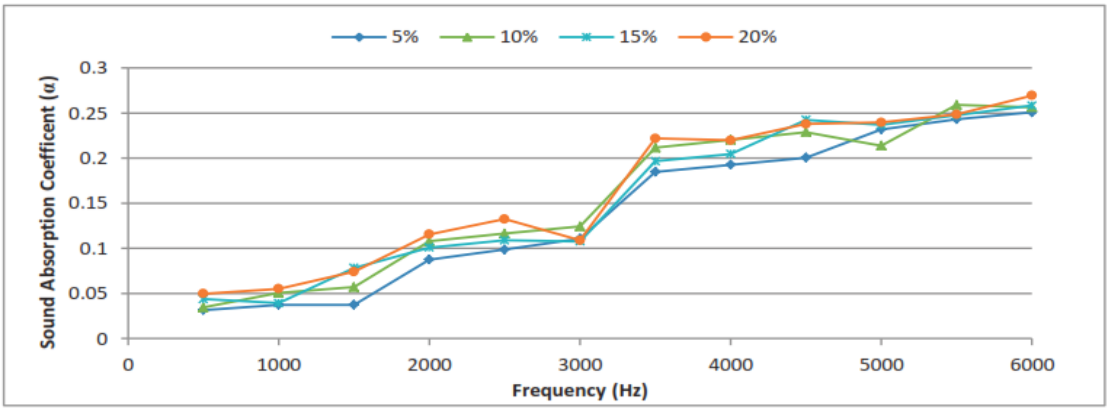
The cast of each composite was cured under a load of 50 kg for 24 hours before it was removed from a mould. The dimension of the specimen were cut as per ASTM standard by using a diamond cutter for dynamic mechanical and water absorption testing[8]. In the solution mixing method, a technique was developed by our group in which the fibre was mixed with a viscous slurry of polypropylene in a toluene/xylene mixture (1:1 ratio) prepared by adding toluene/xylene mixture to a melt of the polymer. The mix was then completely dried to remove the solvent and was then subjected to extrusion through a hand-operated injection moulding machine. Composites sheet of dimensions 120 mm12.5 mm 2.5 mm were prepared by compression moulding[9]. The composites were prepared by moulding in a hot press. Each composite specimen contained 12 g of sisal fibres that were divided into three layers of 4 g each prior to introduction into the mould. This ensured proper wetting of the fibres when the resin was poured onto the individual layers in sequence. Preparation of the polyester composites involved moulds curing at a pressure of 60 bars and temperature of 50° C for 20 min followed by post curing overnight at 80 °C. Epoxy resin composites were prepared by mould curing at a pressure of 60 bars and temperature of 80 °C for 20 min. Epoxy matrix samples were cured at 23 ± 1 °C for 23 h followed by curing at 100 °C for 4 h[11]. Fibres of different lengths (5, 10, 15 and 20 mm) and weight percentages (8, 12, 16 and 20) were mixed with epoxy for the initial preparation of composites. The moulds are cleaned and dried before applying epoxy. The fibers were laid uniformly over the mould before applying any releasing agent or epoxy. After arranging the fibers uniformly, they were compressed for a few minutes in the mould. Then the compressed form of fibers (banana and banana/sisal) is removed from the mould. This was followed by applying the releasing agent on the mould, after which a coat of epoxy was applied. The compressed fiber was laid over the coat of epoxy, ensuring uniform distribution of fibers. The epoxy mixture is then poured over the fiber uniformly and compressed for a curing time of 24 h. After the curing process, test samples were cut to the required sizes prescribed in the ASTM standards [12]. Betel nut fruits were soaked in water at room temperature for 5 d to loosen the fibre. The BNH fibres were separated manually from the nut part by hand stripping method and washed thoroughly with distilled water before drying in the oven at 70 C for 24 h. The dried BNH fibres were kept in desiccators to keep the fibres from the moisture from the atmosphere [15]. Coir fibre is extracted from coconut (one of the major crops in Polynesian countries) while banana fibres come from the banana pseudostem. Annual production of these fibres in India alone is about 0.16 million tonnes and 3600 tonnes respectively. These fibres are lignoceUulosic multicellular materials having cellulose and lignin as the major constituents. The length-to-diameter ratio of individual cells in coir, banana and cotton fibres are in the range of 35, 150 and 1300, respectively. Coir fibre is weather resistant[19].

2.2 Experimentation

Tensile testing was performed with an LS-28011-50 Universal Testing Machine T-machine Technology Co., LTD, Taiwan using ASTM D638 as the control specimen. The sound absorption properties of the composites were assessed using a locally fabricated and calibrated two-microphone transfer function method according to ASTM E1050-10, The sound absorption data were obtained with an impedance tube in the frequency range of 300 to 6000 Hz. All measurements were performed in accordance with ASTM E1050-10 using the standard setup depicted in Fig.1.

Fig.1. Effect of betelnut fiber content on sound absorption coefficients of composites[1].

The variation of tensile strength as a function of fibre loading is represented in figure 1. It



was observed that the mechanical properties of the untreated betel nut/Unsaturated Polyester composites increased linearly with the increase in fibre loading from 0% to 15%. This great increase in the mechanical strength is primarily attributed to reinforcing effect imparted by the fibres, which allow a uniform stress sharing from continuous polymer matrix to dispersed fibre phase. However, a noticeable decrease in mechanical strength of the composites was observed, as the fibre loading was increased from 15% to 20%. This decrease in the mechanical properties at high fiber loading implied poor fiber-matrix adhesion which promoted micro-crack formation at the interface as well as non-uniform stress transfer due to fiber agglomeration within the matrix [1]. Thermal analysis of composite samples Thermal gravimetric analysis (TGA) was carried out using approximately 25 mg of each sample. The sample was placed in a sample holder in a pre-calibrated Perkin Elmer testing machine and heated at the rate of 10 C/min under nitrogen flow of 20.0 ml/min for a temperature range of 30–900 C. The weight loss was obtained with respect to temperature [2]. Flexural strength and modulus of epoxy and short sisal reinforced epoxy composites are tabulated in Table 2 and corresponding data are plotted in Fig. 2. The result of the flexural test shows the positive effect of sisal fibre reinforcement into the epoxy matrix. The value of flexural strength was found a maximum of the composite S10 and flexural modulus for the composite S15. The flexural strength of S15 was found 25.05%, 41.29%, 22.91% and 1.34% more than E, S5, S10 and S20 respectively while the flexural

modulus of S10 was observed 167.33%, 10.62%, 16.68% and 10.86% more than E, S5, S15 and S20 respectively. Fig. 4. Effect of increasing sisal fibre length on flexural properties of sisal composite. [4].

The capability of the material to withstand suddenly applied load is its impact strength. The impact strength of the laminates was tested by Izod impact test rig. This test measured the kinetic energy needed to initiate the fracture and to continue until the breakage of a specimen. The standard dimension for the Izod test is ASTM: D4812. The test specimen was kept vertically with the help of grippers and the pendulum was blown from one side which strokes it with kinetic energy. The energy absorbed by the material before it fractured is recorded on the scale which was used to measure the toughness and ductility. The different Izod impact testing specimens are shown in Fig. 3. [6].Fig. 2.

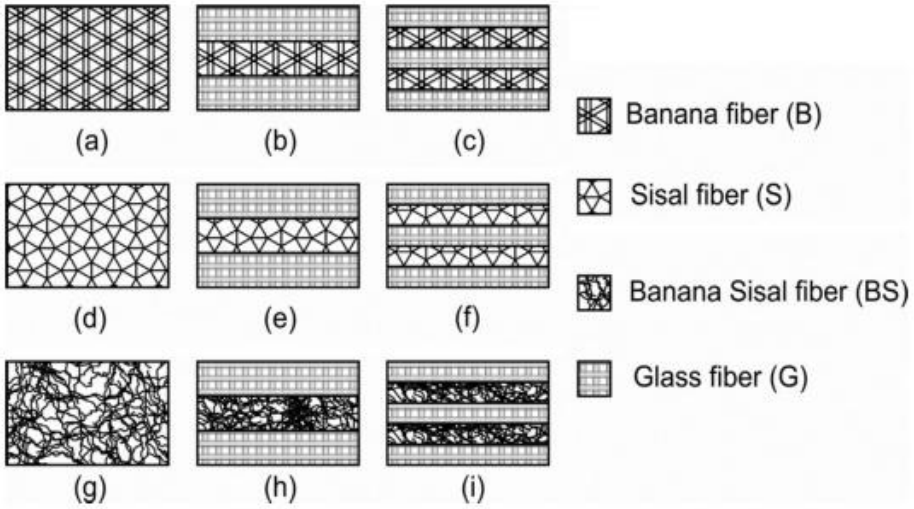


Fig. 2. Stacking sequence of the laminates (a) B, (b) G/B/G, (c) G/B/G/B/G, (d) S, (e) G/S/G, (f) G/S/G/S/G, (g) BS, (h) G/BS/G and (i) G/BS/G/BS/G. [6].

The water absorption tests were carried out by immersing the RSOPU based composites in the water bath for 24 h and 720 h, respectively, at 30 °C ± 2. Rectangular specimens of dimensions 40 * 10 * 3 mm were prepared. The specimens were dried in an

Oven at 105 °C, cooled in a desiccator using silica gel, immediately weighed and immersed in water. After immersion for 24 h, samples were carefully dried with a piece of soft cloth and weighed. The difference between the final (mf) and initial weights (m) of water uptake was Used to calculated percentage water uptake as shown in Eq. (1) thus:

$$\text{Water uptake}, M(\%) = \frac{m_f - m_0}{m_0} \times 100$$

For mechanical studies, the composite samples were maintained in these conditions for 30 days, a period in which the sample have attained equilibrium moisture content. This period was taken as equilibrium period in this study since no further remarkable change in their weights were detected

Table 3
Tensile, flexural and impact properties of hybrid composite.

Fiber content banana/ sisal	Tensile strength MPa	Tensile modulus MPa	Flexural strength MPa	Flexural modulus MPa	Impact strength kJ/m^2
100/0	16.12	642	57.33	8920	13.25
75/25	17.39	662.25	58.5085	9025	15.57
50/50	**18.66**	682.5	**59.687**	9130	**17.9**
25/75	19.93	702.75	60.8655	9235	20.22
0/100	21.2	723	62.044	9340	22.54

The determination of final moisture contents was also performed on at least three specimens for each sets of samples used for flexural and tensile analysis as described previously in Section 2.4. The water immersed samples, dried and weighed are regarded as wet samples in this study[7]. In order to improve the mechanical properties of the banana/epoxy composite, sisal fiber was added to bring the hybrid effect.

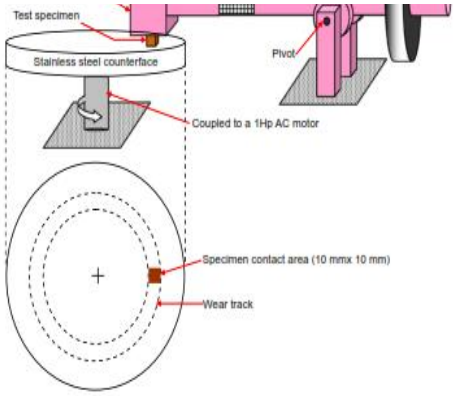
From the above results, the fiber weight of the composite was fixed to 16% and fiber length to 15 mm. Within this fiber weight percentage, the sisal fiber percentage is varied from 0–100%. Results of hybridization are tabulated in Table 5. From the Table, the addition of sisal up to 50% increases the tensile strength, flexural strength and impact strength around 16%, 4% and 35% respectively[12].The results of the analysis of the FTIR spectra for the PP/sisal fibre blend are shown in Table 4. As in the case of the previous blend, the presence of carbonyl groups of the aldehyde type is observed (Table 3) as well as bands characteristic of PP. Based on the FTIR studies, the presence of carbonyl groups in the PP/wood flour and PP/sisal fibre blends can be confirmed, but it cannot be assured that this is a consequence of the chain scission caused by irradiation. To estimate the approximate concentration of radicals in the samples, ESR spectra were analysed. These spectra show that the formation of radicals of the peroxide type strongly increases as the irradiation dose applied is higher. This effect is more marked in the PP/wood flour blend. Concentration values, expressed in relative units, of the free radicals present in the PP/wood flour and PP/sisal fibre blends as a function of the different radiation. These curves indicate that, independently of the filler used, irradiation causes radicals in the blends to increase as irradiation dose is also increased, the variation being insignificant at low doses (under 10 kGy) [13].

Table.4

Results of the FTIR spectra of irradiated PP/sisal fibre at different radiation dose

Functional group	Wavenumber (cm^{-1})					
	0 kGy	10 kGy	25 kGy	50 kGy	60 kGy	70 kGy
O (1700 cm^{-1}) ‖ R-C-H (2700cm^{-1}) Aldehyde	2724.7 (f) 1720.4 (f)	2724.7 (f) 1723.1 (f)	2755.6 (m) 1721.0 (f)	2723.1 (d) 1719.3 (d)	2726.7 (m) 1717.0 (m)	2755.7 (f) 1716.1 (f)
C = C [Olefins]	1649.1 (m)	1618.0 (d)	1618.8 (d)	1619.8 (d)	1634.2 (d)	1635.0 (d)
$-CH_2$	1456.6 (f)	1455.0 (f)	1410.1 (f)	1454.2 (f)	1453.6 (f)	1409.7 (f)
$-CH_3$	1373.7 (f)	1371.3 (f)	1371.6 (f)	1371.5 (f)	1371.1 (f)	1370.9 (f)

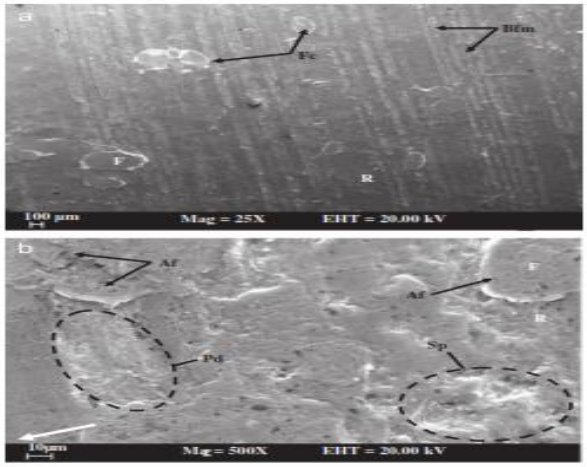
Frequency: f, strong; m, medium; d, light.



A Block on a Disc (BOD) tribotesting machine was used for the current work, Fig. 4. Test specimens with the dimension of 10 mm *10 mm * 20 mm was fitted into the specimen holder of the BOD machine while an applied normal load of 30 N was exerted on the test specimens under adhesive dry mode. Fibre mats of the test specimens were orientated anti-parallel to the sliding direction of the stainless steel counterface (1250 HB) at a fix sliding velocity of 2.8 m/s throughout the test for duration of 6.72 km of sliding distance. The test was carried out in accordance to the ASTM G9905 standard. However, it is to be highlighted here that, the parameters (i.e. 30 N of applied load, 2.8 m/s of sliding velocity and 6.72 km of sliding distance) were selected due to significant wear damages (observation through the naked eyes and SEManalysis) done/incurred onto the counterface and the test specimen contacting surfaces. Since the current work focuses on the effect of abrasiveness to processing equipment (i.e. stainless steel counterface of the BOD machine) using natural and synthetic fibres reinforced polyester composites, the authors found an interest to analyse the different wear modes of

damages through examination of surface roughness on the counterface and test specimens followed by the assistance of SEM analysis of the composite worn surfaces. Results of the wear and friction performance of the composites had been Previously reported by the participating authors of [16]

Fig.4.Schematic illustration of the BOD machine and test specimen



The SEM morphology of the virgin composite and the worn composite surfaces for T-BFRP and CSM-GFRP composites are shown in Figs. 4 respectively. Fig. 5 & 6. SEM images of T-BFRP composite virgin surface and after testing at 30 N of applied normal load, 2.8 m/s counterface sliding velocity and 6.72 km of sliding distance at different magnifications. (a) Virgin T-BFRP. (b) T-BFRP at 500 X and (c)T-BFRP at 3.00 KX.

T-BFRP composite. SEM image of the virgin cross section surface of the T-BFRP composite is presented in Fig. 8. From the figure, two different regions are noted, 'R' and 'F' indicating resinous and fibrous regions. Since the fibres were randomly distributed in mat form, many thin layers of betelnut fibre mats marked 'Bfm' corresponding to several fibre cross section can be observed. When the composite was tested against the BOD tribotesting machine, different wear modes after the test were observed at different magnifications. Fig. 7b indicates that the predominant wear after the test (i.e. subjected to 30 N of applied normal load, 2.8 m/s of stainless steel counterface sliding velocity and 6.72 km of sliding distance) was plastic deformation and adhered fibre namely at the resinous region due to the high intimate contact achieved (i.e. between counterface and composite test specimen).Besides this, there was an evidence of softening polyester on the worn surfaces due to the high thermal mechanical loading incurred during the dry sliding adhesive test.[18].

3. SUMMARY AND FUTURE RESEARCH

The synthetic fibres are replaced by natural fibres for polymer composite due to their several benefits. Sisal and betel nut fibre is one of the largely used materials in the field of automobile field(brake pad body panels,), aerospace, insulating materials rope, brush, mat, string, cable, cord, welding helmet, chair, table, roof etc. because of its environmental friendly, low cost and high specific mechanical performance. The sisal and betel nut fibre, its low density, lower flexural strength to betel nut and other material. The properties of sisal and betel nut could be improved according to the application-oriented areas. The ash and glass material used in the fabrication process should possess the properties of thermal stability, light weight, excellent bonding. There are so many work deals with the thermal stability, mechanical properties of the randomly oriented sisal and betel nut fibre reinforced polyester and epoxy resin composite. The composites were prepared by compression moulding method with short length fibre or long length fibre but different weight percent of sisal and betel nut fibre content. There will be more interests in the study on the sisal and betel nut fibre and the following studies could be done on future.

- Thermal behaviour with the aim of resisting the thermal characteristics
- Mechanical properties
- The composite can be characterised by XRD, FTIR, sem,tga,tem.

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