EFFECT OF FRICTIONAL DUST ON THE MECHANICAL PROPERTIES OF HYBRID BIOCOMPOSITE MATERIALS

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Increasing threads of the global warming and issues in disposals in municipal solid waste without compromising the mechanical properties the existing composite materials requires some additional materials. The traditional glass fiber, basalt fiber and epoxy based hybrid composite material is accommodate with bio waste tamarind seed polysaccharides and cashew nut frictional dust with different mesh with that the mechanical properties are improved based on the results of tensile, impact and flexural tests. The biodegradable test confirms the biodegradation of the fabricated samples with frictional dust.

Keywords: *Frictional Dust, Hybrid biocomposite, biodegradation, tensile property, Tamarind seed polysaccharides*

1. Introduction

The increasing awareness of the materials that works against environment and cause serious issues even to the mankind was attained after the annual usage of plastic materials and Asbestos materials was increased. As per the literatures annual utilization of plastic and environmental hazardous materials are increased to 16% annually on 2006 [1]. These wide range of consumption not only affect the environment but also affects the municipal solid waste management system. To solve the white pollution without compromising the mechanical properties, the composite materials was the choice because of their biodegradability and ability to suit for all kind of applications[2].

The composite material formation requires one matrix and one filler material but in order to strengthen itsproperties more filler materials can be added and that results as hybrid composites. In this work biowaste material Tamarind seed polysaccharides (TSP) is added along with filler materials in the view of reducing municipal solid waste and preserving the environment due to their degradability[3]. previously banana, rice husk, jute, bamboo were utilized along with glass fiber and considerably improved the properties along with polymer matrices. Tamarind seed polysaccharides (TSP) are obtained from tamarind trees which are large in India and used for various applications[4]. But the seeds are left as residual waste which contains cellulose, hemicelluloses, and lignin. preassembly TSP can be utilized along with polymer matrix material as a filler material[5].

The matrix material is the binder that binds the reinforcements as well as filler materials. The most widely used polymer matrix is epoxy because of its properties and curing activity along with hardener[6]. The adhesion of epoxy along with glass fiber and basalt fibers produced notable properties. Glass fibers are mostly used in the aircraft parts like basalt fiber which is the byproduct produced by the volcano[7].

In order to improve their mechanical properties more to meet the industrial requirements as well as to act as complete remedy for environmental problems the frictional dust with different mesh has been introduced[8]. The spongy organic material with lowest MOHS hardness is the cashew friction dust which obtained by the direct polymerization of cashew nut shell liquid[9]. The polymerization with curing agent yields an amorphous material which is then pulverized to granules[10]. Based on the mesh of the cashew friction dust the 40, 60 and 100 mesh were used in this work.

To study or evaluate the presence of friction dust in the hybrid biocomposite materials the samples were tested with mechanical, thermal, barrier and biodegradability tests. The hybrid combination of both basalt fiber and glass fibers are already reported but the natural filler like cashew frictional dust as well as TSP included BF/GF hybrid composite materials are not developed best of our knowledge.

2.Materials and Methods

2.1.Materials

Glass Fiber

The primary reinforcement of this hybrid composites is glass fiber and its properties are listed in Table(1). The glass fiber was purchased in the form of bidirectional mat from covaiseenupvt. ltd, Coimbatore, India.

Basalt Fiber

In this investigation, The excellent chemical as well as adhesion properties of the basalt fibers inspire to choose in the fabrication of hybrid composites. The

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Table 1

Properties of glass fiber

Sl.no	Properties	Value
1	Density	2.56 g/cm^3
2	Filament Diameter	15 μm
3	Tensile Strength of Single Filament	3250 MPa
4	Elastic modulus	74GPa
5	Elongation at break	4.7%
6	Specific gravity	2.6
7	Thermal Conductivity	0.032 W/m k
8	Thermal expansion coefficient	5.4 ppm/°c

Table 2

Properties of basalt fiber

Sl.no	Properties	Value
1	Density	2.7 g/cm^3
2	Filament Diameter	12 μm
3	Tensile Strength of Single Filament	4020 MPa
4	Elastic modulus	102 GPa
5	Elongation at break	5%
6	Specific gravity	2.66
7	Thermal Conductivity	0.038 W/m k
8	Thermal expansion coefficient	8 ppm/°c

Table 3

Properties of epoxy

Sl.no	Properties	Value
1	Density	1290 kg/m^3
3	Tensile Strength	30 MPa
4	Elastic modulus	2.7 GPa
5	Elongation at break	2%

basalt fibers used in this fabrications were purchased from covaiseenupvt. ltd, Coimbatore, India as a bidirectional mat sheet(380 GSM). The properties are listed in the table(2).

Epoxy

The excellent adhesion property and ready usability of the Epoxy made us to choose as the resin for this hybrid composite. The hardener, promoter and Accelerator for this resins also purchased from the covaiseenupvt. ltd, Coimbatore, India.

Tamarind Seed Polysaccharide and its Preparation

In order to study the effect of natural filler materials in the hybrid composites TSP is purchased from Nema seeds, Theni.

The tamarind seed polysaccharide (TSP) were cleaned thoroughly and crushed through shear mixer until fine powder was obtained. Then, the TSP was dried in a hot air oven at 100 °C for one hour to remove the moisture content. With the aid of a sieve, the powder with particle size less than 20 μm was obtained and used in the present work

Frictional Dust preparation

A slurry of phosphorylated cashewnut shell liquid prepolymer and organic solvent is prepared like slurry. In a conventional mixer the slurry was mixed for a period of 20 to 30 minutes. The resultant powder was then pulverized in order to obtain granules. Then the obtained granules are sieved to various meshes like 40 mesh, 60 mesh and 100 mesh. The frictional dusts were thermohardened in the temperature range of 80°C for a period of 20 minutes[11].

Methods

Fabrication of FD/TSP/GF/BF Composite materials

Compression molding process is used to fabricate TSP/GF/BF/Epoxy composites. The different amount of FD (40 , 60, 100mesh) has been added to the resin to prepare hybrid composite samples with 60% volume fraction of fiber. To manufacture hybrid composite by compression molding (CM), a steel mold frame has been used in this work as shown in figure (1). By percentage calculations the mixture of epoxy/TSP with hardener (10:1) resin has been poured uniformly over fiber mat stacked above the aluminum foil sheet of 0.1 mm thickness. Then the top and bottom mold is closed properly and placed in compression molding setup (CM) as shown in figure (1).During placement of top mold over the stacked laminate some of the resin mix has been squeezed out. Uniform pressure of 30–50 Kg/cm^2 and temperature of 150ºc is applied over top and bottom mold and maintained throughout the process. The specimen was cured in the compression molding for period of 1 1/2 hr. After curing the samples were taken out from the mold, and as per ASTM

Fig. 1 - Compression molding Machine and mold for fabrication

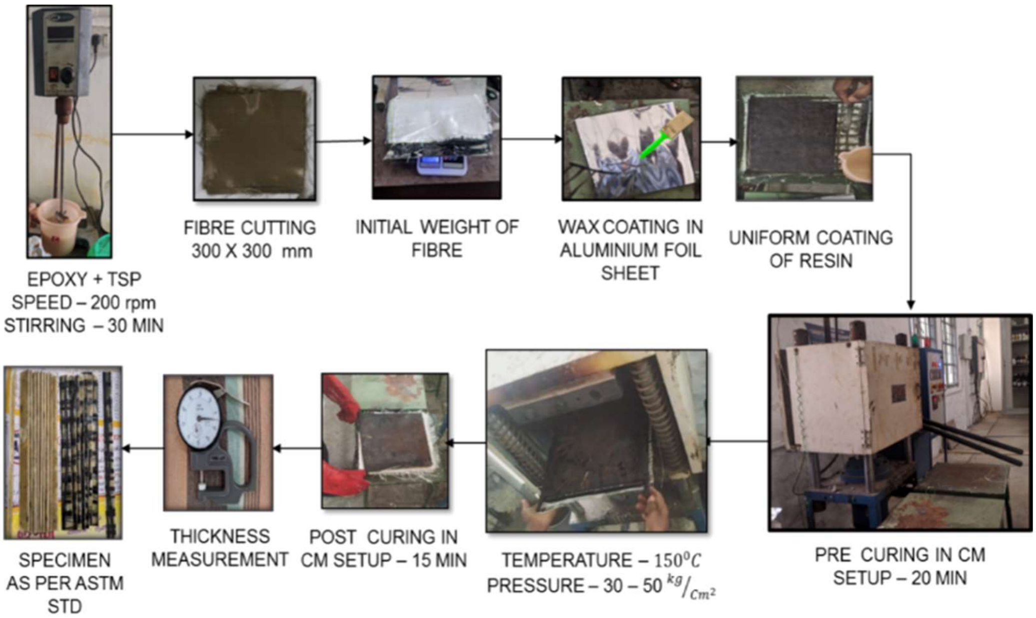

Fig. 2 - Various process involve in manufacturing of hybrid composites

testing standards (D3039/D3039M) and (D7264) the specimens are cut using switch board cutter to required shape, size for mechanical testing. For the purpose of comparison, the prepared composite specimen is weighted and thickness is measured using thickness measurement gauge. The entire flow process is shown in Figure(2).

Characterization of Composite Materials

FTIR

A SHIMADZU spectrometer FTIR interferometer was used to find the presence of unknown components and to identify the functional group of the prepared samples. It works on the scanning rate of 45 scans per second and with a resolution of 4. The spectrum recorded the wavenumber range of 4000cm-1-500cm-1.

XRD

The experiment was carried out by the XPERT-PRO diffractometer system under an ionic scan and the signal was recorded between 10o to 80o. The optimum generator setting of current was 30mA and tension of 40 kV with Cu as an anode material at a temperature of 25oC. The crystalline size (CS) of the samples are calculated by Scherrer's formula [12]

$$CS = \frac{K\lambda}{\beta \cos\theta} \quad (1)$$

Tensile Test

The tensile properties like tensile strength and % of elongation were determined by using the Zwick/Roell apparatus. The prepared samples were taken as per ASTM D882 [13]specifications. The samples were cut into and allowed to test under nominal test speed and preload of 1.5 mm/min and

0.3 N respectively. Totally 10 specimens were tested for each category of the hybrid composite.

Surface morphology (FESEM)

The surface morphology of the prepared samples was investigated by capturing micrographs of the representative samples using Nova Nano SEM 450, a field–emission scanning electron microscope (FE –SEM) equipped with an energy dispersive X-ray (EDX) analyzer. The operating voltage is 2 kV, (Make: carl Zeiss (USA), Model: sigma with Gemini column), and resolution of 1.5 nm. The samples were prior coated with gold for 2 minutes using EMITECH SC7620 Mini Sputter Coater.

Flexural Test

Flexural strength is also known as bending strength or rupture strength. It is the property of a material defined as the stress in a material just before it yields in a rupture test or simply it is said as the maximum stress observed by the materials. Dark system Inc device is used to perform the 3-point bending test for the prepared composite specimen following the recommended standard procedure (ASTM D7264/D790)[14].

Impact Test

By following the ASTM standard ASTME2248 the samples were dimensioned (65mm × 13 mm × 3mm)for impact test[15]. The test was carried out on the Charpy impact machine.

Water absorption

The gravimetric method is used to determine the water absorption of the fabricated samples. The samples are sized into 3cm × 5cm and kept in an oven for 24 hrs at 50°C. After the completion of the drying process, the weight of the samples is noted as W_1 and the dried film samples are immersed in distilled water of 100ml for 24hrs. The weight of the films is measured after the immersing time and noted as W_2.[16]

$$\text{Water absorption } \% = \frac{W2-W1}{W1} \times 100 \quad (2)$$

30 days BiodegradabilityTest

The degradation property of fabricated hybrid biocomposite are studied through the Soil burial degradation method. Soil burial degradation method is described by (Balavairavan&Thakore paper 110,111) [17]and the same procedure is followed with slight modification in this work. A pot of almost 10lit capacity filled with agricultural soil and a proper drain hole is entertained in the bottom of the pot. The samples are sized into 300mm × 100mm (W×L) rectangular pieces before the experiment. These rectangular specimens are placed in the pot at a depth of 5cm. The pot arrangement is kept at room temperature in absence of direct fall of sunlight. The soil is water on the surface to maintain 40-50% humidity. The excess water is allowed to drain through the drain hole in the pot. The samples are monitored for the degradation behavior for 30 days and the samples are removed from the soil and washed gently with distilled water to remove soil dust on it. After the removal of dirt, the samples are dried at the oven at 60°C to remove excess moisture or water particles on it. Then the samples are weighed to find the weight loss due to degradation. The degradation behavior is calculated by the loss of weight concerning the initial weight and expressed in terms of percentages.

Result and Discussion

FTIR

The presence and category of interfacial bonds in the system was examined by Fourier transform infrared experiment and the Figure (3) illustrates the recorded spectrum. In this all the prepared composites shows almost same spectrum of FTIR, which shows the proper distribution of TSP& FD and matrix materials along with reinforcements. The functional group presence are decided through the peaks around 1850 and 1700 cm^{-1}[17]. The OH bond and C-H bond presence were decided through the broad peak at 3630 cm^{-1} and 2995 cm^{-1}. The OH bond presence was due to the cashew nut frictional dust's cellulose components. The confirmation of C=C stretching because of peak at 1634 cm^{-1} and 1743cm^{-1} shows the acetyl groups in the hemicellulose of TSP& FD[18]. The peak at 619 cm^{-1} sugar units by glucosidic linkages. From this the Frictional dust as well as TSP particles present in the hybrid composites does not disturb any functional groups of the hybrid composites and are attached electro statically to the surface of the composites. With this attachments in the surface likely to enhance the barrier as well as mechanical properties of the hybrid composites.

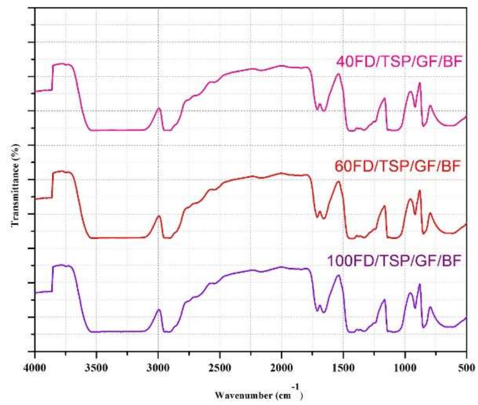

Fig. 3 - FTIR analysis of (100,60,40) FD/TSP/GF/BF hybrid composite

XRD

X-ray diffractograms of composites are shown in FIG(4). There is a common peak at 2ϴ=18.9° indicates the cellulose presence[19]. The cellulose presence were confirmed due to the inclusion of TSP and frictional dust. The higher intensity peak is observed in the 100 meshFD composites because of the presence of cellulose content in them. The intensity of the peaks gets reduced as the mesh of the FD decreases.

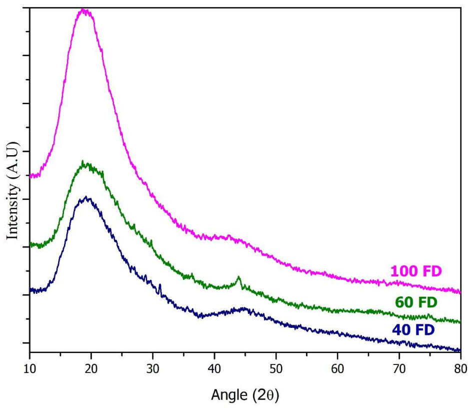

Fig. 4 - XRD pattern of (100,60,40) FD/TSP/GF/BF hybrid composite

The crystallite size (L) of the fabricated samples are fabricated with the scherer's equation in Equation (4). The calculated crystallite size is tabulated in Table (4). The crystallite size of 100 meshFD is 16.21nm and it is the highest crystallite size among all the fabricated composite samples. The 40 meshFD composite has a crystallite size of 14.12nm.

Tensile test

Tensile properties of the hybrid composites with FD particles are listed in the Table(5). Tensile strength of the 100 mesh FDpossess maximum tensile strength and tensile modulus as 281MPa and 6.32GPa respectively. Whereas the 40 meshFDincorporated hybrid composite shows the minimal tensile property with the value of 241MPa and 4.7GPa as tensile strength and tensile modulus. This increased tensile property is due to the surface roughness formed by the FD & TSP which are attached electro statically on the surface of the hybrid composite.

The elongation at break (%) is decreasing with an increase in the mesh of the FD content in the composites. The 100 meshFD based hybrid composite shows the highest elongation at break with 16.4% whereas the 40 meshFDproduced the value of 11.1% as the elongation at break. The composite with 60 mesh FD posses the elongation at break of 13.5% respectively. This decrease in elongation is due to the lack of flexibility or surface roughness resulted from the inclusion of TSP & FD filler materials in the hybrid composites.

Morphological Analysis

FESEM

Figure (5) shows the proper adhesion of FD &TSP on the surfaces of glass fiber as well as basalt fiber. This might happens because of the gluing between the organic components present in glass fiber, basalt fiber surfaces and FD- TSP. This interaction strengthen the bonding between glass fiber, basalt fiber and epoxy matrix. Also the fiber pullout is observed on the few areas due to the tensile fractured samples. There is an increase in surface roughness observed in the samples with increase in the mesh of the FD.

EDX

The elemental components of the samples are determined through energy dispersive X-ray. The X-ray spectrum shows the components like Si, Ca, Na, Al, Mg, K, Fe which confirms the presence of Basalt fiber in the Figure(6). Likewise the presence of components like C,O, Mg, Al, Si and Ca are confirmed through the respective peaks at spectrum, which made the conclusion of presence of glass fiber[20]. The presence of TSP& FD can also be confirmed with the presence of Carbon peak. From this edx analysis it is confirmed that proper distribution of reinforcement materials in the epoxy matrix.

Table 4

Diffraction data of (100,60,40) FD/TSP/GF/BF hybrid composite

Sl. No	**Film**	**Peak at 2θ (°)**	**Crystallite Size (nm)**
1	100 FD/ TSP/GF/BF	18.9	16.21
2	60 FD/ TSP/GF/BF	18.9	15.40
3	40 FD/ TSP/GF/BF	18.8	14.12

Table 5

Tensile Properties of (100,60,40) FD/TSP/GF/BF hybrid composite

Sl.no	Hybrid Composite	Tensile Strength	Tensile Modulus	% of Elongation
1	100 FD/ TSP/GF/BF	281	6.32	16.4
2	60 FD/ TSP/GF/BF	262	5.10	13.5
3	40 FD/ TSP/GF/BF	241	4.7	11.1

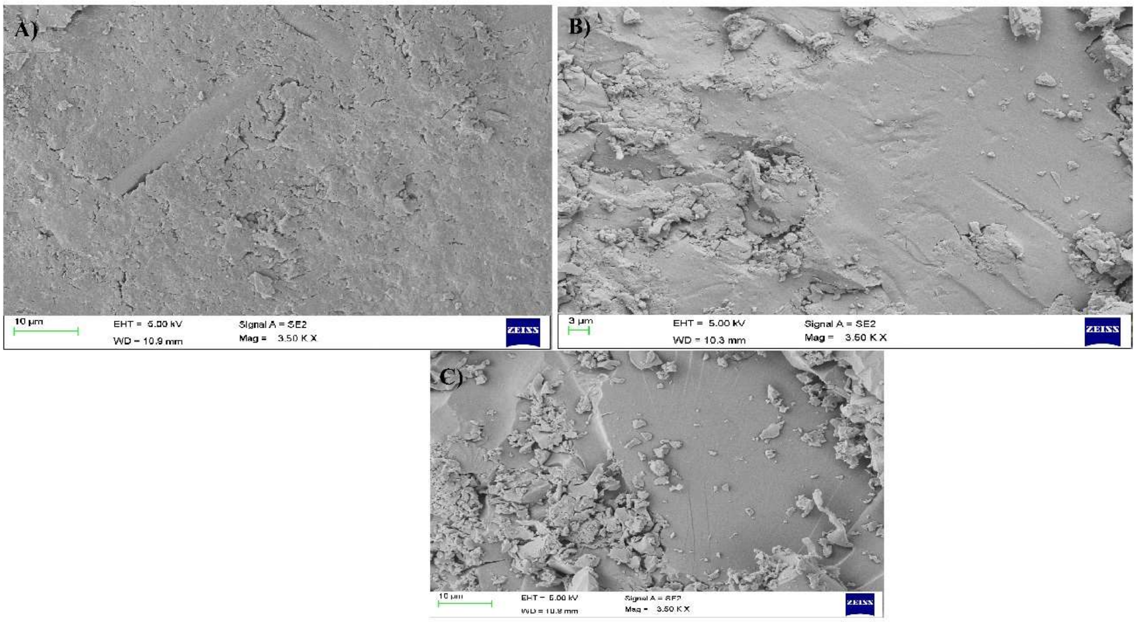

Fig. 5 - SEM image of (100,60,40) FD/TSP/GF/BF hybrid composite.

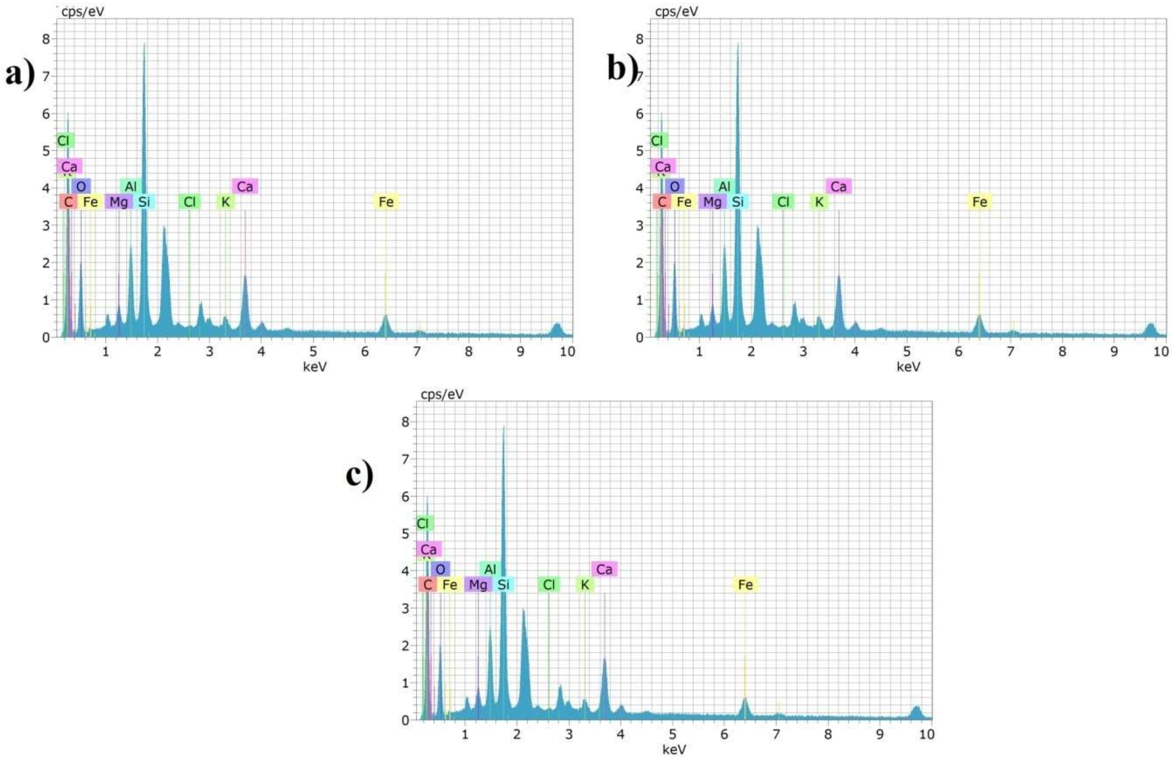

Fig. 6 - EDX spectra of (100,60,40) FD/TSP/GF/BF hybrid composite

Flexural Test

The influence of TSP& FD particles on the flexural behavior of glass fiber/basalt fiber based hybrid composite materials were studied through flexural test. The similar tensile property trend is observed in the flexural properties also. Due to the bending and shearing moment flexural failures are occurred in the prepared hybrid composite. The improvement in the hybrid composites flexural strength with the inclusion of higher amount of the Mesh FD and TSP filler is due to the shear force resistance developed by TSP. The flexural strength possessed by the 100 meshFD hybrid composite is maximum with 965.3MPa in contrast 40 meshFD hybrid composite possessed 766.9MPa. The higher inclusion of TSP shows maximum flexural strength with the reason stated earlier.

Table 6

Flexural test report (100,60,40) FD/TSP/GF/BF hybrid composite

Sl.no	Hybrid Composite	Flexural Strength (MPa)
1	100 FD/ TSP/GF/BF	766.9
2	60 FD/ TSP/GF/BF	905.5
3	40 FD/ TSP/GF/BF	965.3

Table 7

Impact test of (100,60,40) FD/TSP/GF/BF hybrid composite

Sl.no	Hybrid Composite	Impact Strength (J/mm^2)
1	100 FD/ TSP/GF/BF	16
2	60 FD/ TSP/GF/BF	22
3	40 FD/ TSP/GF/BF	32

Table 8

Water absorption property of (100,60,40) FD/TSP/GF/BF hybrid composite

Sl.no	Hybrid Composite	Before Weight (W_1)	Wet weight (W_2)	Increase in Weight(%)
1	100 FD/ TSP/GF/BF	4.178	5.09716	0.22
2	60 FD/ TSP/GF/BF	4.442	5.24156	0.18
3	40 FD/ TSP/GF/BF	4.608	5.16096	0.12

Impact Test

Izod Machine was utilized to analysis the impact test of the hybrid composite, the least value possed by the 40 mesh FD with 16 J/mm^2. The 100 mesh FD shows the maximum impact strength of 32 J/mm^2. This shows the higher mesh inclusion of FD maximize the impact strength of the hybrid composite.

Water absorption Test

Water absorption behavior of FD influenced hybrid composites at a certain environment is determined by various factors including type of matrix, filler technique involved for fabrication and mainly composition of composites as well as duration of immersion. The water absorption behavior is illustrated in the Table (8). It is evident that inclusion of FD at higher mesh improves the water absorption behavior of the hybrid composites because of the OH bond in the FD and TSP. since maximum FD mesh has large area it absorbs more water. The 40 mesh FD hybrid composite shows 0.22% improved weight to its initial weight whereas40 mesh FD involved hybrid composite shows only 0.12% of improved weight due to the hydrophobic nature of polymeric materials present in the hybrid composites.

30 Days Biodegradability Test

Degradation property of the fabricated sampleswere analyzed by the soil burial test which is more effective than the enzymatic test . The samples are buried in the soil for a period of 30 days. The degradation process is done by the involvement of various microorganisms. In this test, the weight loss during the proposed period has been found and is represented in weight loss % to initial weight. The degradation behavior of fabricated samples are represented in Figure (7). The 100 mesh FD/TSP/GF/BF shows the degradation behavior of 2.5% concerning its initial weight. The 40 mesh FD/TSP/GF/BF has a weight loss of 27.53% to its initial weight. The weight loss % concerning initial weight is increased with lowering the mesh size of the FD[21,22]. Even though all the components in the fabricated samples are biodegradable materials, the FD behaves as more biodegradable than the Epoxy and other filler materials in the hybrid samples. So, the biocomposite are more biodegradable by the inclusion of FD and they can be chosen as a substitute for non-eco friendly materials used in the field where plastics dominating.

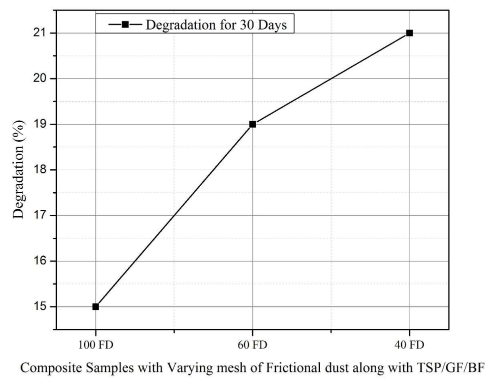

Fig. 7 - Biodegradability test of(100,60,40) FD/TSP/GF/BF hybrid composite

Conclusion

The hybrid composite with frictional dust material concludes that the functional group of the materials don't get disturbed by the frictional dust and FD are held in the surface of the composites electrostatically. The XRD analysis confirms the presence of the cellulose and hemicellulose due to the FD and TSP components and the crystalline sizes are increased with the inclusion of FD at higher mesh. Tensile strength, flexural and impact strength of the hybrid composite were increased with the inclusion of the FD at higher mesh. 30 days biodegradability test confirms the biodegradation of the composite materials at a high rate. Herewith it is concluded that FD/TSP/GF/BF hybrid composites can be utilized for the applications like aircraft materials where hybrid composites were utilized earlier with the benefit of biodegradation and can be solution to all the environmental problems like white pollution and solid waste disposal.

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