STUDY ON MECHANICAL BEHAVIOUR OF POLYMER BASED COMPOSITES WITH AND WITHOUT WOOD DUST FILLER

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Bachelor of Technology in Mechanical Engineering

BY

SANJAYA KUMAR BEHERA
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DEPARTMENT OF MECHANICAL ENGINEERING
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Under the guidance of

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CERTIFICATE

This is to certify that the thesis entitled "***Study on Mechanical Behaviour of Polymer Based Composites with and without Wood Dust Filler*"** submitted by **Sanjaya Kumar Behera (Roll Number: 10603025)** in partial fulfillment of the requirements for the award of ***Bachelor of Technology*** in the department of Mechanical Engineering, National Institute of Technology, Rourkela is an authentic work carried out under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to elsewhere for the award of any degree.

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A C K N O W L E D G E M E N T

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Date**:**

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ABSTRACT

Particulate fillers are of considerable interest, not only from an economic viewpoint, but as modifiers especially the physical properties of the polymer. A notable advance in the polymer industry has been the use of fiber and particulate fillers as reinforcements in polymer matrix. Over the last few decades, the considerable attention has been devoted towards wood dust filled polymer composites due to its many advantages. These include mainly the improved environmental performance, due to the use of biodegradable materials and the reduction in the use of non-renewable (oil based) resources throughout the whole life cycle of the composite; the low cost of wood flour; the lower specific weight of these fillers, in comparison to the traditional mineral-inorganic ones; the improvement in safety for the production employees and the special aesthetic properties of the composites. Although there are several reports in the literature which discuss the mechanical behavior of wood/polymer composites, however, very limited work has been done on effect of wood dust fillers on mechanical behavior glass fiber based polymer composites. Against this background, the present research work has been undertaken, with an objective to explore the potential utilization of wood dust filler as a reinforcing material in polymer composites and to investigate its effect on the mechanical behaviour of the resulting composites. Finally, the SEM analysis has been made on fractured surfaces of composites after different tests.

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Chapter 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1. Composite Overview

Owing to their excellent mechanical properties, composite materials have been widely used throughout the last four decades. A composite material is defined as a combination of two or more materials that results in better properties than when the individual components are used alone. As opposed to metal alloys, each material retains its separate chemical, physical and mechanical properties, etc. Composite materials are consisting of one or more discontinuous phases embedded in a continuous phase. The discontinuous phases are usually harder and stronger than the continuous phases and are called the 'reinforcements' or 'reinforcing materials', whereas the continuous phase is termed as the ' matrix' which is more ductile and less hard. The reinforcements serve to strengthen the composites and improve the overall mechanical properties of the matrix. Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergistic way resulting in improved or better properties. Apart from the nature of the constituent materials, the geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent. The concentration distribution and orientation of the reinforcement also affect the properties. The interface has characteristics that are not depicted by any of the component in isolation. The interface is a bounding surface or zone where a discontinuity occurs, whether physical, mechanical, chemical etc. The matrix material must "wet" the fibre. To obtain desirable properties in a composite, the applied load should be effectively transferred from the matrix to the fibres via the interface. This means that the interface must be large and exhibit strong adhesion between fibres and matrix. Failure at the interface (called debonding) may or may not be desirable.

1.2. Composite Types

Composites can classify on the basis of the type of matrix employed in them- for example, polymer matrix composites, metal matrix composites and ceramic matrix composites. The details of these types are discussed below:

(a) Metal Matrix Composites

A composite material consisting of metal as matrix is called metal matrix composites. It have many advantages over monolithic metals like higher specific strength and modulus, lower coefficient of thermal expansion and better properties at elevated temperatures. Due to their above advantages, metal matrix composites are under consideration for wide range of applications viz. combustion chamber nozzle (in rocket, space shuttle), tubing, cables, heat exchangers, structural members, housings etc.

(b) Ceramic matrix Composites

If the matrix material is ceramic, then the composite is called ceramic matrix composite. One of the main objectives in producing ceramic matrix composites is to increase the toughness. Naturally it is hoped and indeed often found that there is a concomitant improvement in strength and stiffness of ceramic matrix composites. The most commonly used matrix materials are SiC, Al_2O_3 etc.

(c) Polymer Matrix Composites

Most commonly used matrix materials are polymeric. The reasons for this are twofold. In general the mechanical properties of polymers are inadequate for many structural purposes. In particular their strength and stiffness are low compared to metals and ceramics. These difficulties are overcome by reinforcing other materials with polymers. Secondly the processing of polymer matrix composites need not involve high pressure and doesn’t require high temperature. Also equipments required for manufacturing polymer matrix composites are simpler. For this reason polymer matrix composites developed rapidly and soon became popular for structural applications.

The composite may also classify on the basis of the type of reinforcement the employ such as particulate reinforced composites and fiber reinforced composites. The details have been discussed below:

- **Particulate Reinforced Composites**

If the reinforcement in composite material is in the form particle then the composite material is called particulate reinforced Composites. It may be spherical, cubic, tetragonal, a platelet, or of other regular or irregular shape, but it is approximately equiaxed. In general, particles are not very effective in improving fracture resistance but they enhance the stiffness of the composite to a limited extent. Particle fillers are widely used to improve the properties of matrix materials such as to modify the thermal and electrical conductivities, improve performance at elevated temperatures, reduce friction, increase wear and abrasion resistance, improve machinability, increase surface hardness and reduce shrinkage. Also, in case of particulate reinforced composites the particle can be either randomly oriented or preferred oriented.

- **Fibrous Reinforced Composite**

If the reinforcement is in the form of fiber, then the composite material is called fibrous reinforced romposite. A fiber is characterized by its length being much greater compared to its cross-sectional dimensions. The dimensions of the reinforcement determine its capability of contributing its properties to the composite. Fibers are very effective in improving the fracture resistance of the matrix since a reinforcement having a long dimension discourages the growth of incipient cracks normal to the reinforcement that might otherwise lead to failure, particularly with brittle matrices. Man-made filaments or fibers of non polymeric materials exhibit much higher strength along their length since large flaws, which may be present in the bulk material, are minimized because of the small cross-sectional dimensions of the fiber. In the case of polymeric materials, orientation of the molecular structure is responsible for high strength and stiffness. Again composites with long fibers are called continuous fiber reinforced composites and those with short fibers, discontinuous fiber reinforced composites. The continuous fibers in single layer composites may be all aligned in one direction to form a unidirectional composite. Such composites are fabricated by laying the fibers parallel and saturating them with resinous material. The bidirectional reinforcement may be provided in a single layer in mutually perpendicular directions as in a woven fabric. The bidirectional reinforcement may be such that the strengths in two perpendicular directions are approximately equal. The orientation of discontinuous fibers cannot be easily controlled in a composite material. So fibers can be either randomly oriented or preferred oriented. In most cases the fibers are assumed to be randomly oriented in the composites. However, in the injection molding of a fiber reinforced polymer, considerable orientation can occur in the flow direction and which a case of preferred oriented fibers in the composites.

In a fiber reinforced composite, the fibers carry the bulk load and the matrix serves as the medium for the transfer of the load. Addition of filler materials, further improves the functional properties of these composites. Such a multi-component composite system consisting of matrix, fiber and particulate filler is called a hybrid composite. Applications of such structures are observed in aircraft components, offshore and marine, industrial, military and defense, transportation, power generation etc. The filler materials include organic, inorganic and metallic particulate materials in both micro and nano sizes. Various kinds of polymers and polymer matrix composites reinforced with metal particles have a wide range of industrial applications. These engineering composites are desired due to their low density, high corrosion resistance, ease of fabrication, and low cost. Similarly, ceramic filled polymer composites have been the subject of extensive research in last two decades. The inclusion of inorganic fillers into polymers for commercial applications is primarily aimed at the cost reduction and stiffness improvement. Along with fiber reinforced composites, the composites made with particulate fillers have been found to perform well in many industrial applications.

1.3. Fiber Reinforced Polymer Composites

Polymer composite materials have generated wide interest in various engineering fields, particularly in aerospace applications. Research is underway worldwide to develop newer composites with varied combinations of fibers and fillers so as to make them useable under different operational conditions. Although extensive work has been reported in the literature on the mechanical behaviour of fiber reinforced polymer composites, however, very limited work has been done on effect of filler content on mechanical behaviour of glass fiber reinforced epoxy composites. Against this background, the present research work has been undertaken, with an objective to explore the potential of wood dust as particulate filler in glass fiber based epoxy composites and to investigate its effect on the mechanical behaviour of the resulting composites.

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Chapter 2

LITERATURE SURVEY

CHAPTER 2

LITERATURE SURVEY

This chapter outlines some of the recent reports published in literature on mechanical behaviour of polymer matrix composites with special emphasis on the particulate filled polymer composites.

The polymers have replaced many of the conventional metals/materials in various applications over the past few decades. This is owing to the advantages of polymers over conventional materials such as ease of processing, productivity, cost reduction etc. Research is underway worldwide to develop newer composites with varied combinations of fibers and fillers so as to make them useable under different operational conditions. In most of these applications, the properties of polymers are modified using fillers and fibers to suit the high strength/high modulus requirements. A notable advance in the polymer industry has been the use of fiber and particulate fillers as reinforcements in polymer matrix. Particulate fillers are of considerable interest, not only from an economic viewpoint, but as modifiers especially the physical properties of the polymer. It is well documented in the literature that majority fillers have a positive influence on mechanical properties.

Hard particulate fillers consisting of ceramic or metal particles and fiber fillers made of glass are being used these days to dramatically improve the properties of composite materials, even up to three orders of magnitude [1]. Various kinds of polymers and polymer matrix composites reinforced with metal particles have a wide range of industrial applications such as heaters, electrodes [2], composites with thermal durability at high temperature [3] etc. These engineering composites are desired due to their low density, high corrosion resistance, ease of fabrication and low cost [4-6]. Similarly, ceramic filled polymer composites have been the subject of extensive research in last two decades. The inclusion of inorganic fillers into polymers for commercial applications is primarily aimed at the cost reduction and stiffness improvement [7, 8]. Along with fiber-reinforced composites, the composites made with particulate fillers have been found to perform well in many real operational conditions. When silica particles are added into a polymer matrix to form a composite, they play an important role in improving electrical, mechanical and thermal properties of the composites [9, 10]. Currently, particle size is being reduced rapidly and many studies have focused on how single-particle size affects mechanical properties [11-17]. The shape, size, volume fraction, and specific surface area of such added particles have been found to affect mechanical properties of the composites greatly. In this regard, Yamamoto et al. [18] reported that the structure and shape of silica particle have significant effects on the mechanical properties such as fatigue resistance, tensile and fracture properties. Nakamura et al. [19-21] discussed the effects of size and shape of silica particle on the strength and fracture toughness based on particle-matrix adhesion and also found an increase of the flexural and tensile strength as specific surface area of particles increased.

In the literature, many works devoted to the mechanical properties of natural fibres from micro to nano scales are available. In these, the effects of reinforcement of matrix (thermoplastic starch) by using cellulose whiskers, commercial regenerated cellulose fibres are also proposed. A number of investigations have been conducted on several types of natural fibers such as kenaf, hemp, flax, bamboo, and jute to study the effect of these fibers on the mechanical properties of composite materials [22-25]. Mansur and Aziz [24] studied bamboo-mesh reinforced cement composites, and found that this reinforcing material could enhance the ductility and toughness of the cement matrix, and increase significantly its tensile, flexural, and impact strengths. A pulp fiber reinforced thermoplastic composite was investigated and found to have a combination of stiffness increased by a factor of 5.2 and strength increased by a factor of 2.3 relative to the virgin polymer [25]. Information on the usage of banana fibers in reinforcing polymers is limited in the literature. In dynamic mechanical analysis, Laly et al. [26] have investigated banana fiber reinforced polyester composites and found that the optimum content of banana fiber is 40%. Mechanical properties of banana–fiber–cement composites were investigated physically and mechanically by Corbiere-Nicollier et al. [27]. It was reported that kraft pulped banana fiber composite has good flexural strength. In addition, short banana fiber reinforced polyester composite was studied by Pothan et al. [28]; the study concentrated on the effect of fiber length and fiber content. The maximum tensile strength was observed at 30 mm fiber length while maximum impact strength was observed at 40 mm fiber length. Incorporation of 40% untreated fibers provides a 20% increase in the tensile strength and a 34% increase in impact strength. Joseph et al. [29] tested banana fiber and glass fiber with varying fiber length and fiber content as well. Luo and Netravali [30] studied the tensile and flexural properties of the green composites with different pineapple fibre content and compared with the virgin resin. Sisal fibre is fairly coarse and inflexible. It has good strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in seawater. Sisal ropes and twines are widely used for marine, agricultural, shipping, and general industrial use. Belmeres et al. [31] found that sisal, henequen, and palm fibre have very similar physical, chemical, and tensile properties. Cazaurang et al. [32] carried out a systematic study on the properties of henequen fibre and pointed out that these fibres have mechanical properties suitable for reinforcing thermoplastic resins. Ahmed et al. [33] carried out research work on filament wound cotton fibre reinforced for reinforcing high-density polyethylene (HDPE) resin. Khalid et al. [34] also studied the use of cotton fibre reinforced epoxy composites along with glass fibre reinforced polymers. Fuad et al. [35] investigated the new type wood based filler derived from oil palm wood flour (OPWF) for bio-based thermoplastics composites by thermo-gravimetric analysis and the results are very promising. Schneider and Karmaker [36] developed composites using jute and kenaf fibre and polypropylene resins and they reported that jute fibre provides better mechanical properties than kenaf fibre. Sreekala et al. [37] performed one of the pioneering studies on the mechanical performance of treated oil palm fiber-reinforced composites. They studied the tensile stress-stain behavior of composites having 40% by weight fiber loading. Isocyananante-, silane-, acrylated, latex coated and peroxide-treated composite withstood tensile stress to higher strain level. Isocyanate treated, silane treated, acrylated, acetylated and latex coated composites showed yielding and high extensibility. Tensile modulus of the composites at 2% elongation showed slight enhancement upon mercerization and permanganate treatment. The elongation at break of the composites with chemically modified fiber was attributed to the changes in the chemical structure and bondability of the fiber. Alkali treated (5%) sisal-polyester biocomposite showed about 22% increase in tensile strength [38]. Ichazo et al. [39] found that adding silane treated wood flour to PP produced a sustained increase in the tensile modulus and tensile strength of the composite. Joseph and Thomas [40] studied the effect of chemical treatment on the tensile and dynamic mechanical properties of short sisal fiberreinforced low density polyethylene composites. It was observed that the CTDIC (cardanol derivative of toluene diisocyanate) treatment reduced the hydrophilic nature of the sisal fiber and enhanced the tensile properties of the sisal-LDPE composites. They found that peroxide and permanganate treated fiber-reinforced composites showed an enhancement in tensile properties. They concluded that with a suitable fiber surface treatment, the mechanical properties and dimensional stability of sisal-LDPE composites could be improved. Mohanty et al. [41] studied the influence of different surface modifications of jute on the performance of the biocomposites. More than a 40% improvement in the tensile strength occurred as a result of reinforcement with alkali treated jute. Jute fiber content also affected the biocomposite performance and about 30% by weight of jute showed optimum properties of the biocomposites.

The use of wood dust filled polymer composites has been considerably studied both from a scientific and a commercial point of view over the last decades, as these materials are particularly attractive for their reduced environmental impact and the globally pleasant aesthetical properties. They have many advantages includes biodegradability, non-abrasive during processing, ease of handling and widespread availability etc. There are some researches about the influence of the filler and its size over the mechanical and physical properties of wood-flour reinforced thermoplastics [42, 43]. It has been observed that the elongation at break and the impact strength of the composites decrease with the addition of filler independently of its size. The behavior of the tensile modulus and the tensile strength seems to depend on the shape of the particles. This behavior can improve with the load as the aspect ratio does so. Although there are several reports in the literature which discuss the of wood/polymer composites [44, 45, 46, 47], however, very limited work has been done on effect of wood dust on mechanical behaviour of glass fiber reinforced polymer composites.

In view of the above, the present work is undertaken to investigate the mechanical behaviour of glass fiber based polymer composites filled with sal wood dust. The objectives of this work include fabrication of a new class of low cost composites using wood dust as the reinforcing filler with an objective to improve the mechanical properties of composites.

2.1 Objectives of the Research Work

The objectives of the project are outlined below.

- To develop a new class of polymer matrix composites filled with both particulate filler (wood dust) and fiber (glass fiber).
- To study the effect of filler content on mecjanical behaviour of glass fiber reinforced epoxy composites.
- Evaluation of mechanical properties such as: tensile strength, flexural strength, tensile modulus, micro-hardness, impact strength etc.

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Chapter 3

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

This chapter describes the details of processing of the composites and the experimental procedures followed for their characterization evaluation. The raw materials used in this work are

1. E-glass Fibre
2. Epoxy resin
3. Sal wood dust
4. Hardener

3.1. Specimen preparation

Cross plied E-glass fibres are reinforced in epoxy resin to prepare the composite. The composite slabs are made by conventional hand-lay-up technique. Sal wood dust (Figure 3.1) is used as particulate filler in this composite because sal wood is abundantly available in India. Wood dust is collected from local supplier is sieved to obtain particle size in the range 300 μm. The low temperature curing epoxy resin (LY 556) and corresponding hardener (HY951) are mixed in a ratio of 10:1 by weight as recommended. Epoxy LY 556 resin is chemically belonging to the 'epoxide' family and its common name is Bisphenol A Diglycidyl Ether. The epoxy resin and the hardener are supplied by Ciba Geigy India Ltd. Composites of three different compositions (0 wt%, 10 wt% and 20 wt% alumina filling) are made and the fiber loading (weight fraction of glass fiber in the composite) is kept at 50% for all the samples. The castings are put under load for about 24 hours for proper curing at room temperature. The designations of these composites are given in Table 3.1. The mix is stirred manually to disperse the fibres in the matrix. The cast of each composite is cured under a load of about 50 kg for 24 hours before it removed from the mould. Then this cast is post cured in the air for another 24 hours after removing out of the mould. Specimens of suitable dimension are cut using a diamond cutter for mechanical testing.

Figure 3.1 Sal wood dust

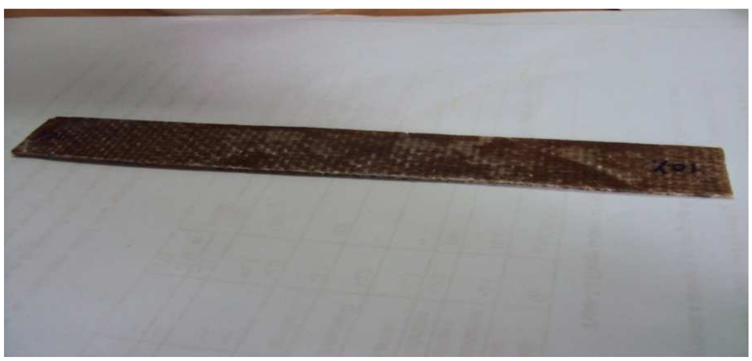
Table 3.1 Designation of Composites

Composites	Compositions
C_1	Epoxy (50 wt%) + Glass fiber (50 wt%) + Wood dust (0 wt%)
C_2	Epoxy (50 wt%) + Glass fiber (50 wt%) + Wood dust (5 wt%)
C_3	Epoxy (50 wt%) + Glass fiber (50 wt%) + Wood dust (10 wt%)

3.2. Mechanical Testing

After fabrication the test specimens were subjected to various mechanical tests as per ASTM standards. The tensile test and three-point flexural tests of composites were carried out using Instron 1195. The tensile test is generally performed on flat specimens. A uniaxial load is applied through both the ends. The ASTM standard test method for tensile properties of fiber resin composites has the designation D 3039-76. Micro-hardness measurement is done using a Leitz micro-hardness tester. A diamond indenter, in the form of a right pyramid with a square base and an angle 136^0 between opposite faces, is forced into the material under a load F. The two diagonals X and Y of the indentation left on the surface of the material after removal of the load are measured and their arithmetic mean L is calculated. In the present study, the load considered F = 24.54N. Low velocity instrumented impact tests are carried out on composite specimens. The tests are done as per ASTM D 256 using an impact tester. The charpy impact testing machine has been used for measuring impact strength. Figure 3.2 shows the tested specimens for tensile, flexural, impact and hardness test respectively. Figure 3.3 shows the experimental set up and loading arrangement for the specimens for tensile and three point bend test.

(a)



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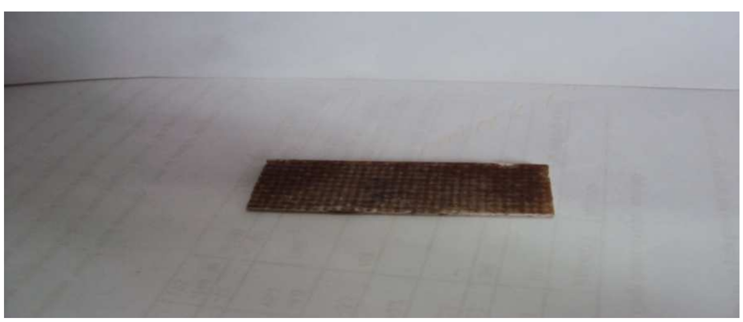

(c)

(d)

Figure 3.2 Tested specimens

Figure 3.3 Experimental set up and loading arrangement for the specimens for tensile test and three points bend test.

3.3. Scanning electron microscopy (SEM)

The scanning electron microscope (SEM) JEOL JSM-6480LV (Figure 3. 4) was used to identify the tensile fracture morphology of the composite samples. The surfaces of the composite specimens are examined directly by scanning electron microscope JEOL JSM-6480LV. The samples are washed, cleaned thoroughly, air-dried and are coated with 100 Å thick platinum in JEOL sputter ion coater and observed SEM at 20 kV. Similarly the composite samples are mounted on stubs with silver paste. To enhance the conductivity of the samples, a thin film of platinum is vacuum-evaporated onto them before the photomicrographs are taken.

Figure 3.4 SEM Set up

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Chapter 4

MECHANICAL CHARACTERISTICS OF COMPOSITES: RESULTS & DISCUSSIONS

CHAPTER 4

MECHANICAL CHARACTERISTICS OF COMPOSITES: RESULTS & DISCUSSIONS

This chapter presents the mechanical properties of the wood dust filled glass fiber reinforced epoxy composites prepared for this present investigation. Details of processing of these composites and the tests conducted on them have been described in the previous chapter. The results of various characterization tests are reported here. This includes evaluation of tensile strength, flexural strength, impact strength and micro-hardness has been studied and discussed. The interpretation of the results and the comparison among various composite samples are also presented.

4.1. Mechanical Characteristics of Composites

The characterization of the composites reveals that the filler content is having significant effect on the mechanical properties of composites. The mechanical properties of the composites with different filler content under this investigation are presented in Table 4.1.

Table 4. 1 Mechanical properties of the composites

Composites	Hardness (Hv)	Tensile strength (MPa)	Tensile modulus (GPa)	Flexural strength (MPa)	Impact energy (KJ/m^2)
C_1	16.31	72.32	4.106	19.03	9.8
C_2	18.6	86.52	4.458	24.09	12.5
C_3	19.4	133.2	4.683	43.29	15.5

4.1.1 Effect of filler content on Micro-hardness

Figure 4.1 shows the influence of filler content on micro-hardness of wood dust filled glass fiber reinforced epoxy composites. From the figure it is clear that filler content has significant influence over micro-hardness. With the filler content the micro-hardness value increases and reaches maximum up to 19.4 Hv for filler up to 20 wt%.

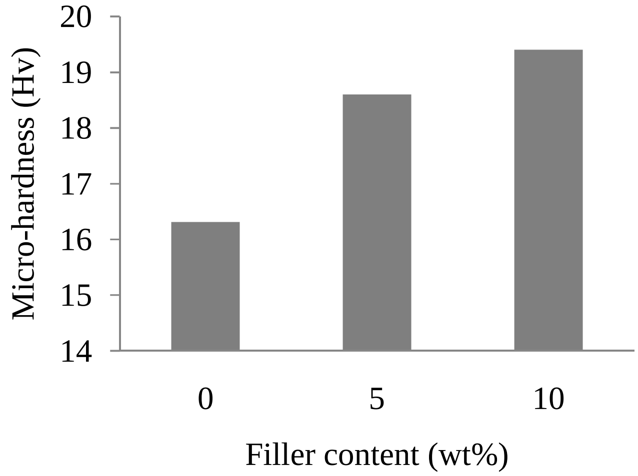


Figure 4.1 Effect of filler content on micro-hardness of the composites

4.1.2. Effect of filler content on Tensile Properties

The influence of filler content on tensile strengths and moduli are shown in Figures 4.2 and 4.3, respectively. It is seen that the tensile strength of the composite increases with increase in filler content. There can be two reasons for this increase in the strength properties of these composites compared. One possibility is that the chemical reaction at the interface between the filler particles and the matrix may be too strong to transfer the tensile. From Figure 4.3 it is clear that with the increase in fiber length the tensile moduli of the wood dust filled glass fiber reinforced epoxy composites increases significantly.

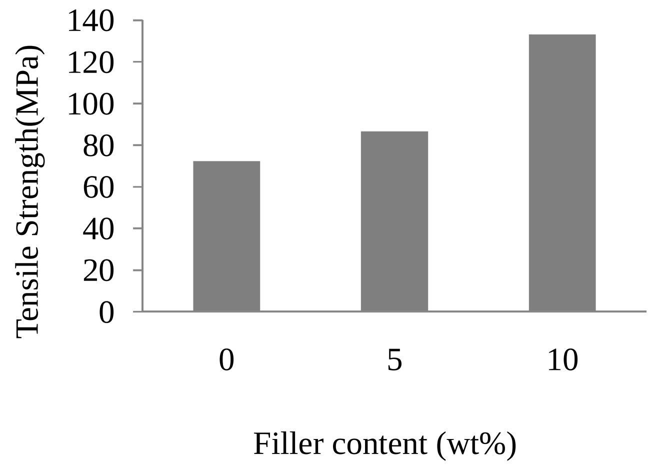


Figure 4.2 Effect of filler content on tensile strength of composites

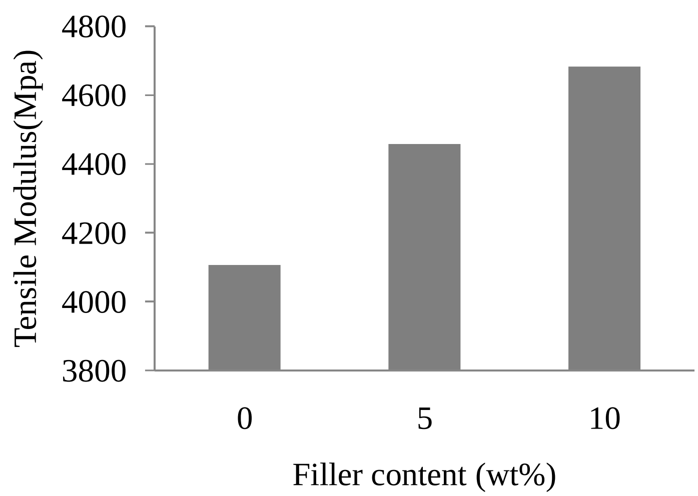


Figure 4.3 Effect of filler content on tensile modulus of composites

4.1.3. Effect of filler content on Flexural Strength

Figure 4.4 shows the comparison of flexural strengths of the composites obtained experimentally from the bend tests. It is interesting to note that flexural strength increases with increase in filler content. This may be due to the good compatibility of filler and epoxy resin.

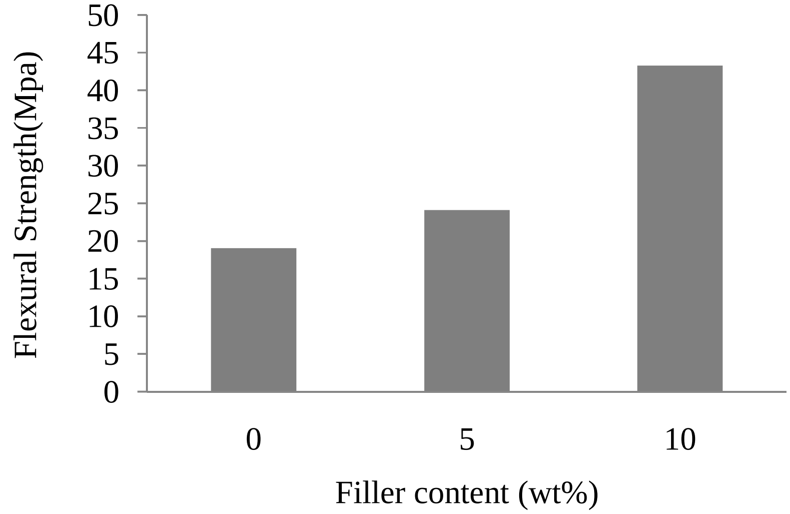


Figure 4.4 Effect of filler content on flexural strength of composites

4.1.4 Effect of filler content on Impact Strength

The impact energy values of different composites recorded during the impact tests are given in Table 4.1. It shows that the resistance to impact loading of wood dust filled glass fiber reinforced epoxy composites improves with increase in filler content as shown in Figure 4.5. High strain rates or impact loads may be expected in many engineering applications of composite materials. The suitability of a composite for such applications should therefore be determined not only by usual design parameters, but by its impact or energy absorbing properties.

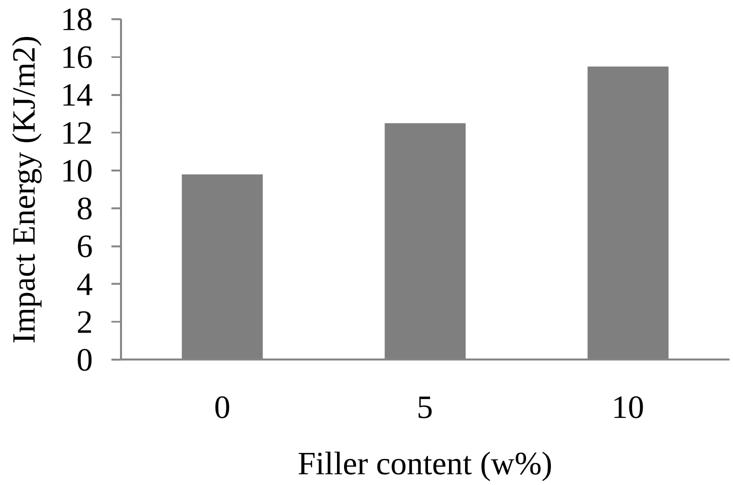
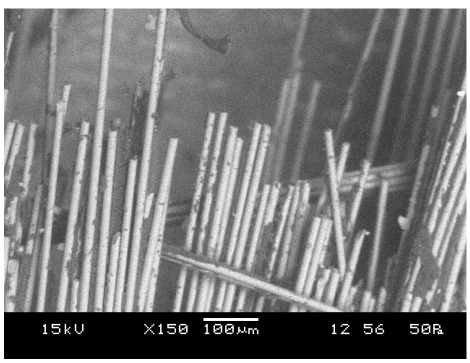


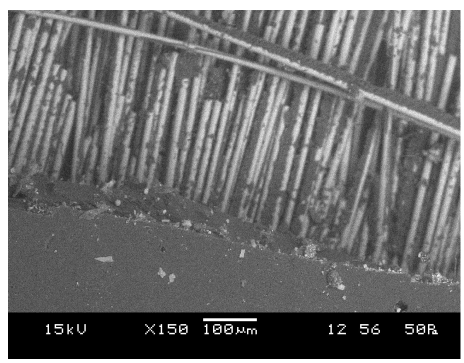
Figure 4.5 Effect of filler content on impact strength of composites

4.2. Surface morphology of the composites

The fracture surfaces study of glass fiber reinforced epoxy resin filled with sal wood dust composites after the tensile test, flexural test and impact test has been shown in Figure 4.6. Figures 4.6a-b show the SEM of tensile failure surfaces of wood filled glass-epoxy composites with 0wt% to 10wt% at an interval of 5wt%of wood dust filler has been added. In the present work with increase in wood dust from unfilled to filled composites the tensile strength goes on increase. It can be seen that at 5wt% wood dust there is very high pull-out of glass fiber on the fracture surface of the composite. The surfaces of composites show that failure occurred at the wood dust due to strong adhesion between dust and matrix (Figure 4.6a). However, the failure surface of other composites with slightly higher wood dust content i.e 10wt% shows higher tensile strength (Figure 4.6a) and from Figure 4.6b the tensile fracture is less as compared with 5wt% of wood dust composites.



(a)



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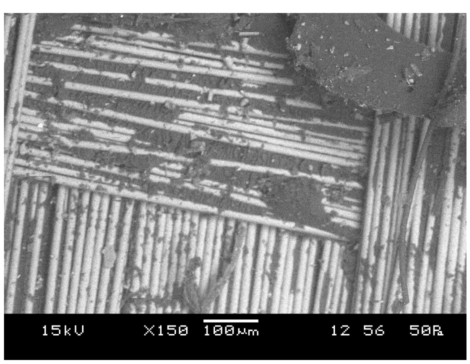

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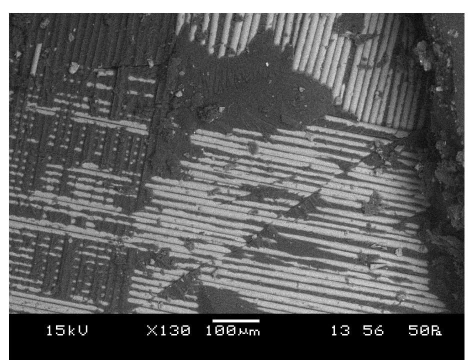

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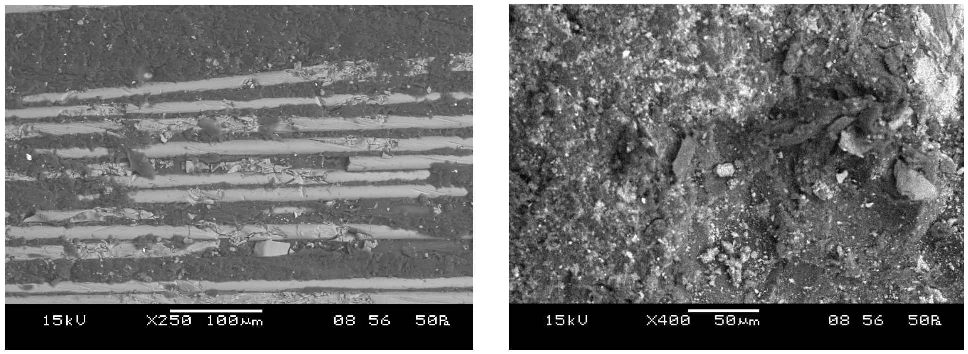

(e) (f)

Figure 4.6 SEM of fracture surfaces of wood dust filled glass fiber reinforced epoxy composites.

Under a flexural strength loading situation, the fillers apparently aid the load bearing capability of a composite, rather than act as stress raiser as is the case in tensile loading. This is due to compressive stresses tends to close cracks on the upper surface of the composites and flaws that are perpendicular to the applied stress, contrary to the crack opening mechanism occurring in a tensile loading situation [48, 49].It is well known that bearing failure occurs in the material immediately adjacent to the contact area between the fastener and the laminate and is caused primarily by compressive stresses acting on the hole surface. At higher weight fractions of wood dust particle, the poor interface bonding or adhesion between the wood dust and the epoxy resin matrix, or the presence of a large agglomerate phase in the matrix may occur and cause the lower bearing strengths [48, 49]. The presence of agglomeration in the composites obviously deteriorates their mechanical properties. Agglomerations may easily happen for smaller particles at higher filler contents due to the reduced inter particle distance [48]. Agglomerates are weak points in the material and break fairly easily when stress is applied. Broken agglomerate then behaves as a strong stress concentrator. However, as per literature available above generally inclution of filler material in the base matrix form weak interfacial bond, but by addition of sal wood dust the bonding between wood dust and epoxy matrix shows strong interfacial strength as shown in Fig. 4.6c. On further addition of wood dust in the base matrix the flexural strength increases further as shown in Figure 4. 6d. Also, the composite specimens with 10wt.% wood dust content have higher bearing strength than that of the composite specimens with 5 wt.% wood dust particle content and unfilled composite specimens. This is probably due to the lower void content of the composite specimens with 10wt.%wood dust particle content. It is well known that high void content have negative effects on the mechanical properties of composite materials [50].

Figures 4.6e and f show SEM graphs of impact fractured surfaces of wood dust epoxy composites. The impact strength of composite goes on increasing with the increase in wood dust content. Also, some fiber traces are visible in case of wood dust composite and more amounts of wood dusts and epoxy matrix removed out from the composite surface. This is evidence of poor interface bonding at 5wt% of wood dust. In further addition of wood dust in the base matrix, there is less pronounced plastic deformation of the surrounding matrix involved as shown in Figure 4.6f. It is well known that the interface between the polymer Matrix and the wood dust content plays a major role in enhancing the properties of composites. In fact, when particulate wood dust filler is dispersed into glass epoxy composites, the impact strength, tensile strength and flexural strength are increases with the increase in wood dust content. Therefore, from the above micro structural analysis it can be concluded that sal wood dust can be used as potential filled material in polymer composites for structural applications.

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Chapter 5

CONCLUSIONS

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The present investigations of mechanical behaviour of wood dust filled glass fiber reinforced epoxy composites leads to the following conclusions:

- In the present research work, glass fiber reinforced epoxy composites filled with wood dust filler has been successful fabricated by simple hand lay-up technique.
- It has been noticed that the mechanical properties of the composites such as micro-hardness, tensile strength, flexural strength, impact strength etc. of the composites are also greatly influenced by the filler content
- The morphology of fractured surfaces is examined by using SEM after various testing. From this study it has been concluded that the good interfacial bonding is responsible for higher mechanical properties.

5.1. Scope for Future Work

This work leaves a wide scope for future investigators to explore many other aspects of particulate filled composites. This work can be further extended to study other aspects of such composites like effect of other types of fillers, filler size, loading pattern etc. on mechanical behavior of wood dust filled polymer composites and the resulting experimental findings can be similarly analyzed.

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REFERENCES

1. S.W. Gregory, K.D. Freudenberg, P. Bhimaraj and L. S Schadler, A study on the friction and wear behavior of PTFE filled with alumina nanoparticles, J. Wear, 254 (2003) 573–580.
2. K. Jung-il, P.H. Kang and Y.C. Nho, Positive temperature coefficient behavior of polymer composites having a high melting temperature, J. Appl. Poly Sci., 92 (2004) 394–401.
3. S. Nikkeshi, M. Kudo and T. Masuko, Dynamic viscoelastic properties and thermal properties of powder-epoxy resin composites, J. Appl. Poly. Sci., 69 (1998) 2593-8.
4. K. Zhu and S. Schmauder, Prediction of the failure properties of short fiber reinforced composites with metal and polymer matrix, J. Comput. Mater. Sci., 28 (2003) 743–8.
5. M. Rusu, N. Sofian and D. Rusu, Mechanical and thermal properties of zinc powder filled high density polyethylene composites, J. Polymer Testing, 20 (2001) 409–17.
6. I. H. Tavman, Thermal and mechanical properties of copper powder filled poly (ethylene) composites, J. Powder Tech., 91 (1997) 63–7.
7. R.N. Rothon, Mineral fillers in thermoplastics: filler manufacture, J. Adhesion, 64 (1997) 87–109.
8. R.N. Rothon, Mineral fillers in thermoplastics: filler manufacture and characterization, J. Adv. Polym. Sci., 139 (1999) 67–107.
9. L.E. Nielsen and R.F. Landel, Mechanical properties of polymers and composites. second ed., Marcel Deckker, New York, 1994, pp.377–459.
10. S.T. Peters, Handbook of composites, second ed., Chapman and Hall, London, 1998, pp. 242–243.
11. R.J. Young and P.W.R. Beaumont, Failure of brittle polymers by slow crack growth Part 3 Effect of composition upon the fracture of silica particle-filled epoxy resin composites, J. Mater. Sci., 12(4) (1977) 684–92.
12. A.J. Kinoch, D.L. Maxwell and R.J. Young, The fracture of hybrid particulate composites, J. Mater. Sci., 20 (1985) 4169–84.
13. R. Young, D.L. Maxwell and A.J. Kinloch, The deformation of hybrid particulate composites. J. Mater. Sci., 21 (1986) 380–388.

14. S.W. Koh, J.K. Kim and Y.W. Mai, Fracture toughness and failure mechanisms in silica-filled epoxy resin composites: effects of temperature and loading rate, J. Polymer, 34(16) (1993) 3446–3455.
15. W.J. Cantwell and A.C. Moloney, Fractography and failure mechanisms of polymers and composites, Elesvier, Amsterdam (1994) 233.
16. M. Imanaka, Y. Takeuchi, Y. Nakamura, A. Nishimura and T. Lida, Fracture toughness of spherical silica-filled epoxy adhesives. Int. J. Adhesin Adhes., 21 (2001) 389–396.
17. H. Wang, Y. Bai, S. Lui, J. Wu and C.P. Wong, Combined effects of silica filler and its interface in epoxy resin, J. Acta. Mater., 50 (2002) 4369–4377.
18. I.Yamamoto, T. Higashihara and T. Kobayashi, Effect of silica-particle characteristics on impact/usual fatigue properties and evaluation of mechanical characteristics of silica-particle epoxy resins, Int. J. JSME, 46 (2) (2003) 145–153.
19. Y. Nakamura, M. Yamaguchi, A. Kitayama, M. Okubo and T. Matsumoto, Effect of particle size on fracture toughness of epoxy resin filled with angular-shaped silica, J. Polymer, 32(12) (1991) 2221–2229.
20. Y. Nakamura, M. Yamaguchi, M. Okubo and T. Matsumoto, Effect of particle size on impact properties of epoxy resin filled with angular shaped silica particles, J. Polymer, 32(16) (1991) 2976–2979.
21. Y. Nakamura, M. Yamaguchi, M. Okubo and T. Matsumoto, Effects of particle size on mechanical and impact properties of epoxy resin filled with spherical silica, J. Appl. Polym. Sci., 45 (1992) 1281–1289.
22. Satyanarayana K. G, Sukumaran K, Mukherjee P. S, Pavithran C and Pillai S. G. K, “Natural Fiber-Polymer Composites”, Cement and Concrete Composites, 12(2), 1990, pp. 117-136.
23. Satyanarayana K. G, Sukumaran K, Kulkarni A. G, Pillai S. G. K, and Rohatgi P. K, “Fabrication and Properties of Natural Fiber-Reinforced Polyester Composites”, Composites, 17(4), 1986, pp. 329-333.
24. Mansur M .A and Aziz M. A, “Study of Bamboo-Mesh Reinforced Cement Composites” Int. Cement Composites and Lightweight Concrete, 5(3), 1983, pp. 165-171.

25. Lundquist L, Marque B, Hagstrand P. O, Leterrier Y and Månson J. A. E, “Novel Pulp Fiber Reinforced Thermoplastic Composites”, Composites Science and Technology, 63(1), 2003, pp. 137-152.
26. Pothana L. A, Oommenb Z, and Thomas S, “Dynamic Mechanical Analysis of Banana Fiber Reinforced Polyester Composites”, Composites Science and Technology, 63(2), 2003, pp. 283-293.
27. Corbière-Nicollier T, Laban B. G, Lundquist L, Leterrier Y, Månson J. A. E, and Jolliet O, “Life Cycle Assessment of Biofibers Replacing Glass Fibers as Reinforcement in Plastics”, Resources, Conservation and Recycling, 33(4), 2001, pp. 267-287.
28. Pothan L.A, Sabu T, and Neelakantan N. R, “Short Banana Fiber Reinforced Polyester Composites: Mechanical, Failure and Aging Characteristics”, Journal of Reinforced Plastics and Composites, 16(8), 1997, pp. 744-765.
29. Joseph S, Sreekala M.S, Oommen Z, Koshy P, and Sabu T, “A Comparison of the Mechanical Properties of Phenol Formaldehyde Composites Reinforced with Banana Fibers and Glass Fibers”, Composites Science and Technology, 62(14), 2002, pp. 1857-1868.
30. Luo S and Netravali A. N, “Mechanical and thermal properties of environmentally friendly green composites made from pineapple leaf fibres and poly(hydroxybutyrate-co-valerate) resin”, Polymer Composites, 20(3), 1999, 367-378.
31. Belmares H, Barrera A and Monjaras M, “New composite materials from natural hard fibres. Part 2: Fatigue studies and a novel fatigue degradation model”, Industrial Engineering Chemical Product Research and Development, 22, 1983, pp. 643-652.
32. Casaurang M, Herrera P, Gonzalez I and Aguilar V. M, “Physical and mechanical properties of henequen fibers”, Journal of Applied Polymer Sciences, 43, 1991, pp. 749-756.
33. Ahmed E. M, Sahari B and Pedersen P, Non-linear behaviour of unidirectional filament wound COTFRP, CFRP, and GFRP composites.

In: Proceedings of World Engineering Congress, WEC 99, Mechanical and Manufacturing Engineering, Kuala Lumpur; 1999, pp. 537-543.

34. Khalid A. A, Sahari B and Khalid Y. A, Environmental Effects on the Progressive Crushing of Cotton and Glass Fibre/Epoxy Composite Cones. In: Proceedings of the Fourth International Conference on Advances in Materials and Processing Technologies, 98, Kuala Lumpur; 1998, pp. 680-689.
35. Fuad M. Y. A, Rahmad S, Azlan M. R. N, Filler content determination of bio-based thermoplastics composites by thermogravimetric analysis In: Proceedings of the Fourth International Conference on Advances in Materials and Processing Technologies, 98, Kuala Lumpur; 1998, pp. 268-275.
36. Schneider J. P and Karmaker A. C, “Mechanical performance of short jute fiber reinforced polypropylene”, Journal of Materials Science Letters, 15, 1996, pp. 201-202.
37. Sreekala, M. S, Kumaran M.G, Joseph S, Jacob M and Thomas S, “Oil palm fiber reinforced phenol formaldehyde composites: influence of fiber surface modifications on the mechanical performance” Applied Composite Materials, 7, 2000, pp. 295-329.
38. Mishra, S, .Misra M, Tripathy S. S, Nayak S. K and. Mohanty A. K, “The influence of chemical surface modification on the performance of sisal-polyester biocomposites”, Polymer Composites, 23(2), 2002,164-170.
39. Ichazo, M. N, Albano C, González J, Perera R and Candal M.V, 2001. “Polypropylene/wood flour composites: treatments and properties”. Composite Structures, 54, 2001, 207-214.
40. Joseph K and Thomas S, “Dynamic mechanical properties of short sisal fiber reinforced low density polyethylene composites”, Journal of Reinforced Plastics and Composites”, 12(2), 1993, 139-155.
41. Mohanty, A. K, Khan M. A and Hinrichsen G, “Influence of chemical surface modification on the properties of biodegradable jute fabrics-

polyester amide composites”, Composites Part A: Applied Science and Manufacturing, 31(2), 2000, pp. 143-150.

42. Berenbrok P. A and Liles B. E, “Effect of WF fillers on polyethylene”, In:Proceedings of the annual technical conference of the society of plastic engineers (ANTEC),” Totonto, April 1997, pp. 2931-2934.
43. Zaini M. J, Fuad M.Y, Ismail Z, Mansor M. S and Mustafah J, “The effect of filler content and size on the mechanical properties of polypropylene/oil palm flour composites”. Polymer International, 40, 1997, pp. 51-55.
44. Mantia F. P. L and Morreale M, “Accelerated weathering of polypropylene/wood flour composites”, Polymer Degradation and Stability, 93, 2008, pp. 1252-1258.
45. Bengtsson M, Gatenholm P and Oksman K, “The effect of crosslinking on the properties of polyethylene/wood flour composites” Composites Science and Technology, 65, 2005, pp. 1468-1479
46. Mishra A. K and Luyt A. S, “Effect of solegel derived nano-silica and organic peroxide on the thermal and mechanical properties of low-density polyethylene/wood flour composites”, Polymer Degradation and Stability, 93, 2008, pp. 1-8
47. Da´nya´di L, Janecska T, Szabo´, Nagy Z, Mo´czo´ J and Puka´nszky B, “Wood flour filled PP composites: Compatibilization and adhesion”, Composites Science and Technology, 67, 2007, pp. 2838-2846
48. Friedrich K, Fakirov S, Zhang Z.Polymer composites, from nano-to macro-scale. Springer 2005.
49. Nielsen LE, Landel RF. Mechanical properties of polymers and composites. New York: Marcel Dekker;1994.
50. Varna J, Joffe R,Berglund A. Effect of voids on failure mechanisms in RTM laminates. Compos Sci Technol 1995; 53: 241–9.

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