STUDY ON MECHANICAL BEHAVIOUR OF WOOD DUST FILLED POLYMER COMPOSITES

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

Bachelor of Technology in Mechanical Engineering

BY

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NATIONAL INSTITUTE OF TECHNOLOGY
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CERTIFICATE

This is to certify that the thesis entitled " ***Study on Mechanical Behavior of Wood Dust Filled Polymer Composites",*** submitted by ***Debabrata Chowdhury (Roll Number: 10603001)*** 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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A B S T R A C T

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. Wood dusts are attractive fillers for thermoplastic polymers, mainly because of their low cost, low density and high-specific properties. They are biodegradable and non-abrasive during processing etc. 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 types on mechanical behaviour polymer composites. Against this background, the present research work has been undertaken, with an objective to explore the potential of wood dust types as a reinforcing material in polymer composites and to investigate its effect on the mechanical behaviour of the resulting composites. The present work thus aims to develop this new class of natural fibre based polymer composites with different wood types and to analyse their mechanical behaviour by experimentation. Finally the morphology of fractured surfaces is examined by using scanning electron microscopy (SEM).

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INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1. Introduction to composite materials

In recent years, the interest in composite materials is increasing due to its advantages as compared to monolithic metal alloys. Composites materials can be defined as engineered materials which exist as a combination of two or more materials that result in better properties than when the individual components are used alone. Composites consist of a discontinuous phase known as reinforcement and a continuous phase known as matrix. In practice, most composites consist of a bulk material (the ‘matrix’), and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix.

Matrix Phase: The matrix phase generally comprises the bulk part of a composite. Materials in fibrous form are seen to be showing good strength property and for achieving this property the fibers should be bonded by a matrix. Matrix may consist of any of the three basic material types mainly Polymer, ceramics or metals.

Reinforcement: The reinforcement is generally responsible for strengthening the composite and improves its mechanical properties. All of the different fibers used in composites have different properties and so affect the properties of the composite in different ways. It also provides stiffness to the composites.

1.2. Classification of Composites

Composite materials can be classified into many categories depending on reinforcing material type, matrix type etc. They are namely:

- ***According to the type of matrix material they can be classified as:***

(*a*) *Metal matrix composite*: It consists of a metallic matrix (Al, Mg, Cu, Fe). There are several reasons for the re-emergence of interest in metal matrix composites, the most important one being their engineering properties. They are of light weight, and exhibit good stiffness and low specific weight as compared to other metals and metal alloys. It is generally considered that these materials offer savings in weights, at the same time maintain their properties. Although it has many advantages, cost remains a major point of interest for many applications.

(b) Polymer matrix composite: Polymer matrix composites are considered to be a more prominent class of composites when compared to ceramic or metal matrix composites once in commercial applications. It comprises of a matrix from thermosetting (unsaturated polyester, epoxy) or thermoplastic (nylon, polystyrene) and embedded glass carbon, steel or Kevlar fibers (dispersed phase). The industries supporting reinforced polymer markets include transportation, marine accessories, electronic products etc.

(c) Ceramic matrix composite: It comprises of a material consisting of a ceramic combined with a ceramic dispersed phase. The availability of new technologies, processing methods and the demand for high performance products, have together promoted the growth of advanced ceramic products, but the brittleness of ceramics still remains a major disadvantage.

- ***According to the type of reinforcing material composites can be classified as:***

(a) Particulate composites: The reinforcement is of particle nature (platelets are also included in this class). 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. Some of the useful properties of ceramics and glasses include high melting temp., low density, high strength, stiffness, wear resistance, and corrosion resistance. Many ceramics are good electrical and thermal insulators. Some ceramics have special properties; some ceramics are magnetic materials; some are piezoelectric materials; and a few special ceramics are even superconductors at very low temperatures. Ceramics and glasses have one major drawback: they are brittle. An example of particle reinforced composites is an automobile tyre, which has carbon black particles in a matrix of poly-isobutylene elastomeric polymer.

(b) Fibrous composites: Fibers, because of their small cross- sectional dimensions, are not directly usable in engineering applications. They are, therefore, embedded in matrix materials to form fibrous composites. The matrix serves to bind the fibers together, transfer loads to the fibers, and protect them against environmental attack and damage due to handling. In discontinuous fibre reinforced composites, the load transfer function of the matrix is more critical than in continuous fibre composites. An example of particle reinforced composites is an automobile tyre, which has carbon black particles in a matrix of poly-isobutylene elastomeric polymer.

Fibers: These *are* generally classified into two groups:-

- Synthetic Fibers
- Natural Fibers

Synthetic Fibers: These are man made fibers which are a result of research by scientists to improve natural occurring plant and animal fibers. Before synthetic fibers were developed artificially manufactured fibers were from cellulose which comes from plants. Nylon was the first synthetic fiber.

Natural Fibers: Natural fibers include those made from plant, animal and mineral sources. Natural fibers can be classified according to their origin. Natural fibers can be classified according to their origin.

- Fruit fibers are extracted from the fruits of the plant, they are light and hairy, and allow the wind to carry the seeds.

- Bast fibers are found in the stems of the plant providing the plant its strength. Usually they run across the entire length of the stem and are therefore very long.
- Fibers extracted from the leaves are rough and sturdy and form part of the plant's transportation system, they are called leaf fibers.

It is again classified into short fiber and long fiber.

Short fiber: It consists of a matrix reinforced by a dispersed phase in the form of discontinuous fibers either of random or preferred orientations.

Long fiber: They consist of a matrix reinforced by a dispersed phase in the form of continuous fibers. They can be either unidirectional or bidirectional.

Laminate composites: when a fiber reinforced composite consists of several layers with different fiber orientations, it is called multilayer composite.

1.3. Advantages of Composites

- ❖ Composites generally have good resistance to corrosion.
- ❖ They generally increase mechanical damping.
- ❖ Increase in toughness.
- ❖ They have excellent fatigue strength.
- ❖ They are of low cost.
- ❖ They have good tensile strength.
- ❖ They have good resistance to fire.

1.4. Applications of Composites

- ✓ In automotive applications like door frames, engine components etc.
- ✓ Interior part of the elevators so that less smoke is produced in case of fire emergency.
- ✓ It is also used in the construction of fuel tanks.

1.5. Natural Fiber Reinforced Polymer Composites

Over the past two decades, natural plant fibers have been receiving considerable attention as the substitute for synthetic fiber reinforcement such as glass in plastics [1,2]. The advantages of plant fibers are low cost, low density, acceptable specific strength, good thermal insulation properties, reduced tool wear, reduced dermal and respiratory irritation, renewable resource and recycling possible without affecting the environmental damage, and together with biodegradable ability [3–7]. In the literature, many works devoted to the 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.

The past decade has seen fast and steady growth of wood plastics industry. Among many reasons for the commercial success, the low cost and reinforcing capacity of the wood fillers provide new opportunities to manufacture composite materials. Although the use of wood-based fillers is not as popular as the use of mineral or inorganic fillers, wood-derived fillers have several advantages over traditional fillers and reinforcing materials: low density, flexibility, during the processing with no harm to the equipment, acceptable specific strength properties and low cost per volume basis. The main application areas of wood flour filled composites are the automotive and building industries in which they are used in structural applications as fencing, decking, outdoor furniture, window parts, roofline products, door panels, etc. [8,9]. There are environmental and economical reasons for replacing part of the plastics with wood but the wood could also work as reinforcement of the plastics. The elastic modulus of wood fibres is approximately 40 times higher than that of polyethylene and the strength about 20 times higher [10]. The increased interest in the use of wood as filler and/or reinforcement in thermoplastics is due to the many advantages. Low density, high stiffness and strength, and low price are some of these advantages [11-14]. The environmental awareness of people today is forcing the industries to choose natural materials as substitutes for non-renewable materials. Wood has been used as building and engineering material since early times and offers the advantages of not just being aesthetically pleasing but also renewable, recyclable and biodegradable [15].

Although there are several reports in the literature which discuss the mechanical behaviour of wood/polymer composites, however, very limited work has been done on effect of wood dust types on mechanical behaviour polymer composites. Against this background, the present research work has been undertaken, with an objective to explore the potential of wood dust types as a reinforcing material in polymer composites and to investigate its effect on the mechanical behaviour of the resulting composites. The present work thus aims to develop this new class of natural fibre based polymer composites with different wood types and to analyse their mechanical behaviour by experimentation.

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Chapter 2

LITERATURE SURVEY

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LITERATURE SURVEY

This chapter outlines some of the recent reports published in literature on mechanical behaviour of natural fiber based polymer composites with special emphasis on wood/polymer composites.

Composite materials are created by combining two or more components to achieve desired properties which could not be obtained with the separate components. During the last few years, a series of works have been done to replace the conventional synthetic fiber with natural fiber composites. For instant, hemp, sisal, jute, cotton, flax and broom are the most commonly fibers used to reinforce polymers. In addition, fibers like sisal, jute, coir, oil palm, bamboo, wheat and flax straw, waste silk and banana have proved to be good and effective reinforcement in the thermoset and thermoplastic matrices. Composites made from non-traditional materials obtained directly from agro-wastes such as coir fiber, coconut pith, jute sticks, ground nut husk, rice husk, reed, and straw became one of the main interests of researchers.

The properties of natural-fiber reinforced composites depend on a number of parameters such as volume fraction of the fibers, fiber aspect ratio, fiber-matrix adhesion, stress transfer at the interface, and orientation. Most of the studies on natural fiber composites involve study of mechanical properties as a function of fiber content, effect of various treatments of fibers, and the use of external coupling agents. Both the matrix and fiber properties are important in improving mechanical properties of the composites. The tensile strength is more sensitive to the matrix properties, whereas the modulus is dependent on the fiber properties. To improve the tensile strength, a strong interface, low stress concentration, fiber orientation is required whereas fiber concentration, fiber wetting in the matrix phase, and high fiber aspect ratio determine tensile modulus. The aspect ratio is very important for determining the fracture properties. In short-fiber-reinforced composites, there exists a critical fiber length that is required to develop its full stressed condition in the polymer matrix. Fiber lengths shorter than this critical length lead to failure due to debonding at the interface at lower load. On the other hand, for fiber lengths greater than the critical length, the fiber is stressed under applied load and thus results in a higher strength of the composite. For, good impact strength, an optimum bonding level is necessary. The degree of adhesion, fiber pullout, and a mechanism to absorb energy are some of the parameters that can influence the impact strength of a short-fiber-filled composite. The properties mostly vary with composition as per the rule of mixtures and increase linearly with composition.

In the literature, many works devoted to the 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 [16-19]. Mansur and Aziz [18] 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 [19]. Information on the usage of banana fibers in reinforcing polymers is limited in the literature. In dynamic mechanical analysis, Laly *et al*. [20] 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*. [21]. 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*. [22]; 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*. [23] tested banana fiber and glass fiber with varying fiber length and fiber content as well. Luo and Netravali [24] 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 dye stuffs, and resistance to deterioration in seawater. Sisal ropes and twines are widely used for marine, agricultural, shipping, and general industrial use. Belmeres et al. [25] found that sisal, henequen, and palm fibre have very similar physical, chemical, and tensile properties. Cazaurang et al. [26] 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.[27] carried out research work on filament wound cotton fibre reinforced for reinforcing high-density polyethylene (HDPE) resin. Khalid et al. [28] also studied the use of cotton fibre reinforced epoxy composites along with glass fibre reinforced polymers. Fuad et al. [29] 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 [30] 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. [31] 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. Isocyanante-, 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 [32]. Ichazo et al. [33] 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 [34] studied the effect of chemical treatment on the tensile and dynamic mechanical properties of short sisal fiber reinforced low density polyethylene composites. It was observed that the CTDIC (cardanol derivative of toluene di-isocyanate) 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. [35] 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.

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 [36]; the low cost of wood flour and of natural-organic fillers in general (since they often come from wastes); the lower specific weight of these fillers, in comparison to the traditional mineral-inorganic ones; the improvement in safety for the production employees (reduced hazard in the case of accidental inhalation); the special aesthetic properties of the composites, which can be conveniently processed and refined, obtaining wood-like looking products; the full recyclability of the composites. These materials can be used for many indoor and outdoor applications (panels for the automotive industry, decking, furnishing, packaging, etc.) [36-43]. Polyolefins, in particular polypropylene, one of the most widely used plastics, have been extensively studied in combination with wood derivatives (flour, flakes, fibres) [44-47]. Several researchers have focused their attention on the improvement of the mechanical properties (usually deteriorated after the addition of the wood flour, particularly the ductility), achieved with the use of small amounts of coupling agents, which improve the interfacial polymer–filler adhesion and the dispersion of the filler within the matrix [48-50].

There are some researches about the influence of the filler and its size over the mechanical and physical properties of wood-flour reinforced thermoplastics [51, 52]. 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 behaviour can improve with the load as the aspect ratio does so.

Hence keeping the above references as back ground wood dust of woods namely sal, teak and rubber wood has been taken as reinforcement for developing composites with an objective to study the mechanical behaviour of the materials which will subsequently help us to implement the composite into practical usage.

2.1 Objectives of the Research Work

- Fabrication of wood dust filled epoxy based composites.
- Evaluation of mechanical properties of the composites such as tensile strength, flexural, hardness, impact strength etc.
- To study the effect of wood dust type on mechanical properties of composites.

Besides all these the main objective is to develop a low cost natural fiber based composite that can be used for commercial usage.

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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 mechanical characterization. The raw materials used in this work are

1. Wood dust
   - Teak wood
   - Sal wood
   - Rubber wood
2. Epoxy resin
3. Hardener

3.1. Specimen preparation

Wood dusts of three different wood types (Figure 3.1-3.3) are reinforced with Epoxy LY 556 resin, chemically belonging to the 'epoxide' family is used as the matrix material. Wood dust was supplied by a local vendor. The maximum particle size was 500 µm. The wood dust is dried before manufacturing in a vacuum oven for 24 h at 80^{o}C in order to remove moisture. The epoxy resin and the hardener are supplied by Ciba Geigy India Ltd. The fabrication of the composites is carried out through the hand lay-up technique. The low temperature curing epoxy resin (Araldite LY 556) and corresponding hardener (HY951) are mixed in a ratio of 10:1 by weight as recommended. Three different types of composites have been fabricated with three different types of wood dust such as teak, sal and rubber wood. Each composite consisting of 20wt.% of wood dust and 80wt.% of epoxy resin. 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. Utmost care has been taken to maintain uniformity and homogeneity of the composite.

Figure 3.1. Rubber wood dust

Figure 3.2. Sal wood dust

Figure 3.3. Teak wood dust

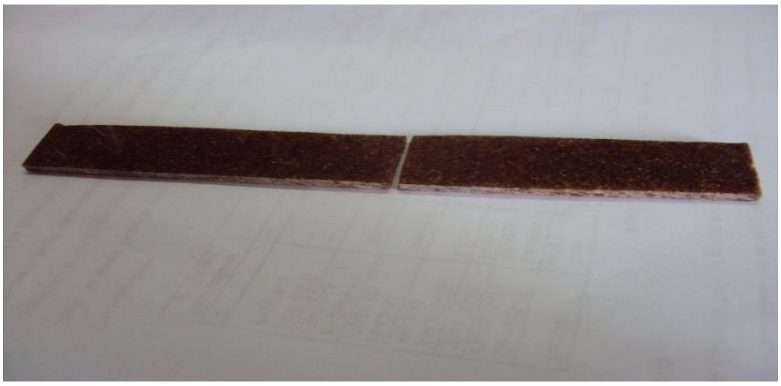
Table 3.1. Designation of Composites

Composites	Compositions
C_1	Epoxy (80wt%)+wood dust (teak wood) (20wt%)
C_2	Epoxy (80wt%)+ wood dust (rubber wood) (20wt%)
C_3	Epoxy (80wt%)+ wood dust (sal wood) (20wt%)

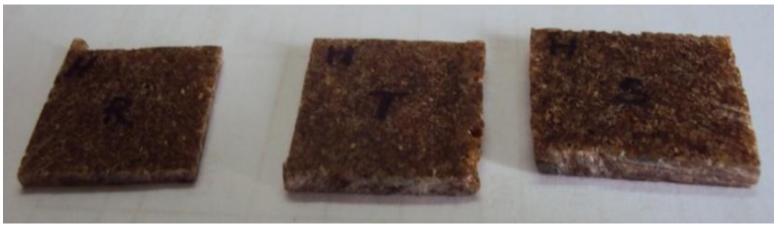
3.2. Mechanical Testing

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 Vicker's 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 = 1Kgf. 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. 4. (a-c) shows the tested specimens for flexural, tensile and hardness test respectively. Figure 3.5a and b. show the experimental set up and loading arrangement for the specimens for tensile and three point bend tests respectively.

(a)



(b)



(c)

Figure 3.4. Tested specimens

Figure 3.5. 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. 6) 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 3.6. 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 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 wood types is having significant effect on the mechanical properties of composites. The properties of the composites with different wood types 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 (MPa)	Flexural strength (MPa)	Impact energy (KJ/m^2)
C_1	18.8	19.5	1820	25.41	20
C_2	13.6	5.766	1499	4.20	10.5
C_3	17.1	6.748	1788	9.6	14.5

4.1.1. Effect of wood types on Micro-hardness

The measured hardness values of all the three composites are presented in Figure 4.1. It can be seen that the hardness value of teak wood dust filled epoxy composites is more as compared to rubber wood and sal wood dust filled epoxy composites. Among three types of wood dust filler, rubber wood dust filled epoxy composites showing less hardness value.

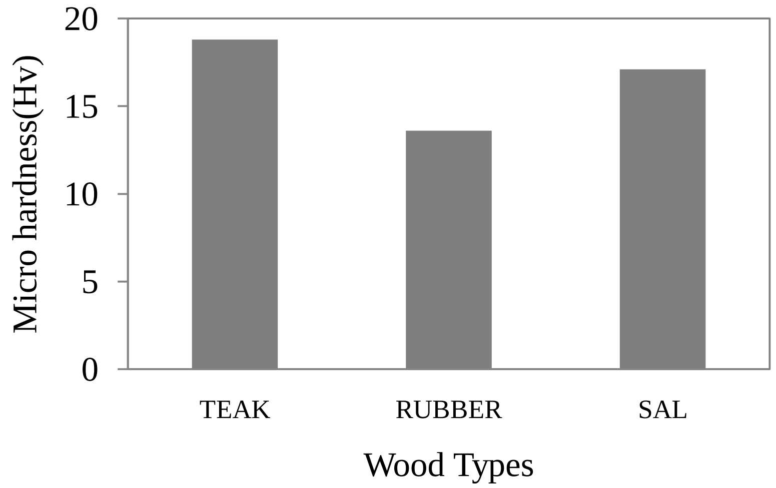

Figure 4.1. Effect of wood types on micro-hardness of the composites

4.1.2. Effect of wood types on Tensile Properties

The test results for tensile strengths and moduli are shown in Figures 4.2 and 4.3, respectively. It can be seen that the tensile strength of teak wood dust filled epoxy composites is more as compared to rubber wood and sal wood dust filled epoxy composites. This may be due to the good compatibility of teak wood dust and epoxy resin. Among three types of wood dust filler, rubber wood dust filled epoxy composites showing less tensile strength value. From Figure 4.3 it is clear that the similar trend is observed for tensile modulus of different wood types as observed for tensile strength.

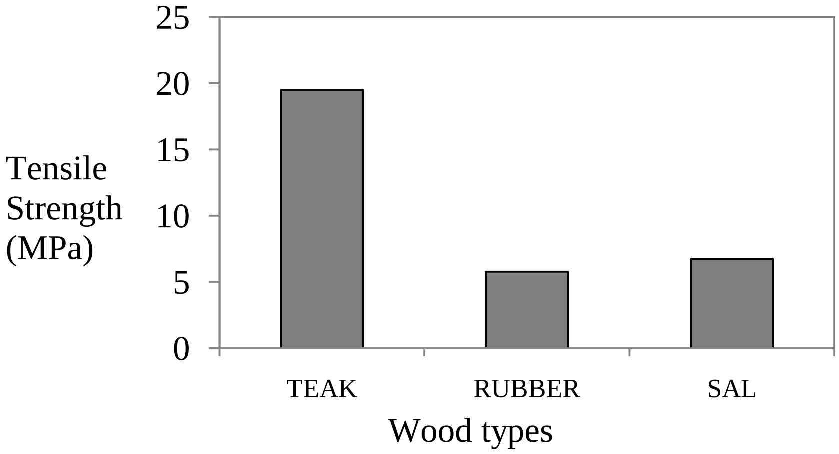

Figure 4.2. Effect of wood types on tensile strength of composites

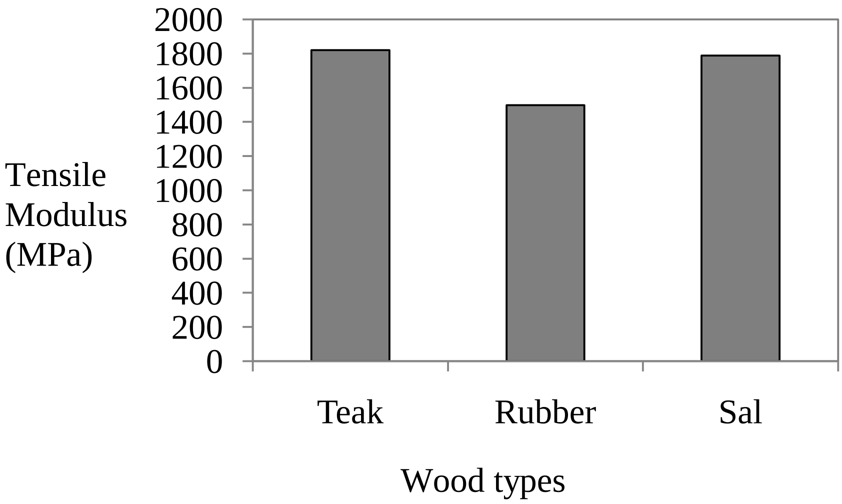

Figure 4.3. Effect of wood types on tensile modulus of composites

4.1.3. Effect of wood types 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 teak wood dust filled epoxy composite much more superior as compared to other two types of wood dust filled composites. This may be again due to the good dispersion of teak wood dust filler in epoxy resin. However rubber wood dust filled epoxy composite is showing less flexural strength.

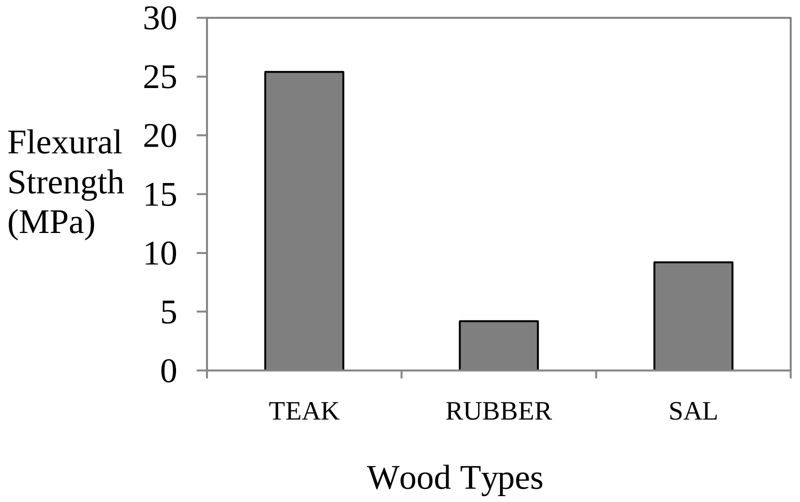

Figure 4.4. Effect of wood types on flexural strength of composites

4.1.4. Effect of wood types on Impact Strength

Effect of wood types on impact energy values of different composites is shown in Figure. 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. From the figure it is observed that resistance to impact loading of teak wood dust filled epoxy composites is more as compared to sal and rubber wood dust filled epoxy composites.

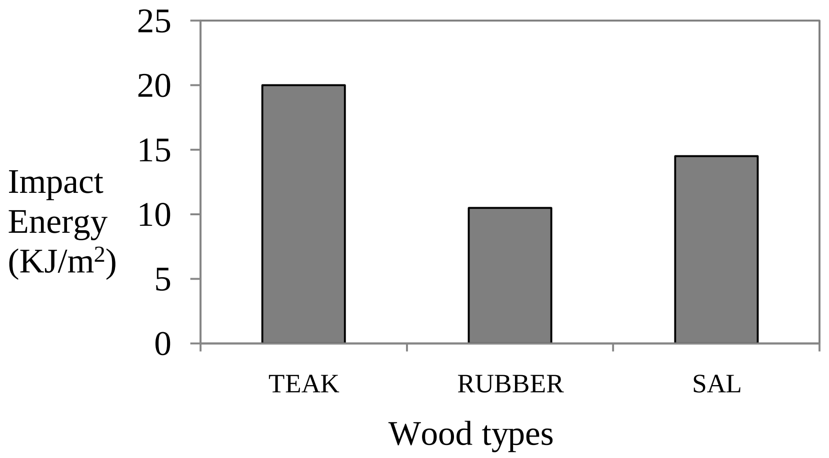

Figure 4.5. Effect of wood types on impact strength of composites

4.2. Surface morphology of the composites

The fracture surfaces study of wood dust filled epoxy composite after the tensile test, flexural test and impact test has been shown in Figure 4.6. Figures. 4.6a-c show the SEM of tensile failure surfaces of teak wood, rubber wood and sal filled epoxy composites with 20wt% of wood filler loading. The failure surfaces show feature of well-developed interfacial interaction. It can be seen there is very low pull-out of wood dust on the fracture surface in case of teak wood dust 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 two composites (rubber and sal wood dust) show lesser tensile strength (Figure 4.2) and from Figs. 4.6b and c the tensile fracture is more as compared with the teak wood dust composites as shown in Fig. 4.6a. This may exhibit the weak interfacial adhesion between the dust and epoxy matrix. Figs. 4.6b and c show many holes left after the dust are pulled out from the matrix when the stress is applied and the failure occurred at the interface.

Figs. 4.6d-f show the bending fracture surface of all the three wood dust filled epoxy composites. The flexural stress of the teak wood dust composites is found to be higher (see Fig. 4.6d) than that of rubber wood and sal wood dust composites (Figs. 4.6e-f). .But this result seemed to be very low compared to the results of Luo and Netravali [53].The results for deflection also seemed to below. The flexural properties showed decreasing trend for composites with volume fraction above 5.4%. The reasons why flexural properties are lower for volume fraction above 5.4% are possibly due to the fibre-to-fibre interaction, void and dispersion problems. Asri and Khalil [54] reported that lower flexural stress of thermoplastic composites might be attributed to the low interaction and poor dispersion of the fibre in the matrix. It can be seen that both properties increase in case of teak wood dust composites as compared with other two composites with similar weight fraction. These results indicate the fact that the incorporation of teak wood dust into the epoxy matrix enhanced the stiffness of the composites.

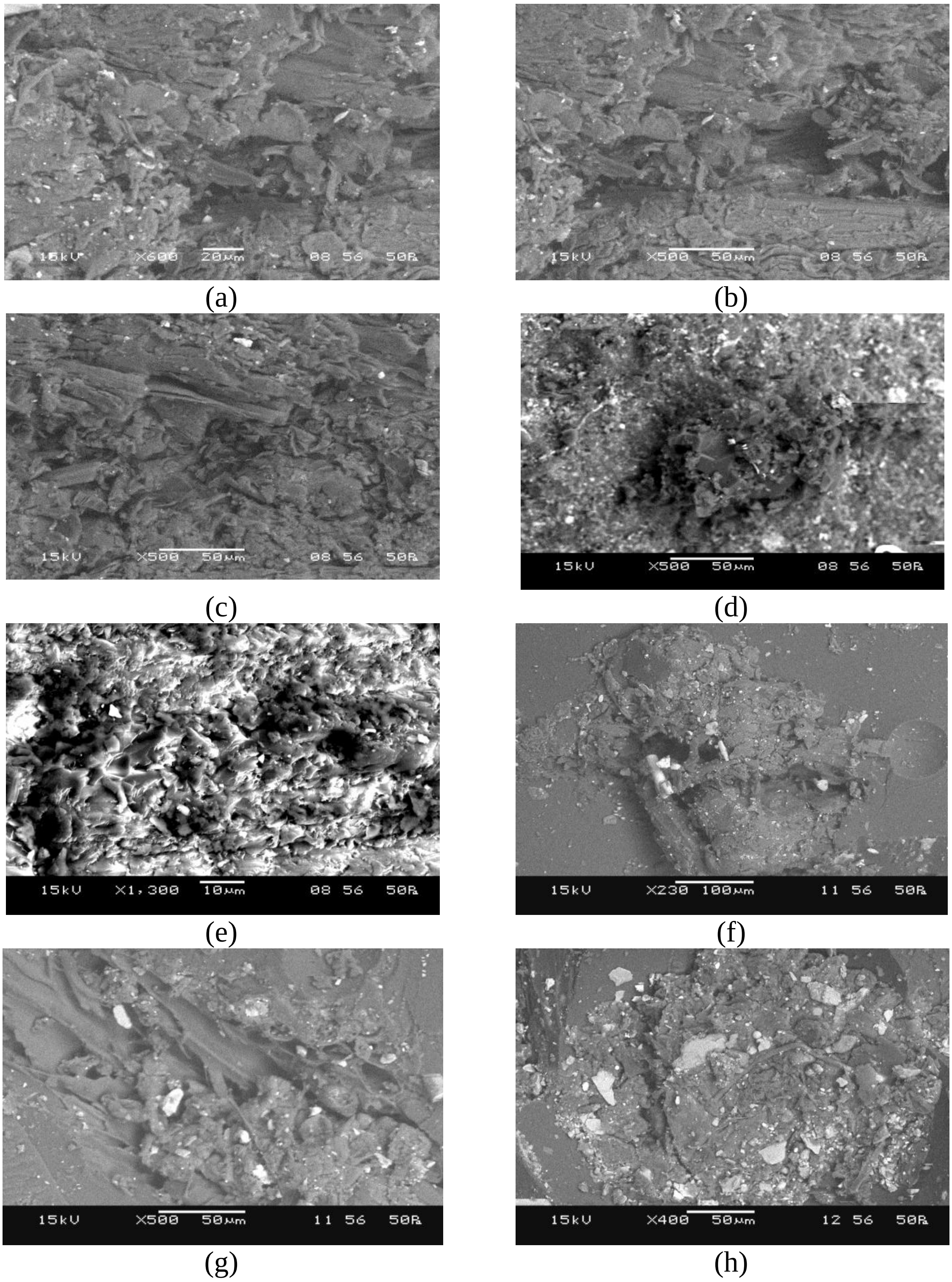

Figure. 4.6. SEM of fracture surfaces of all the wood dust filled epoxy composites.

Observation of the fracture surfaces of the composites by SEM can provide an insight into information related to interfacial adhesion and impact energy dissipation mechanisms involved during impact testing. Fig.4.6g-h show SEM graphs of impact fractured surfaces of teak and rubber wood dust epoxy composites. The impact strength of teak wood dust composite has higher than (Fig. 4.6g) that of rubber and sal wood dust composites (Fig. h). Also, some traces can be visible in case of rubber wood dust composite and more number of rubber wood dusts is pulled-out from the matrix materials. This is evidence of poor interface bonding. In addition, there is less pronounced plastic deformation of the surrounding matrix involved. It is well known that the interface between the polymer Matrix and the lignocellulosic filler plays a critical role in ensuring that the properties of each component contribute to bulk properties and indeveloping composite materials without standing physical and mechanical properties [55]. Infact, when particulate wood dust filler is dispersed into a epoxy composttes, it is quite difficult to achieve a strong bond between particles and matrix. A Possible reason, among others, is the poor wettability of the fine wood dust filler particles in the epoxy compostes. Finally, a weak boundary layer at the interface may be formed by contaminants present on the surface of the filler particles [56].

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Chapter 5

CONCLUSIONS

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This experimental investigation of mechanical behaviour of wood dust filled epoxy composites leads to the following conclusions:

- This work shows that successful fabrication of a wood dust filled epoxy composites with different types of wood is possible 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 wood types.
- The fracture surfaces study of wood dust filled epoxy composite after the tensile test, flexural test and impact test has been done. From this study it has been concluded that the poor interfacial bonding is responsible for low mechanical properties.

5.1. Scope for Future Work

There is a very wide scope for future scholars to explore this area of research. This work can be further extended to study other aspects of such composites like effect of fiber content, fiber orientation, loading pattern, fiber treatment on mechanical behavior of wood dust filled polymer composites and the resulting experimental findings can be similarly analyzed.

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