EXPERIMENTAL EVALUATION OF WOOD DUST PARTICULATE REINFORCED POLYMER COMPOSITES

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Abstract: 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 analyze their mechanical behaviour by experimentation.

KEYWORDS: Wood dust, Polymer-matrix composites, Hardness, Tensile strength, Flexural Strength, Impact Energy.

I. INTRODUCTION

In recent years, the interest in composite materials is increasing due to its advantages as compared to other engineering materials. Composites materials can be defined as engineered materials which exist as a combination of two or more materials that result in better properties than 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: The matrix 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.

A. Classification of Composites

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

1. *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, polyester) 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.

2. *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. 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.

B. Fibers: These are generally classified into two groups:-

Synthetic Fibers

Natural Fibers

Synthetic Fibers*:*

These are manmade 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.

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 plants transportation system, they are called leaf fibers.

C. 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. 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. 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.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. 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. 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.

II 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

2. Polyester resin
3. Hardener

A. Specimen preparation

Wood dusts of three different wood types (Figures1,2,3) are reinforced with Polyester 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 80oC in order to remove moisture. The polyester 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 polyester 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 polyester resin. The designations of these composites are given in Table 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 1. Rubber wood dust

Figure 2. Sal wood dust

Figure 3. Teak wood dust

Table 1. Designation of Composites

Composites	Compositions
C_1	Polyester (80wt%) + wood dust(Teak) (20wt%)
C_2	Polyester (80wt%) + wood dust (Rubber) (20wt%)
C_3	Polyester (80wt%) + wood dust (Sal) (20wt%)

B. 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 1360 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.

III 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 the below table

Table 2. Mechanical Properties of 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	1778	9.6	14.5

A. Effect of wood types on Micro-hardness

It can be seen that the hardness value of teak wood dust filled polyester composites is more as compared to rubber wood and sal wood dust filled polyester composites. Among three types of wood dust filler, rubber wood dust filled polyester composites showing less hardness value.

B. Effect of wood types on Tensile Properties

The test results for tensile strengths and modulus are shown in Figures 4 and 5, respectively. It can be seen that the tensile strength of teak wood dust filled polyester composites is more as compared to rubber wood and sal wood dust filled polyester composites. This may be due to the good compatibility of teak wood dust and polyester resin. Among three types of wood dust filler, rubber wood dust filled polyester 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.

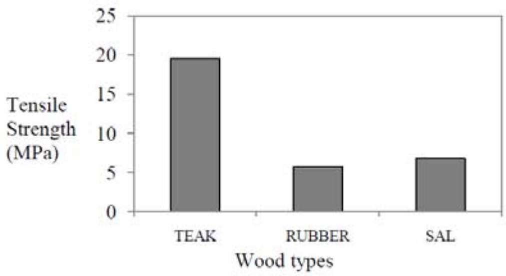

Figure 4. Effect of wood types on tensile strength of composites

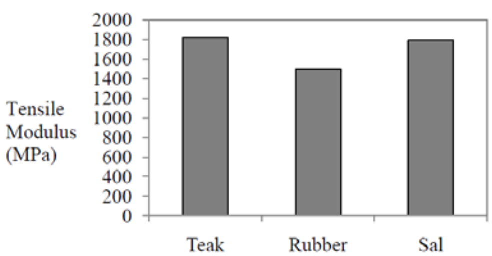

Figure 5. Effect of wood types on tensile modulus of composites

C. 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 polyester composites is more as compared to sal and rubber wood dust filled polyester composites.

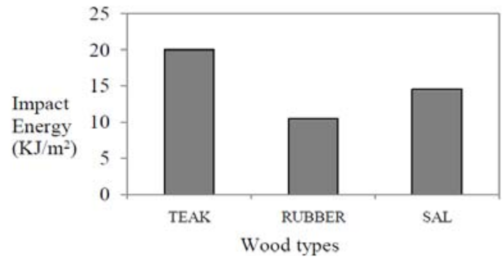

Figure 6. Effect of wood types on impact strength of composites

IV 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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