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“I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure and Material)”

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Date : 27/6/2013

**MECHANICAL PROPERTIES OF POLYPROPYLENE FILLED WOOD FIBER
COMPOSITES**

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**This report submitted in partial fulfillment of the requirements for the award of
Bachelor of Mechanical Engineering (Structure & Materials)**

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DECLARATION

“I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledgement.”



Signature :
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DEDICATION

Special for
My beloved family

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ABSTRACT

In this study, attempt has been made to combine the advantages of polymer and natural fiber. Polypropylene filled wood fibers (PP/WF) composites were prepared by using the Z-blade mixer at processing temperature 180°C and a speed of 50rpm with different filler loading varying between 0% and 40% by weight. A titanate coupling agent, Acrylic Acid was added to improve the adhesion of matrix and filler material. PP/WF composites have been characterized from the point of view of mechanical properties. Generally, PP/WF composites have successfully increased several mechanical properties as compared to the pure PP polymer. The increase in filler loading has decreased the tensile strength and elongation at break while Young's modulus was increased. The incorporation of WF in PP increases the flexural strength and flexural modulus of the composites. Based on morphological investigation, the increasing of filler loading has transformed the failure mode from ductile to brittle manner. The water absorption test reveals that with the increasing of filler loading, swelling rate of PP/WF composites also increase due to hydrophilic nature of natural fiber which is tend to absorb water.

ABSTRAK

Kajian ini telah dijalankan untuk menggabungkan kelebihan-kelebihan sifat bahan polimer dan gentian semula jadi. Komposit polietilena berketumpatan tinggi terisi sekam padi (PP/WF) disediakan dengan menggunakan mesin pencampuran bilah Z pada suhu pemprosesan 180°C dengan kelajuan putaran motor 50rpm. Komposit ini dihasilkan mengikut peratus berat pengisi yang berbeza di antara 0% hingga 40%. Agen pengkupel Acrylic Acid dicampur untuk menambah baik lekatan antara matriks dan pengisi. Kajian sifat-sifat komposit PP/WF dijalankan melalui ujian-ujian mekanikal. Secara amnya, komposit PP/WF telah berjaya meningkatkan beberapa sifat-sifat mekanikal berbanding polimer PP tulen. Peningkatan peratus pengisi telah mengurangkan kekuatan tegangan dan pemanjangan pada takat putus tetapi meningkatkan modulus keelastikan. Penambahan serbuk kayu ke dalam PP juga meningkatkan kekuatan dan modulus pelenturan. Berdasarkan kajian ke atas permukaan patah PP/WF komposit, didapati peningkatan peratus pengisi menyebabkan komposit mengalami perubahan mod patah daripada mulur kepada rapuh. Ujian peyerapan air menunjukkan bahawa dengan peningkatan berat pengisi, kadar serapan air komposit PP/WF juga meningkat kerana sifat hidrofilik fiber semulajadi yang cenderung untuk menyerap air.

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LIST OF SYMBOLS

| | |
|--------------------|--|
| $^{\circ}\text{C}$ | Degree Celsius |
| A | Area |
| CMC's | Ceramic-Matrix Composites |
| E | modulus of elasticity or Young's modulus, flexural modulus (E_B) |
| % EL | ductility, in percent elongation |
| F | Load |
| E_f | Flexure modulus |
| PP | Polypropylene |
| LDPE | Low-density polyethylene |
| AA | Acrylic Acid |
| MAPE | Maleic Anhydride Polyethylene |
| MI | Melt index |
| MMC's | Metal-Matrix Composites |
| PMC's | Polymer-Matrix Composites |
| WF | Wood Fiber |
| T_g | Glass transition temperature |
| T_m | Melting temperature |
| F_t, TS | Tensile strength |
| wt% | Weight percentage |
| ε | Engineering strain |
| σ | Engineering stress, flexural stress (σ_{fs}) |

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CHAPTER 1

INTRODUCTION

1.1 Polymer Composites

With the growing concern for the impact of human activities on the environment, the idea of using natural fibers instead of synthetic fibers for reinforcement in composites, especially plastic composites have been developed. The reason behind this research is due to the environmental benefits of natural fibers and low cost compared to synthetic fibers. Within the last 15 to 20 years the research about natural fiber has attracted a lot of interest, particularly with its known potential as a replacement for glass fibers within composite materials. Whereas most of the initial fabricated composites in this area focused on using thermosets as matrices, partly due to their ease of fabrication, the fact that thermosets are hard to recycle has led to the use of thermoplastics. The focus is now towards the use of more recyclable thermoplastics (Thimothy, 2008).

Natural fiber thermoplastic composites have recently received considerable attention from the wood and plastic industries because of the advantages of these materials over conventional reinforcement materials such as low cost, renewability, low specific gravity, abundancy, high specific strength and non-abrasiveness (Gupta, 2005).

Polypropylene (PP) was selected as the matrix because it is one of the major commodity plastics which may be processed below the decomposition temperature of lignocellulosic fibers (about 200°C). Wood fibre is a natural structure made of cellulose fibres which contains numerous hydroxyl groups that are strongly

hydrophilic. Wood fibers are particular interest as filler and/or reinforcement agents in polymer composites because wood fibers are abundant, renewable, recyclable, biodegradable; have high specific strength and stiffness; cause less machine wear; and are generally of low cost compared to inorganic fillers. Wood fibres in thermoplastics have also favorable weight ratio, low hardness and abrasiveness (Zafeiropoulos, 2002).

Polymer composites featuring both stiffness and strength have been of great commercial interest for a century now. Although inorganic filler such as calcium carbonate, mica, fiberglass, talc and clay have been widely used, composites containing organic filler derived from renewable resources have aroused broad interest because of growing environmental concerns and the increasing costs of inorganic fillers. In particular, cellulose-based fillers, such as wood flour (WF) and cellulose fibers have been used to yield composites with the additional advantages of density relative to inorganic systems, biodegradability, and non abrasiveness to processing equipment. Although opportunity exists for other sources of wood to be used as filler materials for thermoplastics, wood flour being a commercially available resource derived from postindustrial scrap, is one of the most commonly used wood-derived fillers today.

Wood-reinforced plastic composites have found application in various areas, including automotive interior, household, ornament, building and packaging uses. However, the use of cellulose based materials as reinforcements or fillers for polyolefins has only recently gained acceptance. This is because the inclusion of cellulosic fillers in polyolefins usually gives rise to reduces toughness and poor-stress transfer efficiency that result from incompatibility between the polar and hydrophobic filler and the non polar of hydrophobic matrix. When polyolefins are used as thermoplastic matrices, there must be some form of interaction between the thermoplastic matrix and filler for useful composites to be realized.

The improvement in interfacial adhesion between cellulosic fillers and thermoplastics has been the focus of a large amount of research during the past two decades. Several comprehensive reviews have been published recently (Zadorecki, 1989). Cellulosic fillers can be modified by physical and chemical methods. Among

various ways of chemical modification for polyolefin-wood flour composites (Klason, 1984), the functionalized polyolefins are most often tested because of their efficiency and commercial availability.

1.2 Objectives of Study

This project was focused on a study of chemical modification of wood fiber on polypropylene/wood fiber composites. There are 2 major studies:

- a) To study the effect of different filler loading on mechanical properties, morphology studies and water absorption of PP/wood fiber composites.
- b) To study the effect of compatibilizer on properties of PP/wood fiber composites.

Several testing had done to investigate the properties of the composites such as tensile test, morphology studies and water absorption. Tensile test was performed to measure tensile strength, elongation at break and Young's modulus for each composition of the composites. Studies of the morphology of the tensile fracture surface of the composites were carried out by using a Scanning Electron Microscope (SEM). SEM was used to examine qualitatively the dispersion of wood fibers in the polypropylene matrix. The water absorption is a study about the potential of composites to absorb water.

1.3 Scope of Work

This research consists of two phases of samples preparation. The first phase is the compounding of the PP (matrix) with Wood Fiber (filler) using Z-blade mixer. The blend ratio of PP to wood fibers is 100:0, 90:10, 80:20, 70:30 and 60:40 percentages from the total weight of 100g per mixture. The materials were mixed in the Z-blade mixer which was set to 180 °C with rotor speed of 50 rpm for about 30 minutes or until the mixture is homogenous. The second phase was pressing the mixture into thin layer using hot press machine. The mixture was pressed into mold using hot press to get the desired thickness. There are two platens of hot press and both were set at 180 °C with 170 Pascal pressure. All the samples were gone through these

same processes during compression; 4 minutes of preheat, 8 minutes of compression and 4 minutes of cooling down. Then the samples were prepared for tensile and water absorption.

CHAPTER 2

LITERATURE REVIEW

2.1 Composites

A composite material is a materials system composed of a suitably arranged mixture or combination of two or more micro- or macro constituents with an interface separating them that differ in form and chemical composition and are essentially insoluble in each other. The engineering importance of a composite material is that two or more distinctly different materials combine to form a composite material that possesses properties that are superior, or important in some other manner, to the properties of the individual components (Smith, 1991).

Thus composites are those materials formed by aligning extremely strong and stiff constituents such as fibers and particulates in a binder called matrix. The materials in this class have exceptional mechanical properties. One of the components is that accommodate stress to incorporate component called reinforcing phase and provide a strong bond called matrix. Polymers, ceramic and metals have found application as matrix materials. The reinforcing phase is other component and is called reinforcement and can be fiber, particulate or laminar (Gupta, 2005). The composite properties depend on those of the individual components and on their interface compatibility. Many research works has been carried out to identify the parameters that govern mechanical behavior of particulate composites. Generally, it has been found that the reinforcement effect increases with decreasing particle size and with increasing adhesion to the matrix (Marcovich, 1998).

2.2 Matrix

In choosing to reinforce an engineering material the matrix are effectively selecting for a composite. This matrix is required to perform several functions, most of which are vital to the satisfactory performance of the composite. The matrix binds the fibers together, holding them aligned in the important stress direction. Loads are applied to the composite, are then transferred into the fibers, which constitute the principal load bearing component, through the matrix, enabling the matrix to withstand compression, flexural and shear force as well as tensile loads. The ability of composites reinforced with short or chopped fibers to support load of any kind is exclusively dependent on the presence of matrix as the load transfer medium and the efficiency of this transfer depends on the quality of the fiber-matrix bond.

The composite performance is influenced by the following matrix properties (Gupta, 2005):

- i. Elastic constants
- ii. Yield and ultimate strength under tension, compression or shear
- iii. Failure strain or ductility
- iv. Fracture toughness
- v. Resistance to chemicals and moisture
- vi. Thermal and oxidative stability

2.3 Fillers

Fillers were considered as additives, which, due to their unfavorable geometrical features, surface area or surface chemical composition, could only moderately increase the modulus of the polymer, while strength (tensile, flexural) remained unchanged or even decreased. Their major contribution was in lowering the cost of materials by replacing more expensive polymer, other possible economic advantages were faster molding cycles as a result of increased thermal conductivity and fewer rejected parts due to warpage. Depending on the type of filler, other polymer properties could be affected; for example, melt viscosity could be significantly increased through the incorporation of fibrous materials. On the other hand, mold shrinkage and thermal expansion would be reduced, a common effect of most

inorganic fillers. The term *reinforcing filler* has been coined to describe discontinuities additives, the form, shape, and/or surface chemistry of which have been suitably modified with the objective of improving the mechanical properties of the polymer, particularly strength.

2.3.1 Functional Fillers

Fillers are define as a variety of solid particulate materials (inorganic, organic) that may be irregular, acicular, fibrous or plate-like in shape and which are used in reasonably large volume loadings in plastics. There is significant diversity in the chemical structures, forms, shapes, sizes, and inherent properties of the various inorganic and organic compounds that are used as fillers. They are usually rigid materials, immiscible with the matrix in both the molten and solid states, and as such, form distinct dispersed morphologist. Their common characteristics is that they are used at relatively high concentrations (>5% by volume), although some surface modifiers and processing aids are used at lower concentrations. A more convenient scheme, first proposed by Mascia, for plastic additives, is to classify fillers according to their specific function, such as their ability to modify mechanical, electrical or thermal properties, flame retardancy, processing characteristics, solvent permeability, or simply formulation costs. Fillers, however, are multifunctional and may be characterized by a primary function and a plethora of additional functions. Classification of fillers according to five primary functions, as follows:

- i. Mechanical property modifiers (and further subdivision according to aspect ratio);
- ii. Fire retardants;
- iii. Electrical and magnetic property modifiers;
- iv. Surface property modifiers;
- v. Processing aids.

Additional functions may include degradability enhancement, barrier characteristics, anti-ageing, bioactivity, radiation absorption, warpage minimization, etc (Gupta, 2005).

2.3.2 Particle Shape

Particle shape is very important in determining the stiffness, or rigidity, of a composite, the flow and rheology of a melt or liquid, tensile and impact strength, and the surface smoothness of a component i.e., many of the important properties of a composite.

Shape is determined by the genesis of the filler, by its chemistry, its crystal structure and by the processing it has undergone. Unfortunately, it is usually poorly defined, the literature abounding with vague terms such as roughly spherical, blocky, irregular, platy, acicular and etc. All the fillers commonly used are microscopic in size imposing major difficulties both in how to measure, and then how to describe and quantify shape in any simple yet meaningful way. Fillers are used because of their shape in a very wide range of polymers to give specific properties. For example, conventional clays are used in hose and chemical lining because their shape reduces permeability to fluids; platy talcs give rigidity to PP; the complex aggregate structure of precipitated calcium carbonates contributes to the structure of liquid polysulfides; and the special structured shape of many carbon blacks and synthetic silicas is important to their performance in elastomers. A further example is the emerging use of very high aspect ratio, nano-clays as reinforcing, fire retarding and gas and fluid barrier fillers.

2.3.3 Particle Size

Particle size is a very important, property of filler, but is a particularly complex area where great confusion still occurs. For an individual, naturally occurring, filler it will have been determined by the origin and the mineralogy of the deposit from which it has been extracted, by the method used in mining, and by separation procedures used during processing. Size is one variable that can be controlled, and its importance is felt at all stages of composite production and use. Hence, there is considerable interest in its measurement. Particle size distribution is more useful than single average values, although the latter have the merit of simplicity. Size is an easy property to measure reproducibly using a variety of technique including sieving, sedimentation, optical scattering and diffraction from particulate suspensions.

2.4 Matrix-Filler Interface

Incorporation of fibres (man-made or natural) into a polymer is known to cause substantial changes in the mechanical properties of composites. A good interfacial bond between fibre and matrix, can substantially improve the mechanical properties of the composite. Interfacial shear strength is one of the means of determining bonding between fibre and matrix.

The term “interface” has been defined as the boundary region between two phases in contact. The composition, structure or properties of the interface may be variable across the region and may also differ from the composition, structure or properties of either of the two contacting phases. This interfacial region exhibits a complex interplay of physical and chemical factors that exerts a considerable influence on and controls the properties of reinforced or filled composites. The interfacial interaction depends on the fibre aspect ratio, size of the interface, strength of the interaction, anisotropy, orientation, aggregation, etc. Extensive research has been done on the interfacial shear strength (ISS) of man-made fibre and for the natural fibres by using methods such as fibre pull-out tests, critical fibre length and microbond tests.

The problems encountered when attempting to combine any plant fibres or any lignocellulosic material with a thermoplastic or thermoset matrix is one of incompatibility. The reason for this is due to the abundant hydroxyl functionality of fibre cell wall polymers which ensures that the material is hydrophilic. The problem then is one of ‘wetting’ the fibre. There are various methods available to improve the compatibility between lignocellulosic and the matrix:

1. Chemical modification of the lignocellulosic.
2. Grafting of polymers onto the lignocellulosic.
3. The use of compatibilizers and coupling agents.