UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Mechanical Properties of Wood Plastic Composite Made of Recycled Polypropylene and Recycled Wood Flour

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Materials Engineering) with Honours.

by

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ABSTRACT

This research investigated the stability, mechanical properties, and the surface microsgraphs of wood–plastic composites (WPCs), which were made by combining the recycled Polypropylene (rPP) together with waste wood four. Virgin Polypropylene (vPP) will also be used as control sample for the comparison purposes. The rPP were obtained from the 3 in 1 drink wrappers. WPCs panel are fabricated by using a single-screw extruder and compression moulding machine. The test of the resulted composites based with different ratio of the filler content, 0%, 30% and 40% were carried out by using the Universal Testing Machine (UTM). Composite panels made from rPP and recycled wood flour (rWF) exhibits lower tensile and flexural properties compared than vPP-WF composite panel. Microstructural analysis of the WPCs' microstructure surfaces was further investigated. The experiment results showed that the tensile and flexure modulus are increased with the increasing of WF. The results are contradictory for the tensile and flexural strength as their value decreased with the increasing of WF percentage of addition. The composite panel also went through water immersion test for 24 hours and the composites made of rPP-WF exhibits better results than composites made of vPP-WF. As a conclusion, the unsuccessful objective in proving the rPP-wf composites have better mechanical properties than the virgin PP-WF composites are due to the difficulties and improper ways of processing the rPP-WF, and also due to the voids and impurities exists in the recycled material composites.

ABSTRAK

Kajian ini membincangkan tentang kestabilan, sifat mekanikal dan mikrograf permukaan komposit plastik-kayu yang diperbuat dengan menggabungkan plastik kitar semula bersama dengan sisa-sisa kayu. Polipropilena asli juga akan digunakan sebagai sampel kawalan untuk tujuan perbandingan. Polipropilena(PP) kitar semula diperolehi dari sisa-sisa plastik pembungkusan minuman tiga dalam satu. Panel komposit plastik-kayu difabrikasikan dengan menggunakan penyempritan skru solo dan mesin kompres. Ujian panel komposit yang dihasilkan berasaskan komposisi gentian kayu yang berbeza, iaitu 0%, 30% dan 40%, dilaksanakan dengan menggunakan Mesin Penguji Universal. Panel komposit kayu kitar semula menghasilkan moduli ketegangan dan kelenturan yang lebih rendah berbanding panel komposit kayu asli. Keputusan eksperimen menunjukkan moduli ketegangan dan kelenturan meningkat dengan meningkatnya kuantiti serbuk kayu. Keputusan adalah berlawanan bagi kekuatan tegangan dan lenturan di mana nilai keputusan menurun dengan meningkatnya peratusan penambahan gentian kayu.. Panel komposit juga melalui ujian rendaman air selama 24 jam dan komposit kayu kitar semula menghasilkan keputusan ujian yang lebih baik berbanding komposit kayu asli. Sebagai rumusan, kegagalan objektif dalam membuktikan sampel kitar semula mempunyai ciri-ciri mekanikal yang lebih baik berbanding sampel yang menggunakan bahan asli adalah disebabkan kesukaran dan cara yang tidak betul semasa pemprosesan, dan juga disebabkan oleh kecacatan dan bendasing yang wujud dalam komposit kitar semula.

DEDICATION

For my beloved father and mother and also to my family who always give me support.

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LIST OF ABBREVIATIONS

LCPs	-	Liquid Crystal Polymers
MOE	-	Modulus of Elasticity
NaOH	-	Sodium Hydroxide
PP	-	Polypropylene
PE	-	Polyethylene
PP/WF	-	Polypropylene/Wood Flour
SEM		Scanning Electron Microscope
UTeM	-	Universiti Teknikal Malaysia Melaka
UTM	-	Universal Testing Machine
rPP	-	Recycled Polypropylene
rPP/WF	-	Recycled Polypropylene/ Wood Flour
rWF	-	Recycled Wood Flour
vPP	-	Virgin Polypropylene
vPP/WF	-	Virgin Polypropylene/ Wood Flour
WF	-	Wood Flour
WPCs	-	Wood Plastic Composites

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, million tones of wastes are produced by people all around the world. The problems with the waste are not enough dumping area, creating bad scenery and contribute to the various diseases. Attempts have been made to recycle the post-consumer plastics in order to reduce the environmental impact and consumption of virgin plastics. Statistics very clearly demonstrates the rapid increase in the consumption of plastics. The quantity of plastics, excluding rubber and fiber, produced in the world in 1930 was 100,000 tons. This amount reached 25 million tons in 1976. Along with new developments in technology, the production of the plastics reached 90 million tons in 1990. In the year 2005, this number exceeded 500 million tons (Hannequart, 2005). Hannequart (2005) also stated that when looking at the consumption between the years 1990 and 2005, it can be observed that the amount of annual metal consumption duplicates once in every nine years, but plastic consumption duplicates every four years.

Millions of tons of plastics are produced and consumed in the world every year. Further, there are various kinds of plastics that are produced and used. By looking at the various plastics produced throughout the world, it can be observed that they are manufactured in the percentages of 31% of Polyethylene (PE), 17% of Polyvinyl Chloride (PVC), 15% of thermosets, 14% of Polypropylene (PP), and 9% of Polystyrene (PS). In addition, other kinds of plastics not mentioned here comprise 14% of the world production. (Hannequart, 2005). Thermoplastics constitute 85% of consumed plastics. For this reason, the recycling of the thermoplastics and the usability of the recycled materials are gaining significance. It is clearly very important to produce and consume plastic materials in an environmentally friendly way.

Previous studies showed that the properties of the recycled high density Polyethylene (rHDPE) obtained from the post-consumer milk bottles was not largely different from those of virgin resin and thus could be used for various applications (Pattanakul *et. al*, 1991); considering that mechanical properties of PP is almost the same with PE, shows that mechanical properties of recycled Polypropylene (rPP) is not largely different from the virgin polypropylene (vPP). Also the recycled plastics are cheaper than in the virgin form. Thus, increased use of recycled plastics offers the prospect of lessening waste disposals and reducing the product costs.

In the case of wood utilization, a large amount of wood waste is generated at different stages of the wood processing and such waste is mainly destined for landfill. The use of waste wood in wood plastic composites (WPCs) helps to offsets these disposal costs. It was well established that waste wood in the form of wood flour, fibres or pulp are suitable as a filler for polyolefins based composites (Woodhams *et al*, 1984). Miller *et al.* (1994) states that, wood fibre possesses physical and mechanical properties is suited for the reinforcement agent for plastic materials.

There are environmental and economical advantages to produce WPCs. 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 the traditional fillers and reinforcing materials such as low density, flexibility during the processing with no harm to the equipment, acceptable specific strength properties and low cost per volume basis. There are some researches about the influence of the filler and its size over the mechanical and physical properties of WF-reinforced thermoplastics (Zaini *et al.*, 1997). It has been observed that the elongation at break and the impact strength of the composites decreased with the addition of filler independently of its size. The behavior of the tensile modulus and the tensile strength seems depended on the shape of the particles. This behavior can be improved with the increasing of load (Osswald *et al*., 2003).

However, due to the inherent poor compatibility between hydrophobic general-purpose thermoplastics and hydrophilic cellulosic fibers, several treatments have been reported to improve the fiber-matrix interfacial bonding (Kuruvilla and Sabu, 1996). The effect of chemical treatments with alkali, permanganate, isocyanate and peroxide on the tensile properties of short sisal fiber-reinforced PE composites has been studied before by Kuruvilla and Sabu (1996). Considerable enhancements of the tensile properties of composites were observed (Pramanick and Dickson, 1997). Polymers that are modified with reactive functional groups improved the tensile strength of WF reinforced post-industrial recycled polypropylene (Pramanick and Dickson, 1997). The WF and compatibilizer have marginal influence on the Izod impact strength of the composites (Pramanick and Dickson, 1997).

1.2 Objectives

a) Investigate the mechanical properties of wood plastic composite made of various compositions of rPP and vPP with rWF.
b) To prove that the products made of rPP based on wood reinforcement are better than products made of vPP-wood composites.

1.3 Problem Statement

There are two kinds of materials use in this world that is either of natural origin or synthetic. Plastics are synthetic whereas woods are materials of natural origin. Plastics and woods constitute a large portion of waste materials. The problem of waste materials, which has grown to large dimensions in recent years, has played an important part in the strategic agendas of countries since the 1980s. With the large portion of wastes, there is no enough dumping area to dump very much of wastes. Indirectly, this will create bad scenery for our country. On the other hand, the wastes will also contribute to various diseases. Plastics and wood are among those of few materials that are extensively used in engineering industry. Thus, these two materials can be used to fabricate wood plastic composites (WPCs).

During the last decade, wood-plastic composites (WPCs) have emerged as an important family of engineering materials. They have become prevalent in many building applications, such as decking, docks, landscaping timbers, fencing and many more, partially due to the need to replace pressure-treated solid lumber. Although WPCs are commercialized, they are mainly used in semi structural applications because they do not possess the bending strength and modulus which required for long spans and load-bearing structural applications. Indeed, most of the WPCs have lower bending stiffness and strength compared to solid wood (Matuana, 2007). Enhancing the bending properties of WPCs could expand their acceptance in load bearing structural applications. This project is about combination of rPP and WF to be composites that can be as or more durable than vPP-WF composites and yet still environmental friendly.

1.4 Scope of work

Literature on WPCs was surveyed in order to prepare the WPCs with different features such as by using virgin and recycled PP, and rWF. The scope is also to combine two materials in such a way, as to produce a product that is environmental friendly from rPP and rWF. The WF will be used as the reinforcement while the PP is the matrix of the composite. The characteristics and properties of resulted composite materials are evaluated based on mechanical and physical testing such as tensile test, flexural test, water immersion test and morphology observation.

1.5 Thesis Outline

In Chapter One, the background, objectives, scope of work and problem statement about the project were discussed. For Chapter Two, this project discussed about wood plastic composite, PP as the matrix, and the WF as the reinforcement. Then it continues by discussing about the mechanical test and physical test done to the specimen.

In Chapter Three, raw materials preparation that involved in this research is explained. WF has been chosen as the reinforcement to produce a new design of a new material. rPP and vPP will be the matrix of the material. The recycled PP is used to be compared with the samples produced by using the virgin materials as the matrix. The sample preparation for recycled and virgin Polypropylene (PP), recycled wood flour (rWF) and the compound by percent of weight were determined. Hot press would be the technique to produce the composite. After that, the specimens will be tested by following the dimension of specimens, referring to international standard. The wood plastic composites (WPCs) samples of different composition were tested experimentally; which are consist of the tensile test, flexural test, impact strength test and water immersion test. The results of each testing were evaluated to obtain the characteristics of every each composition.

In Chapter Four, the results obtained from the testing are showed and data analysis is explained. Analyses of tensile and flexural properties were carried out in order to investigate and obtain the optimum value of the mechanical properties. The samples were analyzed for its amount of water absorbed and thickness swelling in water immersion (24h) test and lastly undergo the surface morphological study by using the Scanning Electron Microscopy (ZEISS, EVO 50). The discussions of the results are also discussed in this chapter. Lastly, the conclusion and suggestion for future research is covered in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Wood Plastic Composite

Wood-plastic composites (WPCs) are non-recyclable composite material lumber or timber made of recycled plastic and wood wastes. Its most widespread use is in outdoor deck floors, but it is also used for railings, fences and indoor furniture. Manufacturers claim that wood-plastic composite is more environmental friendly and requires less maintenance than the alternatives of solid wood treated with preservatives or solid wood of rot resistant species (http://www.toolbase.org/Technology-Inventory/Decks-Patios-Fences/recycled-composite-lumber- accessed on 13th July 2008). Due to resistant to cracking and splitting, these materials can be moulded with or without simulated wood grain details. Even with the wood grain design, these materials are still visually easy to distinguish from natural timber as the grains are the same uniform colour as the rest of the materials (http://www.toolbase.org/Technology-Inventory/Decks-Patios-Fences/recycled-composite-lumber- accessed on 13th July 2008). Although these materials continue the lifespan of used and discarded materials, and have their own considerable half life, the polymers and adhesives added make wood-plastic composite difficult to be recycled again after used due to the many impurities in such a compound (http://www.toolbase.org/Technology-Inventory/Decks-Patios-Fences/recycled-composite-lumber- accessed on 13th July 2008)

Wood-plastic composite is composed of wood recovered saw dust and virgin or waste plastics including high-density PE, PP, PVC and many more (Andrea Wechsler, 2006). Wood makes an excellent functional filler, but within limits. While the heat used to melt and process plastics does not affect mineral-based fillers, it does affect wood (Livia Daryadi, 2006). Therefore, great care must be practiced when using wood as a functional filler. For the fabrication, the powder of fibers is mixed to a dough-like consistency and then will undergo extrusion process or moulding process to get the desired shape. Colorants, coupling agents, stabilizers, blowing agents, reinforcing agents, foaming agents, lubricants are the examples of additives that help tailor the end product to the target of application. The material is formed into both solid and hollow profiles or into injection moulded parts and products. With the diversity of organic components used in wood-plastic composite processing, there is no single answer to reliably handling these potentially difficult materials (http://en.wikipedia.org/wiki/Plastic_lumber- accessed on 13th July 2008).

A major advantage over wood is the ability of the material to be moulded to achieve almost any desired spatial conditions. It can be also bent and fixed to form strong arching curves. Due to its high cellulose content, that is up to 70 percent, wood-plastic composites behave like wood and can be reshaped using conventional woodworking tools (http://en.wikipedia.org/wiki/Plastic_lumber- accessed on 13th July 2008). At the same time, they are moisture-resistant and resistant to rot, although they are not as rigid as wood and may slightly deform in extremely hot weather. The porosity of the material causing the material to be sensitive to staining from a variety of agents (http://en.wikipedia.org/wiki/Plastic_lumber- accessed on 13th July 2008). A major selling point of these materials is their lack of need for paint as they are manufactured in a wide variety of colours.

Stark (1999) found that the reinforced polypropylene with wood fiber derived from recycled hardwood and softwood pallets provides improved bending and tensile strength over the use of wood flour. Stark (1999) also found that the use of maleated Polypropylene as a coupling agent further enhanced the mechanical properties of these recycled PP-WF composites. Shusheng Pang *et.al* (2007) stated that the mechanical behaviour of wood plastic composites based on recycled plastics are no different than based on virgin plastics.

2.2 Polypropylene

Polypropylene (PP) is a thermoplastic polymer, with molecular formula of C_3H_6 made by the chemical industry and used in many different settings, both in industry and consumer goods. It has a wide variety of applications, including packaging, textiles, stationery, plastic parts and reusable containers of various types, automotive components and many more. Most PP used is highly crystalline and geometrically regular; for example isotactic, and is opposite to amorphous thermoplastics, such as polystyrene (PS), Polyvinylchloride (PVC) and polyamide (PA), which radicals are placed randomly (atactic) (http://en.wikipedia.org/wiki/Polypropylene- accessed on 14th July 2008). PP can be used both as a structural plastic and as a fiber. PP has an intermediate level of crystallinity between the low density Polyethylene (LDPE) and high density Polyethylene (HDPE). On the other hand, PP has higher working temperatures and tensile strength than polyethylene. PP is not as sturdy as polyethylene, but it has benefits that make it the better choice in some situations. One of the examples of these situations is creating hinges from a plastic, such as a plastic lid on a travel mug. Over time, plastics will fatigue from the repetitive stress of being opened and shut, and eventually will break. PP is very resistant to this sort of stress, and is the plastic most often used for lids and caps which require a hinging mechanism (http://www.lenntech.com/Polypropylene.htm- accessed on 14th July 2008). Most PP parts are produced by injection molding, blow molding, or extrusion of either unmodified or reinforced components.

2.2.1 Properties of Polypropylene

Polypropylene (PP) is low in its density. Table 2.1 shows that PP has the lowest density of the commercial resins used in packaging. The molded plastic has a density in the range of 0.910-0.928, lower than PE (http://www.lenntech.com/Polypropylene.htm- accessed on 14thJuly 2008).