PRODUCTION AND CHARACTERIZATION OF ENVIRO-RECYCLED WOOD PLASTIC COMPOSITES (ER-WPC) FOR THE STRUCTURAL APPLICATION

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

by

NURUL AYUNNI BT ABDUL LATIF

FACULTY OF MANUFACTURING ENGINEERING
2010
TAJUK: "Production and characterization of Enviro-Recycled-Wood Plastic Composites (ER-WPC) for the structural application"

SESU PENGAJIAN: 1/20092010

Saya NURUL AYUNNI BT ABDUL LATIF mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (V)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia yang termaktub di dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☐ TIDAK TERHAD

(TANDATANGAN PENULIS) ____________________________

(TANDATANGAN PENYELIA) ____________________________

Alamat Tetap: Cop Rasmi:
59, JALAN SEKILAU, BUKIT SEKILAU
25200, KUANTAN

19 APRIL 2010 ____________________________ Tari...
DECLARATION

I hereby, declared this report entitled "Production And Characterization Of Enviro-Recycled-Wood Plastic Composites (ER-WPC) For The Structural Application" is the result of my own research except as cited in the references.

Signature : ........................................

Author's Name : Nurul Ayunni Bt Abdul Latif

Date : 19 April 2010
This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Material) with Honours. The member of the supervisory committee is as follow:

(MR. JEEFERIE BIN ABD. RAZAK)
JEEFERIE BIN ABD RAZAK
Pensyarah
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka
ABSTRACT

Composites of polymer reinforced with natural fibres have been widely received great attention by the entire engineering community. Natural fibers that explored such as hemp, sisal, jute and wood fibers provide greater reinforcing capabilities when it perfectly compounded with the polymers matrix. Thus, the potential from the induction of wood flour fibers in the thermoplastics Polypropylene (PP) for the structural application required the materials which can up stand the load in a prolonged duration with unpredictable service environment. This research aims to study and analyze the effects of different fiber loading on the mechanical properties and its relationship to the microstructural behavior of the wood flour fiber reinforced polypropylene composites. The major raw materials used in this project is polypropylene (PP) as matrix materials which based on two type which is the virgin and the recycle resin and wood flour fiber as reinforcement materials for the composite fabrication. The composite plate were fabricated by using an extruder and compression molding machine and were then cut into the specific dimension according to the specific ASTM standard of testing. The specimens primarily were tested for the Critical Properties Analysis -Tensile Test. The best compounding formulation of composite was found at the weight percentage (wt%) of 60wt% of PP matrix and 40wt% of the wood flour fibers for both of virgin and recycle. Further analyses for various mechanical properties of the composite were done accordingly to all composites formulation. The microstructures of tested specimens fracture surface were observed by using an optical microscope as to understand the fracture behavior, the fiber distribution and the surface morphology and its significant correlation to the mechanical properties studied. The results showed that the increasing of fiber loading had significantly increased the mechanical properties of the fabricated composite. Through the study, the enhancement of fabricated composite could be applied to the structural engineering applications through the
advantage of the mechanical properties performance of tensile, flexural and impact properties. Conclusively, it is hope that the research will contribute to the development of newly environmental friendly advance material specifically for the structural application.
ABSTRAK

ACKNOWLEDGEMENT

BISMILLAHIRAHMANIRAHIM....... 

By the name of Allah, the most merciful, who is still listening to all prayers His humble servants; I would like to express our boundless gratitude to Allah, for without His will I could have never completed this dissertation in time.

First and foremost, I would like to express my appreciation to the individuals who had played a part in ensuring a successful occurrence and flow of activities throughout the duration of my final year project.

My sincerest appreciation and gratitude to my supervisor, Mr. Jeeferie B. Abdul Razak for the encouragement and willingness to spend time in guidance me to the path of excellent report. Not forgetting, the lecturers in the Department of Engineering Material who directly and indirectly giving idea in making this research. Their knowledge and experience really inspired and spurred myself. I truly relished the opportunity given working with them.

A warmth gratitude to my family as well as friends for their priceless assistance and patronage throughout the motivation and love endorsed. Thanks for giving me the opportunities to further my study.

Last but not lease, my appreciation to all technicians involved to complete this project especially to polymer and material lab in UTeM.

THANK YOU VERY MUCH.
# TABLE OF CONTENT

Declaration .......................... i  
Approval ................................ ii  
Abstract ................................ iii - v  
Acknowledgement ...................... vi  
Table of Content ....................... vi - ix  
List of Tables .......................... xi - xv  
List of Figures ........................ xiii - xv  
List of Abbreviations ................. xvi  
List of Symbols ......................... xvii  

## 1.0 INTRODUCTION

1.1 Research Background ............... 1 - 2  
1.2 Problem Statement .................. 3 - 4  
1.3 Research Objectives ................. 4  
1.4 Research Scope ...................... 5  
1.5 Research Hypothesis ................. 5  
1.6 Importance of the Research ........ 6  
1.7 Thesis Organization ................. 6  

## 2.0 LITERATURE REVIEW

2.1 Introduction ....................... 7  
2.2 Composite Material ................. 7  
2.2.1 Composite Classification ....... 8 - 9  
2.2.2 Polymer Matrix Composite ....... 10  
2.2.2a Matrix .......................... 10  
2.2.2b Polypropylene .................. 11  
2.2.3 Reinforcement .................... 12  
2.2.3a Nature Fiber .................... 12  
2.3 Wood Polymer Composite .......... 14
2.3.1 Polymer: Structure and Properties  
2.3.1a Molecular Structure  
2.3.1b Properties  
2.3.2 Wood: Structure and Properties  
2.3.2a Wood Anatomy  
2.3.2b Properties  
2.4 Manufacturing Technologies  
2.4.1 Compounding Technologies  
2.4.2 Molding Technologies  
2.5 Rules of Mixture (RoM)  
2.5.1 Elastic Modulus  
2.5.2 Density  
2.6 Fiber Loading  
2.7 Tensile and Flexural Properties  
2.8 Impact Properties  
2.9 Water Absorption  
2.10 Morphological Study  

3.0 METHODOLOGY  
3.1 Introduction  
3.1.1 Flow Chart of Methodology  
3.2 Materials  
3.2.1 Polypropylene  
3.2.2 Wood Flour Filler  
3.3 Raw Material Preparation  
3.3.1 Crushing Process  
3.3.2 Wood Flour Drying Process  
3.4 Characterization of Wood Flour  
3.4.1 Density Measurement  
3.4.2 Water Absorption  
3.5 Sample Fabrication  
3.5.1 Compounding of PP with wood flour  
3.5.2 Hot Compression Molding  

viii
6.2 Recommendation

REFERENCE
LIST OF TABLES

2.1 Comparison between natural and glass fibers. ................................................. 14
2.2 Structural units for selected polymers with approximate Tg and Tm .......... 15
2.3 Typical room temperature properties of common polymer .......................... 17
2.4 The Charpy impact energy of wood flour and 40% wood fiber .................. 27

3.1 Variation of the sample types and the parameter ......................................... 33
3.2 Physical properties of virgin polypropylene ............................................... 36
3.3 Standard mesh sizes used to classify the wood flour ................................. 37
3.4 Dumbbell-shaped specimen dimension ....................................................... 45

4.1 Total weight loss of wood flour fiber (in gram) throughout the drying process .......................................................... 51
4.2 Measurement of wood flour fiber density .................................................... 52
4.3 Tensile properties of virgin PP and vPP/wood flour fiber composite .......... 55
4.4 Tensile properties of recycle PP and rPP/wood flour fiber composite ........ 55
4.5 Impact properties of virgin PP and vPP/wood flour fiber composite .......... 60
4.6 Impact properties of recycle PP and rPP/wood flour fiber composite ........ 60
4.7 Flexural properties of pure virgin PP and virgin PP/wood flour fiber composite .......................................................... 62
4.8 Flexural properties of pure recycle PP and recycle PP/wood flour fiber composite .......................................................... 63
4.9 Weight deflection and percentage of weight gain of virgin PP/WF specimens at the different composition of wood flour fiber addition .................................................. 65
4.10 Weight deflection and percentage of weight gain of recycle PP/WF specimens at the different composition of wood flour fiber addition .................................................. 65
4.11 Thickness deflection and percentage of thickness swelling for virgin ... 68
PP specimens at different composition of wood flour fiber addition

4.12 Thickness deflection and percentage of thickness swelling for recycle PP specimens at different composition of wood flour fiber addition

5.1 Mechanical properties of polypropylene composites, filled with 40-mesh wood flour
## LIST OF FIGURES

2.1 Composite composition  
2.2 Tailored composite  
2.3 A classification scheme for various composite types  
2.4 Properties of different natural reinforcing fiber  
2.5 Diagram for reinforcing natural fibers  
2.6 Schematic of wood  
2.7 The relationship between tensile strength and filler loading with and without coupling agent  
2.8 Tensile strength of ABS-WPC.  
2.9 Effect of Plastic type and wood loading levels on properties of WPC  
2.10 Reversed Izod impact strength of ABS-WPC  
2.11 Moisture uptake of 20\% WF composites as a function of exposure time  
2.12 Moisture uptake of 40\% WF composites as a function of exposure time  
2.13 Effect of the water absorption of the strain  
2.14 Fracture surface of impact specimen along the machine direction by SEM.  
2.15 Hardwood fiber in PP matrix  
2.16 Hardwood fiber in PP matrix with added MAPP  
3.1 Flow chart of methodology  
3.2 The Polypropylene  
3.3 Wood Flour  
3.4 Rotor Mill Machine  
3.5 Drying oven model UFB 400, MEMMERT, Germany
3.6 Electronic Densimeter MD-300S
3.7 Optical Microscope
3.8 Extrusion Machine
3.9 Extruded Composition
3.10 Hot press machine
3.11 Illustration of dumbbell-shaped specimen dimension (ASTM D638)
3.12 Dimension of the notched Izod sample (ASTM D256)
3.13 Direction of sample for Izod Impact Test
3.14 Flexural Testing at three-point bending process
3.15 Image for Optical Microscope (OM)

4.1 Total weight loss of wood flour fiber in gram (g) during the drying process.
4.2 The sequences of sample fabrication process
4.3 Tensile Strength of the VPP and RPP composites at different composition of WF loading percentages.
4.4 Tensile Modulus of the VPP and RPP composites at different composition of WF loading percentages.
4.5 The optical microscope images of the fractured surface of virgin PP/wood flour composite
4.6 The optical microscope images of the fractured surface of recycle PP/wood flour composite
4.7 Impact energy of the vPP/WF and rPP/WF composite at different composition of fiber loading
4.8 Impact strength of the vPP/WF and rPP/WF composite at different composition of fiber loading
4.9 Flexural strength of the vPP/WF and rPP/WF composite at different composition of fiber loading
4.10 Flexural modulus of the vPP/WF and rPP/WF composite at different composition of fiber loading
4.11 Weight deflection of the vPP/WF and rPP/WF composite at different composition of fiber loading 66

4.12 Percentages of weight gain at the ambient temperature after 24 hours immersion for the vPP/WF and rPP/WF composite at different composition of fiber loading 66

4.13 Thickness deflection of the vPP/WF and rPP/WF composite at different composition of fiber loading 69

4.14 Percentages of thickness swelling at the ambient temperature after 24 hours immersion for different specimen composition of recycle PP 69

5.1 The Optical Microscope image show the addition of the wood flour to the virgin polypropylene causes the formation of heterogeneous microstructures 71

5.2 The Optical Microscope image show the addition of the wood flour to the recycle polypropylene causes the formation of heterogeneous microstructures 73

5.3 Tensile properties and morphological behaviour (20x magnification) of the virgin PP/WF composite 75

5.4 Tensile properties and morphological behaviour (20x magnification) of the recycle PP/WF composite 76
**LIST OF ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM</td>
<td>American Society For Testing And Material</td>
</tr>
<tr>
<td>ABS</td>
<td>Acrylonitril Butadine Styrene</td>
</tr>
<tr>
<td>BS</td>
<td>British Standard</td>
</tr>
<tr>
<td>PMC</td>
<td>Polymer Matrix Composite</td>
</tr>
<tr>
<td>PP</td>
<td>Polypropylene</td>
</tr>
</tbody>
</table>
LIST OF SYMBOLS

°C - Degree Celsius
E - Stiffness
Kg - Kilogram
m/s - Meter/second
Mm - Millimeter
v - volume fraction
w - weight fraction
ε - Ultimate Strain
σ - Strength
CHAPTER 1
INTRODUCTION

This chapter presents the general ideas of the research. Basically in this chapter, there are consists of six main sections. Including research topic, background, problem statement, research objectives, research scopes, importance of the research and thesis organization.

1.0 Research Title

Production and characterization of Enviro-Recycled-Wood Plastic Composites (ER-WPC) for the structural application.

1.1 Research Background

In this new era, the technologies of developing and designing a new material are rapidly growth. This phenomenon is actually a tradition since in primitive or ancient epoch, entire human being were adapting their daily live by implicated all material surrounds them to become better and practical (Stark et al., 2003). The applications of the engineering materials in human life were started with the stone edge then evolved to the wood and after that metal, followed by the polymer and composite era. The latest invention of material is the combination of the polymer (non-biodegradable) with some of biodegradable natural fiber such as jute, hemp, ramie, flax, coconut and sugar cane dregs.
As we know, the thermoplastic resins, such as polypropylene, polyethylene, polystyrene, and polyvinyl chloride, soften when heated and harden when cooled. This property allows other materials, such as wood, to be mixed with the plastic to form a composite products. The resulting wood-flour-filled polymer composites can be easily processed into various shapes and can be recycled (Richardson et al., 2006). In WPCs, a polymer matrix forms the continuous phase surrounding the wood component. These matrix polymers are typically low-cost commodity polymers that flow easily when heated, allowing for considerable processing flexibility when wood is combined with them. These polymers tend to shrink and swell with temperature but absorb little moisture and can be effective barriers to moisture intrusion in a well-designed composite (Rowland, 2002). Wood itself contains polymers such as lignin, cellulose, and various hemicelluloses but have very different properties from the synthetic polymers with which it is most often combined. Wood is less expensive, stiffer, and stronger than these synthetic polymers, making it a useful filler or reinforcement (Stark and Clemons, 1997). Even though wood does not shrink and swell much with the temperature, it readily absorbs moisture, which alters its properties and dimensions and can lead to degradation if not well protected.

The primary advantages of using a biodegradable filler in plastic are low density, non-abrasive, high filling levels that possible resulting in high stiffness properties, easily recyclable, low energy consumption and low cost of production (Kahraman et al., 2005). Thus, the main purpose of using the filler in composite is to improve the mechanical properties of existing polymeric material for the structural application.

In the structural application, the material is desired to have greater stability to withstand the load or stresses applied in a prolonged duration. Due to the outdoor used, it also requires vast resistivity of external environmental influence such as weather, fungal growth and etc; which may lead to degradation. Throughout the performances of wood flour as filler for plastic, this tends to increase the stiffness and its strength. In principle, it is expected WPCs should display superior mechanical properties, dimensional
stability, greater resistance to chemical and biological degradation, and less moisture absorption.

Therefore, the development of this research is to characterize all related engineering properties which mandatory for the structural application. This research works focused on the study of the mechanical properties of the fabricated composite emphasizing on the impact, tensile and flexural properties at the laboratory scale. There are several processing stage involved in the fabrication of the samples. The internal mixer was utilized extensively in this research to produce good compounding of resulted composites. After that, the compounded materials are designed into the practical shape by using hot and cold compression molding. This followed by testing stage in order to investigate the mechanical properties and others. The analysis of data was further compare the performance of the fabricated WPC to the existing materials used in order to verify that this new developed composites has great potential to be used as the substitution or alternative materials in the structural application.

1.2 Problem Statement

WPCs can be labeled as true composite materials, possessing properties of both major ingredients. The key mechanical property such as strength and stiffness of these composite materials lies between those for polymer and wood. The structural morphology plays a vital role in defining most of the functional attributes of the fabricated WPC. The excellent moisture resistance of polymers compared with wood directly related to the molecular structure of plastic material that being used, making WPC more durable and attractive. Environmental, biological, chemical, mechanical, and/or thermal modes of degradation are all contribute to the degradation of WPCs. Outdoor durability, by its nature, exposes WPCs to degradation modes that can act synergistically (Stark et al., 2003). The major drawback of wood flour composites is probably their propensities to swell on water uptake since wood flour are hygroscopic. The hydrophilicity and swelling of the polymer matrix are usually limited for the matrix
materials. Thus, the overall focus of this research is on reducing the effects of major drawbacks mentioned by investigating the effects of various loading of wood flour addition to the final properties of the fabricated WPC.

1.3 Research Objectives

The purposes of this research were as followed:

(a) To study the effects of different loading percentages of wood flour to the mechanical properties of the fabricated composites develop from virgin Polypropylene (PP) and recycled PP.

(b) To further investigate the structural integrity of the fabricated WPC through the water absorption and thickness swelling study.

(c) To understand the failure mechanism of the tensile fractured composites through the microstructural observation by using Optical Microscope (OM).

1.4 Research Scope

The main raw material that will be used during the research is basically a virgin and recycled Polypropylene (PP) which will be combined with the wood-flour. Internal mixer and hot press compression molding set up will be used to fabricate the intended composite. Then, the samples were tested destructively by using the tensile test (ASTM D638), impact test (ASTM D256), flexural test (ASTM D790) and weathering test (ASTM D570). All of the test procedures are in accordance to the American Standard Testing Method (ASTM) as to ensure the accuracy and reliability of the testing data.

In line with the purposes of this research, the weight percentage of wood flour to the fabricated composite will be varied. The percentages of wood flour which employed in this study are 0 %, 10 %, 20 %, 30 %, 40% and 50%. The optimum formulation of wood
flour in the fabricated composites will be recommended. As the percentage of wood flour increase, the mechanical properties are expected to be escalating as well.

1.5 Research hypotheses

In this research, the different filler weight percentages of wood flour in the fabricated composites will influence the mechanical properties. This expectation is basically according to the rule of mixture (ROM) which explaining the more reinforcement in composite will provide better resulted properties. The extended properties of this fabricated composite are very useful to be applied in a structural application where the material is forced to withstand higher load and stress in an outdoor environmental atmosphere.

1.6 Importance of the Research

This research is conducted with determination to fully utilized the recycled polypropylene and to value add the wood by-product that is wood flour which significance in term of the economical consideration. Apart from that, the utilization of recycled PP is to appreciate the important of environmental concern which can reduce the pollution due to the uncontrolled disposal. By the end of this research, it is hope that it will produce novelty to the material application especially in the structural field. It is also expected that this development may contribute to the enhancement of the advance material.

1.7 Thesis Organization

At the beginning of the research, the report starts with the introduction chapter. This chapter includes the background of the study, problems statement, research objectives,