DURABILITY OF RUBBER WOOD FLOUR-POLYMER COMPOSITE EXPOSED TO ACCELERATED FREEZE THAW CYCLING

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

by

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I hereby, declared this report entitled "Durability of Rubber Wood Flour-Polymer Composite Exposed to Accelerated Freeze Thaw Cycling" is the result of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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ABSTRACT

Environmentally, composite reinforced with natural fibers due to great potential to substitute the traditional composite reinforced with glass fiber. Wood Polymer Composite (WPC) have more consistent mechanical properties. Despite such advantages, WPCs are prone to deterioration from causes such as moisture and freeze-thaw cycling, fire exposure, and biological attack. Deterioration of WPCs negatively impacts performance, limits expected service life, and inhibits consumer confidence, which prevents the widespread use of WPCs as a preferred material for suitable construction applications. In this study, the objective is to study the effect of freeze thaw cycle onto the mechanical properties of the rubber wood reinforced recycled polypropylene. Then, to correlate the effect of freeze thaw cycle onto the fracture surface of rubber wood reinforced recycled polypropylene by using Scanning Electron Microscopy (SEM) to evaluate the rubber wood flour-plastic composite in terms of durability performance on mechanical properties using Universal Testing Machine (UTM). This experimental were carried out by the preparation of the rubber wood flour-polymer composite pallet then optimize of the morphological structure using SEM and crystalline structure using XRD to be analyzing the crystal structure to identify crystalline phase in a material. The result showed the durability performance on mechanical properties using UTM. An addition, to identify the testing, the WPC pallets must freeze thaw cycling for 2, 3, 4, 5 cycles respectively to control behavior in considering the performance. Moreover, the result indicated that study of the potential of WPCs application for the purpose of better durability performance on mechanical properties and the data collected after completing the sample fabrication and testing experiment. All the hypotheses and discussions will be supported by the previous research statement based on the effect of water absorption, flexural behaviour and properties, fracture surface analysis, mechanical and physical properties.

ABSTRAK

Dari segi alam sekitar, komposit diperkukuh dengan gentian semula jadi kerana potensi besar untuk menggantikan komposit tradisional yang diperkukuh dengan gentian kaca. Komposit Polimer Kayu (WPC) mempunyai sifat mekanikal yang lebih konsisten. Walaupun terdapat kelebihan sedemikian, WPC terdedah kepada kemerosotan daripada punca seperti kitaran kelembapan dan beku-cair, pendedahan kebakaran dan serangan biologi. Kemerosotan WPC memberi kesan negatif terhadap prestasi, mengehadkan jangka hayat perkhidmatan dan menghalang keyakinan pengguna, yang menghalang penggunaan WPC secara meluas sebagai bahan pilihan untuk aplikasi pembinaan yang sesuai. Dalam kajian ini, objektifnya adalah untuk mengkaji kesan kitaran pencairan beku ke atas sifat mekanikal polipropilena kitar semula bertetulang kayu getah. Kemudian, untuk menghubungkaitkan kesan kitaran pencairan beku ke atas permukaan patah polipropilena kitar semula bertetulang kayu getah dengan menggunakan Scanning Electron Microscopy (SEM) untuk menilai komposit tepung-plastik kayu getah dari segi prestasi ketahanan pada sifat mekanikal menggunakan Mesin Pengujian Sejagat (UTM). Eksperimen ini dijalankan dengan menyediakan palet komposit tepung-polimer kayu getah kemudian mengoptimumkan struktur morfologi menggunakan SEM dan struktur hablur menggunakan XRD untuk menganalisis struktur hablur bagi mengenal pasti fasa kristal dalam sesuatu bahan. Keputusan menunjukkan prestasi ketahanan pada sifat mekanikal menggunakan UTM. Selain itu, untuk mengenal pasti ujian, palet WPC mesti membekukan kitaran pencairan untuk 2, 3, 4, 5 kitaran masing-masing untuk mengawal tingkah laku dalam mempertimbangkan prestasi. Selain itu, keputusan menunjukkan bahawa kajian tentang potensi aplikasi WPC untuk tujuan prestasi ketahanan yang lebih baik pada sifat mekanikal. dan data yang dikumpul selepas melengkapkan fabrikasi sampel dan eksperimen ujian. Semua hipotesis dan perbincangan akan disokong oleh pernyataan kajian terdahulu berdasarkan kesan penyerapan air, kelakuan dan sifat lentur, analisis permukaan patah, sifat mekanikal dan fizikal.

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DEDICATION

Only
my beloved father, Mohd Zainuddin
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for giving me moral support, money, cooperation, encouragement, and understandings.
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LIST OF SYMBOLS

cm	-	Centimeter
m	-	Meter
%	-	Percent
g/cm^3	-	Grams per centimeter cube
wt. %	-	Weight percent
mm	-	Millimeter
MPa	-	Mega Pascal
°C	-	Degree Celsius
nm	-	Nanometer
kg.cm3	-	Kilogram centimeter cube
kg	-	Kilograms
mm/min.	-	Millimeter per minute
kN	-	Kilo newton
W	-	Sample width
S	-	Span length
a	-	Notch length
B	-	Sample thickness
K_{IC}	-	Fracture toughness
W_m	-	Matrix mass
W_f	-	Fibre mass
T_i	-	Thickness before immersion
T_f	-	Thickness after immersion
m	-	Mass
v	-	Volume
°C/min	-	Degree Celsius per minute

LIST OF ABBREVIATIONS

ASTM	-	American society for testing and materials
DSC	-	Differential scanning calorimetric
SEM	-	Scanning electron microscope
XRD	-	X-ray diffraction
TA	-	Thermal analysis
FT	-	Freeze thaw
WF	-	Wood fibre
WPC	-	Wood plastic composite

CHAPTER 1
INTRODUCTION

1.1 Research Background

A composite material is a macroscopic blending of two or more distinctive materials which have a conspicuous interface between them. According to Friedrich, (2018) described that the WPCs contain up to 70% of wood fibres embedded in a thermoplastics matrix such as polypropylene (PP), polyethylene (PE) or polyvinyl chloride (PVC). As a composite, the wood fibre reinforcement adds strength and stiffness, while the polymeric matrix transfers the applied load throughout the material. In addition, WPCs have more consistent mechanical properties, which enables reduced member cross-sections and a corresponding decrease in the amount of material needed for design. Moreover, WPCs are lightweight and can be formed into a wide variety of custom shapes using different processing techniques.

The demand for WPCs primarily stems from the automotive and construction sectors for applications such as interior or exterior car parts and decking, fencing or siding materials. Based on Luible (2016) by consolidating essential material, composites can be intended to provide structural properties and as additional fundamental materials that have exceptional properties for electrical, thermal, tribological, environmental, and biomedical application. For construction, WPCs have some advantages over competing products, but they are also susceptible to environmental deterioration mechanisms. Moreover, Román (2019) indicated

WPCs is a material containing pigments. In fact, inorganic pigments have an excellent UV absorption, good IR-reflective properties, and heat stability and a good choice as additives used for making composites for outdoor applications.

Further research work needs to be done to achieve study to estimate the durability of the composites manufactured from plastic waste of different sources. Researchers like Turku, (2018) and Marossy, (2019) are more focused on using another method in which composite samples were weathered under accelerated freeze-thaw cycling and xenon-arc light standard conditions. Then the results showed that the composites had significant changes in their flexural properties and behaviour. In the same weathering conditions, the property changes in the reference, processed from virgin polymer, were insignificant according to the ANOVA test. Thus, the focus is on the performance of WPCs especially particularly with respect to the effect of moisture and freeze thaw cycling onto the mechanical properties of the WPCs.

1.2 Problem Statement

WPCs are prone to deterioration from causes such as moisture and freeze-thaw cycling, fire exposure, and biological attack. Deterioration of WPC negatively impacts performance, limits expected service life, and inhibits consumer confidence, which prevents the widespread use of WPCs as a preferred material for suitable construction applications.

Currently, the literature lacks consensus on whether freezing temperatures in the presence of moisture cause freeze-thaw-induced damage in addition to moisture-induced damage in WPCs. Furthermore, the wood fibre reinforcement swells due to the absorption of moisture, and the absorbed moisture further expands upon freezing. Therefore, according to a study reported (Wang et al, 2005) that the outdoor applications of these materials have raised concerns about their durability, including fungal resistance, ultraviolet resistance, moisture resistance and dimensional stability. A few weathering test methods have been developed to stimulate natural weathering at an accelerated rate so that long term weathering effects can be rapidly estimated.

In addition, since the WPCs have become increasingly used for outdoor applications, a need to understand their physical and mechanical behaviour under weathering conditions has risen. Based on the research above, the previous studies have generally concentrated on the performance of the effect of water immersion freeze-thaw cyclic treatment on the mechanical properties. Thus, this research is focusing on WPCs effect of influence of moisture and freeze thaw cycling onto the mechanical properties to optimize the performance of WPCs.

1.3 Objectives

The objectives are as follows:

(a) To study the effect of freeze thaw cycle onto the mechanical properties of the rubber wood reinforced recycled polypropylene.

(b) To correlate the effect of freeze thaw cycle onto the fracture surface of rubber wood reinforced recycled polypropylene.

1.4 Scopes of the Research

The scopes of study are as follows:

a) From objective 1: Within the first objective, the effect of aging onto the composite will be characterized by flexural testing using Universal Testing Machine.
b) From objective 2: Within the second objective, the fracture surface of the aged and non-aged composite will be evaluated using SEM and their correlation with mechanical will be investigated. Within this objective also can determine the crystallographic structure of material using XRD analysis.

1.5 Report Organization

The organization of this report is as follows. Chapter 1 begins with research background, problem statement, objectives, and scope of the research. The rationale of research is delineated to better define this thesis. Chapter 2 literature review comprises previous study or research about the durability of rubber wood floor-polymer composite that is exposed to accelerated freeze–thaw cycling. Chapter 3 methodology describes all the raw materials, testing method used will be stated in the research about the effect of moisture and freeze thaw cycling onto the mechanical properties of the WPCs, testing method, theory of interface and interphase. Chapter 4 is analysing the information collected after running testing through tensile and fracture testing machines, then discussing the effect of moisture and freeze thaw cycling onto the mechanical properties of the WPCs. In Chapter 5, conclusions and recommendations about this research are examined.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Wood polymer composites (WPC) consist of natural plant fibres which are combined in a polymer matrix, such as polypropylene (PP), polyethylene (PE), or polyvinyl chloride (PVC). (Machado et al., 2016) described that WPCs can be produced from environmentally friendly materials, such as wood fibres, unused natural resources, and recycled thermoplastic resins. WPCs commonly used in many building applications which consist of several applications of WPCs such as outdoor exposure or ground contact. Although WPCs technology continues to grow together as the manufacturing processes start to polish up, WPCs can also be used in other industries, such as the automobile and consumer electronics sectors according to Kim & Pal (2011). WPCs are identically a solid wood with high moulding performance and typically as an action such as combining the best properties of wood and plastic which good performance resulting which makes a product brittle and may become more brittle by cold exposure but further can increase the mechanical properties such as high durability, specific strength, specific stiffness, and long-term resistance to wear.

2.2 Polymer Composite

A composite is a combination of two or more combinations of two or more materials which can be categorized into two categories which are plant-based and animal-based fibres that are made to become a single material according to Butylina (2011). To be used as reinforcement, pure fibres as shown in Figure need to be extracted and separate from all next connections that were existence in the natural plant or animal raw material (hemicelluloses, lignin, wax, proteins).

Zini & Scandola (2011) explained that wood is a fibrous composite because it is commonly used in the form of wood pulp. Figure 2.1 shows the specific mechanical properties of natural fibres closer to the synthetic fibres and specific tensile strength of the flax fibres compared with the glass fibres. Additional advantages of using the natural fibres in composites are their renewability, biodegradability, nontoxicity, good insulation properties and low machine wear.

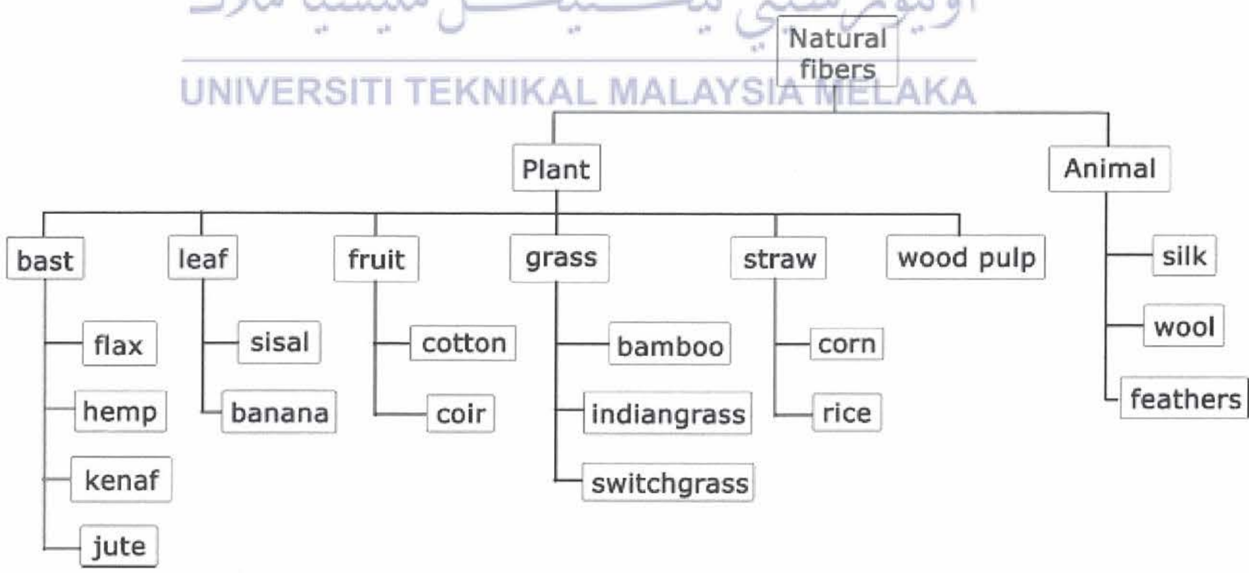

Figure 2.1: Classification of Natural Fibres (Zini & Scandola, 2011)

2.3 Wood Fibre

Wood fibre are elements of cellulosic that are extracted from trees and used to make materials. Wood Fibre can be categorized into two classes which are softwood and hardwood. However, Valente (2016) described that cellulose, hemicellulose, and lignin are the structural polymers of hardwoods. Hardwoods contain a smaller number of extractives of non-structural constituents compared to the softwoods as shown in the Figure 2.2.

In North America, virgin (non-recycled) wood fibre was extracted from hardwood (deciduous) trees and softwood (coniferous) trees. Besides, wood fibre can be a primary product. Thus, wood fibres can also combine with thermoplastics to produce strong, waterproof products for outdoor usage such as deck boards or outdoor furniture. Ashori (2010) investigated that by using wood fibres as reinforcement to thermoplastic resins, it can yield composite materials with increasing strength and stiffness.

(a) (b)

Figure 2.2: Structure of (a) Hardwood (Beech) Structure and (b) Softwood (Scots Pine) Structure (Valente et al., 2016)

2.4 Thermoplastic

Thermoplastics are the most important elements of plastic materials that are available in their consumption which is approximately 80% or more of plastic consumption. Thermoplastics are softened and sometimes melted when heated to a flow-able state and under high pressure so that they can repeat the cycles of heating and cooling without causing severe damage. In addition, thermoplastic is often added as an additive or filler to improve specific properties such as both mechanical properties and thermal properties.

The thermoplastic has many advantages including recyclability, short processing cycles, the melting and softening by heating which allows thermoforming. In contrast, the disadvantage is decreasing in strength and stiffness and giving high relaxation behaviours which increase temperature. However, thermoplastic is popular in the application of WPCs including PE, PP and PVC.

2.4.1 Polypropylene (PP)

Polypropylene has a similar chemical structure to polyethylene, but PP has better strength, stiffness, and heat resistance but at low temperature, the impact strength is quite poor. The properties of the PP such as chemical resistance, dimensional stability, heat resistance, rigidity, toughness, surface gloss and low cost. However, the pure PP are not suitable for use in load-bearing applications due the specific heat for PP is lower than PE. Therefore, due to excellent quality and versatility, PP were manufactured using injection, extrusion, and compression moulding. PP has also been used in the textile industry and PP also in thin-film packaging according to John Wiley & Sons (2003).