UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Study on the Strength and Mechanical Properties of Bio-composite of Maize Stamp Fiber Sandwich Matrix with Resin/Polymer for Shield Ballistic Armor

Thesis submitted in accordance with the partial requirements of the Universiti Teknikal Malaysia Melaka for the Degree of Bachelor of Manufacturing Engineering (Engineering Material) with Honours

By

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Faculty of Manufacturing Engineering

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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JUDUL: **STUDY ON THE STRENGTH AND MECHANICAL PROPERTIES OF BIO-COMPOSITE OF MAIZE STAMP FIBER SANDWICH MATRIX WITH RESIN/POLYMER FOR SHIELD BALLISTIC ARMOR**

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APPROVAL

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ABSTRACT

The purpose of this research is to study the strength of maize stamp fibers and resin/polymer material. This study is start from the preparation of maize fiber where maize fiber is produced from the stamp of the maize. When the preparation maize fibers are done, these maize fibers will be submerged into the NaOH solution for 24 hour. The concentrations of NaOH are 5%. Beside that, the orientation of fiber also has been study where the options are one straight layer and two perpendicular layers. In the fabrication process, cold-press process has been chosen. The sample dimensions are chosen according the ASTM standard. The testing that is done in this study are tensile test and flexural test. The purpose of the test is to analyze and observe the composite quality in order to produce optimum material. The result of the project does not achieved for the application of shield ballistic armor due to several factors especially in low bonding ability between maize fiber and resin /polymer.

ABSTRAK

Tujuan kajian ini dijalankan adalah untuk mengkaji kekuatan gentian dari batang jagung dan polimer. Kajian ini bermula dengan penyediaan gentian jagung. Gentian jagung diperolehi daripada batang tumbuhan jagung. Setelah selesai dengan penyediaan gentian jagung, gentian tersebut akan dirndamkan di dalam larutan NaOH selama 24 jam. Kepekatan larutan NaOH yang digunakan adalah 5%. Selain itu, susunan fiber juga dikaji dimana susunan yang akan dikaji ialah satu lapisan lurus dan 2 lapisan berserenjang. Dalam proses pembuatan, proses cold-press telah dipilih. Ukuran bahan uji di rujuk kepada piawai ASTM. Ujian yang perlu dijalankan dalam penyelidikan ini adalah ujian ketegangan dan ujian kelenturan. Tujuan ujian dijalankan adalah untuk melakukan analisa selain memerhatikan kualiti komposit yang bertujuan bagi mendapat hasil optima pada bahan. Sifat dan kekuatan bahan ujikaji tidak sesuai untuk aplikasi perisai kalis peluru kerana beberapa sebab terutamanya ikatan yang lemah di antara gentian jagung dan polimer.

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TABLE OF CONTENTS

Abstract i
Abstrak ii
Acknowledgement iii
Table of Contents iv
List of Figures vii
List of Tables viii
List of Abbreviations, Symbols, Specialized Nomenclature ix

1. INTRODUCTION 1
1.1 Background and Problem Statement 1
1.1.1. Background of Study 1
1.1.2. Problem Statement 1
1.2 Research Objectives 2
1.3 Research Scope 2

2. LITERATURE REVIEW 3
2.1 Polymer 3
2.1.1. Thermoset 4
2.1.2. Thermoplastic 5
2.2 Composite 6
2.2.1. Polymer Matrix Composite 7
2.2.2. Advantages 8
2.2.3. Composition 9
2.2.4. Resin 9
2.2.5. Reinforcements 10
2.2.6. Additives and Modifiers 11
2.2.6.1. Additive Functions 11
2.2.7. Catalysts, Promoters and Inhibitors 13
2.2.7.1.Release Agents 13

2.2.7.2.Adhesives ... 13
2.2.8. Gel Coats ... 14
2.3 PMC Processing ... 15
2.3.1. Cold Press Process ... 15
2.4 Maize ... 15
2.4.1. Use as a Crop Plant ... 16

3. METHODOLOGY ... 19
3.1 Raw Material ... 19
3.1.1. Polyester ... 19
3.1.1.1. Polyester Characteristics ... 21
3.1.1.2. Properties of Polyester ... 22
3.1.2. Maize Fiber ... 23
3.1.2.1. Preparation of Maize fiber ... 23
3.1.2.2. Alkalization Process ... 24
3.2 Specimen Preparation ... 24
3.2.1. Preparation of Polypropylene ... 24
3.2.2. Composite Formulation ... 24
3.3 Fabrication Process ... 25
3.3.1. Cold Press Process ... 25
3.4 Testing ... 26
3.4.1. Tensile Sample Preparation ... 26
3.4.2. Tensile Test ... 26
3.4.2.1. Testing Calculation ... 28
3.4.2.2. Specimen specification ... 28
3.4.3. Flexural Test ... 29
3.4.3.1.Testing Calculation ... 29
3.4.3.2. Specimen specification ... 30

4. RESULT ... 31
4.1 Tensile Test ... 31
4.1.1. Tensile Test Data ... 31

4.1.2. Tensile Test Data Analysis 32
4.2 Flexural Test 33
4.2.1. Flexural Test data 33
4.2.2. Flexural Test Data Analysis 34

5. DISCUSSION 36
5.1 Data Analysis 36
5.1.1. Tensile Test Data 36
5.1.2. Flexural Test Data 38
5.2 Material Comparison to Kevlar 39
5.3 Factor Affect the Composite Properties 40

6. CONCLUSION AND RECOMMENDATION 41

REFERENCES 42

LIST OF FIGURES

2.1 Classification of Polymers ... 3

2.2 Epoxy Structure ... 4

2.3 Polyurethane Structure ... 4

2.4 Maize Production Worldwide ... 17

3.1 Polyester Structure ... 19

3.2 Maize Stamp before Fiber Preparation Process ... 23

3.3 Two Layer Perpendicular Fiber Orientations ... 25

3.4 One Layer straight Fiber Orientation ... 25

3.5 Flow of Cold-press Process ... 26

3.6 Hardness Plastic Specimen Cutting Machine ... 26

3.7 Stress-Strain curve ... 27

3.8 Three Point Bending ... 29

4.1 Comparison of Tensile Strength ... 32

4.2 Comparison of Young's Modulus ... 33

4.3 Comparison of Young's Modulus ... 35

4.4 Comparison of Flexural Strength ... 35

5.1 Elongation at Tensile Fracture ... 36

5.2 Tensile Strength ... 37

5.3 Young's Modulus ... 37

5.4 Flexural strength ... 38

5.5 Flexural Modulus ... 39

LIST OF TABLES

2.1 Consumption of Maize *per capita* by Country 17

3.1 Tensile Test Value 27

4.1 Result of Tensile Test of Polyester with One Layer 5% Alkalization Maize Stamp 31

4.2 Result of Tensile Test of Polyester with Two Layer 5% Alkalization Maize Stamp 31

4.3 Result of Tensile Test of Polyester with Non-alkalization Layer Maize Stamp 32

4.4 Data Analysis for Tensile Test 32

4.5 Result of Flexural Test of Polyester with One Layer 5% Alkalization Maize Stamp 33

4.6 Result of Flexural Test of Polyester with Two Layer 5% Alkalization Maize Stamp 34

4.7 Result of Flexural Test of Polyester with Non-alkalization Layer Maize Stamp 34

4.8 Data Analysis for Flexural Test 34

LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

°C	-	Degree Celsius
°F	-	Degree Fahrenheit
ASTM	-	American Standard Test Method
BMC	-	Bulk-molding compounds
HDT	-	Heat Distortion Temperature
ISO	-	International Standards Organization
MEKP	-	Methylethylketone Peroxide
NA	-	Not Available
NaOH	-	Natrium Hydroxide
PAI	-	Polyphenylene Sulfide Polyaimide-imide
PEEK	-	Polyetheretherketone
PEI	-	Polyetherimide
PES	-	Polyethersulphone
PMC	-	Polymer Matrix Composite
Sdn Bhd	-	Sendirian Berhad (Limited)
SEM	-	Scanning Electron Microscope
SMC	-	Sheet-molding compounds
TBC	-	Tertiary Butyl Catechol
Tg	-	Glass Transition Temperature
UHMW	-	Ultra High Molecular Weight
UV	-	Ultraviolet
UTeM	-	Universiti Teknikal Malaysia Melaka
VIP	-	Vacuum Infusion Process

CHAPTER 1

INTRODUCTION

1.1 Background and Problem Statement

1.1.1 Background of Study

A product of bio-composite consists of maize fiber and resin/polymer as the matrix develops through the project. In this project, the composite material used as raw material in producing shield ballistic armor which is commonly used by police from all over the world. The strength and mechanical properties of the material were studied and examined through experiment and testing which determine whether the composite material fulfill the requirement of shield ballistic armor mechanical and physical properties.

1.1.2 Problem Statement

In millennium century, waste of daily human use increasing everyday and recycling is the best solution to decrease the amount of waste. Maize is among the common plant which can be found all over the world due to its uses as routine food. Maize ranks third most grown crop in the world with an area of more than 118 million hectares with an annual production of about 600 million metric tones. Maize product regularly related to food product such as flour, popcorn, and sweet corn. Corn is the only product out of maize plant so the other part of maize will become waste. The use of maize part as fiber will bring add value to the plant rather than being waste. This maize fiber has great potential value for making into a commercial product where proper procedures and method will change the waste into useful material which can be use in daily life. It can be fabricated into bio-composite product which has better mechanical properties.

1.2 Research Objective

There are several purposes for this project:-

(a) To study the strength of maize stamp fibers and resin/polymer material.

(b) To study the mechanical properties of bio-composite of maize stamp fibers with resin/polymer sandwich matrix/laminates.

(c) To study the bonding that consists in the bio-composite of maize stamp fibers with resin/polymer sandwich matrix/laminates.

(d) To analyze the product's strength application for product design of shield ballistic armor.

1.3 Research Scope

The project conducts polymer matrix composite process which is cold-press process. Tensile and flexural test were carried out to determine the mechanical properties of the composites. The application of ballistic shield was analyzed in order to determine the properties of the material are suitable or not.

CHAPTER 2

LITERATURE REVIEW

2.1 Polymer

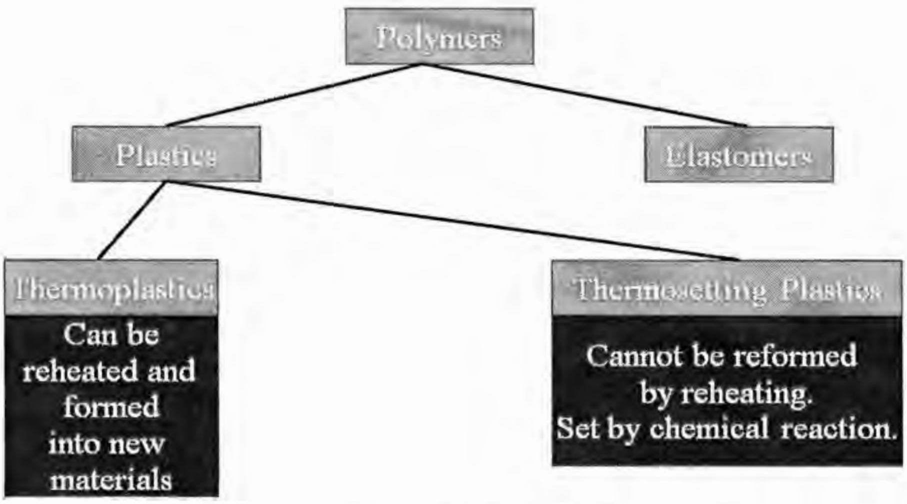

Figure 2.1: Classification of Polymers

Polymers are a large class of materials consisting of many small molecules (called monomer) that can be linked together to form long chains, thus they are known as *macromolecules* . Polymer is a group of organic, semiorganic or inorganic. While, monomer is a molecule that can combine with others to form a polymer

2.1.1 Thermoset

Thermosets materials can not be softened on heating. In thermosetting polymers, the polymer chains are joined (or cross-linked) by intermolecular bonding. Thermosets are usually supplied as partially polymerized or as monomer-polymer mixtures. It is solidifies irreversibly when heated. This polymer has higher strength and properties than thermoplastic. Cross-linking is achieved during fabrication using chemicals, heat, or radiation; this process is called curing or vulcanization. Usually, it has three dimensional network structures which there is a high degree of cross-linking. The examples of thermoset are epoxy, polyester and polyurethane. Example of thermoset polymer:

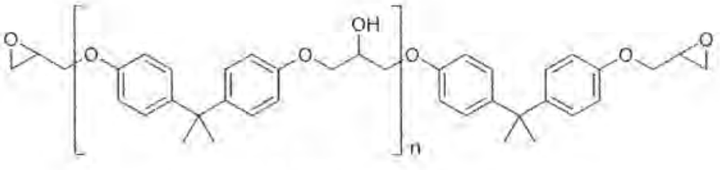

Figure 2.2: Epoxy structure

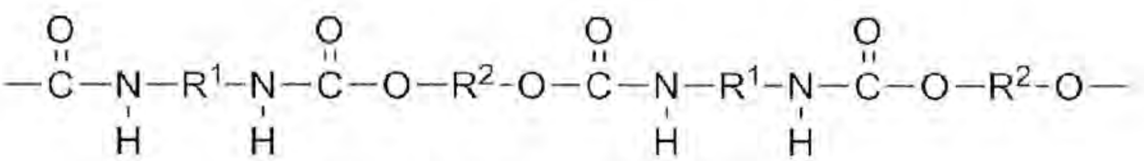

Figure 2.3: Polyurethane structure

2.1.2 Thermoplastic

A thermoplastic material will soften when heated above glass transition temperature. It can then be easily shaped and on cooling will harden in this form. However, on reheating it will soften again and can be reshaped if required before hardening when the temperature drops. They are "melt processable", which means they can be formed into useful shapes while in the melted or viscous phase. In most manufacturing processes, thermoplastics are heated, then formed by injection molding, extrusion or thermoforming and finally cooled so the end product retains its shape.

Today, many types of thermoplastics are available with a wide range of useful properties. Common types of thermoplastics are Polyethylene, Polypropylene, Polystyrene, Polyetheretherketone (PEEK), Polyetherimide (PEI), Polyethersulphone (PES) Polyphenylene Sulfide Polyaimide-imide (PAI). They can be made as flexible as rubber, as rigid as metal and concrete or as clear as glass, for use in a wide range of piping and other products. Some can withstand temperatures of up to 600°F (315°C). Others retain their properties down to 100°F (-73°C). They do not oxidize, are highly corrosion resistant and are excellent thermal and electrical insulators. Their combination of light weight, high strength and resistance to environmental factors make thermoplastics the ideal material for industrial, municipal, commercial and residential piping applications.

In a comparison of thermoplastics and thermosets on a mechanical performance, thermoplastics composites are often tougher, but do not appear to have any advantage in static properties or fatigue over thermosets. The compression strength of thermoplastics may often also be inferior. Thermoset plastics generally have superior abrasion and dimensional characteristics when compared to thermoplastics, which have better flexural and impact properties. Thermoplastics are not cross-linked and derive their stiffness and strength from the inherent properties of the monomer units. Their very high molecular weight ensures high levels of molecular entanglement which acts like cross-links.

2.2 Composite

Composite materials, on the other hand, consist of two or more materials combined in such a way that the individual materials are easily distinguishable. A common example of a composite is concrete. It consists of a binder (cement) and reinforcement (gravel). Adding another reinforcement (rebar) transforms concrete into a three-phase composite.

The individual materials that make up composites are called *constituents*. Most composites have two constituent materials: a binder or *matrix*, and a *reinforcement*. The reinforcement is usually much stronger and stiffer than the matrix, and gives the composite its good properties. The matrix holds the reinforcements in an orderly pattern. Because the reinforcements are usually discontinuous, the matrix also helps to transfer load among the reinforcements.

Reinforcements basically come in three forms: particulate, discontinuous fiber, and continuous fiber. A particle has roughly equal dimensions in all directions even though it does not have to be spherical. Gravel, microballoons, and resin powder are examples of particulate reinforcements. Reinforcements become fibers when one dimension becomes long compared to others. Discontinuous reinforcements (chopped fibers, milled fibers, or whiskers) vary in length from a few millimeters to a few centimeters. Most fibers are only a few microns in diameter so it does not take much length to make the transition from particle to fiber.

With either particles or short fibers, the matrix must transfer the load at very short intervals. Thus, the composite properties cannot come close to the reinforcement properties. With continuous fibers, however, there are few if any breaks in the reinforcements. Composite properties are much higher, and continuous fibers are therefore used in most high performance components such as aerospace structures or sporting goods.

Matrix materials are usually some type of plastic, and these composites are often called reinforced plastics. There are other types of matrices, such as metal or ceramic, but plastics are by far the most common. There are also many types of plastics, but a discussion of them is beyond the scope of this week's column. Suffice it to say for now that the two most common plastic matrices are epoxy resins and polyester resins.

Composite materials are available as plies or lamina. A single ply consists of fibers oriented in a single direction (unidirectional) or in two directions (bidirectional; for example a woven fabric). There are other forms but these are the most important for this discussion.

Composite properties are best in the direction of the fibers. Perpendicular or transverse to the fibers, the matrix properties dominate because load must be transferred by the matrix every fiber diameter. Because most structures are not loaded in a single direction, even though one direction may dominate, it is necessary to orient fibers in multiple directions. This is accomplished by stacking multiple plies together such a stack is called a laminate.

The most efficient composites have most of their fibers oriented in the primary load direction, and just enough fibers oriented in the other directions to carry secondary loads and hold the structure together. Efficiency means both low weight and low cost because any fibers which do not carry much load could probably be removed.

2.2.1 Polymer Matrix Composite

Polymer Matrix Composite (PMC) is defined as a polymer matrix, either thermoset or thermoplastic, that is reinforced with a fiber or other reinforcing material with a sufficient aspect ratio (length to thickness) to provide a discernable reinforcing function in one or more directions. PMC are different from traditional construction materials such as steel or aluminum. PMC are anisotropic where properties only apparent in the direction of the applied load while steel or aluminum is isotropic which uniform properties in all directions, independent of applied load. Therefore, PMC properties are directional, meaning that the best mechanical properties are in the direction of the fiber placement. Composites are similar to reinforced concrete where the rebar is embedded in an isotropic matrix called concrete.

2.2.2 Advantages

PMC have many benefits to their selection and use. The selection of the materials depends on the performance and intended use of the product. The composites designer can fit the performance of the end product with proper selection of materials. It is important for the end-user to understand the application environment, load performance and durability requirements of the product and express this information to the composites industry professional. A summary of composite material benefits include:

(a) Light weight
(b) High strength-to-weight ratio
(c) Directional strength
(d) Corrosion resistance
(e) Weather resistance
(f) Dimensional stability
(g) Low thermal conductivity
(h) Low coefficient of thermal expansion
(i) Radar transparency
(j) Non-magnetic
(k) High impact strength
(l) High dielectric strength (insulator)
(m) Low maintenance
(n) Long term durability
(o) Part consolidation
(p) Small to large part geometry possible

2.2.3 Composition

Composites are composed of resins, reinforcements, fillers, and additives. Each of these constituent materials or ingredients plays an important role in the processing and final performance of the end product. The resin or polymer is the "glue" that holds the composite together and influences the physical properties of the end product. The reinforcement provides the mechanical strength. The fillers and additives are used as process or performance aids to impart special properties to the end product.

The mechanical properties and composition of PMC can be modified for their intended use. The type and quantity of materials selected in addition to the manufacturing process to fabricate the product, will affect the mechanical properties and performance. Important considerations for the design of composite products include:

(a) Type of fiber reinforcement
(b) Percentage of fiber or fiber volume
(c) Orientation of fiber (0°, 90°, +/- 45° or a combination of these)
(d) Type of resin
(e) Cost of product
(f) Volume of production
(g) Manufacturing process
(h) Service conditions

2.2.4 Resin

The primary functions of the resin are to transfer stress between the reinforcing fibers, act as a glue to hold the fibers together, and protect the fibers from mechanical and environmental damage. Resins are divided into two major groups known as thermoset and thermoplastic. Thermoplastic resins become soft when heated, and may be shaped or molded while in a heated semi-fluid state and become rigid when cooled. Thermoset resins, on the other hand, are usually liquids or low melting point solids in their initial form. When used to produce finished goods, these thermosetting resins are "cured" by the use of a catalyst, heat or a combination of the two. Once cured, solid thermoset resins cannot be converted back to their original liquid form. Unlike thermoplastic resins, cured thermosets will not melt and flow but will soften and lose hardness when heated and once formed they cannot be reshaped. Heat Distortion Temperature (HDT) and the Glass Transition Temperature (Tg) is used to measure the softening of a cured resin. Both test methods (HDT and Tg) measure the approximate temperature where the cured resin will soften significantly to yield under load.

2.2.5 Reinforcements

The primary function of fibers or reinforcements is to carry load along the length of the fiber to provide strength and stiffness in one direction. Reinforcements can be oriented to provide required properties in the direction of the loads imparted on the end product. Reinforcements can be both natural and man-made. Many materials are capable of reinforcing polymers. Some materials, such as the cellulose in wood, are naturally occurring products. Most commercial reinforcements, however, are man-made. Of these, by far the largest volume reinforcement measured either in quantity consumed or in product sales, is glass fiber. Other composite reinforcing materials include carbon, aramid, UHMW (ultra high molecular weight) polyethylene, polypropylene, polyester and nylon. Carbon fiber is sometimes referred to as graphite fiber. The distinction is not important in an introductory text, but the difference has to do with the raw material and temperature at which the fiber is formed. More specialized reinforcements for high strength and high temperature use include metals and metal oxides such as those used in aircraft or aerospace applications.

2.2.6 Additives and Modifiers

A wide variety of additives are used in composites to modify materials properties and modify the laminate's performance. Although these materials are generally used in relatively low quantity by weight compared to resins, reinforcements and fillers, they perform critical functions.

2.2.6.1 Additive Functions

Additive used in thermoset and thermoplastic composites include the following:

(a) Low shrink/low profile: when parts with smooth surfaces are required, a special thermoplastic resin, which moderates resin shrinkage, can be added to thermoset resins.

(b) Fire resistance: Combustion resistance is improved by proper choice of resin, use of fillers or flame retardant additives. Included in this category are materials containing antimony trioxide, bromine, chlorine, borate and phosphorus.

(c) Air release: most laminating resins, gel coats and other polyester resins might entrap air during processing and application. This can cause air voids and improper fiber wet-out. Air release additives are used to reduce such air entrapment and to enhance fiber wet-out.

(d) Emission control: in open mold applications, styrene emission suppressants are used to lower emissions for air quality compliance.

(e) Viscosity control: in many composite types, it is critical to have a low, workable viscosity during production. Lower viscosity in such filled systems is usually achieved by use of wetting and dispersing additives. These additives facilitate the wet-out and dispersion of fillers resulting in lower viscosity (and/or higher filler loading).

(f) Electrical conductivity: most composites do not conduct electricity. It is possible to obtain a degree of electrical conductivity by the addition of