STUDY OF BAMBOO FLAKES REINFORCED POLYMER COMPOSITE MATERIAL IGNITION AND FLAME SPREAD PROPERTIES

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THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR DEGREE OF BACHELOR OF MECHANICAL ENGINEERING

FACULTY OF ENGINEERING

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DECLARATION

I hereby declare that this final year project paper, entitled "Study of Bamboo Flake Reinforced Polymer Composite Material Ignition and Flame Spread Properties," submitted to University Malaysia Sabah as a partial fulfilment of the requirement for the degree of Bachelor of Mechanical Engineering and has not been submitted to any other university for any degree. I also certify that the work herein entirely my own, except for quotations and summaries sources of which have been fully acknowledged under the supervision of Dr. Choong Wai Heng.

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1st July 2022

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ABSTRACT

A study on the bamboo reinforced composite materials ignition and flame spread properties had been conducted. Bamboo had been widely engineered for enhancing its material application, especially as architect building materials. Flammable property study is crucial in determining the fire hazardous of the material. The study is involving 5 types of materials (bamboo reinforced epoxy composite material, bamboo reinforced polyester resin, pure epoxy/ polyester resin matrix materials and raw bamboo). The materials tested under vertically and horizontally burn test, which accordance to ASTM D635 and ISO 3795. This study includes a vertical burning test to determine the entire flame time of the materials tested, as well as a horizontal burning test to investigate the burning rate and flame spread of the materials examined. Flammability property includes combustion time, flame dripping and burning rate. The flame spread of both composite materials increase as time and the flame period is significantly greater when bamboo flakes strengthen the resins. The average flame time of unsaturated polyester resin reinforced with bamboo flakes is 6.71 minutes and that of epoxy resin reinforced withbamboo flakes is 3.96 minutes. As for the average burning rate of unsaturated polyester resin reinforced with bamboo flakes and epoxy resin reinforced with bamboo flakes are 56.33 mm/min, 73.89 mm/min. The study findings provided a crucial information in determining the material application feasibility and flammability property improvement.

ABSTRAK

KAJIAN PENYALAAN BAHAN KOMPOSIT POLIMER BERTETULANG SERPIHAN BULUH DAN SIFAT PENYEBARAN API

Satu kajian mengenai bahan komposit bertetulang buluh penyalaan dan sifat penyebaran nyalaan telah dijalankan. Buluh telah direka bentuk secara meluas untuk meningkatkan penggunaan bahannya, terutamanya sebagai bahan binaan arkitek. Kajian harta mudah terbakar adalah penting dalam menentukan bahaya kebakaran bahan. Kajian ini melibatkan 5 jenis bahan (bahan komposit epoksi bertetulang buluh, resin poliester bertetulang buluh, bahan matriks resin epoksi/ poliester tulen dan buluh mentah). Bahan yang diuji di bawah ujian pembakaran menegak dan mendatar, mengikut ASTM D635 dan ISO 3795. Kajian ini termasuk ujian pembakaran menegak untuk menentukan keseluruhan masa nyalaan bahan yang diuji, serta ujian pembakaran mendatar untuk menyiasat kadar pembakaran dan penyebaran nyalaan bahan yang diperiksa. Sifat mudah terbakar termasuk masa pembakaran, nyalaan menitis dan kadar pembakaran. Penyebaran nyalaan kedua-dua bahan komposit meningkat mengikut masa dan tempoh nyalaan menjadi lebih besar apabila serpihan buluh menguatkan resin. Purata masa nyalaan resin poliester tak tepu yang diperkukuh dengan kepingan buluh ialah 6.71 minit dan masa nyalaan resin epoksi yang diperkukuh dengan kepingan buluh ialah 3.96 minit. Manakala bagi kadar pembakaran purata resin poliester tak tepu yang diperkukuh dengan kepingan buluh dan resin epoksi yang diperkukuh dengan kepingan buluh ialah 56.33 mm/min, 73.89 mm/min. Penemuan kajian memberikan maklumat penting dalam menentukan kebolehlaksanaan aplikasi bahan dan peningkatan sifat mudah terbakar.

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LIST OF ABBREVATIONS

ASTM	American Standard Testing Materials
CAMC	Carbon Matrix Composites
CMC	Ceramic Matrix Composites
CO2	Carbon Dioxide
FYP	Final Year Project
H_2O	Water
LIFT	Lateral Ignition And Flame Spread Test
LOI	Limiting Oxygen Index
MMC	Metal Matrix Composites
NFPC	Natural Fiber Polymer Composite
ISO	International Organization for Standardization
PMC	Polymer Matrix Composites
UPR	Unsaturated Polyester Resin

CHAPTER 1

INTRODUCTION

1.1 Overview

With the advancement of technology, material characteristics in term of its strength, flammability properties, durability is alter and improved to fulfill the industry requirement. A composite material is one that is made up of two or more distinct materials with diverse qualities on a macro scale to create a new material with characteristics that are wholly different from the original pieces without dissolving or blending them together (Australian Academy of Science, 2021). The first uses of composites are by early Egyptians and Mesopotamian settlers that utilized a mixture of mud and straw to build robust and enduring structures around 1500 B.C (Johnson, 2018). Bamboo has gained popularity thanks to its ability to grow in a variety of climates and it is lightweight. Despite the fact that bamboo is an old and traditional building material, it is still widely used today. Its structural diversity, mechanical properties, fibers extraction, chemical modification, and thermal properties made it adaptable to use in the composite sector (Amada *et al.*, 1997). Furthermore, it has been utilized as a raw material for structural composites such Oriented Strand Board (OSB), Glue Laminated Timber (GLT), Parallel Strip Lumber (PSL), and Oriented Strand Lumber (OSL) in numerous studies (Chaowana, 2013).

Plants, animals, and geological processes produce natural fibers, which are biodegradable over time. Plant fibers are primarily composed of cellulose, which is frequently mixed with other components such as lignin. Cellulose, lignin, pectin,

waxes, and hemicellulose are all components of natural fibers. Natural fiber offers range of benefits for its use in reinforced composite compared to synthetic fiber. Plant fibers have been a renewable resource for thousands of years, with variations in qualities and characterization that have been replenished by nature (Ramesh *et al.*, 2017). When bamboo culms reach maturity, the bamboo fibers are oriented longitudinally along the length of the culm, giving it strength comparable to mild steel as steel with a limited proportion of carbon, strong and robust but not easily softened (Okubo *et al.*, 2004). In a range of industries, natural fiber-reinforced composites - *NFRC* are being developed to reduce energy consumption and environmental impacts.

Bamboo composite material is fabricated based on the combination of unsaturated polyester resin and bamboo flakes or epoxy with bamboo flakes. Unsaturated polyester resin (UPR) is a polymer material, which is made by reacting dibasic organic acids with polyhydric alcohols. Due to aromatic groups in the structure, UPRs have insufficient fire resistance due to their relatively high flammability and smoke output when burned. As for epoxy, it is capable withstand heat up to 150 degrees. The development of a cost-effective, environmentally friendly fire retardant system that minimizes the detrimental impact on polymer performance attributes has been a problem. The key worry in this research is the composite material's fire characteristics, as this material has historically had issues when exposed to fire. Bamboo flake reinforced polymer composite material is chosen for this project research for its excellent performance in various of industries, particularly those based on wood. Therefore, this project aim to study the material ignition and flame spread properties of bamboo flake reinforced polymer. The burning rate, materials ignition, and flame spread characterizations are determined by the tests carried out in this study. This is critical in improving the development of composite materials. The successful of this project shall be able to demonstrate the potential of composite materials applications such as polymer board,which is like a plywood board.

1.2 Problem Statement

Fibre reinforced polymeric materials have become the focus of research. A composite

material is made up of two or more separate materials that are combined to create qualities that are distinct from those of the individual materials. One substance act as a matrix, while the other acts as a reinforcing material that is embedded in the matrix to improve its mechanical and physical properties. Low maintenance, high stress to weight ratio, high corrosion, impact resistance, non-conductive, avoids electrical risks, low cost, easy installation due to lightweight, and fire retardant are all advantages of natural fiber reinforced composites.

This project takes use of the opportunity to research and describe low-cost bamboo flake reinforced polymer composite materials ignition and flame spread properties. More research is needed on the qualities of bamboo such as flammability properties and ignition characteristics. This is because bamboo has a greater ability to be transformed into a wide range of products using current processes and technology, allowing it to compete successfully with wood and other raw materials in the future. Malaysia's wood-based industry, which includes the production of sawn timber, veneer, panel products and builder joinery and carpentry, as well as furniture and furniture components, has become one of the country's key income producers in the last 20 years (Malaysian Investment Development Authority, 2021). Flammability characterization can helps wood-based industry in improving their products from bamboo reinforced composite materials such as Oriented Strand Board based on their fire properties. Currently, there is limited knowledge regarding bamboo flake reinforced polymer composite material, only a few studies have been conducted to establish or characterize the mechanical properties, thermal insulation, and use of bamboo fiber as a reinforced polymer composite material. Characterizing material ignition and flame spread characteristics through standard test will be beneficial to researchers for future works. Various approaches have been considered to study the bamboo flake reinforced composite material ignition and maximizing the performance of material in flame spread characterization to ensure that this project can be completed.

Study on bamboo reinforced polymer material fire performance are limited, and existing testing methods do not offer the knowledge needed to construct fire-safe bamboo structures. Unsaturated polyester resin emits a lot of thick black smoke when they burn as well as harmful gas emissions like hydrogen chloride (HCI),

especially when flame-retardant halogen polyester resins are used. Thus, when a fire occurs, the situation will only get worse as rescue operations become increasingly difficult, if not impossible to carry out. Unsaturated polyester resin also used as tiles for roof, bathroom accessories and many more. Aside from that, the composite material is designed for plywood or floor laminate application. The composite material should then have an excellent ignition and flame result than the current plywood or floor laminate requirement.

1.3 Research Objectives

The main objective of this project paper is to characterize bamboo flake reinforced polymer composite material ignition and flame spread properties. The project main objective was specified intro three specific objectives as following:

I. To design an experiment for characterizing the material ignition and flame spread properties with ISO 3795, IEC 60695-11-10 and ASTM D635 as reference.

II. To characterize the flammability properties of bamboo flake reinforced polymer composite material;

III. To confirm the material feasibility for the selected application based on material ignition and flame spread properties.

1.4 Scope of Works

The scope of work for this project paper is organized into the following task:

a. Material Identification and Preparation

Leads in the identification and materials preparation. Composite material are identified based on previous study and literature review. Materials with specific weight ratio of 350:48 g is prepared properly for experimental assessment (Nur Ikhmalisya Izzati Rosni, 2020).

b. Experiment

Oversee the overall testing of specimens and ensuring the testing method is correctly implemented according to standards and codes to prevent any injury-causing incidents. Experiment conducted for the characterization of material ignition and flame spread properties as well as char production.

1.5 Research Methodology

This study was carried out according to a set of methodology that had been planned, as following:

i. Literature Review

For a better understanding and research guideline, this project paper used both international and local journals, as well as articles, books, websites, and any other online resources. A comparison of bamboo-reinforced polymer composites studies undertaken by a few researchers was made in order to improve the methodologies employed and the goal of this project paper.

ii. Experimental Assessment

Based on the parameters acquired, five materials are examined in this topic: two varieties of bamboo flake reinforced composite materials of polyester resin and epoxy, pure resin (polyester resin and epoxy), and pure bamboo. Five specimens of each material were prepared for testing. A number of tests are performed on the test specimen in order to determine the material ignition and flame spread characteristic.

iii. Result Verification and Validation

The findings of the test performed on the specimen are verified and discussed in detailed to confirm that the project paper's goal is met. To validate the results achieved in this experiment, the test specimen results are compared to previous researchers' work.

iv. Documentation and discussion.

All the findings or outcomes from this project paper, as well as academic references from the literature review, were documented and discussed for future use.

The research project is conducted according to the flowchart shown in Figure 1.1 below.

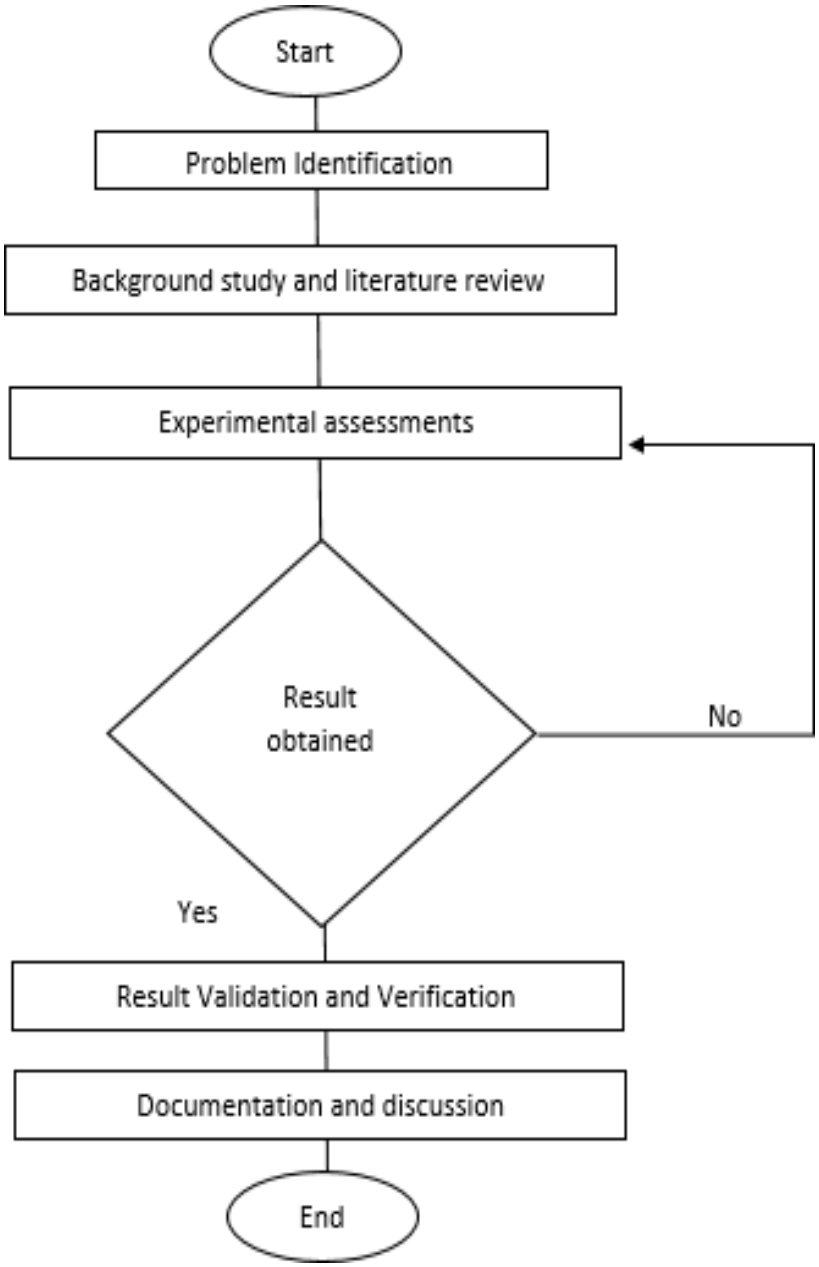

Figure 1. 1: Project paper methodology flowchart.

1.6 Thesis Organization

This project paper is organized as follows:

Chapter 1

This section introduced this bamboo flake reinforced polymer composite material

ignition and flame spread properties. This chapter listed the main objectives of this experiment, followed by the methodology, flowchart, scope of work, and so on. Other than that, this chapter also explains how this project is carried out specifically.

Chapter 2

This section is a compilation of different literature reviews of the same topic, which is composite material ignition and flame spread. This chapter discussed previous research conducted by researcher, flammability characteristics and characterization method related to the project paper. This chapter also includes summaries of the literature review to highlight the main findings.

Chapter 3

This section showed the methodology of the project study on material ignition and flame spread characterization. Materials specification were outline thoroughly along with the parameters from the testing in this chapter.

Chapter 4

It is the section where the results of the specimen after being tested with flammability testing are gathered and compared as well as discussed. This part also included a detailed discussion of the result reasoning for validation.

Chapter 5

This section provided the summary of the projects where it illustrated the achieved objectives of the projects. This section also elaborated the improvements and recommendation should be done for future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Bamboo reinforced composite materials which is a natural fiber help to remove carbon dioxide from the environment and minimize carbon emissions. This composite material is made from renewable resources, is environmentally benign, and is cost effective. Because of its excellent physical, chemical, and mechanical qualities, bamboo has been a part of human development from the dawn of time and known in the east as the plant of a thousand uses (Datschefski, 2001). Bamboo composite is used to make a variety of products, including furniture, transportation, and vehicle bodywork. Since 2005, a great deal of research has been conducted on numerous platforms to support the application of the same. Researchers are actively researching the use of bamboo composite in the manufacture of durable furniture, bicycles, tricycles, and automobile bodywork. Bamboo composites, according to Sen and Reddy (2011), can be employed in structural upgrades as a frame, beam and joint. Bamboo flake reinforced composite material is a material that has to be studied more because research on these materials is limited, despite the fact that it can assist industries such as wood application, building, and even research and development. The majority of study on this composite has focused on physical features such as tensile strength rather than the flammability properties, which are just as important as the strength properties. The literature review of bamboo composite flame spread,

and related topics is presented as following section.

2.2 Composite Material

A composite material is one that is made up of two or more materials that have different superior material properties physically and chemically compared to the individual components. Composite materials can increase a material'sstrength and stiffness. The matrix, which is a continuous bulk phase, and the dispersed phase make up a composite material. The most typical characteristics of composite materials include a scattered or contiguous phase, which is viewed as a tougher and stronger component. Aside from that, the three categories of compositematerials are particle-reinforced composites, structural composites, and fiber- reinforced composites. A composite material has several advantages over bulk materials, including high strength and stiffness combined with low density, allowingfor a weight reduction in the finished item. Strength and stiffness are provided during the reinforcing phase.

The characteristics and characterization of composite materials vary depending on the matrix and reinforcement utilized to construct the composites. Most reinforcements and matrices are made of proprietary materials for whichno industry standards. The two categories of particle-reinforced composites are largeparticles and dispersion-strengthened composites, and they were classified based on the manner of reinforcement and strengthening. The main difference between large-particle composites and dispersion-strengthened composites in terms of strengthening mechanism is that particle-matrix interactions in large-particle composites are not treated at the molecular level, whereas in dispersion-strengthened composites these interactions are treated on the molecular level. Figure 2.1 below shows the classification and characterization of composite material combinations.

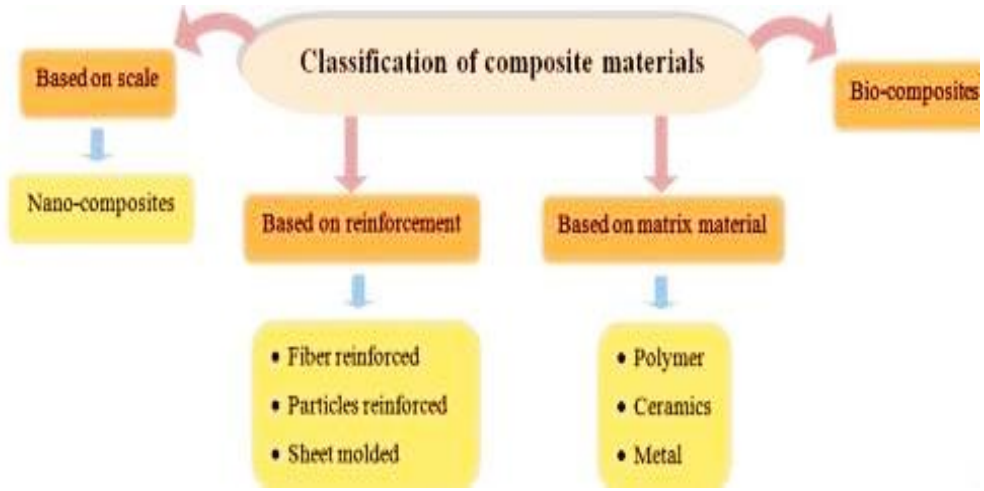

Figure 2.1: Classification and characterization of composite materials.

Source: Rajak *et al.*, (2019).

Fiber-reinforced composites are classified according to the arrangement or orientation of the fibers, with continuous fibers being usually aligned and discontinuous fibers being aligned or randomly oriented. Structural composites are further subdivided into laminates and sandwich panels. Laminates composite are two-dimensional sheets of high strength direction, continuous and aligned fiber reinforced polymers. The layers are piled and cemented together, and the high strength direction varies with each layer. Sandwich panels, on the other hand, are made up of two outer sheets or faces that are separated by and adhered to a thicker core. The four basic classes of solid materials are polymers, metals, ceramics, and carbon, each has its own set of features that distinguishes it from the others. In these four categories, reinforcement and matrix can both be found.

2.2.1 Matrix material

Matrix phase (primary phase) and dispersed phase (reinforcing phase) are the distinct phase that composed a composite material. In a matrix phase, as the characterization of matrix is ductile and less hard phase, matrix has a continuous character that holds the dispersed phase and shares a load with it. Thus, this phase is a continuous phase where matrix are held together. Despite the fact that the reinforcement improves the matrix's overall qualities, the matrix holds the