UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Technology and Engineering

THE EFFECT OF PARTIAL REPLACEMENT OF FIBER GLASS IN EPOXY COMPOSITE BY USING DATES PALM FIBER FOR MECHANICAL PROPERTIES

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THE EFFECT OF PARTIAL REPLACEMENT OF FIBER GLASS IN EPOXY COMPOSITE BY USING DATES PALM FIBER FOR MECHANICAL PROPERTIES

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A dissertation submitted
in partial fulfillment of the requirements for the degree of
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DECLARATION

I declare that this dissertation entitled “The Effect of Partial Replacement of Fiber Glass in Epoxy Composite by Using Dates Palm Fiber for Mechanical Properties” is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this dissertation and in my opinion this dissertation is sufficient in terms of scope and quality as a partial fulfillment of Master of Mechanical Engineering

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DEDICATION

Alhamdulillah, thanks, and praise to the Almighty Allah S.W.T

This thesis is dedicated to:

My dearest family, My Parents, My Supervisor, My Lectures, and all my friends. Thanks for their encouragement and support.

ABSTRACT

In the field of hybrid composites, the combination of date palm fiber(natural fiber) with fiberglass(synthetic fiber) provides an alternative approach that emphasises on the advantages of both materials to create a composite with unique properties and applications. In this experimental study, hybrid composites were fabricated using different mixing ratio of the epoxy, fiberglass and date palm fiber. Every sample have different mixing ratio of glass fiber and date palm fiber but same epoxy with weight fraction 70% of matrix ratio while 30% balanced consist of glass fiber and dates palm fiber. The study evaluate the impact of this substitution on the overall performance of the hybrid epoxy composites, including aspects like tensile strength, flexural, impact test and morphological structure. For the tensile strength, sample A1(26% Glass Fiber, 4% Dates Palm Fiber) obtained the highest value 87.7MPa. Sample A4(30% Glass Fiber) is the highest value of flexural strength with 218.0MPa while Sample A2 with 101.4KJ/m^2 for highest value of the impact test. Then, different structures such as fiber breakage, delamination and debonding are also observed by using Scaning Electron Microscope (SEM). However, the results offer valuable guidance for optimizing the mechanical performance of these composites in various applications It delves into the potential advantages and limitations of using date palm fiber as an alternative to conventional fiber glass in composite materials, aiming to assess the feasibility and efficiency of this substitution in various applications.

ABSTRAK

Dalam bidang komposit hibrid, gabungan antara serat kurma(serat semulajadi) dengan gentian kaca(gentian sintetik) memberikan pendekatan alternatif yang menekankan kelebihan bagi kedua bahan untuk menghasilkan komposit dengan sifat dan aplikasi yang unik. Dalam kajian eksperimen ini, komposit hibrid telah difabrikasi menggunakan nisbah campuran berbeza bagi epoksi, gentian kaca dan serat pokok kurma. Setiap sampel mempunyai nisbah campuran gentian kaca dan serat pokok kurma yang berbeza tetapi epoksi yang sama dengan berat pecahan nisbah matriks ialah 70% manakala 30% tersebut terdiri daripada gentian kaca dan serat pokok kurma. Kajian ini menilai kesan penggantian ini ke atas prestasi keseluruhan komposit epoksi hibrid, termasuk aspek seperti kekuatan tegangan, lenturan, ujian impak dan struktur morfologi. Untuk kekuatan tegangan, sampel A1(26% Gentian Kaca, 4% Serat Pokok Kurma) memperoleh nilai tertinggi 87.7MPa. Sampel A4(30% Gentian Kaca) adalah nilai tertinggi kekuatan lenturan dengan 218.0MPa manakala Sampel A2 dengan 101.4KJ/m2 untuk nilai tertinggi ujian impak. Kemudian, struktur yang berbeza seperti pemecahan gentian, delaminasi dan penyahikatan juga diperhatikan dengan menggunakan Scanning Electron Microscope (SEM). Walau bagaimanapun, hasilnya menawarkan panduan berharga untuk mengoptimumkan prestasi mekanikal komposit ini dalam pelbagai aplikasi. Ia menyelidiki potensi kelebihan dan batasan penggunaan serat pokok kurma sebagai alternatif kepada gentian kaca konvensional dalam bahan komposit, bertujuan untuk menilai kebolehlaksanaan dan kecekapan penggantian ini dalam pelbagai aplikasi.

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LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Material
CFRP	-	Carbon Fiber Reinforced Polymer
CMC	-	Ceramix Matrix Composite
FKM	-	Fakulti Kejuruteraan Mekanikal
GFRP	-	Glass Fiber Reinforced Polymer
MMC	-	Metal Matrix Composite
NaOH	-	Sodium Hydroxide
PGFRPC		Pultruded Glass Fiber-Reinforced Polymer Composite
PLA	-	Polylactic Acid
PMC	-	Polymer Matrix Composite
PPE	-	Personal Protective Equipment
SEM	-	Scanning Electrone Microscopy
SOP	-	Standard Operating Procedure
UTeM	-	Universiti Teknikal Malaysia Melaka

LIST OF SYMBOLS

σt	-	tensile stress, MPa
σf	-	flexural stress, MPa
ϵt	-	tensile strain
ϵf	-	flexural strain
Ft	-	tensile load, N
Ff	-	flexural load, N

CHAPTER 1

INTRODUCTION

1.1 Background

Glass fiber has indeed seen an increasing use in manufacturing in Malaysia over the years. The composite made of Glass Fiber Reinforced Polymer (GFRP) has been adopted for crossarm manufacturing and has successfully served 275 kV lines for a few decades (Rahman et al., 2021). The pultruded glass fiber-reinforced polymer composite (PGFRPC) cross-arms have been installed in Malaysia as a pilot project (Amir et al., 2021). Glass fiber-reinforced plastics, particularly epoxy glass-reinforced composites, are widely used in the construction, aviation, and maritime industries in Malaysia due to their advantageous mechanical properties, lightness, resistance to atmospheric conditions, and low price (Matykiewicz, 2020).

In recent years, there has been a trend of using natural fibers in combination with glass fibers to fabricate boat structures, as natural fibers are seen as a more cost-effective option (Suriani et al., 2021). Additionally, glass fiber composites have been used in various applications such as dentistry, wind energy, and wood industry in Malaysia (Purnama et al., 2022; Romani et al., 2020; Guo et al., 2016). The use of glass fiber composites in the automotive industry is also prevalent, where glass fibers are used as reinforcement material in the production of field hockey sticks and automobile bumpers (Khalid et al., 2021; Batista et al., 2019).

Furthermore, glass fiber composites have been used in the fabrication of hybrid composites with jute, carbon, and other natural fibers to improve their mechanical properties (Sezgin & Berkalp, 2016; Shadhin et al., 2021; Olszewski et al., 2021). The mechanical properties of glass fiber composites have been extensively studied, including their impact resistance, tensile strength, bending properties, and interlaminar shear properties (Amir et al., 2021; Suriani et al., 2021; Sezgin & Berkalp, 2016; Ren, 2023; Batista et al., 2019). The use of glass fiber composites in various industries and their mechanical properties make them a valuable material for manufacturing in Malaysia.

The manufacturing process often generates a significant amount of waste, including materials that are transformed into new products or food that is processed from raw ingredients. Date fruit processing, for example, results in various by-products such as whole cull dates, date stones, and sugar-extracted date pulp (Attia et al., 2021). These by-products contain a substantial amount of fiber, making dates one of the fruits with a high fiber output. Additionally, the waste generated from date palm trees, such as leaflets, rachis, fruit pruning, and trunks, has been assessed for its energy potential, with a total potential of 87 thousand tonnes per annum identified for energy production (Kumar et al., 2019).

Date palm fibre is a natural fibre derived from the leaves, stems, or bark of the date palm tree (Phoenix dactylifera L.). It has gained attention in various manufacturing processes due to its unique properties and potential applications. Date palm fibre has been used as a reinforcement material in composite materials, such as biopolymer composites (Gokulkumar et al., 2023), epoxy composites (Fiore et al., 2016), and cement composites (Labib, 2022). It has been found that the combination of date palm fibres with different polymers can enhance the properties of the resulting composites (Gokulkumar et al., 2023). Chemical treatments, such as NaOH and silane, have been employed to improve the surface characteristics of date palm fibres and address their hygroscopic tendencies (Gokulkumar et al., 2023).

The mechanical properties of date palm fibres have been investigated in several studies. It has been observed that the tensile strength of date palm fibres can be improved through chemical treatments, such as NaOH treatment (Bourmaud et al., 2017). However, the increase in NaOH concentration may worsen the tensile properties of the fibres (Fiore et al., 2016). The length and volume fraction of date palm fibres have also been found to affect the bending resistance of composite materials (Labib, 2022). Surface modification techniques, such as removing cellulose, lignin, wax, and oil content, can increase the surface roughness of date palm fibres and improve their mechanical interlocking (Zalinawati et al., 2020).

Furthermore, investigations into the mechanical properties of hybrid composites using natural additives, including date palm fibers, have revealed an increase in compression strength when incorporated into epoxy (Chlob & Fenjan, 2022). The use of date palm fibers in hybrid composite plates for ballistic protection has also been explored, with expectations of enhancing the ballistic properties of the composite plates while offering economic and environmental advantages (Alkhatib et al., 2021).

In the context of composite materials, the incorporation of natural fibers, such as date palm fibers, has been shown to improve the mechanical and thermal properties of the resulting hybrid composites. Studies have reported improvements in the thermal behavior of date palm fiber-reinforced epoxy hybrid composites, indicating the potential to enhance the thermal properties of materials used in lightweight sandwich structures (Jawaid et al., 2021). Additionally, the utilization of date palm fibers in mortar mixtures has been found to enhance the thermal and mechanical properties of the resulting materials, contributing to their lightweight and high-performance characteristics (Boubaaya et al., 2023).

1.2 Problem Statement

The epoxy and fiberglass composites lies to limitation in mechanical properties and environmental concerns. It have been widely used due to their excellent specific strength, corrosion resistance, electrical insulativity, and cost efficiency (Yang et al., 2018). However, there are several mechanical and performance issues associated with these composites. So, there is the hybridized jute fiber with glass fiber to improve the mechanical properties of jute/epoxy composite, indicating the potential for natural fibers like date palm to enhance the performance of epoxy composites (Erkliğ et al., 2022). Moreover, the use of natural fibers in epoxy composites aligns with the growing emphasis on sustainable and biodegradable materials, addressing the concern of synthetic and non-biodegradable materials in composites (Puspita et al., 2018). Therefore, the integration of date palm fiber in epoxy composites presents an opportunity to overcome the mechanical limitations of fiberglass composites and contribute to the development of sustainable and high-performance composite materials.

Natural fibers, including date palm fibers, have been considered as potential substitutes for traditional synthetic fibers like glass or carbon in composite materials for various reasons. In this globalization era, the natural fiber can help the sustainability of the renewable resource. Date palm fiber are renewable resource, and their use in composites can contribute to reducing the dependence on non-renewable resources, making the manufacturing process more environmentally friendly.

Moreover, the weight of the glass can be decrease because natural fibers, such as date palm fiber, are lighter in weight compared to glass fibers as stated in Sia et al. (2018). It states that natural fibers are lightweight compared to synthetic fibers. Based on the, Jeyasekaran (2016) also mentions that natural fibers have higher economic impact and lower density compared to glass fibers. Additionally, Sia et al. (2018) highlighted that natural fibers are lightweight and renewable in comparison to synthetic fibers. The natural fibers are generally lighter than traditional glass or carbon fibers, which can be advantageous in applications where weight reduction is essential, such as automotive or aerospace industries.

Date palm fiber is one of the materials that can be used to partially replace glass fiber because its properties are suitable for the material but with the correct division to maintain the strength and properties of fiber glass.

1.3 Research Objective

i) To evaluate the effect of the partial replacement of the glass fiber by date palm fiber on mechanical properties in hybrid epoxy composites on the tensile, flexural and impact strength.

ii) To investigate the relationship between the partial replacement of the glass fiber by date palm fiber on mechanical properties in hybrid epoxy composites with the morphological structure.

1.4 Scope of Research

This research focuses on making composites out of date palm fiber on the partial replacement of the glass fiber. In this study, different weight percentages of date palm fiber were employed as a criterion. The sandwich structure used to produce the all samples due to their lightweight and high mechanical properties. The use of lightweight sandwich structures in various industries, including automotive, sustainable energy, aerospace, marine, and building, is driven by their high flexural stiffness-to-weight ratio, excellent thermal insulation, and high-energy absorption capacity Zaharia et al. (2020). These structures offer an excellent strength-to-weight ratio, making them suitable for applications such as ship structures, where innovative lightweight materials provide superior mechanical properties (Tuswan et al., 2023).

Furthermore, the mechanical properties of lightweight sandwich structures have been enhanced through the use of all-composite honeycomb sandwich structures, demonstrating superior specific mechanical performance (Zhang et al., 2023). Sandwich structures made of glass fibers are widely used in various industries such as aerospace, automotive, medical, and energy (Buican et al., 2021). The sandwich configuration typically consists of two outer skins, or face sheets, and a core material sandwiched between them. The face sheets are reinforced with glass fibers, which enhance the mechanical properties of the structure. Then, the date palm fiber is between the face sheets of the glass fiber. The experimental of mechanical properties performed in terms of tensile, flexural dan impact test. The Scanning Electron Microscope (SEM) was used to examine the sample's morphological structures.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Natural fibers are fibrous materials derived from plants, animals, or minerals that are used as a reinforcement in composite materials. They are considered an alternative to synthetic fibers due to their renewable and sustainable nature (Kamarian & Song, 2022). Natural fibers have gained attention in various industries, including aerospace, automotive, construction, and packaging, due to their lightweight and eco-friendly characteristics (Kamarian & Song, 2022). In the engineering field, natural fibers refer to fibers derived from natural sources such as plants, animals, or minerals. These fibers are often used as reinforcing materials in composite materials, which are engineered materials made by combining two or more different materials to create a new material with improved properties.

In the context of composites, natural fibers are primarily used as reinforcements to enhance the mechanical properties of the composite material. When mixed with a matrix material (such as a polymer, cement, or other binder), natural fibers form a composite that takes advantage of the respective strengths of both components.

Natural fibers are used in engineering for a number of reasons, including the fact that they are renewable, biodegradable, and need less energy to produce than synthetic fibers. A natural fiber's possible limitations, such as susceptibility to moisture, insect damage, or changes in qualities depending on the source, must be looking in to it, as well as the application's unique requirements for performance.

2.2 Composites

A composite is made up of a matrix and a reinforcement that, when combined, have qualities that are superior to those of the individual components (Skoczylas et al., 2019). Most composites are made up of only two materials. Composite materials come in two phases. The matrix, also known as a binder, is the initial step. It encircles and ties together the other material's fibers or fragments. The other is referred to as reinforcement. When two or more different materials are mixed to create a superior and unique substance, it is called a composite. Composite materials are used in engineering applications where a pure material cannot provide the specific qualities required. Composites are made up of two or more materials that the addition of another has upgraded. Matrix and reinforcement are usually found in composites. Each one has its own distinct physical or chemical qualities that can be combined to improve performance through composites (Karaduman, 2021). We discovered that composite materials have three main physical phases based on their composition and internal structure. One is the continuous matrix phase, while the other is the reinforcement phase, which is scattered and surrounded by the matrix. The other is the composite interface, which is a transition point between the reinforcement and matrix phases (Skoczylas et al., 2019).

Unlike a ceramic matrix composite, where the reinforcement is primarily utilized to improve fracture toughness, a polymer matrix composite's reinforcement provides strength and stiffness that the matrix lacks. The mount in the composite is designed to support the