EFFECTS OF KENAF FIBRE SURFACE TREATMENT TO THE MECHANICAL PROPERTIES OF RECYCLED POLYPROPYLENE COMPOSITES

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

by

ABG MUHD FAKHRULLAH BIN ABANG AHMAD

B051810090

970719135879

FACULTY OF MANUFACTURING ENGINEERING

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The members of the supervisory committee are as follow:

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(Ts. Dr. Jeefferie Bin Abd Razak)

ABSTRAK

Polimer yang diperkukuh dengan pengisi gentian semula jadi berpotensi mencipta bahan hijau dengan bahan yang lebih mampan dan mesra alam untuk alam sekitar. Justeru, penyelidikan ini dijalankan untuk membangunkan gentian kenaf (KF) yang diperkukuh dengan komposit berasaskan polipropilena (r-PP) kitar semula. Sifat mekanikal dan fizikal komposit telah ditentukan melalui kajian ini. Gentian semulajadi dirawat dengan larutan NaOH 10% dan larutan NaOH Silane 10% dan dikeringkan dalam ketuhar selama 24 jam pada suhu 80°C. Komposit polimer bertetulang gentian asli (NFRPC) telah diadun menggunakan pengadun dalaman diikuti dengan pengacuan mampatan. Pemilihan komposisi optimum bagi komposit berasaskan r-PP/KF bergantung kepada pemuatan gentian dan rawatan. Oleh itu, dalam kajian ini, pemuatan gentian yang berbeza bagi gentian semula jadi (0, 10, 20, 30, 40 wt.%) dan rawatan (NaOH dan NaOH Silane) dengan saiz 62μm digunakan untuk menyiasat mekanikal, dan fizikal komposit yang direka. Kemudian, morfologi rekah sampel dianalisis dengan pemerhatian mikroskop elektron imbasan (SEM). Pada akhir kajian ini, sampel yang mempunyai kekuatan mekanikal tertinggi akan dicadangkan. KF yang dirawat NaOH telah berjaya dipertingkatkan ciri mekanikal KF, dari segi kekuatan tegangan dan lenturnya. Sampel yang dirawat NaOH 10wt% menghasilkan peningkatan yang luar biasa dalam ciri mekanikal dan fizikal sekali gus menunjukkan rawatan ini telah berjaya meningkatkan sifat KF. Penyelidikan ini amat penting untuk dijalankan bagi menyediakan alternatif yang lebih baik untuk bahan yang lebih hijau yang lebih mampan dan mesra alam dalam penggunaan kehidupan seharian.

ABSTRACT

Polymer reinforced with natural fibres filler potentially creates a green material with more sustainable and eco-friendly alternatives for the environment. Thus, this research was carried out to develop kenaf fibre (KF) reinforced with recycled polypropylene (r-PP) based composites. The mechanical, and physical properties of the composites had been determined through this study. The natural fibres are treated with 10% NaOH solution and 10% NaOH+Silane solution and oven dried for 24 hours at 80°C. The natural fibre reinforced polymer composites (NFRPC) were compounded using an internal mixer followed by compression moulding. The selection of optimum composition of r-PP/KF based composites depends on the fibre loading and treatments. Therefore, in this study, different fibre loadings of natural fibres (0, 10, 20, 30, 40 wt.%) and treatments (NaOH and NaOH+Silane) with the fibre sizes of 62µm were used to investigate the mechanical, and physical properties of the fabricated composites. Then, the fracture morphology of the samples was analysed by scanning electron microscopy (SEM) observation. At the end of this study, samples with highest mechanical strength performance was proposed. The NaOH treated KF had successfully enhanced the mechanical characteristic of KF, in terms of their tensile and flexural strength. The 10wt% NaOH treated kenaf sample has yielded an extraordinary improvement in mechanical and physical characteristics thus suggesting the treatment was successfully enhanced the properties of KF for composites application. This research is significantly important to be carried out to provide better alternatives for greener material that are much more sustainable and eco-friendly in daily life use.

DEDICATION

Dedicated to

My beloved parent, Abang Ahmad Bin Abg Abd Wahab and Nurul Izza Tiong

My appreciated siblings, Dayang Nurfaezah, Dayang Nurshafiqa, Abg Mohd Fathullah, Lau Siew Chui, Abg Mohd Faadhillah and Dayang Nurathirah

My friends, housemates, coursemates for giving me encouragement, motivation, and support, understanding, and also cooperation.

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LIST OF ABBREVIATIONS

aPP	-	Atactic Polypropylene
ASTM	-	American Society for Testing and Materials
CMC	-	Ceramics Matrix Composites
FTIR	-	Fourier Transform Infrared Spectroscopy
iPP	-	Isotactic Polypropylene
KF	-	Kenaf Fibre
MMC	-	Metal Matrix Composites
NaOH	-	Sodium Hydroxide
NaOH+Silane	-	Sodium Hydroxide and (3-aminopropyl) triethoxysilane
NFRC	-	Natural Fibre Reinforced Composite
PMC	-	Polymer Matrix Composites
PP	-	Polypropylene
r-PP	-	Recycled Polypropylene
SEM	-	Scanning Electron Microscopy
sPP	-	Syndiotactic Polypropylene
UV	-	Ultraviolet

CHAPTER 1

INTRODUCTION

This chapter presents full explanation on the background of the study. The research objectives to be accomplished to solve the stated problem statement, rationale of research, and the thesis organisation are also included. The impact of conducting this study is also comprehensively justified. Besides, this chapter also emphasize the limitation of the study through the scope of work.

1.1 Background of Study

Our world has always been filled with a variety of materials. Materials has evolved through time to become what they are now. Over the millennia, man has dealt with a wide range of materials, from the stone age, progressing through the metal age, and finally the polymer age (Smith, 2019). The shift in material ages occurred as human continue to evolve throughout the future, demand for the improvement of materials to meet current requirements and functions. A polymer, undebatable one of the finest materials ever created due to its distinctive characteristics, has achieved dominance in a wide range of applications. Corresponding to Wang (2011), also stated polymers are undoubtedly one of the best materials ever produced. It was not surprisingly said that the polymer is the material of the century. Polymer alone somehow not able to provide strength and load bearing capability, especially for structural application, due to their limited mechanical properties. Hence, composites are often made by reinforcing polymers with other materials, in order for them to appropriately acquire the required characteristics for ultimate performance in a broad selection of applications. As a result, the creation of polymer composites has continued to remain as one of the most effective ways of influencing the polymeric materials properties. There has been an increasing need for materials that are lighter, stiffer, stronger, and more environmentally friendly, because of the rapid growth in manufacturing industrial sectors. It has become amongst the most promising materials for a diverse applications because of its improvement in characteristics and versatility (Chukov et al., 2019; Sherif et al., 2019; Yashas Gowda et al., 2018).

In conjunction to this, Zampaloni (2007) mentioned that as industry work their way to reduce its reliance on petroleum-derived products, there is a growing need to develop alternative eco-friendly, renewable sources, long lasting sustainable materials to replace existing carbon fibre and glass fibre reinforced composites. Thus, natural fibre reinforced composites (NFRC) have been lately under the spotlight for their development and performance characteristics. Kenaf, flax, sisal, and hemp, are some of the natural fibres that were previously studied as alternatives for non-recyclable fibres. A wide variety of fibres are available at low cost and good ecological traits. Other benefits include the high strength, matching specific toughness properties, low density, ease of separation, reduced tool wear, and easy to fabricate (Mohanty et al., 2000).

Thermoplastic polymer, specifically commercial polypropylene (PP) is used as the matrix for composites applications. The benefits of utilising polypropylene (PP) as a matrix include its low processing temperature and minimal cost which are necessary due to natural fibres' limited thermal stability. PP based composites have gained much attention among eco-friendly polymer composites because of their recyclability (John et al., 2010). The study done by Srebrenkoska (2008) learned that polypropylene composites reinforced with kenaf fibre were less vulnerable to repeated process cycles and their characteristics are remained intact even after recycling. In conjunction with reducing plastic waste worldwide, recycled polypropylene (r-PP) will be significantly reused to fabricate the NFRC.

NFRC has always been difficult to fabricate due to the relatively low processing stability. NFRCs can be manufactured by using conventional production processes, such as vacuum infusion, injection moulding, or compression moulding. Even today, these procedures are extensively used as efficient methods for the manufacturing of high-quality composite materials. However, using these approaches to produce NFRCs requires a thorough understanding of the structural features of natural fibres, which have less mechanical resistance to shear, limited thermal stability, hygroscopic, and lack of homogeneity with standard thermoplastics (Ho et al., 2012). Hence, pre-treatment of NFRCs has always been a critical consideration for improving their processability. Improvement of the interfacial contact between the reinforced filler and the matrix polymer requires chemical treatment and modification of the fibre surface. A direct link between materials and processing, as well as composite qualities, is crucial (Arifur Rahman et al., 2015). As for these studies, the natural fibre specifically kenaf fibre (KF) is chemically treated using sodium hydroxide, (NaOH) solution and sodium hydroxide and (3-aminopropyl) triethoxysilane (NaOH+Silane), solution for the treatment before blending it with the recycled polypropylene (r-PP).

This study aims to explore the effects of KF fillers surface treatment and filler loadings to the resulted mechanical, and physical, properties of recycled polypropylene (r-PP) based composites. The effect of treated and untreated KF was also examined further for the overall performance of produced NFRCs, for several potential structural and multi-functional applications.

1.2 Problem Statement

Plastic pollution has threatened the global ecosystem due to its resistance to degradation and widespread use in the production industry. There are several harmful and environmentally effects of plastic waste in the aquatic ecosystem. Plastic product is a direct hazard to nature and wildlife, with numerous and diverse species having been proven to be harmed by plastic waste (Webb et al., 2013). Hirai (2011), also mentioned that ocean plastic has high amounts of organic contaminants. There have been harmful compounds detected countless times in ocean plastic wastes. The existence of these contaminants heightens the potential risks with wildlife consumption of plastic debris. Moreover, most of these plastics can undergo numerous biomagnifications and may directly threaten public health. These toxic chemicals have been connected with many health problems, including cancer, arthritis, diabetes, neurobehavioral changes, development impairment, and endocrine disruption (Ali et al., 2021; Schecter et al., 2010; Vethaak & Leslie, 2016).

According to Chamas (2020), the rate of degradation of each plastic may varies and the knowledge on the degradation kinetics and mechanisms are still not adequate. The rate of the plastic degradation often differs between several report. But more often, regardless of the insufficiency of scientific data. Media has depicted the expected periods for a plastic bags to decompose is around 500 to 1000 years (Delaney, 2013). While, some media had described that the plastics are non-degradable (Kari O., 2011). However, the type of plastics used in these claims is frequently uncertain, and the environmental factors are not clarified. Furthermore, the method used to deduce the outcome is still unknown. Every one of those variables has a significant impact on degradation rates. Besides that, scientific research on the degradation times of plastics is changing, and approximated lifespans of plastic waste can change drastically based on new evidence (Chamas et al., 2020).

The study of green product development has been performed lots of researchers to overcome the increasing waste that has been contributed mostly by plastic disposal after food and paper. According to Kaza & Yao (2018), the world made a total of 242 million tonnes matrix of plastic waste in 2016 alone, which most of the plastic wastes are contributed by East Asia and the Pacific with 57 million tonnes, 45 million tonnes from Central Asia and Europe, and North America with 35 million tonnes. More research studies are currently focusing on environmentally friendly composite materials such as natural fibres to reduce the world's environmental impacts, carbon footprints, and pollutions. In a sense that the natural fibres are biodegradable, low cost, low density with no toxic traits, good mechanical properties, and widespread availability (Gurunathan et al., 2015).

Commonly, the production of plastics is still depending mainly on fossil-based materials, which is the main cause of the increasing waste worldwide. Hence, replacing the filler part with natural fibres instead of synthetic fibres to develop natural fibre-reinforced composites (NFRC) could help overcome the future problem in managing plastic waste. Although NFRC can reduce the plastic waste produced globally, blending plastic or polymer with natural fibre is not an easy task. Plastic is a hydrophobic material that is water-resistant. At the same time, natural fibres, which are lignocellulosic and contain strongly polarised hydroxyl groups, are hydrophilic by nature and require an accurate chemical treatment to improve bond and compatibility between fibres and matrix (John et al., 2010). There is not much specific research done regarding NFRC blends with the proper ratio to produce the most efficient polymer composites using recycled polypropylene reinforced with natural fibres. Therefore, the idea of considering KF to substitute the filler part in polymer composite to produce new green bio-composites polymer are taken into consideration.

There are several possible problems that will be facing in producing natural fibre reinforced polymer composites. When natural fibre particles incorporated into polymer matrix, it can easily aggregate and agglomerate. Agglomeration could occur during the fabrication of natural fibres filler or during reinforced them into polymers. Agglomeration is a term used to describe strong and dense particle collectives of natural fibres. In addition, agglomeration occurs when particles are loosely combined and can be easily damaged by mechanical pressure (Zare, 2016).

Overall, by considering all these matters, the motivation of doing this research is clearly spelled-out and essential to be further explored. This is because no previous similar study has been detected in the existing literature, specifically about the KF reinforced r-PP polymer composites with an accurate loading formulation and specific surface treatment that has available or obtainable explored.

1.3 Objectives of Research

The following are the research's objectives:

(a) To evaluate the success of surface treatment performed to the kenaf fibre (KF) using an FTIR analysis method.

(b) To study the effects of surface treatment of KF natural fibre added as filler in recycled polypropylene based composites at various filler loadings (0wt.%, 10wt.%, 20wt.%, 30wt.%, 40wt.%) by using several mechanical, and physical testing.

(c) To observe the fracture morphology of KF/r-PP composites by using the Scanning Electron Microscope (SEM) for fabricated r-PP filled composites.

1.4 Scope of Research

The research scopes are as follow:

(a) Develop a polymer-based composites using r-PP as matrix with kenaf natural fibres as a filler through melt blending method by using an internal mixer melt compounding machine.

(b) Characterise the polymer-based composite's various mechanical, and physical properties. The properties that were evaluated are tensile strength, tensile module, elongation at break, flexural strength, density, and moisture absorption.

(c) Study the performance of KF/r-PP reinforced polymer composites categories based on surface treatment types which are untreated, treated with NaOH and treated with NaOH+Silane

(d) Analyse the characteristic of failure mechanism and resulted morphologies of KF reinforced r-PP polymer composites system by using the Scanning Electron Microscopy (SEM) observation.

1.5 Rationale of Research

The rationales of research are detailed as follows:

(a) Green composite product would be developed from this research. This is because, by embedding natural fibre into r-PP, the strength of r-PP based composite might be enhanced. This research analyses how the KF natural fibre could enhance the composite strength when incorporated to the r-PP recycled based materials.

(b) Develop more information and deep understanding about the role of added natural fibre when it incorporates to the r-PP matrix to improve the properties of the fabricated polymer composites.

(c) To gain new knowledge for natural fibre reinforced polymer (r-PP) composite by conducting some related testing (mechanical, physical, and morphological).

(d) To develop an alternative green material that possesses a sustainable solution and high-performance attributes. Kenaf is natural fibre that are biodegradable, and r-PP is waste that are abundantly available in Malaysia. Therefore, a greener way and superior performance green composites material can be developed through this research.

1.6 Thesis Organisation

This research is about to study the effects of KF fillers surface treatment to the mechanical, and physical properties of recycled polypropylene-based composites. In the meantime, the effects of fibre loadings (at 0, 10, 20, 30, 40 wt.%) would also be inspected and evaluated.

The arrangement of the thesis begins with Chapter 1. The first chapter is all about the research's background, problem statement, objectives, and scope. The second chapter comes next. Chapter 2 is a review of previous related research on polymer, kenaf fibre, and fibres surface modification of the polymer composites. All those criteria must be met in order to create a natural fibre reinforced polymer composite system. The methodology in Chapter 3 describes the entire raw materials that will be used, as well as related manufacturing processes that will be used to produce the r-PP reinforced with KF composites. Aside from that, standard testing procedure according to the ASTM standard will be covered in this chapter. The outcome and discussion were later included in Chapter 4. The fourth chapter is about data analysis and discussion. This section will go over all of the data obtained and gathered from various tests. These will include the mechanical, and physical properties, as well as morphological observations. Finally, the conclusion section, which was included in Chapter 5, brought the thesis to an end. All of the discussion will be concluded and critically summarised in this chapter based on the stated and aimed objectives of this research, together with several recommendation for future improvement.

1.7 Summary

Chapter 1 summarises the introduction of the study, which involves identifying the research's problem statement. The background of the study was also concisely explained, and the research’s objectives are clearly by following the stated scope of study for limitation and boundaries. This chapter also has included the thesis arrangement of the whole thesis. Finally, the significance of research also described in this chapter.