THERMO-MECHANICAL PROPERTIES OF NAPIER PARTICLES FILLED POLYESTER POLYMER

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by

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LIST OF ABBREVIATIONS

ADF	Acid detergent fibre
ASTM	American Society for Testing and Materials
CMCs	Ceramic Matrix Composites
CP	Crude protein
DCS	Differential scanning analysis
FESEM	Field Emission Microscopy
IMCs	Intermetallic Matrix Composites
MEKP	Methyl Ethyl Ketone Peroxide
MMCs	Metal Matrix Composites
OH	hydroxyl
PEEK	Poly ethyl ketone
PMCs	Polymer Matrix Composites
TGA	Thermogravimetry analysis
UP	Unsaturated Polyester resins
UTM	Universal testing machine

LIST OF SYMBOLS

A	Specimen original cross sectional in m^2
F	Load applied in Kn
ΔL	Change in specimen in m
Lo	Specimen original length in m
ρ_f	density of the Napier filler in g/cm^3
ρ_c	density of the composites in g/cm^3
W	weight fraction of the constituent within the composites

Ciri-Ciri Thermo-Mekanikal Komposit Napier Diisi Poliester

ABSTRAK

Dalam tahun-tahun kebelakangan ini, penubuhan gentian asli sebagai ejen dalam polimer komposit mengukuhkan telah mendapat peningkatan minat yang meningkatkan penggunaan optimum sumber asli dan terutamanya sumber yang boleh diperbaharui. Gentian asli telah terbukti sesuai untuk bahan tetulang untuk komposit; gabungan mekanikal yang baik, tinggi elektrik (penebat), rintangan hentaman, ciri-ciri penebat haba dan akustik yang baik dan dengan kelebihan terhadap alam sekitar seperti pembaharuan dan bio-degradasi, setanding dengan gentian sintetik polimer bertetulang. Oleh sebab itu, ia tidak menghairankan bahawa penggunaan bahan-bahan semula jadi dalam pengeluaran komposit telah mendapat kepentingan yang besar dalam pelbagai bidang dari barang-barang rumah sehingga ke bidang automotif. Kajian ini telah menggunakan rumput Napier sebagai kandungan pengisi kepada sifat-sifat polimer polyester. Napier diisi adalah untuk meningkatkan modulus elastik, kekuatan dan keliatan tanpa mengorbankan terikan kegagalan dan kestabilan haba poliester. Kesan resin poliester dengan kandungan pengisi Napier berbeza 1, 3 dan 5wt.% telah dikaji. Spesimen telah disediakan berdasarkan piawaian ASTM D695 dan ASTM D638 untuk masing-masing mampatan dan ujian tegangan. Walau bagaimanapun, perkembangan digunakan Napier polyster dipenuhi polimer belum mencapai potensi penuh mereka sebagai bahan kejuruteraan lanjutan disebabkan oleh beberapa halangan seperti zarah penumpuan dan penyebaran penyebaran miskin memperkenalkan kegagalan pra-matang sistem, lemah pengisi-matriks antara muka ikatan mengurangkan perpindahan tegasan dan pemahaman penyebaran Napier pengisi dalam sistem matriks. Cabaran utama ialah untuk mencapai pengelupasan susunan besar pengisi Napier ke dalam sistem matriks dengan mengambil kira batasan proses pembuatan. Pelbagai kaedah penyebaran (pencampuran tangan, mandi shaker air dan plat stirrer panas) disiasat mencapai campuran yang terbaik oleh itu pembangunan sistem matriks lebih keras dan lebih keras yang meningkatkan rintangan retak inisiasi dan pembiakan. Napier poliester dipenuhi sampel polimer telah dijalankan di bilik dan suhu tinggi (suhu bilik (25 ° C), 35 ° C, 55 ° C dan 75 ° C) untuk mengkaji kesan suhu pada polimer. Dalam kajian ini, keputusan menunjukkan bahawa sifat-sifat mekanik mampatan dan ujian tegangan poliester Napier penuh telah bertambah baik pada modulus dengan meningkatkan kandungan pengisi. Kestabilan terma Napier polimer poliester yang penuh meningkat sebagai kandungan pengisi Napier telah meningkat. Sampel yang disediakan oleh kaedah plat panas kacau (putar pencampuran) menghasilkan kekuatan yang paling tinggi berbanding dengan manual pencampuran tangan dan mandi shaker air (ricih pencampuran). suhu yang mempunyai walaupun kesan yang lebih ketara. Ia adalah diperhatikan bahawa sebagai suhu berkurangan bahan menjadi rapuh, mempunyai kekukuhan yang lebih tinggi dan gagal pada strain yang lebih rendah. suhu tinggi mempunyai kesan yang sebaliknya, dalam itu, apabila suhu meningkatkan bahan kehilangan ketegangan dan menjadi lebih mulur. Keputusan ini

menunjukkan bahawa pengisi Napier yang diperkenalkan mekanisme tambahan penyerapan tenaga, meningkatkan sifat-sifat mekanikal.

Thermo-Mechanical Properties of Napier Filled Polyester Composites

ABSTRACT

In recent years, the incorporation of natural fibers as reinforcing agent in polymer composite has gained increasing interest which enhances optimal utilization of natural resources and particularly of renewable resources. Natural fibers have proven to be suitable reinforcement materials for composite; combination of good mechanical, high electrical (insulating), impact resistance, good thermal and acoustic insulating properties and with environmental advantages such as renewability and bio-degradability, comparable to synthetic fiber reinforced polymer. Hence, for these reasons it has not been surprising that the use of natural materials in the production of composites has gained significant importance in various fields from household articles to automotives. This research is to use Napier grass as filler contents on the properties of Napier filled polyster polymer are to enhance the elastic modulus, strength and toughness without sacrificing the strain to failure and thermal stability of the polyester. The effects of polyester resin with different Napier filler contents i.e 1, 3 and 5wt.% had been studied. Specimens were prepared based on ASTM D695 and ASTM D638 standards for compression and tensile test respectively. However, proliferation used Napier filled polyster polymer have not yet reached their full potential as advanced engineering materials due to several hindrances such as agglomeration particles and poor dispersion dispersion introducing premature failure of the system, weak filler-matrix interface bonding reducing the stress transfer and the understanding of the dispersion of Napier fillers in matrix system. The main challenges is to achieve exfoliation of large stacks of Napier fillers into matrix system keeping in mind the manufacturing process limitations. Various methods of dispersion (hand mixing, water shaker bath and hot plate stirrer) be investigated to achieve the best mix hence development of a stiffer and tougher matrix systems which improving the resistance to crack initiation and propagation. Napier filled polyester polymer samples were performed at room and elevated temperatures (Room temperature (25 °C), 35 °C, 55 °C and 75 °C) to study the effects of temperatures on polymers. In this research, the results show that the mechanical properties of compression and tensile test of Napier filled polyester were improved in modulus with increasing the filler content. Thermal stability of the Napier filled polyester polymer increased as the Napier filler content was increased. The samples prepared by the hot plate stirrer(rotary mixing) method yielded the highest strength compared with manual hand mixing and water shaker bath (shear mixing). The temperature has even a more significant effect. It was observed that as the temperature decreases the material becomes brittle, has higher stiffness and fails at lower strains. High temperatures have the opposite effect, in that,as the temperature increases the material loses stiffness and becomes more ductile. This result suggests that the Napier filler introduced additional mechanisms of energy absorbtion, improving the mechanical properties.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Over the last decades, researchers have gain attention on the development natural of composites material due to its biodegradability, low density, low cost, nontoxic and environmentally friendly properties (Mohanty, Misra, & Drzal, 2002) . Numerous researchers have reported the advantages of the properties of thermoplastic and thermosetting composites reinforced with natural fibres and their potential to replace the synthetic fibres (Azwa, Yousif, Manalo, & Karunasena, 2013). Synthetic fibres, like carbon fibres and glass fibres create several ecological, and health hazard problems for the workers employed in manufacturing of their corresponding composites as compared to composites derived from natural fibres (Wambua, Ivens, & Veroest, 2003).

Natural fibres require very little energy to produce, and because they possess high calorific values, can be incinerated at the end of their lifetime for energy recovery. All plant-derived fibres utilize carbon dioxide when they are grown and can be considered CO_2 natural, meaning that they can be burned at the end of their lifetime without additional CO_2 being released into the atmosphere (Mohanty, Misra,& Drzal, 2002). On the other hand, glass fibres are not CO_2 natural and require the burning of fossil fuels to provide the energy needed for production. The burning of fossil fuel-based products releases enormous amounts of CO_2 into the atmosphere and this phenomenon is believed to be the main cause of the greenhouse effect and the climatic changes that are being observed in the world today (Wambua, Ivens, & Verpoest, 2003). The geometry and properties of natural fibres depend, for example, on the species, growing conditions, cambium age, harvesting, defibration and processing conditions. Since cellulose fibres have the possibility to show a wide range with both poor and strong bonding to polymer matrix materials, depending on fibres-matrix modification and compatibility, the optimal interface is typically somewhere between the two extreme cases. For instance, if the interface is too strong, the composite material can become too brittle, resulting in a notch-sensitive material with low strength, since stress concentrating defects are inevitable.

Natural fibres reinforced thermoset composites are now finding extensive uses in various fields from household articles to automobiles. The primary advantages of natural fibres over synthetic fibres have been their low cost, light weight, high specific strength, renewability, and biodegradability. The physical and mechanical properties of the natural fibres are determined by their chemical and physical composition, such as the structure of the fibres, cellulose content, microfibrillar angle, cross section, and the degree of polymerization. Absorption of moisture causing swelling of the fibres has been a major drawback for natural fibres, which leads to a weak bond at the fibres resin interface in the composites. Natural fibres, however, display large variations in fibres properties from plant to plant, such as strength, stiffness, fibres length and cross sectional area. These variations can ultimately lead to difficulties in composite design and performance predictions. Natural fibres are also thermally unstable compared to most synthetic fibres, and are limited to processing and working temperatures of 200°C. Another major drawback when using natural fibres is the fact that they are hydrophilic (absorb water) and polar in nature (Placket D., 2002) whereas common thermoset matrices such as polyester resin are hydrophobic (do not absorb water) and non-polar.

Todays, it is becoming increasingly hard to omit the important role of natural fibres composites in advanced technology. Many natural fibres composites are used nowadays due to the environmental factors. Natural fibres composites are mainly found in advanced application like internal parts of automotive and building industry. The examples uses of natural fibres to reinforce plastic for automotive application are flax, kenaf and sisal. There are being introduced for interior parts of car like roofing, door and window panels as shown in Figure 1.1. Panel made from natural fibres not only good in mechanical properties but they have a lighter weight than glass fibres feinforced panels, which cause lower fuel consumption and make cost saving. Furthermore, natural fibres product have a better environmental interest compared with oil-based plastics. Recently, Mercedez-Benz Travego have been used plant fibres in exterior composite components in the engine and transmission covers. As a results, 20% weight saving achieved with use flax and sisal thermoset door panels (Evans,Isaac, Suddell,& Crosky, 2002). The use of natural fibres composites not limited to the automotive industries only, but there has been increasing interest for building materials also like panels for partition boards, wall, floor and door frames(Nickel,&Riedel, 2003). The strength and stiffness of the composites is necessary to improve, as well as, issues of confront like water absorption and also thermal instability before these composites can be used to their full extent in the industry. Figure 1.2 shows the some constructive parts application made by the natural fibres composites.

Figure 1.1 : Mercedez-Benz with flax thermoset door panels

Figure 1.2: Constructive application

1.2 Problem Statement

Environmental awareness among all over the world focused the attention towards the use of natural fibres as reinforcement in polymer matrix because of their high specific strength and modulus. Commonly, composites using high strength fibres such as graphite, aramid and glass are used in broad range of applications from aerospace structure to automotive parts and from building materials to sporting goods. In recent years, a significant amount of interest has been shown in the potential of natural fibres to replace glass fibres in composites. The Napier reinforced composites is reasonable strong, lightweight, and free from health hazard, biodegradable and hence they have potential to be used as building materials. But they have some limitations such as lower modulus, poor moisture resistance to absorbtion and low strength when compared with synthetic fibres such as glass and carbon. Although there are some previous research works conducted on Napier grass fibre available in the literature, their thorough study and potential as reinforcing fibres in polymer composites have never been fully explored. Nevertheless, few early studies suggest that this type of natural fibres has the potential to be used as the reinforcing materials for development of green composites. Based on the early findings, and the readily available Napier grass in the state of Perlis, the potential of Napier grass fibre reinforced composite is to be investigated in this research .

1.3 Research Objectives

By referring to the problem statement, therefore this research is aimed to:

I) To evaluate the physical and thermal properties of Napier particles filled polyester polymer.

II) To determine the effect of temperature on compressive and tensile properties of Napier particles filled polyester polymer.

III) To investigate the failure mechanisms during compression based on morphological structure of fractured specimens.

1.4 Scope of the investigation

This investigation involved formulating a procedure for using Napier grass fibres to be used as reinforcement materials. The leaves and the roots of Napier grass were manually removed only stem was used. The Napier grass stem were cleaned by using water to remove impurities such as sand, soil and mud. The Napier grass stem were then dried, grinded, and sieved until the finest size particles with an average size of 17-45 μm were achieved. Napier filled polyester samples can be prepared by using 3 different mixing process at various Napier filler content (1,3 and 5wt.% Napier). The static uniaxial compressive tests and tensile test were conducted to studied the effects of mixing process and the weight % of Napier filler on the mechanical properties of the composites.The Napier filled polyester at different weight % were tested at elevated temperatures to simulate the temperature effects and Field Emission Microscopy (FESEM) was used to analyse and characterize the morphology and failure surface.

1.5 Organization of thesis

In Chapter 1, a brief introduction of fibres including natural fibres and composites including natural fibre composites is presented. Also briefly described are the main constituents of natural fibres.

Chapter 2 presents the literature review collected to conduct this investigation. This chapter intends to give some review to the readers about the scope of a project that has been done. It is also to show that how much journals and articles are reviewed before get going on this project. This chapter also includes the theories that have been taken into consideration.

Chapter 3 and 4 deal with the materials and method undertaken in this project. This investigation consists of the preparation of Napier filler filled polester composites.These chapter also presents the results and discussion obtained from this investigation. In this chapter, readers will see set of results obtained from the experiments. This chapter covered: compressive strength, tensile strength, Young's modulus and thermal properties compare with the neat resin. To observe the relationship between the processing parameters and mechanical properties (mixing method and ratio of filler)

Chapter 5 provides the conclusion of this thesis. In this chapter, readers can find the effects of Napier filler on the compressive and tensile properties of an unsaturated polyester polymer at various temperatures. Also, the FESEM based morphological study of the fractured surfaces of the Napier filled polyester polymer is presented. There is also stated here some recommendation and future works that can be applied to this project.