CHARACTERIZATION OF THERMOPLASTIC POLYURETHANE ELASTOMER COATED PINEAPPLE LEAF FIBER

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DEDICATION

To my beloved husband, parents, family and friends

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ABSTRACT

Pineapple leaf fibers (PALFs) have several advantages such as low cost, eco-friendly and high specific strength but their brittleness limit the application. To overcome this limitation, PALFs were coated with thermoplastic polyurethane elastomer (TPU) to enhance their elasticities and flexibilities. TPU was synthesized using a two-stage route method which consists of polyurethane (diisocyanate react with polypropylene glycol), forming pre-polymer (polyurethane with short chain), and to increase the chain length, chain extender was added into pre-polymer. Prior to this coating, PALFs were treated with sodium hydroxide at 5% concentration to improve their surface areas of the PALF. Three parameters were varied during the preparation of TPU coated PALF which were dipping times (5 min, 10 min, 15 min and 20 min), curing temperatures (30 °C, 55 °C, and 85 °C) and curing times (6, 12 and 24 hours). From scanning electron microscope it was found that sample with 10 minutes dipping time showed a clean and rough surface which favorable for coating with TPU. These were supported by tensile strength that showed sample with 10 minutes high in modulus around 900 MPa with 30% elongation at break. The formation of hydrogen bonding was thought contributed to the increase as shown by the plots of Fourier Transform Infrared at 3300 cm^{-1} and at 1530 cm^{-1} indicates PALF fully coated with TPU. Thermal analysis has been studied by using differential scanning calorimetry. The existence of hydrogen bonding had increased the thermal stability as measured with thermogravimetric analysis at around 500 °C of end set temperature. It was found that there is a formation of hydrogen bonding between PALF and TPU. The optimum requirement of TPU coated PALF were 10 minutes dipping time at 85 °C curing temperature and for 6 hours curing time in order to enhance the elasticity and flexibility of the fiber due to their brittleness. As a conclusion, coated PALF with TPU with optimum condition have improved the properties of an elastic yarn.

ABSTRAK

Serat daun nanas (PALF) mempunyai beberapa kelebihan seperti kos rendah, mesra alam dan kekuatan yang tinggi tetapi kerapuhan mereka telah menghadkan penggunaannya. Untuk mengatasi masalah ini, PALF telah disalut dengan elastomer poliuretana termoplastik (TPU) untuk meningkatkan keanjalan dan kebolehlenturan. TPU telah disintesis menggunakan satu kaedah jajaran dua peringkat yang mengandungi poliuretana (diisosianat bertindak dengan polipropilena glikol), menjadi pra-polimer (poliuretana dengan rantai pendek) dan untuk menambahkan panjang rantai, penyambung rantai ditambah ke dalam pra-polimer. Sebelum salutan ini, PALF telah dirawat dengan natrium hidroksida pada 5% kepekatan untuk memperbaiki luas permukaan PALF itu. Tiga parameter telah dianalisa semasa penyediaan TPU menyalut PALF iaitu masa celupan (5 min, 10 min, 15 min dan 20 min), suhu pematangan (30 °C, 55 °C dan 85 °C) dan masa pematangan (6 jam, 12 jam dan 24 jam). Dapatan dari morfologi mikroskop elektron imbasan mendapati 10 minit adalah masa celupan, menunjukkan permukaan yang bersih dan kasar yang sesuai untuk salutan dengan TPU. Ini telah disokong melalui kekuatan tegangan yang menunjukkan 10 minit masa celupan mempunyai modulus yang tinggi sekitar 900 MPa dengan 30% pemanjangan pada waktu putus. Pembentukan ikatan hidrogen telah menyumbangkan peningkatan seperti ditunjukkan plot spektroskopi inframerah Fourier pada 3300 cm^{-1} dan pada 1530 cm^{-1} menunjukkan PALF disalut sepenuhnya dengan TPU. Analisis terma telah dikaji dengan menggunakan kalorimeter imbasan pembezaan. Kehadiran ikatan hidrogen telah meningkatkan kestabilan terma kepada 500 °C suhu set hujung yang diukur dengan analisis termogravimetri. Ia menunjukkan bahawa terdapat pembentukan ikatan hidrogen antara PALF dan TPU. Keperluan optimum untuk TPU menyalut PALF adalah masa mencelup 10 minit pada suhu pematangan 85 °C dan selama 6 jam masa pematangan bagi meningkatkan keanjalan dan kebolehlenturan serat disebabkan oleh kerapuhan mereka. Kesimpulannya, PALF bersalut TPU pada keadaan yang optimum telah menambahbaik sifat-sifat untuk benang elastik.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In the recent years, biofibers have gained considerable attention from researchers and industrial players all over the world because natural fibers are renewable, biodegradable, creating a greener environment impact and causing less health hazards. Natural fibers can be generally classified according to their origins such as leaf, seed, fruits, wood, stalk, grass and bats which includes jute, flax, hemp and kenaf. In tropical countries, biofibers can be easily, even from agricultural crops. One of them is the agro waste, which are abundant and has low price to obtain biofibers. The unique composition, properties and structure of agro waste like biofibers make them suitable material for several applications such as composite, textile, pulp and paper manufacturing. On top of that, biofibers are also suitable materials to produce fuel, chemicals, enzymes and food, (Mohammad et al, 2009). An example of tropical plant that provides biofibers is pineapple. This plant from the Bromeliaceous family is one of an important fruit in Malaysia and can be found abundantly. Moreover, this plant is harvested for its flesh or pulp, leaving behind the leaves and trunks. Manufacturers and farmers tend to discard these wastes by means of incineration or burning, which leads to serious environmental problems, (Sena Neto et al, 2013).

Pineapple wastes especially the leaves can be benefited as they are natural cellulose fiber source for textiles as their long fiber, composites and paper. In textile application, cotton is a famous sources but it was under short fiber. As the individual cells in pineapple and also banana fibers are relatively longer in size, they are suitable for the production of long fibers. This is a point worth to be taken as the length to diameter ratio (L/D) of individual cells in a fiber affects the flexibility and resistance to rupture of the fibers and the products produced from them especially textiles and papers. Pineapple leaf fiber also produces a silky and soft long fiber just like silk, (Yusof and Yahya, 2013).

1.2 Problem Statements

Currently, a major challenge in the pineapple industry is the environmental issue arising from it. In some countries, paper industries using pineapple fiber are facing great pressure to reduce pollutant emissions (Rahman, 2011). Method of incinerating these wastes creates environment issues. To overcome this problem, pineapple leaves are usually extracted mechanically or chemically for their fiber. The leaves are of the lower lignin content than other fiber which can undergo bleaching quite easily therefore low usage of chemicals during alkaline treatment (Kumar and Siddaramaiah, 2005).

Conventionally, this type of pineapple fiber is commonly used as thread and textile in some country like Philippine as reported from Textile Today by Tinyla L. (2014), but recent modifications in term of fiber treatments have improved the properties of pineapple leaf ; fibers for example their brittleness, making them in trend with current textile industry and commercial textile materials. The brittleness of the fiber need to have some improvement or treatments in order to suit with industrial environment. This is because the production lane need a specific parameter such as temperature and concentration. Normal processing of wood fiber shows a loss of production at the output parts because the virgin fiber itself will loss during processing. Therefore its need some treatments are needed in order to entangle the full capacity of wood fiber with added some acetone during cleaning or surface treatment (Richard et al, 2011). The variety of surface treatment such as mechanical using decorticator, chemical using alkaline treatment, physically using hand scrapping or biologically using retting process by microbes which applied on the leaves to gain their fiber will decide the quality of the long fiber later on. Thus, it is important for the natural fiber coated with the polymer to make easy to handle manually or by machinery as reduce their fiber brittleness. The result of tensile test or observations only were not enough to ensure their fiber's quality. The processing of pineapple leaves also quite complicated which need specific machinery to handle the fibers. This has driven the textile manufacturers to seek for new approaches to produce environmental friendly products, especially green, recyclable and biodegradable textile materials and easy to handle for further processing. In previous research study, bamboo fiber has been coated with polyurethane and polystyrene to provide better result which improved their tensile properties. Alternatively, pineapple fiber was studied without modification to evaluate its strength, (Barikani and Barmar, 1996, Tye A. L and Richard D. G, 2012). Herein, modifications are made on pineapple leaf fibers using thermoplastic polyurethane elastomer to investigate its properties and reusability. It also known as a polymer that has high tensile strength, good resistance to abrasion, oil, fuel and solvents, low temperature flexibility, heat resistance and high adhesion to many substrates. Polyurethane material is widely utilized in industry and daily lives due to its versatile chemistry and relatively easy handling (Barikani and M. Barmar, 1996; Wu et al, 1995).

The pineapple leaf fiber (PALF) is a good fiber obtained after mechanical and chemical extraction process of the leaves. These two methods are commonly used as they were easy steps required and processed in a short period (John and Thomas, 2008). Thermoplastic polyurethane elastomer is a versatile polymer in the market that plays important roles in our daily lives. The use of thermoplastic elastomer polyurethane (TPU) as one of the matrix possesses numerous advantages as this material is an excellent abrasion resistant, good mechanical property in order modifying the brittle fiber to have elastic material (Rahman, 2011). In addition, it exhibits rubber-like elasticity and tear resistance. Therefore, natural long fiber such as PALF obtained from Josapine cultivar was chosen as fiber in textile application due to its enhanced mechanical properties together with the characteristics offered by TPU through two stage method to produce homogeneous TPUs with constant quality. The sampels were differentiated with some parameters which are dipping time,curing time and curing temperature in modifying the fiber to behave elastically. Previously, these three parameters were not really define yet. Kenaf fiber have a dipping time of 5 minutes and its curing temperature is room temperature. The curing time was not stated as it takes several hours (Abu A. S. et al, 2012, Barikani and Barmar, 1996). Therefore, PALF was characterized with Fourier transform infrared analysis (FTIR), Scanning Electron Microscope (SEM), Differential scanning calorimetric (DSC), thermo gravimetric analysis (TGA). For the mechanical analysis, tensile test (ASTM D3822) was carried out to evaluate the Young modulus, tensile strength and elongation at break. Meanwhile the chemical analysis was done to observe the resistant of coated PALF with several chemicals.

1.3 Objective

The objectives of this study are:

i. To obtain the treated fiber from pineapple leaves using mechanical and chemical methods and to synthesis TPU using a two stages method.
ii. To choose the optimum pre-determine dipping time, curing time and curing temperature of TPU coated PALF.
iii. To characterise and evaluate the mechanical and chemical properties of TPU coated PALF.

1.4 Scope of Study

PALF from Josephine cultivar used was obtained from MARDI Pontian. This type of species was chosen because of their characteristics such as long and strong which is suitable for textile applications. These fibers were first undergo mechanical extraction and followed by chemical treatment using sodium hydroxide. TPU was prepared by a two-stage route using toluene diisocyanate (TDI) as isocyanate, poly (propylene) glycol (PPG) as diols and glycerol propoxylate (GPO) as chain extender. PALF was coated with TPU solution by dipping method to obtain the elastic properties. Dipping times were varied from 5 min to 30 min in this study. Different curing times ranging from (6 hours, 12 hours, and 24 hours) and different curing temperatures ranging from (30 °C, 55 °C, and 85 °C) were also evaluated on the fiber samples to gain the optimum condition. Characterisation using ATR was conducted in order to identify the presence of –OH functional group in the fiber and the presence of functional group for PALF after alkaline treatment and after coated with TPU. Next, SEM was run to study the morphology of the treated and coated fiber. DSC also has been conducted for thermal analysis. Then, TGA was run to find the range of usage temperature on the samples. Several testing were also evaluated in this research for mechanical and chemical analysis to evaluate PALF coated TPU. First of all, tensile test (ASTM D3822) was run for mechanical testing. Then, chemical analysis was conducted to find the chemical interaction with thermoplastic polyurethane coated on the fiber (Wu et al, 1995).

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