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Mechanical properties of Napier grass fibre/polyester composites

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ABSTRACT

The mechanical properties of Napier grass fibre-reinforced composites were characterised. Napier grass fibres were extracted through water retting process. The effect of alkali-treatment on the tensile properties and morphology of the fibres was investigated. The fibres were alkali-treated using NaOH solutions of various concentrations and subjected to single fibre testing. The morphology of the fibres was observed using scanning electron microscopy. The 10% alkali-treated Napier grass fibres yielded the highest strength. To fabricate the polymer composites, Napier grass fibre and polyester resin were used as the reinforcing material and polymer matrix, respectively. The tensile and flexural properties of the composites were studied. In general, up to a certain threshold value, the tensile and flexural strengths of the composites increased as the fibre volume fractions increased, following which, there was a reduction in strength. The maximum tensile and flexural strengths of the composites were obtained at 25% fibre loading.

1. Introduction

Artificial polymer composite materials are broadly utilised in many industrial areas to accommodate the light-weight and high-strength property requirements for certain applications. However, with the current growing use of synthetic fibre materials, environmental issues such as waste disposal, waste removal services, and pollution from incineration are becoming more important [1]. The utilisation of natural fibres as substitutes for traditional synthetic fibres, such as glass and carbon, has recently received increased attention to overcome these environmental issues [2]. However, there are still concerns regarding the use of natural fibres in reinforced composites, such as poor interfacial bonding between the cellulose fibres and the thermoplastic matrix, restricted thermal properties of the composites, and poor fibre partition and dispersion within the composites.

Elzubair and K.L. Pickering reported that the low melting point of natural fibres and the poor moisture resistance between the polymer matrix and the natural fibre often restrict their potential use as reinforcing agents [3,4]. A.K. Bledzki and J. Gassan found that the mechanical and physical properties of natural fibres are extremely variable and can be influenced by certain factors, such as the ligno-cellulosic structure, climate conditions, and preparation methods [5]. With regard to engineering applications, there are serious concerns regarding the compatibility of the natural fibre and polymer matrix owing to a lack of interfacial bonding within the matrix [6,7].

H.L. Bos et al. studied the compressive properties of flax fibres. In that paper the compressive properties of composites with different natural fibres was measured and compared with their tensile properties [8]. Joseph et al. and De Rosa et al. both studied long and short sisal fibre-reinforced composites. Longitudinally and randomly orientated fibre composites were studied. They demonstrated that continuous fibres can be used for applications requiring high strength and stiffness in a single direction. However, randomly oriented short fibres offer lower strength but improve the isotropic properties of the composite [9,10]. R. Kumar examined the potential of banana fibre-reinforced composites utilising soy protein resin as a binding material, and suggested that the mechanical properties of the composites were highly dependent on the volume fraction of the fibre [11]. S. Ochi et al. investigated the mechanical properties of kenaf fibres and demonstrated that the tensile and flexural strength of kenaf reinforced PLA composites, increase linearly with fibre contents up to 50% [12].

X. Li et al. demonstrated that the structural stability and bonding properties of natural fibre-reinforced composites were improved by applying a chemical treatment to the fibres [13].

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The tensile strength of banana plant fibres was investigated by A.V. Kiruthika and K. Veluraja. The authors compared the results with those of non-treated fibres and fibres treated with various chemical compositions [14]. K.G Satyanarayana et al. discussed the physical and chemical properties of various natural fibre composites with epoxy resin matrices [15].

Using alkaline treatments and other numerous chemical modifications were performed to improve the bonding between the natural fibres and matrix [16,17]. F.E. El-Abbasi obtained results stated that the alkali treatment increases significantly the Young's modulus and tensile strength of the Alfa fibre reinforced polypropylene composites and reduces their loss during water ageing. [18]. K.M. M. Rao reported that the physical properties of natural fibres are primarily determined by their chemical and physical compositions, such as the fibre structure, cellulose content, cross-sectional shape and the density [19]. The characterization of flax fibre-reinforced composites has shown that the fibre arrangement and bonding within the polymer matrix are key factors to achieve high-performance composites [20,21]. A. Valadez reported that the adhesion characteristics of natural fibre surfaces were enhanced by the application of a chemical treatment [22]. H. Abral et al. reported the effects of moisture absorption for untreated and treated water hyacinth fibres. They observed that alkaline treatment did not significantly reduce the moisture absorption [23].

Currently, the utilisation of natural fibres as reinforcing materials in specific applications has great importance for composite engineering industries. Therefore, it is essential to continue research on natural fibre resources to enable simple and practical extraction that does not impair the properties of the fibres. The natural fibres must be thoroughly analysed to determine their physical, chemical, and tensile properties as well as their morphology [24,25]. During the current study, a common natural fibre was extracted from an abundant, locally-available plant, Napier grass. Napier grass, scientifically known as *'Pennisetum purpureum'*, is a newly-identified plant which forms robust bamboo-like clumps and is highly sustainable throughout Malaysia. These fibres were extracted using a simple manual water retting process before being subjected to an alkaline treatment. Subsequently, this study examined the fabrication of Napier grass fibre-reinforced polyester laminates and investigated their tensile and flexural properties. The obtained results were subsequently analysed and compared with other prevalent natural fibre-based composites.

2. Experimental procedure

2.1. Fibre materials

The Napier grass was harvested from a local farm near Bukit Kayu Hitam, Kedah, in northern Malaysia. These Napier grasses are easily grown, particularly in drier areas. The Napier grass fibres were extracted by using a conventional water retting process. Retting is a microbial procedure that separates the compound bonds that hold the stem together, and allows the bast fibres to detach from the woody centre. Water retting produces homogenous, high-quality fibres. The stems were immersed in water tanks, and their progress was monitored daily. Prior to retting, the Napier leaves were removed from the internodes of each stem. Subsequently, the stems were crushed with a mallet and immersed in a water tank filled with tap water for approximately three to four weeks, as shown in Fig. 1(a). Subsequently, the soaked Napier grasses were thoroughly cleaned and each fibre strand was

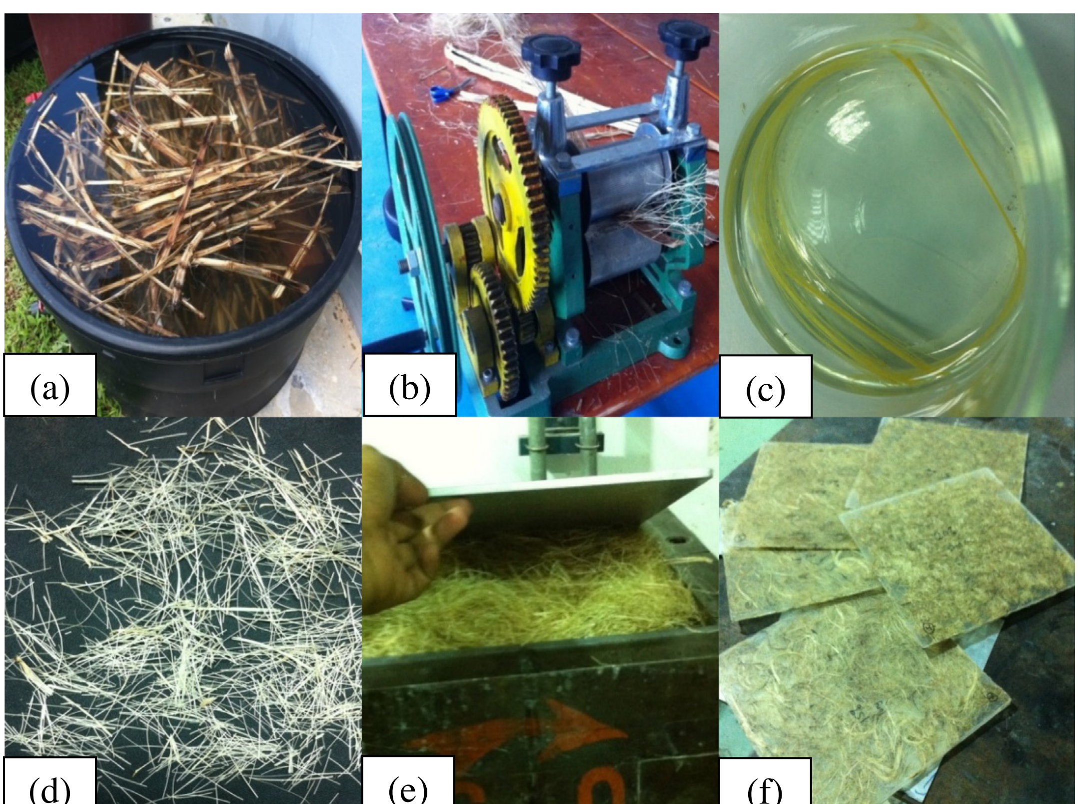

Fig. 1. (a) Soaked Napier grass fibres in tank, (b) roll-out machine for fibre extraction, (c) chemical treatment (NaOH) of Napier fibres, (d) short Napier grass fibres, (e) fabrication of Napier/polyester composites, (f) Napier/polyester composites with different fibre volume fractions.