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Journal of Bionic Engineering 13 (2016) 426–435

Effect of Alkali and Silane Treatments on Mechanical and Fibre-matrix Bond Strength of Kenaf and Pineapple Leaf Fibres

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Abstract

Natural fibres are very versatile materials, their properties vary with chemical composition and physical structure. The effects of alkali, silane and combined alkali and silane treatments on the mechanical (tensile), morphological, and structural properties of Pine Apple Leave Fibres (PALF) and Kenaf Fibres (KF) were investigated with the aim to improve their compatibility with polymer matrices. The effectiveness of the alkali and saline treatments in the removal of impurities from the fibre surfaces was confirmed by Scanning Electron Microscopy (SEM) and Fourier Transform Infrared spectrometry (FTIR) observation. The morphological study of treated PALF and KF by SEM indicates that silane treated fibres have less impurities and lignin and hemicelluloses removed than those by other chemical treatments. Silane treated PALF and KF display better tensile strength than those of untreated, alkaline and NaOH-silane treated. Droplet test indicates that the Interfacial Stress Strength (IFSS) of alkali and silane treated PALF and KF are enhanced whereas silane treated fibres display highest IFSS. It is assumed that fibre treatments will help to develop high performance KF and PALF reinforced polymer composites for industrial applications.

Keywords: pineapple leaves fibre, kenaf fibre, chemical treatment, tensile properties, structural properties, droplet test

doi: 10.1016/S1672-6529(16)60315-3

1 Introduction

Natural fibres are the most important components of various industrial applications such as textile, paper making, packaging and building materials[1]. Since natural fibres are renewable and biodegradable materials, products made from such materials are also environmental friendly[2]. Natural fibres have many desirable advantages over synthetic fibres such as good acoustic property, thermal insulation[3], low density, low cost and high flexural strength[4]. These advantages are being utilized for various applications and highly recommended for building material applications[5]. Natural fibres are composed of cellulose, hemicellulose, lignin, pectins, waxes and water soluble substances[6]. However, the chemical composition and physical characteristics also defer with climatic conditions, age and retting process[7].

Many fibre plants are available which have potentials to be use in industries as raw materials such as pineapple, kenaf, coir, abaca, sisal, cotton, jute, bamboo, banana, Palmyra, talipot, hemp, and flex. PALF are abundantly available waste materials of south-east Asian countries, used in producing fibres. PALF are constituted by cellulose (70% – 82%), lignin (5% – 12%), and ash (1.1%)[8]. PALF exhibit very good mechanical properties like tensile flexural and impact strength, which are highly desirable for making high quality of polymer composites. One drawback associated with PALF is the difficulty to make good interaction with hydrophobic polymers because it is hydrophilic in nature.

Another example of natural fibres which can be an excellent substitute of synthetic fibres in south east Asian countries is Kenaf Fibre (KF)[9,10]. KF is very attractive option because of its fast growth, low cost, abundant availability and climatic tolerance[11]. The

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plastic and petroleum–based industries have huge demand of kenaf based materials[12]. Many treatments have been developed to improve interfacial bonding[13] and achieve better qualities in mechanical and water resistance properties.

The most serious drawback of these natural fibres is their hydrophilic nature, which causes the weak interfacial bonding between fibre and matrix in polymer composites. Various physical impurities and the presence of hydroxyl groups on the fibre surface create difficulties to be used as enforcement materials[14]. Previously, several research works were carried out on treatments and modification of natural fibres to achieve desired qualities[15–17]. However, the mechanical performance of a composite material depends on the orientation and natures of fibres and matrix, the bonding between fibres and matrix also plays a very important role[18]. These weak bonding between fibres adversely affects the mechanical strength of fibre board[14]. Surface modification of natural hemp fibres using silane helped to minimize hydrophilic character[7].

In Ref. [19] PALF were treated with NaOH solution of various concentrations (1% w/v, 3% w/v, 5% w/v, and 7% w/v) and the treatment with 5% NaOH provided the best improvement of composite strength as compared with that of untreated fiber. In this paper, we studied the treatment of PALF with NaOH concentration 6% for 3h. In another work, KF were immersed in NaOH solution with different concentrations (3%, 6% and 9% NaOH) for 3h at room temperature and interesting to note that 6% NaOH yields the optimum concentration of NaOH for the chemical treatment[20]. Our study in a similar way, we considered optimum treatment, NaOH (6% for 3h) for KF and PALF, and comparing with silane (2% for 3h) and combination of alkali and silane treatments. In another study, surface of PALF was pre-treated with sodium hydroxide and modified with two different functionalities such as γ-aminopropyl trimethoxy silane and γ-methacryloxy propyl trimethoxy silane[21]. In this work, we used different procedure, chemical concentration and soaking time for PALF and KF. Alkali, silane and combine NaOH-silane treatments have been used on PALF and KF to modify the surface for good interfacial bonding with matrix. The aim of these treatments is to optimise chemical treatment of PALF and KF to fabricate high performance PALF/phenolic and KF/phenolic composites for aerospace components.

2 Experimental

2.1 Materials

KF (*Hibiscus cannabinus*) was harvested from West Malaysian and retted while PALF (*Ananas comosus)* were harvested from Indonesia. The chemical used in this research are NaOH (Sodium Hydroxide 6% w/v soln, R&M) and Triethoxy(ethyl)silane (96%, Sigma Aldrich, Jasa Sejiwa Enterprise). For interfacial testing, phenolic resins modified powder (Grade- PH 3507) was used.

2.2 Chemical treatment

PALF and KF were treated with three types of chemicals. The fibres were immersed into distilled water with different chemicals, combination of 2% silane and 6% NaOH, and combination of 6% NaOH and 2% silane (NaOH-silane) for 3h. After treatments, the fibres were thoroughly washed with running water several times until pH values were neutralized. Then, the fibres were dried in oven at 80 ˚C 48h.

3 Characterizations

3.1 Scanning Electron Microscopy (SEM)

Morphological investigations were performed on the untreated and treated PALF and KF with SEM machine Model (HITACHI S-3400N). SEM instrument was used at an emission current of 58 μA and acceleration voltage of 5.0 kV, and the working distance was set to 6.2 mm. Before the SEM analysis, samples were coated with gold. SEM helps to do microscopic analysis and characterization of fibres on the basis of surface morphology and structural changes.

3.2 Diameter measurement

Diameter test was performed on single fibre at room temperature. Accuracy of diameter measurement in natural fibre is very difficult to achieve because natural fibres are irregular in shape and thickness is not uniform[22]. Natural single fibre bundle consists of large amount of element fibres along with matrix of lignin and hemicelluloses. So, cross section of single fibre bundle is not circular. However, circular cross section was supposed in calculation of tensile properties, though cross section was irregular along to the length of fibre[23]. Untreated and treated single fibre bundle diameters were measured using an image analyser (Fig. 1). Five replicates of each sample were measured at four locations