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Material characterization of blended sisal-kenaf composites with an ABS matrix

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ABSTRACT

Natural fibre-based materials are becoming a valid alternative to traditional synthetic based products for composite reinforcing and sound attenuating treatments. In recent years, natural fibres have been used more frequently in the development of structural components and sound absorbing panels due to their low density, low cost and environmentally-friendly attributes. Based on a literature review of previous studies on natural fibres and their application in the automotive industry, this work investigates the mechanical characterization of various natural fibre composites with an Acrylonitrile Butadiene Styrene matrix (ABS). According to the literature review and the knowledge of the authors, the ratios of fibre and ABS presented have not yet been investigated. The tensile strength, impact strength and air flow resistivity of samples with different densities have been measured, and have been found to vary. In the conclusion some suggestions for the use of these natural fibre composites, for automotive applications, are reported.

1. Introduction

1.1. Purpose of study

The purpose of this work was to develop poroelastic natural fibre composites that have sufficient strength properties, in order to withstand compression from vibration (structural vibration in automotives), and to have airflow resistivity properties comparable to industrial products. The composites developed in this study have not yet been developed according to the literature review and the knowledge of the authors. The ability of a material to attenuate sound energy is highly dependent on the thickness of the material [1]. In order to prevent the thickness of the composite from varying it is important for the material to be stiff. This will prevent the material from compressing under the influence of sound waves and impact loads. Both of these factors are thus necessary for the purpose of sound attenuation in automobiles. Furthermore, this study was also done for the purpose of material characterization required to verify the validity of a developed numerical model used for the prediction of noise levels inside a vehicle passenger cabin. It should also be noted that there is an increase in the need for environmentally-friendly, renewable, recyclable products that are also effective. This is in part due to the European Commission setting goals for industry, e.g. automotive recyclability [2]. Hence, this paper will look at the use of natural fibres for the development of sound absorbing panels that are of a renewable environmentally-friendly nature.

1.2. Literature review

An increased awareness of the environment, growing competition between industries and stringent requirements for lighter more cost-effective products that have limited environmental impact, has developed a renewed interest in natural fibre based products amongst researches and industry [3]. This renewed interest has led to a variety of natural fibres being used, for the development of reinforced natural fibre based composites that are able to meet multi-functional requirements. These materials also generally require less energy in their production than conventional materials [4]. It is interesting to note that the production of one metric ton of jute products only requires 7% of the energy required for the production of one metric ton of polypropylene (PP). Where jute absorbs carbon dioxide (CO_2) from the atmosphere, the production of one metric ton of PP generates 3.7 metric tons of CO_2 [5]. According to Pickering, natural fibres can contribute to a cost reduction of 20% and a weight reduction of 30% in the production of automotive products. This has resulted in the push by automo-

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tive industries to incorporate natural fibres into their product line [6]. A composite can be defined as a combination of two or more materials in which the one is the reinforcing phase e.g. (fibres) and the other is the matrix phase e.g. (polymer). The natural fibre composite reinforcing phase can be made from natural fibres, such as plant, animal or mineral fibres [7]. The matrix phase can be made from materials, such as polymers, metals or ceramics. The combination of a fibrous material with a matrix can produce a porous material if desired. Porous materials are widely used as sound absorbing materials in vibration and noise control [8]. In a porous fibrous material viscous effects due to internal friction between the fibre wall and airflow and thermal losses due to heat transfer are the mechanisms that cause sound absorption [9]. Much work has been done on the development of sound absorbing composites using plant fibres with a polymer matrix. The automotive industry is one of the largest consumers of natural fibres due to their light weight and good sound absorption properties. Therefore, natural fibres, such as coir, hemp, jute and sisal are being used in the manufacturing of many interior and exterior parts, such as door panels, bolsters, pillars, seat back panels, instrument panels and seat upholsteries [2]. Sakthivei et al. manufactured natural fibre reinforced composites using coir, banana and sisal as the reinforcing and epoxy resin as the matrix. It was shown that natural fibre composites, using banana fibre for the reinforcing, could be used for automotive seat shells [10]. Neher et al. investigated the reinforcing of acrylonitrile butadiene styrene (ABS) with palm fibre. The palm fibre reinforced composite showed highest tensile and flexural properties at 10%, by weight, fibre content [11]. George et al. studied the effect different volume fractions, of jute, hemp and flax natural fibre-nonwoven-mats with an epoxy matrix, had on the mechanical properties of the composite. It was found that impact strength of flax and hemp composites increases with an increase of fibre volume fraction [12]. Kamath et al. showed that by suitably combining cotton, flax and kenaf with appropriate biodegradable binder fibre, such as polylactic acid (PLA) and bio-polyethylene terephthalate (Bio-Pet) in the right combination, a mouldable fabric that is suitable for automotive applications can be produced [13]. Parikh et al. showed that it is possible to manufacture cellulosic-based nonwovens, with weight and thickness comparable with normal practice, that have sound absorbing properties suitable for use as noise reducing components in automotives [14]. Mohd et al. developed sound attenuating composites using coir as the reinforcing fibre and latex as the matrix binder [15]. Koizumi et al. developed a reinforced bamboo fibre composite which had acoustic properties equivalent to those of glass wool [16]. Latif et al. investigated the potential, oil palm mesocarp fibre with a polyurethane matrix, had in terms of being a useful sound absorbing material. It was shown that this natural fibre has the potential to be a sound absorbing material [17]. Sambu et al. investigated the sound absorption of kenaf fibre with a natural rubber (latex) matrix. The results showed that the kenaf-latex composite performs well as a light and environmentally-friendly sound absorbing material [18]. Othmani et al. presents a study on sugarcane waste with a resin matrix. The investigated material proved to be an efficient sound absorber with a high sound absorption coefficient reaching one in some frequency rages [19]. Berardi et al. studied the sound absorption performance of a number of natural fibres such as, kenaf, hemp, coconut, straw and sheep wool. Measurements carried out on these fibres showed that these materials have good sound absorption coefficients, especially at medium and high frequencies [20]. As can be seen natural fibres have great potential to serve as efficient and effective sound absorbers. This is due to their lightweight, low cost, nontoxic and nonabrasive qualities, thus offering a more environmentally-friendly and recyclable alternative to synthetic based sound absorbers [21]. The only negative aspect of passive noise control is that it is effective in the high frequency range, but tends to be ineffective at low frequencies [22]. This leads to increasing the absorber thickness out of necessity in order to get reasonable sound absorption.

1.3. Structural loading

Acoustic energy attenuating materials placed in interior passenger compartments of vehicles as internal trims, such as carpet backing, door panels and headliners may bear structural loads as well as be subjected to vibration [23]. These natural fibre composites are to serve as an environmentally-friendly alternative to synthetic based products in the automotive industry. However, commonly used sound absorbing materials in the automotive industry include, polyurethane foams, cotton shoddy and ethylene-vinyl acetate (EVA) moulded with foam [24]. Sound absorbing materials, placed in interior passenger compartments of vehicles do not experience severe mechanical loading, because they are not major load bearing structural supports. They do however bear periodic loads. The loading experienced by these materials, are those induced by passages, their self-mass and impact loading when a door is shut or when the vehicle hits a bump. According to Stanciu et al. the shock caused by slamming the door is seen to be the main cause that influences the life of door panels [25]. Thus, the mechanical properties of commonly used synthetic sound absorbing materials, currently implemented in the automotive industry, will be used as the benchmark, in which the materials developed in this study will be measured against. Since there is a need for new innovative light-weight materials that have the ability to attenuate sound energy within the passenger cabin of vehicles. The natural fibres chosen, to develop poroelastic natural fibre composites, in this work have proven to be potential replacements for synthetic fibres in the automotive industry, hence the reason for selection [14,26]. Although these natural fibres have the potential to replace synthetic products, their mechanical properties suffer from high moisture absorption, thus the need for development and optimization of new innovative composites. Furthermore, natural fibres have limited fungal and parasite resistance and limited fire resistance comparable to synthetic fibres [4]. Therefore, binders such as ABS matrix provides a protective layer which helps protect the natural fibres form environmental degradation, hence making these fibres more appealing to industry.

2. Natural fibre preparation and manufacturing

2.1. Natural fibres used

Based on the literature review the natural fibres selected for this study are the kenaf and sisal fibres. Kenaf, which is from the *Hibiscus cannabinus* family, was selected due to its low cost, low density, good toughness, recyclability, good sound absorption performance, acceptable strength properties and biodegradability [27,28]. Furthermore, kenaf fibre was selected because it has already been utilized in the automotive industry, and thus does not have to prove itself as a reliable product [29]. Sisal, which is from the Agavaceae family, is mostly used for the manufacturing of carpets and rope [30]. Sisal fibre was selected due to its good sound absorption performance, low cost, biodegradability and recyclability [2,28,31].

2.2. Fibre preparation

In preparation for the natural fibre composites, raw untreated kenaf and sisal natural fibres were weighed for accuracy using a calibrated digital scale as seen in (Fig. 1). In order to give reasonable composite density the mass of natural fibres used for each