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Review Article

Some Insights on Current Research Trends in Bamboo Fibres

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Abstract

The article explores the potential of bamboo fibres. Some of the important properties of bamboo fibres have been studied and compared with other fibres. The effect of lateral crushing on the tensile properties of bamboo, modal and Tencel fibres has been investigated. Bamboo cellulose fibres have been coated with polypyrrole and the coated fibres are then characterized for various properties. The changes in surface morphology and particle distribution are studied by scanning and transmission electron microscopy which indicate the formation of Nano-coating of polypyrrole over the fibre surface, as the average diameter of the particles forming the surface layer is found 50nm. a hybrid composite of bamboo/Kevlar K29 with epoxy matrix has been developed with different staking sequences. The variation in mechanical properties, such as tensile, compressive and flexural of composite due to variation in staking sequence is analyzed and presented.

Keywords: Bamboo fibre; Crushing force; Dielectric properties; Nano coating; Kevlar; Stacking sequence

Introduction

Textile fibres may be considered elastic when subjected to very small strain, but when the strains become large, viscoelastic and permanent deformations occur [1]. Under the influence of tensile stresses, fibres may be damaged or broken by mechanical forces that are transverse to the fibre axis. The effect of lateral crushing on the tensile properties of various textile fibres has been investigated [2]. This was the only concentrated research on lateral crushing and the loss in tensile strength was observed due to lateral crushing. The data on wool, silk, viscose and acrylic fibres after crushing were provided. Cellulose, considered as the most abundant organic compound derived from biomass, is mostly found as a natural fibrous material, but use of synthetic cellulose is also increased because of its diverse applications. Natural cellulose with hierarchical self-assembly of polymer chains exhibits physical and chemical properties which are not seen in synthetic fibres, but it was possible to control these properties in synthetic fibres by means of surface coating of polymers [3,4]. Owing to the high price, depletion of natural reservoir and threat to the environment, the researchers, in the past few years, are forced to develop environment friendly, bio-degradable and recyclable material for using as reinforcement in polymer composite materials [5-9]. Natural fibres like bamboo, jute, sisal, coir, etc. possess unique properties, which make them feasible for application in polymer composites.

Influence of lateral crushing force on tensile properties

With the advent of new types of fibres, it is imperative that the effects of lateral crushing on the properties of these fibres are studied. The notable omissions by researchers are bamboo, Tencel and modal. Hence, a study on the loss in tensile strength due to lateral crushing of these fibres is needed. The present study has addressed all these issues. In this study, to apply the crushing force, the fibre crushing apparatus has been used. With this apparatus, the influence of transverse compression on the axial mechanical properties of bamboo, Tencel and modal fibres has been studied [10]. The first reported studies on the lateral crushing of fibres which are very relevant to the area of carpet wear.

Subsequently, the presented data on the effect of crushing them for some more fibres have been omitted initially [11]. The work was more concerned with the wear of carpets which are subjected to crushing during their regular use. They have provided useful data on the loss in tensile strength of fibres such as wool, viscose and acrylic due to lateral crushing. Another researcher went a step further and demonstrated how the data on crushing force of acrylic fibres could be used for explaining spinning behavior fibre rupture by opening rollers in rotor spinning and yarn properties [12]. It was further shown that crushing test could also predict the trend of work of rupture during processing and could rationalize the application of fibres. Although the application of crushing force has been carried out on acrylic fibres because of their use in carpets, the other areas where it can be fruitfully used have not been explored. The tensile behavior of laterally crushed filaments has been predicted using finite element method and highlighted the importance of this process with respect to fishing net applications [13].

The uniqueness of the study is the fact that for bamboo, modal and Tencel fibres, data are provided for the first time. The effect of lateral crushing on the tensile property of some recent fibres such as Tencel, modal and bamboo has been investigated to provide some new data. It is found that modal fibre sustains a higher loss in tensile properties in comparison with bamboo and Tencel [14]. The percentage loss of strength and breaking extension varies from one fibre to another, depending on fibre type and morphology. This information could be used while spinning the yarns from these fibres on ring and rotor spinning, and also to know the potential of these fibres. It will also enable the manufacturers to consider redesigning of the various parts.

Studies on morphology, structure and electrical properties

Cellulose was reported to have a strong affinity for certain conducting polymers (CPs) like polypyrrole (PPy) and polyaniline (PAni) [15]. Recent advances in surface coating of individual cellulose fibres with metal oxide gel layers is a step towards fabricating smart materials for producing conductive textiles, but surface layer of organic polymer makes the natural fibres more user friendly than a metal oxide layer [16]. However, chemical and electrochemical coating of CPs over the cellulose fibre was a challenging task for a long time because of the difficulties in controlling the surface agglomeration as the CP particles are prone to deposit in irregular form over the polymer chain and hinder its uniform layer formation on the fibre surface. As a result, the fine structure of the fibrous cellulosic material was disrupted due to the inhomogeneous deposits of CP material. The problem could be minimized by nanocoating of a surface layer on the cellulose surface. The first successful experiment on Nano-coating of polypyrene on natural cellulose was reported [17]. They reported a polymerization induced adsorption process for producing an ultrathin film of insoluble polymer over a substrate of cellulose fibres in commercial filter papers. In this study, a similar surface layer of PPy has been deposited over the bamboo fibres by means of polymerization induced adsorption, without disrupting its hierarchical cellulosic structure.

Deposition of the PPy on the bamboo fibre surface was confirmed from the microscopic as well as spectroscopic observations. The nature and size of the particles incorporated over the fibre surface were investigated by scanning electron microscope (SEM) and transmission electron microscope (TEM) which indicated modifications in the surface morphology of the fibres. Fourier transform infra-red (FTIR) spectroscopy is used for determining any structural change in the bamboo fibre after incorporation of PPy. It was found that the PPy coating rendered certain drastic changes in the electrical properties of the fibres which were studied by current voltage characterization and impedance analysis in the low frequency range.

It was found that the PPy coating on the fibular structure of bamboo cellulose resulted in a PPy-cellulose bi-hybrid composite. The material produced as such can be used in conductive textiles6 due to its considerable DC conductivity and dielectric relaxation, resulting in increased AC conductivity over a useful range of operating frequency.

Oxidative polymerization of pyrrole leading to formation of a thin uniform coating of PPy over the cellulose fibre extracted from bamboo has been achieved by a process of polymerization induced adsorption [18]. On incorporation of the coating layer, composition of bamboo cellulose remains preserved, but its surface morphology and electrical conductivity are found to change drastically. Some interesting changes in these properties are observed while keeping it chemically intact. The electrical resistance decreases with increasing layer concentration while the dielectric properties exhibit strong low frequency dispersion as shown by standard conducting polymers like PPy, PAni, etc. Thus, the bamboo fibre which has characteristic Ohmic resistance like other cellulose has exhibited a changeover to CP like dielectric behavior and a remarkable AC conductance in the low frequency range, enlarging the prospect of its use as a semiconductor material in electronic industries. The main feature of this study lies in the simplicity of the technique which is successfully used for making the PPy monolayer without using any dopant and without disturbing the chemical structure of cellulose in the fibre substrate. Hence, the properties of PPy can be blended in the bamboo fibre for its potential use as conducting textile, as well as a semiconductor material in the low frequency range of AC operating voltage.

Influence of Tacing Equence on Mechanical Strength

Nowadays these are considered as one of the new classes of engineering materials due to its wide range of application domains. The interest in this type of composite materials is rapidly growing both in terms of their industrial applications and fundamental research [19]. Among natural fibres, bamboo fibre, which is extracted from bamboo plant, is one of the most favourite constituents for using as reinforcement in FRP composites. In Asia and South America, it is found in large quantities. Chemically, it consists of cellulose (73.83%), hemi-cellulose (12.49%), lignin (10.15%), aqueous extract (3.16%) and pectin (0.37%) [20,21]. Due to its high cellulose content and lower micro-fibrillar angle, it possesses very good mechanical properties9. It is quite flexible in its applications in composite industries due to its structural variation, better mechanical and thermal properties, and highly versatile nature of its extraction processes [22-24]. Compared to other synthetic fibre composites, the natural composites acquire lower modulus, lower strength and relatively poor moisture resistance properties. Therefore, in a view to improve its properties and develop superior but economical composites, these are hybridized with synthetic fibres to achieve the best properties of both [25-27]. The additions of glass fibre to pineapple leaf fibre and sisal fibre reinforced polyester have improved the mechanical properties of the composite [28]. The hybridization of bamboo fibre reinforced composites with glass fibre brought changes to their thermal as well as mechanical properties and improves its resistance to the chemicals [29-32].

Further, the interplay hybridization of two different fibre laminates helps in preventing the catastrophic failure of composite

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material due to failure of fibre with lower elongation properties. Mismatch of Poisson's ratio and coefficient of mutual influence between adjacent layers, cause high inter-laminar normal and shear stresses at the free edges of the laminates. This inter-laminar normal stress can be changed from tensile to compressive by changing the ply staking sequence, so that opening mode delamination can be suppressed, thereby improving its mechanical properties [33]. In a study, the effect of stacking sequence on tensile, flexural and interlaminar shear properties of untreated woven jute and glass fabric reinforced polyester hybrid composites has been presented [34]. It was found that the composite with glass plies at extreme ends exhibited superior properties. In another work, the effect of staking sequence on woven coir/glass hybrid laminated composite was investigated experimentally [35] of all the synthetic fibres, the aramid fibre known as Kevlar fibre acquire unique properties.

It exhibits higher stiffness, lower fibre elongation, superior tensile strength and modulus in comparison to other synthetic fibres [36-43]. Different varieties of Kevlar with different grades are available. Of these, K29 and K49 are most commonly used. For this work, K29 is selected because of its cost effectiveness, enhanced properties 32 and wide range of industrial and ballistic applications [44-47]. It also exhibits very good high temperature properties for a polymeric material. There has been very little work reported in the characterization of bamboo and Kevlar hybrid polymer composite material. Among the polymeric material, epoxy (thermoset) possesses very good mechanical properties with low cure shrinkage. It consists of an epoxide group (one oxygen and two carbon atoms). It is cured by introducing cross linkage between the epoxide and hydroxyl groups of adjacent chains. This crosslink is achieved by reacting with an organic amino or acid compound [48]. Since, triethylenetetramine (TETA) consists of considerably high amount of amine groups, it is selected as a curing agent for epoxy in this work. About 10-15% by weight of amines or acid anhydrides is mainly used for proper curing of epoxy resin36. In this work, an attempt has been made to hybridize bamboo fibre with Kevlar K29 woven fibre in epoxy matrix composite and the effect of stacking sequence of composite laminates on mechanical properties like tensile, compressive and flexural strength of the composite is analyzed and presented.

In this study, an attempt has been made to experimentally investigate the effect of staking sequence on tensile, compressive and flexural properties of bamboo/Kevlar K29 inter-ply hybrid laminated composite material [49]. The following conclusions are drawn from the test results: Under tensile and compressive load, the sandwich composite with Kevlar layer at both the ends exhibits superior properties. This is attributed to higher inter laminar strength and load transfer capacity of bamboo fibre. On the other hand, the composite with both the bamboo layers on the upper side displays better flexural strength.

Conclusion

The influence of transverse compression on the axial mechanical properties on bamboo, modal and Tencel fibres has been analyzed. The study reveals that modal fibre sustained a higher loss in tensile properties compared to bamboo and Tencel. The general phenomenon obtained from the study is that the percentage loss of strength and breaking extension varies from one fibre to another based on the fibre type and morphology. Fourier transform infrared spectroscopy on bamboo cellulose fibres have been coated with polypyrene reveals that the chemical structure of the natural fibres remains unchanged even after the Nano coating, though the individual characteristics of pyrrole appears therein. Electrical resistance of the coated fibres as measured by two probe method shows decreasing trend with increasing pyrrole concentration. The value ranges from 1075 KΩcm-1 to 0.159 KΩcm-1 from 0.1% to 5% pyrrole. Further, it shows Ohmic nature for both the coated and uncoated fibres.

Dielectric behavior of the current-voltage (I-V) plots of the coated fibres exhibits highly dispersive dielectric loss and similar behavior in its AC conductance, at low frequency range up to 7kHz; beyond which its conductance is stabilized. Studies on the variation in mechanical properties, such as tensile, compressive and flexural of hybrid composite of bamboo/Kevlar K29 with epoxy matrix composite due to variation in staking sequence is analyzed and presented. From the analysis, it is observed that the sandwich composite with Kevlar laminates at both the ends exhibits better tensile and compressive properties and on the other hand, the composite with both the bamboo layers on the upper side displays better flexural properties.

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