

Bamboo Fibre Extraction and Its Reinforced Polymer Composite Material

P. Zakikhani, R. Zahari, M. T. H. Sultan, D. L. Majid

Abstract—Natural plant fibres reinforced polymeric composite materials have been used in many fields of our lives to save the environment. Especially, bamboo fibres due to its environmental sustainability, mechanical properties, and recyclability have been utilized as reinforced polymer matrix composite in construction industries. In this review study bamboo structure and three different methods such as mechanical, chemical and combination of mechanical and chemical to extract fibres from bamboo are summarized. Each extraction method has been done base on the application of bamboo. In addition Bamboo fibre is compared with glass fibre from various aspects and in some parts it has advantages over the glass fibre.

Keywords—Bamboo fibres, natural fibres, mechanical extraction, glass fibres.

I. INTRODUCTION

POLYMER composite materials have been widely used in various industries such as aircraft, automotive and submarine due to their great mechanical and thermal properties. However, the end of life disposal of polymer and synthetic materials is unknown and non-biodegradable. Therefore, the utilization and the manufacturing procedure of these materials will harm the nature. In contrast, natural fibres are renewable and environmentally friendly materials; they have low density, low price, and acceptable mechanical properties. Hence, many scientists are interested in replacing them with synthetic materials to conserve the environment. Natural fibres base on their sources are divided into three categories: plant fibres (sisal, hemp, flax, bamboo, etc.), animals parts involving protein (silk, hair, wool, etc.) and minerals [1]. The main parts of Plant fibres are cellulose, hemicellulose, lignin, and pectin.

In the structure of plant fibres lignin and hemicellulose matrix held cellulose fibrils together [2]. By increasing the amount of cellulose the mechanical properties of fibres increase [1]. Cellulose fibre has been applied as reinforced polymer composite in building, bridge construction and automotive.

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Although researchers have attempted to utilize natural fibres in aerospace industry in the recent years, they have faced a great challenge to overcome the fire resistance during working with natural fibres [3].

The first natural fibre composite which was used as one part of airplane component to reduce the weight was between 1920s and 1930s [4]. Some studies revealed that natural plant fibres are environmentally better than glass fibres; hence the cellulosic fibre-reinforced composite is able to be replaced with glass fibre [5], [6].

Bamboo in comparison with other natural fibres is eco-friendly with high growth rate and fixing the carbon dioxide of atmosphere, which makes it the most important plant fibres. It is found that more than 1000 species of bamboo and around 70 genera grow naturally in diverse climates, especially in Asia and South America abundantly [7], [8]. Bamboo has several advantages such as light weight, high strength, stiffness, biodegradability, and even its roots and leaves keep the soil together and protect it against the sun respectively [9]. These properties are caused that bamboo to be used traditionally for manufacturing of living tools. Beside the massive utilization of bamboo in building construction and living tools, it also can be used as reinforced composite materials base on extracting appropriate fibres in a controlled manner [10]. However, there are some problems that provide barriers to a broad usage of bamboo fibres. These are as follow:

- Moisture resistance of bamboo is low and its mechanical and chemical properties are inadequate at the fundamental stage.
- The existing extraction process of the fibres from bamboo culm is not appropriate for industrial and commercial production.

The main purpose of this study is to gain a better understanding of a bamboo culm's advantages as a natural plant fibre and its benefits over glass fibre. There is also a brief overview of different extraction procedures that have been utilized to extract fibres from bamboo.

II. THE ANATOMICAL STRUCTURE OF BAMBOO

A. Bamboo Structure

Bamboo culms are hollow, and every culm from inner side is divided by several diaphragms which are seen as rings on the outside. The part between two rings is called "Internode" where branches grow [9]. Distance between each node varies and it depends on the type of the species.

The microstructure of a bamboo culm consists of many vascular bundles which are embedded in parenchyma tissue

and distributed through the wall thickness. Parenchyma tissue only keeps the vascular bundles in the longitudinal direction. The number of vascular bundles is highly concentrated close to the outside of the bamboo culm wall, and this amount reduced on the inside. They involve vessels, sclerenchyma cells, fibre strand and sieve tubes with companion cells [11]. The fibre strand consists of many elementary fibres with the

shape of hexagonal and pentagonal, where Nano-fibrils are aligned and bounded together with lignin and hemicellulose. The strength of a bamboo culm is defined by its vascular bundles. Therefore it is essential to use a suitable method to separate the parenchyma tissue from fibre strands and vascular bundles without any destructive effect on the extracted fibres. The structure of a bamboo culm is shown in Fig. 1.

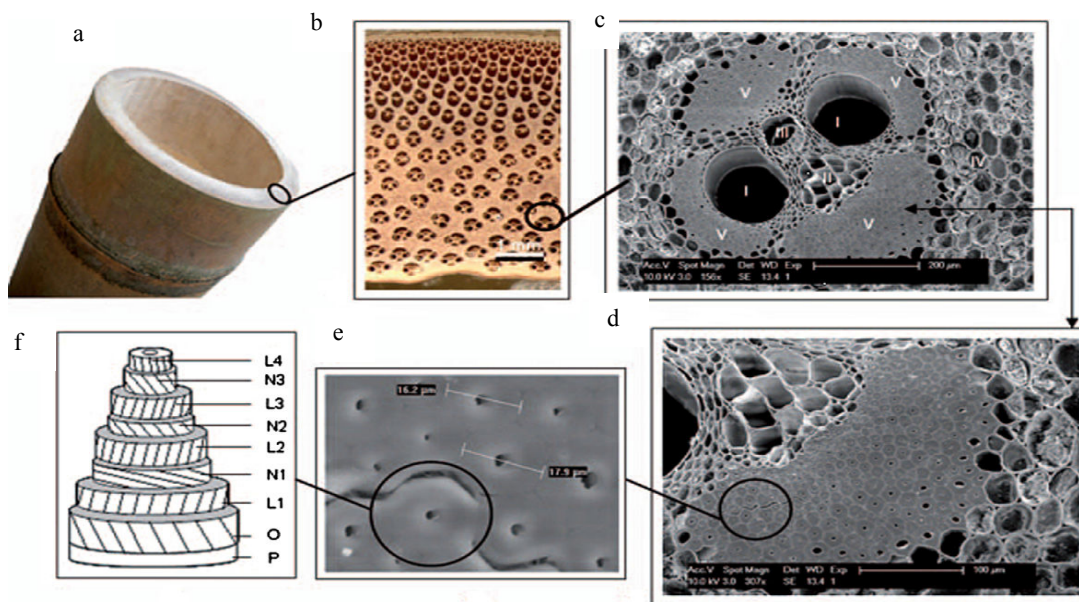


Fig. 1 a) bamboo culm, b) cross-section of bamboo culm, c) vascular bundle, d) fibre strand, e) elementary fibres f) model of polylamellae structure of bamboo [12]

B. Extraction of Bamboo Fibre

There is a limited knowledge regarding bamboo fibre extraction, only a few investigations have been done with different processes to define the mechanical properties and the usage of bamboo fibre as reinforced polymer composite. In more scientific studies in order to extract fibres from bamboo culm firstly, the diaphragm and node has been removed, and then the hollow portions have been used for processing. Subsequently, various methods have been used to extract bamboo fibres based on their application in the industries. These processes are classified as chemical, mechanical and combination of mechanical and chemical [13], [14]. The usual methods to extract fibre are follows:

1. Chemical Extraction

In chemical procedure alkali or acid retting and Chemical Assisted Natural (CAN) are used to remove the amorphous regions and reduce the lignin content of the elementary fibres [15]. In addition this treatment has effects on other components of bamboo microstructure such as pectin, and hemicellulose. In chemical procedure after removing the bamboo nodes the internodes are sliced into the defined dimensions. Bamboo strips with the size of chips was soaked in 4% mass over volume of NaOH for 2 hours to influence on cellulosic and non-cellulosic parts. This method was repeated

several time under a certain pressure for extracting fibre in the form of pulp [16]. The problem of this technique was that some macro meter size of fibre bundles were formed during extraction. On the other hand Abhijit et al. [17] soaked bamboo strips with the small size in 1N sodium hydroxide for 72 hours to facilitate fibre extraction. Jianxin et al. [18] extracted fibre by using different percentage of sodium sulphite, sodium silicate and sodium polyphosphate solution. Bamboo chips were dried for 30min at 150°C and dipped in water at 60°C for 24 hours and then dried in air. Later, the fibres were washed with hot water and then treated with xylanase. After, cooking and bleaching bamboo fibres, they were treated in sulphuric acid solution. The size of obtained fibre was 2.5mm. In order to produce a long fibre some cell parts of the plant such as pectin and lignin were needed to be connected.

2. Mechanical Extraction

This method involves different mechanical procedures such as steam explosion or heat steaming, high pressure refinery, crushing and super grinding [13], [19]. All these mechanical methods have some advantages and disadvantages. For instant: in heat steaming method the natural strength of the bamboo fibres reduce. The steam explosion procedure can remove lignin from the woody materials of a plant. Shunliu et al. [20] used steam explosion to extract fibre from bamboo. In

this method the bamboo chips were exploded under 2 MPa pressure and 210°C temperatures for 5 minutes. The lignin is discharged from the cell wall and covered the surface of the fibre. Kazuya et al. [21] used the same method but they were not able to remove lignin completely from the fibres. Rao and Rao [22] compared both mechanical and chemical methods. The method that was used in chemical procedure was degumming and in mechanical the fibres were extracted with retting process. They found that chemical procedure to extract fibre in spite of being expensive, reducing the tensile strength and modulus; it could increase the strain in comparison with mechanical methods. Moreover mechanical process is more eco-friendly. Osorio et al. [12] extracted fibre with a pure novel mechanical procedure. In this process they could extract long and fine fibre and the mechanical properties of treated fibres with various concentration of alkali and untreated fibres were compared. In untreated fibre the longitudinal flexural strength was the highest.

3. Combination of Mechanical and Chemical Extraction

Commonly this procedure is used for pulping, in paper and pulp industries. There are two techniques such as compression moulding and roller mill technique which are usually used after chemical treatment. In this method firstly the bamboo strips are treated by alkali in both techniques. Then the treated bamboo strips based on compression moulding technique were pressurised between two plates with 10 tons loads. Starting bed thickness and time are two parameters were affected on the quality of the fibres. In the second technique the alkali treated strips were rolled by force between two rollers. The combination of these two methods separated fibres easily [17].

III. POLYMERIC MATERIALS REINFORCED FIBRES

Usually, in the process of embedding bamboo fibres in resin, the bamboo strips are moulded and pressed under the certain pressure. Kushwaha and Kumar [23] used bamboo strips mat to reinforced epoxy and unsaturated polyester materials. The prepared composites were cured in oven at 80°C for 4 and a half hour. As compared the treated to untreated bamboo fibre composite, the elastic modulus of treated bamboo fibre composite increased. To improve the mechanical properties of fibre reinforced thermosetting resin, cyanoethylation technique was used. In this method cellulosic fibres can be chemically modified. Phenolic resin has been used widely in wood industry to make composite. Yang et al. [24] adjusted phenolic resin to bamboo fibre bundles at room temperature. The glued specimen were pressed with a cold press machine in a mould under 82 MPa pressure and then cured in an oven. In contrast with raw bamboo fibre and other bamboo based composites, both tensile and compression strength of bamboo fibre composite were increased.

The specific properties of long bamboo fibres such as low density and specific strength and stiffness can be compared with glass fibre [12], [25], [24]. The created products based on bamboo have been used in many applications such as transport, furniture, packing and other fields [8]. Recently, the utilization of bamboo fibres as reinforced polymer composite

material has been increased by advanced processing technology. Table I displays the advantages of bamboo fibres over glass fibre which is one of the most common polymer materials.

TABLE I
COMPARISON OF BAMBOO AND GLASS FIBRE [13], [23], [26]

	Bamboo	Glass
Density	Low	Higher than bamboo fibre
Cost	Low	Higher than bamboo fibre
Disposal	Biodegradable	Non-biodegradable
CO ₂ Absorption	Yes	No
Recyclability	Yes	No
Renewability	Yes	No
Energy for extraction	Low	High

IV. CONCLUSION

Bamboo fibre has several advantages over other plant natural fibres such as high growth rate, strength, and fixing the carbon dioxide. It also can be compared with glass fibre because of its light weight, biodegradability, and low cost. Therefore, there is a great interest in using bamboo fibre as a reinforced composite material in different applications. Several methods and adhesions have been used to improve the mechanical properties of bamboo fibres as reinforced composite. This can help to comprehend that bamboo fibre and bamboo fibre reinforced composite have ability to be used in more applications.

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