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Review

An overview on bamboo culm flattening

Chang-Hua Fang, Ze-Hui Jiang, Zheng-Jun Sun, Huan-Rong Liu, Xiu-Biao Zhang, Rong Zhang, Ben-Hua Fei *

SFA and Beijing Co-built Key Laboratory of Bamboo and Rattan Science & Technology, State Forestry Administration (SFA), Department of Biomaterials, International Centre for Bamboo and Rattan, 8 Futong Eastern Street, Chaoyang District, 100102 Beijing, China

HIGHLIGHTS

- Flattening technologies offer a novel way to better use bamboo resource.
- The main difficulties for bamboo culm flattening are explained.
- The possible solutions for overcoming the difficulties are analyzed.
- Some examples of bamboo culm flattening process are introduced.

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ABSTRACT

Bamboo is an abundant, sustainable resource in the tropics and subtropics. Owing to faster growth, shorter rotation and higher mechanical strength compared with other species, bamboo, as a supplement to timber, has gained increasing attention for its economic and environmental values over the last three decades. Due to the hollow cylindrical shape of bamboo culms, it is not possible to get large flat surface board directly by sawing or cutting. Research and many novel technologies on bamboo culm flattening have been reported and attempted during the last decades. This paper synthesizes the knowledge and gives an overview on bamboo culm flattening in an effort to inspire researchers and entrepreneurs to further improve and spread the technologies for better using this abundant biomass resource.

Contents

* Corresponding author.
E-mail address: feibenhua@icbr.ac.cn (B.-H. Fei).

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1. Introduction

1.1. Bamboo resources as timber supplement

In substitution for energy-intensive materials such as iron and concrete, woody biomass, as low energy-demanding materials, may contribute to reducing greenhouse gas emissions. Harvested wood products can also play a role in carbon storage by providing greenhouse gas sequestration benefits. However, as human populations continue to grow and demand for food and land increases, the world's forest resources continue to dwindle. In 1990 the world had 4128 million ha of forest; by 2015 this area has decreased to 3999 million ha. This is a change from 31.6 percent of global land area in 1990 to 30.6 percent in 2015 [1]. Larger forest areas are being designated for conservation all around the world [1]. Searching for alternative sources to wood material helps relieve the pressure of logging from existing natural forests to meet the growing global demand of wood products. Owing to faster growth, shorter rotation and higher mechanical strength compared with other species [2–4], bamboo has great potential to supplement timber [5].

Bamboo is the fastest-growing and most versatile plant on earth [6], distributed in the tropics and subtropics. Bamboo is an abundant, sustainable resource. Accounting for around 1% of the world's total forest area [7], globally, there is a total area of 31.5 million hectares of bamboo [8], 60% of which concentrated in the rapidly developing countries of China, India and Brazil [8]. Bamboo belongs to the subfamily Bambusoideae of the grass family Poaceae (or Graminaceae) [6,9]. There are about 75 genera with approximately 1300 species and varieties[6]. Within a few months, bamboo can reach a height of 3–30 m with a diameter up to 30 cm and is ready for harvest in 3–4 years [6,10].

There are over 1500 documented uses for bamboo [11], and more are being discovered by modern science and technology, including housing, crafts, pulp, paper, panels, boards, veneer, flooring, roofing, fabrics, oil, gas, charcoal and food [7].

1.2. Engineered bamboo products

Engineered bamboo products have received increasing attention over the last decades. Though a substitute for wood materials, due to its different structure, bamboo cannot be processed same as wood. A bamboo culm consists of nodes and internodes. Internodes are generally hollow and cylindrical. The internodes have a culm wall surrounding a large cavity, called lacuna. In the internodes, the cells are strongly axially oriented [12]. Culm wall is mainly composed of parenchymatous ground tissue in which vascular bundles are embedded [12,13]. The vascular bundles are composed of metaxylem vessels and sheaths of sclerenchyma fibers which appear dark in contrast to the surrounding light parenchymatous ground tissue [14,15].

Due to the hollow cylindrical shape of bamboo culm, it is not possible to get large flat surface boards directly by sawing or cutting. However, some other kinds of engineered bamboo boards have been developed during the last decades, including laminated bamboo board, bamboo scrimber, bamboo rotary cutting veneer, ply bamboo, oriented strand board, particleboard, fiberboard, bamboo plastic composites, etc. [6,16–22].

To produce laminated bamboo boards, bamboo culms must be split into strips. Due to the arc shape, strips have to be planed on four sides to be uniform and rectangular. After the application of resin, uniform and rectangular strips are assembled and glued together with press to get laminated bamboo boards of various forms and dimensions. In order to get uniform and rectangular strips from split arc-shaped bamboo slivers, a large part (more than 60%) is removed during four-side planing. The low utilization rate of bamboo biomass is a primary disadvantage of laminated bamboo boards. Furthermore, the outermost culm wall tissue, which has the highest mechanical strength, is removed and wasted during processing.

Bamboo scrimber, a more recent engineered bamboo product, can have a very high utilization rate of bamboo materials. Strips split from bamboo culms are crushed by motor-driven rollers with protrusions to become bamboo bundles. Bundles are then treated to reduce sugar and starch content before immerging in adhesive. Adhesive-impregnated bundles are compressed with hot or room-temperate press, depending on final thickness, to get high-density bamboo scrimbers. One of the drawbacks of bamboo scrimber is its high content (15–30%) of adhesive.

Bamboo culms can also be rotary-cut as wood logs to produce thin veneers [23]. However, due to the small diameter, hollow tube-like shape, and high rigidity, rotary peeling of bamboo culms is much more difficult than that of wood. This approach also imposes stringent requirements on the shape of culm wall. Furthermore, because density and mechanical strength gradually change from outer to inner layer [15], the quality of rotary-cut veneers from the same culm is not uniform and a big difference may affect the final applications.

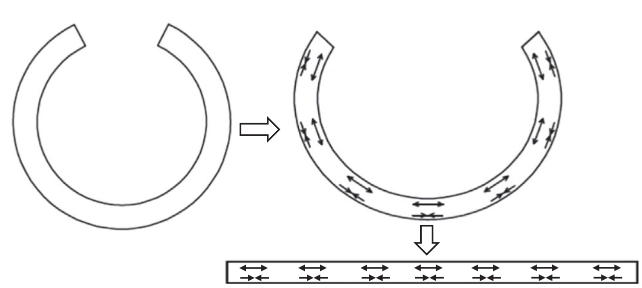

Fig. 1. During opening and flattening of bamboo culm, inner zone is under tension (divergent arrows) and outer zone is under compression (convergent arrows).