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Effect of holding time and the amount of fiber content on the flexural properties of Bagasse /bamboo fiber reinforced biodegradable composite

Rahman Muhammad BOZLUR, Shinichi SIBATA, Siddiqua Farah DIBA and Magali UONO
Department of Mechanical Systems Engineering, University of the Ryukyus, Nishihara, Okinawa, 903-0213, JAPAN. E-mail: rahman_942000@yahoo.com

***Abstract*—This paper describes a method to fabricate short bagasse /bamboo fiber reinforced biodegradable composites and investigated their flexural properties. Bagasse/bamboo fibers were simply randomly mixed with biodegradable resin, and composite specimens were fabricated by a cylindrical steel mould by the press forming. The effects of holding time and fibers content on the flexural properties of bagasse / bamboo fiber composites were investigated. The flexural properties of bagasse / bamboo fiber reinforced biodegradable composites were strongly affected by the holding time and amount of fiber content. During fiber processing on different holding time, it was found that flexural properties increased with the increased the holding time upto 10 min. Above 10 min. flexural properties decreased due to insufficient resin. In processing on fiber content, it was observed that the flexural properties increased with the increase the fiber content upto 50% & above 50% flexural properties decreased due to high fiber weight fraction and poor bonding between fibre and matrix. The flexural modulus for holding time showed maximum of 2384 MPa for bagasse and 2403 MPa for bamboo composites. The cross sectional structure of bagasse fibre was porous and bamboo fiber was solid.**

INTRODUCTION

The disposal methods and recycling processes for glass fiber reinforced plastics are important current subjects because many environmental problems have become visible and degenerate throughout the world. Glass fibers are the most widely used to reinforce plastics due to their low cost (compared to aramid and carbon) and fairly good mechanical properties. However, these fibers have serious disadvantage to carry out suitable disposal processing. Moreover, it is essential to reduce environmental collisions, such as global warming, that are generated by consumption of petroleum, a non-renewable resource. The build-up of synthetic fibres, specially glass fibre significantly decreased and the use of natural fibers increased day by day. Therefore, natural fiber composites such as flax, hemp, bagasse, jute, ramie, bamboo, coir, and sisal are emerging as a viable alternative to glass fiber composites. The main application of natural fibre is textile, building, plastic and automotive industries[1]. The flexural properties of natural fiber composites affected by many factors such as variety, moisture content, climate, harvest, maturity, retting degree, decortications, disintegration (mechanical, steam explosion treatment), fiber modification, and technical processes.

In recent years, studies about the utilization of lignocellulosic materials as reinforcement in polymeric composites are increasing due to the improvements that natural fibers can provide to the product, such as low density and biodegradability, besides the fact that these materials are from renewable and less expensive sources [2]. Natural fibres are strong, light in weight, abundant, non-abrasive, non-hazardous and inexpensive; they can serve as an excellent reinforcing agent for plastics. There were very few researchers to study on the effect of holding time and the amount of fiber content on the flexural properties of bagasse / bamboo biodegradable composites in the world. Hitoshi Takagi and Yohei Ichihara examined both tensile and flexural strengths of bamboo fiber reinforced "green" composites (BFGC) were strongly affected by fiber aspect ratio and fiber content [3]. Shinichi Sibata has investigated the effects of the volume fraction and lengths of natural fibers on flexural properties of biodegradable composites. Kenaf and bagasse were mixed with corn-starch biodegradable resin, and composite flexural specimens were fabricated by press forming. The flexural modulus of the natural fiber composite made from Kenaf and bagasse increased, with an increase in fiber volume fraction up to 60% for Kenaf, and up to 66% for bagasse [4].

EXPERIMENTAL AND METHOD

Materials and flexural test:

Bagasse fibers were collected after they were crushed for extracting juice by using a crushing machine. These fibers were then spread on a water proof sheet to reduce the moisture content. After approximately two weeks, the long bagasse fibers were shortened into a length of 10mm, breadth of 1mm and width of 1mm with a pair of scissors. Small size fibers were selected in order to design a composite with consistent properties. Due to the low moisture content of the bagasse samples, no fungi grew during the storage. The bagasse samples were then cleaned via pressurized water for about one hour. This procedure removes fine bagasse particles, sugar residues and organic materials from the samples. Then the fibers were dried at room temperature.

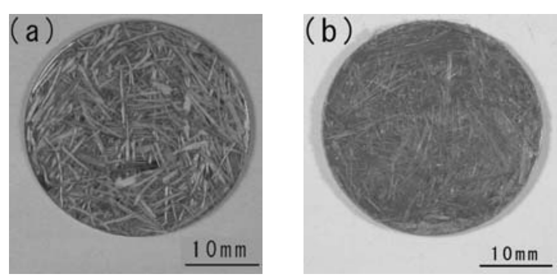

Fig. 1: Press forming with the cylindrical mould, (a) Before moulding, (b) After moulding.

The composite specimen was fabricated by two hot press forming methods. Fig.1 shows the fabrication process of bagasse / bamboo fiber reinforced composites. At first half of the bagasse / bamboo fibers were put into the cylinder and then put resin and then finally put half of the bagasse / bamboo fibers without any previous mixing. The fibers put into the cylinder randomly. The fiber mixed with resin in the form of rules of mixture. The molded specimens were circular shaped (30 mm diameter and 1.5–2.0 mm thickness) as shown in Fig. 2. An emulsion-type starch–base biodegradable resin, CP-300 was used supplied by Miyoshi Oil & Fat Co. Ltd., Japan (Tg: -60^{0}C, Softening temperature 55-62^{0}C). The resin was chopped into uniform pellets 1-2 mm diameter.

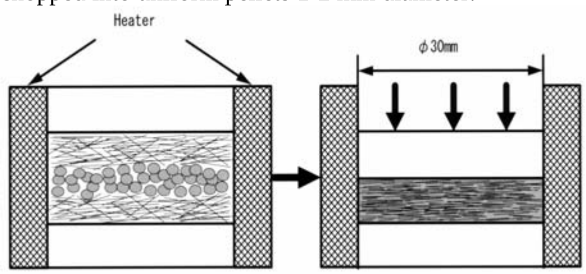

Fig. 2: Appearance of bagasse / bamboo composites after press forming.

Three points flexural test was conducted in accordance to ISO178 specifications at least five specimens. The dimension of specimens and span length were 25x 15 x 1.5 mm. The cross-head speed was 1 mm/min. The flexural modulus was determined by the initial derivative of the load-displacement curve. The derivative part was from 0 to 15 % of maximum load. The flexural strength was calculated by maximum load.

Results And Discussion

Effect of holding time on flexural properties of bagasse / bamboo composites

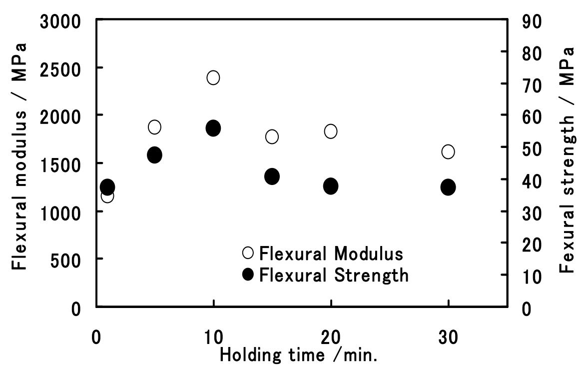

Fig.3. Effect of holding time on the flexural properties of bagasse composites.

Fig.3 and Fig. 4 shows the effect of holding time on flexural properties in the bagasse / bamboo composites at temperature 160^{0}C, pressure 150 Kgf/cm^2. Both the flexural properties increased with increasing the holding time upto 10 min. The flexural modulus showed maximum of 2384 MPa for bagasse and of 2403 MPa for bamboo composites. Above 10 min., the both flexural modulus and flexural strength decreased. Flexural modulus of a short fiber reinforced composite is calculated by the following modified cox's model refer to "(1)",

$$E_{comp} = K \eta_\theta \eta_f V_f \cdot E_f + (1 - V_f) \cdot E_m \quad (1)$$

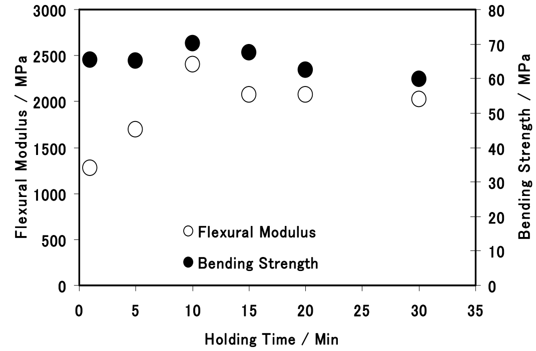

Fig.4. Effect of holding time on the flexural properties of bamboo composites.

Where E_f , Em and V_f denote the Young's modulus of the fiber, the matrix, the volume fraction of the fiber and the matrix, respectively. η_f and η_θ denote efficient factors of fiber length and orientation. Fig.5. and fig.6.shows the effect of holding time on the fiber weight fraction and compression of the bagasse /bamboo composites. The compression ratio, K, is calculated by refer to "(2)"

$$K = V_{f'} / [V - (\frac{W - W_f}{\rho m})] \quad (2)$$

Where $V_{f'}$, V, W, W_f and ρ_m denote volume of the fiber, volume of the composite, weight of the composite, weight of the fibers and density of the matrix, respectively.

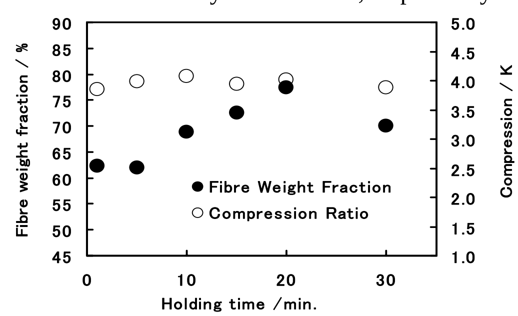

Fig.5. Effect of holding time on the fiber wt. fraction and compression ratio of the bagasse composites.

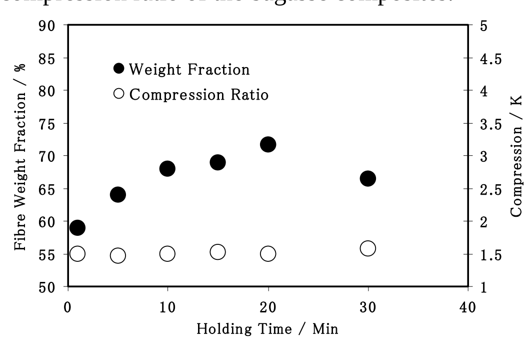

Fig.6. Effect of holding time on the fiber weight fraction and compression ratio of the bamboo composites.

As seen in fig., the fiber volume fraction increased with increase of holding time while compression ratio was rather constant. It was found that at 10 min holding time the good wetting between fiber and resin as shown in fig. but above 10 min holding time poor wetting between fiber and resin. This is why flexural properties decreased. The fiber weight fraction increased which depend on the fiber surface area of the composites. Fig.7 and fig. 8 shows the relationship between holding time and fiber density of bagasse / bamboo composites. It was seen that density of fiber linearly increased with increasing the holding time for bagasse and bamboo composites.

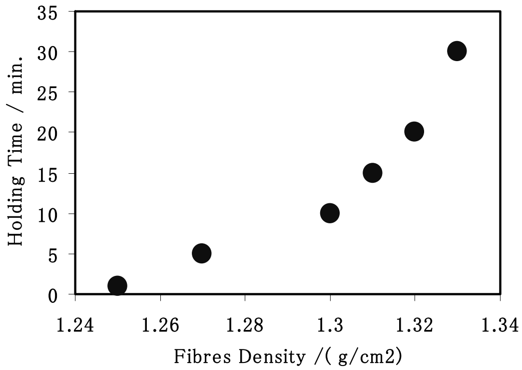

Fig.7. Relationship between holding time and fiber density of the bagasse composites.

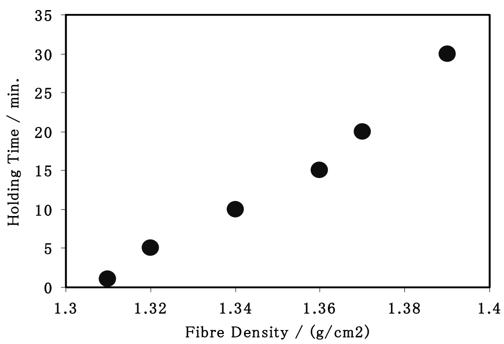

Fig.8. Relationship between holding time and fiber density of the bamboo composites.

Effect of the amount of fiber content on the flexural properties of bagasse composites

The effect of the amount of fiber content on the flexural properties of the composites can be seen in Fig.9

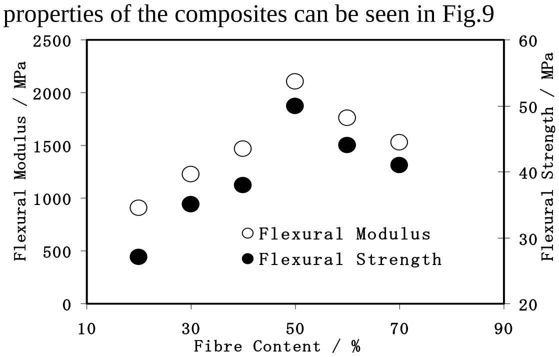

Fig.9.Effect of fiber content on flexural properties of bagasse composites

Both flexural modulus and flexural strength increased linearly with increase the amount of fiber content upto 50 % and then begins to decrease with further increase in the amount of bagasse fiber. This increase in the flexural properties is primarily attributed to reinforcing effect imparted by the fibers, which allowed a uniform stress distribution from continuous polymer matrix to dispersed fiber phase [5]. Above 50 % fiber content, flexural modulus and flexural strength decreased. This decrease in the flexural properties at high fiber content implied poor fiber–matrix adhesion which promoted microcrack formation at the interface as well as non-uniform stress transfer due to fiber agglomeration within the matrix. [6]. Similar results have also been reported by Mohanty et al. [7] for jute reinforced polyester amide composites in which the broken fiber ends caused crack initiation & potential composite failure at 53% fiber loading. This is why, the flexural modulus showed maximum of 2100 MPa at 50% for bagasse. Fig.10. shows the effect of the amount of fiber content on the compression ratio of bagasse composites. As shown in the fig., compression ratio increased with increasing the amount of fiber content. The compression ratio increase due to cross sectional structure of bagasse fibers and the fiber-matrix distribution is good into the mould cylinder.

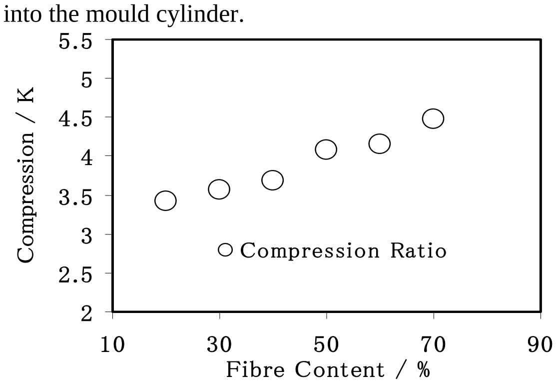

Fig.10. Effect of fiber content on the compression ratio of bagasse fiber composites.

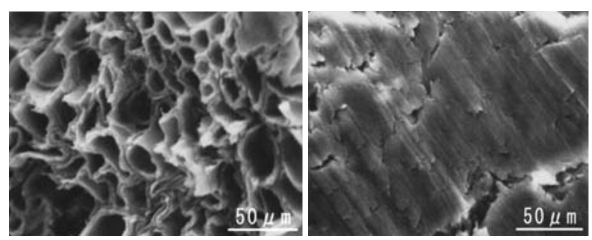

Fig.11. Cross section of a) bagasse fiber and b) bamboo fiber

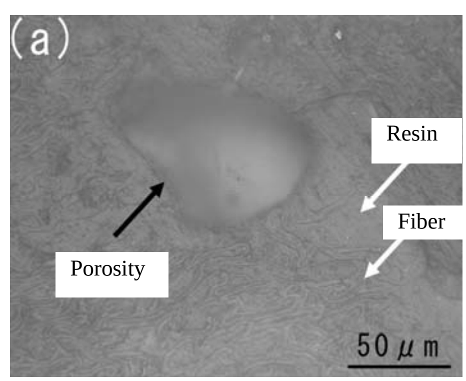

Fig.12a. Optical microphotographs of the cross section of the bagasse composite specimens

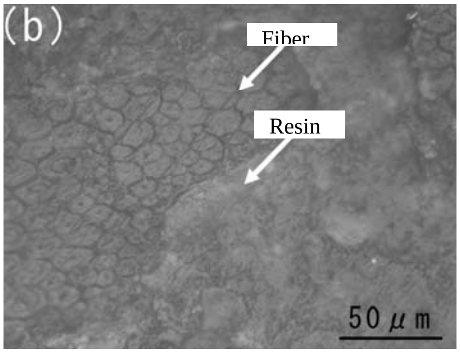

Fig.12b. Optical microphotographs of the cross section of the bamboo composite specimens

CONCLUSIONS

Effect of holding time and the amount of fiber content on the flexural properties of Bagasse /bamboo fiber reinforced biodegradable composites were investigated. The following conclusions were as follows:

- Both flexural modulus and flexural strength increased with increasing the holding time upto 10 min and above 10 min holding time, both flexural modulus and flexural strength decreased due to insufficient wetting between fiber and matrix. The flexural modulus and flexural strength of 2384 MPa & 55.84 MPa for bagasse and 2403 MPa & 70.26 MPa for bamboo fiber composites.
- The fiber weight fraction also increased with increasing the holding time while compression ratio was rather constant. It is very much interesting that the compression ratio was constant due to the matrix between bagasse /bamboo fibers was insufficient and some of the fibers was not well bonded each other due to the high fiber volume fraction.
- The cross sectional structure of bagasse fibres ware porous and bamboo fibres ware solid.

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