J Wood Sci (2006)
DOI 10.1007/s10086-005-0749-0

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Cross-sectional cutting of bamboo with a pair of shearing blades for bamboo cube production

Received: February 18, 2005 / Accepted: July 1, 2005

Abstract As a new use of bamboo, bamboo cubes may be useful as a shot-blast material for surface treatments. However, a suitable processing technique for bamboo cubes has not been established. In this study, to obtain basic knowledge regarding the processing technology for bamboo cubes, we installed shearing blades (upper and lower blades) in a universal testing machine to test cross-sectional shearing of bamboo. The shearing force generated in this shearing was composed of a vertical component (F_v), a forward component (F_f), and a side component (F_s). This shearing force (F_v, F_f, and F_s) and the machining accuracy were investigated under various processing conditions. The shearing force became larger as the thickness of bamboo increased. In particular, F_v showed a tendency to increase rapidly. Changes in the shear angle of the upper blade had a remarkable influence on F_v. This result suggests that the shearing force could be greatly decreased by adjusting the shear angle. The shearing force within bamboo of 3mm in thickness was almost unaffected by the blade angle, and the change of shearing force with increasing clearance was almost indiscernible. It was clearly demonstrated that a large number of bamboo cubes could be made when the shear angle was large and cross-sectional shearing was performed from the bark side. However, a consequence of a large shear angle is that burr area increases.

Key words Bamboo cube · Shearing blades · Shearing force

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Part of this article was presented at the 53rd Annual Meeting of the Japan Wood Research Society, Fukuoka, March 2003

Introduction

In attempting to align the production of bamboo forests with demand, an effective use for unused large-diameter bamboo is needed. One possible use is as a shot-blast material for surface treatments such as the removal of flaking paint or surface burrs.

Shot-blast processing is a method of surface treatment in which shot-blast material is projected onto a surface to remove dirt and burrs. In the case of using bamboo cubes that contain pieces of hard bark as the shot-blast material, a moderate blast cleaning effect is demonstrated, and no deformation in the material is caused. Disposal of the used bamboo cubes after they are used as a blast material should not pose an environmental problem.

To date, the processing technology of bamboo cubes, which need hardness and a shape with distinct corners, has not been established, and at present the cubes must be made from a thin strip of bamboo using a manual shearing blade. To use bamboo cubes effectively, it is important to develop the most efficient technique for processing these cubes. Previous work in bamboo cutting had only investigated the effects of various cutting conditions and various workpiece conditions on the frictional coefficient on the knife rake face in orthogonal cutting.[1]

In a previous study of veneer clipping with shearing blades,[2] the authors studied the shearing cracks caused by shearing forces occurring at the same time as the clipping and concluded that the processing that made the best use of the shearing crack caused by cross-sectional cutting of a thin strip of bamboo with shearing blades could be adjusted in processing bamboo cubes. Moreover, many studies on clipping[3,4] and cross-sectional shearing[5–9] have been conducted in the past.

In this study, to obtain basic knowledge regarding the processing technique for bamboo cubes, we installed a pair of shearing blades in a universal testing machine and tested the cross-sectional shearing of bamboo to make bamboo cubes. Moreover, cross-sectional shearing under various processing conditions was performed, and the shearing

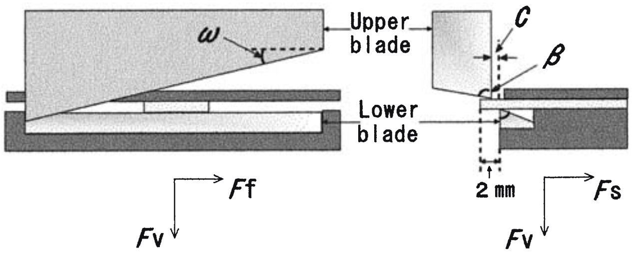

Fig. 1. Shapes of upper and lower blades. *β*, Blade angle; *ω*, shear angle; *C*, clearance, F_v, vertical force; F_f, forward force; F_s, side force

force generated in this shearing and the machining accuracy of bamboo cubes were investigated.

Materials and methods

Shearing tools and work material

A pair of shearing blades composed of a blade with a shear angle (upper blade) and a flat blade (lower blade) was used in this test. The shapes of these blades are shown in Fig. 1. The blade material was SKH-3. We prepared the upper blades having a shear angle of 15 degrees and tested eight blade angles in the range from 50 to 90 degrees, and we then prepared the upper blades having a blade angle of 84 degrees and tested six shear angles in the range from 0 to 25 degrees. Lower blades with the same blade angle as the upper blades were prepared.

The work material used in this test was bamboo (*Phyllostachys pubescens*). The mean moisture content was 8.7%. The work pieces (thin strips of bamboo) were 11.3 mm wide and 1, 2, 3, and 5 mm thick.

Experimental apparatus

The apparatus of cross-sectional cutting with shearing blades is shown in Fig. 2. The shearing force generated in this shearing is composed of a vertical component (F_v), a forward component (F_f), and a side component (F_s). The upper blade was installed under the cross head of the universal testing machine through both the octagonal dynamometer used for the measurement of F_f and the load cell for the measurement of F_v. The steel base was situated on the steel frame, and the lower blade was installed at the edge of this base. The load cell for the measurement of F_s was adjacent to the base. Work material set up on the base was fixed using a steel plate and bolts, and was sheared by means of the descending upper blade and the lower blade. The shearing crack caused by the shearing force occurring at the same time as cross-sectional shearing of bamboo with a pair of shearing blades, and bamboo cubes were processed as shown in Fig. 3.

The shearing force (F_v, F_f, and F_s) was recorded using a pen recorder through an amplifier, and each maximum value was assumed to be a measurement value. The clearance (*C*), i.e., the distance between the upper and lower blades, was adjusted by means of a bolt.

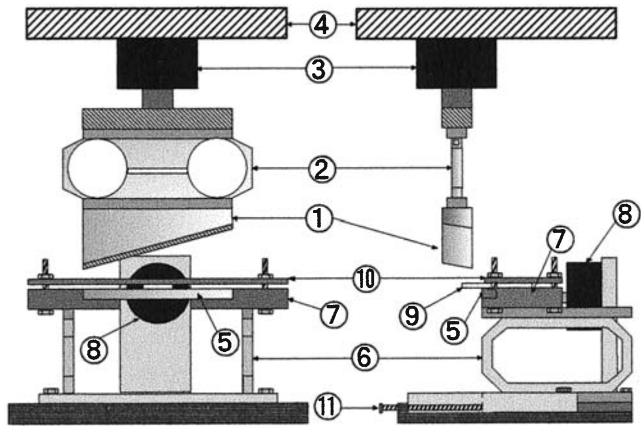

Fig. 2. Cross-sectional shearing apparatus. *1*, upper blade; *2*, octagonal dynamometer (F_f); *3*, load cell (F_v); *4*, cross head; *5*, lower blade; *6*, steel frame; *7*, steel base; *8*, load cell (F_s); *9*, work piece; *10*, steel plate; *11*, bolt

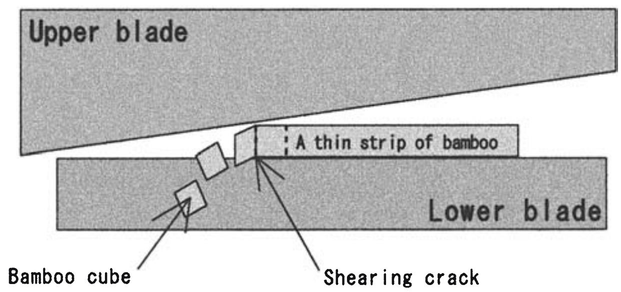

Fig. 3. Outline of bamboo cube processing by cross-sectional cutting with shearing blades

Shearing conditions

A series of experiments was carried out under three cases, as listed in Table 1. The upper blade was set at a feed of 100 mm/min, and the thin strip of bamboo was sheared from its bark side and from its inner side, respectively. Cross-sectional shearing was repeated three times per test condition.

Evaluation method of the bamboo cube and burr

After the experiment, pictures of the cross section of bamboo cube were taken using a digital camera. The height, position, and area of burr, and the number and width of the bamboo cubes were measured by using image analysis software, and the processing accuracy was evaluated. In these measurements, the position of the upper blade at the start of shearing is considered to be the start position of shearing, while the position of the upper blade at the end of shearing is considered to be the end position of shearing, as shown in Fig. 4. The height and position of the burrs were measured

Table 1. Shearing conditions

Experiment	Blade angle (°)	Shear angle (°)	Thickness (mm)	Clearance (mm)
1	84	0 5 10 15 20 25	1 2 3 5	0.5
2	50 60 69 75 81 84 87 90	15	1 2 3 5	0.5
3	84	15	2	0.1 0.2 0.3 0.4 0.5

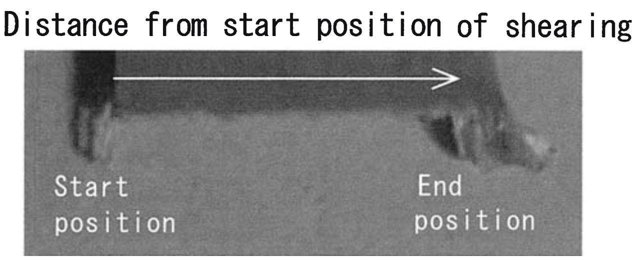

Fig. 4. Burr height and position of burr formation

based on this start position. When determining the number of bamboo cubes, we counted the number of cubes that were less than 3 mm wide, which made them suitable for shot-blast material. The area of burr and the number of bamboo cubes were evaluated three times per test condition.

Results and discussion

Effects of various factors on shearing forces

Figure 5 shows the typical relationships between shearing force and thickness in the case of a blade angle of 84 degrees, a shear angle of 15 degrees, and a clearance of 0.5 mm. The shearing forces became larger with increasing thickness. In particular, F_v showed a tendency to increase rapidly. This tendency was similar under other conditions, and difference in the shearing force between the shearing directions from the bark side and from the inner side was not recognized.

Figure 6 shows the typical relationships between shearing force and shear angle in the case of a blade angle of 84 degrees and a clearance of 0.5 mm. In all cases, the influence on the F_v is large with increasing shear angle, and the effect of decreasing the shear angle is remarkable. This decrease is considered to be due to F_f acting on the shearing direction with increasing shear angle. This result suggests that the shear forces could be greatly decreased by adjusting the shear angle.

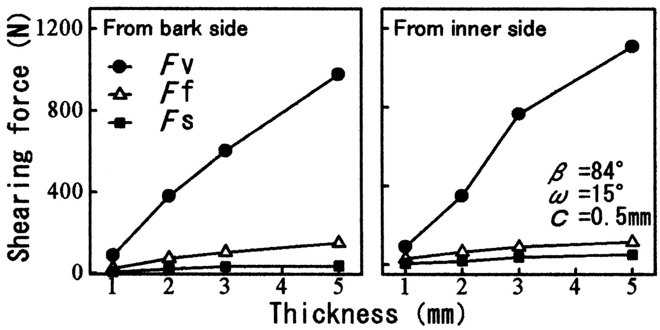

Fig. 5. Relationships between shearing force and thickness for when shearing from the bark side (*left*) and from the inner side (*right*)

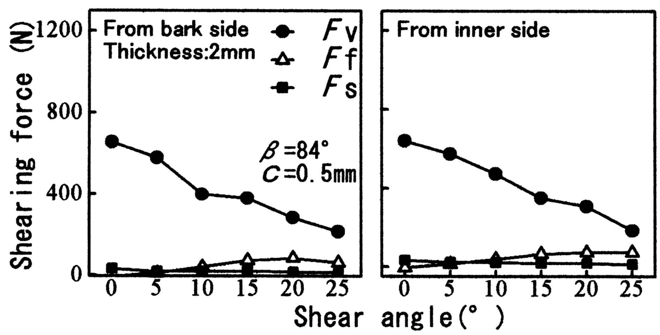

Fig. 6. Relationships between shearing force and shear angle

The shearing force within bamboo of 3 mm in thickness was almost unaffected by the blade angle, but F_v and F_f became slightly larger in the case of 5-mm-thick bamboo. It was clear that the influence of the blade angle was smaller than the influences of thickness and shear angle. Furthermore, the change of shearing forces with increasing clearance was almost unrecognized in all shearing conditions. Thus, it was clear that within the range of these experimental conditions, clearance exerted negligible influence on shearing force.

Machining accuracy of bamboo cube and burr formation

Figure 7 shows the typical relationships between the number of bamboo cubes and shear angle when cubes are made using a blade angle of 84 degrees, a clearance of 0.1 mm, and a thickness of 2 mm. The number of bamboo cubes increased as the shear angle increased. More bamboo cubes could be processed when they were cut from the bark side than when cubes were cut from the inner side.

Figure 8 shows the relationships between burr area and shear angle for the same shearing conditions as shown in

Fig. 7. The burr area increased as the shear angle increased. The burr area tended to increase more when shearing was performed from the bark side than from the inner side, except in the case of a shear angle of 20 degrees. At that angle, it appears that the inner fiber becomes detached from the upper blade and many burrs are formed because the soft inner fiber is cut after the hard bark fiber.

Figure 9 shows the typical relationship between burr height and burr position in the case of shear angles of 0, 10, and 25 degrees. The tendency for a lot of burrs to be formed at the start position and the end position of shearing in all conditions was shown. Moreover, burr formation was confirmed to occur in a large area at the end position of shearing compared with the starting position of shearing when shearing was performed from the bark side. This tendency was seen to a remarkable degree as the shear angle increased.

These results demonstrated that a large number of bamboo cubes could be made when the shear angle was set large and cross-sectional shearing was performed from the bark side. However, the burr area increased when the shear angle increased.

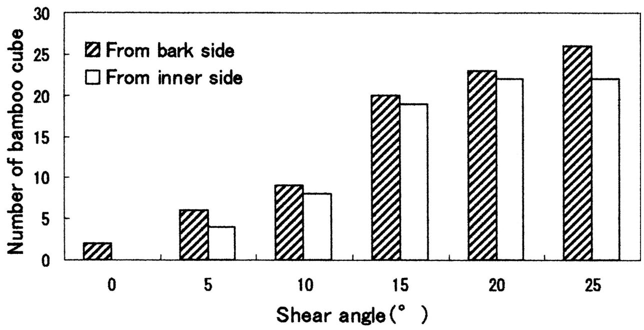

Fig. 7. Relationships between the number of bamboo cubes and shear angle

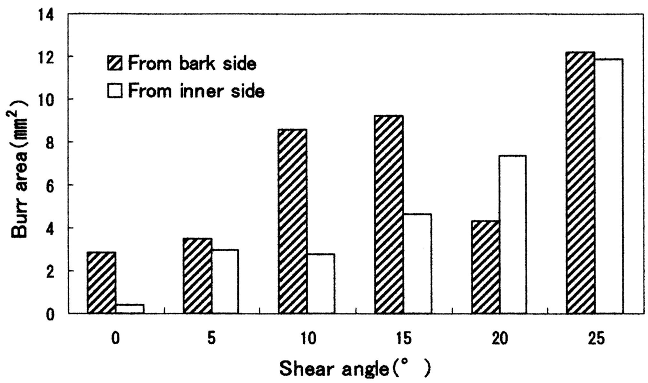

Fig. 8. Relationships between burr area and shear angle

Conclusions

In this study, to obtain basic knowledge regarding the processing technique for obtaining bamboo cubes by cross-sectional cutting with shearing blades, we investigated the shearing force and the machining accuracy of bamboo cubes under various processing conditions. The main results obtained are summarized as follows:

1. The shearing forces became larger as the thickness of bamboo increased. In particular, F_v showed a tendency to increase rapidly.
2. The influence on F_v is large with increasing shear angle, and the effect of decreasing the shear angle is remarkable. This result suggests that the shear force could be greatly decreased by adjusting the shear angle.
3. The shearing force within bamboo of 3 mm in thickness was almost unaffected by the blade angle, and the change of shearing force when the clearance was increased was almost unrecognized within the range of these experimental conditions.
4. It was clearly demonstrated that a large number of bamboo cubes could be made when the shear angle was large and cross-sectional shearing was performed from the bark side. However, a consequence of a large shear angle is that burr area increases.

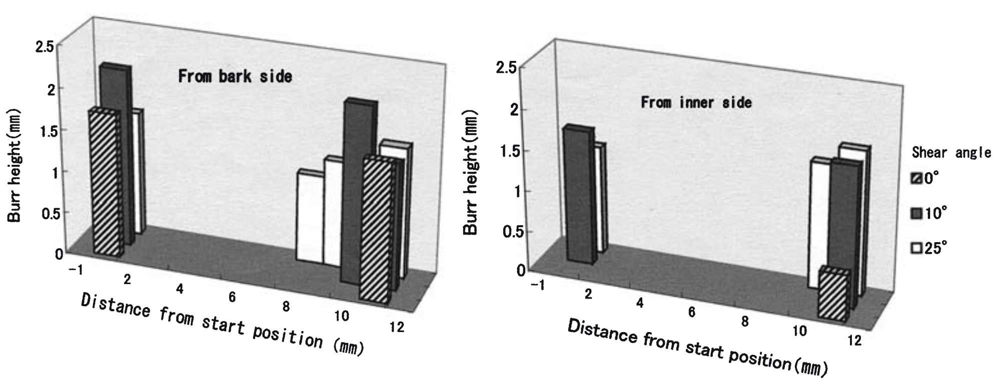

Fig. 9. Relationships between burr height and burr position

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