Flattening of Bamboo by Thermo mechanical Treatment

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Abstract

The flattening of cylindrical green bamboos with and without node has been carried out by using the thermo mechanical treatment. Cracking of bamboos occurred sometimes when flattening conditions were not adequate and it depended strongly on flattening temperature, speed, moisture contents and the thickness of bamboo. The flattened bamboos had superior mechanical properties, water resistance and elegant colors due to having original surfaces. The flattening of bamboos by thermo mechanical treatment could expand the use of bamboos such as floor, wall, furniture, sports goods, handcrafts and constructions.

1. Introduction

Since a sick house syndrome which is atopic allergy from chemicals contained in the indoor materials of new house has risen as a serious common health problem it becomes a hot topic to develop environmental friendly natural materials. Woods are very good natural materials for this purpose because of its low price and abundance. The woods, however, are too weak to use as it is for interior materials. Therefore woods have been normally used for interior materials with chemical coating where strength is not so important. Bamboo is a kind of wood, but it has a much higher mechanical strength and thermal conductivity compared to woods. The surface of bamboo is especially hard and water resistant with natural elegant color. In addition to these, the characteristic features of bamboo are a rapid growth(within 2 months),a short incubation time till utilization(2-3 years), unnecessary of planting except once and abundance in supply. Thus bamboos have been used for various purposes such as farming tools, furniture, hand crafts and constructions.

Nevertheless the use of bamboo has been limited considerably and used mostly for indoor materials due to some serious problems such as cylindrical shape, cracking upon drying and getting musty under humid atmosphere.

Flattening of bamboo can overcome the cylindrical shape of bamboo, consequently diversifies a use of bamboo. The 2 types of bamboo flattening methods are known. One is so-called cutting and gluing method in which cylindrical bamboo is cut into many small and long pieces of rectangular shape and then glued together. This method is very simple but takes time and labor. Other problem of this method is that the surface of bamboo which is very hard and water resistant should be removed out. Thus the bamboo plate made by this method has a better but not so much strength than that of woods. Another method of bamboo flattening is so-called grooving and gluing in which many V-shape grooves are made at the surface of bamboo along longitudinal direction and then glued under pressure to make flat. Both methods described above adopt cutting and gluing process which needs removal of bamboo surface, resulting in sacrifice of strength and water resistance.

In this study a thermo mechanical treatment has been applied to flatten bamboo without cutting and gluing process. The flattening mechanism of bamboo for the thermo mechanical treatment was discussed and several examples of applications of the flattened bamboos were shown.

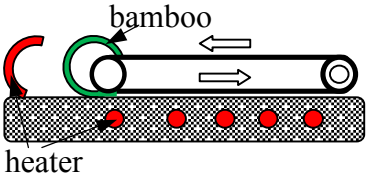
2. Experimental

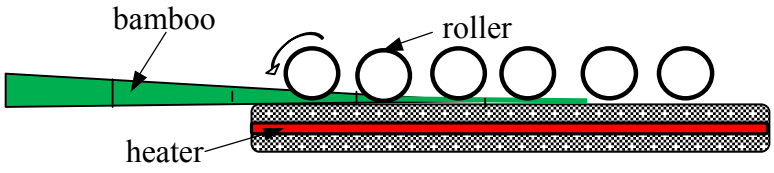
2.1 Flattening of cylindrical green bamboos without node

Cylindrical green bamboos (Korean king bamboo, O.D: about 80-100 mm, L:25-30mm, t:5-7mm) without node were cut along longitudinal direction. Then the bamboos were placed in an oven at the temperature of about 200℃. After waiting for bamboo to be opened enough the

bamboos were put into the flattening machine which could flatten bamboo gradually in transverse direction as shown schematically in fig.1.

The temperature of flattening was 150- 200℃ and the flattening speed was 10-20cm/min depending on the thickness, the moisture content and the age of bamboo. The rectangular-shape bamboo plates could be obtained without making crack.





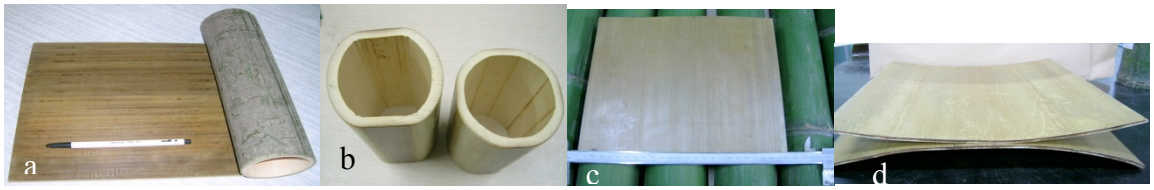
<Fig.1><Fig.2>

2.2 Flattening of cylindrical bamboos with nodes

To flatten bamboo with nodes the extruding parts of nodes should be removed. For this,the bamboo should be cut along longitudinal direction into two hemi-cylindrical pieces. The externally extruding parts of nodes were removed easily by using a belt grinder. The internally extruding parts of nodes were removed by using a specially designed grinder. Then the hemi-cylindrical pieces of bamboo were put into the other flattening machine which could flatten bamboos with or without node gradually in longitudinal direction as shown schematically in fig.2. The temperature of flattening was 150- 200℃ and the flattening speed was 30-100cm/min depending on the thickness, the moisture contained and the age of bamboo. The long rectangular-shape bamboo plates with nodes could be obtained without making crack.

3. Results

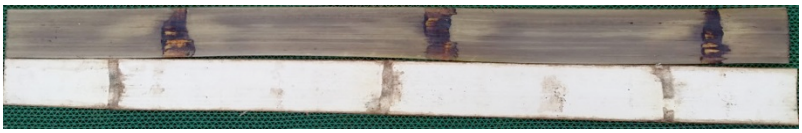
The flattened bamboos without node obtained by the thermo mechanical treatment were shown in fig.3.



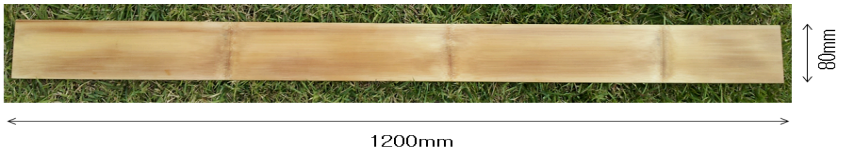
<Fig.3>

The color of bamboo surface depends on the temperature and the flattening speed. Fig.3-b shows a partial flattening of a bamboo cylinder without cut. Fig.3-d shows the under and the over flattened bamboos.

The flattened bamboos with nodes obtained from the hemi-cylindrical bamboos by the thermo mechanical treatment were shown in fig.4 and fig.5 for the natural and the abraded surfaces respectively.



<Fig.4>



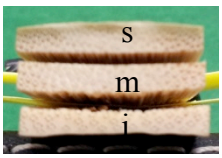
<Fig.5>

4. discussion

4.1 Mechanism of flattening bamboo by thermo mechanical treatment

4.1.1 Stress arisen during drying of a green bamboo

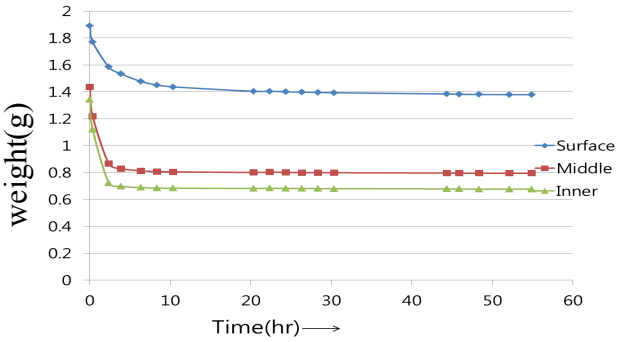
In order to understand the mechanism of flattening bamboo one piece of green bamboo which was submerged in water for a week was cut into three (surface, middle and inner) parts as shown in fig.6.



<Fig.6>

Those were placed in an oven at temperature of 60℃ and measured their weights with time.

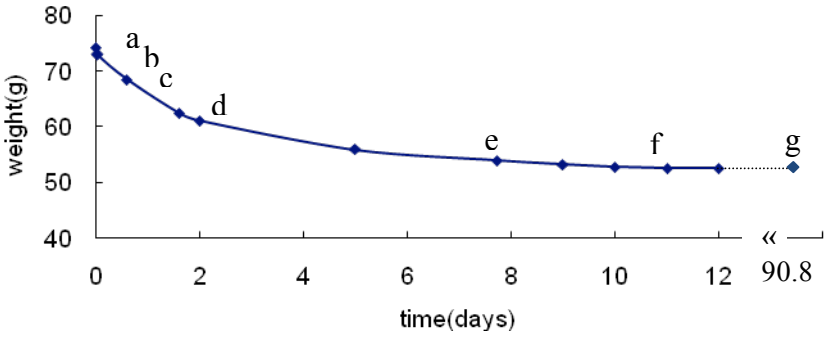
The weight changes at 60℃ of three parts of a green bamboo were shown in fig.7.



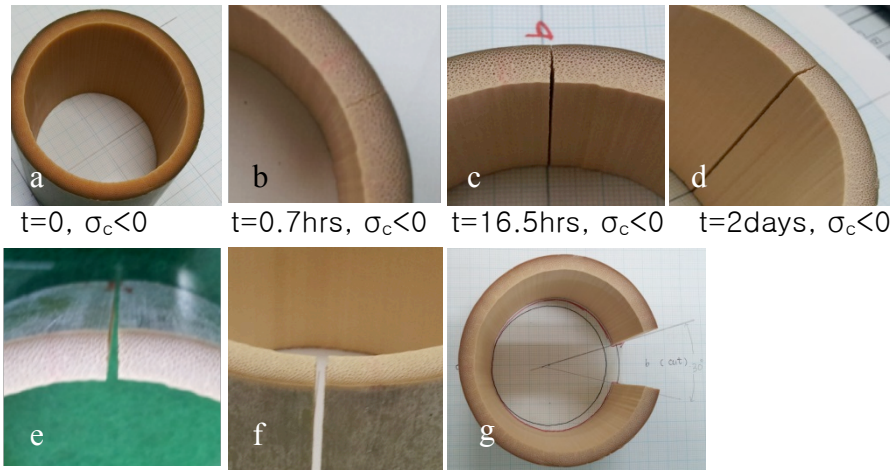
<Fig.7>

It was found that the weights decreased rapidly within 2 hrs. At this initial stage the moisture dried would be from large open tubes which were included in vascular bundles. Although the amount of this moisture was large the stress arisen from this should be small because of large tube size. At the late stage of drying the weight loss of the surface part was considerable and kept continuously and slowly whereas that of the inner part almost ceased. The middle part showed a bit more weight loss than the inner part but much less than the surface part.An artificial crack was made on a cylindrical green bamboo by cutting one place by knife and investigated the weight changes of the bamboo and the variation of crack shape with drying time at room temperature of about 25℃. The results were shown in Fig.8 and Fig.9.

At the initial stage the weight of bamboo decreased very fast resulting in evaporating almost of moisture in the bamboo within about 5 days. The bamboo cylinder, however,was under a considerable compressive stress in a circumferential direction and thus the surface part was still closed although the inner part was opened slowly. The reason for this seemed to be the higher evaporation rate of water in the inner part compared with that of the surface as shown in fig.4. After a few days (about 5 days) the compressive stress has been gone and the crack was opened completely. Opening of the crack increased continuously until three months although the almost of moisture in bamboo was gone already.



<Fig.8>



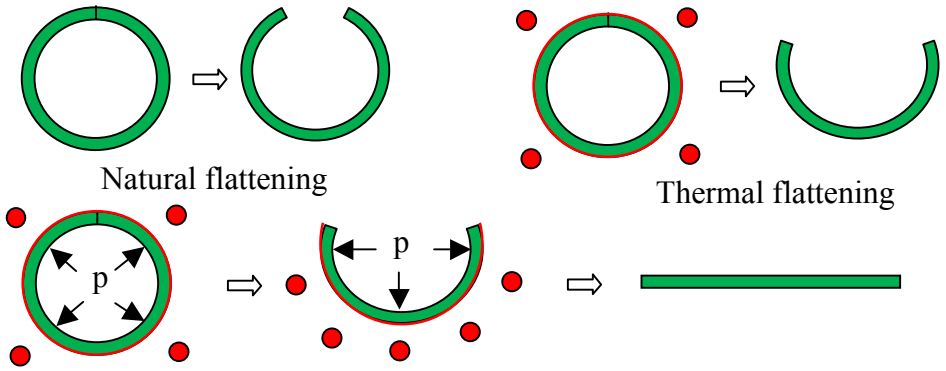
<Fig.9>

In general a crack can be formed by a tensile stress butnot by a compressive stress. A (residual) tensile stress without any external force can arise when the material is contracted under fixed state. On the other hand opening of a crack on a cylindrical shape comes from a different strain between the surface and the inner. That is a larger compressive strain at the surface than at the inner. During drying of bamboo the surface part of bamboo dried slower than the inner part. This causeda decrease in a diameter of bamboo at initial stage and a compressive stress at the surface and tensile stress at the inner part. (See fig.9-c,d) The tensile stress arisen at the inner part would be not so large due toa large tube size and the compressive stress existing already when it is alive. Thus if there is not an artificial crack cracking would not be appeared. A significant tensile stress able to cause cracking on bamboo appears at the late stage when the most of moisture is consumed. After bamboo is cracked once there is nearly free from stress. At this late stage although the drying is very slow it comes mainly from the surface, resulting in a compressive strain at the surface and consequently opening of the crack. Opening of a crack during drying a cylindrical bamboo means a natural partial flattening of bamboo. When a cylindrical bamboo was heated up to high temperature of 200℃ a more opened(flattened) bamboo but not completely flattened was obtained.

4.1.2 Flattening by a thermo mechanical treatment

In order to flatten a bamboo completely to addition of the natural partial flattening, an additive compressive strain at the surface must be achieved. This can be carried out by a thermo mechanical treatment for the bamboo. The thermo mechanical treatment provides two different temperatures and stresses for the bamboo as shown in fig.10. The surface is subjected under the high temperature and a compressive stress and the inner is subjected under the low temperature

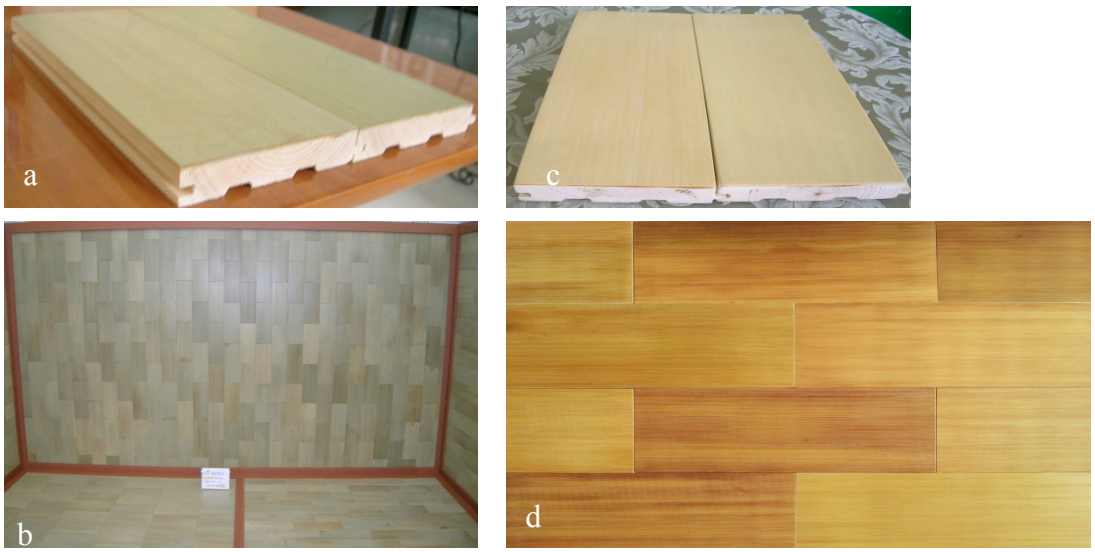
and a tensile stress. The high temperature provides three effects. One is thermal softening of bamboo which decreases the flattening stress and protects bamboo from cracking. The second is a contraction (compressive strain) of bamboo with a fast drying rate. The third is a thermal expansion which is normally small but sometimes can cause a reversely concaved bamboo plate when it is cooled down to a room temperature. The mechanical pressing of bamboo provides a compressive strain at the surface, in addition to this it gives an acceleration of drying surface by a compressive stress and a good thermal contact, resulting in much more compressive strain at the surface. The tensile stress at the inner sometimes can cause a cracking when the tensile stress is over a certain critical value. To avoid this, the flattening temperature and the speed should be adjusted.



Thermo mechanical flattening
<Fig.10>

5. Applications of flattened bamboos

It was shown in Fig.11 the applications of the flattened bamboos without node for wall and floor. The natural surfaces have some undesirable scars as shown in fig.11-a,b. Thus the surfaces of flattened bamboo are normally sanded or ground by emery papers. (Fig.11-c,d)

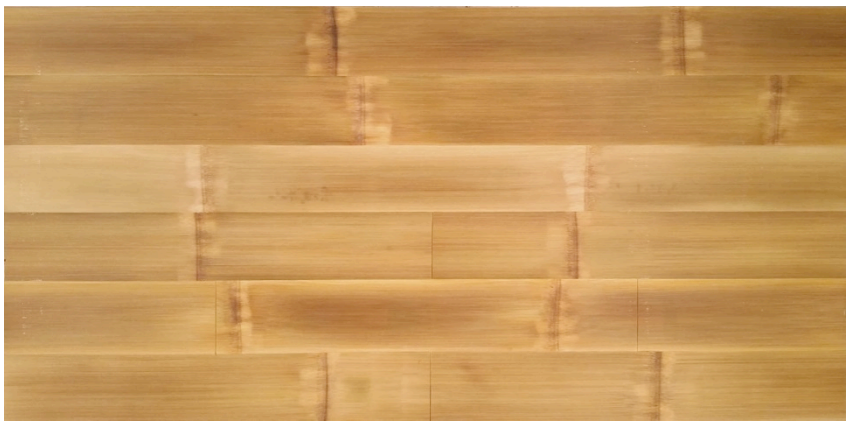


<Fig.11>

Small flattened bamboo plates are useful for oriental painting (fig.12-a), sculpture (fig.12-b left), burning painting (fig.12-b right), press printing (fig.12-c) and press burning painting (fig.12-d).

<Fig.12>

The flattened bamboos with nodes can be used for wall, floor, furniture, sports goods, handcrafts and constructions. The examples are shown in fig.13-16.



<Fig.13>

<Fig.14>

<Fig.15>

6. conclusions

The bamboos of cylindrical and hemi-cylindrical shapes without and with nodes respectively could be flattened without cracking. At inadequate conditions, however, longitudinal cracks were found. Success in flattening was strongly dependent on the temperature, flattening speed, pressing timing, the thickness of bamboo, the moisture content, the age of bamboo and a kind of bamboo. The thinner, the slower, the moister, the younger bamboos were the easier to be flatten without cracking.Since the flattened bamboos have the original bamboo surfacesthey have unique and superior properties in contrast to woods and the bamboo plate made by cutting and gluing process. Thus the flattened bamboos, as environmental friendly natural materials, are very suitable to interior (floor and wall), furniture, handicraft and sports goods materials, and have a high possibility of substitutive structural materials for the metals and plastics.

Figure captions

Fig.1 Schematic diagram of the machine for flattening cylindrical bamboos without node
Fig.2 Schematic diagram of the machine for flattening hemi-cylindrical bamboos with nodes
Fig.3 Flattened bamboos without node obtained by the thermo mechanical treatment
Fig.4 Flattened bamboos with nodes obtained from the hemi-cylindrical bamboos by the thermo mechanical treatment (natural surface)
Fig.5 Flattened bamboos with nodes obtained from the hemi-cylindrical bamboos by the thermo mechanical treatment (abraded surface)
Fig.6Three parts of bamboo used for drying test
Fig.7 Weight changes of the three parts (surface, middle and inner) of bamboo with drying time at 60℃. The bamboo has been submerged in water for a week.
Fig.8The weight changes of a green bamboo during drying at 25℃
Fig.9The variation of the artificial crack on a green bamboo during drying at 25℃
T: drying time, σ_c: circumferential stress
The photographs were taken from the samples denoted in Fig.8.
Fig.10 Natural, thermal and thermo mechanical flattening of bamboos
Fig.11 Applications of the flattened bamboos without node for wall and floor
Fig.12 Applications of the flattened bamboos without node for arts
Fig.13 Applications the flattened bamboos with nodes for wall and floor
Fig.14 Applications the flattened bamboos with nodes for a skate board
Fig.15 Applications the flattened bamboos with nodes for furniture