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Steam Integrated Flattening Machine for Bamboo Culms

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Abstract. Bamboo is a fast growing grass plant abundant in tropical and subtropical countries. Bamboo culms can be used in a variety of applications and thus needs to undergo different process one such process is the flattening process. Traditional flattening process uses the bolos, machetes and hand splitters to make slats of the bamboo. This paper aimed to present a flattening machine with a presser mechanism which utilizes heat and steam to help in the flattening process. The output of the machine was flattened semi-circular bamboo culms from varying radius a bamboo culm with minimal to no cracks. The parameters that were observed were the thickness of the culm, flattening time, heating temperature and length of the culm. From the testing, it showed that flattening time varies directly with the thickness of the bamboo culm.

1. Introduction

Bamboo as a fast growing plant is being used as the main material in handicrafts and in producing export-quality goods in the Philippines. The bamboo culm is the most utilized part of the bamboo in the industry. Flattening process for bamboo culms have been under study for years in order to yield a good quality flattened bamboo culm where waste and cracks are reduced. The objective of the study is to introduce new strategy and way of flattening semi-circular bamboo culms through the design and fabrication steam-integrated flattening machine for semi circular bamboo culms. The machine is focused to address the cracking of bamboo culms when flattened since mostly of the fabricated flattening machines results to cracked flattened bamboo.

Recent design o bamboo culm flattener only flattens the half of a bamboo culm through a series of rollers. The output of the flattener is cracked strip of bamboo [1]. It only made the traditional way of flattening easy. In the flattener designed, it aimed to minimize the cracks produced in flattening the bamboo culm through direct press, gradual press and continuous press [2]. Before it undergoes the process of pressing, bamboo culms are immersed in hot water to soften the bamboo culm. Another flattening machine where it flattens the bamboo culm by passing through a series rollers and heater beneath the rollers [3]. The bamboo culms are softened while it is being rolled flat. Other process requires the modification of the bamboo such as cutting the bamboo into square sticks then adhering them together [4].

2. Materials and methods

The flattening machine was fabricated on the residence of one of the researchers using available materials selected from qualitative material selection [5]. Testing of the machine after the fabrication was done and made some modifications and corrections before conducting an official test for experimentation.

The specie of the bamboo that was used in the testing and experimentation was Buho *(Schizostachyum lumampao),* which was cut 1/3 to ½ of a diameter of the bamboo culm. The length and thickness of the culm was also measured. In order to determine the degree of flatness of the bamboo culm, the method done by [6] was used as seen in figure 1. H is the height of the semi-circular bamboo culm which is equal to the radius of the bamboo culm at the initial condition. At the final condition after load is applied, the height should be equal to the culm wall thickness. Degree of flatness should result to a value of 1 which will indicate the successful flattening of the semi-circular bamboo culm.

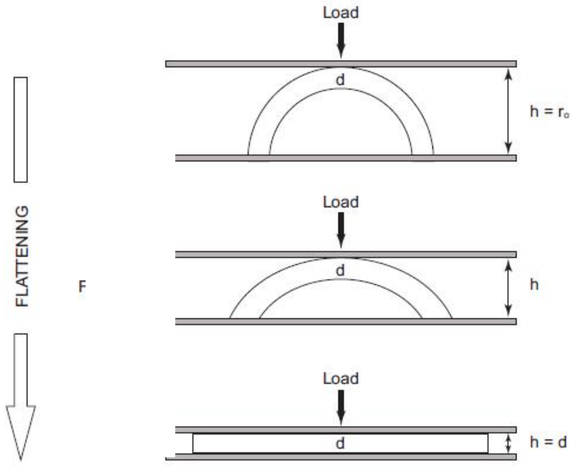

Figure 1. Schematic Representation of determination of the degree of flatness [5].

3. Design
The fabricated flattening machine is shown in figure 2. It consists of three heaters: Submersible heater for steam generation, and two flat plate heaters for bamboo. The presser plates were made of mild steel plate. The presser heater was designed so as the heaters could move accordingly to stay in contact with the surface of the bamboo while the bamboo culms are being flattened, aiming a constant and equally distributed heat on the outer surface of the bamboo. The bamboo table was made of mild steel plate with 9.50mm steam holes. The water tank was made from a 1-mm thick G.I sheet with insulation boards. The whole dimension of the flattening machine was 836.70 mm x 455.70 mm x 1240 mm.

Figure 2. Steam-Integrated Flattening Machine for Bamboo Culms.

4. Experimentation
The experiment was composed of mutiple trials. The lengths and radii of bamboo culm samples were measured. The operating heating temperature of steam used during flattening is at least 110°C. The

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final height and elapsed time of flattening were recorded. In order to test if the number of steam holes would affect the output of the machine, one section of the bamboo table has some of its holes on the center covered as shown in figure 3 while the other section has all holes opened as seen in figure 4. The holes were covered by a cork made from a piece of wood. A stopwatch was used to determine the time it takes to flatten the culms as well as the specific time where the bamboo culms started to show visible cracks. The test was made to have three trials by varying the number of holes on the center of the bamboo table to be covered. The bamboo culms that were used were ensured to all have the same dimensions. Three arrangements for the test were made all holes on the center were covered, alternating pattern of holes on the center were covered, and no holes were covered.

Figure 3. All Holes Covered on the Center.

Figure 4. Alternating Pattern of Holes Covered on the Center.

For the first trial shown in figure 5, the first bamboo culm started to show visible cracks after 30 minutes have elapsed on its flattening time and had fully cracked 10 minutes after. The bamboo culm was still allowed to be fully flattened. The flattening time for the first trial was 58.38 minutes. For the second trial as seen in figure 6, the second bamboo culm showed visible cracks after 36 minutes, however, the bamboo culm did not fully crack. The cracks were not directly formed on the center of the bamboo culm and were only visible on the inner surface. The flattening time for the second trial was 47.65 minutes. The third trial depicted in figure 7, the third bamboo culm did not show any visible cracks and was fully flattened after 40.26 minutes.

Figure 5. Flattened Bamboo Culm from the First Trial.

Figure 6. Flattened Bamboo Culm from the Second Trial.

Figure 7. Flattened Bamboo Culm from the Third Trial.

5. Results and Discussion

Thickness affects the flattening of the bamboo culms, there is a direct relation with the thickness and the flattening time, as well as, the temperature needed to flatten the bamboo culms as seen in table 1 and figure 8. The thicker the bamboo, the more time it would require for the bamboo to be heated thoroughly and evenly, thicker bamboos also tend to be harder and stiffer. The length of the said bamboo culms also affected the flattening time and the output of the bamboo culms. As the length increased, there was an increase of time flattening; also, an increase in length entails the presence of nodes and these increased the formation of cracks in the flattened bamboo. This occurrence may be because the nodes are thicker and stiffer than that of the internodes, this creates an inconsistency in the culm. It is observed that a thicker bamboo requires a higher temperature and more time to flatten than a thinner one. The radius may also play into the flattening process as more area is needed to be heated thus increasing the flattening time, cutting the bamboo into smaller sections may be adapted to lessen the time.

Table 1. Testing and Experimentation Results.

Trial	Length (m)	Radius (mm)	Thickness (mm)	Final Height (mm)	Temperature (°C)	Time Elapsed (sec)	Time Elapsed (mins)
1	0.20	41.5	6.00	6.50	120	450	7.5
2	0.20	41.5	6.50	6.50	110	450	7.5
3	0.230	41.5	6.50	6.50	115	504	8.4
4	0.443	41.5	6.50	23.0	115	738	12.3
5	0.157	41.5	6.50	6.50	115	432	7.2
6	0.254	41.5	6.50	6.50	132.25	682	11.38
7	0.25.4	41.5	6.50	6.50	132.25	862	14.38
8	0.453	42.0	9.00	10.0	130	2280	38
9	0.452	50.0	10.5	10.5	134.5	2406	40.1
10	0.381	50.0	11.0	11.0	137.75	2413	40.23
11	0.254	50.0	11.0	12.0	137.75	2625	43.75
AVE	0.2983	43.9	7.80	9.60	125.41	1258.36	20.97

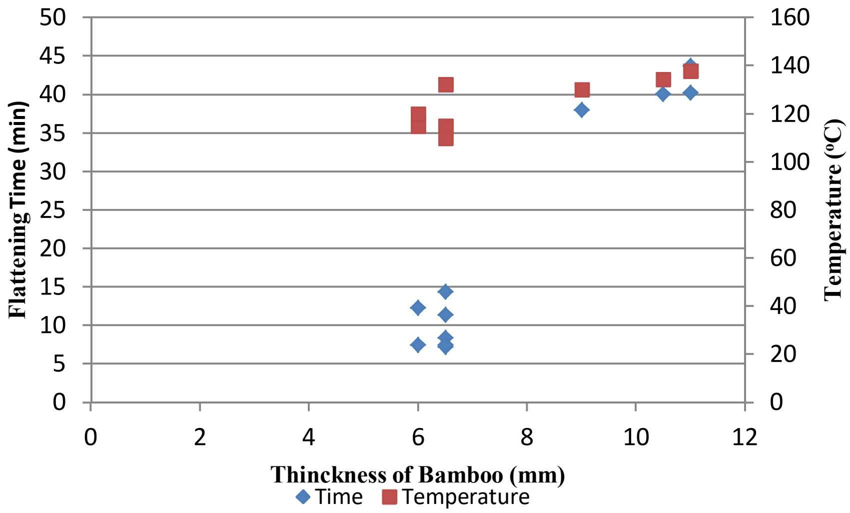

Figure 8. Relation of Bamboo Thickness to Flattening Time and Temperature.

This test proves that the number and location of steam holes designed for the bamboo table were the optimum. Based from the gathered results from table 2, the number of steam holes opened would affect the time it would take for the bamboo culms to be flattened. Moreover, based from the output of each trial, reducing the number of opened steam holes would also reduce the quality of the flattened bamboo.

Table 2. Effect of Number of Opened Steam Holes Results.

Trial	Length (m)	Radius (mm)	Thickness (mm)	Temperature (°C)	Time Elapsed (sec)	Time Elapsed (mins)
1	0.381	50	11.0	125	3480	58.38
2	0.381	50	11.0	120	2859	47.65
3	0.381	50	11.0	120	2415.6	40.26

6. Conclusion

Flattening time and temperature varies directly with the thickness of the bamboo culm as shown in the data. The designed number of steam holes is optimal to produce minimal to no cracks of flattened bamboo culms. Reducing the number of steam holes opened would increase the time to flatten a bamboo culm and also reduce the output quality. The fabricated flattening machine successfully flattened bamboo culms generating an efficiency of 95%. During the conduct of the experiment for the bamboo flattening, the researchers suggested the use of fresher bamboo culms with its nodes removed. Also, cutting the bamboo culms using a fine-toothed saw in order to prevent splints is recommended. In order to further boost the productivity of the flattening machine, it is more convenient to add automation system.

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References

[1] Bamboo Veneer Lathe and Bamboo Flattening Machine. (2018, August 3). DOST-FPRDI. Retrieved from http://fprdi.dost.gov.ph/index.php/technologies/bamboo-veneer-lathe-and-bamboo-flattening-machine

[2] Zhang Q 1988 Studies of bamboo Plywood-I. the softening and flattening of bamboo, *J. Nanjing Fores. Univ.* **4** 13-20.

[3] Park, C N 2015 Flattening of Bamboo by Thermo-mechanical Treatment. 10th World Bamboo Congress, Korea. Retrieved from https://worldbamboo.net/wbcx/Sessions/Theme%20Product%20Design%20Technology/Park,%20Choong%20Nyeon.pdf

[4] Madhavi M, Clouston P L, Arwade, S R 2011 Development of Laminated Bamboo Lumber: Review of Processing, Performance, and Economical Considerations, *Journal of Materials in Civil Engineering,* **23(7)**, 1036–1042.

[5] Farag M M 2015 Quantitative Methods of Material Selection, *Mechanical Engineers's Handbook,* 1-22.

[6] Parkkeeree T, Matan N, Kyokong B 2014 Flattening of half tubular bamboo culms and fixation of bamboo boards, *Journal of Tropical Forest Science* **26(1)**: 101−114.