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Design, Fabrication and Validation of Thin Bamboo Slicing Machine for Bamboo Fiber Processing

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Abstract: Bamboo is a highly renewable and sustainable resource that has a wide range of uses in construction, textiles, pulp and paper, food, medicine, furniture and landscaping. However, the traditional manual methods of bamboo slicing are time-consuming and labor-intensive.This is because the process typically involves cutting the bamboo by hand using a machete or other cutting tool. This can be a slow and physically demanding process, especially for large quantities of bamboo.To address this issue, a bamboo slicing machine was designed and fabricated to automate the process of bamboo slicing. The machine consists of a feeding mechanism and slicing mechanism. The feeding mechanism is used to align the bamboo before slicing, while the slicing mechanism uses a blade to slice the bamboo into the desired thickness. Through detailed research, analysis, and experimentation, a functional prototype of the machine was developed. The results of this research demonstrate the feasibility and practicality of using this machine in real-world applications. The fabrication of this bamboo slicing machine can greatly improve the efficiency and accuracy of bamboo slicing, reducing labor costs and increasing production capacity.

Keywords: Fabrication of Bamboo Slicing Machine, Bamboo Properties

1. Introduction

Bamboo is a grass that grows mostly in warm or tropical areas, where it can play a significant role in the ecosystem. Bamboo provides far too many advantages and products such as food, furniture and many more.[1] Each product will go through different processing due to the final product. From a raw bamboo until get the final product, there is a lot of process that need to be done. Because bamboo have a very different nature from one another, such as type, size, thickness and many more.[2] It make the process become more slower.

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Processing bamboo is a complex and unique process according to their end applications. To get outcome and benefits from bamboo it required a lot of processing and method. For an example, traditionally to splitting a bamboo they used a bamboo splitting knife.[3] Which is required a human skill and a lot of energy. There is too much work to carry out which cause too many workers are needed to succeed the bamboo splitting process. This conventional method also plays with the quality, the time consuming, production rate and consistency.

When we work with humans, we look from the consistency process. Human beings need rest and human beings have different workforce limits each person and have different earnestness daily. Each day will get a different output according to the capacity of the workforce. Every company's overall success depends on its ability to maintain consistency. When you provide consistent, high-quality products, your customers know exactly what to expect each time they buy from you. This improves consumer trust in your brand and can boost the quantity of things you sell. When people buy a product from a well-known and trusted brand, they have high expectations. [4] As we can see there is no consistency that we can promise when we use human workforce to consistently do work.

So that there is a lot of machine that have been create to give a simplify to done all the work [5]. It start from removing the knot, cutting bamboo into similar long,split the bamboo, until slice the bamboo to get the thickness that required.This can greatly increase efficiency and reduce the amount of manual labor required.This can not only make the process faster and more efficient, but it can also reduce the risk of injury to workers who would otherwise have to perform these tasks manually

2. Material and method

2.1 Design Review

First method that need to be done is review all the design and idea that had been displayed in market. Figure 2.1 show the design of thin bamboo slicing machine. All the reviewed design had compared and search for the weakness and all the data collected be analyse and make it as the improvement for the next thin bamboo slicing machine for this project.

Figure 2.1: Design reviewed for a thin bamboo slicing machine

2.2 Design and Modelling

The first step to take is to design and modelling. All the data collect were sketch and design. Figure 2.2 show the sketch made before 2D drawing. The thin bamboo slicing machine will be design using a solid work software. The machine will be design part by part such as the rail, gear and the platform. All the part designed will be joined or combined using mate features in the *Solidwork* software.

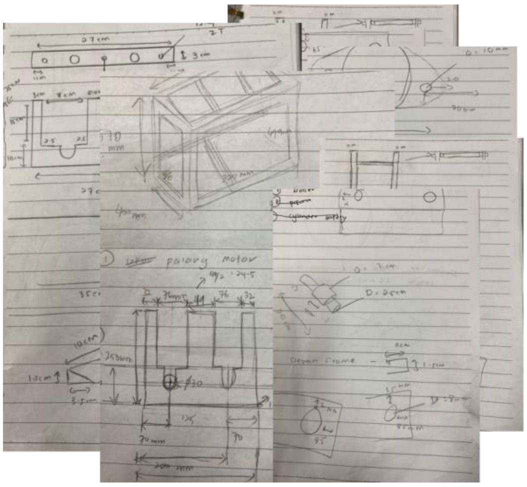

Figure 2.2: Sketch of thin bamboo slicing machine

2.2.1 Part and assembly

For this part, the thin bamboo slicing were sketch using solidwork part by part. Start form choose a plane , sketch and extrude. Figure 2.3 show the sketching method for making part by by of thin bamboo slicing machine.

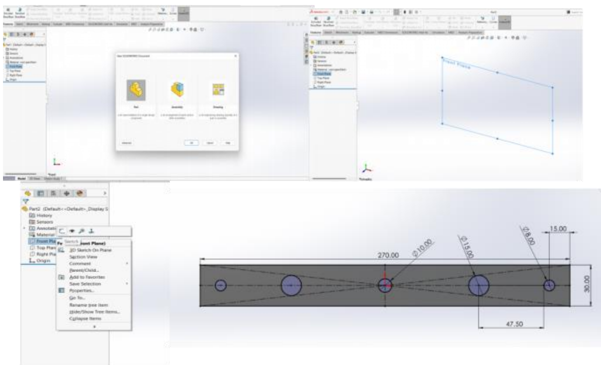

Figure 2.3: Sketching part using solid work

Next, after all the part are ready. The part were assemble become one complex machine. Figure 2.5 show the step to assemble a drawing. First open the new drawing and select assembly, next browse the part that had been draw (B) and mating the part until it become a complete machine.

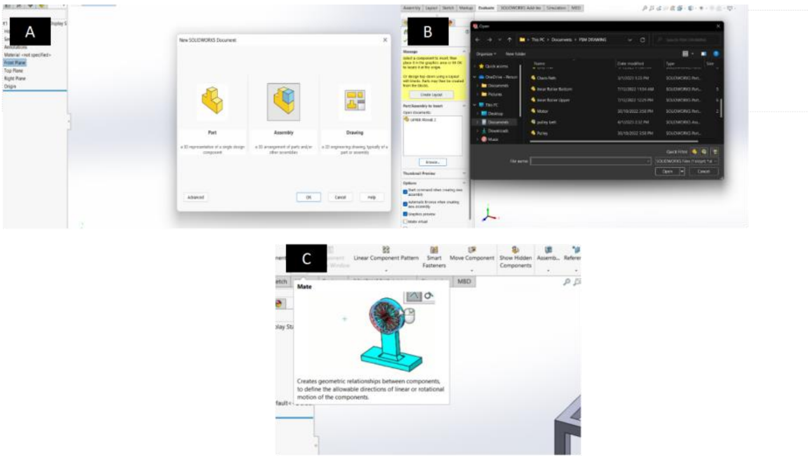

Figure 2.5: Drawing assembly step

2.2.2 Machine Fabrication (outsource fabricator)

The fabrication process were done by the outsource fabricators. The final design were shares out to fabricator. A briefing will be done with the fabricator to explain the situation and the needs of the project. The detail drawing in 2D and 3D were produced and explained to the fabricator. A few meetings were held with the fabricator to explain the material to be used, the tolerance, the critical dimension and all the specification of the machine. The design were show to the fabricator as the guide and clearing which can be done and which should not be done. Throughout the manufacturing of the machine by the fabricator, several visits were made to evaluate and observe the progress of machine manufacturing whether its need improvement or not. Figure 2.6 shows the machinefbricated by the outsource fabricator.

Figure 2.6: Machine fabricated by outsource fabricator

2.3 Machine Evaluation

In this section the evaluation were on the physical evaluation and the machine performance.

2.3.1 Physical evaluation

In the physical evaluation, the activity that were evaluate are visual inspection, dimensional measurement compare to drawing and functional testing.Physical machine evaluation is often used to identify any issues or problems with the machine that may need to be addressed, such as wear and tear, mechanical failures, or other types of damage.Figure 2.7 shows the evaluation made with the fabricator.

Figure 2.7: The physical evaluation with the fabricator

Other than that in the evaluation also, the power connection will be test. it is important to test the power connection during machine evaluation to ensure that the machine is receiving an appropriate and stable supply of electricity. This can involve checking the voltage, current, and power factor of the power supply, as well as testing the quality of the power connection itself. Testing the power connection can help to identify any issues or problems with the power supply that could affect the machine's performance, such as voltage fluctuations, power surges, or grounding issues.

The machine's electrical system were check either it was properly grounded and that all electrical connections are secure and free of damage, as this can help to prevent electrical accidents or fires. All this evaluation are made visually by checking the wire connection.

2.3.2 Machine performance

In this part, is commissioning and testing work. The machine were run and test to make sure it was functioning correctly and meet the requirement. These tests include running the machine without any input or sample material to ensure that it is operating correctly under normal conditions. The first step after on the power was to check the rotational speed using the tachometer. The rotational speed were measured without any sample for the first run. The rotational speed that measured must be same to the rotational speed that already set up before the fabrication process. After the machine has been run without a sample, it may be tested with sample material to ensure that it is able to process or analyze the sample correctly and to determine its performance characteristics.

For the machine evaluation, the angular velocity were measured also. Measuring angular velocity can be useful in machine evaluation for a number of reasons. Angular velocity can be used to determine the speed at which a machine or component is rotating, which can be important for evaluating its performance and ensuring that it is operating within safe and efficient limits. Angular velocity can also be used to detect imbalances or other issues with the machine's mechanical systems, which can cause vibrations or other problems if left unchecked. In addition, measuring angular velocity can help to identify trends or patterns in a machine's performance over time, which can be useful for predictive maintenance or for identifying potential issues before they become serious problems.

Figure 2.8 show the section for the measurement in thin bamboo slicing machine. There is three section which is cutting section (S1) , transmission section (S2) and feeding section (S3).

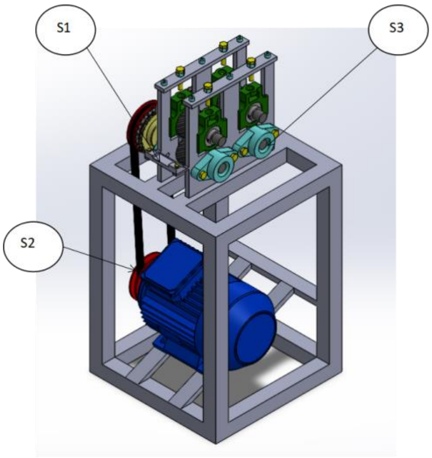

Figure 2.8: Section in thin bamboo slicing machine.

Table 2.1: Measuring method for section in thin bamboo slicing machine

Point of measurement	Measuring tool/ method
S1	Calculation, Vernier Carliper
S2	calculation, Tachometer
S3	Calculation, Tachometer, Vernier Carliper

3. Results and Discussion

3.1 Machine design

Figure 3.1 there is three section in the thin bamboo slicing machine which is transmission section, cutting section and feeding section. All the design have their own specification and use.

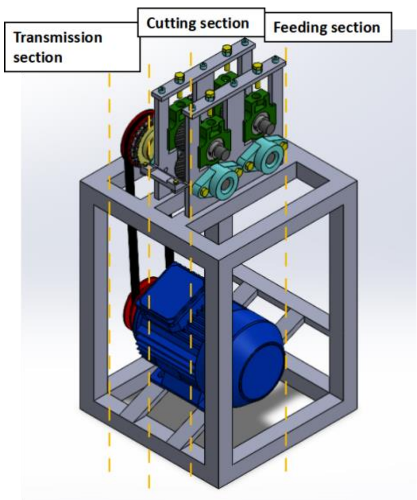

Figure 3.1: Section in thin bamboo slicing machine.

3.3 Physical evaluation

Physical evaluation is a process of testing and assessing the performance and functionality of a machine or mechanical system. After machine were received from fabricator, the physical evaluation were made to ensure that the machine performs as intended, as well as more detailed inspections to check for any defects or issues in the fabrication process.The thin bamboo slicing machine that have completely fabricated. Figure 4.2 shows the overall machine that had been fabricated followed as designed. The fabricated part is still at the acceptable tolerance.

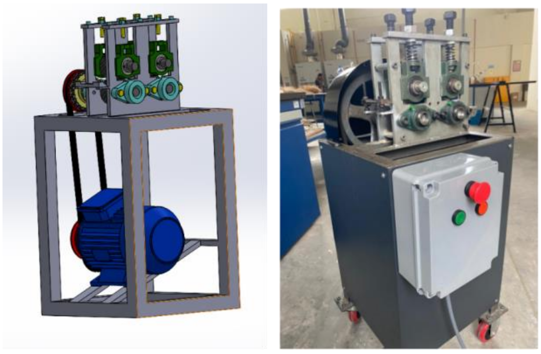

Figure 4.2: Thin bamboo slicing machine

The machine had been test and have meet the intended purpose which is thin bamboo slice. The blade and roller were function well and it make an impact to the bamboo slicing process start from now.

3.4 Machine performance

In this following result discuss about the revolution per minutes of the machine, the velocity and the efficiency of the machine.

3.4.1 Machine performance validation

i. Revolution per minutes

The revolution per minutes of the thin bamboo slicing machine were measured. The RPM of a machine were measured using a tachometer, which is a device that measures the rotational speed of an object. RPM is calculated by dividing the number of revolutions that an object makes in a minute by the number of minutes it takes to make those revolutions. RPM can be a useful measure of the speed of a machine or device because it allows to compare the speed of different machines or devices on a RPM of lower roller common sale.

Table 3.1: Validation of feed section

Type of roller	Rotational speed (RPM)		
	Calculated	Measured	Erorr %
Upper	373.34	366.5	1.83
Lower	373.34	366	1.97

Table 3.2: Feeding performance

Sample type		Fed section (RPM)	
		upper	lower
without sample	t= 0 mm	366.5	366
with sample	t= 2mm	359.6	365.7
	t= 4mm	357.3	365.7
	t= 6mm	344.03	365.7

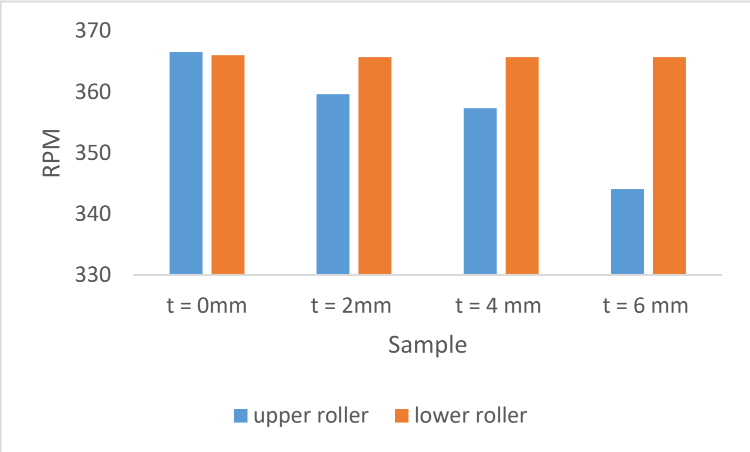

Figure 3.3: Analysis of feeding performance graph

Figure 3.3 shows the RPM for the upper roller and the lower roller of thin bamboo slicing machine. As in the table the machine move without sample have two value of RPM which is calculated value and measured value. The calculated value are the expecting RPM that we put to the machine. The calculated RPM value for the upper roller is 373.34rev/min and the measured is 366.5 rev/min with 1.83% of error. While for the lower roller, the calculated value is 373.34 rev/min which is parallel to the upper roller. The measured value is 366.0 rev/min give it with 1.97% of error. The error is still in the acceptable value.

Other than that, the machine performance had been test by using three different thickness of bamboo which is 2mm, 4mm and 6mm. For the upper roller, the RPM for the roller when the 2mm of bamboo is 359.6 rev/min while the RPM of the roller when 6mm bamboo fed is 344.30. The more the thickness of the bamboo, the lower the value of the RPM.The thickness of the bamboo that is fed into a roller can affect the RPM of the roller because it can change the load on the roller. If the bamboo is thick, it may require more force to move it through the roller, which can cause the RPM of the roller to slow down. On the other hand, if the bamboo is thin, it may require less force to move it through the roller, which can allow the RPM of the roller to increase.

For the lower roller, the RPM are constant which is slightly 366 rev/min. It is possible for the lower roller of the machine have a constant RPM compared to the upper roller, depending on the design of the system and the way that the rollers are powered. The lower rollers in the machine are driven by motors, in which case the RPM of the lower roller can be independently controlled. RPM of the lower roller are constant, while allowing the RPM of the upper roller to vary based on the load of the bamboo.

ii. Linear velocity

Velocity is significant because it has an impact on how long an operation, such machining a part, takes to complete. If an acceleration analysis is to be done, a mechanism's velocities must be determined.

Table 3.3: The velocity of roller (feeding section)

Sample type		Upper roller		Lower roller	
		Mesured (m/min)	Efficiency	Measured (m/min)	Efficiency
without sample	t= 0mm	80.38	97.70	80.49	97.84
With sample	t= 2mm	79.08	96.12	80.40	97.73
	t= 4mm	78.57	95.50	80.42	97.75
	t= 6mm	75.66	91.97	80.43	97.76

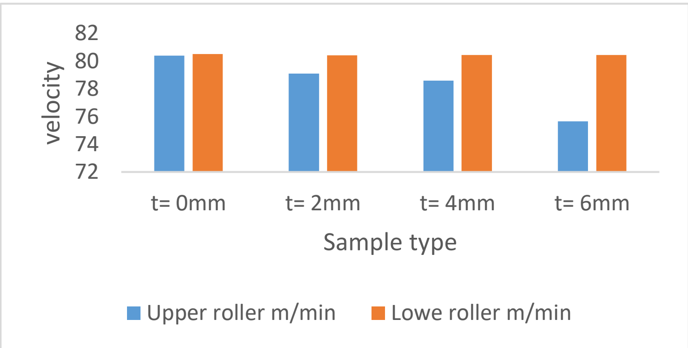

Figure 3.4: The velocity of the upper and lower roller

Figure 3.4 show the velocity of the upper and lower roller of the machine. The velocity of the upper and the lower roller when it was test without sample were same as the upper roller will follow the rotational of the lower roller.

When the roller is fed with the 2mm thickness of bamboo the velocity for upper roller is 79.08 m/min while when the 6mm thickness of bamboo is fed to the upper roller the velocity is 76.66 m/min which is lower than the 2 mm thickness. Theoretically, an increase in RPM will result in an increase in velocity for a rotating object. This is because RPM is a measure of the speed at which an roller is rotating, and velocity is a measure of the speed at which an roller is moving. There are some limitations to this relationship, however. If the load on the roller is increased, it may be more difficult to increase the velocity, even if the RPM is increased.

As the theory of RPM, the measured velocity for the lower roller remain slightly same which is 80.4 m/min. The velocity of the upper roller will typically be slightly different from the velocity of the lower roller. This is because the distance between the two rollers will cause the lower upper to rotate at a slightly different speed. The difference in speed is known as slip, and it is typically a small fraction of the speed of the lower roller.

3.5 Machine productivity

Machine productivity and efficiency are important factors to consider when designing and operating any type of machinery or equipment. Productivity refers to the amount of output produced by a machine in a given period of time.

Table 3.5: Production rate and Production capacity of machine

Sample type	Production rate (unit/min)	Production capacity kg/h
t = 2mm	67.64	54.00
t = 4 mm	59.64	47.58
t = 6mm	50.72	40.44

In the table 3.5, production rate for the 2mm thickness slice of bamboo is the highest which is 67.64 unit/min while the production rate for the 6mm thickness of slice bamboo are the lowest which is 50.72 unit/min. This is show the thickness of bamboo fed into a roller increases, the production rate will decrease. This is because thicker bamboo will require more force to pass through the rollers, leading to more resistance and a slower production process. The increase in resistance is due to the fact that thicker bamboo has more fibers, which are more tightly packed, making it harder for the rollers to compress and process the bamboo. Additionally, the increased thickness of the bamboo may also cause the rollers to wear out more quickly, which can further decrease production rate.Additionally, if the rollers are not designed to handle thicker bamboo, they may become jammed or damaged, further slowing down production.

Other than that, with the production rate we can get the production capacity of the machine. The production capacity for the 2mm slice bamboo is higher with 54kg/h while the production for the 4 mm and 6 mm are decrease with 47.58 kg/h and 40.44 kg/h respectively. The production rate the machine can affect the production capacity, in that if the production rate is low, the total output over a certain period of time will also be low. Therefore, a low production rate can limit the production capacity. In case of bamboo, if the production rate decreases due to an increase in bamboo thickness, production capacity will also decrease.

3.6 Cutting evaluation

Figure 3.5: Bamboo that have been slice

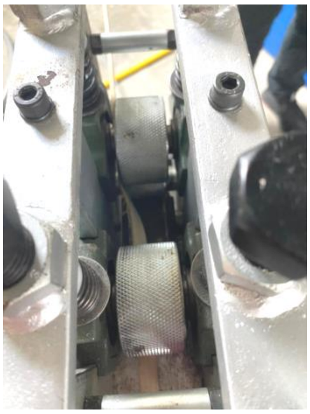

Figure 3.6: Bamboo stuck in the roller

Such shown in the figure 3.5, The machine have been successfully slice the bamboo into the required thickness. Unfortunately, every design will not be perfect with just one attempt. There is a few failed that have been occur while running the machine which is the bamboo will once in a while do not follow the groove that has been made, making the bamboo stuck and unable to be cut such as figure 3.6.

Different nature of bamboo make the bamboo hard to split. Bamboo is a type of grass that is known for its strength and durability. The stems, or culms, of bamboo are hollow and filled with a thick, fibrous material that gives the plant its strength. This thing maybe make the bamboo difficult to split, as the fibers in the stem are tightly packed and difficult to separate.

Another possible that the machine is getting jammed and stuck is because the debris or dust that's building up in the cutting mechanism or roller, preventing the bamboo from moving smoothly through the machine. This could be addressed with regular cleaning and maintenance.

4. Conclusion

On the accomplishment of the project,can be conclude that the thin bamboo slicing machine was fully fabricated. The main objective to design and fabricated the machine is a success. The machine can efficiently slice the thin bamboo. This machine has the potential to significantly simplify the process of slicing bamboo, making it more efficient and less labor-intensive.

The machine, process, and product can all be improved with recommendations. These are some recommendations based on the tests and analyses that were done for additional study that will be conducted soon. The recommendations are as follows: change the blade to a sharper one. This will reduce the force needed when cutting the bamboo. Lastly, the bamboo path into the roller need to give more attention. The roller of the machine need to be aligned to prevent the bamboo derailed and make the bamboo stuck between the roller.

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