JURNAL TEKNIK MESIN DAN MEKATRONIKA
Journal of Mechanical Engineering and Mechatronics
ISSN: 2527-6212, Vol. 10 No. 2, pp. 34 - 45

Preliminary Design of a Local Bamboo Shaving Mechanism for Improve Domestic Stick Production

Rolan Siregar[1,a], Joko Susilo[2,b], Rusli Ottovery[3,c], Yefri Chan[4,d], Yendi Esye[5,e], Suzuki Syofian[6,f], Danny Fatturachman[7,g]

[1,2,3,4]Departmens of Mechanical Engineering, Faculty of Engineering, Darma Persada University, Indonesia
[5]Departmens of Electrical Engineering, Faculty of Engineering, Darma Persada University, Indonesia
[6]Departmens of Information Engineering, Faculty of Engineering, Darma Persada University, Indonesia
[7]Departemens of Marine Engineering Systems, Faculty of Engineering, Darma Persada University, Indonesia

[a]Corresponding authors: rolansiregar@ft.unsada.ac.id

Abstract
Indonesia has abundant natural resources such as bamboo. Almost throughout Indonesia, bamboo growth can develop well, but bamboo processing is relatively low and even bamboo products are still widely imported from abroad such as bamboo sticks. So, in this study, a bamboo stick production machine design was carried out as an effort to improve domestic technology. Furthermore, observations were made on the quality of local bamboo sticks produced by the machine. The method used is product design which is continued to the machine manufacturing process. After the machine is finished being manufactured, a qualitative analysis of the local bamboo sticks produced by the machine is carried out. The results of the study showed that the bamboo stick production machine can work according to expectations. Of course, continuous optimization needs to be carried out so that appropriate domestic technology is obtained that is useful for the community which is called a domestic product. Furthermore, based on observations of the bamboo sticks produced, it can show great potential for use in various ways. But it needs to be continued to achieve maximum quality. Ultimately, technological independence in bamboo processing can contribute to national development from the agricultural sector.

Keywords: Bamboo processing, Bamboo stick, Domestic technology, Gigantochloa apus

Introduction

Bamboo is a type of giant grass where there are around 147 types of bamboo that grow well in Indonesia, as in [1]. The types of bamboo that are most commonly found in the community are betung bamboo (dendrocalamus asper) and tali bamboo (gigantochloa apus) [2]. According to Musdhalifah Machmud in the 2021 National Integrated Bamboo Development Strategy discussion group forum, "bamboo is very important to be developed towards a people's economy with a touch of technology so that the added value of bamboo is even better [3]". In many regions, bamboo is still primarily sold as raw material in the form of long pieces for use as ladders in building construction. This bamboo is sold at a lower price than processed bamboo. Therefore, it is very important to carry out research and development continuously and from various sides to create bamboo products with high economic value.

In general, the limited bamboo processing technology owned by the community is one of the obstacles to economic growth [4]. According to Adil et al. 2014 [5], market demand for bamboo products is very high both domestically and internationally, of course with more optimal bamboo processing technology. When viewed from the physical properties of bamboo ropes to be used as raw materials for crafts, it shows that all parts from the base, middle, and tip can be used optimally [6]. This shows that bamboo rope pieces are not wasted much so that the value of one whole stem is more economically valuable. The potential for processing bamboo into other forms needs to be considered to support the community's economy such as bamboo walls [7], carrying facilities [1], plywood, food ingredients (bamboo shoots), musical instruments, furniture, charcoal, fish farming equipment, medical devices [8], and advanced materials [9][10]. Of course, bamboo stick processing is one of the most promising potentials to be developed because the need for sticks is very high in Indonesia, such as for food skewers such as sausage and satay skewers. To get added value and quality of bamboo, various methods need to be carried out such as preservation, drying, and color stabilization processes.

Another form of bamboo processing that is currently developing is processing with lamination and bending techniques into furniture products with good aesthetic value [11]. Another craft that has added value in bamboo processing that currently exists is non-woven bamboo crafts, such as frames that are given patterns [12] according to consumer demand. In addition, innovative bamboo products are household products made from bamboo such as storage for small items [13], and building construction materials [14]. These various innovations need to be socialized to bamboo producing communities, so that they get a lot of information for consideration in developing bamboo processing. The type of bamboo discussed in this study is tali bamboo or what is often called apus bamboo (gigantochloa apus). This choice was made because the availability of apus bamboo in Indonesia is very large and the processing of apus bamboo is relatively easier than other types of bamboo.

One of the greatest potentials of bamboo processing is to create a bamboo stick production machine [15]. Where, bamboo sticks are widely used for community needs such as food skewers and incense sticks [16]. Usually, these bamboo stick production machines are still limited in the market and the price is still relatively expensive. In addition, some machines are still imported from abroad, this creates a dependency on foreign products. Therefore, in this scientific paper, the design of a bamboo stick production machine will be discussed. So the formulation of the problem is The problem formulation is how the mechanical system for shaving bamboo works and how to produce bamboo sticks with maximum quality. It is hoped that this research can play a role in creating domestic products with quality and prices that are able to compete in the market. Of course, this innovation has great benefits such as creating business opportunities for farming communities in bamboo processing and automatically has the potential to create new jobs and support the community's economy.

Materials and Methods

Properties of apus bamboo (Gigantochloa apus)

Gigantochloa apus has local names in Indonesia including awi tali, bambu tali, deling apus, bambu apus, pring tali, and pring apus [17]. In general, the physical characteristics of apus bamboo are light green to dark green, relatively straight, tough stems, reaching 8-13 m in height, 45-65 cm in internode distance, 5-8 cm in diameter, and 3-15 mm in thickness and growing in both lowlands and mountains [17]. In Figure 1 below, you can see a pile of apus bamboo stems that have just been harvested by farmers for sale.

Fig. 1 Photo of apus bamboo in Bojongmangu, Kab. Bekasi, West Java

This bamboo has sufficient strength and resilience so it is widely used in bamboo crafts and also for building construction [18]. According to Ndale 2013 [17] and Wulandari 2020 [6] the physical and mechanical properties of apus bamboo (Gigantochloa apus) need to be known to determine the material properties before being applied to its function. Several things that affect the physical and mechanical properties of bamboo are the position of the bamboo sample from the base to the tip, diameter, age of the bamboo, thickness of the bamboo flesh, loading position, specific gravity, and water content of the bamboo [17]. Based on research [6] where the physical properties of rope bamboo consist of fresh bamboo water content (72.22 - 162.94%), air dry content (12.03 - 33.33%), fresh volume specific gravity (0.24 - 0.61 gr / cm3), and dry air volume specific gravity (0.67-0.68 gr / cm3). From the properties of apus bamboo, it will be supporting data in improving the quality of bamboo stick production in the future.

Specifications of bamboo stick production machine

The design of this bamboo stick production machine was made by referencing various sources so that it is attempted to have advantages over existing machines [4], [9], [14], [15], [19]. This machine has a relatively low motor power specification so that it is easier to use by household industries with small electrical power quantities. In addition, the machine is made with a relatively small size so that it is easier for moving operations. The specifications of the machine designed are a bamboo stick production machine with a capacity of 10,000 sticks / hour. The diameter of the bamboo stick is 3 mm with a stick length between 15 cm to 25 cm. One planing process takes 1.5 seconds where there are four chisel holes, so it is estimated to reach 9600 sticks per hour or close to 10,000 sticks per hour. In general, the specifications of the stick production machine can be shown in Table 1.

Table 1. Machine and product specification

Parameters	**Specifications**
Process stage	Shaving
Bamboo type	Gigantochloa apus
Max. machine dimension	500x600x1000 mm
Production number	10000 / hour
Stick length	15 - 25 cm
Stick diameter	∅3 mm
Motor Power	1500W

Research methods

In general, this research method uses an experimental approach. Machine performance testing is conducted to determine the machine's performance in producing local bamboo sticks. The design of this bamboo stick-making machine consists of several stages that are described systematically. The machine design method is carried out as the stages of the product development process in engineering [20]. The stages of the bamboo stick production machine manufacturing process can be made in a flowchart as in Figure 2.

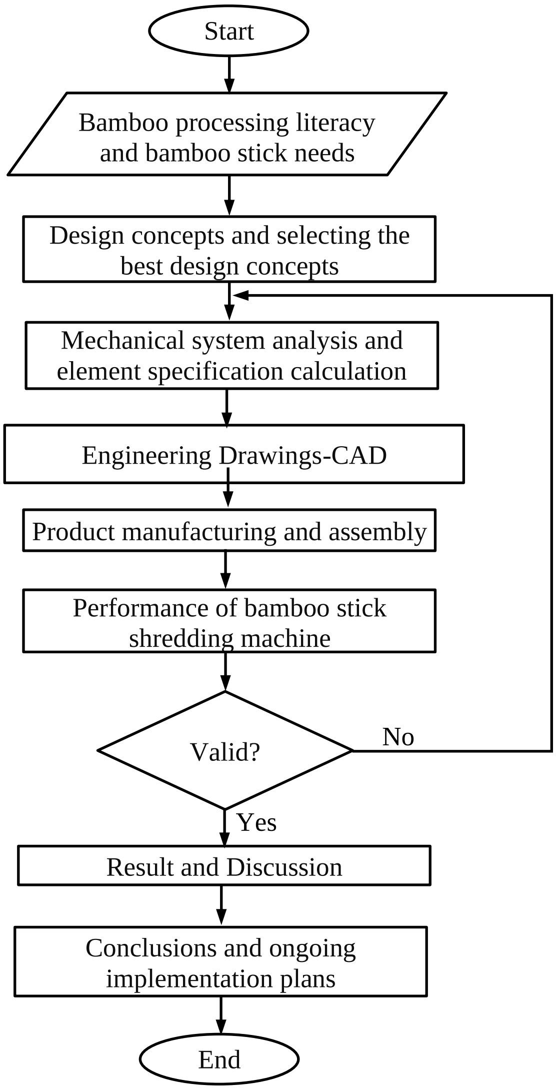


Fig. 2 Bamboo stick machine manufacturing flowchart

It can be explained that the manufacturing process begins with a literature study on bamboo properties, urgency, and benefits in bamboo management. After that, design considerations will be made, mechanical system analysis and component specification calculations, presenting technical drawings, fabrication and machine assembly. In general, the bamboo planing process consists of cutting the bamboo by removing the nodes, splitting the bamboo, and thinning the bamboo to achieve ideal shapes before entering the planing machine. The preparatory stages before planing are not discussed in this research. The focus is on the planing process because the research objective is to determine the effectiveness of the designed machine in producing bamboo sticks. The bamboo species studied was apus bamboo. If a more optimal shaving result is needed, it can be continued to the drying and smoothing stage of the stick so that the fibers on the surface can be reduced [19].

The design of the production machine is designed in such a way that it can produce bamboo sticks, and this machine is of course still in prototype form which of course must be developed further so that it is more possible to be distributed to users of this technology. After the bamboo stick production results are available, a quality analysis needs to be carried out so that in the future it can be optimized again in the process of making bamboo sticks from local materials and with even better quality. In general, bamboo management needs to be carried out sustainably, even though it may be simple, this activity can help bamboo producing communities in developing their economic potential.

Results and Discussion

The results of the bamboo stick machine design

The machine design results are made in the form of a Computer Aided Design (CAD) based design and based on the results of mechanical calculations and design concepts. This bamboo stick design can be seen in Figure 3.

Item	Qty	Description
1	1	Structure
2	4	Wheel
3	20	Bearing
4	10	Axle
5	8	Sprocket
6	1	Motor
7	8	Roller Rubber
8	32	Spring
9	36	Thread axlle
10	1	V-Belt
11	1	Pan
12	1	Shaved chisel
13	1	Track
14	1	Chain 2
15	10	Gear
16	1	Pulley 1
17	1	Pulley 2
18	2	Chain 2
19	1	Turn off
20	1	Dimmer Stepper

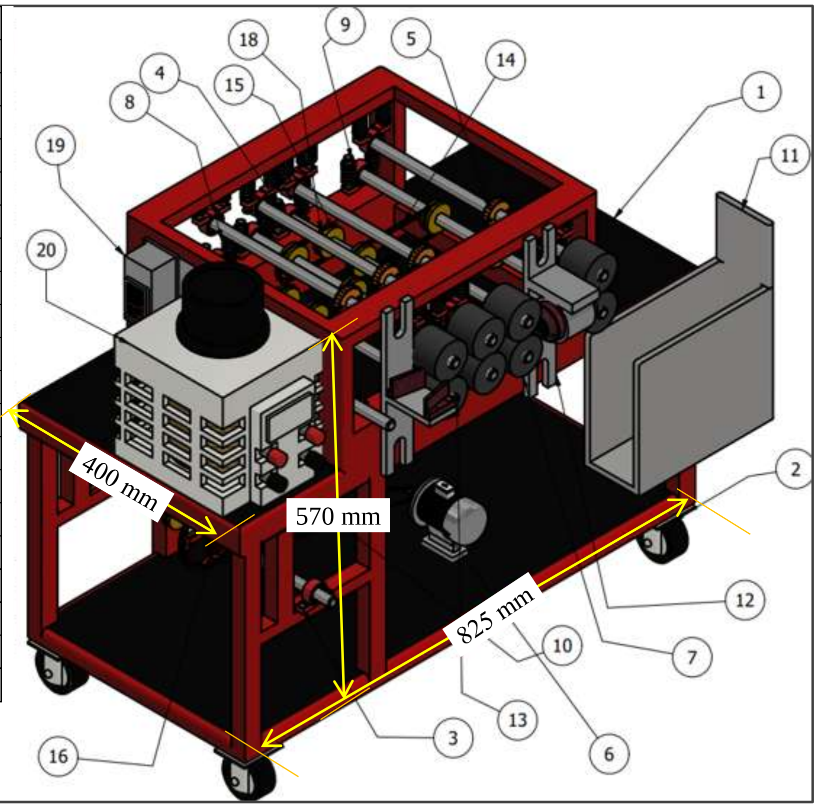


Fig. 3 Design of bamboo stick production machine

Based on this design (Figure 3), then proceed to manufacturing the bamboo stick machine. This will ensure all components are integrated into a synergistic system. Machine component calculations are performed to achieve optimal performance. Some component calculations are shown in this article such as roller shaft strength.

Mechanical system of bamboo stick production machine

The mechanical system in the bamboo stick planer can be seen in Figure 4, where bamboo pieces that have been split into ideal shapes are fed into a pair of rotating rubber rollers that transport them to the planer chisel. This chisel has a hole with a diameter of 3 mm, the tip of the chisel is made very sharp and tapered so that the bamboo pieces can fit into the chisel hole. The chisel hole will shave the bamboo pieces to form bamboo sticks.

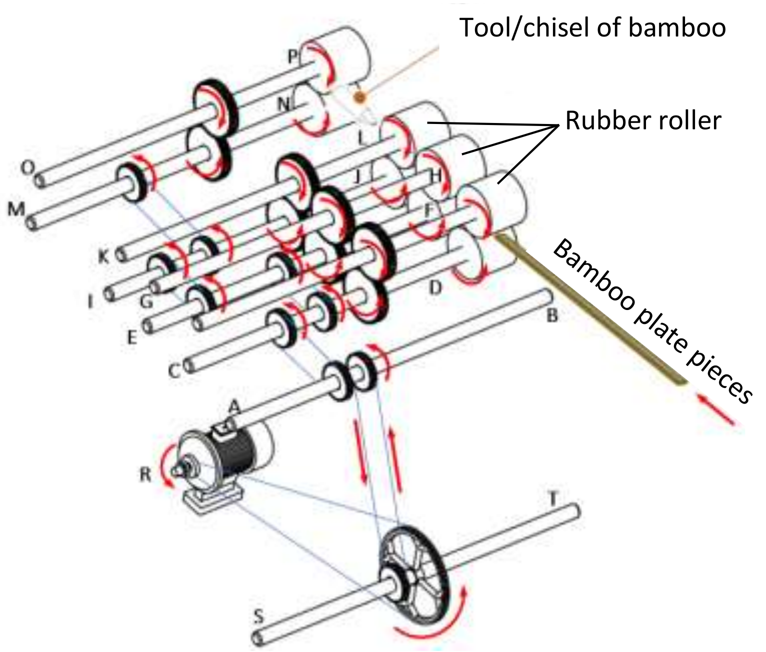
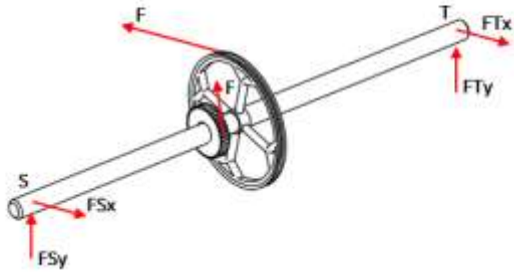
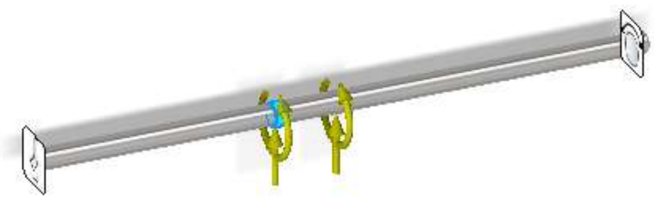


Fig. 4 General form of the mechanical system of the bamboo stick production machine

The rotation of the drive motor is transmitted to a larger pulley to obtain higher torque. Then the torque from the pulley will be transmitted to the gear on the rubber roller shaft. It consists of three pairs of rubber rollers to deliver bamboo pieces to the planer chisel. To determine the specifications of the rods that make up the mechanical system can be calculated with Engineering mechanics calculations. From Figure 4 it can be seen that the power source comes from an electric motor that drives the S-T rod/shaft and this rod is what makes the rotation on all the shafts in the machine. The torque acting on the S-T shaft is obtained by reviewing the free body diagram as shown in Figure 5a and the form of loading can be seen in Figure 5b below.



a



b

Fig. 5 Loading on the drive shaft (ST): a- Load modeling; b- Boundary Conditions in FEA simulation

The simulation approach is based on fixed supports at both ends (statically indeterminate). This is because finite element-based stress simulation modeling takes into account the effects of various stress types, such as principal stresses and shear stresses from various directions. This simulation, of course, is an approach to analytical free-body diagram modeling.
Based on the data from the motor power (the motor power obtained is 1500 W) and rotational speed obtained, the magnitude of the torque acting along with the force on the gear and pulley can be calculated. The assumption of support in the simulation is that the T support is approximated by a fixed support and the S support is approximated by a pin support. The forces acting on the S-T shaft can be seen in Table 2 below.

Table 2. Load on the S-T shaft

No	Item	Value	Unit
1	Force from gear to shaft, F	237	N
2	Torque from gear to shaft, T	4,74	N.m
3	Force from pulley to shaft, F	118	N
4	Torque from pulley to shaft, T	5,93	N.m

Furthermore, the stress and deflection that occur in the rod can be simulated using the Finite Element Analysis (FEA) method as shown in Figure 6.

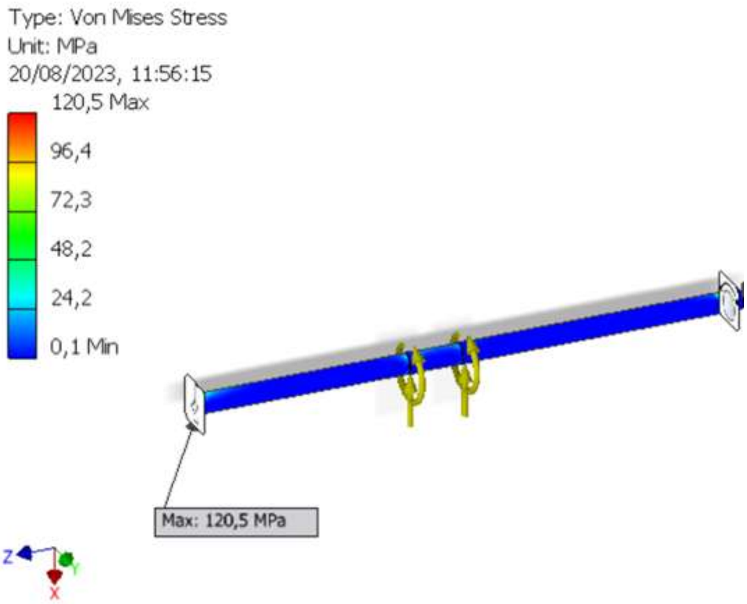


Fig. 6 Stress analysis with Autodesk Inventor-FEA

From Figure 6, the maximum stress is 120.5 MPa, where this simulation is carried out by defining the number of elements and boundary conditions according to the basic science of the finite element method to produce almost the same output from several simulation trials with various types of elements. The material used is AISI 1045with an estimated allowable stress (yield) of 350 MPa. This material is estimated as medium carbon steel in software for stress analysis based on finite element method. Therefore, the shaft used in the structure is safe, with a large Safety factor of 2.9. The diameter of the shaft used is 1.5 cm as the material is easily available in the market. On the same rod, a displacement or deformation simulation was also carried out as seen in Figure 7.

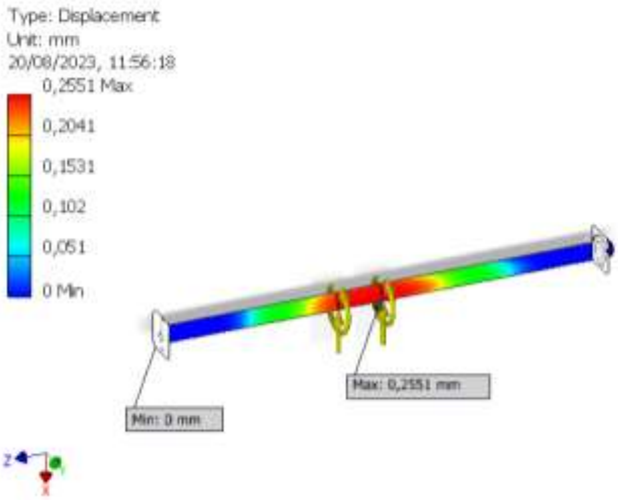


Fig. 7 Deflection that occurs in the ST rod

Based on the results of the displacement simulation in Figure 7, it can be seen that the maximum deflection that occurs is 0.25 mm. This deflection category is estimated to be within the safe limit because it is in elastic deformation, and the small deflection indicates that the shaft design is appropriate. In the same way, a structural strength simulation was also carried out on one of the roller shafts, namely the AB shaft, with the results obtained being 190.9 Mpa with a safety factor of 1.83. Therefore, the design has been included in the safe category. The AB shaft is assumed to have almost the same load as the surrounding shafts, so the AB shaft simulation is considered a representation of the CD, EF, GH, IJ, KL, MN, and OP shafts.

Machine Manufacturing Results

Bamboo stick machine fabrication can begin after the mechanical design of each element has been completed, including calculations of the mechanical structure specifications and other drive machine elements. Figure 8 below shows the results of the bamboo stick machine fabrication.

Fig. 8 Results of bamboo stick machine manufacturing

The capacity of this bamboo stick production machine is designed to achieve a production capacity of up to 10,000 sticks/hour. To adjust the quality of production results, it can sometimes be done by conditioning the rotational speed of the roller. To adjust the size of the drive rotation can be adjusted via a stepper dimmer, so that it can adjust the machine in producing quality sticks. The way this bamboo stick machine works is by turning on the on-off button first then setting the engine rpm using a Dimmer, when the rpm is appropriate the electric motor transmits the V-belt to the Pulley, the Pulley moves to rotate the Iron Axle and gears and chains, the chain moves up to run the V-belt conveyor, then runs the Bamboo to the rubber roll, the rubber roll also pulls the bamboo towards the bamboo planer chisel, the bamboo is shredded and collected in the bamboo container.

Engine Performance Test Results

The machine's performance test was conducted on apus bamboo by first cutting the bamboo (Figure 9a). These pieces were adjusted to the roller capacity for further stick shaving (Figure 9b).


a


b

Fig. 9 Shaving process: *a*- Cutting apus bamboo; *b*- Stick shaving process on the machine

The stick planing process is certainly affected by the bamboo's age and dryness level. However, the machine performance used here assumes air-dried apus bamboo.
Under the designed machine conditions, the bamboo planing process did not always produce perfect sticks. There were still failures in several tests. However, the majority of tests produced good bamboo sticks. Frequent problems in the stick production process are thought to stem from the quality of the bamboo, both in terms of maturity and dryness, as well as the sharpness of the planing chisel, inappropriate bamboo thinning thickness, and the roller thrust may be insufficient.. Table 3 below shows the success rate of apus bamboo stick production.

Table 3. Performance testing of bamboo stick shaving machine

Testing to	1	2	3	4	5	6	7	8	9	10
Feasibility	NG	G	G	G	G	G	G	NG	G	G

Information: G = Good , NG : Not Good

Table 3 shows that the success rate for producing bamboo sticks reached 80%. This percentage is representative of the results of the tests conducted. The quality of the raw materials significantly determines the results of bamboo stick production using this machine. Figure 10 below shows an example of bamboo stick production results.

a *b*

Fig. 10 Example of production results: *a*- Stick shaving failed; *b*- Stick shaving successful

Figure 10b shows that stick production results still need to be improved so that the quality of bamboo sticks is cleaner from fine fibers. The level of bamboo quality is seen from the cleanliness of the sticks assessed from the cleanliness of the fibers and the straightness of the bamboo sticks. Therefore, further research is needed regarding the dryness level of bamboo stick raw materials and also the level of more optimal machine technology. Bamboo has various mechanical properties [21][22] so it is necessary to conduct testing for several types of bamboo. The quality of local bamboo shavings consisting of bamboo tali sticks or apus bamboo (Gigantochloa apus) using this machine still needs to be improved.

Conclusions

Overall, the bamboo stick production machine design has performed as expected. However, the machine's performance still needs to be improved to produce high-quality bamboo sticks. The initial design called for a capacity of 10,000 sticks per hour with a diameter of 3 mm. However, testing has not yet demonstrated this capacity due to several failures in the shaving process. The machine's success rate in producing sticks has reached 80%. Issues that need to be resolved in the machine's construction include the push and pull force of the rollers and the sharpness of the chisel.

In the future, optimization of the drive motor will be carried out to make it more suitable, pulley diameter, roller speed, and chisel sharpness. An in-depth analysis is needed regarding the fine fibers appearing on the stick surface and the cleanliness of the stick surface from fine bamboo dust. The bamboo raw material to be shaved must be carefully considered, such as the level of maturity and dryness. If the bamboo shaver machine is optimally produced, it is expected to contribute to increasing the economic potential of bamboo farming communities. Furthermore, successfully creating a domestic product can contribute to supporting national progress.

Acknowledgment

Thank you to Lembaga Penelitian dan Pengabdian Masyarakat (LPPM) of Darma Persada University for their research and community service grants for the 2024-2025 fiscal year. We would also like to express our gratitude to all our community service teams and partners for their tireless cooperation.

References

[1] W. Anita, "Processing Gigantochloa Apus Bamboo Stems into Carrying Products with Additional Modular Accessories," CALYPTRA, vol. 5, no. 1, page. 1–13, 2016.
[2] E. A. Nurdiah dan A. Juniwati, "Bamboo architecture as a learning project for community development of rural area in Indonesia," in IOP Conference Series: Earth and Environmental Science, IOP Publishing, 2020, hal. 12004.
[3] Ekon, "Sustainable Bamboo Development," Kementerian Koordinator Bidang Perkeonomian Republik Indonesia, 2021. https://www.ekon.go.id/publikasi/detail/2966/pengembangan-bambu-berkelanjutan (diakses 20 Februari 2025).
[4] B. Baihaqi, I. H. Sutrisno, M. Jamil, dan A. Adnan, "Introduction of Eco-Friendly Bamboo Planers for Added Value Creation in the Oloh Aceh Tamiang Farmers Group," JMM (Jurnal Masy. Mandiri), vol. 7, no. 6, page. 5636–5647, 2023.
[5] Z. Adil, H. Sidabutar, C. Susilo, dan A. Justisia, "Market demand study for bamboo products and assessment of bamboo processing technologies," Jakarta Badan Revital. Ind. Kehutan., 2014.
[6] F. T. Wulandari, "Characteristics of the Physical Properties of Bamboo Rope (Gigantochloa Apus Kurz), as a Raw Material for Bamboo Crafts," J. Belantara, vol. 3, no. 1, page. 69–79, 2020.
[7] M. Z. Umar, M. Arsyad, S. Santi, dan A. Faslih, "Principles of sustainable architecture in the production of bamboo woven wall materials (dendrocalamus asper)," Sinergi, vol. 24, no. 1, page. 57–64, 2020.
[8] E. D. Markus, F. Kulor, M. W. Apprey, dan K. T. Agbevanu, "Low-cost electronic bamboo walking stick: an innovative assistive mobility aid for the blind," TELKOMNIKA (Telecommunication Comput. Electron. Control., vol. 20, no. 4, page. 883–891, 2022.
[9] E. Arsad, "amboo processing technology and benefits," J. Ris. Ind. Has. Hutan, vol. 7, no. 1, page. 45–52, 2015.
[10] D. B. S. Dessalegn Ahmed, "Design and Manufacturing of Bamboo Processing Machine with Sanding Bamboo Surfaces, Grinding Knots & Splitting Functions," 2018.
[11] H. Nugraha, "Processing bamboo materials using lamination and bending techniques for furniture products," Widyakala J. J. Pembang. Jaya Univ., vol. 1, no. 1, page. 1–9, 2014.
[12] T. S. Widyaningsih, E. Fauziyah, dan D. P. Kuswantoro, "Bamboo Processing and Added Value in Tasikmalaya, Jawa Barat".
[13] I. W. D. Prayatna, A. M. Gunawan, dan N. A. P. Dewi, "amboo Waste Processing into Household Products: Bamboo Lazy Susan Organizer," J. Desain, vol. 11, no. 2, page. 412–421, 2024.
[14] U. Sayed et al., "Bamboo stick diameter, volume and aspect ratios effect on the compressive behavior of bamboo sticks reinforced concrete mixed with sea sand and seawater," Constr. Build. Mater., vol. 369, page. 130437, 2023.
[15] C. Baseganni, S. Suhel, dan H. Pujar, "Design and analysis of bamboo stick cutting machine," Adv. J. Grad. Res., vol. 3, no. 1, page. 34–40, 2018.
[16] A. K. Sinha dan S. Deb, "A study on the status of incense stick making in Tripura, Northeast India.," J. Bamboo Ratt. (Kerala For. Res. Institute), vol. 15, 2016.
[17] F. X. Ndale, "Physical and mechanical properties of bamboo as a construction material," AGRICA, vol. 7, no. 2, hal. 22–31, 2013.
[18] A. Muhsin, L. M. Febriany, H. N. Hidayati, dan Y. D. Purwanti, "Bamboo material as construction in the great hall of the eco campus outward bound Indonesia," Reka Karsa J. Arsit., vol. 3, no. 3, 2015.
[19] K. A. Widi, N. Sudiasa, W. Sujana, dan L. D. Ekasari, "Development of Modified 3-in-1 Machine Knife Model for Making Incense Sticks in Wagir District, Malang Regency," in Prosiding Seminar Nasional Pengabdian Masyarakat Universitas Ma Chung, 2020.

[20] S. Rolan, A. Husen, P. Akbar Dwi, dan S. Kurnia, “Design and Performance Test of Sieving Machine Technology to Increase Time Efficiency in the Damar Filtering Process,” J. ROTASI, vol. 22, no. 2, page. 95–103, 2020.

[21] Y.-H. Yang, M.-J. Chung, T.-L. Wu, C.-H. Yeh, dan T.-C. Yang, “Characteristic properties of a bamboo-based board combined with bamboo veneers and vacuum heat-treated round bamboo sticks,” Polymers (Basel)., vol. 14, no. 3, hal. 560, 2022.

[22] D. Awalluddin et al., “Mechanical properties of different bamboo species,” in MATEC web of conferences, EDP Sciences, 2017, hal. 1024.