

Design of Air-Jet Assisted Vertical Rotation Natural Fiber Opener

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Abstract

Banana pseudo-stem fibers have great potential to be developed into high value fibers that can be produced into yarns and felts. Loose raw fiber is prepared by extracting the fibers from banana pseudo-stem and breaking it into loose fibers. The current method of fiber breaking process utilizes horizontal spiked drums technique. It has challenges such as fibers are being cut too short, irregular fiber orientation and inconsistent opening. With Air-jet Assisted Vertical Rotation Natural Fiber Opener design, it can improve fiber alignment and uniformity which can improve the separation and produce finer fibers. Additionally, the air-jet assisted design allows for more gentle opening of the fibers, reducing damage and breakage compared to previous mechanical opening techniques. In this study, the method used is by taking fiber weight samples before and after the opening process at a predetermined minute rate which is the first, fifth and tenth minutes and then make a comparison. Two fiber weights have been set which are 30g and 60g. As a result, the fiber opener design works well in the fiber opening process and the fibers are opened more finely and cleanly from contaminants with the help of air jets. The combination of air jets and vertical rotation design contributes to the effectiveness of the opening mechanism, making it a valuable tool for various applications in the textile industry.

1. Introduction

Natural fibers are being used in large quantities to make non-woven by replacing synthetic fibers due to environmental awareness [1],[2]. Natural fibers are being used to replace synthetic fibers due to increased environmental awareness because synthetic fibers give negative impact on the environment, contributing to the accumulation of non-biodegradable waste and the release of harmful chemicals during production and disposal. Products made without weaving (non-woven) are considered profitable or beneficial due to cost-effective production, versatility, and sustainability. They offer lower production costs, faster turnaround times, and unique material properties, making them a cost-effective choice for businesses. Additionally, non-woven materials can be engineered for specific applications, are often made from recycled or renewable resources, and find use in a wide range of industries, contributing to their sustainability and profitability. Non-woven is often praised for their positive qualities, such as durability, cost-effectiveness and also specific characteristics that make them suitable for certain uses. These include high absorbency, effective filtration, breathability, softness and comfort, as well as exceptional strength and durability - all of which allow non-woven to be used in a wide range of applications across various industries, from personal care products and protective clothing to industrial

filters and reinforcement materials. Fiber from banana stems has great potential to be developed into material fiber high-value composites [3], including as replacement materials in the industrial and medical fields [4].

The textile industry is experiencing a paradigm shift towards sustainable practices that increasingly emphasize the use of natural fibers. However, efficient natural fiber processing presents challenges such as irregular fiber orientation, ununiformed length with many broken fibers, and inconsistent openings. Instead of waste material, it is converted into fiber, so the problem that can be detected is that the yarn produced will be of poor quality as a result of the improper fiber opening process [5]. Traditional methods of opening natural fibers are relatively slow in processing impurities from the epidermis, and also in achieving the desired level of uniformity and efficiency, which affects the downstream manufacturing process [6],[7].

The existing fiber opening process is using a horizontal cylinder opener which has several limitations and drawbacks [5]. The horizontal cylinder opener has a limited throughput capacity, which can restrict overall production efficiency. Additionally, the design can result in uneven fiber opening that breaks into short fibers, leading to inconsistencies in the final product. The horizontal cylinder opener also requires frequent maintenance and cleaning, increasing operational costs and downtime. Furthermore, the mechanical action of the opener can potentially damage the fibers, reducing their quality and performance. Finally, the inflexible design of the horizontal cylinder opener makes it difficult to adapt to changes in fiber types or processing requirements, limiting the versatility of the fiber opening process [5]. To address the weaknesses of the horizontal cylinder opener in the fiber opening process, the fiber opener needs to be upgraded to a more efficient opener design, optimizing the operating parameters as well as exploring more alternative fiber preparation methods. By taking these steps, it can reduce the limitations of the horizontal cylinder opener, such as low throughput, uneven fiber opening, potential fiber damage and lack of flexibility and improve the overall efficiency and quality of the fiber opening process [8]. The design and implementation of the proposed opener aims to overcome the limitations of traditional approaches, and provides a promising way to achieve a uniform opening size [9].

By critically analyzing the strengths and limitations of existing designs, the results include the effect of air flow speed and rotational spike speed on the separation and efficiency of open fibers, which ultimately break into separated single fibers, as well as their mechanical properties such as the weight and thickness of finer and smaller fibers in their dimensions. By developing an air-jet assisted vertical rotation natural fiber opener mechanism, it will be possible to produce finer fiber materials.

Nomenclature is included if necessary

g	gram
cm	centimeter
V	Voltage
%	percent
AC	Alternating current
DC	Direct current

2. Materials and Methods

Basically, there are four main stages to complete this research; the design stage, fabrication and assembly, materials and samples preparation and finally the testing stage. In the first stage, fiber opener mechanism was designed. Current and existing fiber opener had been studied and reviewed. Based on the existing concept, few mechanism models were shortlisted and finalized. The structural mechanism frame was fabricated in the laboratory and electromechanical components were installed accordingly. The assembled mechanism prototype was tested for the operation sequence verification, functionality and its efficiency in parameter.

2.1 Mechanism Design

A fiber opening machine is a textile industry tool used for the purpose of separating and opening raw fibers. The fibers are subjected to spiked beaters or rollers when entering the work area. The beater is equipped with blade, serving as its main function to break up and disperse fiber clumps into individual fibers. The presence of blade facilitates fiber breakage while producing more homogeneous fiber dispersion. Fig. 1 shows the design structure of Air-jet Assisted Vertical Rotation Natural Fiber Opener is sketched in design modeling. The main part in assembling the design is the beater in the middle which is the rotor during the fiber opening process test assisted by the rotation of the motor.

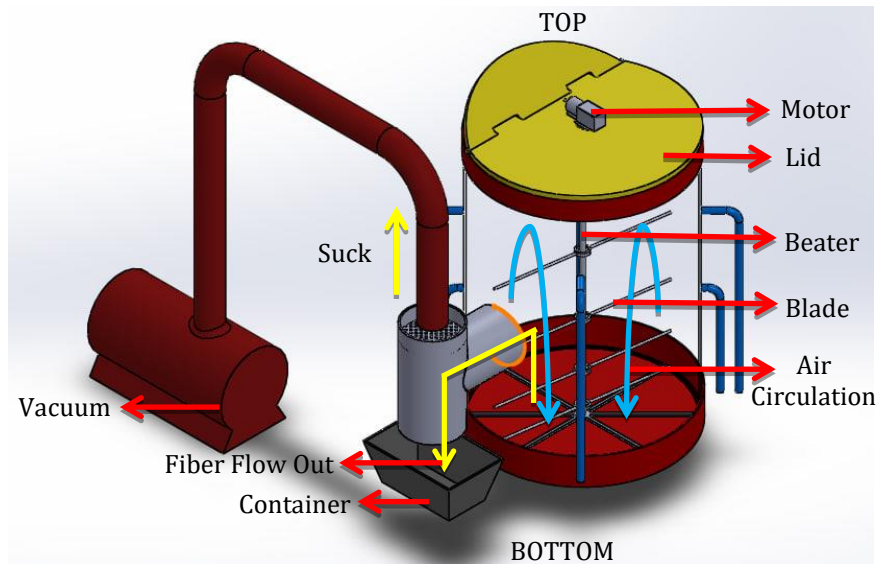


Fig. 1 Design Structure of Air-jet Assisted Vertical Rotation Natural Fiber Opener

2.2 System Design

Fiber separation is achieved through a combination of the vertical rotation, blade configuration and air jet assistance. The overall design aims for user-friendly operation, energy efficiency and compliance with regulatory standards, providing a complete solution for natural fiber processing. As outlined in Fig. 2, the system configuration for the design of Air-jet Assisted Vertical Rotation Natural Fiber Opener involves an orderly arrangement of the main components. The power supply ensures efficient distribution of electricity to all system components. This comprehensive design ensures a balanced and efficient control system for specific openers.

The system consists of several main components, including a motor, a motor speed controller, and an AC to DC switching power supply (PSU). A 3-pin cable wire plug has been installed on the AC to DC switching power supply to ensure a stable power supply. Next, the gear motor speed controller as an input component is also connected to the PSU to enable precise control over the motor speed, which is important to maintain a consistent fiber processing rate. As for the output component, a 12V 470RPM motor provides the necessary rotational energy to drive the fiber opener. In the design of vertical rotation natural fiber openers with the help of air jets, system design plays an important role in ensuring efficient and controlled processing of natural fibers. The integration of the motor, motor speed controller, and AC to DC switching power supply provides a reliable and stable power supply to the system, while the air jet mechanism improves processing efficiency by segregating the fibers all around in the chamber/cylinder.

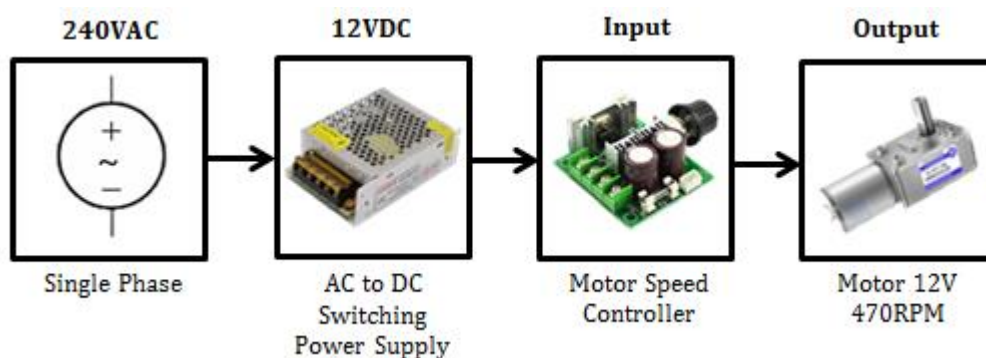


Fig. 2 System Configuration

2.3 Materials and Samples Preparation

The raw banana pseudo-stem fiber is produced from raw until it is extracted and dried. The fiber is harvested from mature banana trees and extracted using a manual decorticating process. After extraction by using 3 phase powered fiber extractor machine (FEM-3P), the fibers are washed with water to remove any impurities or residues. The fiber was then air-dried under ambient conditions for 24 hours. Next, a random sample of 20

fibers was selected and their length was measured using a ruler. The average fiber length was found to be 220cm with a standard deviation of 10cm. The fibers were then cut into 7cm lengths and stored at room temperature until further processing as shows in Fig. 3.

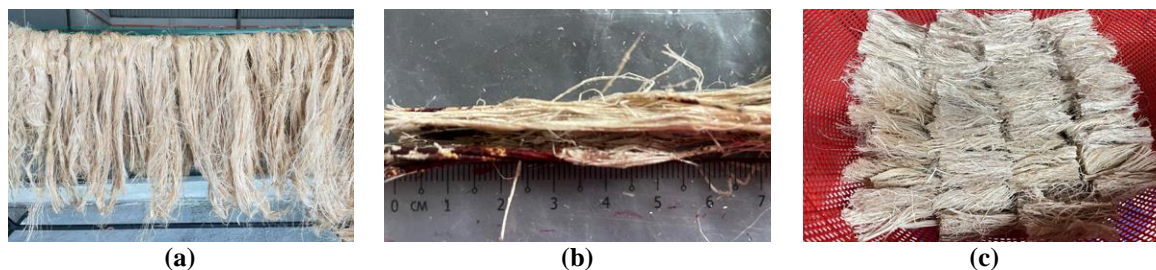


Fig. 3 Materials and samples preparation (a) Banana fiber are dried; (b) Fiber are measured; (c) Fiber was cut to 7cm in length

2.4 System Testing

The test is carried out by dividing $1/3$ and $2/3$ of the total weight of the fiber to be tested. The test is calculated by observing the fiber opening at three different minutes namely 1 minute, 5 minutes and 10 minutes. The testing process is carried out by taking the fiber weight per minute that has been stated to find out the percentage of soluble banana fiber. The fiber weight is recorded for each time the machine is stopped. Tests were conducted on banana pseudo-stem fiber weights of 30g and 60g by taking 3 samples at minutes 1, 5 and 10.

3. Result and Analysis

3.1 Machine Functionality Test

The ability of a mechanism to effectively open natural fibers is evaluated by evaluating its ability to consistently produce high-quality fibers with minimal defects. The results of the study show that the mechanism is capable of achieving a high level of reliability where this fiber opener can not only be used on banana fiber, but it can also be used to open other fibers such as pineapple, jute, kenaf and others. By referring to Table 1, the efficiency can also be measured by calculating the percentage of soluble and cleaned fibers. Therefore, the calculation to determine the percentage of impurities that have been removed according to the minutes that have been set on two separate samples of 30g fiber and 60g fiber has been made. The percentage has been recorded in Table 2 and illustrated in the form of a graph in Fig. 6 to find out the effectiveness of the fiber opener with the weight of the fiber that has been used.

As in Table 1, it clearly shows the banana fiber opening process by using a fiber opener with an air jet system works well. At 30g of banana fiber, when it was put into the fiber opening machine, the minute 1 recorded as much as 27.88g of insoluble fiber weight of which the dirt that had been removed was as much as 2.12g. At the minute of 5, the fiber weight decreased to 25.93g and 23.97g at the 10 minute. This shows that the final weight of dissolved fiber for a 30g sample is 23.97g with 6.03g of dirt removed which makes the fiber finer than before.

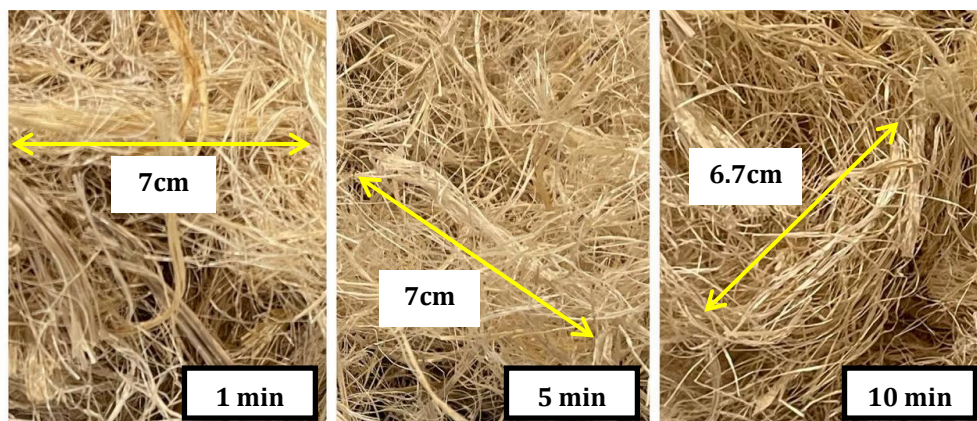
To record the weight before and after the banana fiber is processed in the fiber opening machine, the length of the fiber after processing is also observed, which in the 30g fiber sample, there have a change in the fiber length is at the 10th minute which is from 7cm to 6.7cm as shown in Fig. 4. This is likely because as the fibers get smaller, the spike hits the fiber faster which can result the fiber being cut. Fig. 5 shows the length of banana fiber in a 60g sample. In the 60g sample, the length changes only in the first minute which is 6.9cm. At this point, there is a possibility that the fiber will change as a result of putting a lot of fiber into the container, causing it to become compacted and possibly snag or tear on the air-jet tube, which may be the cause of the changed fiber length.

Table 1 Table of data and results that are evaluated.

Type of Fiber: Banana pseudo-stem fiber		
Length of Fiber: 7cm		
Air Pressure: 0.8Mpa		
Speed of Motor: 1 = 157RPM		
Weight of Fiber	30g	60g
Time Taken		
1min	27.88g	56.00g
5min	25.93g	53.39g
10min	23.97g	51.96g

Table 2 Percentage of impurities that have been removed during fiber opening.

Type of Fiber: Banana pseudo-stem fiber		
Length of Fiber: 7cm		
Air Pressure: 0.8Mpa		
Speed of Motor: 1 = 157RPM		
Weight of Fiber	30g	60g
Time Taken		
1min	7.07%	13.33%
5min	13.57%	22.03%
10min	20.10%	26.80%

**Fig. 4** Length of banana pseudo-stem fiber for 30g after going through the fiber opening process

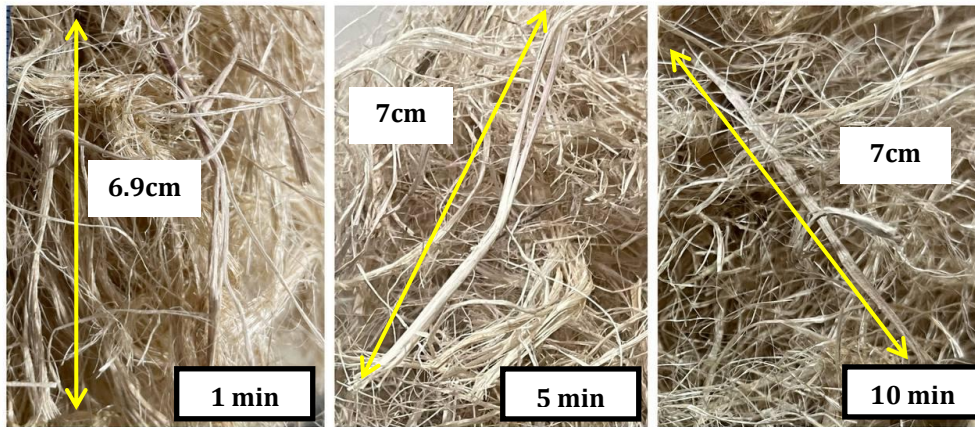


Fig. 5 Length of banana pseudo-stem fiber for 60g after going through the fiber opening process

3.2 Process Efficiency

The air-jet assisted mechanism helps improve the quality of the opened fibers by reducing the force required to open the fiber and minimizing damage. Fig. 6 shows a graph of the effectiveness of the fiber opener in dissolving the fiber by weight, the percentage of dirt that is removed from the fiber per minute. The graph is illustrated to find out the effectiveness of the fiber opener with the weight of the fiber that has been used. The validation of the mechanism's function in terms of efficiency shows the effectiveness of the design in achieving the desired result, making it a valuable innovation in the textile industry. This results in higher quality fibers with better mechanical properties, making them more suitable for various textile applications. The air jet assisted mechanism also enables the production of high quality fibers at a faster rate, which is essential for efficient fiber production. This is particularly important in the textile industry where high volume production is often required to meet demand. The air jet assist mechanism in vertical rotation natural fiber openers improves efficiency by improving the stretching and alignment of fibers, reducing the force required to open it, and increasing the production rate of high quality fibers.

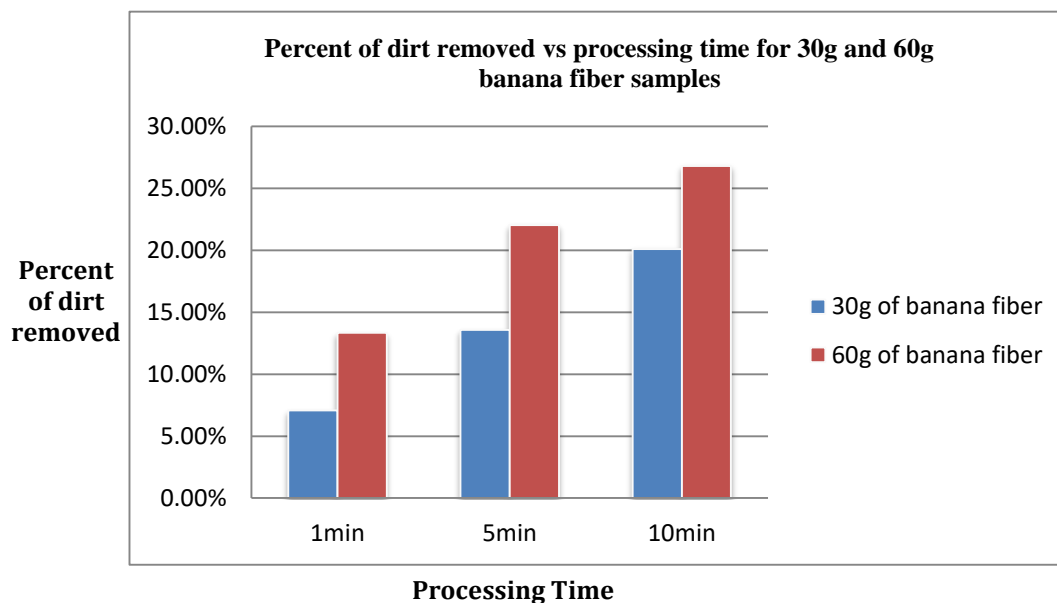


Fig. 6 Graph of the percentage of dirt that are removed from the fiber per minute for 30g and 60g of banana pseudo-stem fiber.

4. Conclusion

A vertical rotation-assisted natural fiber opening mechanism has been successfully designed, fabricated and validated. This mechanism has demonstrated reliability and efficiency in its function, making it a promising solution for natural fiber processing. This design provides an efficient and effective solution for opening natural

fibers while minimizing fiber damage and improving the overall quality of the opened fibers. The effectiveness of this mechanism shows that the fibers can be dissolved and opened effectively at minutes of 10. The weight produced after the opening process is lighter indicating that it is well dissolved. At a fiber weight of 60g, it shows an effective weight reduction that indicates a better fiber opening process. The weight of fiber before dissolving that is suitable to be put into the fiber opener is in the range of 20g - 120g. To be specific, the appropriate weight is 80g. The successful implementation of this mechanism can significantly improve the efficiency and quality of natural fiber processing, ultimately contributing to the sustainable development of the textile industry.

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