

DESIGN AND EXPERIMENT TO DETERMINE OPERATING PARAMETERS FOR SUGARCANE PEELER ACCORDING TO THE PRINCIPLE OF CIRCULAR BRUSH

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Abstract – *This paper presents a two-stage experimental process to determine the reasonable operating parameters of the sugarcane peeling machine based on the principle of circular brush. The first stage is to qualitatively determine the quality of sugarcane peeling to determine the speed range of the brush disk. The second stage specifies the value of rotational speed and cane push speed to be able to clean sugarcane with a diameter of the cane stem of about 20-40 mm. Based on a reasonable set of parameters, the authors designed and fabricated a prototype of a sugarcane peeling machine with a spinning speed of 750 rpm and a cane pushing speed of 15-20 s/m. The machine has a productivity of 70 canes/hour and wears away an average thickness of about 0.767 mm, satisfying the condition of cleaning sugarcane. The research results are the basis for the mass production of sugarcane peeling machines according to the principle of circular brush with lower cost and higher productivity than other sugarcane peeling machines according to the principle of knife.*

Keywords: *circular brush, experimental procedure, peeling efficiency, sugarcane, sugarcane juice, sugarcane peeler.*

I. INTRODUCTION

Sugarcane juice is a delicious drink, bringing a lot of nutritional and health value to people. In addition, sugarcane is also a main raw material for sugar factories and monosodium glutamate, which is an indispensable condiment for

consumers. Preliminary processing of sugarcane such as peeling off the bark in large quantities to supply factories is an urgent job and needs to be automated. Today, there are many types of sugarcane peeling machines on the market, as well as domestic and foreign publications referring to the design and manufacture of these machines.

II. LITERATURE REVIEW

Wan et al. [1] conducted experiments in Hubei Province, China, to investigate the peeling and burning capabilities of green-skinned sugarcane. However, the study only yielded qualitative results such as determining the change in tool load when peeling off the head, stem, root, and internodes of sugarcane, but did not give a formula or an experimental procedure to find the optimal operating parameters for sugarcane peeling with the razor principle. Trinh Thanh Cuong [2] and Ho Hoang Minh [3] propose to design a sugarcane peeling machine based on listing the ideas of each machine part, then using tools such as quality house concept, evaluation matrix, decision matrix, idea evaluation diagram, functional analysis diagram, etc. to compare and evaluate the ideas for combining ideas, thereby giving a final design based on knife principles shave. However, this principle has many disadvantages such as high tool cost, difficulty in manufacturing tool holders, and difficulty maintaining and replacing tools. Other studies proposed a new design is for a sugarcane peeling machine [4, 5]. However, the authors do not specify the method of calculating the cutting mode to peel sugarcane, do not present the experiment to determine the operating parameters of the machine, and do not provide a real machine image when working, so

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the conclusions of the author's claim that this is a simple, efficient and highly competitive machine is not convincing. El-Yamani et al. [6] developed a prototype of a small-scale sugarcane peeler to test the influence of key design and operating parameters on machine performance and finished product quality. The surveyed parameters included three different types of peeler brushes: zigzag, straight, and spiral, four peeler speeds of 3.53, 5.30, 7.47, and 9.18m/s, three peel gaps of 1.0, 1.5, and 2 cm and three feed rates are 3, 6 and 9 bars/min. Pandey et al. [7] presents the characteristics, prospects, performance evaluation, and limitations of some types of sugarcane peeling machines in the world such as fixed outer drum peeling machines, automatic sugarcane peeling machines, and sugarcane peeling machine self-loading knives, in which speed, output power, peeling efficiency, and sugarcane loss were evaluated. However, this is an overview article to summarize the types of sugarcane peelers based on the principle of the knife already on the market. The paper does not have further studies on cutting modes, razor geometry, experiments, etc., so it has not made significant contributions to this field.

Recently, on the market, a new type of sugarcane peeling machine has appeared using wheels, a scrubber with a structure of thick woven steel fibers and large roughness, which is said to have many advantages and wide potential applications. However, with this new design, no studies have been conducted to accurately evaluate their effectiveness and productivity. In a further investigation [8], the author also proposes a new low-cost sugar cane peeling machine for small-scale sellers. The design of the machine consists of four conical rollers that apply to the diameter of the cane and when rotated, it creates abrasive friction for the cane shell. However, looking at the schematic diagram, the contact cross-section of the four conical shafts with the cane peel does not cover the entire surface of the circumference of the cane. Therefore, although the productivity of this machine is quite high (3 canes/min) each sugarcane has to go into the machine to be shaved

three times to be relatively clean. Not to mention when putting in the second and third times, the user has to rotate the cane stem so that the four cone shafts are in contact with the areas that have not been scrubbed thoroughly in the previous shaves, which wastes the user's time.

Because of its ease of use, low cost, and effectiveness in cleaning the sugarcane peel, it is clear that the circular brush sugarcane peeling machine has a lot of potential in today's sugarcane peeling. However, no experiments have been conducted to determine the operating parameters for machines that employ this principle. In this paper, the experimental procedure will be presented to find out the operating parameters for the sugarcane peeling machine using the principle of circular brush. From there, the authors built a prototype sugarcane peeling machine and tested its operation.

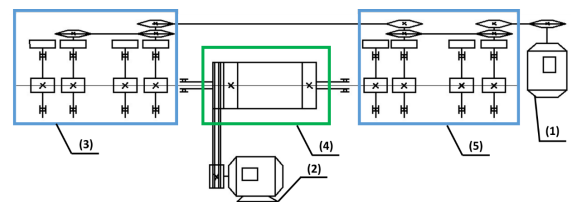


Fig. 1: Diagram of the working principle of sugarcane peeling machine according to the principle of circular brush: (1) – (2) motor; (3) – cane feed roller system (put sugarcane in); (4) – set of circular brush to peel sugarcane; (5) – cane exit roller system (put sugarcane out).

III. RESEARCH METHODOLOGY

A. Working principle of the sugar cane peeling machines uses the principle of circular brush

The working principal diagram of the sugar cane peeling machine using the principle of circular brush is shown in Figure 1. To achieve the desired productivity, the cane push speed of the cane feed roller system (3) and cane exit roller system (5) are determined. The problem is how the sugarcane goes into the circular brush (4) while spinning the cane shell will be cleaned.

Therefore, finding the operating parameters of the circular brush (4) is the most important element in this study. To do this, an experimental prototype has been designed and built.

B. Experimental model of the circular brush

The task of the experimental process is to find the speed of rotation of the brush disc and the time it takes for 1 m of sugarcane to pass through the circular brush to be cleaned. The experimental model of the circular brush is shown in Figure 2. The model uses circular brushes mounted on a fixed rotating disc. The fibers of the cake are made of steel, when the disc rotates, the fibers come into contact with the sugarcane, creating friction from which the cane shell is cleaned.

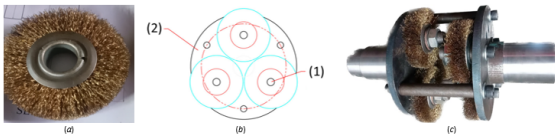


Fig. 2: Experimental model of the circular brush: (a) circular brush; (b) installation scheme of circular brushes; (1) – fixed shaft for circular brush; (2) – spinning disc; (c) Cluster of circular brush.

C. Experimental determination of reasonable operating parameters of the circular brush set used when peeling sugarcane

To reduce the number of experiments, this procedure is divided into two phases [9]:

- Stage one: three rotational speeds of 350 rpm, 450 rpm, and 750 rpm were considered and observed with the naked eye to choose the speed range. The experimental results are shown in Table 1.

- Stage two: the study examined three rotational speeds of 550, 650, and 750 rpm with periods for 1 m of sugarcane to pass through the circular brush to clean the peel of 10, 15, 20, and 25 s, respectively. The parameter of time for

the circular brush to peel 1 m of sugarcane is an important and convenient parameter for experimental investigation, so it is represented by the speed parameter and is measured in units [s/m]. Simultaneously measure the cane peel variation according to the diagram of Figure 3.

The speeds 350, 450, 550, 650, and 750 rpm were chosen due to the limitations of the cost of performing the experiment as these are standard speeds on existing motors. According to the expertise of food experts [2, 6, 9], the thickness of the cane rind that needs to be beaten $\Delta d = d_b \sim d_a$ is in the range [0.65; 0.95] mm to meet the hygienic standards for extracting the juice; with d_a – sugarcane stem diameter before scrubbing and d_b – sugarcane stem diameter after scrubbing. If it is less than 0.65 mm, it is not clean enough and if it is higher than 0.95 mm, it will cause unnecessary waste of sugarcane. The experimental results are shown in Table 2.

Based on Table 2, the study found that using the cane pushing speed $v_t = 10$ [s/m] was too fast and the majority of $\Delta d < 0.65$ was not of clean quality. With cane pushing speed $v_t = 25$ [s/m], Δd mostly satisfies the condition but is too slow. For the remaining two speeds $v_t = 15-20$ [s/m], it was necessary to rotate the circular brush at 750 rpm to be able to clean the sugarcane with a diameter of 20-40 mm, and the remaining speeds of 550 and 650 rpm did not guarantee cleaning for all diameters.

IV. RESULTS AND DISCUSSION

A. Design and manufacture machine

Based on computational and experimental data, the design of a sugarcane peeler based on the principle of the circular brush was performed and presented in Figure 4. The crank motor is a 3-phase electric motor with a capacity of $P = 0.75$ kW. The motor driving the sugarcane is a single-phase electric motor with a capacity of $P = 0.1$ kW. The machine is manufactured and assembled as shown in Figure 5.

Table 1: Experimental results of stage 1

Speed (N) (rpm)	Times (t) (s)	Diamete r (d _b) (mm)	Picture	Results
350	10	15 – 30		Sugarcane peel has not been cleaned
	15			
	20			
450	10	15 – 30		The sugarcane peel has been scrubbed, but there are still a few places that are still not clean
	15			
	20			
750	10	15 – 30		Sugarcane peel is scrubbed relatively clean. Need to experiment with step two to find more accurate speed and time parameters
	15			
	20			

Note: From the first experiment, we draw the conclusion: the rotation speed of the circular brush should be in the range of 550-750 rpm.

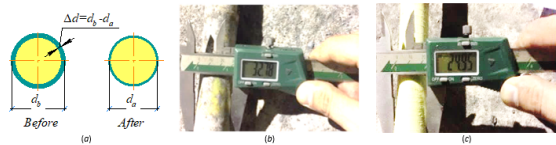


Fig. 3: Diagram of measuring the variation of sugarcane peel thickness: (a) – Diagram; (b) – measure before scrubbing; (c) measure after scrubbing.

Table 2: Experimental results of stage 2

No.	d _b [mm]	n [rpm]	v _t [s/m]	10	15	20	25
1	20-25	750	Δd [mm]	0.5	0.66	0.75	0.82
		650		0.35	0.41	0.59	0.65
		550		0.3	0.35	0.42	0.59
2	25-30	750		0.62	0.75	0.85	0.91
		650		0.45	0.6	0.72	0.86
		550		0.46	0.57	0.65	0.77
3	30-35	750		0.67	0.72	0.91	1.01
		650		0.52	0.67	0.86	0.92
		550		0.46	0.49	0.67	0.72
4	35-40	750		0.72	0.86	0.91	1.2
		650		0.69	0.73	0.86	0.94
		550		0.61	0.64	0.71	0.86

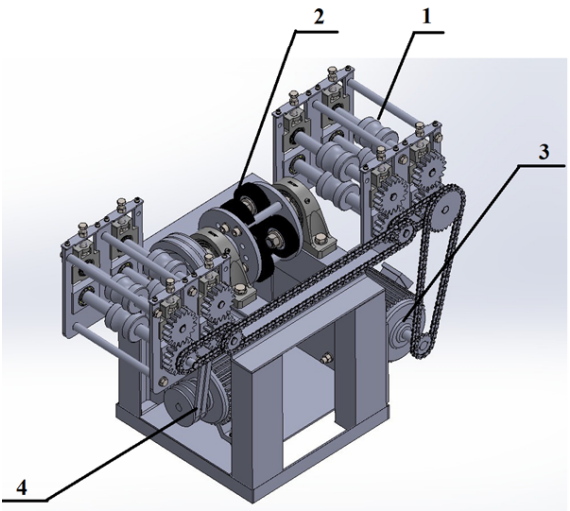


Fig. 4: Design of sugarcane peeler according to the principle of circular brush: 1 – Sugarcane drive mechanism; 2 – Cluster of circular brush; 3 – motor of sugarcane drive mechanism; 4 – motor of cluster of circular brush.

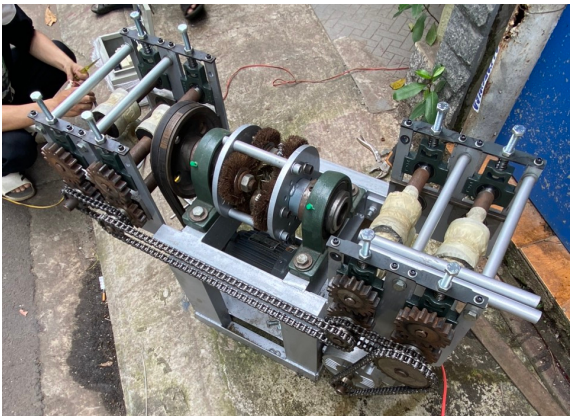


Fig. 5: Prototype of sugarcane peeler based on the principle of circular brush.

B. Experimenting with sugarcane peeling

The experiment was carried out on the basis of the machine developed by the research team. To experiment with peeling sugarcane, a bunch of sugarcane from about 8 trees was processed, and an electronic caliper was used. Before putting the sugarcane into the peeler, the diameter of the

sugarcane at nodes 5, 9, and 13 (root, stem, and top) was measured and recorded. After putting it into the peeler to run it once, the diameter at the original cane nodes again was measured. The data of 8 sugarcane trees is shown in Table 3.

Based on experimental data (Figure 6), the machine with the average thickness of the cane peel being cleaned is 0.767 mm, which is consistent with the initial experimental results of the machine and meets the requirements for cleanliness in the range [0.65; 0.95] mm. The time to peel the bark of a sugarcane is 35 – 45 seconds, allowing the sugarcane peeler’s capacity to be 70 canes/hour. This is the good productivity that all machines on the market are aiming for.

Table 3: Experimental results of prototype of sugarcane peeler

No.	Position	d_b [mm]	d_s [mm]	Diameter before peeling	Diameter after peeling	Δd (mm)
1	Root	27.15	26.49			0.66
	Stem	27.23	26.39			0.84
	Top	27.44	26.59			0.85
2	Root	28.66	27.82			0.84
	Stem	26.09	25.36			0.73
	Top	28.06	27.35			0.71
3	Root	28.52	27.72			0.8
	Stem	29.2	28.56			0.64
	Top	26.88	26.19			0.69

Table 3: Experimental results of prototype of sugarcane peeler (cont.)

4	Root	30.53	29.85			0.68
	Stem	26.25	25.48			0.77
	Top	27.08	26.24			0.84
5	Root	29.48	28.67			0.81
	Stem	29.05	28.38			0.67
	Top	30.06	29.19			0.87
6	Root	28.81	28.04			0.77
	Stem	30.17	29.37			0.8
	Top	30.24	29.54			0.7
7	Root	28.8	28.06			0.74
	Stem	29.23	28.58			0.65
	Top	28.72	27.87			0.85
8	Root	29.45	28.58			0.87
	Stem	32.04	31.03			1.01
	Top	34.24	33.63			0.61
Average		28.891	28.124			0.766666667

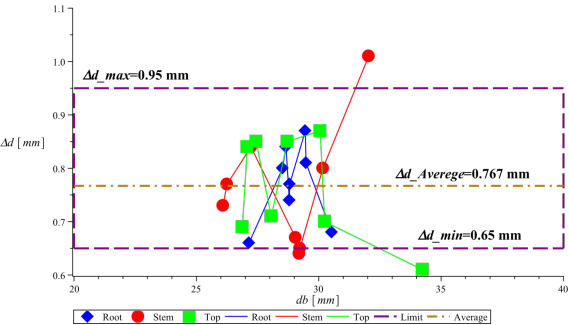


Fig. 6: Result graph

V. CONCLUSIONS

In this study, the authors successfully experimented with the process of determining the operating parameters for the sugarcane peeler according to the principle of scrubbing by rotating the circular brush. The set of circular brushes was installed in three equal positions on the disc circle and installed in two sets to ensure the quality of cleaning. With the two-step experimental process, the appropriate operating parameters of the rotating disc speed were 750 rpm with the required cane put speed of 15 – 20 s/m. With such operating parameters, the prototype machine was manufactured and tested successfully, resulting in sugarcane peel cleaning with an average cleaned peel thickness of 0.767 mm and productivity of 70 canes/hour (with the average length of a sugarcane 2 m), satisfying the requirements for cleanliness of sugarcane peeling. The experimental process and these results allow the manufacturer to mass-produce peeled sugarcane according to the principle of circular brush with less cost than other types of sugarcane peeling machines according to the principle of razor, with faster productivity. At the same time, the machine also has the potential to increase productivity further, depending on the adjustment of the rotation speed of the circular brush as well as the speed of cane pushing according to the experimental procedure in Section 2.

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