Semi-Automated De-Husking Machine for Coconut Industry in Sri Lanka

Silva SAPS, Dahanayaka AJGS and Rajawatta KMW

Abstract: Coconut is one of the major perennial plantation crops in Sri Lanka. Furthermore, Coconuts play an important role in the daily life of Sri Lankans because most of the Sri Lankan cuisines are made by using coconut milk, coconut oil and scraped coconut. Therefore, all the processes of the coconut processing cycle of the coconut industry including coconut de-husking have become very important. Moreover, labour shortage is a major problem in manual de-husking which is one of the most important stage of coconut processing. A manual de-husking is a very tedious and unsafe work; also likely to cause health problems like back pain. Therefore, people are reluctant to engage in de-husking and employers cannot meet their production targets regularly. The aim of this project was to develop an efficient, semi-automated coconut de-husking machine for Sri Lankan coconut industry. The machine consists of two rollers rotating in opposite directions having number of rectangular steel bars connected to the circumference of the rollers in axial direction and top of these two rollers there is a rotating flat rubber belt to press and hold the nut while it is in the de-husking process. The husk is gripped by these rollers and starts to peel with the further rotation of rollers. Then, the de-husked coconut feeds into another rotating roller mechanism which removes the remaining part of the husk (Mudda). The movement of the coconut is facilitated by spiral shaft fixed along the two rollers. The capacity of the developed de-husker is 1200 nuts per hour with 2% of nut breakage. The nut breakage percentage is significantly lower than that of existing machines in the industry.

Keywords: Coconut; de-husking; semi-automated de-husking machine, Mudda

1. Introduction

Coconut is one of the most important industrial perennial plantation crops in Sri Lanka. The total land extent of about 400,000 hectares is used for coconut cultivation and produces about 3000 million nuts per year. Local consumption of nuts is about 70% while export component is about 30% (Pathiraja *et* al., 2015). Each part of the coconut tree has its own commercial value that can be formed into various products and usages. Coconut plays an important role in the daily life of Sri Lankans because most of the Sri Lankan cuisines are made by using coconut milk, coconut oil and scraped coconut. Therefore, maintaining a coconut plantation, harvesting, de-husking and all other processes of the coconut industry have become very important.

Coconut cultivation and post-harvest processing is still highly manual labour involved processes. The people in Sri Lanka gradually exists the hard labour work in every field. At present, coconut industry is an industry which is facing a many problems due to labour shortage (Pathiraja *et al.*, 2010). Coconut de-husking is a major role in post-harvest processing. Today manual de-husking which is done by using a spike is widely used in Sri Lanka although it is a very tedious and unsafe work; also likely to cause health problems like back pain. Hence, the people are reluctant to engage in de-husking and employers cannot meet their production targets regularly. Also the rate of production and productivity is very low when manual labour is employed. A skilled worker can de-husk 120 nuts per hour and workers are paid Rs. 1.25 per a nut presently. Therefore it is a necessity to introduce an automated de-husking machine for the coconut industry.

Based on the literature, there are two major methods for de-husking coconuts; manually operated coconut de-husking machines and machines which are powered by an external power source such as by IC engine or electric motor (Vargheser and Jacob., 2014).

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Most of the traditional methods have more drawbacks including long-term damages to the de-husker. Moreover developed coconut de-husking machines which are powered by human power or an external power source, include deficiencies such as incomplete de-husking, low rate, high skill requirement for operation, high cost, low mobility, fibre distortion and shell breakage. These adverse effects arise by the shortcomings in mechanisms used in coconut de-husking machines. Most of them are lack of adjustment according to the size of coconut, improper fracture initiation, improper moving paths of blades and lack of holding mechanism.

The objective of this project was to design an automated de-husking machine to minimize involvement of human labour and to increase productivity and the rate of production while minimizing the hazards and danger in de-husking.

2. Design considerations

This design is based on gripping the husk between two webbed rollers which rotate in opposite direction. When the rotation continues, the gripped husk part separates from the nut. The two rollers are powered by an electric motor coupled through a gear reducer and chain drive. There is a belt conveyor fixed under the roller mechanism to move separated husk away from the machine. The de-husked nut then feed into a crown removing mechanism. This mechanism consists of two webbed rollers (Figure 1) rotating in oppose direction to grip the crown and spiral shaft to move the nut forward.

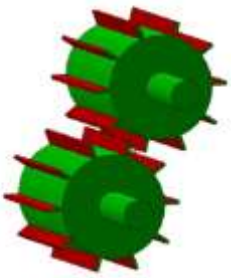

Figure 1: Schematic diagram of the machine

2.1 Determination of force required to separate husk from the nut

Simple equipment was fabricated for finding the load required for removing husk by using a broach. The arrangement is shown in Figure 2.

Figure 2: Experimental equipment for removing husk by broach

The husk was removed by using the broach and applied load was measured by the spring balance. This experiment was conducted several times by using coconuts in various conditions and sizes and tabulated the applied load in Table 01.

Average applied load from above tabulated results = 28 kg

Actual applied load (Considering lever advantage) = $28 \times 9.81 \times 370/150$

= 678 N

= 700 N

As per the results, 700 N load is required for removing husk by using broach i.e. this is the force required to separate one part of the husk from the nut.

2.2 Determination of forces due to gripping husk between rollers

When the husk is gripped between two rollers reaction forces and friction forces is developed at the gripping point where a web of one roller is pressed the husk to the gap between two webs of other roller. Therefore, the similar part was fabricated and loaded by using a hydraulic press. The experimental setup is in Figure 2. The husk was pressed by a web against gap between same size webs. It was found the load applied while the husk is travelling through the two rollers. Minimum clearance between the two webs was maintain at 10 mm. The pressure gauge reading was taken for several husks with various conditions and sizes. Observations were tabulated and maximum load was taken for load calculations. The maximum length and thickness of husks were 5 cm and 25 cm respectively. From the results it was found that the applied load is vary in between 1 to 2 MT for various husks (Dry husk, green husk and adult husk).

Figure 3: Experimental setup 02

As per the results, reaction load from each side was considered as 2 MT (maximum load) for the design. The rollers moves against tangential load developed at that point. It is the frictional force developed due to the radial load. Next it was required find the friction coefficient between coconut husk and mild steel. The experimental setup 03 (Figure 5). A known load was kept on a coconut husk and it was placed on a steel bed. The husk was moved by applying horizontal force as shown in the Figure 4. The results were tabulated in Table 2 for several trials.

Figure 4: After pressing the husk

Figure 5: Experimental setup 03

From above observations it was found that the maximum friction coefficient as follows,

Based on the Table 1, it was found that the maximum friction coefficient as follows,

Friction coefficient = force/reaction force
= 5.25/13.29
= 0.39

So from above friction coefficient and the load from experimental setup 02 (Figure 3) it was found the tangential force required for rotating the two rollers as follows, Reaction force = 2 MT

Tangential force= Friction coefficient × Reaction force
= 0.39 × 2000 × 9.81 N
= 7.65 kN

Table 1: Determination of the required forces

Condition of husk	Applied load on the husk/(kg)	Spring balance reading (start to move)/(kg)	Spring balance reading (after moving)/ (kg)
Dried	13.29	5.25	4.80
Green	13.29	4.00	3.75
Adult	13.29	4.40	3.80

Considering the machine size, production capacity, the availability of the materials in the market and the literature it was used 100 mm steel cylinders for fabricating the webbed rollers. It was used 20 mm width 6 mm thick flat irons for webs. Hence, effective radius of the cylindrical rollers were 70 mm.

Required torque for rotating the cylindrical rollers = 70 × 7.65
= 535 Nm

Torque required to separate a husk part
= 700 * 70/1000
= 49 Nm

So required maximum torque = 535 + 49
= 584 Nm

In our design, it should be required two input chutes for fulfilling the production capacity and the speed should maintain at around 40 rpm. But easiness for maintain the speed it was decided to use 1:40 gear reducer to reduce the motor speed to get desired speed. (Output speed for four pole motor = 1440 rpm). Therefore, maximum torque required for rotating two cylinder sets is as follows,

Required maximum torque = 584*2
= 1168 Nm

Power requirement = Torque*Angular velocity
= 1168*36*2π/60
= 4.4 kW

So this machine required to run other systems (conveyor belts etc.) while in the operation. Finally selected the 5.5 kW motor for this machine

2.3 Design of a shaft for this machine

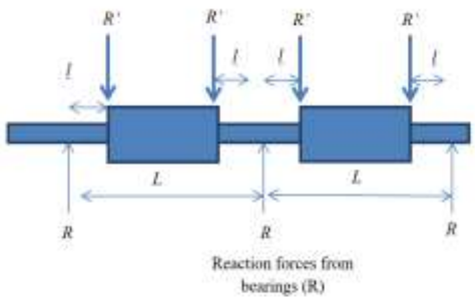

Figure 5: Schematic diagram of the shaft

R - Reaction force from the bearings
R'- Reaction from the husk
L - Distance between two bearings
L - Distance from bearings to cylinder
d - Diameter of the shaft

So the load applied from the husk is located in the middle of the two adjacent bearings and that location is the higher loading location.

l = 50 mm

Bending moment from the husk (M) = R'*l

= 1000*9.81*50/1000

= 490.5 Nm

T = P/w

P=5.5kW, w= 2π*1440/60 rad/s

Bending stress of a shaft (σb) = $\frac{32M}{\pi d^3}$

Torsional stress of a shaft (σT) = $\frac{16T}{\pi d^3}$

Required stress to the sharft

$= \sqrt[2]{\sigma b^2 + \sigma T^2}$

Allowable stress for bri-steel sharft = 240 Mpa
Safety factor for bri-steel = 1.4

Allowable stress ≥ required stress

d ≥ 38.2mm

So considering the availability of the bri-steel shafts, it was selected 50 mm diameter shaft for this machine.

According to the all above design considerations, the machine was designed and fabricated (Figure 7, 8 and 9 (I,II and III)).

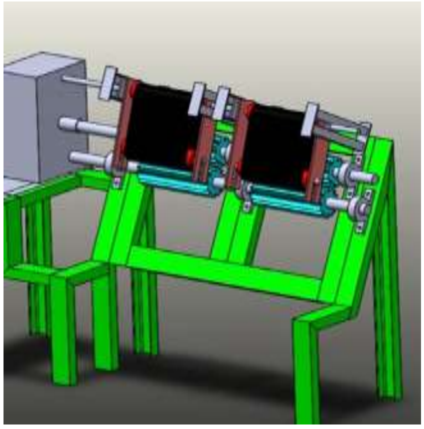

Figure 7: 3D view of the designed machine without mudda remover

Figure 8: While in the fabricating

Figure 9 (I): Final view of the machine

Figure 9 (II): Final view of the machine

Figure 9 (III): Final view of the machine

3. Results

The developed machine was handed over to the coconut de-huskers for a one month period. Table 2 shows the collected data in several trials.

Results of the Table 2 Revealed that the developed machine can de-husked 1200 nuts/h. Therefore the production capacity of the developed machine is 1200 nuts with average 2% nuts breakage. After installing the mudda removing machine (Modification to the previous machine) to this can eliminate the number of nuts with mudda up to 0.2%.

4. Conclusions

The de-husking machine was successfully designed, fabricated and developed as per the design considerations. It gives the expected capacity of 1200 nuts per hour with 2% percent breakage of nuts. Furthermore, it was identified that the breakage of coconut was caused due to immature coconut or very small coconuts in size. The developed machine is easy to operate by a single user. Therefore, this machine gives a solution to labour scarcity problem in the coconut plantations. It will also increases the production capacity of the coconut production lines. The machine is still in the testing stage to identify the further improvements.

Table 2: De-husking results at the field

Date	Process time		De-husked nuts	Damaged nuts	Nuts remain mudda	Remarks
	Start	End				
20/06	11.00	11.45	500	6	78	
21/06	9.00	12.00	2100	26	228	
02/07	10.25	11.00	348	2	18	
21/08	10.00	12.15	1400	10	10	
23/08	8.00	2.30	3000	28	12	Lunch 1h
29/08	8.00	3.00	3300	70	20	Lunch 1h
30/08	8.00	5.30	4800	60	8	Lunch 1h (Installed new mudda removal machine

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