Design Consideration of the Semi-automated Coconut De-husking Machine

S.A.P.S. Silva[1], A.J.G.S. Dahanayaka[1], K.M.W. Rajawatta [1,2]

[1] National Engineering Research and Development Centre, Ekala, Ja-ela, Sri Lanka.
[2] Faculty of Technology, University of Ruhuna, Karagoda-Uyangoda, Sri Lanka.
E-mail:shalinda@nerdc.lk

Abstract: The process of de-husking which is the most important phase in coconut processing has faced a crisis in Sri Lankan coconut industry due to the scarcity of skilled labor and the complexity in manual de-husking. In an effort to mitigate these issues, this research aims at finding the most suitable design considerations to fabricate an efficient and a semi-automated coconut de-husking machine which will assure the safety while maximizing the rate of productivity. Machine will be designed with 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 in the de-husking process. Based on the calculations, required force to separate one part of the husk from the nut was 700 N. The expected capacity of the machine is 1200±50 nuts per hour with 2% of nut breakage.

Keywords: Coconut; de-husking; design consideration; semi-automated de-husking machine.

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.

Fruit of the coconut is the most economical part of the tree and it is called as a nut. Structurally, nut has three layers; exocarp, mesocarp, and endocarp. Coconut husk consists of exocarp and mesocarp. Removing of this husk from the nuts is called as de-husking (Alonge and Adetunji, 2011) and it is one of the highly manual labour involved processes. Nowadays, labour shortage is a big issue in Sri Lanka. There are two kind of machines for coconut de-husking; manually operated machines and machines which are powered by an external power source such as by Internal Combustion engine or electric motor. The traditional methods such as use of spike or machete have more drawbacks such as injuries to de-husker, long term damages to muscles, and joints. In Sri Lanka, widely used method is using a spike even in the large scale plantations although it is a very tedious and unsafe work. Hence, the people are reluctant to engage in de-husking and employers cannot meet their production targets regularly. A skilled worker can de-husk 120 nuts per hour and workers are paid Rs. 1.25 per a nut, presently. That supports to reduce their productivity.

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, fiber distortion, and shell breakage. The following shortcomings were identified in presently used coconut de-husking machines; lack of adjustment according to the size of coconut, improper fracture initiation, improper moving paths of blades, lack of holding mechanism. Therefore, it is a necessity to introduce an automated de-husking machine for the coconut industry. Therefore, the objective of this research was to find out the most suitable design considerations to fabricate an efficient, semi-automated coconut de-husking machine for Sri Lankan coconut industry 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-husk nut then feed into a crown removing mechanism. This mechanism consist of two webbed rollers rotating in oppose direction to grip the crown and spiral shaft to move the nut forward.

2.1 Determination of Force Required to Separate Husk from the Nut

Simple equipment was fabricated to find out the load required for removing husk by using a broach (Figure 1). The husk was removed by using the broach and applied load was measured by the spring balance. Based on the series of trials, 700 N load is required for removing husk by using broach which is the force required to separate one part of the husk from the nut.

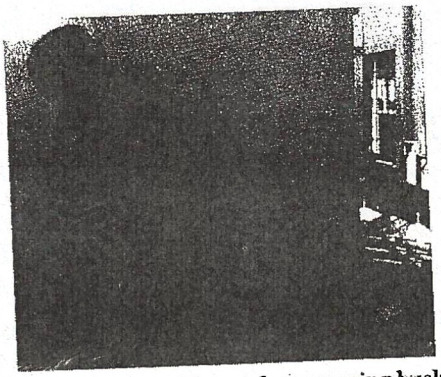

Figure 1. Experimental equipment for removing husk by broach.

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, suitable model was fabricated and loaded by using a hydraulic press. 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 maintained 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.

Results revealed that the applied load was vary in between 1 to 2 MT for various husks (Dry, green, and adult husks). As per the results and the further calculations (Table 1), reaction load from each side was considered 2 MT as a 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.

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 selected 100 mm steel cylinders for fabricating the webbed rollers. Further, it was selected 20 mm width and 6 mm thick flat irons for webs. Therefore, the effective radius of the cylindrical rollers was 70 mm.

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). Calculated value of required maximum Torque for one cylinder was 584 Nm and it was calculated through tangential force and the radius of the cylindrical rollers. 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

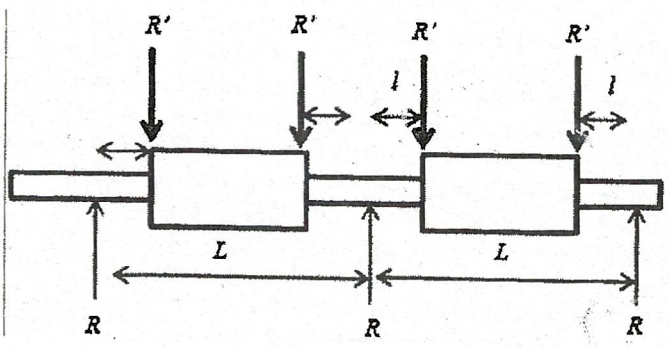

Figure 2. Schematic diagram of the shaft.

Where R is the reaction force from the bearings, R' is the reaction from the husk, L is the distance between two bearings, l is the distance from bearings to cylinder and d is the diameter of the shaft.

Load applied from the husk is located in the middle of the two adjacent bearings and that location is considered as the higher loading location (Figure 2). Required shaft diameter was $d \geq 38.2$ mm. Therefore, by considering the availability of the bri-steel shafts, it was selected 50 mm diameter shaft for this machine.

3. Conclusion

The design considerations; shape, size, and rotating directions of the rotators, required force to separate one part of the husk from the nut, required force at the gripping points and the shape and size of the shafts were successfully determined. Shaft diameter was 50 mm, required capacity of the motor for the machine was 5.5 kW, and minimum clearance between the two webs was 10 mm. The semi-automatic de-husking machine will be fabricated according to the above design considerations. The expected capacity of the machine is 1200±50 nuts per hour with 2% percent breakage. The prototype of the machine is still in the testing stage to identify the further improvements. The nut breakage percentage will be significantly lower than that of existing machines in the industry.

References

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