Design and Fabrication of a Coconut Sorting Machine

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Abstract— *Sri Lanka is among the leading countries in coconut production and holds a significant share in the world coconut product market. However, the process of sorting coconuts is not precise in the Sri Lankan marketplace. This project aims at designing and fabricating an efficient sorting machine for husked coconut. The machine is designed for sorting of husked coconuts according to the size into three categories. It uses the roller conveyor technology, and seven main rollers are used in the design which are driven by a 400 W single phase motor. The center-to-center distance between the rotating shafts is the key feature for the sorting mechanism which were decided after the proper data collection from the related organizations, authorities, employers in the field and the customers. The designed components are tested, and the finite element analysis results were examined to ensure the safe working conditions of the machine. Arduino technology is used to count the sorted coconuts in the three categories. Machinery has improved the quality* of life and *facilitated the smooth flow of large-scale businesses by increasing economic benefits through the efficiency, accuracy, time management and cost effectiveness. The efforts required in achieving the outputs can be effectively and economically be decreased by the implementation of better designs.*

Keywords— **Sorting Machine, Conveyor, Coconut, Design**

I. INTRODUCTION

Sri Lanka is the fifth largest coconut producer in the world. According to the industrial capability report, January 2022 of Sri Lanka export development board, 1,095,982 Acres are under coconut cultivation and 178,675 Acres are under estate section. 917,307 Acres are under small holdings. Almost two third of the coconut production in our country is consumed by own and rest one third is used for coconut based productions and is exported to various destinations. Sorting according to the size is an important value adding technique for most agricultural products. Due to the generation of new opportunities in the open market at competitive prices, improvement of quality and value addition of agricultural products has gained the importance. In SL, the post-harvest crop handlers like collectors, whole sellers, retail sellers and cultivators do not use quality or standard techniques to sort and grade. Sorting is not precise in the marketplace. Sri Lankan government recently tried to introduce a technique to sort and grade coconuts according to their size, but it could not be properly implemented. A sorting machine is designed to create an environment to sort the coconuts according to a standard.

III. METHODOLOGY

A. Data Collection

The data was collected from various locations of the county including Dambulla, Polpithigama, Kuliyapitiya, Marawila, Ja Ela, Ratmalana, Katubedda, Galle and Walasmulla. Questionnaires were given to the sellers and to the customers to get information related to the sorting, grading, and pricing of coconuts. The dimensions of the husked coconuts as well as the weights were recorded from those locations and the data was analyzed. Three main size categories were identified using the data collected and with the information obtained from the Export Development Board (EDB). The diameter of the coconuts ranging from 80 mm to 100 mm falls to the first category. Diameters in the range of 100 mm to 130 mm and greater than 135 mm falls into the second and third categories respectively. The average weight of a husked coconut was found to be around 800 g.

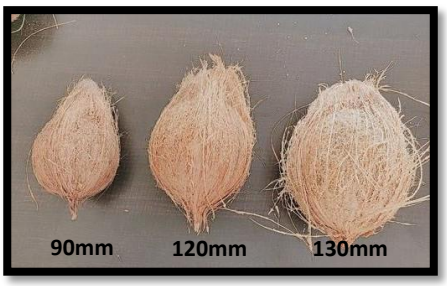

Figure 1. Average Size Categories of the Coconuts

B. Literature Review

The literature review was conducted to understand the existing technologies in the industry for various products using various sorting mechanisms. Through the literature review it was able to understand the limitations of the existing systems and the capability or incapability of using those mechanisms in the process of sorting coconuts. D.M.C.C Gunathilake, W. M. C. B Wasala, K. B. Palipane in 2015, has carried out a project

on designing and developing a size grading machine for onion. The grading cylinder made with PVC has been used to get the output with the minimum damage to the onions. Design Expert Version 7 software has been used by the research group to optimize the design. (Gunathilake, et al., 2015).

The project by V. K. Behere, S. J. Maniyar, S. G. Mohale, and P. Balkrishna, was also to design and fabricate a machine to grade the onions according to the size. The main aim of the project was to reduce the human effort and the time consumption in grading onions, hence obtaining precise outputs. A conveyor and a grading tray have been used here where the conveyor runs on rollers powered by an electrical motor. (Behere, et al., 2019).

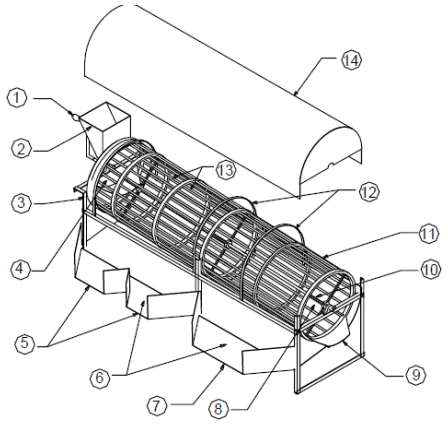

Figure 2. Onion Grading Machine
Source: Behere, et al., 2019

An automated single line egg sorting machine has designed by P. Q. Erwin, C. S. Delfin, and M. B. Pepito in 2018, with locally available materials to reduce the cost of production. The assembly was attached to a shaft that drives the belt to move samples. Metal shafts fastened on the conveyor frame were used to support the belt. These act as rollers for the belt to glide over. The sorting arm was constructed from the ribbed aluminium sheet for durability and lightness and was installed at the end of the conveyor belt after the vision chamber. The sorting was done according to the weight of the eggs. A camera, computer equipped with a frame gripping source, and a light source have been used as the main components of the vision setup.

G. Bahadirov, T. Sultanov, B. Umarov, and K. Bakhadirov have conducted the project to fabricate an advanced machine for potato sorting. It was found that to achieve 95% accuracy of sorting, at a feed speed of potato heap onto the belt surface of the machine 4.5 kg per second, the angle between the belts should be 0.46′26, the speed of the slow-moving belt should be 0.4 m/s and the speed of the second should be 0.6 m/s.

G. M. Trilok, L. Prashanth, and C.G. Ramesh have developed an automated system for husked coconut segregation. The design of specialized rollers in segregating unit can categorize the husked coconut into 3 size categories. The size categories were in the range of 90 mm to 110 mm and more. the time taken to segregate 20000 coconuts was 5.28 hours where the annual process takes up to 12 hours. (Trilok, et al., 2020).

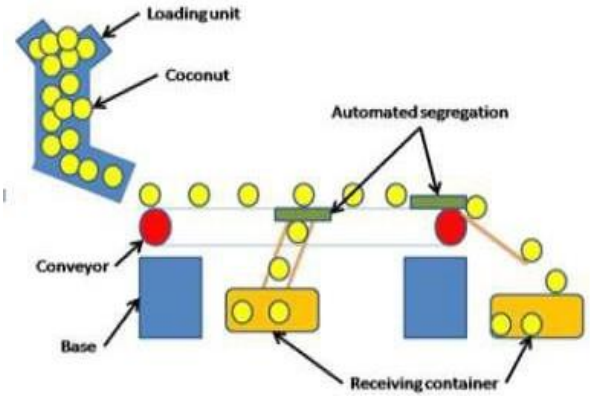

Figure 3. Conveyor Concept for Coconut Seggregation
Source: Trilok, Prashanth, and Ramesh, 2020

C. Conceptual Design

Considering four conceptual designs for the machine that are capable of sorting coconuts in a reliable, accurate and efficient manner, the final design was completed using the SOLIDWORKS 3D modelling software. The cost for fabrication was one of the main factors considered during the design and the selection of the most appropriate design since the usage of such a machine should give economic benefits for the users over the manual sorting mode. The necessary components were designs and the engineering calculations were done to select the suitable design aspects in order to give the best performance while saving energy and resisting to failure.

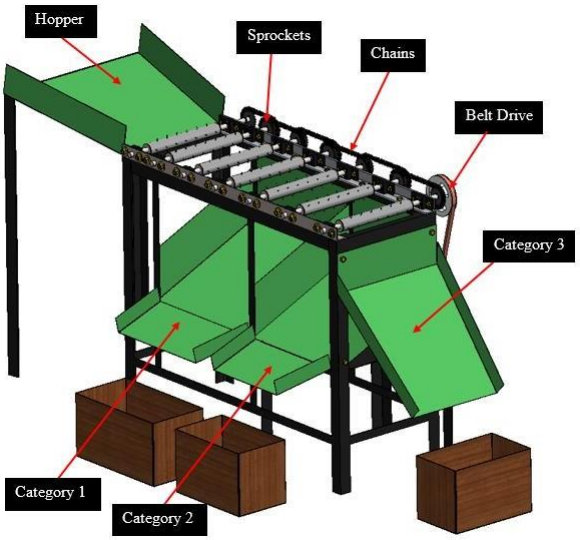

Figure 4. Conceptual Design of Coconut Sorting Machine

The fundamental roller conveyor mechanism is used here but the center to center distances between the rollers are given the first priority in the design. This is because, the center to center distance between the rollers directly contribute to the high accuracy in the sorting process. The spacing between the rollers are set in order to sort the coconuts according to the size.

The hopper with the slope in it directs the coconuts to the rollers that rotate. The first set of rollers are to orientate the coconuts and the next are to sort them according to the size. The coconuts are sent to the next respective roller along the conveyor and when the gap between the rollers are lesser than that of the diameter of the coconut, the coconuts will come out through the conveyor rollers. The largest coconuts of the third category will be sent to the end of the conveyor and then to the respective basket. Engineering design calculations were performed for the components of the design to select the most suitable components with the most dimensions to ensure the safe working conditions and proper functioning of the system.

Table 1. Summary of Design Calculations

Component	**Material**	**Value**	
Solid Shaft	Mild Steel	Outer Diameter	16 mm
Hollow Shaft	Galvanized Steel	Outer Diameter	20 mm
		Inner Diameter	16 mm
Keys	Mild Steel	Width	8 mm
		Thickness	7 mm
Bearings	Deep Groove Ball Bearing	Dynamic Capacity	2.3 kN
Sprockets	Cast Iron	No. of Teeth	31
		Pitch	12.7 mm
		Outer Diameter	125 mm
Pulley	Steel	Outer Diameter	125 mm

A belt drive is used to transmit the power from the motor to the shafts. A single phase motor of 400 W and 75 rpm was selected to power up the machine by considering the total length of the conveyor design, available speeds of the motors along with the power requirements to provide the capability of sorting the average number of coconuts that are usually sorted manually in the industry. An Arduino circuit with an infrared sensor and a LCD display is used to display the number of coconuts that are being sorted to each category. The circuit was simulated using Proteus8 software.

D. Finite Element Analysis

Finite element analysis was conducted on the rollers, conveyor frame and the sprockets which are subjected to various loading conditions to ensure the ability of the components to withstand failures. Mesh was created to divide the geometry into smaller elements to run the study. The results were obtained for stress, strain, and displacement variations. A mesh convergence test was performed by reducing the element size of the mesh to get accurate results that are independent of the change in the mesh.

E. Assembling and Maintenance of the Machine

The machine was designed in such a way that the assembling and the disassembling of the machine can be done by any unskilled person for the purposes of cleaning, and maintenance. In all the possible places to mount one component to another nuts and bolts were used to provide the ability for the user to easily remove and assemble components in case of cleaning, lubricating or replacing. Different environmental conditions, vibrations, unexpected loading changes and wrong operating practices may occur the machine failures. Hence it is required to undergo a specific maintenance procedure to ensure the reliability and the efficient working conditions of the machine. With the proper maintenance, the unnecessary high costs due to machine breakdowns can be minimized while increasing the lifetime of the equipment. By adhering to the proper maintenance practices not only the safety of the machine but also the safety of the operators and the environment can be increased. To obtain the optimal performance it is very important to ensure the proper tension and alignment of a belt drive and the chain drive system. The shafts which hold the chain drives were designed and mounted to the support in a way such that the shafts can be moved in either direction to loosen or tighten the chains whenever required to ensure the proper working conditions while maintaining the exact velocity ratio. The bolts which fix the motor to the main frame is also allocated with slots to move the motor in order to tighten the belt when required. The chain drives are covered with the housing to avoid contamination with the dust particles which may affect the performance of the system. Petroleum jelly is used as the initial lubricant for the chain drives. Mineral oil, synthetic oil or light grease is used to lubricate the bearings. It is always recommended to clean the surroundings of the machine daily to avoid unnecessary failures of the components as dust is one of the major factors that affect the performance.

III. RESULTS AND DISCUSSION

The coconut sorting process is currently done manually in Sri Lanka and therefore it was important to consider the cost of the machine which was designed. The cost was tried to keep at the minimum possible value to ensure that the machine gives economic benefits for the users over the manual mode of sorting the coconuts. The data collected in various methods including the questionnaires given to the employers and the customers provided useful information to decide the best design parameters for the machine. The motor of the machine which was one of the most costly

item was carefully selected. It was found with the data collected that an average requirement of 450 to 500 coconuts must be sorted within an hour. Therefore by considering the total length of the conveyor design, available speeds of the motors along with the power requirements in the market and the price, the rotating speed of the motor was finally calculated to be 75 rpm.

A. Results from Finite Element Analysis

Finite element analysis was done to the main components in the design and the stress, strain, displacement, and buckling results obtained in the FEA was compared with calculated results to ensure that the components are within the safe limits.

Table 2. Results from Finite Element Analysis

Component	Stress (MPa)	Strain	Displacement (mm)
Solid Shaft	5.739×10^{-3}	0.0248×10^{-6}	0.122
Hollow Shaft	1.472	4.192×10^{-6}	4.895×10^{-5}
Sprocket	414	3.06×10^{-3}	5.34×10^{-3}
Frame	0.2038	3.504×10^{-6}	4.652×10^{-3}

B. Testing of the Machine

The machine was operated and tested after the fabrication and some changes were required to be done in the rollers according to the results obtained during the testing process and the errors which could not be found during the designing of the machine. Initially the rollers were covered with spikes to lift the coconut to move them to the next roller. For the conveyors which move goods from one end to another, the concept is that the item which is sent in the conveyor should be in contact with at least three rollers in the conveyor system. The rule was not able to fulfil here as the main objective was to sort the coconuts according to the size and take them out in respective spaces between the rollers. There was a large possibility that the coconuts get struck in between the rollers and affect the rotation of the rollers when spikes were used. The arrangement of the spikes on the rollers, length of the spikes and the material used to create the spikes were changed accordingly and tested several times.

Figure 5. Testing the Rollers with Spikes

The rollers were covered with rubber sheets to increase the friction between the roller and the coconuts and the machine was tested again. The coconuts were not found to be getting struck between the rollers there but the movement of the coconuts from one roller to another was an issue.

Figure 6. Testing the Rollers with Rubber Sheets

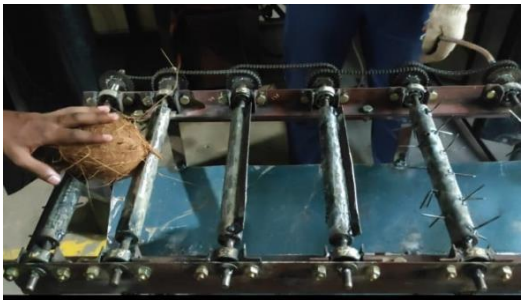

Figure 7. Testing the Rollers with Flat Iron

The rollers were then provided with flat iron plates to lift the coconuts up whenever the coconuts get into the space between the two rollers. This method was found to be more efficient than the other designs used on the rollers and the sorting was tested for coconuts in the size range from 90 mm to 140 mm.

The light and compact design of the machine enables the user to move the machine from one location to another according to the requirement. The availability of the components used in the design in the market ensures the convenience in maintaining and repairing the machine.

IV. CONCLUSION

This sorting machine provide a precise and efficient method to sort the coconuts into three size categories. The materials were selected considering the calculations, stress analysis, cost and the availability in the market. The designed sorting machine has the ability to fulfil the requirement of sorting 450-500 coconuts within an hour and in comparison, to the manual mode, time consumption and cost is reduced with the machine. When the labour cost incurred in manually sorting coconut is compared against the cost for fabrication of the machine, the investment turnover of this asset will economically benefit the users within six months after the initial installation of the machine. The dimensions were taken for the machine design as per the capacity requirement in the Sri Lankan

market. According to the requirement, the size of the machine can be increased or decreased and the same mechanism will work for similar processes. The designed machine is eco-friendly as it does not use any fossil fuels and there are no harmful gases emitted to the atmosphere. No bi-products are produced during the operation and the impact to the environment by this machine is at the lowest level. The operator of the machine does not have to interact with the sorting process after the coconuts are fed to the conveyor through the hopper and the safety of the operator is also assured. The Arduino system used in the machine provides the ability to easily get the count of the coconuts sorted in each and every category and the data can be used to analyze the size distribution of a coconut lot. The Arduino system can be further developed to provide a signal when the collectors are full, to measure the mass of the coconuts and also to activate a conveyor to move the sorted coconuts from the collected baskets. Moreover, the machine can be combined with a coconut de-husking machine where the grading and sorting of the nuts can be done just after the process of de-husking.

Coconut being one of the main export crops in Sri Lanka and holding a significant share in world coconut products market, with this design, a fair pricing technique can be introduced to be used in the large-scale coconut industries to sort and grade the coconut efficiently and precisely. Sorting according to the size is an important value adding technique for most of the agricultural products. Since there is no precise sorting mechanism available in the Sri Lankan market for the sorting process of husked coconuts, the government tried to introduce some techniques to sort the coconuts which could not be properly implemented and turned out to be an utter failure. The new technique will be beneficial for both the businessmen and the consumers as a transparent system for pricing will be introduced by this sorting machine.

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