Presented at the 5th DLSU Innovation and Technology Fair 2017
De La Salle University, Manila, Philippines
November 28 & 29, 2017

Design Implementation of a Tedding Mechanism for Grain Sun Drying

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Abstract: The rice paddy drying process is one of the most crucial procedures in rice production as it greatly affects the quality of the output as it is used to achieve the correct percent moisture in the paddy. One process in managing the pavement solar drying process involves manually tedding the paddy, which refers to the manual process of turning over and spreading out grain, a process still widely used today by Filipino farmers. This is due to it being the cheapest and cleanest method available. The automation of this process will not only have a better management of the time it is tedded but can increase the quality of the rice paddy. This study aims to design a tedding mechanism for grain sun drying. Different designs include a tossing design, a plow design, a vacuum design, and a sweeper wheel design. The selected mechanism was fabricated and tested for its effectivity. Results show that the model can sweep up and collect grains laid on a pavement with an error of less than 3%.

Key Words: automation; tedding; grain sun drying

1. INTRODUCTION

Rice is one of the main crops produced to solve the economic and food security problems in the Philippines thus, bringing great importance to the production process of rice farming and milling in the country. Despite the increase in rice paddy production over the past decade the total yield of produce has reduced due to under-developed and unreliable post-harvest procedures specifically, paddy drying. The drying process is one of the most crucial procedures in rice production as it greatly affects the quality of the output as it is used to achieve the correct percent moisture in the paddy. Exceeding or receding the recommended percent moisture of 14%, according to the International Rice Research Institute (IRRI) (IRRI Knowledge Bank, n.d.), can lead to breakage or discoloration and spoilage (IRRI Knowledge Bank, 2013). There is great importance on the keen monitoring and proper maintenance of the grain's temperature leading to the development of modern mechanical dryers. Although, due to the high cost, strict maintenance, and technical knowledge required, the process of pavement sun drying became more widely used being the cheapest and cleanest method available (Thompson, 1998). It is recommended by IRRI that the grain should be tedded every thirty (30) minutes as the paddy is spread sufficiently in thick layers for even drying (IRRI Knowledge Bank, 2013).

There is also great importance in mechanising the process of collecting the paddy spread on the wide pavement. Mr. Jorge Aguilar, owner of a rice mill at San Leonardo, Nueva Ecija and President of Lasaltech Academy, stated that the difficulty of the manual collection of paddy was stressed as one of the major problems of most rice millers because of the lack of technology that can be used for that project and the speed they require. This is important when packing up the paddy when the rain is about to start; he stated that it will take more than an hour or more when manually collecting the paddy depending on the size of the field. The larger the drying field, the more man power you need to quickly collect the paddy since they're process of collecting is only by sweeping the grain. A machine that can automate the process and prove to have a faster pace than the manual procedure will be of great help to many post-harvesters.

2. OBJECTIVES

- To determine the best mechanical design that can effectively turn over grains on the pavement based on the needs of farmers and millers and, the recommended standard tedding process of the International Rice Research Institute (IRRI).
- To assess the designs and select one based on accessibility, complexity of design, power requirements, and adaptability/flexibility to the application.
- To test the selected design on the effectiveness of tedding the grains and thoroughness of sweeping

3. DESIGN CONSIDERATIONS

Different designs were considered for implementing a mechanised tedding mechanism. These designs were the tossing design, the plow design, the vacuum design, and the sweeper wheel design. The objective is to have a mechanism that can effectively gather and collect the grains, is easy to assemble and execute, and has low power requirements. Furthermore, the design should have no, if not less, breakage of grains during the process.

2.1 Sweep and Catch Design

The first design for the process of both stirring and collecting the grains performs a sweeping and catching motion using brushes and ramps (See Fig. 1). The design involves a circular wheel design that will sweep the paddy from the floor with the intention of tossing it into the air. According to the rice miller interviewed for the research, it is common for workers to toss the paddy to let air pass through the paddy allowing it to dry faster. To achieve this, the ramp for the sweeper wheel designs are shorter and they follow the arc of the wheel. To perform the tossing motion, a high-speed motor should be used to spin the wheel. This is also necessary for the sweeping mechanism to keep up with the speed of the robot given that it has only one point of contact to the floor for every sweep. The first type is the sweeper wheel that tosses the paddy to the conveyor that moves towards the opposite direction as the wheel. The conveyor is designed to catch the tossed paddy which will then rotate and drop the paddy back to the floor.

The second design as shown in Fig. 2 is a modified sweeper wheel design but still with the same purpose. This design separates the brushes into smaller segments to form a slanted pattern. Each brush segment is attached to a spring return cylinder that is meant to adjust its length depending on the amount of paddy being swept and the evenness of the terrain.

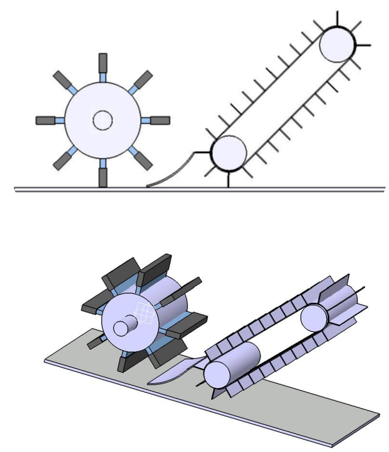


Fig. 1. Sweep and Catch CAD Design 1

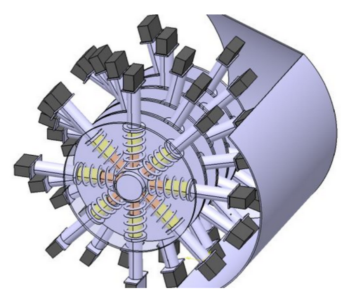


Fig. 2. Sweep and Catch CAD Design 2

2.2 Plow Design

This design, as shown in Fig. 3, involves a rigid plow shape intended to flip a layer of paddy as it is driven across the field. It is composed of two sheet metal curves that splits the field and flips it back to its initial position. The first plow is shaped similar to regular snow plows where there is a pointed folded tip in the middle while both ends of the metal sheet fold back to form a wall. In this design, the walls of the plow also curve inwards to initiate the flipping process as it passes through at moderate speed. The first plow is positioned at the front and center of the robot. Then, a pair of curved metal sheets on each end behind the first plow catch the paddy left by the first plow and flips it back to the center of the plot. Each of the second plows are curved inward to the center of the robot.

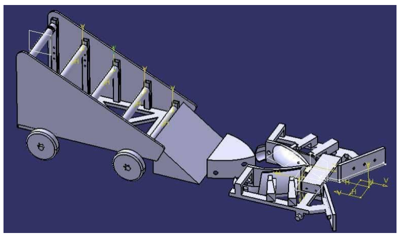


Fig. 3. Plow CAD Design

2.3 Vacuum Design

The vacuum pump design makes use of a cyclone separator to stir and collect the paddy instead of driving a mechanism on the field. This design is composed of a vacuum nozzle, a cyclone separator, and a ring blower (See Fig. 4). It uses the same principle as an ordinary cyclone separator but once it is separated from the air, it stores the paddy in a cylinder and decides whether it dispenses the grains in a bag or back to the pavement. The storage cylinder contains a servo driven segment-shaped plate that covers both exit paths for the paddy. One exit leads to the bagging mechanism and the other allows the paddy fall on a slide and back on the pavement. The percent moisture is taken from inside the storage cylinder then the cover rotates as dictated by the program. This design needs a generator needed to power the ring blower and the robot.

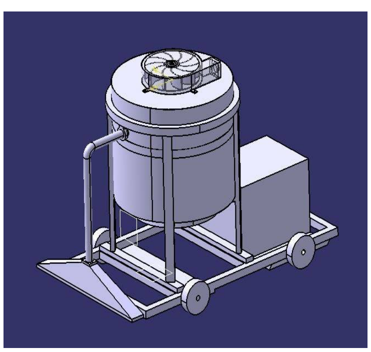


Fig. 4. Vacuum CAD Design

2.4 Sweeper Wheel Design

The conveyor is the central and most important mechanism of the design as it is meant to accomplish the objectives of the robot, which is to stir and collect the paddy, making its design crucial to the overall performance of the robot. This design is composed of the shafting, the conveyor belt, the brush mechanism and the ramp. Conveyor and brush mechanism sweeps the grains from the ground and up to the ramp. The ramp has a slanted end platform to have the paddy slide down to the either a bin or to the ground once it reaches the top end. Figure 5 shows the drawing of the model.

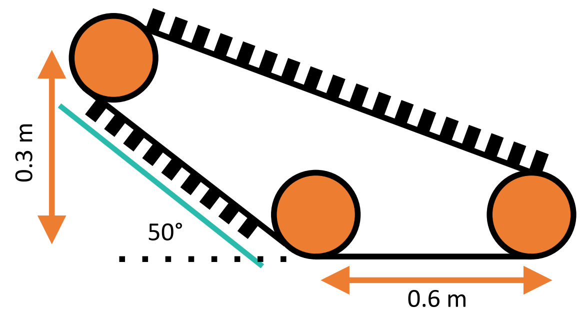


Fig. 5. Sweeper Wheel Design

4. METHODOLOGY

The optimum design will be assessed based on power requirements, practicality, simplicity, and assumed limitations. The selected design will be fabricated and tested.

4.1 Sweep and Catch Design Analysis

One of the main problems with this design is how the paddy may be vigorously tossed by the high-speed wheel. This may lead to fractures or breakage in the paddy. Another is the use of high powered motors namely, one high speed motor for the sweeper wheel and a high torque motor for the conveyor. For the second design, the separated cylinder design opens gaps that the grain may enter and may eventually damage the mechanism. The springs for the second design may also be prone to damage and hard to reach for repair in the occurrence of the mentioned event.

4.2 Plow Design Analysis

The difference of this design to the others is that there is no mechanical movement needed to stir the paddy. The plow is simply bulldozed by the mobile robot across the field. Although, the disadvantages of this design oppose to all its features. The plow should be well supported by a rigid frame which may increase the weight of the robot and, therefore, the torque needed for the motors. Another, is that this design is only good for stirring the paddy and not for collecting. Thus, a separate mechanism is needed behind the plow for collection, which will affect the size of the robot. This project intends to lessen the expenses needed in maintaining the quality of paddy in the process of sun drying and a single mechanism that performs both objectives is needed to achieve this and the target efficiency.

4.3 Vacuum Design Analysis

This is an efficient design as it no longer uses a mechanism that directly handles the paddy or is in contact with the floor which means it will not be greatly affected by environmental factors. It will also be able to rapidly collect the paddy with the power of the cyclone but this speed may also damage the paddy. The speed of the vacuum will cause the paddy to stir and toss hitting the walls inside the cyclone before it passes the separator. The paddy may also be damaged by the separator as it is a turbine that spins below the cyclone. These factors can affect both wet and dry paddy. Furthermore, this design has high power requirements especially for the ring blower.

4.4 Sweeper Wheel Design Analysis

This design still uses mechanical movement but utilizes only one motor to perform both sweeping and collecting functions without the need of a high-speed motor. It is also flexible in terms of adjusting the volume of grains collected per sweep. Moreover, the simple design may cause the least amount of breakage of grains due to the exclusion of a tossing mechanism like the one in Section 2.1 and 2.3. Although, some grains may still pass through the gap between the ramp and the ground.

Due to the substantial advantages and practicality of this design over the others, the sweeper wheel design is the selected model to be implemented and experimented.

5. EXPERIMENTATION OF SELECTED DESIGN

After choosing the best design option, a full-scale prototype model was fabricated to test the execution of the concept. The prototype was designed with stainless steel to be able to support the weight of the paddy with the resistance of the brushes against the pavement while preventing any sort of contamination on the paddy. The conveyor will be elevated at the height where the bristles may thoroughly sweep the pavement but not too close to the roots to avoid considerable damage.

Stainless steel L-bars were used as conveyor flaps wherein the longer side of the L-bar will be where the brush strips are secured by rivets, while the shorter end will be bolted on the chain belt (See Fig. 6). The ramp is also made of stainless steel sheets formed to ensure that the grains stay inside while the conveyor is moving up the ramp. The conveyor is driven by a 3-phase motor that is mounted on a steel plate positioned at the elevated area of the frame. It is a 0.4kW, high torque motor that is right for the requirements needed. Figure 7 shows the fabricated design mounted on a mobile robot frame. Standard industry roller chains were used to build the conveyor design while improvised, commercially-available meter-long brush bristle strips are attached to the bars.

Fig. 6. Stainless Steel L-bars with brush strips

Fig. 7. Sweeper wheel design mounted on a mobile robot frame

The mobile robot frame can firmly position the main mechanical parts of the design while having an adjustability feature. This adjustability feature is made possible with the design of the leaving optional spaces for the fixed areas of the mechanism such as the rollers of the conveyor. This is important in troubleshooting and configuring the performance of the prototype. The effectiveness of the sweeper wheel design was tested through a series of experiments using actual rice paddy. The experiments were conducted in a controlled environment using actual unmilled or unhulled rice grains. The design was tested on its ability to ted grains by seeing how much of the rice grains is collected for every sweep and how well it is turned over to simulate the highly recommend process for even pavement sun drying.

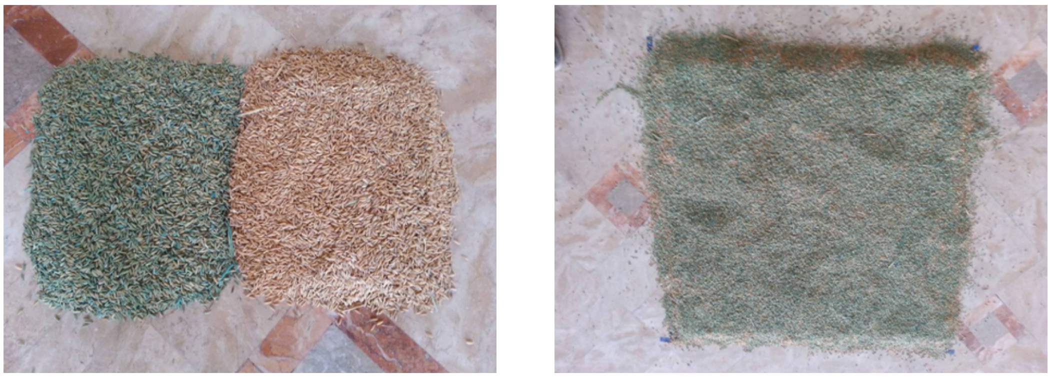
The first experiment focused on the tedding ability of the mechanism. This means being able to prove the function to flipping the bottom layers of grain to the top layers of grain thus, simulating even exposure to the sun resulting to even drying. To do be able to distinguish the layers of rice grains spread on the pavement, a sack of unhulled rice grains was divided into two and one batch was dyed with blue food coloring. The two batches of rice grains were spread in a 1 by 1 meter plot and layered on top of each other with the plain paddy on the bottom layer and the dyed paddy for the top layer as shown in Fig. 8. The mobile robot was, then, maneuvered across the plot to sweep the grain and each pass will be visually inspected. This process will be performed three (3) times to observe the effect of a properly monitored and continuously tedded plot of drying rice grains. This visual assessment documented and used to determine efficiency of tedding the paddy.

The second experiment will evaluate the accuracy or thoroughness of the sweeper design in fully collecting the grains spread on a flat surface. This will mainly test the effectiveness in applying brush strips and the sturdiness of the conveyor flap design in displacing the grain smoothly towards the destination. To do this, the mechanism must be operated to sweep all the grain from the pavement and any remaining will be weighed and compared against the total weight of the spread paddy. This experiment was executed running the machine across a plot of measured unhulled rice grains to completely sweep off the produce up the ramp and into a bin, then, the remaining rice grains were collected, weighed, and calculated. The remaining rice grains will be considered the percentage error in the accuracy of the process.

6. RESULTS AND DISCUSSION

At the first experiment, remnants of the top layer, dyed paddy was still observed on the plot after the first pass of the robot. It was observed in the process that each sweep of the mechanism divides the plot and teds each segment separately from the one next to it. This effect can show the effectiveness of the tedding process as each segment lands with the top layer facing down with each mound leaving a trail of dyed rice grains or top layer after each segment. A second pass was conducted and visible signs of the dyed paddy have significantly reduced. Cutting through the edges of the plot will reveal that majority of the rice grains at the bottom layer are dyed. This presents results of the mechanism being able to effectively ted the grains after two passes, which is equivalent to one hour of drying. On the third pass, the color of the dyed paddy has been toned down by the plain paddy and the visual results can already consider the tedding process acceptable to a complete turning over process of the layers (See Fig. 9). In the Figure, the color of the dyed paddy was intensified to clearly see the difference. This can be attributed to the wrong speed ratio of the robot and the conveyor. The robot moves forward faster that the conveyor sweeps the grains up the ramp and back to the ground.

After sweeping and collecting all the paddy, the remaining grains resulted to an average loss in collection of 2.88%. Some factors that affect the outcome include the unevenness of the grains laid on the ground - some are more or less than expected. Moreover, the gap between the ramp and the ground was also a factor since some grains passed through it and remained uncollected. The ramp also had an impact on the collection as it was not flat resulting to grains not fully being sweeped up the ramp.



(a) (b)

Fig. 8. (a) Dyed and plain paddy, (b) Dyed paddy on top of the plain paddy layer

(a) (b) (c)

Fig. 8. (a) First pass of the mobile robot on the plot of paddy, (b) Second pass, (c) Third pass

7. CONCLUSION

The design considerations of a tedding mechanism for grain sun drying were discussed. Fabrication and testing of a working prototype was based on the best option in terms of practicality and effectiveness of the design. Out of the four (4) designs conceptualized, the sweeper wheel design was chosen to be the most advantageous to be further analysed and tested. It is the least susceptible to breakage of grains compared to the Vacuum Design, and Sweep and Catch Design based on the condition of the grains during the operation of the mechanism. It is considered to be more practical than the other designs in terms of number of parts to be manufactured and the power requirements of the whole system. The selected design proven to be effective in sweeping with only a loss in collection of 2.88%. The tedding of the grains with the design, however, still needs improvement since the mobile robot with the conveyor have to sweep the grains 3 times to be acceptable. But these results may also be considered acceptable when being applied to an actual grain sun drying operation with proper monitoring and continuous, timely tedding because it can accomplish partial tedding every 30 minutes and complete tedding every 1 and half hour which is only a portion of the complete drying period.

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