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DESIGN AND DEVELOPMENT OF RICE MILLING AND GRINDING MACHINE

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Abstract:-
The main objective of the study is to design and construct a prototype of a rice huller with rice grinder. Experimental research approach is used in this study. It is an attempt by the researcher to maintain control over all factors that may affect the result of an experiment. The researchers had successfully fabricated a prototype of a rice huller than can efficiently husk and bran of the rice using the principle of friction resulting from the rotating motion of the steel roll. A vacuum fan was also installed to suck the remaining light husk at the exhaust of the rice huller. The resulting output from the rice huller with vacuum fan had a husk to rice ratio of less than one cup of husk per 30 cups of rice.

Keywords:- *Rice Milling, Grinding Machine*

INTRODUCTION

Rice (Oryza sativa) or locally known as palay, bigas, kanin is common to the Filipinos, that is rarely every missing on the table be it breakfast, lunch or dinner. As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population, especially in Asia. It is the agricultural commodity with the third-highest worldwide production, after sugarcane and maize, according to data of Food and Agriculture Organization of the United Nations (2014).

Milling is the process wherein the rice grain is transformed into a form suitable for human consumption, therefore, has to be done with utmost care to prevent breakage of the kernel and improve the recovery. Brown rice is milled further to create more visual appealing white rice. After harvesting and drying, the paddy is subjected to the primary milling operation which includes de-husking as well as the removal of bran layers (polishing) before it is consumed (Shankar, 2014).

Throughout history, there have been numerous techniques to hull rice. Traditionally, it would be pounded using some form of mortar and pestle. An early simple machine to do this is a rice pounder. Later even more efficient machinery was developed to hull and polish rice. Nowadays, a rice huller or rice husker is an agricultural machine made to automate the process of removing the chaff (the outer husks) of grains of rice.

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The purpose of a rice milling system is to remove the husk and the bran layers from paddy rice to produce whole white rice kernels that are sufficiently milled, free of impurities and contain a minimum number of broken kernels (International Rice Research Institute). As mentioned by Tangpinijkul (2010), a rice milling system can be a simple one or two step process, or a multistage process. In a one-step milling process, husk and bran removal are done in one pass and milled or white rice is produced directly out of paddy. In a two-step process, removing husk and removing bran are done separately, and brown rice is produced as an intermediate product.

The single pass rice mill is an adaptation of the "Engleberg" coffee huller. This type of mill is still very popular in many of the poorer rice-growing countries and is widely used for custom milling of household rice. This mill is a steel friction type mill and uses very high pressure to remove the hull and polish the grain. This results in many broken kernels, a low white rice recovery of 50-55% and head rice yields of less than 30% of the total milled rice (IRRI, 2014).

The steel husker is in fact more than a husker since it also does the polishing. It is an adaptation of the "Engleberg" coffee huller, modified for milling rice. Paddy rice is fed into the machine and passes between a revolving steel shaft and a cylindrical shaped mesh screen. These machines are normally powered by a 1 to 5 hp engine and are very simple to operate (Dhankhar, 2014).

It combines the dehusking and polishing process into one operation. Paddy is fed into the hopper and, because of the rotational direction of the flutes on the revolving cylinder, is forced to move around the cylinder and toward the outlet. Friction between the grains and the steel parts of the huller (particularly the perforated sheet) causes the husk and bran to be scraped off. In the process, the husk and bran are ground into small pieces and most are pushed through the perforated screen (Tangpinijkul, 2010).

Major beneficiaries of the introduction of new technology have been the consumers who benefit from lower rice prices. Those for whom rice represents a major portion of the diet, that is to say the poorest families, clearly benefited the most. National governments also recognized a major political advantage in maintaining low and stable rice prices and were quick to promote and support the adoption of the new technology (Barker & Herdt, 1985).

The core of the rice huller is the steel roller which is a steel friction type mill and uses very high pressure to remove the hull and polish the grain. It combines the de-husking and polishing process into one operation. Paddy is fed into the hopper and, because of the rotational direction of the flutes on the revolving cylinder, is forced to move around the cylinder and toward the outlet. Friction between the grains and the steel parts of the huller (particularly the perforated sheet) causes the husk and bran to be scraped off. In the process, the husk and bran are ground into small pieces and most are pushed through the perforated screen and then is fed into a rice grinder.

This study was made to further improve the old design of rice huller which was more economical since the maintenance costs are less.

Objectives

The main objective of the study is to design and construct a prototype of a rice huller with rice grinder. Specifically, the study aimed: (1) to remove husk or bran on paddy with an output husking ratio of 30 cups of rice per 1 cup husk and (2) to produce fine grind rice from the husked rice.

Materials and methods

Research Design

Experimental research approach is used in this study. It is an attempt by the researcher to maintain control over all factors that may affect the result of an experiment. In doing this, the researcher attempts to determine or predict what may occur. The steps involved in conducting an experimental study are 1.) identifying and defining the problem 2.) Formulating hypotheses and deducing their consequences 3.) Constructing an experimental design that represents all the elements, conditions, and relations of the consequences. 4.) Conducting the experiment

Figure 1. Rice Huller and Grinder

Description of the Rice Huller and Grinder

Figure 1 shows the final design of the Rice Huller and Grinder. It is 23.5 inches long, 21 inches wide and 43 inches tall. The machine consists of main parts like the feeding hopper, roller, sieve, knife, vacuum, plate grinder, screw conveyor, pulley and transmission belt, electric motor.

The rice huller casing is made of steel. This part is where the rice passes and also where the hulling process occurs. Inside the casing is the steel roller, sieve and the blade which was sandwiched between to plates welded into the casing using the clamps.

The roller was made from iron steel. The diameters of the steel roller and the shaft were 4 inches and 1 inch respectively. Steel square bar of 0.5 inch is welded 60 degrees around on one fourth part of the roller that will serve as screw conveyor which conveys the paddy inside the huller. Another set of steel square bar of 0.5 inch is welded horizontally on the remaining length of the roller. The length of the steel roller is 14 inches.

The hopper serves as an entrance to the rice huller. A thin plate is placed on the lower part of the hopper neck than can be opened or closed. The main function of the adjuster plate is to regulate the feed or paddy that will enter the rice huller. The hopper has a square upper and base area which is 7 inches and 1.5 inches on one side respectively. This dimension for a hopper will hold 1 kilo of paddy when full. It also has steel plate installed at the bottom that will serve as the feed regulator.

Figure 2 shows the vacuum fan which is s placed above the grinder. The vacuum is a 600kW fan which operates at 220 V, 2.7 A, 16000 rev/min and 50-60Hz. Its main function is to suck the leftover husk at the exhaust of the rice huller.

The motion of the motor was transmitted through belts and pulleys to rotate the belt driven rice grinder. The torque was computed using a lever attached to the shaft of the huller and the grinder and a spring balance. The lever was 1 ft long. The researchers hooked the spring balance in the lever and pull the spring balance in clockwise direction. The force of 2.2 lb and 1.8 lbs were recorded from the spring balance.

The torque at the huller is equal to 1 ft x 2.2 lb = 2.2 ft-lb. The torque at the grinder is equal to 1 ft x 1.9 lbs = 1.8 ft-lb. The total torque can be measured by adding all the torque from the prototype and is equal to 1.9 + 2.2 = 4.1 ft -lb

Figure 2. vaccum fan

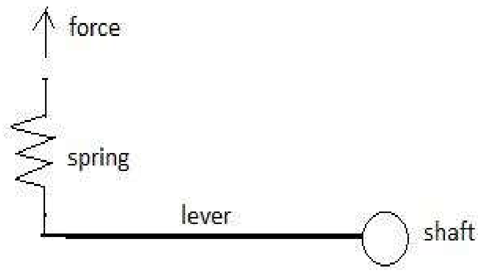

Figure 3. Free Body Diagram of the measurement of Torque

Power is the rate at which electrical energy is converted to another form such as motion. It is given by the formula $P = 2\pi TN$ where T is the torque and N is the number of revolution per minute.

$$P = 2\pi TN$$
$$P = 2\pi(4.1\ ft - lb)(1720\ rpm)$$
$$P = 44309.02279\ \frac{ft\ lb}{min}\ x\ \frac{\min hp}{33000\ ft\ lb}$$

P = 1.34 HP

The available horsepower that can be purchased was 1.5 Hp. The researchers used the 1.5 HP motor for the prototype.

Figure 4. Pulley

Pulleys as shown on Figure 4 are used in transmitting motion from the motor to the drive shaft and other machine driven apparatus. The size of pulley at the motor, roller (right side), roller (left side) and shredder are 2.5 inches, 2.5 inches, 7 inches and 1.5 inches respectively. V belt was computed using the following steps:

Pulley and belt:

$$N_1D_1 = N_2D_2$$
$$(1720)(2.5) = N_2\,(7)$$

$N_2 = 614\ rpm$

Where; N_1 is the rated speed of the motor in rpm, N_2 is the speed of the pulley connected to the shaft of steel roller in rpm, D_1 is the diameter of the motor pulley in inches and D_2 the diameter of the pulley connected to the shaft of steel roller in inches. Given that N_1 = 1740 rpm, D_1 = 2.5 in and D_2 = 7 in, hence N_2 = 614 rpm. The required speed of the shaft of steel roller is 614 rpm.

The driving machine is a single phase electric motor and the driven machine is a hammer mills, then the service factor N_{sf} = 1.6.

$Designhorsepower = NsfxHP$ (from Design of Machine Elements by Faires (1968))

$$Dhp\ =\ 1.6\,x1.5$$
$$Dhp\ =\ 2.4\,HP$$
$$Vm =\ beltspeed$$
$$Vm\ =\ 2\pi rN$$
$$Vm\ =\ (1720\,rpm)(\frac{2\pi c}{1\,rev})(1.25in)(\frac{1\,ft}{12\,in})$$
$$Vm\ = 1125.74fpm$$

, Use type A V-belt.

According to Faires (1968) the length of the transmission belt was calculated using Equation 4

$$L = 2C + \frac{\pi}{2}(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C} \quad (4)$$

Where, C and L are the center-to-center distance and length of the belt, respectively in inches (in). With C = 14.25 in, this center distance is enough to place the motor at the back of steel roller shaft, D_1 = 2.5 in, D_2 = 7 in and π = 3.1416,

$$L = 2(14.25) + \frac{\pi}{2}(7 + 2.5) + \frac{(7 - 2.5)^2}{4(14.25)}$$
$$L = 43.779$$

hence L = 43.778 *in*

The available standard V-belt pitch length are 43.3 for belt number A-42 and 47.3 for belt number A-46. Because there is no available pitch length of belt number A-43, the interpolated value of the pitch length for A-43 is equal to 44.3 *in*.

So the center distance will be adjusted,

$$L = 2C + \frac{\pi}{2}(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C}$$
$$44.3 = 2C + \frac{\pi}{2}(7 + 2.5) + \frac{(7 - 2.5)^2}{4C}$$
$$C = 14.58\,in$$

Hence C = 14.58 *in*

Therefore, use a V-belt of specification A-43, pitch length equals to 44.3 *in*

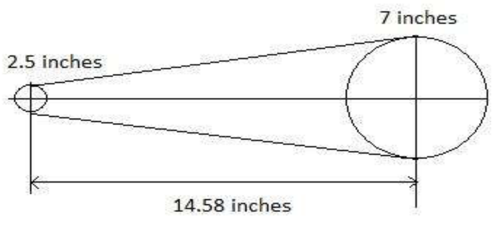

Figure 5. Free Body Diagram of Motor Pulley and the Pulley Connected to the Shaft of Steel Roller

$N2D2' = N3D3$

$$(614)(2.5) = N_3\,(2)$$

$N_3 = 767.5\ rpm$

Where; N_2 is the rated speed of the shaft of steel roller in rpm, N_3 is the speed of the pulley connected to the shaft of grinder in rpm, D_2' is the diameter pulley on the right side of steel roller in inches and D_3 the diameter of the pulley connected to the shaft of grinder in inches. Given that N_2 = 614 rpm, D_2' = 2.5 in and D_3 = 2 in, hence N_3 = 767.5 rpm. The required speed of the shaft of steel roller is 767.5 rpm.

The driving machine is a single phase electric motor and the driven machine is a conveyor, then the service factor N_{sf} = 1.4.

$Designhorsepower = NsfxHP$ (from Design of Machine Elements by Faires (1968))

$$Dhp = 1.4\ x1.5$$

$Dhp = 2.1\ HP$

$Vm = beltspeed$

$$Vm = 2\pi rN$$

$$Vm = (1720\ rpm)(\frac{2\pi c}{1\ rev})(1.25in)(\frac{1\ ft}{12\ in})$$

$$Vm = 1125.74fpm$$

From APPENDIX B, Use type A V-belt.

According to Faires (1968) length of the transmission belt was calculated using

$$L = 2C + \frac{\pi}{2}(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C}$$

where, C and L are the center-to-center distance and length of the belt, respectively in inches (in). With C = 25.5 in, this center distance is enough to place the grinder shaft below the steel roller shaft, D_1 = 2.5 in, D_2 = 7 in and π = 3.1416,

$$L = 2(25.5) + \frac{\pi}{2}(2 + 2.5) + \frac{(2-2.5)^2}{4(25.5)}$$

$$L = 58.071\ in$$

hence L = 58.071 in

The available standard V-belt pitch length are 56.3 for belt number A-55 and 61.3 for belt number A-60. Because there is no available pitch length of belt number A-57, the interpolated value of the pitch length for A-57 is equal to 58.3 in. So the center distance will be adjusted,

$$L = 2C + \frac{\pi}{2}(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C}$$

$$58.3 = 2C + \frac{\pi}{2}(2 + 2.5) + \frac{(2 - 2.5)^2}{4C}$$

$$C = 25.61\ in$$

Hence C = 25.61 in

Therefore, use a V-belt of specification A-57, pitch length equals to 58.3

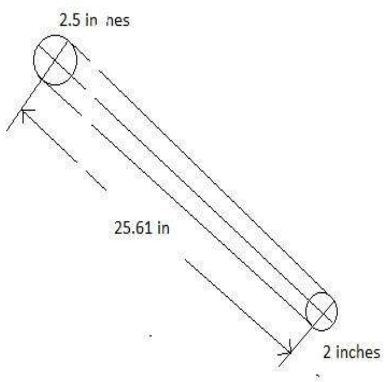

Figure 6. Free Body Diagram of Steel Roller Pulley and the Pulley Connected to the shaft of Grinder

The sieve holes have a thickness of 1 millimeter. The screen is a grid whose holes are big enough to allow the chaff and bran to cross, but also small enough to not allow the hulled rice to cross the grid.

The knife and adjustable screw, in combination with the hulling cylinders; allow the separating of the chaffs and bran of the rice. The knife of the huller must be replaced regularly, because it comes in contact with the chaff of rice which is very abrasive. To limit the wear nevertheless, the knife is made in steel with increased durability. The knife is 14 inches long, 1 inch wide and 0.25 inches thick. At both ends of the knife is a screw to allow the adjustment of the distance between the knife and the hulling cylinders (this distance should be slightly higher than the diameter of hulled rice, but lower than that of the paddy rice).

Figure 7. Rice Grinder

Figure 7 show the grinder, which is composed of the screw conveyor and the stationary and rotary grinding plates and plate clearance adjuster.

Operation

1. Make sure that the machine is free from dust before operating.
2. Check everything including the belts and adjustable screws to make sure the tension is enough to avoid slippage.
3. Place a bowl under the grinder to collect the grinded rice.
4. Place a sack at the exit hose of the fan and at the exhaust to collect the husks and bran.
5. Plug in the machine into 220V power source.
6. Turn on the switch of the vacuum fan.
7. Pour 1kilo of palay into the hopper.
8. Turn on the switch.
9. Slowly open the feed regulator into the desired feed rate.
10. After collecting the produced grinded rice, press the switch off button.
11. Unplug the power source and clean the area.

RESULTS AND DISCUSSION

The researchers conducted series of experiments to analyze the Rice milling and grinding machine. The picture above was the result of the milling process where there is no vacuum fan installed, the clearance of the blade to the cylinder was greater than the paddy width and the feed was half opened. Almost 50% of the produced rice contains husk and almost all of the rice kernels were broken.

In trial number 2, still there was no vacuum fan installed; the clearance of the blade to the cylinder was greater than the paddy width and the feed was adjusted into fully open. The produced rice contains 25% husk but still a considerable amount and the output has few whole kernels at this trial**.**

In trial number 3, there was no vacuum fan installed; the feed was only half open and the clearance of the blade to the cylinder less than the width of the paddy. The result had only 30% husk many broken rice kernels and few whole kernels. In trial number 4, there was no vacuum fan installed, the clearance of the blade to the cylinder less than the width of the paddy and the feed was adjusted into fully open. The result has only 10 -15 % husk and had few whole and broken kernels.

In trial no 5, root diameter was added as another variable of the steel roller. The root diameter was changed from 4 inches to 4.25 inches leaving an allowable clearance of .25 inches for the rice to stay on the roller. Still there was no vacuum fan installed, the clearance of the blade to the cylinder less than the width of the paddy and the feed was adjusted into half open. The result had increased 20 -25 % husk and had few whole and broken kernels. The picture shows the outcome of trial no 5. Vacuum fan was added to suck the remaining husk on the output. The clearance of the blade to the cylinder was less than the width of the paddy and the feed was half open. The result had a decreased husk value and now ranging from 1-2 % husk but still had few whole and broken kernels.

In trial no 6, the vacuum fan was added to suck the remaining husk on the output. The clearance of the blade to the cylinder less than the width of the paddy and the feed was adjusted into fully open. The result had a decreased husk value and now ranging from 1-2 % husk and has many whole kernels.

Conclusions and recommendation

In this study, the researchers had successfully fabricated a prototype of a rice huller than can efficiently husk and bran of the rice using the principle of friction resulting from the rotating motion of the steel roll. A vacuum fan was also installed to suck the remaining light husk at the exhaust of the rice huller. The resulting output from the rice huller with vacuum fan had a husk to rice ratio of less than one cup of husk per 30 cups of rice. Also, the rice grinder installed at the exhaust of the huller was capable of grinding the rice into a course grind rice output.

The researchers recommend that the rpm of the steel roller can be adjusted to minimize the amount of broken rice. Further research may be conducted on grinder that can produce more pulverized grind rice output and a better way of sealing the screen channel to efficiently suck the light husks by the vacuum fan and to achieve good rice milled to be grinded as well.

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