

# OVERVIEW OF THE DEVELOPMENT OF MILLING MACHINE FOR EFFECTIVE UTILISATION, ADAPTATION AND INCREASED RICE PRODUCTION IN NIGERIA

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## Abstract

Nigeria belongs to the leading importers and consumers of rice worldwide. Billions of Naira is spent annually to import rice to increase its total supply. Rice produced by local farmers is processed by cottage mills that produce low quality milled rice, containing mainly dirt, stones, having short grains and unpolished; making the rice unattractive, poorly priced and rarely attractive to the people. In spite of the contributions of different researchers in the country, no locally produced commercial rice processing machine exist since none have been optimized and tested for specific machine parameters. Overview of the development of milling machine for effective utilization, adaptation and increased rice production to meet her local demand was done. Step-by-step reference point on the development of rice processing machines was done. It is suggested that more user friendly rice mills should be installed in all rice producing parts in Nigeria to process grains that have comparable quality with imported rice. Locally developed rice processing machines should be adapted and made available for application by farmers at subsidized prices. Extension services should be intensified to teach the farmers on utilizing and adapting latest technology, with synergy between all stakeholders in order to enhance rice production. Stakeholders must work towards making sure that rice quality is guaranteed during production. More researches should be conducted with funding from relevant organs of governments and institutions. Stakeholders should work towards enhancing rice availability, accessibility, affordability, utilization, stability and improved standard of living of the people.

**Key Words:** Rice, Milling, Machine, Development, Production

## 1.0 INTRODUCTION

Nigeria is one of the leading importers and consumers of rice in the world [13]. According to [21], Nigeria spends billions of Naira on annual basis to import rice from several exporting countries to increase its total supply. Nigeria imports most of its rice from Thailand, India and the USA, incurring a bill of about \$5 million daily (source). Rice is consumed across the entire zones and among the poor and rice classes in Nigeria. It is the third most preferred food items in Nigeria (after maize and cassava) and has become a very popular crop due to its increased importance in the country. Ironically, about 57% of the 6.9 million metric tones of rice consumed in Nigeria annually is produced locally, given a supply deficit of more than 3 million metric tones. There is a growing market for rice in Nigeria due to the estimated population of about 200 million. Rice is cropped in most Nigeria's agro-ecological zones. However, the North West accounts for 72% of total rice production [19] and [5].

[15] asserted that rice cultivation locally competes with imported rice, which is preferred for its extended white, clean grains, pebbles free but not as palatable as its local varieties. Eliminating pebbles and dirt from Nigerian rice, by using locally produced processors, manufactured locally at low cost compared with costly imported types, would encourage local farmers to produce rice of appreciable quality than imported types. Improving rice quality locally might discourage rice importation, whilst increasing local cultivation and processing.

As a result of the high cost and unaffordable machines produced in developed countries, there is a dire need to look inwards towards development of cost effective/efficient machines using locally available materials desirable in food industry that meets the need of the rural farmers. According to [32], even with the rice import ban, Nigeria was still importing several hundreds of thousands of tons of rice per year through illegal trade routes. The researcher concluded that the rice production Statistics in Nigeria clearly shows that the country needs 7.0 million metric tons of its demand.

[25] stated that milled rice obtained from the cottage processors utilizing a steel huller a single pass huller and polisher known for its high breakages of paddy. Local processors manually winnowed milled rice to separate the grains from the chaff. This procedure is tedious, consume lot of time and a substantial quantity of chaff, stones and other particles mixed with

the rice at the end of the day. The rice is normally not graded and not well cleaned. This explains why most local rice available in the market is characterized by a high percentage of broken grains and some foreign particles which attracts low prices in the markets. The main constrain in Nigerian rice industry is poor handling which introduces foreign materials such as pebbles during harvesting and post-harvest process. In spite of the contributions of different researchers in Nigeria in this regard, commercial rice de-stoning machines are not available due to the fact that the equipment have been optimized and tested for different machine parameters.

This negative trend can be reversed as there are a lot of opportunities in the rice value chain that will help the country to achieve self-sufficiency in rice production, and also transform the country from a net importer to an exporter of rice. For the purpose of meeting the demand locally, right investments have to be put in place, such as milling and grading, marketing, road and power infrastructures. Moreover, governments should considerably subsidize farm inputs at different levels as timely access to agricultural inputs can easily raise output level generally [7].

## 1.1 Objective of the study

The study reviews rice milling machine development for effective utilisation, adaptation and optimum rice quality and output in Nigeria. Consideration is given to development of different rice milling machines, identifying specific problems for lack of efficiency and adaptation by famers for increased output and quality of rice to measure up with the demand of the growing population. The review also enumerates step-by-step reference point on the design, fabrication and testing of rice processing machines.

## 2.0 Rice Milling Process

[29] reported that milling is the beginning stage of changing paddy rice into milled rice or brown rice that is suitable for consumption. The moisture content of the grain must be reduced to 13-15 percent. The husk is the outermost layer which protects the interior of the grain. It is made of cellulose and hemicelluloses. Brawn rice is the result after the husk is removed. The brown rice is composed of rice germ (or embryo) and endosperm or white rice covered by rice bran. Rice bran consists of layers of tissues covering the grain.

and it is a rich source of nutrient. Endosperm is the part of the grain that is consumed, primarily consisting of carbohydrate in starch form. For the sale of rice grains, whole kernels can be sold at a higher price than broken grains. Whole kernels refer to complete rice grains containing no broken parts and including at least 90 % of the grain length. Broken grains, on the other hand, mean broken rice grains with lengths of at least 25% of the grain length. Broken grains also refer to split rice grains with less than 80 percent of grain volume. The stages of rice milling process are (a) Milling-Dehulling/ Polishing/ cleaning/ separation and (b) Destoning.

1. Paddy rice has to be cleaned to remove contaminants such as hay, vegetation, dust, powder, gravel and sand from the paddy rice. The destoner Machine works based on the difference in grain specific gravity, grain size, shape, and surface state. When the destoner works, the working table is covered with a woven wire mesh bed, through which air flows from below.

2. Thus revealed that milling is a critical step in post-harvest processing of rice. The basic functions of any milling system are (a) remove the husk and brown layers, and (b) produce an edible white rice kernel that is sufficiently milled and free from impurities. Varieties of rice generally composed of about 20% rice hull, 11% bran layers and 69% starchy endosperm, which is referred to as the total milled rice. The by-products in rice are rice hull, rice grain, rice germ and bran layers and fine broken. [17] recorded that de-hulling is conducted to remove rice husks from the grains. In this stage, a huller consisting of 2 rubber balls which rotate in opposite direction at different speeds or a huller produced from two steel plates padded with rough stone is produces the friction which removes the husks from the grain. The rice obtained from this stage is brown rice, which still contains the fiber coating and embryo.

Most dehullers use frictional force in removing the outer thin layer of seed. This is achieved using a notched surface cylinder or discs with concave screen. The notched cylinder rubs against the crop, removing its outer covering, thereby reducing it to powdery form. This goes through the screen before removal, thereafter, the dehulled seed is removed through the chute. The dehuller is made up of the following: a. Hopper- this holds the agricultural materials, b. Serrated or notched Cylinder or Disc grinder- to de-hull the seeds c. Concave Screen: for separating grain from hulls, and d. Chute: for discharging processed materials [17].

3. Thus, Destoning of the rice is further carried out after successful milling.

4. Whitening and polishing is the stage at which the rice bran is polished from the brown rice, leaving only the endosperm. Rice bran is a byproduct of this stage.

5. In sorting the sizes of rice grains, sieves with openings for different sizes are used to sort head rice from broken grains and rice ends.

### 3.0 Contributions of different Researchers in the Development of Rice Milling Machines

[26] developed machine that utilised three reciprocating sieves with a blower revolving at 240 rpm to produce air velocity of 4.6 m/s for separating the contaminants. The author stated that for a grinding process to be effective, aperture of diameters, 3, 5.5 and 7 mm are selected for the bottom, intermediate and top sieves respectively. Parboiled milled grain produced from one-pass steel huller was fed into the machine and tested at tilt angles of 2, 3, 4, 5 and 6° for the intermediate sieve at blower inclinations of 0 and 5°. The results showed a mean spherical range of 2.85 to 3.45 mm, with sphericity between 0.41 and 0.50 and terminal velocity of 4.81 to 6.36ms<sup>-1</sup>. The machine had cleaning efficiency of 63.97

- 85.38%, with FARO 44 having the highest. Efficiency of grain was from 71.78 - 94.29% and the highest from ITA 150 at a blower inclination angle of 5°. The machine had a capacity of 1000 to 1200 kghr<sup>-1</sup>.

Better performance of the machine was at blower inclination of 5° except for FARO52. The machine was adopted after milling with an upgraded and processed rice quality from grade 2 to grade

1. This machine incorporation into rice processing at cottage industry can function as a secondary processing equipment.

[23] reiterated that in Nigeria, a lot of setbacks has been witnessed during rice processing, especially the problem of many unwanted materials such as stones. In a bid to enhance capacity towards meeting the continuous demand, designed, constructed, and evaluated the performance of a rice de-stoning machine. The machine had design capacity of 3 tons per day, was fabricated in the Faculty of Engineering workshop, Niger Delta University. It had a centrifugal blower, screw conveyor, reciprocating sieves, separating cylinder, transmission shaft rotating at speed, 360 rpm, powered by a 5 hp electric motor. The total cost of constructing the machine was estimated at ₦196,050. Evaluation of the machine revealed a de-stoning efficiency, 78%. The locally developed machine is cost effective and efficient, this helped to improve the quality and market value of rice produced in Nigeria. [11] produced a mini rice mill which consists of drive chain and gear amplification mechanism that rotate huller shaft in housing filled with paddy. The system was employed to remove the husk and the brown layers from paddy rice to produce white rice kernels. The machine contributed to freeing the user from rising energy costs, and can be used anywhere, and are easy to maintain, produce no pollution and provide healthy exercise. This system consists of energy unit - made up of human energy as the source for pedalling bicycle mechanism. On the average, human being can produce power to pedal at the rate of 50-60 pedals per minute. Bicycle mechanism, including chain and sprocket was utilized. Shafts, two pairs of spur gears, a flywheel (50kg) and clutch plate were utilized in the transmission system. The larger sprocket of the driving system was mounted on a shaft (shaft number 1), having a pair of spur gears. The shaft (shaft number 2) which was located directly above shaft number 1, bears the flywheel. This shaft consists of the pinion of the spur gear assembly, as speed amplification is required to store energy at the flywheel. The processing unit has huller shaft within the housing. Hoppers are attached above the housing. Paddy is put into the hopper from it's opening. This is directed to the meshing area of the huller shaft and edge of end plate. As the paddy comes in contact with the meshing area, the husk and rice grain are separated, and the grain is obtained from the outgoing channel of the hopper.

A motorized rice de-stoning machine was locally developed for separating stone pebbles from milled rice [24]. The de-stoning machine was designed to be powered by a high speed (2980 r min<sup>-1</sup>), 0.746 kW electric motor. The electric motor provides power to the reciprocating mechanism alongside the centrifugal blower through an arrangement of pulleys and belt. With the aid of an eccentric drive, the reciprocating mechanism moves in a pendulum motion. The milled mixture of rice and stone ejects from the hopper through the feed gate by gravitational force, the lighter impurities are blown off by air flowing from the blower, since the terminal velocity of the milled rice is higher than that of the impurities. The milled rice is collected on the rice outlet while the stone is collected in the stone outlet. After evaluation, the highest efficiency for de-stoning was between 5 to 7 mm feed gates as 99.75% and the lowest de-stoning efficiency was recorded at a feed gate of 20 mm as 82.5%. The highest rice separation efficiency was recorded at 5 mm feed gate to be 98.89% and the lowest of 93.33% was at 20 mm. The highest values of impurity level and tray loss were recorded at 20 mm as 2.041% and 6.67% respectively, while the lowest values were recorded at 5 mm as 0.028% and 1.11% respectively. The capacity also increased as the feed gate increase. All results showed a high correlation with feed gate.

[29] revealed that the causes of high rice breakage percentage were found to be as follows: Machine - Knob spacing adjustment, inadequate maintenance. Secondly, method of processing - flow rate of paddy rice, motor speed and inadequate knowledge and machine usage ability. Other causes of breakage are moisture of paddy rice, rice strain and paddy rice storage. The authors conducted a study aimed at investigating the optimal parameters for a small rice mill that led to the reduction of % of fragmented rice by applying design of experiment technique. Thus, for improvement in rice milling effectiveness, appropriate levels of machine setup for small-sized rice milling machine was carried out. The results revealed that the optimum parameters were: size of feed hopper at 12 cm<sup>2</sup>, gap adjuster at 5 mm, and outlet regulator at 5 cm. The limitation of this study was in the clean-up of milling sheet that could affect milling performance leading to the bias in the experiment. It is suggested that the milling sheet should be cleaned before each replication. It should also be recorded that the % of fragmented rice is related to the quality, type, moisture content of rice, and temperature. Future study should inculcate Taguchi designs or response surface methodology (RSM) in their experimental design to enhance the findings for suitable parameter settings of rice manufacturing process.

[1] carried out a performance evaluation of a developed rice de-husking/destoning machine at the Federal University of Agriculture, Abeokuta, Nigeria. About 2.8 kg each of Faro 35, 44, 55 and Ofada varieties were obtained for the performance evaluation of the locally developed rice dehusking/ destoning. The rollers of the prototype rice dehusker/destoner were made of 14.74 cm outer diameter knolled Teflon rollers, moving at 995.5 rpm for fixed roller, while adjustable roller moves at 725 rpm. The adjustable slow roller speed was at a speed of about 27% less than the fixed fast roller. [14] reiterated that the adjustable roller runs at about 30% slower than the fixed one to create shearing effect. PNS/PAES (2004) revealed that the rollers are driven mechanically and rotate in opposite directions, the adjustable one rolls normally at about 25% slower than the fixed one, thus 27% slow speed of adjustable roller of this prototype dehusker was close to average speed as suggested in past studies. Coefficient of dehulling, dehulling efficiency, cleaning efficiency, coefficient of wholeness, dehulling recovery and output capacity were optimum at 94.60%, 0.63, 0.85, 50.54%, 61.22% and 18.53 kg/h respectively. The effect of MC and test paddy variety on coefficient of wholeness and dehulling efficiency were found to be significant, while only MC effect was significant at  $P < 0.05$  cleaning efficiency. Paddy varieties had effect on rice quality, long and slender grains had more breakage than shorter grains. After further work of improvement, its coefficient of dehulling, dehulling efficiency and dehulling recovery were 0.82, 65 and 75% respectively.

The Nigerian rice industry is post with poor processing which allows chaff and other foreign materials such as stones, pebbles etc. to be introduced during harvesting and post-harvest operations. In spite of the continuous efforts of different researchers in Nigeria, commercial de-stoning machine for rice could not be made available because the machines have not been optimized and tested for various machine parameters. This review showed the highlights, prospects, performance evaluations, and limitations of some rice de-stoning machines, de-stoning machine modified, and motorized rice destoning machine rotating at 700 rpm had an output capacity of 7.50 t/hr and 80% de-stoning efficiency. It uses two inclined meshes which are each held by six springs. The meshes are rectangular in form, with guides along the lengths to prevent dropping off the mixture of sand and stone. The hopper is at the left end of the upper mesh / screen, the means by which the mixture is poured into the separating chamber, while a collector for the broad stones is located at the right end of the separating chamber [16]. Their unique advantages and operational parameters, for example, de-stoning efficiency, capacity, and operating speed were assessed. The de-stoning efficiency, capacity, and operating speed ranged from 40.8 - 99.75%, 1.8 - 7500 kg/h, and 200 - 2980 rpm respectively. Mechanization of the de-stoning process will ensure the quality and hygiene of products, thus increasing the commercial

value of the final exported or consumed products [28] worked on design and fabrication of rice de-stoning machine. The machine is driven by a 1Hp electric motor with 688.17 W required power. The machine has a capacity of 47.39 Kg/hr and an efficiency of 82.47 % . Due to the low cost of fabrication the machine can be adopted by small scale producers. Rice de-stoning machine is made up of two sets of carriage each comprising of three screens. The first in each working deck serves to separate the stones slightly bigger than the grain; the second screen serves to separate the stones smaller in size than the grains while the third screen serves to convey the stones down to the stone chutes. The screens one and two are special wire gauze designed for separation purposes. The two working decks are designed to be slanted in opposing angles of between 7° to 14° to the horizontal. The angle can be varied in relation to the speed and efficiency required. The two decks are held in position by four flexible suspension reeds by means of belts and nuts on the upper part of the machine frame.

[28] further narrated that two decks are connected together and are mounted on the frame work which connects them to the shaft rotating. The shaft has two exciters on which are meant to excite the system, the offset angle can be arranged to obtain high or low vibration. Also, on the shaft are two bearings giving support to the shaft and pulley which receives drive from an electric motor via a belt. The hopper is fixed on the upper frame to receive charge for the first deck. Rough rice (rice with impurities) when charged through the hopper, gradually passes through the throat of the hopper and falls on the first screen with angle of inclination 7° to 14° as convenient and effective. The rate of flow from hopper is controlled manually. By this time, the prime mover drives the shaft carrying the exciters, thus the whole working deck is vibrated. As the working deck is vibrated, the rough rice is caused to move on the first screen thereby the bigger stone and impurities move down while smaller materials including rice dropped off on the second screen. Now the cleaner rice falls on the second working deck where the process is repeated. The second working deck will improve on the efficiency of the first separation. There are two outlets, the first, to collect the impurities and the second to collect the clean rice.

[9] stated that the final design of the Rice Huller and Grinder 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.

[9] further stated that the rice huller and grinder is equipped with vacuum fan installed above the grinder. The fan is made up of a 600kW fan operating at 220 V, 2.7 A, 16000 rev/min and 50-60Hz. It performs the function of sucking the leftover husk at the exhaust of the rice huller. The motor transmits a motion through belts and pulleys, rotating the belt driven rice grinder. Computation of the torque was done using a lever attached to the shaft of the huller and the grinder and a spring balance. The lever was 1 ft long. The operator 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  $1 \text{ ft} \times 2.2 \text{ lb} = 2.2 \text{ ft-lb}$ . The torque at the grinder is equal to  $1 \text{ ft} \times 1.9 \text{ lbs} = 1.8 \text{ ft-lb}$ . The total torque can be measured by adding all the torque from the prototype and is equal to  $1.9 + 2.2 = 4.1 \text{ ft-lb}$ .

#### 4.0 General Factors Responsible for Ineffective Rice Production in Nigeria

Several factors have been advanced for inadequate rice production by Nigeria to meet the demand of the teeming population. Apart from the challenges of agricultural mechanization including, poor research, poor credit facilities, land tenure problems, high cost and unavailability of machinery, poor extension services, poor attitude of individuals to agriculture, misappropriation of funds meant for agricultural sector, poor infrastructure and many more. Specific factors responsible for poor adaptation, poor utilization and low quality and quantity of rice production in Nigeria are:

- i. A lot of rice produced by local farmers is processed by cottage mills that do not produce high quality milled rice. Most characteristics of dirt, stones, short grains and unpolished. This makes the rice unattractive, poorly priced and poorly accepted by individuals. In order to meet domestic demand for high quality rice, more integrated rice mills will have to be established in different parts of the country to produce local rice that are of premium quality that can replace imported rice [7].
- Another factor is over dependent on imported costly rice processing machineries over locally produced.
  - i. Imported rice processing machineries are usually beyond the reach of farmers, as their cost are usually high. Locally developed rice processing machines must be adapted and made available for use by farmers at subsidized prices.
  - ii. The third factor is meagre engineering research into the design, fabrication, performance evaluation, utilization and maintenance routing of rice processing machineries, mainly caused by poor research and linkages between engineering departments, faculties of tertiary institutions and the institutions themselves, industries and government research institutions. There should be a synergy between all stake holders in order to enhance rice production.
  - iii. Critical factors responsible for low quantity and quality of rice production were that, completed machines were not patented and produced for use by farmers due to lack of linkage between stake holders.
  - iv. There is the issue of poor funding of the educational sector. This has led to poor funding of various researches in the institutions.
  - v. The sixth important factor is poor extension services to teach the farmers on the utilization and adaptation of latest technology.
  - vi. Another important factor as reported by [10] is that Nigerian government and other institutional agencies have been more concerned with production in terms of quantity than ensuring quality assurance of the products during processing. Enforcement of rice quality standards has been neglected without strong controls for implementation unlike the production and ban on importation policies.
  - vii. Another challenge include; processing machine constraints - poor product branding, outdated milling technology, coupled with evident political interests on agriculture.

#### 5.0 Development and Utilization of Rice Milling Machine

##### 5.1 Machine Design Concept

Effective development and application in rice milling like any other engineering design must follow the rules of engagement. The Engineer must recognize the need for such equipment before moving to problem definition and design synthesis. There is a great need for analysis of forces, material selection and design of components for the machine. The final stages are the modification, detailed drawing and production and testing of the equipment. Many Researchers have worked tremendously on the development of rice processing machines. Notable are PNS/PAES

(2004), [14]; [28]; [11]; [9]; [1]; [29]; [26]; [23]; [27]; [8]; [6]; [2]; [4]; [3]; [9] and [5].

#### 5.2 Machine Components Design for Rice Miller

##### 5.2.1 Design Concepts and Considerations

The stages of rice milling process are (a) Milling-Dehulling/Polishing/cleaning/separation and (b) Destoning. Milling removes the husk and bran layers, and produce an edible white rice kernel that is free from impurities.

##### 5.3 Steps in Rice Miller Design

##### 5.3.1 Determination of Torque Required to Comb off Grains from the Stalk and Removes the Husk and Bran Layers

The torque exerted by shaft during operation according to [27]; [3]; [9] and [5] is given by:

$$\text{Torque; } T = Fr \quad (1)$$

Where T is torque, F is force and r as radius respectively.

Assuming that force acts per unit length of tong, taking force per 10mm segment of length.

##### 5.3.2 Determination of Power Required to Mill off Grains from Husk and Brown Layers

The power is determined from the equation,

$$P = T\omega \quad (2)$$

Where  $\omega$  is angular velocity in rad/s, T is torque and P as power respectively.

##### 5.3.3 Determination of Feed Roller Speed

$$N_f = \frac{N_s}{n} \times N_{r1} \quad (3)$$

Where  $N_f$  is feed roller speed,  $\frac{N_s}{n}$  is speed ratio of pulley on comb shaft to the pulley on feed roller shaft,  $N_{r1}$  is speed of radial comb.

##### 5.3.3 Shaft Design Consideration and Analysis

The diameter, d of the rice milling machine transmission shafts was determined from the maximum stress relations given by [27] in equation also used by [18]; [12]; [3] and [5].

$$D = \left[ \frac{16}{\pi \tau} \sqrt{m_b^2 + (k_s m_t)^2} \right]^{\frac{1}{3}} \quad (4)$$

Where;  $\tau$  = allowable shear stress for steel shaft with provision for keyways = 50N/mm<sup>2</sup>;  $m_t$  = maximum twisting moments on the shafts;  $m_b$  = maximum bending moment on the shaft;  $k_s$  = combined shock and fatigue factor for bending;  $k_t$  = combined shock and fatigue factor for twisting.

The maximum twisting moments on the milling drum shaft and blower shaft were determined respectively using the Equation given by [18] in equation 5.

$$M_t = (T_1 - T_2) \frac{D}{2} \quad (5)$$

The maximum bending moment on the driving conveyor shaft is computed for a cylindrical shaft with circular cross sections and sprockets and bearings on them. The shaft will be subjected to fluctuating torque and bending moments, and therefore combined shock and fatigue factors taken are taken into account

##### I. Shaft subjected to twisting moment only

Torsion equation,

$$\frac{\tau}{r} = \frac{T}{J} = \frac{C\theta}{L} \quad (6)$$

Where,  $\tau$  = torsional shear stress

r = distance from neutral axis to outermost fibre,

T = twisting moment (or torque) on shaft

J = polar moment of inertia

C = modulus of rigidity of shaft material

L = length of shaft

$\theta$  = angle of twist in radius on length, l (ASME 1995).

Polar moment for round solid shaft

$$J = \frac{\pi}{32} \times d^4 \quad (7)$$

For  $r =$  and  $F_1 = F_2$ ,

$$\frac{T}{\pi^2} \times \frac{d^4}{2} = \frac{F_1}{d/2}$$

$$T = \frac{\pi}{16} \times f_t \times d^3 \quad (8)$$

Obtaining twisting moment T from

$$P = \frac{2\pi NT}{60} \quad (9)$$

Where, N = speed of shaft in rpm in the case of belt drive,

$$T = (T_1 - T_2)R \quad (10)$$

Where,

$T_1$  and  $T_2$  are tensions on the tight side and slack side respectively,

R = radius of pulley.

From  $P = T\omega$  in equation 2,

$$\text{But } T = \frac{\pi}{16} \times f_t \times d^3$$

### 1. For Shaft subjected to bending moment only

Bending equation is given by

$$\frac{M}{I} = \frac{F_b}{Y} \quad (11)$$

Where,

M = bending moment, I = moment of merits of cross-sectional area of the shaft about axis of rotation,  $F_b$  = bending stress and Y = distance from neutral axis to outermost fibre.

$$\text{But } I = \frac{\pi d^4}{64} \quad (12)$$

From equation 11, then  $M = \frac{F_b}{Y} \times I$

$$= \frac{F_b}{Y} \times \frac{\pi d^4}{64}$$

$$\text{But } Y = r^3$$

$$M = \frac{\pi d^3 \times F_b}{32} \quad (13)$$

(for solid shaft)

For bending moment,  $M = \text{Toque}, T$ .

### 1. Shaft subjected to combine twisting and bending moments based on maximum shear stress theory

$$F_s (\text{Max}) = \frac{1}{2} \sqrt{(F_b)^2 + 4(T)^2} \quad (14)$$

$$\text{But } F_b = \frac{MY}{I} = \frac{32M}{\pi d^3}$$

$$\text{And } T = \frac{16T}{\pi d^3}$$

Substituting this in the equation 14 above

$$F_s (\text{min}) = \frac{1}{2} \sqrt{\left(\frac{32M}{\pi d^3}\right)^2 + 4\left(\frac{16T}{\pi d^3}\right)^2} \quad (15)$$

$$d = \frac{16\sqrt{M^2 + T^2}}{\pi F_s} \quad (16)$$

#### 5.3.4 Determination of the shaft diameter

The diameter of the shaft (d), neglecting the bending moment on the shaft is:

$$d^3 = \frac{16T}{\pi \tau} \quad (17)$$

#### 5.3.5 Determination of Linear Speed of Hammer

The following equation can be used calculate the peripheral speed of the hammer rotation (V) [3],

$$V = \frac{2\pi rN}{60} \quad (18)$$

Where, N is rotation per minute in rpm, r is the radius of hammer.

#### 5.3.6 Centrifugal force of hammer

When the hammer spins, it produces a centrifugal force (F1) [3]

$$F_1 = m \frac{v^2}{r} (N) \quad (19)$$

#### 5.3.7 Weight of hammer

The weight of the hammer is calculated as follows,

$$W_h = M_h g \quad (20)$$

Where  $W_h$  = weight of hammer,  $M_h$ : the mass of hammer, kg, g: gravity force, m/s<sup>2</sup>

#### 5.3.8 Angle of position of Hammer, $\theta$

Angle of position of hammer against radius is  $\theta$  as used by [3] is:

$$\theta = \tan^{-1} \left[ \frac{W_h}{M_h g} \right] = \theta = \tan^{-1} \left[ \frac{W_h}{M_h g} \right] \quad (21)$$

#### 5.3.9 Determination of V belt contact angle

$$\sin^{-1} \alpha = \frac{r_2}{r_1} \quad (22)$$

$$\theta = 180 - \alpha$$

#### 5.3.10 Determination of the belt tension

$$2.3 \log \frac{T_1}{T_2} = \mu \theta \operatorname{cosec}(\beta) \quad (23)$$

$$T_1 = \sigma A(N) \quad (24)$$

Where,  $T_1$  is tensioned in the tight side of the belt, Nm;  $T_2$  tensions in the slack side of the belt, Nm;  $\mu$  is coefficient of friction;  $\beta$  is the groove angle of V-belt,  $\sigma$  is the maximum permissible belt stress, MN/m<sup>2</sup>; A is area of belt [18].

#### 5.3.11 Determination of Belt Length

The belt length, L required were respectively computed as 1590mm and 1200mm combustion engine/milling drum shafts, and feeder/blower shafts, from the following relations given by [27] as and utilized by [30]; [12]; [3] and [5]:

$$L = 2C + 1.57(D_1 + D_2) + \frac{(D_2 - D_1)^2}{4C} \quad (25)$$

They are made to standard lengths and with the standard cross-sectional sizes. Thus, belts of standard pitch lengths are selected based on IS: 2494-1974 for the combustion engine/milling drum shafts and feeder/blower shafts respectively. Thus, the exact centre distances between the adjacent pulleys used in the fabrication of the millers are also calculated for the combustion engine shaft, milling drum shaft, feeder shaft and blower shaft respectively [18] from Equations.

Effective driving (turning) force, is given by

$$T_1 = T_2$$

Power transmitted is given by,

$$P = (T_1 - T_2)V \quad (26)$$

Where;

$T_1$  is Tension in the tight side in N,  $T_2$  is Tension in the slack side N, V is velocity of belts in m/s Selection of belts drive depends on speed of driving and driven shaft, power to be transmitted, space available, driving conditions, centre distance between the shafts and speed reduction ratio'

#### 5.3.12 Determination of drum (flange) diameter

The drum or flange was determined as 404837mm using the equation below

$$D = \frac{UAT_2 M_b}{\pi} \quad (27)$$

#### 5.3.13 Determination of drum (flange) speed

The drum speed was determined as 1040rpm from the equation below:

$$VR = \frac{N_1}{N_2} = \frac{D_2}{D_1} \quad (28)$$

Where;  $N_1$  is speed of rotation of smaller sprocket, 2600rpm

$N_2$  is speed of rotation larger sprocket,

$D_1$  is diameter of smaller sprocket (combustion engine pulley).

100mm

$D_2$  is diameter of larger sprocket (milling drum shaft pulley), 250mm

**5.3.14 Determination of blower speed**

The speed of the blower speed is determined to be 1600rpm from the equation below

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} \tag{29}$$

**5.3.15 Selection of Drive Pulleys and Belts**

The rice milling machine uses a total of four pulleys for its drives, one each mounted on the combustion engine, milling drum shaft, feeder shaft, and the last on the blower shaft. Due to its availability, cost and performance, mild steel pulleys were selected. The respective diameters of the selected driver and driven pulleys for the combustion engine shaft, milling drum shaft, feeder shaft, and blower shaft are 100mm, 250mm, 200mm and 130mm respectively. The speed of the combustion engine is 2600 rpm, thus, the speed of the driven pulleys of the milling drum shaft, and blower shaft are determined as 1040rpm and 1600rpm respectively from the relation given by [18] in equation 22.

$$N_1 D_1 = N_2 D_2 \tag{30}$$

Where  $N_1$  and  $N_2$  are the respective driving and driven pulleys' speeds while  $D_1$  and  $D_2$  are the corresponding diameters of the pulleys. The centre distances,  $C$  between the driving and driven (adjacent) pulleys were determined from Equation (23) as 475mm, and 365mm for the combustion engine shaft, milling drum shaft, feeder shaft and blower shaft respectively [18] in equation as used by [27]; [12]; [3] and [5].

$$C = \frac{D_1 + D_2}{2} + D_1 \tag{31}$$

**5.3.16 Determination of the Velocity Ratio of the Pulleys**

The pulleys velocity ratio revolution per minute of the driven divided by the revolution per minute of the driver. The velocity was determined as 34038.33 using the formula below; Velocity Ratio, V.R = dist. moved by Effort /dist. moved by Load = distance moved by Driven Pulley/dist. moved by Driver Pulley

$$V.R. = \frac{\pi DN}{60} \tag{32}$$

Where;  $N$  and  $D$  are Speed of prime mover and diameter of pulley respectively.

**5.3.17 Prime Mover or Motor Selection**

Selection of prime mover or motor for the miller depends on the designed capacity and power of the machine. Different prime movers exist as diesel or petrol engines of different power ranges. Selection is made based on the design parameters. Motors of different power ranges can also be selected according to [5]; [9]; [3]; [27].

**5.3.18 Hopper Design and Capacity**

To calculate the approximate size of the hopper the following equation is used by [20]:

$$H = \frac{m}{\rho_s A} \tag{33}$$

Where,  $H$ , is the height of the hopper,  $m$  is the mass of product (kg),  $\rho_s$  is the average bulk density (kg/m<sup>3</sup>),  $A$  is the cross-sectional area of the hopper (m<sup>2</sup>).

**5.3.19 Maximum Discharge Rate from the Hopper**

The following equation is used:

$$M = \rho A \sqrt{\frac{2g}{2(1+M) \tan \theta}} \tag{34}$$

Where,  $M$  = mass flow rate (kg/s),  $\rho$  = bulk density (kg/m<sup>3</sup>),  $A$  = outlet area (m<sup>2</sup>),  $B$  = outlet size (m),  $\theta$  = mass-flow angle measured from vertical (deg.).

**5.3.20 Concave screens**

In the milling process, the concave plate can well isolate the straw, and at the same time, the screen holes distributed on the concave plate can make the shedding broad bean seeds leak to the clear screen as reiterated by [33] and [34]. There are two main types of concave structure: grid and punch, and the grid concave has great strength, good rigidity, large sieve hole and good milling and separating effect. Selection is done based on the type of grains.

Concave screen efficiency depends mainly on the length and effective separation area of the concave plate. In a certain range, screening efficiency will increase with the length of the concave screen. At the same time, the larger hole ratio of concave plate screen, the higher screen efficiency of concave screen. The hole ratio of concave plate screen  $A$  is calculated by equation ,

$$A = \frac{a_1 b}{\pi r L} 100\% \tag{35}$$

Where,  $A$  is the hole ratio of concave plate screen,  $a_1$  is the number of sieve holes,  $b$  is the area of sieve hole,  $r$  is the roller radius,  $L$  is the roller length.

Diameter of the sieve can also be determined according to [23]:

$$d = \sqrt{\frac{D^2 Co - Co^2}{Co}} \tag{36}$$

where,  $D$  = average effective diameter of rice grains,  $Co$  = coefficient of opening,  $d$  upper screen diameter.

**5.3.21 Amplitude and Frequency of Vibration of Screen:**

[28] determined the amplitude and frequency of vibration of screen using the expressions:

$$Y = \frac{F/k}{\sqrt{[1 - (\frac{\omega}{\omega_n})^2]^2 + [2\zeta(\frac{\omega}{\omega_n})]^2}} \omega \tag{37}$$

Where,

- $F$  = magnitude of excitation force
- $K$  = stiffness of spring (suspension reeds)
- $Y$  = Amplitude of steady state vibration
- $m$  = mass of system

$$\zeta = \text{coefficient of damping}$$

$$\omega = \text{frequency of excitation force, given by}$$

$$\omega = \frac{2\pi N}{60} \tag{38}$$

$$\omega_n = \text{natural frequency of vibration of the system, given by,}$$

$$\omega_n = \sqrt{\frac{k}{m}} \tag{39}$$

frequency of vibration,  $f$  of the system is therefore,

$$f = \frac{\omega}{2\pi} \tag{40}$$

**5.3.22 Main frame**

Main frame of miller should be designed taking into consideration the stability, rigidity, strength of vibration, and other properties using mild steel – angular bar, rectangular/square bar, solid or flat bar depending on the structure of the machine.

**5.3.23 Fabrication, Testing, presentation and Utilization of Machine**

An excellent design that is not produced, tested, presented and well utilized normally ends up on the shelf. During fabrication, measures must be taken in ensuring that this is done according to specification and the right materials are used. This will ensure standardization, accurate testing and proper utilization. Prototype building should be made taking into cognisance adjustments made during testing prior to industrial production for appropriate utilization [22]; [3].

### 5.3.24 Miller Efficiency and Throughput

This is the ratio of mass collected at the outlet to the mass inputted into the miller. Represented by this equation by [5]; [31]:

$$\text{milling efficiency, } \eta (\%) = \frac{M_r}{M_r + M_{ur}} \times 100 \quad (41)$$

$$\text{Thus throughput (1 hr)} = \frac{M_r + M_{ur}}{\text{time (hr)}} \quad (42)$$

Where,  $\eta$  (%) = milling efficiency,  $M_r$  = Mass of milled rice after milling,  $M_{ur}$  = mass of un-milled grains after milling,  $M_b$  = mass of un-milled rice before milling ( $M_r + M_{ur}$ ). milling Efficiency,  $T_c$  % is the percentage of the milled grains calculated on the basis of the total grains entering the milling mechanism.

Thus, the milling efficiency can also be calculated using these expressions below:

$$T_c \% = \frac{CTG + SPL + SCL}{CTG + TL} \times 100 \quad (43)$$

$$T_c \% = 100\% - \%UT \text{ loss} \quad (44)$$

Where, CTG = cleaned milled grains, SPL = separation loss, SCL = scattering loss, TL = total milling loss, UT = un-milled grains.

### 5.3.25 Variables for Dehulling of Rice

#### a. Dehulling Efficiency

$$E_d = e_c \times e_w \times 100 \quad (45)$$

where  $e_c$  = coefficient of dehulling,  $e_w$  = coefficient of wholeness

$$e_c = 1 - \frac{w_u}{w_b} \quad (46)$$

Where,  $w_u$  = weight of un-hulled paddy,  $w_b$  = mixture of brown rice and un-hulled paddy.

$$e_w = \frac{w_s}{w_b} \quad (47)$$

where,  $w_s$  = weight of whole brown rice in the sample  
 $w_b$  = weight of whole and broken rice.

#### b. Dehulling Capacity, $H_c$

$$H_c = \frac{W_o \times T_o}{T_c} \quad (48)$$

Where,  $H_c$  = Total huller output,  $e_c$  = dehulling coefficient,  $T_o$  = operating time

### 6.0 Conclusion

Development of milling machine for effective utilization, adaptation and increased rice production in Nigeria to meet her local demand for rice production was reviewed. Rice produced by local farmers is processed by cottage mills that do not produce high quality milled rice. Most of the rice produced by small scale farmers possessed mainly dirt, stones, short grains and unpolished. This makes the rice unattractive, poorly priced and poorly accepted by individuals. In spite of the continuous efforts of several researchers in Nigeria, no locally produced commercial rice de-stoning machine is available because the machines have not been optimized and tested for various operational parameters.

In order to meet domestic demands for high quality rice, more integrated rice mills will have to be established in different parts of the country to produce local rice that are of premium quality that can replace imported rice. Locally developed rice processing machines must be adapted and made available for use by farmers at subsidized prices. There should be a synergy between all stakeholders in order to enhance rice production. Extension services should be intensified to teach the farmers on the utilization and adaptation of latest technology. Stakeholders must work towards ensuring quality assurance of the products during processing by enforcement of rice quality standards. With more funding from relevant organs of governments and institution more research should be conducted.

The engineers and other stakeholders should step-up their game in the development, evaluation, utilization and adaptation of the rice processing machineries to enhance quantity and quality of produce, reduction of drudgery, increased income and improved standard of living; as this article enumerates step-by-step reference point on the development of rice processing machines.

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