DESIGN, CONSTRUCTION AND PERFORMANCE ANALYSIS OF A MAIZE THRESHER FOR RURAL DWELLER

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Abstract

The processing of agricultural product into quality forms not only prolongs the useful life of these products but also increases the net profit farmers make from such products. In this work, emphasis was place on demand led design which involved understanding the need of the farmer and designing an appropriate system that meets that need. The objectives of the work were to design, construct, and evaluate a low cost maize sheller for rural farmers in Nigeria. The methods used involved the collection of farmers opinion on their sheller needs, selecting appropriate materials, and utilization of theories of failure that enable the determination of allowable shear stress on the bearing supports. The communication methods used were an interactive sessions with farmers especially the women and children, in other to determine their shelling problems. Comparison was made between the human performance index for shelling and the machine performance index. The human mechanical efficiency, through-put capacity and grain handing capacity are 45%, 26.67kg/hr and 21.1kg/hr at a biomaterial test weight of 20kg with actual shelled weight of 15.8kg at a shelling time 45 minutes. For machine indices, through-put capacity and the grain handing capacity of the sheller are 86%, 119.76kg/hr and 109.99kg/hr respectively. The price difference shows a drastic reduction in the purchase price of maize thresher by N 32,500.00 ($216.67), which represent 56.52% price reduction. Market days were also used as an opportunity to show the farmers and agro-processors the advantage of using the maize sheller.

Keywords: thresher, performance Analysis, design, rural dweller

1. Introduction

Maize, the American Indian word for corn, means literally that which sustains life. It is, after wheat and rice, the most important cereal grain in the world, providing nutrients for humans and animals and serving as a basic raw material for the production of starch, oil and protein, alcoholic beverages, food sweeteners and, more recently, fuel [1]. In Africa, maize has become a staple food crop that are known to the poorest family. It is used in various forms to alleviate hunger, and such forms include pap or ogi, maize flour, and etc. It is because of the importance place of maize that its processing and preservation to an op-

timum condition must be analyzed. The major steps involved in the processing of maize are harvesting, drying, de-husking, shelling, storing, and milling. For the rural farmers to maximize profit from their maize, appropriate technology that suites their needs must be used. The processing of agricultural products like maize into quality forms not only prolongs the useful life of theses products, but increases the net profit farmers make from mechanization technologies such products. One of the most important processing operations done to bring out the quality of maize is shelling or threshing of maize.

1.1. Statement of the problem

Traditional shelling methods do not support large-scale shelling of maize, especially for commercial purposes. Locally in Nigeria, the region that is the highest producer of maize is the northern part of the country it was observed that most shelling of maize was done by hand shelling. Hand shelling take a lot of time, even with some hand operated simple tools. It was also observed in the study area, Nasarawa State, most mechanical shellers were designed for multi-grain threshing or shelling, which causes great damage to the maize seeds besides breaking the cob to pieces. The available shellers locally, were equipped with rotating threshing drum with beaters or teeth, which cause damages to the seed. Besides, the cost of purchasing such shellers were high for the poor rural farmer, and therefore necessitated the design of low-cost system that will be affordable and also increase threshing efficiency but reduce damage done to the seed.

1.2. Objectives of the work

The specific objectives of the work were to design, construct, and test a low-cost maize sheller, to evaluate the efficiency of the maize sheller, and to use the maize sheller in establishing an agro-processing centre for rural farmers.

2. Literature Review

Maize shelling a post harvest operation, is the removal of maize seeds from the cob. This operation can be carried out in the field or at the storage environment. Maize shelling, therefore is an important step towards the processing of maize to its various finished products like flour. The different methods of maize shelling can be categorized based on various mechanization technology used. These includes: hand-tool-technology, animal technology, and engine power technology [2]. Hand technology involves the use of hand tools in shelling, while as observed animals were used in threshing on the field by marching on the maize. Engine powered technology involves the use of mechanical assistance in threshing or shelling the maize. Some examples were seen in [3], the maize sheller that was design and constructed in Nigeria. To facilitate speedy shelling of maize in order to reduce post harvest deterioration, mechanical shellers are recommended, because hand-shelling methods cannot support commercialized shelling.

An average moisture content of 15% to 18% for maize that was to be threshed or shelled was reported by [4]. Moisture content seriously affects the threshability of maize. Another factor that affect the threshability of maize in a mechanized system is the size of the maize cob. The mechanical shellers need to be adjusted to the various sizes of cobs. According to [5] the various sizes of maize cob ranges from 50mm to 85mm depending on variety. There are also engineering design factor that affect the design of mechanical shellers. These factors are the design of the power transmission shaft, selection of the prime mover, type of pulley, appropriate belt design, key and selection of appropriate bearings support.

According to [6], the power delivered by a shaft is given by

$$P = F \times V \qquad (1)$$

Where P = power (Nms^{-1}), F = Force of threshing (N), and V = velocity (m/s).

Force required to thresh the maize is given by

$$F = m\omega^2 r \qquad (2)$$

Where F is force required to thresh maize, m is mass of threshing bars, ω is the angular velocity of shaft. The angular velocity ω is determined by the equation $2\pi N/60$, where N is the speed of threshing which is in revolutions per minute. The power delivered by the shaft is $F\omega r$. The appropriate electric motor is determined or selected when the total power requirement for threshing in determined at an appropriate threshing speed. According to [4] the threshing speed that will give very low mechanical damage, but high threshing output is within the range of 300 - 650 revolutions per minute. The relationship between the driven pulley speed and the speed of the prime mover is as [7];

$$N_1 D_1 = N_2 D_2 \qquad (3)$$

where N_1 is speed of the driver, N_2 is speed of the driven, D_1 is the diameter of the driver pulley, and D_2 is the diameter of the driven pulley. The weight of the pulley on the shaft is given as $m = \rho v$, where m is the mass of the pulley, ρ is the density of the pulley and v is the volume of the pulley. Weight is mass multiplied by acceleration due to gravity (g). The W_p (weight of pulley) $= \rho \times (\pi d^2/4) \times l_p \times g$, where d is diameter of pulley, l_p is the length of pulley.

Appropriate belt selection will assist in effective power transmission. A belt provides a convenient mean of transferring power from one shaft to another. The effective pull on a belt is given by $T = T_1 - T_2$, where T_1 is tension on tight-side, and T_2 is tension on slack slide. T_s (torque on shaft) is $F \times r$, where F is total force of threshing, which is equal to the total torque requirement of the system., therefore, $T_s = T \times r$, T_m (motor torque) $= T \times r$ where $T_s = T_m$. Note that P_m (power of motor) $= \omega T_m$, thus, the effective pull T is $T = P_m/(\omega r)$, and MT (Torsional moment) $= (T_1 - T_2)r_1$.

According to [8], the power transmitted by belt is given by $P = (T_1 - T_2)V$, but $V(\text{velocity}) = (\pi DN)/60$. Also $T_1/T_2 = exp(\mu\theta \csc \beta)$, where β is the grove semi-angle, θ is the angle of lap, α is the angle of contact at the smaller pulley, and μ is the coefficient of friction. According to [9], the μ of friction for rubber belt on cast iron or steel operating on dry surface is $\mu = 0.3$. The angle of lap for open V-belt drive is given as $\theta = (180-2\alpha) \times \pi/180 \, \text{rad}$. Also $\sin \alpha (r_2 r_1)/x$, where $x =$ distance between pulleys, $r_1 =$ radius of smaller pulley, and r_2 is radius of bigger pulley. The length of pulley is given as $L = 2x + (\pi/2 X D + d) + (D - d)2/4x$. The minimum shaft diameter is determined using the [10] code equation which states that $d^3 = [16/(\pi S_s)] \times [(k_b M_b)^2 + (k_t M_t)^2]^{1/2}$, where d is the diameter of shaft, M_t is the overall torsional moment, M_b is the bending moment K_b is the combined shock and fatigue factor applied to bending moment, Kt is the combined shock and fatigue factor applied to torsional moment, S_s is the allowable shear stress. According to [10], the K_b and K_t factors when shock is applied suddenly to a rotating shaft is 1.5 to 2.0 and 1.0 to 1.5 respectively. For shaft without key-way and with key-way, the allowable stress (Ss) is 55 MN/m² and 40MN/m² respectively. The bearing is selected based on the load carrying capacity, life expectancy, and reliability in line with [11]). The threshing force is either by impact loading as seen in cylindrical beaters, or shearing force as seen in hand-threshing.

The shelling machine is tested to determine its effective use with respect to the work to be done. For Agricultural Machines, its performance according to [2], it evaluated base on the throughput capacity, effective throughput capacity and it mechanical efficiency. The throughput capacity (T_p) is given as $T_p = W_T/t_T$ in kg/hr, where W_t is to total weight of material handled, which includes threshed and unthreshed, and t_t is the total time taken in handling the materials. The effective throughput capacity is the ratio of actual weight of grains handled that was not

damaged to the effective time of operation.

$$T_{pe} = W_a/t_e \qquad (4)$$

where T_{pe} is the effective throughput capacity, W_a is the actual weight of grain handled in kg, and t_a is the effective operating time in hour. The efficiency in %, η is the percentage of the ratio of the total weight of grain actually handled (output), W_a(kg) to the total weight of grain to be handled (input), W_t(kg).

$$\eta = W_a/W_t \qquad (5)$$

3. Materials and Methods

3.1. Design considerations

The methods used were in three phases, the first phase involved the collection of rural farmer sheller needs and other problems associated with agricultural operation. The second stage was the design of an appropriate system to meet their needs, and finally to communicate results to the farmers and determine whether their problem was solved. The uniqueness of this design is that it works on a different principle of threshing. The earlier mentioned design by [3], worked on the principle of impact force, while this design works on the principle of abrasion; an application of force tangentially on a surface. On the field determination of farmer shelling capacity was determined. Comparison was made on the time take to shell the quantity of maize harvested per farmer and the time taken before deterioration sets in. it was observed also that appropriate technology for storage was not available including pesticides to handle weevil attack. Pesticides were purchased with the help of local administrators, who was told of he need in the community.

3.2. Design calculations

The average threshing plate speed is 450 rpm. This maize sheller comprises of a hopper design to take three maize cobs lying on its vertical axis ZY plane, a threshing plate with spikes that simulates the tangential force applied tot eh surface of the maize, supporting frame-work, a threshing wall that has groves where the falling maize rotates, and an adjustable spring, that allows the threshing wall adjust to the different sizes of maize. It also had a container for storage besides the threshing cylinder and hopper. The shaft length was 5900mm while the shaft diameter is 60mm. The angular velocity (ω) is 73 rad/sec, with a maximum available threshing force of 501.2N at the tip of spikes. The torque developed at the spike is 36.45Nm. The power delivered at the threshing spikes is 2.92kW, which means that a prime mover power of 4 or 5hp was used. The prime mover was a 4hp Yamaha combustion engine. Figures 1-4 at the appendix shows the completed maize thresher and other view of the thresher parts.

3.3. Performance analysis

The throughput capacity, the actual throughput capacity and the mechanic efficiency was determine using the equation mention tion earlier in the work. 200kg of unthreshed maize was measured using a weighing scale. A local farmer was used to load the cob three at a time into the hopper. The time taking to load and finish threshing the 200kg was read. The total weight of thresh grains was determined. The total weight of the broken or damaged grain was determined, and the weight of the cob was also taken. The percentage mechanical damage was determined. Comparison was between human performance index and the machine performance index.

3.4. Information communication strategy

Experts from the federal Polytechnic Nasarawa Nigeria were invited to access the performance of the machine and communicate to the surrounding rural community. The machine was taken to nearby farms with large hectare of maize, in order to thresh their maize. The thresher was also taken to markets during market days for people to see the

machine in operation. Rich politicians were met to finance the building of agricultural processing centres in the nearby farm settlements, about 5 of them. Agricultural extension workers were called to facilitate information dissemination. The existence of the maize thresher and its price regime was announced at local radio station and the television station of the state showed pictures of the maize sheller.

4. Results

The human mechanical efficiency was determined to be 45% at the biomaterial test weight of 20kg with actually shelted grain weight of 15.8kg. The human throughput capacity was 26.67kg/hr and actual grain handling capacity of 21.1kg/hr at a shelling time of 45mnutes or 0.75hr. This result is base on the spot assessment of shelling done by five selected farmers from different farm settlement, although this efficiency will drop due to increase druggery. The efficiency and throughput capacities of were 86% and 119.76kg/hr respectively. When further evaluation was carried to determine the actual grain throughput capacity based on actual weight of grain threshed but not broken the capacity was 109.99kg/hr. The result showed that the shelter was effective.

Effectiveness communication tools used yielded result with people bringing the maize for threshing, farmers organized themselves in groups to purchase the machine which locally was built at a cost of twenty-five thousand naira (N25,000) or one hundred and sixty-six dollars, sixty six cents ($166.66). The five farm settlement identified were given five shellers each with other machines for cassava grating, and milling. These were donated by the local government council and a senator. More sheller have being constructed and given out. Other states are making requests. In 2009 Polytechnics fair held in Kano Nigeria, the sheller took the second position in the category of processing machinery.

5. Conclusion

From the result above, it is clear that the machine was designed successfully. The actual throughput capacity of 109.99kg/hr was far better than the human actual throughput capacity which was determined to be 21.1kg/hr. The net present value of the thresher which is N25,000 or $166.66 was attractive to the farmers who said that available threshers in the market was about N55,000 to N60,000 or $366.66 to $400. The price difference shows a drastic reduction in the purchase price of maize thresher by N 32,500.00 or $216.67, which represent 56.52% price reduction. The number replaceable parts was low when compared to most threshers available in the market. The machine has an estimated useful life of ten years. The threshing capacity of the maize sheller was such that it handled the threshing needs of the farmers within required time and zero drudgery. Thus farmers had more time for other activities with good strength. Both the farmers and the agro processing centers not only reduced their cost of threshing maize per bag but created more wealth for themselves.

The Agro-processing centres established helped many farmers to process their agricultural products in market acceptable from which gave rise to added value to the market prices at which the farmers sold them. More research should be done to identify the many needs of the rural farmers, so that experts can design system and proffer solution that meets their needs.

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Appendix

Figure 1: A pictorial view of the finished maize thresher.
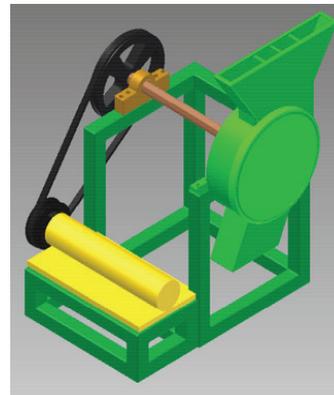

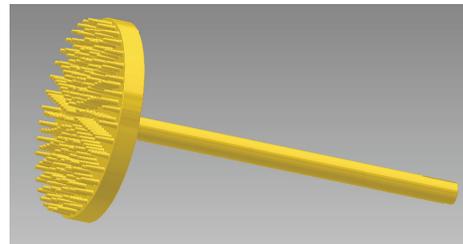Figure 2: An orthographic view of the thresher.

Figure 3: An orthographic view of the thresher power shaft.

Figure 4: An orthographic view of the pulley.