Development Of A Multi-Seed Pneumatic Cleaner

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***Abstract*—Grain constitutes a major source of food and raw material for industrial use, it could be durable or highly perishable. If harvested sound, well processed and kept safe, they could retain their quality for years and increase net profit for farmers. Consequently, grain cleaning is a prerequisite to its further applications. A multi-seed pneumatic cleaner was developed and constructed with an incorporated multiple sprockets mechanism. The multiple sprocket mechanism incorporated allowed the variation of the speed of the machine, which consequently varied the volume of air stream required to clean the grains. Some of the component parts of the machine include: wind duct, grain outlet, grain inlet, chaff outlet duct, fan housing, centrifugal fan, frame, screen, multiple sprockets mechanism, gear, gear cord and lever. The machine was tested with three different samples of grains – rice (A), cowpea (B) and maize (C). The efficiency of the machine on sample A was found to be 86%, while sample B was 90.4% and sample C 88.9%. It was concluded from the result that speed 1 will be effective for the cleaning of sample A, speed 3 for the cleaning of sample C and speed 4 will produce the volume of air to clean sample B. The test carried out showed that with the specified speed mentioned above, the samples of grains could be cleaned as desired.**

Keywords:* *Grains, Centrifugal fan, Multiple sprockets, Speed, Chaff, Pneumatic, Farmers.

Introduction

Industrially, grains are used in the preparation of animal feed where maize is the major component. Corn starch is used largely for food, textile and paper sizing, laundry purposes and adhesives. At times, grain sorghum replaces corn grits in the brewing and distilling industries. The dehulling of melon and groundnut seeds to extract their oil is another important aspect of the industrial use of grains. Grain could be durable or highly perishable. If harvested sound, well processed and kept safe, they could retain their quality for years. The larger percentage of Nigerians do not believe in the quality of locally produced rice and this has been attributed to poor harvesting and post-harvest handling method which encouraged the presence of contaminants such as stones, stick, chaff and leave stalk as well as low operational quality of the processing equipment [1], [2]. They are susceptible to deterioration if attacked by insects, mites and fungi; if not well processed and, or poorly stored. Under these conditions, extensive spoilage occurs within a few days to a few weeks. Grain processing seeks to obtain high quality for grains, and it entails shelling/threshing, decortications, separation, cleaning, sorting, grading, etc. Cleaning, which is the focus of this project is defined as a process or an act of removal of dirt or unwanted material from something. Harvested grains usually contain dirt particles like stone, weeds, chaff, stalks, broken or immature seeds, fungi, insects, among others. If foreign particles are left with the grains, these unwanted materials serve as host to pathogens, which spread diseases and develop moulds while in storage. Similarly, weed infested seeds result in crop-weed competition for water and nutrients. Consequently, grain cleaning is a prerequisite to its further applications.

There are several processing equipment fabricated and use in different parts of the world to process grains, very few of these machines are less expensive and do not require electricity to operate. These are therefore beyond the reach of majority of our farmers (peasant) who produce more than fifty percent of food crops in Nigeria [3]. The existing cleaning machines were designed to clean a type of grain and does not give the required cleaned grains in term of quality and quantity. Threshed or shelled grains are thrown into the wind, which carries away the dead grains and chaff. Mechanical cleaners are based on this principle. For example, [4] studied the pneumatic separation of grain and straw mixtures in a wind tunnel to find the percentage separation of grain, straw and chaff at various air velocities. Part of their conclusion was that complete separation of non-grain materials from the grain was possible in soybean and that approximately 80, 94 and 98 percent separation obtained in oat, wheat and straw respectively.

Reference [5] stated that mechanical methods of separating rice from foreign materials depend on the difference in such characteristics as size, shape and specific weight. It has also been observed that chaff - like materials were removed from cereals like wheat, rye and soybeans at air velocity of 3.05 m/s which is less than their terminal velocities [4]. Terminal velocities of some rice varieties grown in the South West of Nigeria were found to exist in the range of their mean values between 5.06 to 5.19 m/s and there were no significant differences among the different varieties [6]. At low feed rate of 22 - 34 kg/min, chaff materials were dispersed by air blast before reaching the upper sieve of a combine [7]. Reference [8] established that at high feed rate in a combination of aerodynamic and mechanical process, grain – impurity mixture forms a mat on the sieve rather than been separated.

Existing pneumatic separators or cleaners are crop specific, that is, a machine is designed and developed to handle just one crop. The implication of this is that for every new crop requiring cleaning, the fan mechanism of the machine must be changed, however, the development of a multi-grain cleaner would help to further simplify the cleaning process.

1.3 Methodology

Design Considerations

The selection of suitable materials for use after careful analysis and design consideration depends mainly on a full understanding of various properties of materials such as strength, hardness, ductility, malleability, creep and fatigue. Condition such as stress concentration, corrosion, high/low temperature, which may contribute to the durability and reliability of the design. All these factors put together motivated the special consideration given to material selection during the project construction. Mild steel is the chief material used in the construction of this project. The reason for choosing mild steel was its ability to undergo considerable plastic deformation before fracture (i.e. ductility) as well as excellent weldability properties and relatively lower thermal conductivity compared with other materials.

Terminal Velocity

The force of gravity accelerates a body falling in a viscous medium such as air, the resistance offered by the viscous medium grows rapidly as the velocity of the falling body increases and soon equals the gravitational force. The moment equilibrium is attained; the body continues to fall at a constant velocity called terminal velocity. In pneumatic conveying, dust collection, air classifying, fluidization which require that solid matter should be kept freely suspended in a fluid – a knowledge of terminal velocity is of utmost importance. An up current can raise a solid body only if the fluid velocity is greater than the terminal velocity of the solid.

Theory of a Multi-seed Pneumatic Cleaning

The pneumatic grain cleaner is a machine used to clean seeds while terminal velocity is the air velocity required to suspend seed in a confined rising column of air. If the velocity of air in the column is adjusted to a certain level and a mixture of seeds are dropped into the column, each seed, which has a terminal velocity less than the velocity of air will be lifted. However, each seed, which has a terminal velocity greater than the velocity of air, will drop or fall against the rising column of air. The rate of ascent or descent of a seed in the rising column of air is determined by the magnitude of the difference between its terminal velocity and the velocity of the air. The velocity of air is varied via the different diameter of the bicycle sprockets used to power the centrifugal fan, which brings about the possibility of the centrifugal fan running at different speed culminating different air velocities that can handle seeds of their respective terminal velocities. Chain and sprockets were mainly used as a means of power transfer from the electric motor to the centrifugal fan and the sprockets at the fan side is of five different diameters.

The duct used is a straight duct without fittings, bend and joints, design from the point of view of pressure losses is not very essential.

The dimension of the duct is as follows:

Overall height = 103cm (1.03m)

Width = 1.8cm (0.18m)

Breadth = 18cm (0.18m)

Surface area of duct $= L \times B \times H$

$= 1.03 \times 0.18 \times 0.18m^3 = 0.033m^3$

1.3.3 The Fan Speed

A 2.5hp electric motor was used with speed of 1,150rpm. There were 5 sprockets with different diameters with the diameters varying mechanism on the machine, which will consequently vary the speed of the fan.

The diameter of the sprocket on the motor = 18cm (0.18m)

The diameter of the first sprocket on the fan = 12cm (0.12m)

The diameter of the second sprocket on the fan = 10cm (0.1m)

The diameter of the third sprocket on the fan = 8cm (0.08m)

The diameter of the fourth sprocket on the fan = 6cm (0.06m)

The diameter of the fifth sprocket on the fan = 4cm (0.04m)

To determine the speed of rotation on each sprocket:

$N_1D_1 = N_2D_2$

Where N_1 is the number of turns (speed) of driver of the electric motor

D_1 is the diameter of the sprocket on the driver of the electric motor

N_2 is the number of turns (speed) of driver

D_2 is the diameter of the sprocket on the driver

1st Sprocket (1st Speed):

$N_1D_1 = N_2D_2$

$1{,}150 \times 18 = N_2 \times 12$

$20{,}700 = N_2 \text{ x } 12$

$$N_2 = \frac{20{,}700}{12}$$

$= 1{,}725$rpm

$$= \frac{2\pi N}{60} \text{ (ms}^{-1}\text{)}$$

$$= \frac{2 \times 3.142 \times 1.725}{60}$$

$= 10{,}839.9 \text{ ms}^{-1}$

2nd Sprocket (2nd Speed):

$N_1D_1 = N_2D_2$

$20{,}700 = N_2 \times 10$

$20{,}700 = N_2 \times 12$

$$N_2 = \frac{20{,}700}{10}$$

$= 2{,}070$rpm

$$= \frac{2\pi N}{60} \text{ (ms}^{-1}\text{)}$$

$$= \frac{2 \times 3.142 \times 2{,}070}{60}$$

$= 10{,}839.9 \text{ ms}^{-1}$

3rd Sprocket (3rd Speed):

$N_1D_1 = N_2D_2$

$1{,}150 \times 18 = N_2 \times 8$

$20{,}700 = N_2 \times 8$

$N_2 = \frac{20,700}{8}$

$= 2,587.5$ rpm

$= \frac{2\pi N}{60}$ (ms^{-1})

$= \frac{2 \times 3.142 \times 2,587.5}{60}$

$= 270.9$ ms^{-1}

4^{th} Sprocket (4^{th} Speed):

$N_1D_1 = N_2D_2$

$1,150 \text{ x } 18 = N_2 \text{ x } 6$

$20,700 = N_2 \text{ x } 6$

$N_2 = \frac{20,700}{6}$

$= 3,450$rpm

$= \frac{2\pi N}{60}$ (ms^{-1})

$= \frac{2 \times 3.142 \times 3,450}{60}$

$= 361.33$ ms^{-1}

5^{th} Sprocket (5^{th} Speed):

$N_1D_1 = N_2D_2$

$1,150 \times 18 = N_2 \times 4$

$20,700 = N_2 \times 4$

$N_2 = \frac{20,700}{4}$

$= 5,175$rpm

$= \frac{2\pi N}{60}$ (ms^{-1})

$= \frac{2 \times 3.142 \times 5,175}{60}$

$= 541.90$ ms^{-1}

Component parts and manufacturing detail

Table 1: Component Parts and manufacturing Detail

S/N	Component Parts	Manufacturing Details	Tools Used
1.	Wind duct	A sheet metal was out to size 1040 x 760mm, after the cutting it was bent into a square shape of each side having 190mm with an overall height of 1040mm.	Shear cutter, manual bending machine, tape rule, scriber and are welding machine.
2.	Grain outlet	A mild steel sheet metal of gauge 18 was cut into size 60x90 x130mm and later bent to form the shape and welded together using fillet welding.	Shear cutter, tape rule, tri-square, scriber and are welding machine
3.	Chaff outlet duct	Steel metal was cut to size after which it was bent with a size reduction method to the outlet to increase the air velocity to properly discharge the impurities and later butt-welded.	Shear cutter, tape rule, tri-square, scribe and are welding machine.
4.	Fan housing	A divider was used to make a diameter of 370mm on a mild steel metal sheet of gauge 18. Another cut of dimension 370 x 190mm was made and cut out and butt-	Shear cutter, divider, tri-square, scriber, rolling machine, tape rule and are welding machine

		welded. Chisel was used to cut out the round marked part of the metal sheet and on one of the rounds cut out sheet, an air suction space was made on it with diameter 240mm	
5.	The frame	An angle iron of 38x38x6.25mm was cut as follows: 660x4560x2mm 550x2mm and 300 x 4mm and late assembled and welded using butt and filet welding method.	Saw blade, tape rule, scribe, tri-square and are welding machine
6.	The screen	A wire gauge of large holes was cut to size and later wrapped with the one with smaller holes.	Shear cutter, tape rule, tri-square.

Table 2: **Bill of Engineering Measurements and Evaluations**

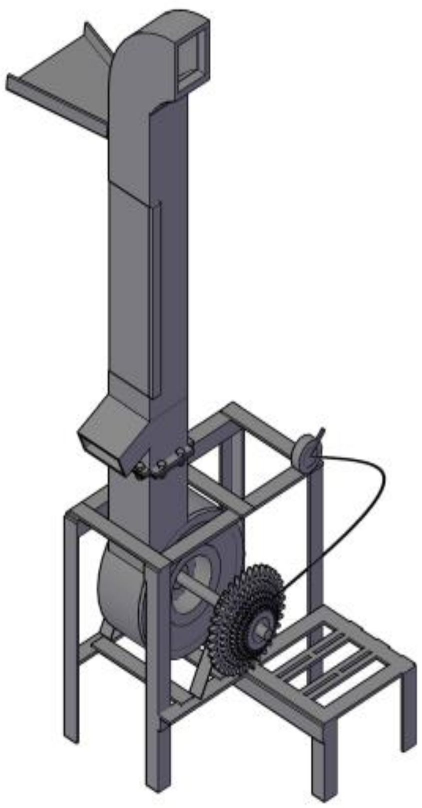
S/no	Item	Description	Quantity	Unit	Rate (₦)	Amount (₦)
1.	Metal sheet	Mild streel gauge 18	I full Length	Mm	7,000	7,000
2.	Chain and Sprocket	Multi-sprocket	Complete mechanism	Cm	5,000	5,000
3.	A/c blower	Medium size	1		8,500	8,500
4.	Electric motor	2.5hp	1	Hp	20,000	20,000
5.	Electrode	Gauge 12	½ packet	Gauge	2,500	1,250
6.	Saw blade		1		250	250
7.	Grinding disc		1		1,200	1,200
8.	Angle iron	(38x38x6.25) mm	I full length	mm	3,500	3,500
9.	Binding wire		I roll	mm	500	500
10.	Bearing	6204zz	2		300	600
11.	Shaft	I" rod	1	mm	3,000	3,000
12.	Hinges	Small size	2		150	300
13.	Bolts and Nuts	M8	4	mm	50	200
14.	Capacitor	5µf	1	µf	1500	1500
15.	Transportation				2,000	2,000
Total						54,800

It is necessary to note that cost of production can be reduced if the machine is produced on a large scale. Considerable expenses, which can be avoided in future construction, were increased to the fact that the multi-purpose pneumatic grain clearing machine is a prototype.

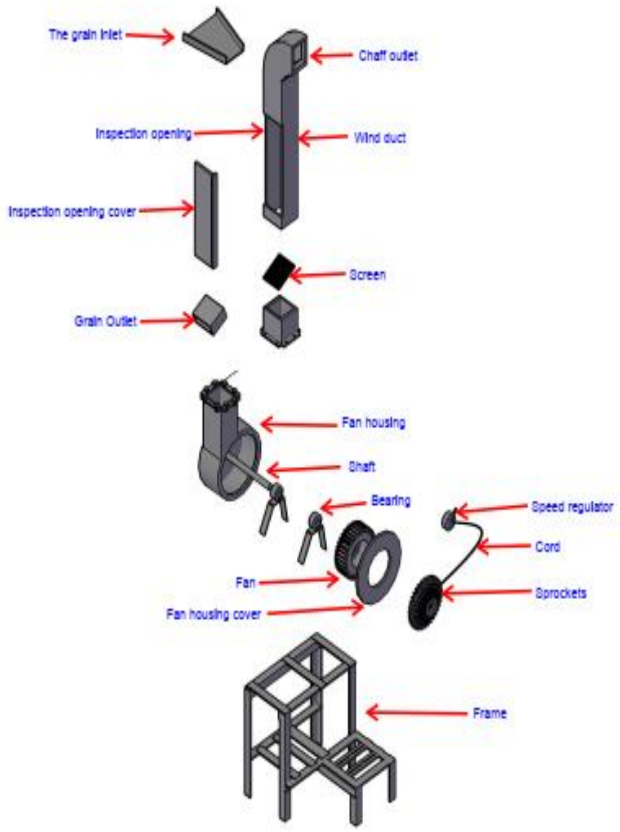
1.7 Testing and Evaluation

Table 3: Weight of the samples used for testing

	Wt. of grain (kg)	Wt. Of chaff (kg)	Total wt. (kg)
Rice	1.347	0.315	1.662
Cowpea	0.882	0.252	1.134
Maize	1.393	0.218	1.611



Isometric Drawing of the Machine



The Exploded View of the Machine

1.7.1 Efficiency of the machine

Cleaning efficiency, Ec (%) is defined as the percentage by weight of chaff collected at the chaff outlet with respect to the total chaff input into the cleaner

$$Ec\ (\%) = \frac{X_a}{X_b + X_d} \times 100$$

Where X_a = Total weight of clean grains received at the grain outlet in kg

X_b = Total weight of chaff received at the grain outlet in kg

X_d = Total weight of chaff received at the chaff outlet in kg

For Rice: X_d = 0.271 kg, X_b = 0.44 kg

$$= \frac{0.271}{0.044+0.271} \times 100$$

$$= 86\%$$

For Cowpea: X_d = 0.197 kg, X_b = 0.021 kg

$$= \frac{0.197}{0.197+0.021} \times 100$$

$$= 90.4\%$$

For Maize: X_d = 0.224 kg, X_b = 0.028 kg

$$= \frac{0.224}{0.224+0.028} \times 100$$

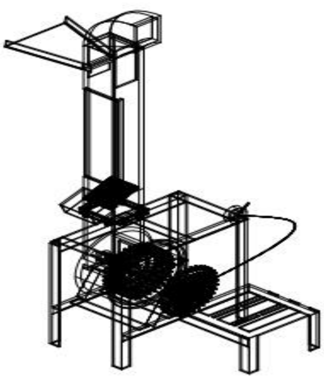
$= 88.9\%$

1.8 Discussion

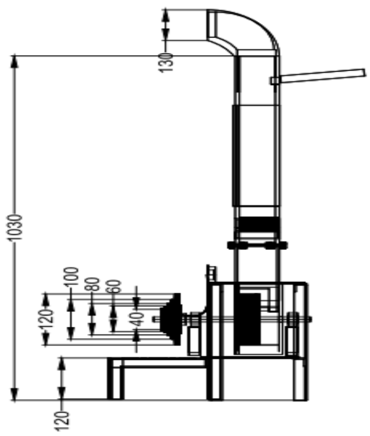
The test revealed that at speed 1, 97.31% of the grain was collected out of 1.347 kg of the sample, while 85.76% of the chaff was blown off out of 0.316 kg of the chaff. 2.67% of the grain came out with the chaff at the chaff outlet and 13.92% of the chaff came out at the grain outlet within l5.80s. The speed was a bit lower than the terminal velocity but too low for sample B and C, which have higher terminal velocities. At speed 2, none of the sample was cleaned properly because the fan speed was more than the terminal velocity of A but very low to the terminal velocity of B and C. From sample A, 78.51% of the sample was collected from 1347 kg of the grain while 19.52% of the sample has been blown out. Sample B and C did not release much of their chaff due to low fan speed, 37.30% and 63.76% was blown out of the chaff of 0.252kg and 0.2 18 kg leaving 49.60% and 44.84% to be collected with the grains respectively. At speed 3, some quantities were blown out of sample A due to low terminal velocity of the sample and high fan speed, 25.54% of the sample was collected through the chaff outlet leaving just 74.46% to be collected at the grain outlet. Out of 0.882kg of sample B, 95.47% was collected at the grain outlet but much of the chaff of 48.62% was collected with the grain from 0.28kg leaving 5 1.38% to be collected through the chaff outlet within 36 s. Sample C released most of its grain of 93.75% from 1.393kg leaving 2.01% to be blown out through the chaff outlet. 72.03% of the chaff was blown through the chaff outlet leaving 27.97% to be collected with the grain within 29.00 s. At speed 4, much of sample A was blown out through the chaff outlet. 96.03% of sample B was collected at the grain while 4.08% was blown out through the chaff opening. Out of 0.218 kg of the chaff, 90.37% was blown out through the chaff outlet within 35 s. 87.22% of sample C was collected at the grain outlet out of 1.393 kg while 12.78% was blown out with the chaff because the speed is a little bit higher than the terminal velocity. The speed of the fan at speed 5 was higher than the terminal velocity of the three samples tested.

1.9 Conclusion

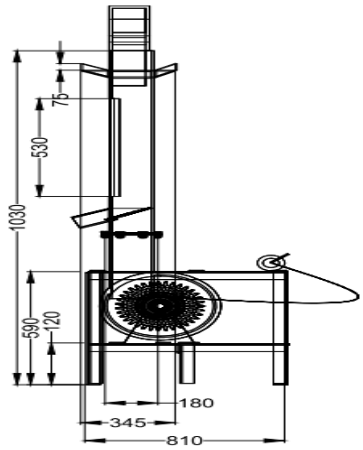
The construction of a multi-seed pneumatic cleaning machine was designed and fabricated. It was to clean the grains and separate the grains from mostly the chaff. Due to the non-complexity of the machine, it can be used by small scale farmers to enable efficient cleaning of grains particularly rice, cowpea and maize. It will also minimize time, energy and cost involved in traditional processing of grains. The efficiency of the machine ranges from 86.0% for rice (sample A), 90.4% for cowpea (sample B) and 88.9% for maize (sample C) at speeds 1, 4 and 3 respectively.



Schematic Drawing of the Machine



Front View of the Machine



Side View of the Machine All dimensions in mm.

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