DEVELOPMENT AND PERFORMANCE EVALUATION OF A DRIED GRAIN COLLECTING MACHINE

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ABSTRACT

A study was conducted to design a grain collecting machine for different grains. The grains considered in this study were rice, millet and guinea corn and the total tome duration for collecting each grain was 40 minutes. The grain collecting machine was carefully designed based on economic consideration which is the basis of any design. The materials used were carefully selected so that it can serve the specific purpose for which it is meant, while at the same time maintaining economy.

The machine was tested by subjecting about 40kg of different grains which includes rice grain, millet grain and guinea corn grain at different time interval. The Average weight value , average collecting capacity , average suction loss value and average collection efficiency computed was 18.89 kg, 0.89kg/h, 4.75kg and 81% respectively for rice grain. Also, the Average weight value , average collecting capacity , average suction loss value and average collection efficiency computed was 9.88 kg, 0.42kg/h, 2.34kg and 79.38% respectively for millet grain while the Average weight value , average collecting capacity , average suction loss value and average collection efficiency computed was 18.84 kg, 0.85kg/h, 3.09kg and 86.35% respectively for guinea-corn grain.

KEYWORDS: Grains, Pipeline, Suction, Capacity, Efficiency

1. INTRODUCTION

The traditional methods of drying and packing grains are so tedious that they discourage increased production of grain crop. It introduces impurities to the grain, causes grain damage (visible and internal); and also reduces the grain quality. Therefore, a study of development of a grain packing machine becomes necessary to overcome the aforementioned problems. Physical, mechanical and aerodynamic properties of grain are necessary for the design of equipment to handle and package the grains. The immediate adoption of new technologies to aid storage system was as a result of a greater demand to increase production to cope with the fast-growing population of Nigeria which was estimated to grow to about 200 million by the year 2019 (UN, 2019). Another factor for adopting the technology for packing was as a result of government encouragement for the citizen to patronise local production of grain (rice) which also lead to increased production, (Adeyemo *et al.,* 2013).The adoption of improved production technology increases yield and likewise gives birth for new challenges on how to deal or handle tons of wet grains that need to be dried to maintain good quality, storability and high commercial value.

Packing of grain seeds from the concrete floor is the process of using either manual method or mechanical methods to pack grain seeds into the storage system after being dried for some time. A long-standing problem in managing the behaviour of a collection of solid grains concerns the nature of the grain packing, a property that is typically controlled by how the grains are poured or shaken (Chen *et al.,* 2006). Packing problems have been much studied in the past decades, in particular, to their wide range of applications in many settings of theoretical and practical interest, including packing/loading, scheduling, and routing (Pergola *et al.,* 2013c).

Several drying technologies were introduced to small scale farmers, large scale farmers and traders. The rate of return from sun drying operation is high while the rate of return from the best mechanical dryers available in the country is low. Farmers unanimously use sun drying and none adopts mechanical dryers. In the light of this development and present practices, it is obvious that sun drying will stay as one of the postharvest technologies in the Nigeria.

There is a great importance in mechanising the process of collecting the grains spread on the wide pavement and also worthy of note that the difficulty of the manual collection of grains was stressed as one of the major problems of most grains packer because of the lack of technology that can be used for that project and the speed they require. This is important when packing up the grains when the rain is about to start, it will take more than an hour or more when manually collecting the grains depending on the size of the field. The larger the drying field, the more man power you need to quickly collect the grains since they're process of collecting is only by sweeping the grain.

The major factor limiting the production of grain seeds are the post-harvest processing problems particularly seed drying and storage.

2.0 METHODOLOGY

2.1 General Description of the Machine

The grain packing machine is made up mild steel sheet, angle iron and flat bar. This is as a result of its workability, durability and its availability.

The belt and the bearings were selected in such a way that can be able to withstand the expected maximum load, stress and power of transmission. The motor selected is such that can provide the required wattage for the maximum load of the grain packing machine.

2.2 Design Consideration and Assumptions

Economic consideration is the basis of any design. The simplest solution to a design problem may not only be the cheapest, but may also be the best. The materials to be used were carefully selected so that it can serve the specific purpose for which it is meant, while at the same time maintaining economy.

In designing the grain packing machine, the basic factors considered include the choice of materials, in addition to their availability and cost which are always of primary consideration. These materials were chosen on the basis of their properties.

The physical characteristics of grains that were examined are shape, size, density, weight while the aerodynamic characteristics studied are the drag coefficient and the terminal velocity of grains.

Design requirements were synthesized based on the analysis of findings in the various literatures reviewed and from patented and commercial pneumatic grain collectors. Some of the identified design requirements were the following:

1) the machine should collect grains at varying thickness under sun drying condition
   and bag at the same;
2) the machine should help reduce drudgery and quicken collecting and bagging of grains during sun drying; and
3) the machine should be of intermediate technology, made from local materials using local manufacturing technology, simple and safe to operate and maintain, functionally and structurally sound, and with minimum cooling.

2.3 Design Calculation

The calculations of each of the parameters were based on the functions to which they performed

2.3.1 Calculation of the Suction Pipe

To design the pipeline which pack spread grain by suction and conveyed it to the bag in air-grain mixture from the starting point to the delivery point, let's consider two sections of the pipe which is placed horizontally and vertically. The vertical height 800mm was chosen in such a way to accommodate the bag to which the grains will be packed and the horizontal pipe of 200mm was selected

2.3.2 Determination of the Pipeline Section

The suction pipe diameter is determined from David Mills (Akhil, 2017) suction pneumatic conveying system design guide

The solid – air loading ratio (φ) is 0.3

Given that the density of the air is 1.2 Kg/m^3

The required mass flow rate (m) =1500kg/hr = 0.42kg/s

The velocity of air to convey the grains is 33m/s in order to enable the machine to convey grains like rice, wheat and corn, (Steinke and Kandlikar, 2005),

$$m = \varphi \times \rho \times A \times V \quad (1)$$

$$D = 0.211m = 211mm$$

2.3.3 Determination of Pipe Pressure

The velocity pressure will be given as expressed below

$$V_p = \frac{1}{2} P v^2 \quad (2)$$

$$= 653.4pa$$

2.3.4 Determination of the Size of Aperture of the Collector

The air discharge through the blower by suction to drive the dried grain, cited by (Ghafori *et al.,* 2011)

Air discharge through the blower = the cross sectional area × Velocity of the air

$$\text{Air Discharge} = A \times V \quad (3)$$

A = Cross sectional area m^2

V = Velocity of air is 33m/s

$$\text{Air discharge} = \frac{\pi D^2}{4} \times V$$

D = is the diameter of the conveying pipe 0.211m

$$\text{Air Discharge} = 1.1548 m^3/s$$

2.3.5 Determination of Fanning Friction

Several equations that we have seen have included terms to represent dissipation of energy due to the viscous nature of fluid flow such as air. This factor is termed fanning coefficient. the ratio of the wall shear stress to the flow kinetic energy per unit volume (Steinke and Kandlikar, 2005)

$$N_{Re} = \frac{D V_g \rho_g}{\mu_g} \quad (4)$$

Where

D = Pipe inside diameter (m)

Vg = Gas velocity (m/s)

P_g = Gas density (Kg/m^3)

$\mu_g$is the gas viscosity in 18.5 Kg/ms at stp (Calısır *et al.,* 2005)

$$N_{Re} = 0.452$$

$$f = \frac{0.331}{\left[\log_n\left(\left(\frac{\varepsilon}{3.7 \times D}\right) + \left(\frac{7}{N_{Re}}\right)\right)\right]^2} \quad (5)$$

Where

ε is the pipe roughness factor which can be estimated as 0.00015 for smooth pipes or 0.0005 for shot-peened pipes.

D = Pipe inside diameter (m)

NRe = Reynold's number

$$f = \frac{0.331}{\left[\log_{10}\left(\left(\frac{0.00015}{3.7 \times 0.211}\right) + \left(\frac{7}{0.452}\right)\right)\right]^2}$$

$$f = 0.2337$$

2.3.6 Determination of Actual Pressure Loss

Head losses experienced in pneumatic conveying systems are the result of the following forces.

Friction of the gas on the inside of the pipe + forces required to move the solids through the pipe + forces required to support the weight of the solid and the gasses in vertical pipe runs + forces required to accelerate the solids + friction between the solids and the inside of the pipe

Note: Friction losses as the result of solids being in contact with the inside of the pipe are usually very small and can be neglected when considering dilutes phase transport.

The total pressure loss of the parameter system (expressed in psi or ibs/in) can be expressed as

$$\Delta P_T = \Delta P_{acc} + \Delta P_g + \Delta P_s + \Delta H_g + \Delta H_s + \Delta P_{misc} \quad (7)$$

Where

ΔP_T = total pressure loss in the system

ΔP_{acc} = pressure loss due to accelerate of the solids from their 'at rest' condition at the pick-up point

ΔP_g = frictional pressure loss of the gas

ΔP_s = frictional pressure loss of the solids

ΔH_g = elevation pressure loss of the gas

ΔH_s = elevation pressure loss of the solids

ΔP_{misc} = pressure loss from miscellaneous equipment

Total pressure loss

$$\Delta P_T = 0.7401 + 24.34 + 5.9 + 0.0083 + 0.01042 = 30.999m$$

2.3.7 Determination Power required

Power delivered at the output of the blower is the product of density of solid material conveyed, volumetric rate of the material movement, acceleration due to gravity and total head of mixture. This is also the power required to ascertain the volumetric discharge and drives the materials (Agarwal, 2011)

$$P_{out} = \rho \times Q \times g \times H \quad (8)$$

$$P_{out} = 0.1276KW$$

Considering factor of safety;

If factor of safety of 1.5 is considered suitable for this design, the safe power output is

$$P_{out} = 0.1914KW$$

Power to be supplied at the input of the blower will be the ratio of the output power to the efficiency of the blower. To ensure that optimum performance is achieved by the blower we are selecting the blower efficiency to be 60%. (Ghafori *et al.,* 2011)

Input power is therefore related to the output power as thus;

$$P_{in} = \frac{P_{out}}{\text{Blower efficiency}} \quad (9)$$

$$P_{in} = 0.3KW$$

2.3.8 Determination of RPM of motor (N)

The velocity of the air exiting the suction pump is proportional to the rotation of the motor (rpm), and it is therefore given as the function diameter of the pipe section of the conveyor and the rotation of the motor (Srivastava *et al.,* 2006)

$$v = \frac{\pi \times N \times D}{60} \quad (10)$$

Velocity of the air V= 33m/s
Diameter of the air column D = 0.211m

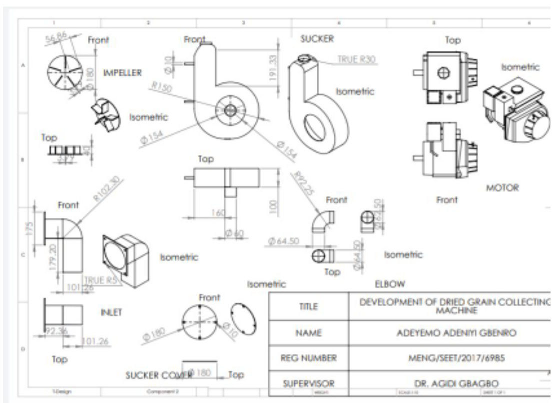
$$N = \frac{60 \times 33}{\pi \times 0.211}$$

$$N = 2985.65 rpm$$

2.4 Principle of Operation

The grain collecting machine works on the principle of pneumatic conveying of product from the ground to a storage medium. The machine consists of three major parts. The power, the sucking and the storage sections. The centrifugal fan would be powered with a diesel engine. As the blade in the centrifugal fan rotates, it sucks in the mixture of air and grain with an high velocity. The grains would be allowed to pass through the centrifugal fan, the effect of damages on grains through the fan is taking care of by using a forward curved fan which are useful for high air flow work.

The grain is discharge into a container capable of holding 100kg of grains, this is removed and replaced when full. The machine is provided with wheel for easy m



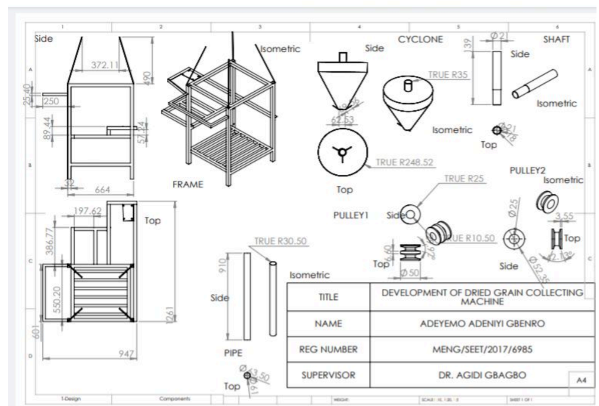
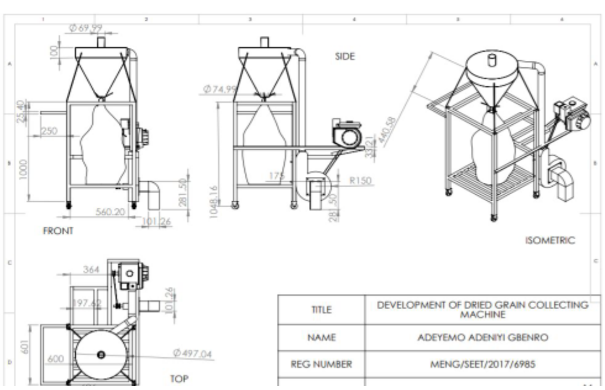


Fig. 2.1: Component Parts of the Machine

Fig. 2.2: Component Parts of the Machine



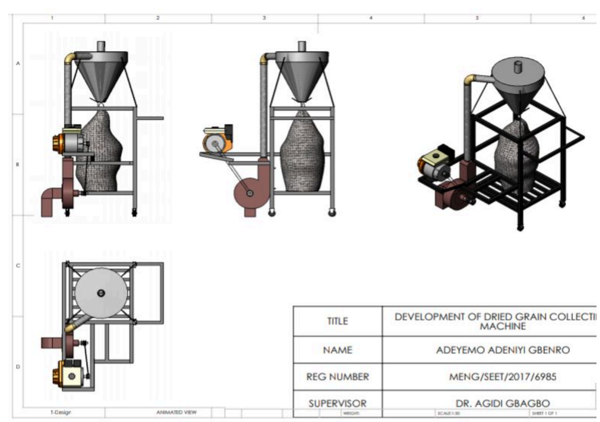


Fig. 2.3: Isometric View of the Machine

Fig. 2.4: Orthographic View of the Machine

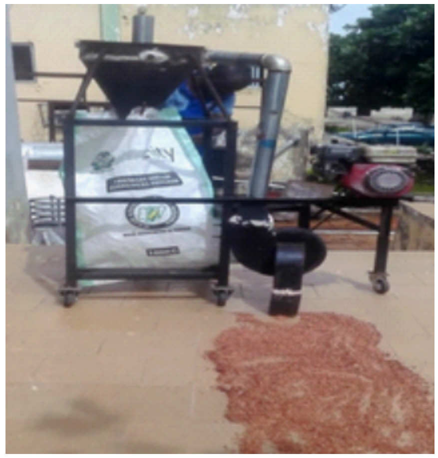


Fig. 2.5: Pictorial View of the Machine

2.5 Procurement of Sample Materials

The samples of grains used as materials were directed gotten from locals after harvesting. 40kg bags of paddy rice, millet and guinea corn were collected to carry out the text on the machine. The samples collected were examines to ascertain the level of quality of the grains before being collected by the machine.

2.6 Sample Preparation

Before the grains are being collected by the machine, the quality of the grains were noted and after each text trial, the collected grains were examined to determine the impact of the machine on the grains

2.7 Performance Evaluation

40 kg of grains (rice, millet and guinea corn) were used as test materials. The grains were spread manually on a 1.5 x 15m concrete pavement evenly at approximately 3m thick. The two parameters that were used for the evaluation of the machine area collecting capacity and collecting efficiency.

2.7.1 Collecting Capacity

This refers to the quantity of grains collected per unit time. Collecting capacity of the machine was determined using

$$Fc = \frac{W_{pc}}{T}$$ (Sony *et al.,* 2013)

(11)

where:

Fc = Collecting capacity, kg/h

W_{pc} = Weight of collected grains, kg
T = Total time of collection,

2.7.2 Collecting Efficiency

The collecting efficiency of the machine is the ratio of grains collected and the sum of grains collected and suction losses. A single pass over the 2-4 cm thick grain using the suction pipe of the machine will be done to collect the grains spread on a 1.5 x 15 m concrete pavement. The collecting efficiency of the machine was determined using

$$C_e = \frac{W_{pc}}{W_{pc} + S_l} \times 100$$ (Sony *et al.,* 2013)

(12)
where:
C_e = collecting efficiency, %
W_{pc} = weight of grains collected, kg
S_l = Suction loss, kg

2.8 Data Analysis

All the data gathered were analyzed using single factor experiment arranged in completely randomized design with five replicates. Analysis of variance (ANOVA) was used to determine if there were significant differences among treatment means.

3.0 RESULTS AND DISCUSSION

3.1 Collecting Efficiency for Rice, Millet and Guinea Corn

Tables 3.1, 3.2 and 3.3 show five parameters that were used to carry out the performance evaluation of the grain packer which includes time, weight of collected grain, collecting capacity, suction loss and collection efficiency. The machine was tested using rice, millet and guinea corn which were subjected to pack grains within a stipulated time frame of 40 minutes at a fragment of 5 minutes each to determine the weight of grain collected, collecting capacity, suction loss and collecting efficiency respectively. At every increment in time there is increase in efficiency, therefore the average efficiency of grain packer subjected to pack rice, millet and guinea corn grains is 84.695% at the end of 40 minutes.

From the ANOVA analysis carried out, it can be deduce that the performance evaluation has a strong positive result from the analysis carried out. The multiple R has an average value of 0.9989 which represent the correlation relationship between the five parameters, time (min), weight of collected grain (Wpc kg), collecting capacity (Cc kg/h), suction loss (St kg), collecting efficiency (Ce %) indicating that time has a strong positive influence on the other four parameters.

Table 3.1 **Collecting Efficiency for Rice**

S/no	Time	Weight of collected	collecting	suction	Collecting

	(min)	Grain (kg)	capacity(kg/h)	loss(kg)	efficiency
%					
1	5	5.5	1.1	0.5	91.70
2	10	10	1	2.2	81.97
3	15	13.4	0.89	4.0	77.01
4	20	17.2	0.86	4.8	78.18
5	25	20	0.8	5.2	79.37
6	30	24	0.8	6.4	78.95
7	35	29	0.83	7	80.56
8	40	32	0.8	7.9	80.26

Table 3.2 **Collecting Efficiency for Millet**

S/no	Time	Weight of collected	collecting		suction
Collecting					
	(min)	Grain (kg)	capacity(kg/h)	loss(kg)	efficiency
%					
1	5	4.2	0.84	0.4	91.30
2	10	5.0	0.5	0.9	84.75
3	15	5.8	0.39	1.5	79.45
4	20	6.2	0.31	2.0	75.61
5	25	6.6	0.26	2.9	69.47
6	30	7.2	0.24	3.2	69.23
7	35	12	0.34	3.8	75.95
8	40	32	0.5	4.0	88.89

Table 3.3 **Collecting Efficiency for Guinea corn**

S/no	Time	Weight of collected	collecting		suction
Collecting					
	(min)	Grain (kg)	capacity(kg/h)	loss(kg)	efficiency
%					
1	5	5.3	1.06	0.8	86.89
2	10	10.2	1.02	1.3	88.70
3	15	12.9	0.86	2.0	86.58
4	20	16.8	0.84	2.5	87.05
5	25	20	0.67	3.4	85.47
6	30	25.5	0.73	4.1	86.15
7	35	29	0.83	5.1	85.04
8	40	31	0.78	5.5	84.93

4.0 CONCLUSIONS

This study was conducted to design, fabricate and carry out performance evaluation on a dried grain machine collector. The machine was tested by subjecting it to three different grains which includes rice grain, millet grain and guinea corn grain at different time interval. It was concluded that guinea had the highest collecting efficiency of 86.35% then followed by rice with collecting efficiency of 81% and lastly millet with the collecting efficiency of 79.38% respectively.

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