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Research Paper

DEVELOPMENT AND TESTING OF A RICE DESTONING MACHINE

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A rice destoner was developed locally for separating stone from milled rice. The major components of the machine includes: reciprocating screen and blower as well as hopper. The separation of stone is achieved by the vertical and horizontal oscillation of the reciprocating screen which as result of the forced air flow (produced by the blower) through the machine causes the rice kernels to float on a cushion of air just above the screen. This, then allows the reciprocating screen to convey the more dense stones up the screen to a discharge chutes, thereby ensuring the separation of the stones from the rice kernel. The machine was designed to be powered by a 2 hp electric motor. It was tested for its efficiencies in terms of stone and rice separation. The tray loss and impurity level after separation were also measured. The results showed that the machine has 69.0% and 87.7% stone and rice separation efficiency respectively. The tray loss and impurity level after separation were 12.8% and 8.1% respectively. The successful development of this machine is expected to solve problem of stone infestation usually associated with the locally produced rice.

Keywords: Destoning, Reciprocating screen, Separation, Efficiency, Rice, Stone

INTRODUCTION

Rice has been the most staple food in Nigeria; almost all ethnic groups in the country take rice in one form of delicacy or the other. The country is blessed with abundant fertile, arable land and the farmers produce adequate quantity of rice which should be enough for local consumption. However, government embark on importation of rice due to poor quality of the locally produced rice which is usually contaminated with stones, hence making them undesirable by Nigerians.

Harvesting and post harvest handling methods of local rice encourage the presence of contaminants such as stones, sticks, chaff, and sand (Ogunlowo and Adesuyi, 1999). Traditional methods of removing contaminants include hand picking (sorting and separation of stones from rice manually) and this is tedious.

To avert this trend, farmers have been trained on how to handle paddy rice right from field but due to the nature of the field where this rice are being grown 100% free-stone-rice has not been

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achieved. The pneumatic winnowers used to clean the threshed paddy only has the ability remove light impurities and sand with rough texture but does not remove sand with similar texture with rice . The wet cleaning (submersion of rice in water) method adopted by some small scale rice processing industries also removes light impurities (unfilled or partially field grains) only and very dense impurities since separation is achieved by difference in specific gravity of paddy and impurities.

However, impurities that are of the same size and density as the paddy remain and parboiled (in the case of parboiled rice). On milling, these stones escaped with the milled rice thereby making the locally produced rice unacceptable by Nigerians. The demand for foreign rice in Nigeria had been attributed to the prevalence of contaminants in locally produced once (Koyo and Adekoyo, 1994).

Rice destoning is to eliminate stones mixed with milled rice. It is possible to separate agricultural products using either one or the combination of the following methods: screening, fluidization, pneumatic and floatation. Previously, research efforts were made to solve this problem with different levels of success. Oguoma *et al.* (1992) established that the separation of sand and stones from rice can be achieved by exploiting the difference in the dimensional features of rice and stone.

This design takes advantages of rice bio-engineering properties which include: gravimetric, aerodynamic, frictional, rheological, mechanical and physical properties.

The development and adoption of locally produced rice destoning machine for use by the farmers will improve the quality of locally produced rice which will go a long way in creating jobs for the teaming young graduates as well as creating wealth for the nation. The objective of the study is to develop a rice destoning machine using locally available materials.

DESCRIPTION AND OPERATION OF THE MACHINE

The main features of rice destoning machine are: The hopper, the reciprocating screen, the blower, the drive and driven assembly and the supporting frame as shown from Figures 1 to 4.

Hopper: The hopper is trapezoidal in shape. It is made of mild steel sheet with sides slanting inward. It forms the feeding chute through which stone contaminated milled rice are fed into the cleaning unit and has stopper at the base to regulate the inflow of the materials into the cleaning unit.

Reciprocating screen: The reciprocating screen arrangement consists of four reciprocating arms; each arm has bearing at both ends and the ends are attached to the frame and the other to the reciprocating screen. The reciprocating screen bears the separating screen which is fixed on the blower casing. Beneath it, is a connection to the cam (eccentric mechanism) which energyzes the reciprocating screen in both horizontal and vertical oscillatory motion as it rotates. The reciprocating screen is arranged at an angle (which is also adjustable) to facilitates the flow of material on the screen.

Blower housing: It is made of mild steel. It accommodates the blower blade and the shaft. The blower provides the air blast for aero-dynamism.

Drive and driven assembly: This consists of electric motor of 2 hp with its pulley and eccentric shaft pulley as well as blower's pulley. The electric motor, the eccentric shaft and blower are connected by v-belts.

Machine frame: The machine frame is made up of angle iron. It holds the machine, drive and driven assemblies in position and stabilizes the system during operation.

Figure 1: Plan of Machine

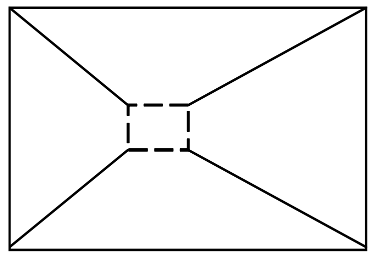


Figure 2: Front View of Machine

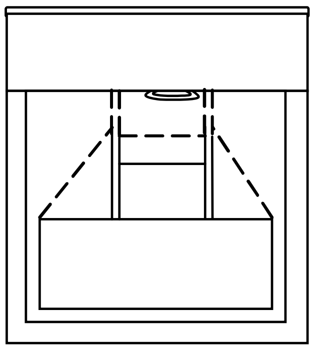


Figure 3: Side View of Machine

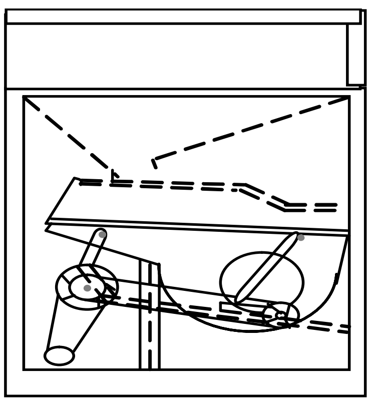
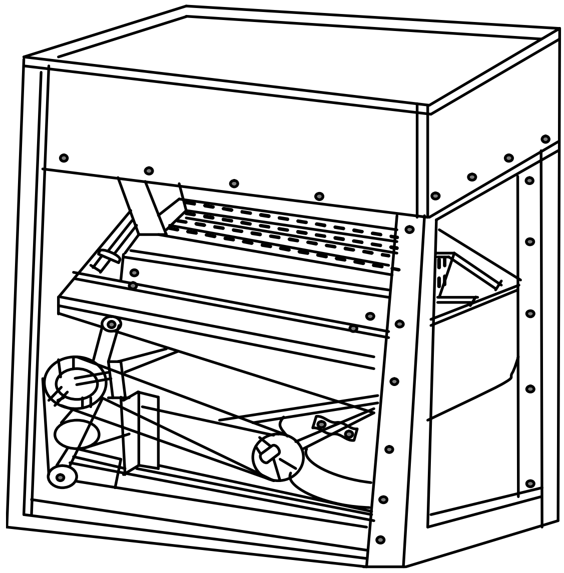


Figure 4: Isometric View of Machine



DESIGN ANALYSIS

Design analysis was carried out to determine the necessary design parameters for selection of the various machine parts, and this was done in order to avoid failure of machine parts during the required working life of the machine.

DETERMINATION OF THE SCREEN CAPACITY

The capacity of the screen is needed in order to ascertain the capacity of the machine which is the paramount parameter needed in the design of the other components of the machine. The capacity of the screen was determined using the standard formula for calculating the capacity of rectangular shape as follows:

$$V = LBH \quad ...(1)$$

where V is the capacity of the screen (m^3),

L is the length of the screen (m);

B is the breadth of the screen (m); and

H is the depth of the screen (m).

EVALUATION OF THE WEIGHT OF THE CLEANING UNIT

The weight of the cleaning unit was determined so as to know the amount of load being exerted on the shaft by the cleaning unit and its content. Hence, the weight of the cleaning unit is expressed as

$$W = mg \quad ...(2)$$

$$m = \rho \upsilon \quad ...(3)$$

where W = weight of the screen and its content (N),

m = mass of the screen and its content (kg),

g =acceleration due to gravity (m/s^2),

ρ = density of the screen (kg/m^3)

v = volume of the screen (m^3).

POWER REQUIREMENT

This is a sum total of various power required to drive the reciprocating screen and blower. The crank speed required to set reciprocating screen in both horizontal and vertical oscillatory motion as well as that of blower is a function of crankshaft speed, which depends on the speed of electric motor and pulley sizes. Both speed and pulley sizes were determined from the following relationship:

$$N_m D_m = N_v D_v \quad ...(4)$$

where

N_m is the speed of electric motor , D_m is the diameter of the electric motor pulley, N_v is the speed of the crank shaft pulley and D_v is the diameter of the crank shaft pulley.

Power required is expressed as

$$P = Tw \quad ...(5)$$

where P is the power required (W)

T is the torque (Nm)

W is the speed (rad/s)

DETERMINATION OF THE TWISTING MOMENT

$$T = 6OP/2\pi N \quad ...(6)$$

where

T is torque (Nm), P is the power transmitted (W); and N is the speed (rpm)

DETERMINATION OF THE CRANK (ECCENTRIC) SHAFT DIAMETER

This was computed to know the shaft size that can withstand the applied load. For a solid shaft, the diameter of the shaft was determined using relationships given by Khurmi and Gupta (2007):

$$D^3 = 16\ (KmM + Te)/\pi\, b_{d...} \quad ...(7)$$

and

$$Te = \sqrt{(Km \times M)^2 + (Kt \times T)^2} \quad ...(8)$$

where Te is equivalent twisting moment (Nm);

Km combined shock and fatigue factor for bending = 1.5;

M is maximum bending moment (Nm);

b_d is the maximum bending stress; and (N/m^2)

Kt is combined shocked and fatigue for torsion equals 1.0.

DETERMINATION OF THE ANGLE OF TWIST OF SHAFT

This enables the designer to know if diameter of the shaft is safe to carry the applied load. Angle of twist of a solid shaft is given as follows:

$\theta = 584M_t l/Gd^4$ ...(9)

where

θ = angle of twist (in degrees)

l = length of shaft (m)

M_t = twisting moment (Nm)

G = torsional modulus of elasticity ($N/m^{2)}$

d = shaft diameter (m)

Determination of centre distance and belt length

Two centre distances were considered, that is, maximum and minimum distances and were given respectively as follows:

$C_{max} = 2(D_v + D_m)$ ...(10)

$C_{min} = 0.55(D_V + D_m)$ ...(11)

The nominal length of the belt is given by.

$L = \pi/2(Dv + Dm) + 2C + (TDv – D_m)^2/4$ ...(12)

where L is the total length of belt required (m),

C is the centre distance between the pulleys (m).

DETERMINATION OF THE ANGLE OF CONTACT

The angle of contact, α, is given by the equation below as suggested by PSG Tech (1982)

$B=180^0-60^0(D_v - D_m)/C$ ...(13)

DETERMINATION OF THE TENSION IN BELT

The tension on the two sides of the belt was calculated as follows:

$T_1/T_2 = e^{K\theta}$ ...(14)

where T_1=the tension of the belt on tight side

T_2= Tension of the belt on the slack side

K= Coefficient of friction between the belt and the pulley

θ = Angle of contact or lap of the belt between the two pulleys.

e= base of napirian =2.728

The power transmitted by the belt is given by

$P = (T_1 – T_2) V$ ...(15)

where p is the power transmitted by the belt (W)

V is the speed of the belt (m/s).

MODE OF OPERATION

The rice destoning machine was designed to separate rice from stone. A two horse power electric motor provides power to the eccentric shaft. The eccentric shaft rotates with the aid of bearings. It also provides drive to the shaft of the blower through belts and pulleys. The reciprocating screen oscillates both vertically and horizontally with the help of bearings, eccentric crank and reciprocating arms. As the stone infested milled rice are being fed into the inclined reciprocating screen through the hopper; this reciprocating screen which as result of the forced air flow (by the blower) through the machine causes the rice grains to float on a cushion of air just above the screen. Thus the screen conveys more dense stones up the screen to a discharge chute and the rice flows down the screen and collected as stone-free rice.

PERFORMANCE ASSESSMENT

The machine was tested for its efficiency in separating stone from rice; determine its capacity as well as other parameters.

MATERIALS AND METHODS

The machine was first run under no load condition using a 2 hP electric motor with speed rating of 1440 rpm while the eccentric shaft which sets the reciprocating screen in vertical and horizontal oscillatory motion was running at speed of 327 rpm. This was done to ensure the smoothness of the machine rotating parts. The performance test of the machine was carried out using Faro 42 rice variety (medium grain type). 2000 g of rice sample was mixed with 500 g of stone and this was done in three replications at three different angles of inclination (35^0, 30^0 and 25^0) of the reciprocating screen. It is noteworthy that the proportion of stone mixed with the rice for the purpose of assessing the machine was practically unrealistic; because the weight of rice to stone was in ratio 4:1. The samples (rice-stone mixtures) were introduced into the machine. The time taken for the separation was recorded. The quantities of cleaned rice and separated stones for all treatments were recorded.

The performance of the machine was assessed using the following relationships given by Ogunlowo and Adesuyi (1999).

(i) Impurity level after separation (IM_L): This is the ratio of the mass of clean rice to the total mass of clean rice and mass of stone in clean rice after separation, expressed in percentage as follows

$$IML = \frac{Mscr}{Mcr + Mscr} \text{ x } 100 \qquad ...(16)$$

(**ii) Tray loss (Tl):** It is the quantity of the rice that was not recovered in the process, expressed as percentage as follows:

$$Tl = 1 - \frac{Mcr}{Mrm} \text{ X } 100 \qquad ...(17)$$

(iii) Rice separation efficiency (RSE): This is the ratio of mass of clean rice to the mass of rice in the mixture before separation expressed in percentage and it is given as

$$RSE = \frac{Mcr}{Mrm} \text{ x } 100 \qquad ...(18)$$

(iv) Stone separation efficiency (SSE): It is a measure of the quantity of stone removed in the process, expressed in percentage as follows:

$$SSE = \left[1 - \frac{Mscr}{Msm}\right] \text{ x } 100 \qquad ...(19)$$

where Mcr is the mass of clean rice (g)

Msm is the mass of stone in the mixture (g)

Mrm is the mass of the rice in the mixture before separation (g)

Mscr is the mass of stone in clean rice after separation (g).

RESULTS AND DISCUSSION

The result of the test carried out with the machine are presented in Table 1 and discussed as follows

i) Stone separation efficiency: The results of the stone separation efficiency of the machine are presented in Table 1. Separation of the stone from rice with reciprocating screen inclined at an angle of 25^o produced the highest stone separation efficiency of 69.0%, while separation carried out at angle of 35^o gave the lowest stone separation efficiency of 59.7%. This could be due to the fact that at larger angle of 35^o, the component of the force of the gravity is very close to the direction of gravity thereby affecting the upward movement of the stones.

ii) Rice separation efficiency: The results of rice separation efficiency of the machine are also presented in Table 1. From the result, it appears that the average rice separation efficiency remains the same at larger angles of inclination but tends to reduce at lower angle of inclination

Table1: Result of the Performance Test of the Locally Developed Rice Destoning Machine

Inclination angle (degree)	Wt. of rice in the mixture (Mm(g))	Wt. of stone in mixture {Msm}(g)	Wt. of rice and stone {Mrm +Msm(g)}	Wt. of separated rice [Mcr(g)]	Wt. of separation stone (g)	Time taken (s)	Losses (g)	Wt. of stone in clean rice[Mscr(g)]	Tray loss [Tl(%)]	Ave tray Loss (%)	Impurity level [IMI(%)]	Ave impurity level (%)	Rice separation efficiency [RSE(%)]	Ave rice separation efficiency (%)	Stone separation Efficiency [SSE(%)]	Ave stone sep. efficiency (%)
35	2000	500	2500	1650	300	49	350	180	17.5		9.8		82.5		64.0	
	2000	500	2500	1800	280	50	200	215	10.0		10.7		90.0		57.0	
	2000	500	2500	1780	285	48	200	210	10.0	12.5	10.6	10.4	90.5	87.7	58.2	59.7
30	2000	500	2500	1700	270	45	300	170	15.0		9.1		85.0		66.0	
	2000	500	2500	1780	290	46	220	185	11.0		9.4		89.0		65.0	
	2000	500	2500	1780	290	59	220	180	11.0	12.3	9.2	9.2	89.0	87.7	64.0	64.3
25	2000	500	2500	1650	355	52	300	135	17.5		7.6		82.5		73.0	
	2000	500	2500	1800	320	50	200	170	10.0		8.6		90.0		66.0	
	2000	500	2500	1800	330	53	200	160	11.0	12.8	8.2	8.1	89.0	87.2	68.0	69.0

of the reciprocating screen.This could be due to the fact that at lower angle, rice moves up the screen along with stone and discharge together with the stone since this inclination is so close to the angle of repose of the rice and influence of gravitational pull on rice becomes infinitesimally small.

iii) Impurity level: From the result (Table 1), the impurity level after separation increases with increasing angles of inclination of the reciprocating screen. The average impurity levels are 10.4% 9.2% and 8.1% at inclination angles of 35, 30 and 25, respectively. Impurity level after separation is proportional to the stone separation efficiency.

iv) Tray loss: From the result (Table 1), the average tray losses remain almost the same for all angles of inclination considered. Therefore tray loss appears to be a function of other factors rather than angle of inclination of the reciprocating screen.

CONCLUSION

The work on the development and testing of a rice destoning machine at the National Cereals Research Institute was completed. Results from tests indicate that the machine had an impressive performance. The followings are some specific conclusions made from the work:

i) The stone separation efficiency of the machine increased with decreasing angle of inclination.

ii) The rice separation efficiency averagely remains almost the same at all inclination angles considered.

iii) The impurity level after separation increased with increasing angle of inclination while tray losses appear to be a function of other factors rather than inclination angles considered.

iv) With these observed results, further work to modify the machine to improve the overall

Performance indices: stone separation efficiency, rice separation efficiency and tray loss/rice retention efficiencies.

Performance indices: stone separation efficiency, rice separation efficiency and tray loss/ rice retention efficiencies.

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