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Design and Construction of Rice De-Stoning Machine

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ABSTRACT

A rice de-stoning machine was designed, fabricated and evaluated for performance. The de-stoning machine will utilize vibrating motion to further separate the rice grains from the impurities. The vibration causes the rice grains to move in a specific direction, while the heavier impurities remain stationary. Mild steel was used in the construction of the machine. The machine is driven by a 2Hp electric motor with 1103W required power. Standard equations were used to determine the dimension of the pass and optimization of machine parameters such as air flow rate and vibration frequency. The effectiveness of the de-stoning machine will be evaluated by testing its performance with different masses of rice samples and impurities. The machine has a capacity of 436.16Kg/hr and an efficiency of 90.03%.

***KEYWORDS:** De-Stoning, Vibration system, Sieve. Separator*

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1. INTRODUCTION

Rice (Oryza sativa) is a popular tropical cereal considered to be an important food item. It is grown in temperate zones like Asia, North America, and the southern part of Europe. Rice has been part of the staple diet in eastern countries for thousands of years. Asian countries were the world's largest producers of rice in 2002. Many rice-importing countries include Nigeria, Cote d'Ivoire, the Philippines, Saudi Arabia and Indonesia. Some rice-importing countries buy rice when drought, floods or any other condition reduces the yield of their rice crop but Nigeria imports rice regularly. Nigeria is currently the largest rice importer in the world. Nigeria imported rice to the tune of 1.8 million dollars alone in 2002, and 1.3 trillion on rice importation in 2007. The importation of rice as a staple food in Nigeria has risen dramatically in the last four decades. Reasonable quantities of rice are produced yearly from different fields in Nigeria, but many Nigerians preferred imported rice. This is partly attributed to the fact that about 80% of rice produced locally in Nigeria contains stones. This is because most of the rice produced locally is processed manually or with insufficient methods. The greater part of stones in Nigerian rice is introduced during threshing, parboiling, drying, milling/de-husking and winnowing.

Many investigators have designed and constructed machines for the removal of stones and other impurities from processed rice to meet consumers' demand for a clean product. This has contributed to many technological advancements and methods of removing impurities from rice.

Okunola AA, Igbeka JC, Arisoyin AG [2015] produced a cereal purifier that is especially suitable for use in processed rice cleaning impurities. Henderson SM, Perry RL [1976] developed a gravity-based and floating separator. However, the difficulty of using a separator in rice cleaning is that adequate drying is necessary after separating and there is the likelihood of storage growth of mold or fungi.

Simonyan KS, Emordi IS, Adama JC [2012] developed a locally produced rice de-stoning machine operating on mechanical principles of

Reciprocating and vibrating sieves. The machine was tested for efficiency in rice separation, efficiency in stone separation, degree of impurity after separation and loss in the tray. The result for rice separation efficiency, stone separation efficiency, tray loss and impurity after separation showed an average of 74.2%, 70%, 16% and 25.8%. The developed machine has the promise to solve the stone infestation problem normally experienced in rice produced locally.

Ismail SO, Ojolo SJ, Orisaleye JI, Okufo OS [2013] designed a rice destoning machine that has the merits of easy operation and convenience but cannot separate stones with relatively the size of the rice.

Usman M, Balogun AL, Oyebanre OD developed a rice destoning machine which had an excellent function in operation but required technical know-how and complex mechanisms

This machine solves the problems of technical problems by making use of the simplest possible method and making sure there is a proper selection of sieve size for any variety of rice to be destined.

2. Materials and method

2.1. Machine description

The destoning machine consists of the following main features; feed hopper shaker mechanism transmission unit, vibrating sieves and discharge unit (see Figure 4)

2.2. Material selection

The particular conditions under which the various parts of the rice de-stoning machine are subjected to makes it necessary to select adequate materials for the fabrication based on functionality, durability, and ability to withstand vibration In chosen the material, their physical properties and behaviour are considered such that when subjected to the machine running condition should be able to withstand the service condition.

In this design, the strength of the materials, serviceability of parts and availability were put into consideration. This led to the selection of mild steel angle bar (40 × 40mm for the frame, mild steel angle bar (25 x 25mm) for the working decks and gauge 24mm mild steel sheets for the protective guards and hopper and an electric motor of 1440rpm. Also, painting of the machine was carried out for aesthetic aspects and to prevent rusting of parts.

2.3. Design Analysis

2.3.1. Design of feed Hopper

The cross-sectional area and volume of the feed hopper were estimated to allow feeding of the admixture into the hopper for destoning. The material used was a 20 gauge steel plate and the shape of the hopper is a frustum of a pyramid.

Base area $A = l \times b$ (1)

The volume of hopper $V = \frac{1}{3} \times A \times h$ (2)

Where, A = base area, h= height.

2.3.2. Design of Sieve A

Taking into consideration the physical properties of rice grain in order to design the sieve at the first stage of the separation, Figure 1 shows the dimension of the average rice grain and Figure 2 is the arrangement of the holes that make up the sieve with the dimension. The dimension of the sieve can be determined by using the table below, considering the maximum length and width of rice grain, the following parameters can be determined.

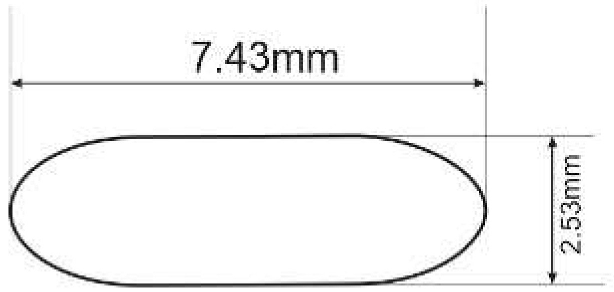


Figure 1: Rice dimension (average size)

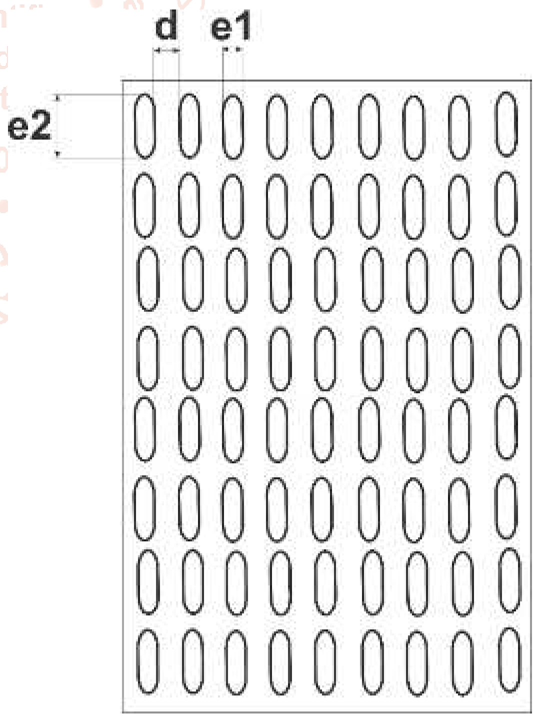


Figure 2: Dimension of sieve A

e_1=2.8 e_2=8.4 d=6mm (distance between the openings)

2.3.3. Design of Sieve B

Sieve B can be designed such that the openings are smaller than the size of the minimum width of rice. So, the opening e_2 was given a dimension of 2.0mm and the distance d between the openings is 3mm.

2.3.4. Weight of Shafts

A. Upper shaft (For Sieve A)

Shaft material is mild steel with a density of 7.83 $\times 10^3$kg/m

Area A = $\pi D^2/4$ (3)

D = 25 mm, A = 490.94 mm^2

Volume of shaft V = A x L (4)

L = 500 mm, A = 490.94 mm^2

Mass of shaft m = p x V (5)

Where, p = density of shaft material = 7.83 X 10^3kg/m

V = volume of shaft = 2.45 X $10^{-4}m^3$

Weight of shaft W = m x g (6)

B. Lower Shaft (For Sieve B)

A = $\pi D^2/4$ (3)

D = 12mm, A = 113mm

Volume of shaft V = Ax L (4)

L = 400 mm, A = 113mm^2

Mass m = p x V (5)

Weight W = m x g (6)

2.3.5. Determination of shaft diameter

For a solid shaft made from malleable material having no axial loading, the shaft diameter is obtained from the American Society of Mechanical Engineers (ASME) code equation according to Khurmi and Gupta [21] and presented in the equation below.

$$\frac{T}{J} = \frac{\tau}{r} \quad (7)$$

(Where; T is the twisting moment, J is the Polar moment of inertia, τ is torsional shear stress and r is the distance from the neutral axis)

$$T = \frac{\pi}{32} \times d^4 \quad (8)$$

(8) Was simplified into

$$T = \frac{\pi}{16} \times \tau \times d^3 \quad (9)$$

To determine the twisting moment transfer by the shaft the equation becomes

$$T = \frac{P \times 60}{2\pi N} \quad (10)$$

Where; P is the power required to run the shaft 2kW, N is the output speed of the transmission shaft 1440rpm

$$T = \frac{2000 \times 60}{2\pi \times 1440} = 13.26 \text{ Nm}/13.26 \times 10^3 \text{Nmm}$$

$$T = \frac{\pi}{16} \times \tau \times d^3$$

(τ =56Mpa for shafts without allowance for keyways according to Gupta and Khurmi 2005)

2.3.6. Belt and pulley design

The belt and pulley were designed following Fenner industrial Belt Drives manual [7]; Motor power: 2hp= 1.5kw Motor speed: 1440 rpm

Speed ratio: 1:4

Belt type: V- belt (A belt section)

Service Factor = 1.0 (the machine will run for less than 10 hours per day)

Belt designed power= 1.0 x 1.5kW =1.5kw

Section: 80mm and One Step Pulley

Driven Speed: At 1:4 speeds gives 360 rpm obtainable with the stock pulleys.

Pulley Diameter: the diameter of the small pulley (driver) and large pulley (driven) are:

d= 100mm D= 400m

Centre Distance: is found using the formula

$$C = 2 \times \sqrt{(D + d) \times d} \quad (11)$$

C= 447.2mm

A. Correction factor = 0.89

B. Number of belts ´= $\frac{\text{corrected designed power}}{\text{Correction factor}} = \frac{1.5}{0.89} = 1.68\text{kW}$

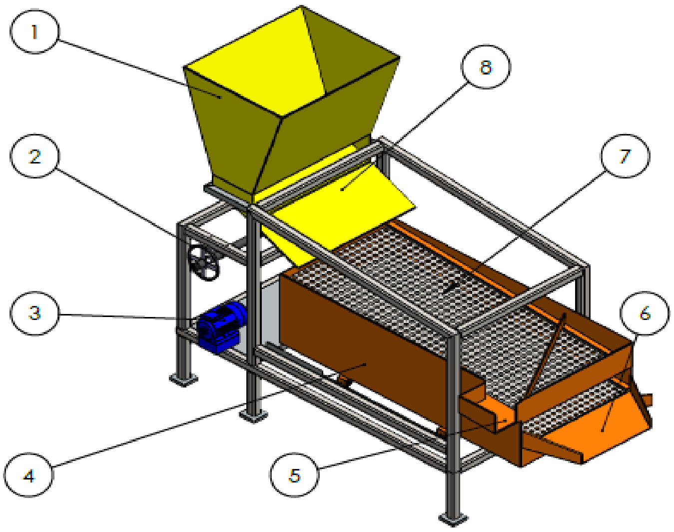
One belt will supply 1.68 kW power which is greater than the corrected designed power (1.5kw); hence a single belt will be sufficient for the shaker mechanism

The parameters used in the design is shown in table , while figure 3 shows an isometric drawing of sieve rice de-stoner after fabrication.

Table 1 Mathematical Design Result

Parameters	Symbol	Quantity	Unit
Volume of hopper	V_h	25,523	cm^3
Diameter of sieve A	D_A	6	mm
Diameter of Sieve B	D_B	2	mm
Area of upper shaft	A_{us}	490.94	mm^2
Volume of upper shaft	V_{us}	2.45×10^{-2}	m^3

Mass of upper shaft	M_{us}	192	Kg
Weight of upper shaft	W_{us}	1885.5	N
Area of lower shaft	A_{ls}	113	mm^2
Volume of lower shaft	V_{ls}	4.52×10^2	m^3
Mass of lower shaft	M_{us}	3539	Kg
Weight of lower shaft	W_{us}	341717.5	N



NUMBER	DESCRIPTION
1	HOPPER FUNNEL
2	PULLEY
3	ELECTRIC MOTOR
4	SIEVING CHAMBER
5	LARGE PARTICLES EXIT
6	FINE PARTICLES EXIT
7	SIEVING CHAMBER
8	HOPPER

Figure 3: Assembled isometric drawing of sieve rice de-stoner

2.4. Principle of operation

The top sieve allows rice and smaller impurities to pass through while larger impurities are retained, the bottom sieve retains rice grains while impurities smaller than rice pass through to a collection tray. The sieve box is attached to a shaker mechanism that assured both horizontal and vertical movement. The structural frame forms the mounting support of all other units. The setup also consists of an electric motor which provides vibratory motion.

3. Results and discussion

In the de-stoning process using a rice de-stoner, certain parameters ought to be taken into consideration such as the size of impurities, the weight of impurities grain size and all these would serve to determine the dimension of the sieve to be applied for the de-stoning process.

The results of the tests are shown in the tables below. The results of the mixture of rice and stones being separated by the machine and weighed separately. Table 2 shows the results of test analysis.

Table 2: Result of Test Analysis

S/No	Clean rice (kg)	Stones sample (kg)	Feed materials (kg)	Clean sample after 1st stage	Time taken (min) 1st stage	Residue (kg)	Clean Grain Outlet (kg) after 2nd stage	Time taken (min)2nd stage	Residue (kg)
1	1.0	0.10	1.1	1.01	0.17	0.08	1.0	0.24	0.01
2	1.5	0.15	1.65	1.51	0.20	0.14	1.49	0.27	0.01
3	2.0	0.2	2.20	2.0	0.22	0.19	1.99	0.31	0.015
4	3	0.3	3.30	3.0	0.26	0.29	2.9	0.36	0.015
5	3.5	0.35	3.85	3.52	0.30	0.33	3.5	0.41	0.015

Therefore, de-stoning efficiency is taken as

$$\int = \frac{\text{mass of grain obtained at clean rice grain outlet}}{\text{the total mass of feed material} \times 100} \quad (12)$$

Hence from Table 1 above,

$$\int_{(1)} = \frac{1.0}{1.1} \times 100 = 90.90\%$$

$$\int_{(2)} = \frac{1.49}{1.65} \times 100 = 90.03\%$$

$$\int_{(3)} = \frac{1.99}{2.20} \times 100 = 90.45\%$$

$$\int_{(4)} = \frac{2.90}{3.30} \times 100 = 87.87\%$$

$$\int_{(5)} = \frac{3.50}{3.85} \times 100 = 90.90\%$$

$$\text{Average efficiency} = \frac{\int_{(1)}+\int_{(2)}+\int_{(3)}+\int_{(4)}+\int_{(5)}}{5} \quad (13)$$

$$= \frac{90.9+90.03+90.45+87.87+90.90}{5}$$

= 90.03%.

And, the capacity of the machine per hour is

$$C = \frac{60 \times \text{Feed material}}{\text{Time taken}} \quad (14)$$

C_1 =275 kg/hr

C_2 = 366.6 kg/hr

C_3 = 425.8kg/hr

C_4 = 550kg/hr

C_5 = 563.4kg/hr

The average capacity of the machine is

$$C = \frac{275+366.6+425.8+550+563.4}{5} = 436.16\text{kg/h}$$

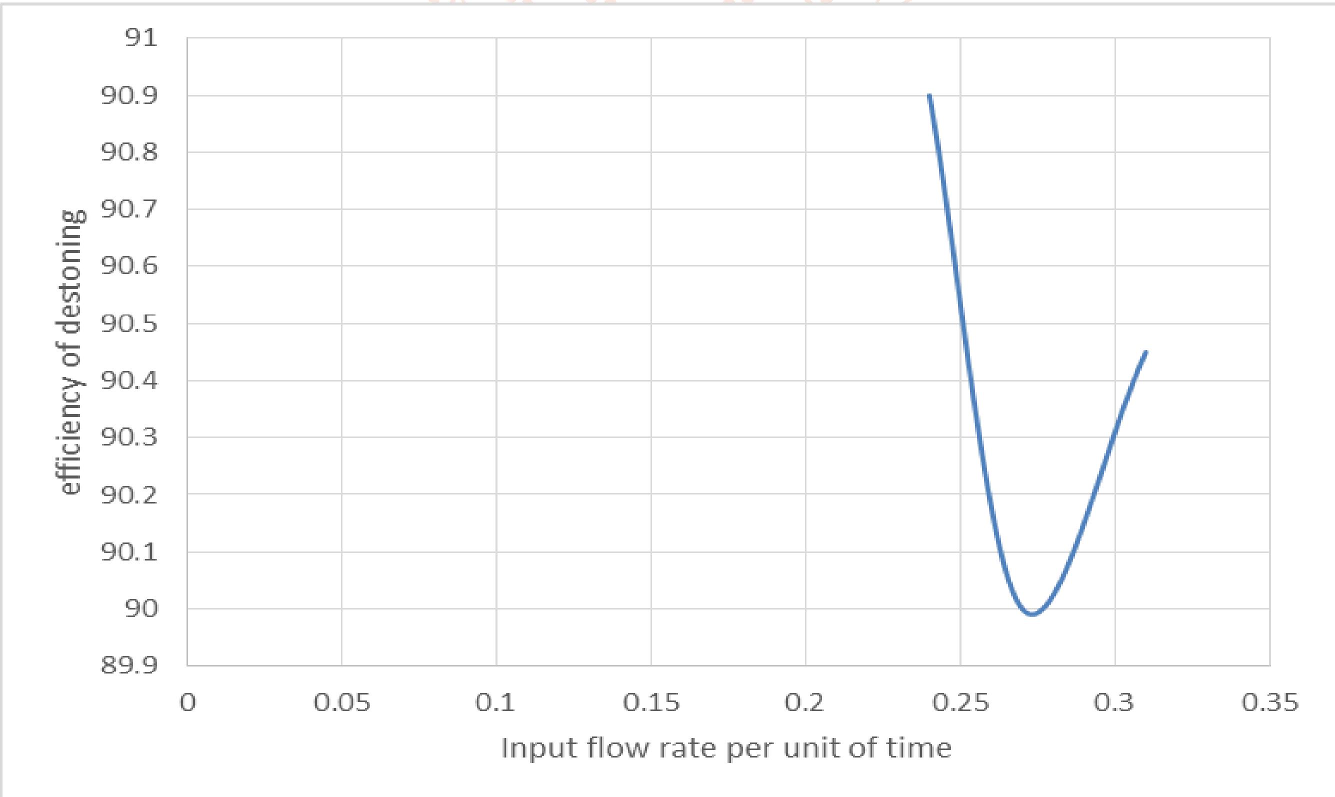


Figure 4: Graph of rice efficiency against the time taken

The curve in figure 4, represents the performance of the destoning machine in terms of its ability to separate stones from rice grains. The x-axis of the curve represents the input flow rate per unit of time, while the y-axis represents the efficiency of destoning, often measured as the percentage of stones removed. The curve shows how the machine's efficiency varies with different input flow rates. A steeper slope indicates higher efficiency, meaning more stones are removed per unit of time. Figure 5 shows the fabricated rice destoning machine.

Figure 5: Fabricated Rice De-Stoning Machine

Conclusion

The design and fabrication of a rice de-stoning machine were successfully carried out by this work with an efficiency of 90.03% attained. The machine was tested and found capable of de-stoning rice. Due to the low cost of fabrication, the machine can be adopted by small-scale producers. Also shown in Figure 4 is the graphical relationship between the performance parameters and the time taken.

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