# Design and Fabrication of Rice De-Stoning Machine

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**Abstract**   This work aims at meeting the ever increasing demands of quality rice, avoiding losses and improving the income of local farmers. Mild steel was used in the construction of the machine. Standard equations were used to determine the dimension of the parts. The machine is driven by a 1Hp electric motor with 688.17 W required power. The machine has a capacity of 47.39 Kg/hr and an efficiency of 82.47 %

**Keywords**   De-Stoning, Separator, Feed Material, Exciter, Sieve

## 1. Introduction

Rice is a popular tropical cereal considered to be an important food item. This because it supplies a quarter of the entire calorific intake of human race as stated by Babatunde (2004).

F. A. O. (1995) gave statistics which shows that rice is a staple food of well over 90 % of the world's population. This means rice has been of very great economic importance.

Therefore, availability of processing machines becomes an important essential aspect of agro-allied industries. In Nigeria most of the agro-allied products are consumed or exported unprocessed, this has negative effects on the economy of our nation. The separation of grains from stone and other impurities before consumption or further processing into various products is one step that is necessary in improving agro-allied industries. This step will ensure the quality and hygiene of products, thus increasing the commercial value of the final exported or consumed products.

Also, with the current increase observed in our local production of rice in Nigeria, owing largely to the present policy of government on imported items, there is need to give attention and organisation to agro-allied industries and their products.

This work therefore aims at producing Rice de-stoning machine with vibrating screens on two stages using simplified exciters. With the development of the machine for processing of rice, demand for our locally produced rice will increase with its attendant gains on the economy.

## 2. Theoretical Analysis

Rice de-stoning machine is made up of two sets of carriage each comprising of three screens. The first in each working deck serves to separate the stones slightly bigger than the grain; the second screen serves to separate the stones smaller in size than the grains while the third screen serves to convey the stones down to the stone chutes. The screens one and two are special wire gauze designed for separation purposes. The two working decks are designed to be slanted in opposing angles of between $7^{\circ}$ to $14^{\circ}$ to the horizontal. The angle can be varied in relation to the speed and efficiency required. The two decks are held in position by four flexible suspension reeds by means of belts and nuts on the upper part of the machine frame.

The two decks are connected together and are mounted on the frame work which connects them to the shaft rotating. The shaft has two exciters on which are meant to excite the system, the offset angle can be arranged to obtain high or low vibration. Also, on the shaft are two bearings giving support to the shaft and pulley which receives drive from an electric motor via a belt.

The hopper is fixed on the upper frame to receive charge for the first deck. Rough rice (rice with impurities) when charged through the hopper, gradually passes through the throat of the hopper and falls on the first screen with angle of inclination $7^{\circ}$ to $14^{\circ}$ as convenient and effective. The rate of floe from hopper is controlled manually.

By this time, the prime mover drives the shaft carrying the exciters, thus the whole working deck is vibrated. As the working deck is vibrated, the rough rice is caused to move on the first screen thereby the bigger stone and impurities move down while smaller materials including rice dropped off on the second screen. Now the cleaner rice falls on the second working deck where the process is repeated. The second working deck will improve on the efficiency of the first separation. There are two outlets, the first, to collect the impurities and the second to collect the clean rice.
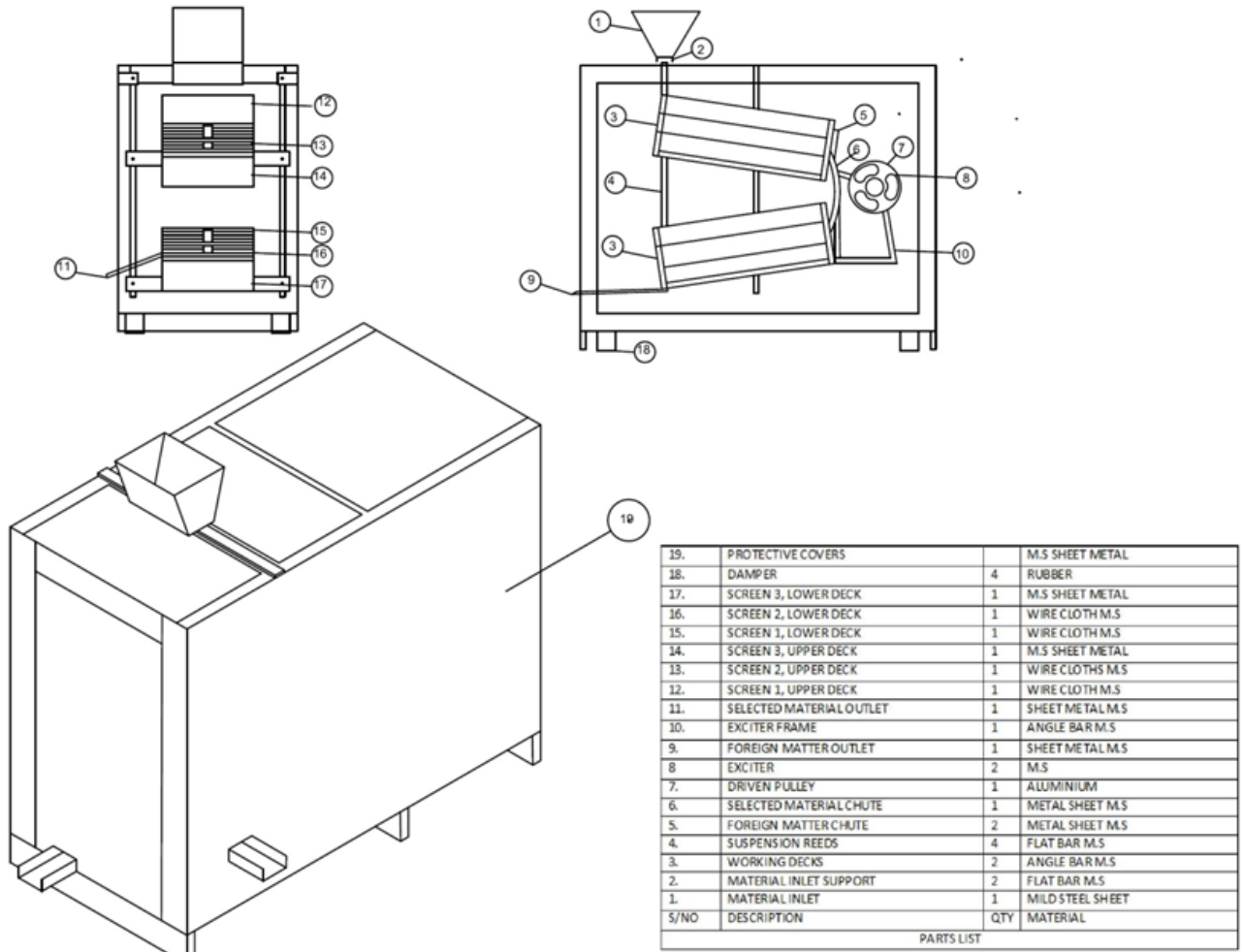
| S/NO | DESCRIPTION | QTY | MATERIAL |
|---|---|---|---|
| 19. | PROTECTIVE COVERS | | M.S SHEET METAL |
| 18. | DAMPER | 4 | RUBBER |
| 17. | SCREEN 3, LOWER DECK | 1 | M.S SHEET METAL |
| 16. | SCREEN 2, LOWER DECK | 1 | WIRE CLOTH M.S |
| 15. | SCREEN 1, LOWER DECK | 1 | WIRE CLOTH M.S |
| 14. | SCREEN 3, UPPER DECK | 1 | M.S SHEET METAL |
| 13. | SCREEN 2, UPPER DECK | 1 | WIRE CLOTHS M.S |
| 12. | SCREEN 1, UPPER DECK | 1 | WIRE CLOTH M.S |
| 11. | SELECTED MATERIAL OUTLET | 1 | SHEET METAL M.S |
| 10. | EXCITER FRAME | 1 | ANGLE BAR M.S |
| 9. | FOREIGN MATTER OUTLET | 1 | SHEET METAL M.S |
| 8 | EXCITER | 2 | M.S |
| 7. | DRIVEN PULLEY | 1 | ALUMINIUM |
| 6. | SELECTED MATERIAL CHUTE | 1 | METAL SHEET M.S |
| 5. | FOREIGN MATTER CHUTE | 2 | METAL SHEET M.S |
| 4. | SUSPENSION REEDS | 4 | FLAT BAR M.S |
| 3. | WORKING DECKS | 2 | ANGLE BAR M.S |
| 2. | MATERIAL INLET SUPPORT | 2 | FLAT BAR M.S |
| 1. | MATERIAL INLET | 1 | MILD STEEL SHEET |
| S/NO | DESCRIPTION | QTY | MATERIAL |

PARTS LIST
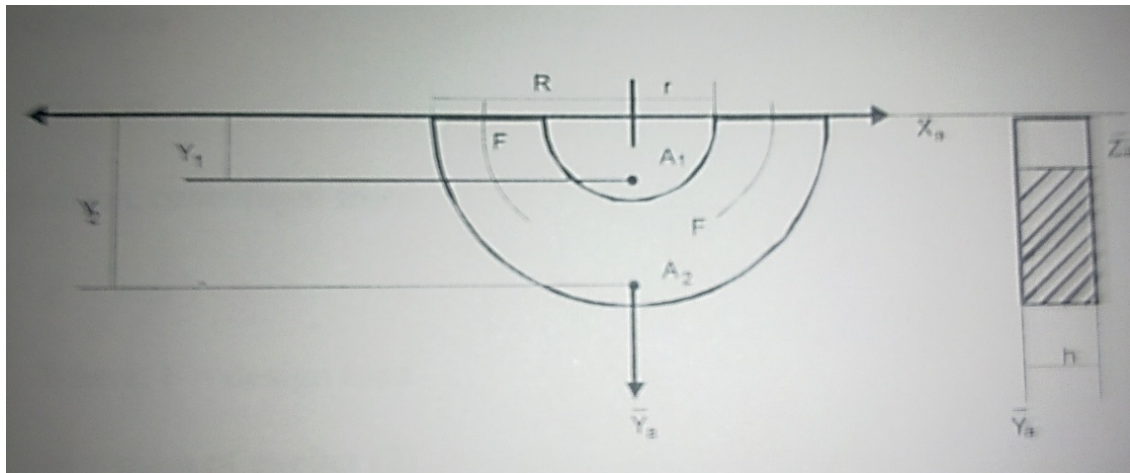
**Figure 1.** Rice de-stoning machine



**Figure 2.** Determination of Exciter disc dimensions

### Design Analysis

Determination of Exciter Disc Dimension, Speed of rotation and Power required to drive sieve.

The assumption: the centrifugal force generated by the two exciters produces the longitudinal action of the working decks.

From Figure 2, the volume of the inner circle (hole) is given by (Charles, 1989)

$$V_1 = \frac{\pi r^2}{2} h$$

The radius of gyration is given by,

$$Y_1 = \frac{4r}{3\pi}$$

Also, the volume of outer circle (solid) is given as,

$$V_2 = \frac{\pi R h}{2}$$

The radius of gyration is given as,

$$Y_2 = \frac{4r}{3\pi}$$

Effective radius of gyration

$$\overline{Y} = \frac{\sum VY}{\sum V} = \frac{V_2 Y_2 - V_1 Y_1}{V_2 - V_1}$$

Effective volume of Revolution

$$V = V_2 - V_1$$

Mass of Exciter

$$M = \rho V$$

By definition, centrifugal force

$$F = m\omega^2 r$$

Where, F = design load
m = mass of Exciter
r = radius of gyration
$\omega$ = angular speed of rotation in radians
Therefore speed of the Exciter required is

$$\omega = \sqrt{\frac{F}{2mr}}$$

Converting to revolutions per minute

$$N = \frac{\omega 60}{2\pi}$$

Torque generated, according to Jonnes (1995)

T = Fr

Where, F = design load
r = radius of gyration
Hence, power required to drive sieve;

P = T$\omega$

**Power Transmission and Belt Tension**

Torque transmitted to pulley according to Rober and Moth (1982), is given by

$$M_1 = \frac{9550(kW)}{N(rpm)}$$

And,

$T_1 = (T_1 - T_2)R$ (Nm)

In a vee-grooved pulley belt drive, the relationship between $T_1$ and $T_2$ is given by

$$\frac{T_1}{T_2} = e^{\mu\theta cosec\frac{\phi}{2}}$$

Where, $T_1$ = tension on tight side of belt
$T_2$ = tension on slack side of belt
$\mu$ = coefficient of friction
$\theta$ = groove angle of pulley
$\phi$ = angle of lapped by belt on pulley
From Figure 2, the angle of wrap of an open belt pulley may be determined by,

$\theta_1 = 180 - 2\beta$

$\theta_2 = 180 + 2\beta$

$\beta = sin^{-2}(\frac{R-r}{c})$

According to Hannah and Hillier (1978), velocity ratio relationship of belt drive power transmission is given as

$N_1 D_1 = N_2 D_2$

**Determination of Shaft Size**

Noting that the shaft is subjected to combined torsional and bending moments, then based on maximum shear stress theory, the maximum shear stress;

$$\sigma_{max} = \frac{1}{2}\sqrt{(\sigma_b^2 + 4\sigma_t^2)}$$

Where,
$\sigma_b$ = bending stress
$\sigma_t$ = torsional stress
According to Ryder (1988)

$$\sigma_b = \frac{32M}{\pi d^3}$$

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

Substituting into equation

$$\sigma_{max} = \frac{1}{2}\sqrt{\left\{\left(\frac{32M}{\pi d^3}\right)^2 + 4\left(\frac{16T}{\pi d^3}\right)^2\right\}}$$

$$= \frac{16}{\pi d^3}\sqrt{(M^2 + T^2)}$$

$$= \frac{16}{\pi d^3}\sqrt{(MK_b)^2 + (TK_t)^2}$$

$$d^3 = \frac{16}{\pi \sigma_{max}}\sqrt{(MK_b)^2 + (TK_t)^2}$$

Where,
$K_b$ = combine shock and fatigue factor for bending
$K_t$ = combine shock and fatigue factor for torsion

**Determination of Bearing Size for Shaft Support**

For a shaft rotating at constant speed, we have

$$L_{io} = \frac{10^6}{60n}\left(\frac{c}{p}\right)^q$$

Where,
$L_{io}$ = basic rating life in hours
c = basic dynamic load rating
p = equivalent dynamic bearing load
q = exponential life of equation
n = angular speed of shaft in revolutions per minute (rpm)
Hence,

$$c = p\left(\frac{L_{io} 60n}{10^6}\right)^{\frac{1}{q}}$$

When c is determined, the bearing is then selected from tables

**Determination of Sieve Suspension Reed (Hanger) Dimensions**

Since there are four hangers (suspension reeds) carrying the sieving unit, we obtain load per support as;

$$F_{sl} = \frac{F_D}{4}$$

Where,
F = design load
Bending moment due to drive mechanism

$$M_b = F_{sl}l$$

Where,
l = distance from upper frame to the lower connection of the working deck.
According to Franklin and Joseph (1981), the yield strength of a material is

$$\sigma_y = \frac{M_b}{Z}$$

and,

$$Z = \frac{bd^3}{6}$$

Also, by definition, deflection of simple beam,

$$\delta_{max} = \frac{F_{sl}l^3}{3EI}$$

Where,
$F_{sl}$ = load per support
E = modulus of elasticity
I = moment of inertia

$$I = \frac{bd^3}{12}$$

Hence, stiffness k of each bar is

$$k = \frac{F_{sl}}{\delta_{max}}$$

For the four bars, total stiffness is

$$k_T = 4\frac{F_{sl}}{\delta_{max}}$$

### Determination of Amplitude and Frequency of Vibration

According to Anderson (1987), for a system of force vibration with single degree of freedom, the amplitude;

$$Y = \frac{F/k}{\left[\left\{1 - \left(\frac{\omega}{\omega_n}\right)^2\right\}^2 + \left\{2\xi\left(\frac{\omega}{\omega_n}\right)\right\}^2\right]^{0.5}}$$

Where,
F = magnitude of excitation force
k = stiffness of spring (suspension reeds)
Y = amplitude of steady state vibration
m = mass of system
$\xi$ = coefficient of damping
$\omega$ = frequency of excitation force, given by

$$\omega = \frac{2\pi N}{60}$$

$\omega_n$ = natural frequency of vibration of the system, given by,

$$\omega_n = \sqrt{\frac{k}{m}}$$

Frequency of vibration, $f$ of the system is therefore,

$$f = \frac{\omega}{2\pi}$$

### Design for Bolted Connection

The exciter is connected to the working decks by a frame with four bolts.
The load per each bolt is $F_b$

$$F_b = \frac{F}{4}$$

Where,
F is design load
To take care of impact load due to sieving, an impact factor of 2 is chosen

$$F_b = \frac{F}{2}$$

Since the pre-stressing diagram cannot be drawn due to lack of bolt, we use the following (Gitin and Parad)

$$F_{max} = 1.5F_{bs}$$

Using a bolt material property class of 4.8 we obtain the material yield stress $T_y$ = 340MPa (Shigley and Mischke, 2001).
Hence, the design stress

$$T_P = 0.3T_y$$

And the required bolt core area

$$A_c = \frac{F_{max}}{T_p}$$

But,

$$A_c = \frac{\pi d^2}{4}$$

$$d = \sqrt{\frac{4A_c}{\pi}}$$

### 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, ability to withstand vibration and the cost of such materials. In the choice of 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 x 40mm) for the frame, mild steel angle bar (25 x 25mm) for the working decks and gauge 24 mild steel sheets for the protective guards and hopper. For the pulley, aluminum was selected for light eight and mild steel plates selected for the exciter disc. Also, painting of the machine was carried out for aesthetic aspect and to prevent rusting of parts.

**Table 1.**　Result of Test Analysis

| S/No. | Clean Rice sample (kg) | Stones sample (kg) | Feed materials (kg) | Clean Grain Outlet (kg) | Foreign matter outlet (kg) | Time taken (min) |
|---|---|---|---|---|---|---|
| 1 | 3.0 | 0.25 | 3.25 | 2.59 | 0.66 | 4.0 |
| 2 | 2.5 | 0.2 | 2.70 | 2.27 | 0.43 | 3.5 |
| 3 | 3.0 | 0.3 | 3.30 | 2.76 | 0.54 | 4.2 |

Therefore, de-stoning efficiency is taken as

$$\int = \frac{mass\,of\,grain\,obtained\,at\,clean\,grain\,outlet}{total\,mass\,of\,feed\,material} \times 100$$

Hence, from Table 1 above,

$$\int_{\zeta 1} = \frac{2.59}{3.25} \times 100 = 79.69\,\%$$

$$\zeta\int_2 = \frac{2.27}{2.70} \times 100 = 84.07\,\%$$

$$\int_{\zeta 3} = \frac{2.76}{3.30} \times 100 = 83.64\,\%$$

Average efficiency $= \frac{\int_1 + \zeta\int + \zeta\int}{3}$

$$= \frac{79.67 + 84.07 + 83.64}{3}$$

$$= 82.47\,\%$$

And, capacity of machine per hour is

$$C = \frac{60\,X\,Feed\,material}{Time\,taken}$$

$C_1 = 48.75$ kg/hr

$C_2 = 46.28$ kg/hr

$C_3 = 47.14$ kg/hr

Average capacity of the machine is

$$C = \frac{48.75 + 46.28 + 47.14}{3} = 47.39\,kg/hr$$

## 3. Conclusion

The design and fabrication of a Rice Destoning Machine was successfully carried by this work with an efficiency of 82.47% 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.

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