ABSTRACT

This paper presents the design, fabrication of a paddy dehusking machine. The machine has the following units – feeding, dehusking and separating unit. The paddy passes through the rolling unit where it is abraded by two knurled shafts and is dehusked by the rotation of the dehusking drum in the dehusking unit. The paddy grain is separated from the chaff by passing the mixture through a current of air supplied by a fan. The materials used for the fabrication of the machine were selected based on the design considerations and analyses of its components. The components of the machine were selected locally and machined to specifications using machines such as lathe, grinding machine, etc. The parts of the machine were assembled at the welding and fabrication workshop of the college. When tested, the machine dehusked 1 kg of paddy in 3 minutes. It has an efficiency of 85-90%.

Keywords: - Paddy, Dehusking, Design, Fabrication.

1. INTRODUCTION

Paddy is one of the oldest cultivated cereals in India. The exact origin of paddy is unknown,[1] but its use as a cereal dates back to the 14th century.[2] It is the smallest specie of millet, cultivated in many Indian countries. It grows well on poor soils.[3] A grain of paddy is oval in shape (i.e 1.5mm long and 0.9mm wide). The average particle size and specific gravity are 1.18 mm and 1.47 respectively. Paddy has a brittle shell and can be dehusked faster when it is dry.[1],[3] It is used for the porridge, couscous, bread. Although its protein content is similar to that of other grains such as millet, it contains amino acids like Methionine, Riboflavin (vitamin B2) and Niacin (Vitamin B3) which are essential to human health., but deficient in other cereals. Paddy digests easily and is recommended for children, old and sick people suffering from diabetes or stomach disease. Doctors sometimes recommended it for people who want to lose weight. Though the uses of paddy are many, its production has remained low (250000 to 300000 tons annually). This is because dehusking of paddy is difficult.[2] In other words, only few dehusking machines are available for processing paddy. These are some of the problems that have resulted to the non – availability of dehusked paddy for human consumption despite its nutritional value. The work has the potential to encourage local famers of paddy to cultivate more of it; increase availability and competitiveness of paddy, resulting in increased consumption of same; create jobs in operation and maintenance of the machine; support sustainable land use and increased agricultural yield with the net effect of boosting food security and rural development. Traditionally, the dehusking of paddy is done in a mortar and the separation of the chaff from the grain is done by washing with water, or winnowing.[2] The traditional methods of processing take 1 hour to dehusk 1 kg – 2 kg of paddy. Many research institutes (National cereals research institute (NCRI), Badeggi, Niger; international plant genetic resource institute (IPGRI) and national research institute of mali) have supported research work on paddy.

2. DESIGN THEORY AND ANALYSIS

To achieve the set objectives, this machine is structured into four units: feeding, rolling, dehusking, and separation units. Each of the units performs specific function as described below:

A. Feeding unit

This unit is made up of a hopper, and a sieve for removing impurities such as metallic particle, stones; etc which are larger than the paddy. The paddy is fed into the hopper manually. The hopper is made of steel sheet.

Fig1. Feeding Unit.
B. Dehusking unit
This unit consists of a split casing carrying two horizontal bars bolted to the lower half of the casing. That facilitate the dehusking rotation of the drum enables the dehusking of the paddy to take place between the casing and the pegs.

C. Separation unit
This unit has an electrically operated fan and collectors for dehusked paddy and the husk. A variable resistor for adjusting the speed of the fan was incorporated.

3. DESIGN
The components were designed based on established theories and principles, considering the loading of each member as follows.

A. Dehusked drum
The dehusking drum is made of mild steel, consisting mainly of a hollow drum with 4 rectangular pegs welded to it. The paddy comes in between the pegs and the horizontal bars on the casing inside which the drum rotates. The loads on the drum were determined as follows:

Weight on drum,

\[ W_d = \rho_f g l_s \left( \frac{\pi (d_i - d_0)^2}{4} \right) \]
\[ W_s = \rho_s g l_s a \]

\[ W_d = W_f + W_s \]

Where, \( l_s \), \( \rho_f, a \), \( W_f, W_s, d_i \) & \( d_0 \) = length of drum, density of paddy, cross-sectional area of peg, weight of one peg, weight of paddy between 2 pegs, internal & external diameter of drum respectively.

Surface area of drum,

\[ A_s = \frac{\pi (d_0^2 - d_i^2) l_s}{4} \]

Pressure on surface of drum,

\[ P_r = \frac{W_d}{A_s} \]

Considering the drum as a pressure vessel, the following parameters were determined

Thickness of drum,

\[ t_d = \frac{P_r d_0}{2 \sigma_{ill}} + \epsilon \]

Internal diameter if drum, \( d_i = d_0 - 2t_d \)
Weight of drum, \[ W_d = \rho_s g \frac{\pi (d_0 - d_0^2) t_s}{4} \]

Total load on drum, \[ W_t = W_d + W_d^2 \]

Torque required to move this load, \[ T = W_t \frac{(d_0 - d_i)}{2} \]

Power required driving the shaft \[ P = \frac{2\pi NT}{60} \]

**B. Diameter of shaft**

The shaft is subjected to both torsional and bending moments. Based on strength, the diameter of the shaft was therefore obtained theoretically using the relation

\[ d = \sqrt[3]{\frac{16N^2 + T^2}{\pi}} \]

Where \( M \) = bending moment, \( N_m \); \( T \) = torque, \( N_m \); \( \sigma \) = shear stress in shaft, \( N/m^2 \); \( d \) = shaft diameter, m;

\[ k = \frac{d_i}{d_o} \]

The shaft diameter was also obtained based on the ASME formula for shaft subjected to both bending and torsional moments as follows

\[ d^3 = \frac{16}{\pi r(1 - k)} \sqrt{(k_bM)^2 + (k_tT)^2} \]

Where \( T \) = torsional moment or torque, \( M \) = bending moment; \( k_b = \frac{d_i}{d_o} \); \( d_i \), \( d_o \) = shaft’s outside and internal diameters; \( k_b \) = combined shock and fatigue factor applied to bending moment; \( k_t \) = combined shock and fatigue factor applied to torsional moment [1]. Based on the theory of rigidity, diameter of shaft was obtained using the relation

\[ d = \sqrt[3]{\frac{8kTR}{6r} \sqrt{1 - k}} \]

**C. Welded joint**

The shaft is joined to the dehusking drum through a fillet weld, which is obviously subjected to torsion in the course of its operation. Shear stress for the material

\[ \tau = \frac{T_r}{J} = \frac{27}{\pi t d^2} \]

This shear stress occurs in a horizontal plane along a leg of the fillet weld. The maximum shear occurs on the throat of the weld which is inclined at \( \theta \) to the horizontal plane.

Length of throat, \( t = s \cdot 0.77s \)

Maximum shear stress,

\[ \sigma = \frac{2.63T}{\pi sd^2} \]

where

\( d \) = diameter of the solid shaft, m;

Taking the allowable stress for mild steel to present the maximum shear stress

\[ R = \text{radius of solid shaft, m;} \]

\[ T = \text{torque acting on the solid shaft, Nm;} \]

\[ S = \text{size (or leg) of the weld;} \]

\[ t = \text{throat thickness, m;} \]

\[ j = \text{polar moment of inertia of the weld section} \]

**D. Bearings:**

Radial ball bearings were employed for the shaft and rollers because of their advantages: they compact in size, able to stand momentary shocks, easy to mount, and reliable in service. They are also known to have low maintenance cost and do not require starting torque.

The following relations were used in designing the bearings:

The bearing life, \[ L = \frac{60N L_n}{(\text{rpm})} \]

Where: \( N \) = speed in rpm, \( L_n \) = working life (hrs)
Separation system An electrically operated fan was used to provide the air required to separate the seed from the husk. It was assumed that 0.01m \(^3\) of mixture of dehusked paddy and impurities will pass through the separation unit per unit time. Out of this quantity 5% will be sand particles. The following relations were used:

Velocity of mixture \( V_a \) = \( \sqrt{\frac{2y}{g}} \)

Force with which paddy falls \( F_f = M_p \times V_f \)

Force with which sand falls \( F_s = M_s \times V_s \)

The force required to separate the mixture of paddy and impurities:

\[ Q_a = A \times \frac{\pi d^2}{4} \]

\[ Q_s = \frac{\pi d^2 V_s^2}{4} \]

The separation force must be equal to the total force exerted by the mixture, \( F_t \):

\[ F_t = F_s + F_f = \rho_f Q_a V_a \]

\[ F_t = \frac{\rho_s \pi d^2 V_s^2}{4} \]

this gives the velocity of air required to achieve separation, thus

\[ V_a = \sqrt{\frac{4F_t}{\rho_f \pi d^2}} \]

Where : density of paddy = \( \rho_f \) kg/m\(^3\); density of sand particles = \( \rho_s \) kg/m\(^3\);

Volume of paddy = \( V_{p} \) m\(^3\); volume of mixture of paddy and impurities = \( V_{f} \) m\(^3\);

Volume of sand particles = \( V_{s} \) m\(^3\);

Mass of sand = \( M_s \) kg; mass of paddy = \( M_p \) kg; velocity of paddy = \( V_f \) m/s; velocity of sand particles = \( V_s \) m/s; velocity of paddy and impurities = \( V_{f} \) m/s;

Diameter of circle swept by fan = \( d \) m; velocity of air = \( V_a \) m/s;

Height from which mixture of paddy and impurities fall = \( S \) m; force exerted by paddy = \( F_f \) N; force exerted by sand particles = \( F_s \) N; volumetric flow rate of air = \( Q \) m\(^3\)/s

4. CONCLUSION

The machine dehusked 2 kg of paddy in 6-7 minutes. From the results, the efficiency of the machine 75%. For further work, the clearance between the top portion of the rollers and bottom surface of the hooper should be slightly decreased to prevent the crushing of some of the paddy. This will in turn increase the efficiency of the machine.

REFERENCES


AUTHOR

<table>
<thead>
<tr>
<th>INPUT</th>
<th>CALCULATIONS</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( l_d = 500 \text{mm} )</td>
<td>Weight on drum, ( W_d )</td>
<td></td>
</tr>
<tr>
<td>( d_o = 110 \text{mm} )</td>
<td>( W_f = \rho_f \cdot g \cdot l_d \cdot \frac{\pi (d_d - d_o)^2}{4} )</td>
<td></td>
</tr>
<tr>
<td>( N = 0 \text{mm} )</td>
<td>( = 8.86 \times 9.81 \times 0.5 \times \frac{\pi (0.110 - 0.01)^2}{4} )</td>
<td>336.61x10^{-2}N</td>
</tr>
<tr>
<td>( A_i = 10 \text{mm} )</td>
<td></td>
<td>3.85 N</td>
</tr>
<tr>
<td>( d_i = 7850 \text{kg/m}^3 )</td>
<td>( W_c = \rho_c \cdot g \cdot A_i \cdot l_d )</td>
<td></td>
</tr>
<tr>
<td>( \sigma_{\text{all}} = 56 \text{Mpa} )</td>
<td>( = 7850 \times 9.81 \times 0.5 \times 0.01 \times 0.01 )</td>
<td>4.186 N</td>
</tr>
<tr>
<td>( \tau_{\text{all}} = 42 \text{Mpa} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( W_d = W_f + W_c )</td>
<td></td>
<td>4.186 N</td>
</tr>
<tr>
<td>( w_d = 4.186 \text{N} )</td>
<td>Surface area of drum, ( A_s )</td>
<td>92 mm</td>
</tr>
<tr>
<td>( A_s = 3.926 \times 10^{-2} \text{m}^2 )</td>
<td>( A_s = \frac{\pi d_i^2}{4} )</td>
<td>4 mm</td>
</tr>
<tr>
<td></td>
<td>( = \frac{3.926 \times 10^{-2} \text{m}^2}{4} )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( = 3.926 \times 10^{-2} \text{m}^2 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pressure on surface of drum, ( R_f )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( R_f = \frac{W_d}{A_s} )</td>
<td>1066.225 N/m²</td>
</tr>
<tr>
<td>( t_a = 4 \text{mm} )</td>
<td>( R_f = 1066.225 \text{N/m}^2 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1935.43N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1999.616 N</td>
</tr>
<tr>
<td>( t_d = 3 \text{mm} )</td>
<td>Internal diameter of drum, ( d_i )</td>
<td></td>
</tr>
<tr>
<td>( t_d = \text{thickness of drum}, l_d )</td>
<td>( d_i = d_o - 2t_d )</td>
<td></td>
</tr>
<tr>
<td>( t_d = 3 \text{mm} )</td>
<td>( = 0.1\cdot(2\times0.004) )</td>
<td>0.092m</td>
</tr>
<tr>
<td>( t_d = \frac{F_{\text{tot}}}{2 \pi \cdot d_o \cdot l_d} + c )</td>
<td>( = \frac{1066.225 \times 0.5}{2 \pi \times 0.01 \times 0.01} + 0.003 )</td>
<td>92mm</td>
</tr>
<tr>
<td>( t_d = 4 \text{mm was adopted for convenience of production.} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( W_{\text{de}} = 1935.43 \text{N} )</td>
<td>Weight of drum, ( W_{\text{de}} )</td>
<td></td>
</tr>
<tr>
<td>( d_i = d_o - 2t_d )</td>
<td>( = 92 \text{mm} )</td>
<td></td>
</tr>
<tr>
<td>( w = 3879.232 \text{N/m} )</td>
<td>T = 879.35x10^{-2} Nm</td>
<td>140W</td>
</tr>
</tbody>
</table>
N = 1510rpm
T = 879.35x10^-8 Nm

\[ W_{dc} = 1935.43N \]

Total load on drum, \( W_c = W_d + W_{dc} \)

\[ W_c = 4.108 + 1935.43 \]
\[ W_c = 1939.016 N \]

This load is distributed along the effective length of the shaft; thus load on shaft =

\[ \frac{1939.016}{9.5} \]
\[ = 3879.232 \text{ N/m} \]

\[ \tau_{max} = \frac{3879232 \times 0.5}{2} \]
\[ = 969 \text{ N/m}^2 \]

\[ R = \tau_{max} = 969.000 \text{ N/m}^2 \]

\[ M_{max} = \frac{3879232 \times (0.5)^2}{2} \]
\[ M_{max} = 121.220 \text{ N/m} \]

Torque required to move this load, T

\[ T = \frac{\pi d^4 - \pi d^4 \text{ Wet LT}}{1440 \pi} \]
\[ T = 879.35 \times 10^{-8} \text{ Nm} \]

Power required driving this shaft.

\[ P = \frac{2 \pi NT}{60} \]
\[ = \frac{2 \times 3.14 \times 1510 \times 879.35 \times 10^{-8}}{60} \]
\[ = 139.048 \]
\[ P = 140 \text{ W} \]
Diameter of the shaft, $d$, on the basis of strength

$$d^2 = \frac{16}{\pi^2(1 - \nu^2)^2} \left( \frac{M^2 d f}{E I} + \frac{K^2 T^2}{E I} \right)$$

$$= \frac{16}{1089.610} \times 10^3 \left( \frac{1(1.220 \times 1.5)^2}{(879.33 \times 10^3 \times 1.5)^2} \right)$$

$$= 9.5 \text{ mm} = 10 \text{ mm}$$

$K_1$ and $K_2$ values taking from

Machine design text book

<table>
<thead>
<tr>
<th>Name of the load</th>
<th>$K_1$</th>
<th>$K_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Stationary shafts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) gradually applied load</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>b) suddenly applied load</td>
<td>1.5 to 2.0</td>
<td>1.5 to 2.0</td>
</tr>
<tr>
<td>2. Rotating shafts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Gradually applied (or) steady load</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>b) Suddenly applied load with minor shocks only</td>
<td>1.5 to 2.0</td>
<td>1.5 to 2.0</td>
</tr>
<tr>
<td>c) Suddenly applied load with heavy shocks</td>
<td>2.0 to 3.0</td>
<td>1.5 to 3.0</td>
</tr>
</tbody>
</table>

On the basis of rigidity:

$$d^2 = \frac{584.71 T}{G B}$$

$$= \frac{584.71 \times 88 \times 10^{-3}}{345 \times 23}$$

$d = 12.83 \text{ mm}$

a standard diameter of 25 mm was adopted.

welded joint:-

the shaft is connected to the hollow drum by fillet weld

$$S = \frac{d}{\sqrt{10}}$$

$$= \frac{25}{\sqrt{10}} \times 10^{-3}$$

$S = 3.42 \text{ mm} = 4 \text{ mm}$

Bearings:-
Life of bearing in revolutions

\[ L = 60 \times Nx \times \frac{L_d}{R} \]

\[ = 60 \times 1020 \times 26280 \]

\[ L = 160833600 \text{rev} \]

\[ d = 25 \text{ mm} \] so we are choosing the 205 bearings.

**Separation unit:-**

Assuming that the volume of dehusked paddy and impurities flowing into the separation unit per second is 0.01 \( m^3 \), out of which 5% sand particles, then

\[ V_p = \frac{5}{100}V_{fa} \]

\[ = 0.0005m^3 \]

\[ V_f = 0.01m^3/s \]

\[ V_f = 0.0095m^3/s \]

\[ N_f = V_f \times \rho_f \]

\[ = 0.0095 \times 8.66 \]

\[ N_f = 0.08227/kg \]

\[ N_s = V_s \times \rho_s \]

\[ = 0.005 \times 13.1 \]

\[ N_s = 0.0655/kg \]

\[ V_{fs} = \sqrt{2g\rho_f} \]

\[ = \sqrt{2 \times 9.8 \times 0.009} \]

\[ V_{fs} = 2.43m/s \]

\[ F_f = \frac{N_f}{V_f} \]

\[ = 0.08227 \times 2.43 \]

\[ F_f = 0.19992 \text{ N} \]

\[ F_s = N_s \times V_s \]

\[ = 0.0655 \times 2.43 \]

\[ F_s = 0.1592 \text{ N} \]

\[ F_r = F_s + F_f \]

\[ = 0.1592 + 0.19992 \]

\[ F_r = 0.259 \text{ N} \]

\[ \left( \frac{V_f}{V_{fa}} \right)^2 = \left( \frac{4F_f}{\sqrt{2g \rho_f d^2}} \right) \]

\[ = \frac{4 \times 0.08227}{\sqrt{1.33 \times 8.66 \times 0.009}} \]

\[ \left( \frac{V_f}{V_{fa}} \right)^2 = 2.621 \text{ m/s}^2 \]
**Fig 4:** Forces on the rollers

**Table 1:** Fabrication Results

<table>
<thead>
<tr>
<th>Test No</th>
<th>Quantity of paddy, kg</th>
<th>Time taken to dehusk, min</th>
<th>% of grain dehusked</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>7</td>
<td>85</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>8</td>
<td>90</td>
</tr>
</tbody>
</table>

**Fig 5.** Paddy Dehusker