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Development of a Rice Threshing Machine

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Abstract

This paper deals with the development of a rice threshing machine. Available evidence suggests that the mode of threshing rice in the rural areas in Nigeria is by traditional use of hand beating of the paddy. This method is time wasting, energy sapping and often the grains are broken. The developed rice thresher has the ability to winnow the premature grains and leaves, which are often lighter, thus, leaving aside the massy grains that, will be collected. It is also capable of reducing time wastage, reduction in breakage of the grains and separation of the stalk from the grains. From the design calculation, the total power required to comb off grains from stalk is 267.04 W and to be driven by a 1.5 Hp electric motor.

Keywords: *Blower, feeder, traditional threshing method, mechanized threshing method, flow thresher, mobile thresher, "through-flow" thresher.*

Introduction

Cereals are the first cultivated grasses belonging to the Poaceae family. The popular cereal crops of the world include wheat, barley, oats, rice, maize, sorghum, and millets, but the major cereals of the developing countries are maize, rice, sorghum, and millet (Okaka 1997).

Harvesting constitutes a major operation among agricultural activities and differs according to the part of the plant to be harvested. A number of small, medium, and large threshers have been in existence for quite a long time, but due to low or poor performance in comparison with the traditional methods, they have not been adopted to a significant extent. Some are hand-held threshers and pedal operated ones (Chabrol, *et al.* 1996). Threshing is a major aspect that is usually carried out after harvesting of grain crops. This involves the beating of the grains from the stalk (Nkama 1992).

Threshing Methods

After being harvested, paddy bunches may be stacked on the plot. The in-field storage method results in a pre-drying of the rice ears before threshing, the purpose of which is to separate seeds from panicles.

Traditional Threshing

The traditional threshing of rice is generally done by hand: bunches of panicles are beaten against a hard element (e.g. a wooden bar log, bamboo table, or stone). In many countries in Asia and Africa, and in Madagascar, the crop is threshed by being trodden underfoot (by humans or animals); this method often results in some losses due to the grain being broken or buried in the earth (Food Agency Organization 1995).

Mechanized Threshing

Two main types of stationary threshing machines have been developed. The machine of Western design is known as "through-flow" thresher, because stalks and ears pass through the machine. It consists of a threshing device with pegs, teeth or loops, and (in more complex models) a cleaning-winnowing mechanism based upon shakers, sieves and centrifugal fan. In the 70s, IRRI developed an axial *flow* *thresher*, which has been widely manufactured at local level (Saxena, *et al.* 1971).

More recently, a small *mobile thresher* provided with either one or two threshers was developed. This machine has been widely adopted in many rice-growing areas (Policarpio and Mannamy 1978). The simple design and work rates of these machines seem to meet the requirements of rural communities (Food Agency Organization 1995). The main disadvantages of these machines are their fragility.

Mode of Operation of the Design

Already sickle plant bearing grains to be threshed out are put into the hopper in the direction of the feed. The feed rollers then swerve the stalk in between them as they are fed into the threshing chamber by the compression rolling action of the rollers. As the grains-bearing stalks come out of the rollers, the grains get combed off the stalk by the tongs on the radial thresh comb. The combed off grains fall on the sloppy tray and slide downwards. Simultaneously, the fan blows air against the direction of slope of the sloppy tray and blows up the lighter constituent and the remaining stalk out of the thresh chamber. The lighter constituents includes premature grains, leaves and in some cases weeds. The denser grains now fall down the slope under the action of gravity and then collected by the sprout of the tray.

Design Analysis

Determination of Torque Required to Comb Off Grains from Stalk

Torque, T= Fr ………………………….. 1

Assuming that force acts per unit length of tong, taking force per 10 mm segment of length.

$= FN \Rightarrow FN/10\ mm$
$= 0.1\ FN/mm$ ……………………. 2

Considering Fig. 1,

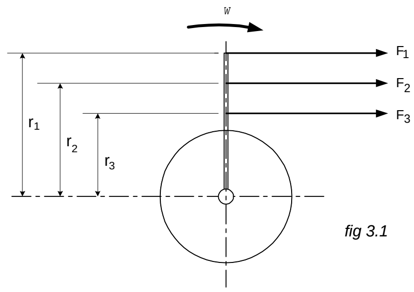

Fig. 1. Cross section of tongs on rotating drum

The torque resulting from individual force is given by,

$$T = F_i \times r_i \quad \text{………………………….. 3}$$

Where, F_i and r_i are ith force and ith radius respectively.

Resultant Torque,

$$T = F_1 r_1 + F_2 r_2 + \text{- - -} F_i r_i$$

$$T = \sum_{i=1}^{i=n} F_i r_i \quad \text{…………………………….. 4}$$

Where n = number of length segments given by,

$$n = \frac{Length\ of\ tong, L}{Length\ of\ segment, \iota} \quad \text{……………… 5}$$

But, $F_1 = F_2 = F_\iota$

$$.: T_{resultant} = F \sum_{i=1}^{i=n} r_\iota \quad \text{…………………… 6}$$

$$= F\left[\frac{n}{2}\left(2a + (n-1)\,d\right)\right] \quad 7$$

Fig. 2 shows the analysis of force acting on each tong.

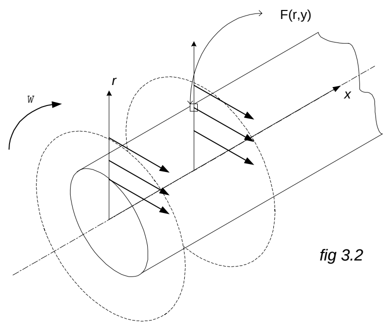

Fig. 2. Analysis of force acting on each tong.

Note: Equation 7 is sum of arithmetic series. This is much applicable in the case being considered,

Where, n = no of terms = no of segments
a = first term
d = common difference
Total torque,
$T_t = T_r \times k$ ……………………………………8

Where, k = number of tongs.

Determination of Power Required to Thresh Off Grains from Stalk

This is given by,
$P = T_t\, \omega$ ……………………………….. 9
Where ω = angular velocity in rad s^{-1}

Determination of Feed Roller Speed

$$N_f = \frac{r_1}{r_2} \times N_{CS} \quad \text{………………………… 10}$$

Where,
N_f = Feed roller speed, r_1/r_2 = speed ratio of pulley on comb shaft to the pulley on feed roller shaft, N_{cs} = Speed of radial comb

Shaft Analysis

i. Shaft subjected to twisting moment only
Torsion equation ⇒

$$\frac{f_z}{r} = \frac{T}{J} = \frac{C\theta}{\iota} \quad \text{……………….. 11}$$

Where, f_z = torsional shear stress, r = distance from neutral axis to outermost fibre,
T = twisting moment (or torque) setting on shaft
J = polar moment of inertia,
C = modulus of rigidity of shaft material,
L = length of shaft
θ = angle of twist in radius on a length, l (ASME 1995)
Polar moment for round solid shaft,

$$J = \Pi/32 \times d^4 \quad \text{...……………………… 12}$$

$$\therefore \frac{T}{\pi/32 \times d^4} = \frac{f_t}{d/2} \quad \text{………………… 13}$$

$$T = \pi/16 \times f_t \times d^3$$

Twisting moment, T can be obtained from

$$P = \frac{2\pi NT}{60} \quad \text{……………………………….. 14}$$

Where, N = speed of shaft in rpm
In the case of belt drive,

$$T = (T_1 - T_2)\, R \quad \text{……………………… 15}$$

Where, T_1 and T_2 are tensions on the tight side and slack side of the belt respectively,
R = radius of pulley.

ii. Shaft subjected to bending moment only
Bending equation is given by,

$$\frac{M}{I} = \frac{f_b}{y} \quad \text{…………………………………. 16}$$

Where,
M = bending moment
I = moment of merits of cross-sectional area of the shaft about axis of rotation
f_b = bending stress,
y = distance from neutral axis to outermost fibre.

$$I = \frac{\pi d^4}{64} \quad \text{………………………………….. 17}$$

$$M = \frac{\pi f_b d^3}{32} \quad \text{………………………………. 18}$$

(for solid shaft)

iii. Shaft subjected to combined twisting and bending moments. Based on maximum sheer stress theory:

$$f_s\,(\max) = \tfrac{1}{2}\sqrt{(f_b)^2 + 4(f_t)^2} \quad \text{……….. 19}$$

From equation 16,

$$f_b = \frac{32M}{\pi d^3} \quad \text{……………………… 20}$$

From equation 11,

$$f_x = \frac{16T}{\pi d^3} \quad \text{……………………… 21}$$

From which,

substituting equation 20 and 21 into 19,

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

$$d^3 = \frac{16\sqrt{M^2 + T^2}}{\pi f_s} \quad \text{…………………… 22}$$

Determination of Size of Weld joining tong to Shaft

i Bending stress,

$$f_b = \frac{M}{Z} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 23$$

Where,
M = bending moment
Z = section modulus
Maximum bending moment, M is given by,

$$M = \frac{qL^2}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 24$$

Where, q = distributed force
l = length of tong (Chakrabarti 1975)

ii Shearing stress, f_s is given by,

$$f_s = \frac{F}{A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 25$$

Where, F = applied force, A = throat Area,

$$A = \pi \mathrm{dt} = 0.7071\pi \mathrm{dx}, \quad \ldots\ldots\ldots\ldots\ 26$$

Where,
d = diameter of tong
x = size of weld.

$$Z = \frac{\pi \mathrm{td}^2}{4} = 0.7071\pi \frac{\mathrm{d}^2 x}{4} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 27$$

iii Based on maximum sheer stress theory:

$$f_s(\max) = \frac{1}{2}\sqrt{(f_b)^2 + 4(\mathrm{f_s})^2} \quad \ldots\ldots\ldots\ldots\ 28$$

$$= \frac{1}{2}\sqrt{\left(M/Z\right)^2 + 4\left(\mathrm{F}/\mathrm{A}\right)^2} \quad \ldots\ldots\ldots\ 29$$

The size of weld, x, can be determined by making the appropriate substitutions into Equation 27 and then solving for x.

Belt Analysis

Considering Fig. 3,

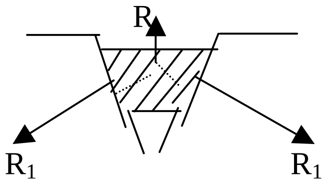

Fig. 3. Cross-section of vee-belt

R_1 = normal reactions between belts and sides of the groove,
R = total reaction in the plane of the groove
μ = coefficient of friction between the belt and the sides of the groove
Resolving the reactions vertically to the groove, we have:

$$R = \mathrm{R_1} \sin\beta + \mathrm{R_1}\sin\beta = 2\mathrm{R_1}\sin\beta \quad \ldots.\ 30$$

$$\mathrm{R_1} = \mathrm{R}/(2\sin\beta)$$

$$Frictional force = 2\mu\mathrm{R}, = 2\mu \ \mathrm{x}\ \mathrm{R}/(2\sin\beta)$$

$$= \mu R/\sin\beta$$

$$= \mu\mathrm{R}\ \mathrm{cosec}\beta \quad \ldots\ldots\ldots\ldots\ldots\ 31$$

For vee-belt, the relation between T_1 and T_2 is given by,

$$2.3\log\left(\frac{\mathrm{T_1}}{\mathrm{T_2}}\right) = \lambda\theta\ \mathrm{cosec}\beta \qquad 32$$

Where,
θ = Angle subtended by the arc along which the belt touches the pulley, at the center.

Determination of Power Transmitted by Belt

Considering Fig. 4,

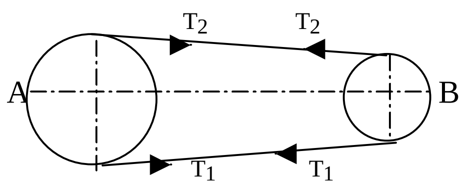

Fig. 4. Power transmitted by belt

Effective driving (turning) force, is given by,

$$T_1 - T_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 33$$

Power Transmitted, is given by,

$$P = (T_1 - T_2)v \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 34$$

Where,
T_1 = Tension in the tight side in N
T_2 = Tension in the slack side in N
v = Velocity of belt in m/s
Torque exerted on driving pulley, is given by,

……………………………. 35

$(T_1 - T_2) x\, r_2$

$(T_1 - T_2) x\, r_1$ 36

Centrifugal Tension, T_c, is given by,

$T_c = mv^2$ 37

Where,
m = mass of belt per met length,
v = velocity of belt,
Tension on tight side of belt, T_1 is given by,

$T_1 = T - T_c$

But,

$T = f\, x\, a$

Where,
T = maximum tension in the belt
f = allowable tensile stress in N/mm^2
a = cross sectional area of belt.

Pulley Analysis

Centrifugal stress induced in the run of pulleys,

$f_c = \rho v^2$, ... 38

Where,
ρ = density of the rim material,
v = velocity of rim, given by,

$$v = \frac{\pi DN}{60} \quad 39$$

Where,
N = speed of pulley in Rpm,
D = diameter of pulley

Arm Considerations

Tangential load per arm,

$$W_T = \frac{T}{R \times n/2} = \frac{2T}{Rn} \quad \text{.................... } 40$$

Where,
T = torque transmitted,
R = radius of pulley,
n = number of arms

Cross section of arms,

$$M/Z = f_b$$

$$Z = \Pi/32 \times d^3$$

$$M = \frac{2T}{R \times n} \times R = \frac{2T}{n}$$

Where,
M = maximum bending moment on the arm at hub end
Z = section modulus of arm
f_b = bending stress for arm material
d = diameter of arms

Determination of Hub Diameter

$d_1 = 1.5d + 20mm$ 41
d_1 = diameter of hub $\subseteq 2d$
d = shaft diameter

Determination of Length of Hub

$$L = \Pi/2 \times d$$

Machine Description

This thresher is comprised of three main units: the feeder unit, the threshing unit, and the blower unit.

The Feeder

This unit comprises of the hopper, whose aperture lays vertical at the base. The hopper has only one of its sides in a slant. Opposite the start side is a vertical side, which has the aperture of the hopper at its bottom. Within the aperture by two feed rollers, the free one is on top of the driven one. The free one is constantly under a vertical force, which tends to compress it downwards upon the lower driven one.

At the two free ends of the free roller's axle, are loads, which provide the downward force mentioned earlier. The loads are varied as required. A pulley is attached to the staff of the driven roller. The input for the shaft is taken from the shaft of the thresh comb via a vee-belt.

The Threshing Unit 37

It is comprised of the thresh comb. This is made up of a shaft upon which small rods (tongs) are welded to it in a line at intervals. There are two of such lines-each welded to opposite sides of the shaft. Each of the tongs is carved to forming an arc of small curvature.

The shaft rests on ball bearings of each end. Attached to one of the ends of the shaft is a pulley for drive. The pulley/shaft rotates in the direction of carve of the tongs. Just a distance beneath the thresh comb is a sloppy tray which slopes downwards into a trench. The trench is also sloppy in the direction perpendicular it the direction of slop of the tray. The trench ends as a sprout.

The Blower

The blower is located just under the hopper and opposite the slope of the tray. It is a centrifugal fan and is comprised of four straight impellers attached to the shaft, all in an in volute casing. A pulley is attached to the shaft at one of the ends.

Conclusion

The design and fabrication of a rice threshing machine has been successfully carried out by this work. The machine is capable of threshing, separation of stalk from grains and reduction in number of broken grains, thereby, giving a better method of threshing than the traditional methods. All the materials used were locally sourced.

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