Development of a Rice Polishing Machine

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Abstract

The development of a frictional Rice Polishing Machine (RPM) is a major effort made to increase the acceptability of local rice owing to the importation ban placed on the imported rice and the willingness of the government to encourage the adequate processing of the local rice. This work is intended to: bridge the wide gap existing between the local/traditional ways of polishing rice and the modern methods; reduce the amount of premium placed on the use of sophisticated imported rice polishers and the local fabricated machines; improve the attractive shinning appearance of polished rice and packing properties; and remove final traces of dust, bran and flour from the rice surface. The machine developed in this work processes local rice at the rate of 25 g/s. As of February 2005, it costs Nigerian Naira (₦) 50,950 (approx. 13,185 Thai Baht) to produce this unit using locally available materials. The machine competes favorably with the imported ones.

Keywords: Rice, polishing, machine, design, fabrication.

Introduction

Rice has been part of the staple diet in eastern countries for thousands of years. According to legend, rice was first eaten in China some 5,000 years ago. Rice (*Oryza sativa*) arrived in Egypt in the 4th century BC and around that time India was exporting it to Greece. The Japanese rated rice very highly, as reflected in the many thousands of shrines, which may be seen across the countryside, which are built to *Inari*, their rice god (Anping 1989). For centuries, rice was a standard of wealth and was often used in place of money. When Japan invaded China, "coolies" were paid in rice. In fact, the growing of rice and the success or failure of the crop affected the history, art, literature, ceremonials and the very way of life of the people of India, China and Japan for centuries (Yan and Wenming 1989). Hence, any research on the improvement of rice is not misdirected.

Prior to the advent of modern polishers, several traditional methods have been used to polish rice. These methods include: pounding in mortar with pestle; beating with clubs on the floor; rubbing on the floor; beating gently with clubs in jute bags and threading under the feet of man or hooves of animals. These crude means are deficient due to the fact that lots of damages are done on the rice, which leads to wastage and labour lost. On the other hand, it involved enormous human energy and time, apart from the fact that these methods are not hygienic.

The available Rice Polishing Machines (RPMs) in most of the rice processing industries were imported with the attendant huge cost of procurement, high cost of maintenance, inadequate spare parts and sometimes complicated mode of operation (Ismail 2006). Though these imported RPMs may be efficient and effective but they require experts to some extent for proper operation, repairs or servicing, and most of them are climatic incompatible.

In recent times, embargo was placed on rice importation into the country. Hence, there comes a need to improve the home technology. Also, in order to meet up with the demand for high quality and well-processed rice, there is the need for locally-made RPMs. Such RPMs

will make the available quality rice at a cheaper price in order to maintain the comfortability and the satisfaction of the consumers. The development will be made possible by: identifying the local engineering materials suitable for the development of RPM; and deciding as to how the materials can be used to develop the machine. These will result into easy operation and affordable running cost.

Available modern rice processing machines include: *Paddy Cleaner-* This machine separates all the impurities like straw, dust, sand, and stones, etc., from paddy, where a blower is attached to the machine for proper cleaning; *Paddy Husker-* This machine is used for dehusking or shelling process. This machine is also called a *Paddy Sheller. Rice Polishing Machine* (RPM) or commonly known as the *Rice Polisher* is one of the newly developed rice processing machines used in rice processing industry. This machine was designed to make the milled rice more attractive in appearance and also to improve the packing properties as well as to remove the final traces of dust, bran, and flour from rice surface. The RPM was well developed and introduced into the rice industry, playing a noticeable role among rice machineries (Dubu 1977, 1988; Li and Jiangzhe 1986).

Other rice processing machines include: *Rice Grader-* After the first or second polishing, he polished rice will come for separating the different qualities of rice according to their size through the elevator. Broken rice and different sizes of rice will be separated through different sieves. This machine is to improve marketability of rice. It is available in different capacities (small, medium and bigger scale). *Four-In-One Rice Machine-* The machine is designated for use in a small rice mills and for the farming households. The machine is capable of carrying out the four main operations of rice processing (i.e., paddy cleaning, dehusking, polishing and rice grading). Hence, it is called four-in-one machine. Moreover, due to the best and latest technology, the machine works with minimum breakage of rice.

RPM is broadly divided into two types, namely: the abrasive type and the friction type.

Also, it is categorized into two kinds based on its shaft (combination of disc and conveyors) arrangement, namely: horizontal and vertical. The focus of this work is to develop a friction-type horizontal RPM.

Basic Design

The aim of this article is to develop a Rice Polishing Machine (RPM) without jeopardizing nutritional value and comfort, high quality and marketability of rice. The machine designed was constructed at minimum possible cost without jeopardizing the efficiency. The designed machine components include: Hopper; Sieve; Belt; Pulleys (for the polisher shaft and electric motor); Shafts (polisher shaft); Bearings (selected); Electric Motor and Support/ Standing.

Hopper Design

Hopper design is based on a common criterion, which is required for it to function. This criterion is called the *"Angle of Repose"*. Angle of repose is the maximum slope at which heap of any loose or fragmented bulk material will stand without sliding (Chelecha 2003). It was also defined as the angle of friction of rest (Eugene and Theodore 1986).

This type of hopper is a gravity discharge one, and the recommended angle of repose for gravity discharge of maize and rice ranges between 15^0 to 20^0 (Chelecha 2003).

The volume was estimated from Eq. (1),

$$V = \frac{\pi(D^2 - d^2)h}{12}, \qquad (1)$$

where: h = vertical height; D = diameter of the upper opening; d = diameter of the lower opening or delivery section.

Note that the slant height, ι, is obtained from the relation, $h = l \cos \phi$, where ϕ is the angle of repose (see Fig. 1).

Sieve Design

The sieve was designed to separate the polished rice from other particles, such as dust,

bran and flour. The sieve design consists basically of the determination of distance d, between two successive holes of the sieve, having holes of oval shape. The sieve has to be made concave so as to be fitted into the shaft. The diameter of the sieve perforation was estimated using Eq. (2) and the required area by Eq. (3) as suggested by Faluyi (2001):
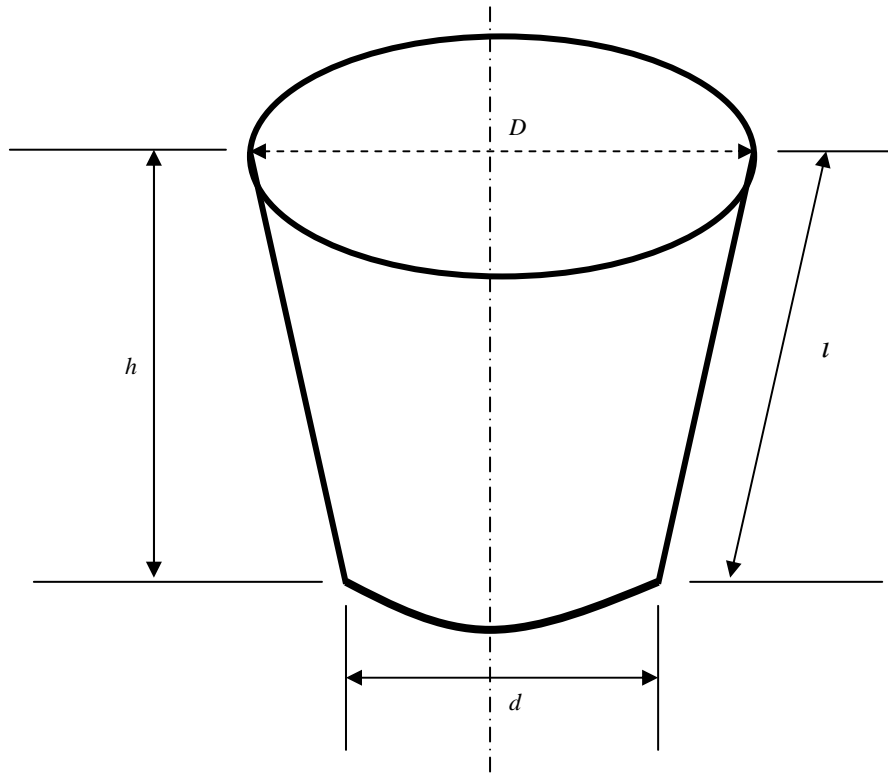

Fig.1. The hopper.

$$d = \sqrt{\frac{D^2(3\pi - 2C_o)}{C_o}} \, , \qquad (2)$$

$$A_c = l_c.b_c \, , \qquad (3)$$

where: $l_c = \dfrac{2\pi R.\theta}{360}$; D = maximum diameter of the required grain size of the polished product; C_o = coefficient of opening; l_c = arc length of the concave sieve; b_c = breadth (width) of the concave sieve; R = the radius of concave, θ = angle of sieve.

Design for Belt and Pulley

Belt Design Considerations

The *V*-belt *class A* type was chosen for the drive of this machine. This belt was chosen from belt table using design calculations. The width of pulley (w) was selected based on the suggestion that the width of pulley must be about 25% more than the width of the belt (Raji and Kuku 2003). Hence,

$$w = t + (25\% \text{ of } t) \text{ (mm)}, \qquad (4)$$

where t = width of the *V*- belt.

Speed Ratio

The speed ratio and the pulley diameters were designed using Eqs. (5) and (6), respectively.

$$\frac{N_1}{N_2} = \frac{D}{d} \, , \qquad (5)$$

$$D = \frac{N_1}{N_2}.d \, , \qquad (6)$$

where: N_1 = speed of motor pulley (rev/min.); N_2 = speed of polisher pulley (rev/min.); D = diameter of the larger pulley (polisher) (mm); d

= diameter of the smaller pulley (electric motor)(mm).

The belt speed was determined using Eq. (7),

$$V = \frac{\pi \, dN_1}{60}, \qquad (7)$$

where V = belt speed (ms^{-1}). An average required speed was estimated from PSG Tech. (1982).

The Maximum Power (kW)

The maximum power, which the belt can transmit, is given by Eq. (8) (Adeolu 2002),

$$P = \frac{0.45}{V^{0.09}} - \left(\frac{19.62}{D_o} + 0.765 \times 10^{-4} \, V^2 \right) V, \quad (8)$$

where D_o = equivalent pitch diameter. If F_b is the small diameter factor to account for the arc

of contact, then $D_o = d.F_b$, where d = diameter of the electric motor pulley.

Determination of Pulley Diameter of the Polisher Shaft

The diameter, D, is given by Eq. (9) as suggested by PSG Tech. (1982),

$$D = d \frac{N_1}{N_2} . \eta, \qquad (9)$$

where η = efficiency of the machine.

Determination of the Centre Distance

Two center distances were considered, they are: minimum and maximum centre distances (see Fig. 2). These two distances are given respectively by Eqs. (10) and (11),
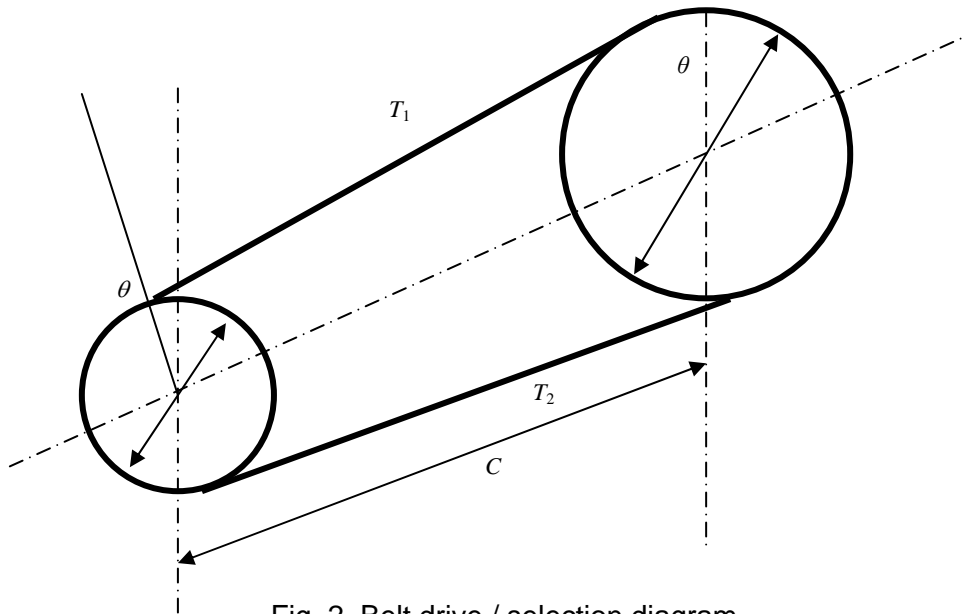

Fig. 2. Belt drive / selection diagram.

$$C_{\min} = 0.55(D + d) + D, \qquad (10)$$
$$C_{\max} = 2(D + d). \qquad (11)$$

The nominal length of the belt is given by Eq. (12),

$$L = 2C + \frac{\pi(D + d)}{2} + \frac{(D + d)^2}{4C}, \qquad (12)$$

where L = the selected closest value to the calculated nominal length of the belt.

Determination of the Arc of Contact

The arc of contact, β, is given by Eq. (13) as suggested by PSG Tech. (1982),

$$\beta = 180^0 - 60^0 \left(\frac{D - d}{C} \right). \qquad (13)$$

Determination of the number of belts, N

The required numbers of belts, N, can be estimated by Eq. (14),

$$N = \frac{(P.F_a)}{(kW.F_c F_d)}, \tag{14}$$

where: F_d = correction factor for arc of contact; P = drive power; F_a = correction factor according to service; kW = rating of the belt; and F_c = correction factor for the length of the belt.

Determination of Tension, T_1 and T_2 of the V-belt

The belt cross-sectional area is given by Eq. (15) as estimated from Fig. 3,
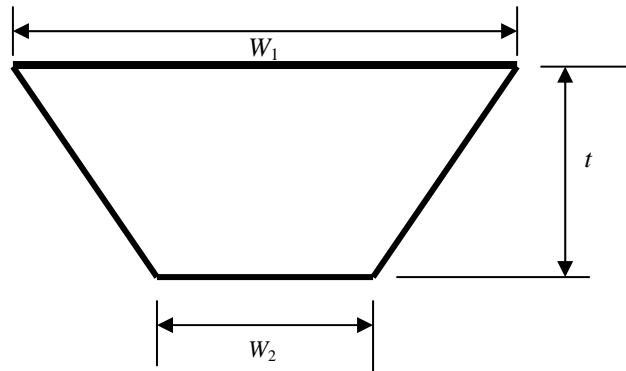
$$A = \left(\frac{W_1 + W_2}{2}\right).t, \tag{15}$$

Fig 3. Tension diagram.

with $W_2 = W_1 t / h$; $\beta = (180 - \theta)/2$; and $h = (W_1/2)\tan\beta$, where: W_1 = top width of the V- belt (mm); W_2 = bottom width of the belt V-belt; h = height of the groove; t = nominal belt thickness; β = arc of contact; and θ = groove angle of sheave.

The maximum tension (T_1) is given by the Eq. (16) while the angles of wraps (α) of the belt are given by the Eqs. (17) and (18), respectively, for smaller and larger pulley,

$$T_1 = T_{\max}.A, \tag{16}$$

$$\alpha = \alpha_1 = 180^0 - 2\sin^{-1}\left(\frac{r_2 - r_1}{C}\right), \tag{17}$$

$$\alpha = \alpha_2 = 180^0 + 2\sin^{-1}\left(\frac{r_2 - r_1}{C}\right), \tag{18}$$

where: r_2 = radius of larger pulley = $D/2$; r_1 = radius of smaller pulley = $d/2$; and C = actual centre distance.

The load carrying capacities of the pulleys are given by Eqs. (19) and (20),

$$C_1 = \ell^{\mu\alpha_1 \cos ec\frac{\theta}{2}}, \tag{19}$$

$$C_2 = \ell^{\mu\alpha_2 \cos ec\frac{\theta}{2}}, \tag{20}$$

where: μ = coefficient of friction (leather-metal); α_1 and α_2 are the angles of wrap of smaller and larger pulley (rad); θ = groove angle of sheave (Groove angle for V- belt = 30^0- 40^0).

Hence, the torsion, T_2, on the slack side is given by Eq. (21),

$$T_2 = \frac{T_1 - MV^2}{C_1} + MV^2. \tag{21}$$

The power, P, transmitted by the belt was estimated from Eq. (22),

$$P = (T_1 - T_2)V. \tag{22}$$

Shaft Design

The detailed design procedure for the shaft can be found in the works, Ogunlaja (2005), Dilureni (2005) and Ismail (2006). Design specifications are shown in Table 1.

Table 1. Design specifications.

Components	Assumed parameters	Designed Parameters
Hopper	r_o = 70 mm; h = 450 mm	V = 32.044x10^6 mm^3
Sieve	D = 1.00; C_o = 0.40; θ as 90^0; R = 52mm	$d \cong$ 5mm; L_c = 81.68mm; Ac = 11,890mm^2
Speed Ratio	N_1 = 1,440 rpm; N_2 = 720 rpm; d = 76mm	D = 152mm
Belt And Pulley	d = 76mm; N_1 = 1,440rpm	V = 5.73 ms^{-1}
maximum power	F_b = 1.0; d = 0.076m	P = 0.7099kW
Electric Motor	From Shaft, Pulley and capacity design	1,440 rpm, 1.0 kW
Width of pulley	t = 11mm	$W \cong$ 14mm
Centre Distance (C)	d =76mm; D = 150mm	C = 225mm; L = 810.9mm; A = 72.5mm; and B = 684.50mm
Arc of Contact, β	D = 150mm; d = 76mm; C = 829.50mm	β = 175^0
Belt Number (N)	F_d = 0.98; F_c = 0.8; F_a = 1.2; P = 0.7099kW	N = 1.024
Tension, T_1 and T_2	W_1 = 13mm; β = 175^0; θ = 34^0; W_2 = 4.89mm; h = 21.26mm; V = 5.73ms^{-1}	A = 7.16x10^{-5}m^2; T_1 = 143.2N; α_1 = 175^0; α_2 = 185^0; Cl_1 = 64.89; Cl_2 = 83.02; T_2 = 4.45N
Bearing (ball type)	F_a = 95.33 and F_r = 143 N	d_b =20mm; D_b = 52mm; B = 21mm; r = 2mm; L = 8.64x10^8; C = 1799.85N
Diameter, d, of shaft	Mb = 69.27Nm; Mt = 10.41Nm; Kb = 1.5; Kt = 1.0; S_s = 55x10^6 N/m^2	d = 21.3mm

Fig. 4. Plate 1 - Front view of the machine under construction showing the outlet.

Fig. 5. Plate 2 - Back view of the machine showing the belt and the electric motor.

Conclusion

In this project, a Rice Polishing Machine (RPM) was designed and constructed as shown in Figs. 4 and 5. The materials used are locally available. The RPM designed is a good replacement for the imported ones. The locally-made RPM is economical for the establishment of small scale industry especially in the developing countries. It can be used also for the processing of livestock and human feeds. The machine can be used for polishing any species (or varieties) of rice grains. It can effectively process at least 1.5 tons of rice grains within eight hours. The overall cost and choice of material would promote mass production and, hence, it can bring about the easy stoppage of the inflow of the expensive conventional rice polishing machines.

Acknowledgements

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