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DESIGN AND FABRICATION OF YAM PEELING MACHINE

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Abstract

Yam, undoubtedly is an important root crop in the tropics which can be processed into a wide variety of forms for consumption as food. However, peeling is an important process which increases the value of the processed food. Yam peeling machines need to be developed for this purpose which normally has always been carried out manually with the use of knives and on domestic scale. A yam peeling machine which has a dual operation was developed in this study. The machine was evaluated for performance and the peeling efficiency ranged between 71.2 and 95%. The peeling rate was 11.15 mm/s during motorized operation and 3.45 mm/s during manual operation. The peeling loss ranged from 3.67 to 14.29% during motorized operation and from 3.91 to 16.96% when the machine was operated manually. The machine can be developed for small scale food industries at reasonable cost and minimal maintenance. Yam peeling, which is the removal of the outer layer of the yam, is one of the major problems of yam processing both for small and large-scale consumptions. Yam belongs to the families called Discoreaceae and Discorea. These families contain about 600 species out of which ten are presently of economic importance. Most of the yams produced in various parts of the world are consumed within the country of production, although appreciable qualities are shipped to the developed countries.

Keywords: **Efficiency, peeling machine, peeling loss, peeling rate, Yam,**

1.0 INTRODUCTION

Garri processing always involves yam peeling process, which is traditionally completed by manual peeling. Some of the problems of manual peeling has to do with time consuming and inefficiency. The idea of mechanical yam peeling machine is to solve these problems and enhance productivity. However, due to the irregular shapes of yam tubers, 100% peeling rate cannot be easily achieved. Therefore, the development of yam peeling machine is a process of improving yam peeling rate and equipment performance. Adetan (2005)

Developing yam peeling machine provides a very important technology which enhances productivity and reduces stress associated with the traditional method is not only tedious, but raises hygienic concerns and has high risk of injury. Pounded yam is a stable food, which is consumed by almost every tribe in Nigeria and some parts of other West African countries. The indigenous process of production is very laborious, the emergence of instant pounded yam flour (IPYF) recently introduced into the market, brings succor to pounded yam lovers as the drudgery of pounding is eliminated. Yam peeling remains a major challenge in the design of yam peeling and processing machines. Aderoba (2008). Initial research efforts in this area resulted in the production of several prototypes with relatively low peeling efficiencies and quality performance. Considering the nutritional values of yam as a stable source of carbohydrate, vitamins, dietary fibre and minerals and its economic importance being the second most important root/tuber crop in Africa, after cassava, the challenges and need for an effective method for the peeling of yam needs serious attention. Ukatu et al (2005), designed industrial yam peeler but with poor efficiency, worked on an improved Rotary Peeling machine. This work looked at the development of an efficient yam peeling machine for yam process.

1.2 TYPES OF PEELING MACHINES

1.2.1 Brush Peeler: When you put the raw material into the feed port, the roller keeps to rolling, and then the water from the shower pipe wets the raw material. Brush roller can process materials with special craft and hence very durable

Fig 1. Manual yam peeling

Fig 2 : Knife type yam peeler

Fig 3: Stainless Steel brush yam peeling machine

Fig 4: Sand roller peeler

1.2.2 Tapioca Peeler

This kind of washing and peeling machine can separately clean, wash and peel work at the same time. The equipment has good appearance, is convenient and can peel large volume with high efficiency, low energy consumption and suitable for continuous work**.**

1.2.3 Burdock Peeler

This is an automatic stainless steel peeling machine. The machine can peel continuously. It is capable of saving water, has perfect appearance free from pollution.

2.0 MATERIALS AND METHODOLOGY

The selection of the appropriate material for engineering purposes is a major interest for any designer. The best material is one which serves the desired objective at the lowest cost.

2.0 DESIGN ANALYSIS

In order to design an effective machine, some physical and mechanical properties of yam are required. Some of the problems to tackle in the design is the wide variation in the sizes and shapes of the tubers; others are the variation of the mechanical properties with the age of the yam tubers. Hence the followings are the major parameters for effectiveness of the peeler, thickness of peel, time of harvest (age), feed of the cutter, and relative speed of rotation. Adetoro (2012)

Some of the equations used in the design are given here:

$$F = \frac{mv^2}{r} + mg \qquad (1)$$

$$F_n = F\cos\Theta, \text{ and } F_t = F\sin\Theta \qquad (2)$$

Where: F = the centrifugal force, m = mass, v = relative velocity.

$$n^2 = \frac{g}{4\pi^2 r} \qquad (3)$$

where; n = speed of rotation and r = radial distance

some of the estimate parameters are given in Table 2

$$S = \frac{\pi d N_1}{60} \tag{4}$$

$$P (0.45 – 0.09 - \frac{19.63}{kd} – 0.765 \times 10^{-4} S^2 \tag{5}$$

Where: P = Power required and S = Belt speed; K = pulley correction factor, d = pulley diameter

$$\gamma = \frac{\varkappa}{\mu} \tag{6}$$

2.2 COMPONENT PARTS AND OPERATION PRINCIPLE OF A YAM PEELING MACHINE

2.2.1 Component Parts of the Machine: The component parts of the machine are generally described as follows. The rotating drum built with wire gauze wounded on a frame, made of iron rods and flat bars in a longitudinal manner. Ayodeji et al (2014). A shaft is made to pass through the center of the drum supported at both ends with pillow bearings and at one end is mounted the pulley that enables the belt to be connected to the electric motor supported at the base with another frame. The entire component is placed on a frame support big enough to give the required rigidity. The drum has only one opening where the tubers are fed and discharged while the peels or wastes are passed through the perforated portion

2.2.2 Mode of operation: To operate the yam peeling machine, the yam tuber is fed through the loading unit into the peeling chamber. Then the power is switched on to allow current into the system, when the button responsible for the rotation of the peeling chamber is pressed, the chamber begins to rotate with the yam tubers inside it. As the yam tuber hits the rough internal surface of the peeling chamber it peels the eternal surface of the yarn off the yarn simultaneously. The, more the chamber rotates the more the yam collides with the rough walls of the chamber thereby removing more of the external surface of the yam.

2.3 DESIGN CALCULATION

The parameters used in describing angular motion.

(a) Angular displacement; (b Angular velocity (W); (c) Angular acceleration; (d) Time (t)

(a) Angular displacement: this is the angle sustained at the center of a circle by an object moving round the circle.

(b) Angular velocity: this is the rate of change of angular displacement.

(c) Angular acceleration: this is the rate of angular velocity.

(d) Time: this is the period in seconds; to take the complete motion of the body.

The respective for the above parameters are;

a. Angular displacement ϴ = wt. (1)

b. Angular Velocity w = $\frac{Linear\ \ velocity}{Radius} = \frac{V}{R}$ (2)

Recall, /revolution = 2 radian

Number of revolution N = 2ton

Number of revolution per minute = 2 ton in rad/second

c. Angular acceleration = $\frac{Linear\ \ acceleration}{Radius} = \frac{Q}{R}$ (3)

Where Q = Linear acceleration, and R = radius

d. Time (T) = $\frac{2\pi}{w}$ (4)

Frequency = $\frac{Revolution}{Second}$

F = $\frac{1}{t}$hertz (Hz) (5)

Electric Motor

The electric motor used for this peeling machine has the following parameter on the plate.

i. Power = 2.5 HP

Recall, 746 watts = 1HP

X watts = 2.5 HP

X = 2.5 X 746/1 = 1865

ii. Frequency = 50Hertz

iii. Revolution per minute = 2900

iv. Voltage supply = 220 volts

v. Weight/mass of electric motor = 1.8kg

vi. Current = power / voltage (Ampere)

1865/220 = 8.4773A

From ohm's law/equation

Voltage = current x resistance

$$\text{i.e } V = IR \qquad (6)$$

$$R = V/I = 220/\ 8.4773 = 25.9517\Omega$$

vii. Resistance = 26 ohm's

viii. Energy = power x time (Joules)

Energy liberated for 1 hour = 60 x 6- seconds

Energy = 1865 x 60 x 60

= 1865.0 x 3600 = 6714000J

= 67154 KJ

ix. Speed (W) = $2\pi f$ (7)

Where f = frequency

W = 2 x 3.1428 x 50

= 314.2857 rev/sec

x. Velocity of electric motor

$$V = \left(\frac{2\pi N}{60}\right)\left(\frac{D}{2000}\right) \text{m/s} \quad (8)$$

$$V = \left(\frac{2\ x\ \frac{22}{7}\ x\ 2900}{60}\right)\left(\frac{70}{2000}\right) \text{m/s}$$

V = 10.6333 m/s

xi. Force = Power / velocity (9)

Force-1865 / 10.633 = 175.3918N

xii. Torque = force x radius (10)

The radius of the disc (i.e pulley) of electric motors

= (0.070/2) m

=0.035m

Torque of electric motor

T = force x radius of disc

175.3918 x 0.035

Torque = 6.1387 Nm

xiii. Linear acceleration (a) = Force / Mass (11)

i.e a = F/m

a = 175.3918/18 = 9.7439 m/s^2

2.4 DETERMINATION OF AXIAL STRESS DUE TO AXIAL LOAD OF THE SHAFT

$$\text{Axial Stress} = \frac{load}{Area} = \frac{4\ x\ F}{\pi d^2} \quad (12)$$

But the total load comprises

- Weights of the: Bearing; Shaft.; Spinning Vane and Coupling i.e. weight of the bearing + weight of the shaft + weight of the spinning

Vane + weight of coupling = 41.55N.

: Axial Stress on the shaft

$$=\frac{4 \ x \ 41.55}{3,142 \ x \ (0.089)^2} = \frac{166.2}{297.638} = 6677.9\text{N/m} = 6.6779\text{KN/m}$$

2.5 SHEAR FORCE AND BENDING MOMENT

Total weight on Pulley

$$W_T = T_1 + T_2 + (Tp \text{ X } 9.81) \text{ N} \qquad (13)$$

Where Tp = pulley weight is 28kg as pulley weight.

$W_T = T_1 + T_2 + (Tp \text{ X } 325.918 + 150.5291 + (28 \text{ x } 9.81\ ) = 751.1271\text{N}$

$W_T = 0.7511\text{KN}$ Fig 6

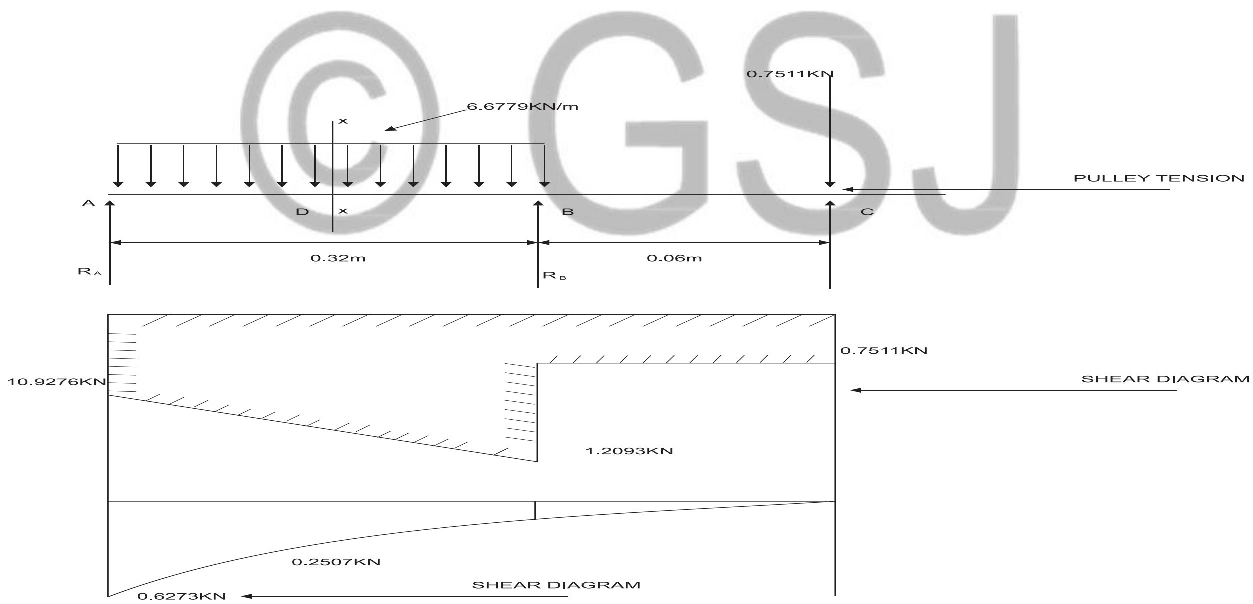

Fig 5

Upward forces = downward forces (14)

$\Sigma f = R_A + R_B$

$R_A + R_B = 6.6779 \text{ x } 0.32 + 0.7511$

$= 2.8880\text{KN}$

Taking moment at point A: let clockwise direction be positive

R_B x 0.32 = 6.6779 X 0.32 x $\left(\frac{0.32}{2}\right)$ + 0.7511 x 0.38

$0.32R_B$ = 0.3419 0.2854 = 0.6273

$R_B = \frac{0.6273}{0.32} = 1.9604$

R_B = 1.960KN

: R_A = 2.8880 – 1.9604 = 0.9276

R_A = 0.9276KN

SHEAR FORCE

Shear force C = -0.751 İKN

Shear force at B = -0.7511 + 1.9604 = 1.2093KN

Shear force from C to A = -0.7511 + 1.9604 - (6.6779 X 0.32) + 0.9276KN = 0KN

BENDING MOMENT

M_C at c = 0

M_B = - (0.751 1 x 0.06) = -0.0451KNm

M_D = (-0.75 1 1 x 0.22) + (-66779 x 0.16 x $\frac{0.16}{2}$)

= -0.1652 – 0.08548

M_D = - 0.25067712 = - 0.2507KNm

M_A = -(-0.7511 X 0.38) + (-6.6779 X O.32 X $\frac{0.32}{2}$)

= - 0.2854 - 0.3419 = - 0.6273KNm

Maximum Bending Moment = 0.6273KNm

DETERMINATION OF TORSIONAL MOMENT ON SHAFT.

Given the diameter of the shaft = 89mm

Then J = $\frac{\pi d^4}{32}$m^4 (15)

where J is the polar second moment of inertia

d = diameter of the shaft.

Applying mathematically approach its means

J = $\frac{22\ x\ (0.89)^4}{7\ x\ 32} = 0.061621843$ m^4

Torsional Moment on the shaft

T = rJR (16)

Where T = Tensional load

r = shear stress of the shaft

R = Radius of the shaft.

Hence, we deduce, T = JC R (17)

Recall that Axial stress = 6.6779KN/m

:- T = 8160503.788 x 6.6779

= 54495028.25N/mm

From above tensional moment of the shaft have been determined as 5449.50 KN/mm2

SHAFT DIAMETER

The shaft diameter can be determined using;

d^3 = $\left(\frac{16}{\pi S_s}\right)$ x $M[(K_b M_b)^2 (K_1 M_1)^2]^{\frac{1}{2}}$ (18)

Where d = shaft diameter

K_b = combined shock and fatigue factor apply to the bending moment

K_t = combined shock and fatigue factor apply to the torsional moment

M_b = Bending moment

M_t = Torsional moment

S_s = Allowable stress

For rotating shaft when load is suddenly applied (minor shock)

K_b = 1.5 to 2.0

K_t = 1.o to 1.5

For shaft without key-way

S_s = 55MN/m^2

for shaft with key – way

S_s = 40MN/m^2

Therefore;

$$d^3 = \left[\frac{16 \ x\ 7}{22\ x\ 40}\right] \text{x}\ [(1.5\ x\ 0.6273)\ ^2 + (1\ x\ 5449.50)^2]^{\frac{1}{2}}$$

d = 8.8518mm

2.5 DETERMINATION OF MAXIMUM BENDING STRESS DUE TO BENDING LOAD

The bending stress for both tension and compression is given below;

$$S_b = \frac{M_b\ x\ r}{I} \quad (19)$$

Hence, $S_b = \frac{32 M_b}{\pi d^3}$ (20)

Where S_b = Bending Stress

M_b = Bending Moment

d = Shaft diameter

I = Moment of inertia

$S_b = \frac{32\ x\ 0.627\ x\ 7}{22\ \ x\ 89^3}$

S_b = 9.06MN/m^3

2.6 DETERMINATION OF TORSION STRESS DUE TO BENDING LOAD.

To determine the torsion stress due to bending load;

$$Б_{xy} = \frac{M_t r}{J} \quad (21)$$

Where J = $\frac{\pi d^4}{32}$

$$Б_{xy} = \frac{16M_t}{\pi d^3} \quad (22)$$

Where $Б_{xy}$ = Torsion stress; M_t = Torsion moment; d = diameter of shaft

J = Polar moment of area

$$Б_{xy} = \frac{16\ x\ 0.5499\ x\ 7}{22\ x\ 89^3}$$

$Б_{xy} = \frac{16\ x\ 5449.5\ x\ 7}{22\ x\ 89^3}$

$Б_{xy}$ = 39.35N/m

3.0 DISCUSSION AND RESULTS:

Table 1 : (Performance Evaluation)

S/N	Tuber length (mm)	Peeling time (secs)	Mass of tuber after peeling (kg)
1	397	113	1.22
2	325	92	1.07
3	417	121	1.37
4	317	89	1.62
5	353	100	1.83

6	326	95	1.80
7	285	80	2.21
8	257	74	2.07
9	244	75	2.02
10	240	76	2.73

Majority of the industries that make this yam peeling machine are either producing or manufacturing them through fabrication process, welding or casting and its parts are assembled with bolts or riveting of different sizes. IITA (2008). After assembling, the machine is always tested on load for a while to check its functionality. Therefore, in this investigation, the mass of the tubers was determined, in 10 replicates each, using the Camry electronic weighing scale; which has high sensitivity with a precision of 0.01 g. The size and shape were determined through the measurement of the tuber diameter, length, thickness or minor diameter in 10 replicates using a measuring tape and Vernier caliper. The surface area of each of the tuber was determined from the data obtained from the tuber dimensions.

4.0 CONCLUTION and RECOMMENDATION

When compared to other food crops, yam limitations are their bulkiness with some the tubers weighing over 5 kg and perishability with a moisture content as high as 90%. With a few exceptions, roots and tubers are produced by small-scale farmers using traditional tools However, the processing of the tubers, especially the peeling operation, is usually labour intensive and requires a high level of mechanization in order to meet the high demand for the products. The peeling operation has become a major bottleneck in tuber processing, especially for cassava and yam, because of the difference in their physical properties. Many research efforts have, nevertheless, been reported for mechanical peeling operations of the root and tuber crops. The new approach for improvement is the major drive in development and vibrant economy. This machine has been designed and fabricated with the use of locally available materials and manual operation. The, machine is simple, less bulky and effective. Yam loss and mechanical visible damage have been very minimal. Performance test has revealed that the efficiency of the machine is 90%. The machine is being powered by an electric motor and is suitable for Nigerian farmers to discourage the use of hands for peeling which results in getting low yield of yam tubers and likely sustained hand injuries. A simple tuber peeling machine has been designed and fabricated for peeling different kinds of tubers irrespective of size and shape. The machine was designed to operate at the speed range of 350−750 rpm and time range of 5−12 min based on the principle of surface scratching. The performance of the machine was determined with respect to the peeling efficiency and the depth of peel. The results showed that the peeling efficiency increased with increase in the shaft speed for all the tubers. Effective peeling was achieved for all the tubers since the amount of flesh loss and percent weight of peel were only 20% and 25% of the total weight of the tubers, respectively. The machine is easy to operate, and it is affordable for commercial and small tuber processors.

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