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DEVELOPMENT OF POTATO SLICING MACHINE

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ABSTRACT

Existing Slicers were reviewed and the potato slicing machine was developed based on appropriate technology. Locally available materials like mild steel, stainless steel, brass and aluminium alloy were used in the fabrication. The machine can be adjusted to slice potatoes to varying thickness, ranging from 4mm to 10mm. The capacity of the machine is 184kg of potato per hour and its performance efficiency is 68%. The production cost of the machine is Twenty five thousand two hundred and eighty two naira, fifty kobo only (₦25, 282.50).

KEY WORDS: Slicing, Machine, Machinability, Formability, Ductility, Torque.

INTRODUCTION

POTATO SLICING MACHINE

The use of machines in industries and homes is gradually taking over manual means of achieving work. While the industries are being automated and computerized, the homes are gradually turning into a mini-industry where different types of machines are used to do the home chores. The introduction of these machines in our homes has brought about effectiveness, efficiency and time and energy saving.

The potato slicing machine consists of a knife that is attached at its midpoint, to a rotating shaft. Two impacts are made by the knife on the potato in one complete rotation of the shaft. The shaft and the knife arrangement will be housed within the casing of the machine. One end of the shaft shall bear the knife while the other end will be connected to an electric motor that effects the rotation. The slicing unit will be rotating within a brass bushing.

STATEMENT OF THE PROBLEM

After careful study of local method of slicing potato it was observed that it involves a lot of physical labour and material wastes. There fore in order to improve the processing method and enhance its hygienic level, there is the need of mechanisation of the slicing method.

SIGNIFICANCE OF THE RESEARCH

1. The potato slicing machine is very important because of the relief it will bring to those who have hitherto used manual means to achieve their slicing.
2. This design would provide opportunity for easy part replacement without recourse to importation or total abandonment.
3. It's simplicity in operation will make it user-friendly.

AIM AND OBJECTIVES

- To fabricate a machine that will serve as import substitute to suite our peculiar situations.
- Using locally available materials and technology to produce an affordable machine to the local populace.
- To ease the problem of slicing, especially for commercial consumption outfits.

METHODOLOGY

The following methods were followed in the development of the machine.

i. Local methods of slicing potato were studied with a view to improving the methods.

ii. The information obtained was used to develop the machine. Selection of materials was based on suitability to operating conditions and availability.
iii. Production of the component was mainly through Casting, machining and welding.
iv. Performance testing and evaluation.

LITERATURE REVIEW

Slicing is the process of cutting through an item using sharp-edge object. Because of the importance of slicing of food items in our day-to-day life there is the need to employ the use of simple mechanical devices to ease the process.

Slicing machines are either manually or electrically powered. In any of the cases, the machine consists of a knife or set of knives arranged in a particular pattern to meet the need of the operation(s) it is intended to perform.

PRINCIPLES OF CUTTING

Cutting involves principally the application of shearing force on an item with the help of a knife. The knife could be stationary or on translational or on rotary motion. Slicing could be achieved in any of the following ways.

i) A knife moving against a stationary one while getting the food cut in-between.
ii) Two knives or cutting elements moving in opposite directions against one another and thereby getting the food item sliced in the process.
iii) A knife moving against a stationary part of the machine.

Mechanical food cutters used in modern kitchens basically consist of either rotating or reciprocating knives. In some instance, which is not very common, the knives are made stationary while food item travels against it and get sliced.

SYSTEM DESIGN AND MATERIAL SELECTION

SYSTEM DESIGN

The following design criteria were used:

i) Mechanical properties, which include strength, rigidity, toughness and ductility.
ii) Machinability or formability
iii) Availability of material
iv) Wear resistance of materials
v) Cost of materials

Transmission Shaft Design

The transmission shaft is stepped and carries the knife at one of its ends. It is driven by an electric motor at the other end, see fig. 3.1

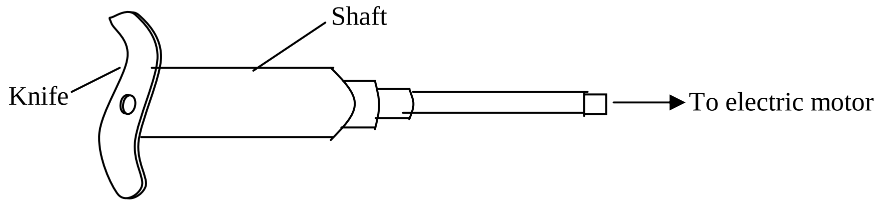


Fig. 3.1 Transmission shaft

The Determination of Shaft Diameter

In the determination of shaft diameter several factors are put into consideration. The shaft must have enough strength to overcome all stresses it shall be subjected to. Such stresses are due to the following forces.

- The reaction of potatoes, the effort of the hand and hopper cover which is also used to push the potatoes against the slicer plate.
- The reaction of the knife on the shaft

- The reaction of the slicer plate on the shaft
- The force exerted by knife to slice the potato.

Reaction of Cover Plate

The cover plate is used to push the potatoes against the slicer plate. Its weight affects the overall force acting on the shaft.

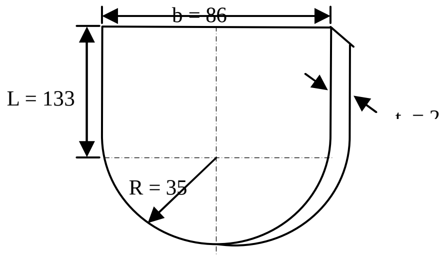


Fig. 3.2 Hopper cover plate

$$F_p = ma = \rho va$$

Where, F_P = weight of cover plate

ρ = density = 7800 kg/m^3 (Galvanised steel sheet)

v = volume = $\{(l \times b) + (\pi/2 \; R^2)\}t$

$$v = \{0.145 \times 0.15) + (\pi/2 \times 0.075^2)\} \; 0.002 = 6.12 \times 10^{-5} m^3$$

$$F_p = 7800 \times 6.12 \times 10^{-5} \times 9.81 = 4.68N$$

Reaction of Potatoes

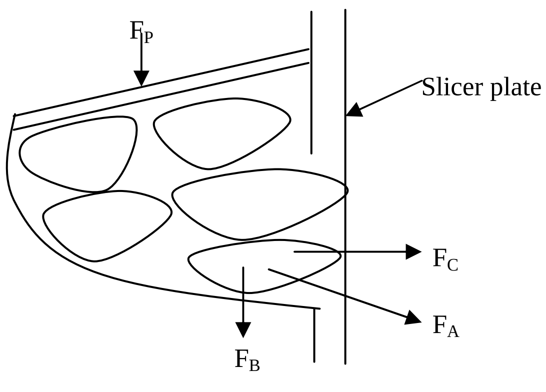
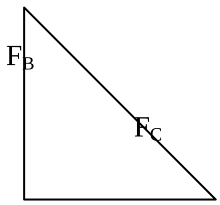


Fig. 3.3. Reaction of potatoes

Assuming the potatoes are pushed against the slicer plate at an angle of 45^0, the forces are as follows:



F_A = the force against slicer plate
F_B = vertical component of the force
F_C = horizontal component of the force

Average weight of potatoes in the hopper = 1.5kg (estimated)
F_{po} = m x a = 1.5 x 9.81 = 14.72N
The average human effort (F_h) = 200N

Assuming only half of this (100N) is applied to push the cover plate with the potatoes against the slicer plate.
Then, the total force against the slicer plate, F_v

$F_v = F_h + F_p + F_{po}$

Where F_h = Force exacted by hand
F_p = Reaction of cover plate
F_{po} = Reaction of potatoes
= 100 + 4.68 + 14.72
F_v = 119.40N

From the figure above the vertical force, $F_B = F_A \cos 45^0$
But $F_B = F_V$
F_B = 119.40 x Cos 45^0
= 62.7N

Average weight of blade (stainless steel)
Length, l = 0.22m, width, w = 0.035m, Thickness, t = 0.006m, density, ρ = 8000 kg/m^3, Volume V_b = 0.22 x 0.03 x 0.006 = 3.96 x $10^{-5}m^3$, m = σ x v = 8000 x 3.96 x 10^{-5} = 0.32 kg, F_b = 0.32 x 9.81 = 3.14N

Average weight of slicer plate (aluminium alloy)
m = density of Al x (vol. of plate + vol. of rim – vol. of slot in plate)
= $\rho[\pi r^2 t + \pi dwt - v_b]$
= 2800 [(π x 0.1152 x 0.006) + (π x 0.23 x 0.01 x 0.006) – 3.96 x 10-5]
= 0.71 kg
F_{sp} = 0.71 x 9.81 = 6.95N

Weight of Brass nut on the shaft

Mass = $\rho\ \pi/4\ [l_1 (r_1^2 - l_2^2) - l_2 (r_1^2 - r_3^2)]$
Where ρ = density of brass, l_1 = length of nut, l_2 = length of groove, r_1 = Outer radius of nut, r_2 = Inner radius of nut, r_3 = Inner radius of groove
Mass = 8530 π/4 [0.03 ($0.045^2 - 0.028^2$) – 0.006($0.045^2 - 0.037^2$)
= 0.223kg, therefore F_n = 2.2N

Force required to slice a potato, Fs = 80N was obtained through the use of Seidner Universal Testing Machine.
A knife was attached to the spindle of the machine. The loading lever was released until the knife cuts through the potato, the reading on the display was recorded.
The slicing torque $T_s = F_s$ x r
Where F_s = slicing force
r = distance from the point of application to the centre of knife
T_s = 80 x 100 = 8000Nmm

Total vertical force on slicer = $F_v + F_{sp}$ = 119.4 + 6.95 = 126.35N
From shear force and bending moment analysis, the moment M and Torque T are:
T = F_s x r = 80 x 100 = 8,000Nmm

$$M = \sqrt{(6949.25)^2 + (4400)}^2$$

= 8225Nmm
The shaft diameter d is

$$d^3 = 16/\pi\tau_{MAX} \sqrt{(C_m M)^2 + (C_t T)}^2$$

τ_{max} (allowable) = 40N/mm^2 per ASME code for shaft, Hall Jr. *et al* (1961).
C_m = 2 and C_t = 1.5 (appendix V)

$$d^3 = 1\frac{16}{\pi x 40}\sqrt{(2x8225)^2 + (1.5x8000)^2}$$

d = 13.7 mm

For operational convenience and its coupling with other component parts e.g nuts spring, key etc, the smallest diameter of the stepped shaft has been taken to be 20mm while the biggest diameter which carries the hub of the slicing unit is taken to be 35mm

Power requirement of the transmission shaft
The power was determined using the following formula

$$P = \frac{2\pi NT}{60}$$

Where, P = Power of motor, w
N = Speed of motor, rev/min.
T = Torque, Nm.
900 rev/min was selected for good slicing operation

$$\therefore \text{ Power, } P = \frac{2 \times \pi \times 900 \times 8}{60}$$

= 0.75398 kW
0.75 kW motor is selected.
3.1.2.1 Available kinetic energy of slicing unit

KE = ½ $I_T\omega^2$

Where I_T = total mass moment of inertia of the rotating unit.
ω = angular speed

COUPLING SELECTION
Universal joint is selected because of its suitability in connections were angular misalignment is unavoidable.

Bearing Design
In the calculation for load carrying capacity, oil flow rates, etc, the performance of bushes and split bearings may be regarded as identical and the choice between them in any given application will usually depend only on their relative convenience of manufacture, supply and assembly, (Welsh 1999).

Bushes are widely employed in general engineering practice particularly in the smaller size (up to say 50mm diameter) and for the less exacting load conditions. Often under relatively poor lubrication conditions.

Types of Lubrication
Based on the speed of operation and total weight of rotating unit (900rev/min and 1.6KN) hydro dynamic lubrication is recommended.

Journal Diameter
The journal being referred to in this case is the hub which forms the shaft rotating in the bearing. With reference to chart in appendix 2 it could be seen that the minimum recommended journal diameter is a little less than 50mm.

Reference to Appendix3 which is for hydrodynamic film-lubricated bearing could be made too. At 900 rev/min (15 rev/s) and the region of 1600N journal load the minimum recommended journal diameter is a little less than 50mm. The journal for potatoes slicing machine has been taken to be 55mm after taking the dimensions of associated components into consideration.

SELECTION OF MATERIALS
The material selection was based on the mechanical properties, operational condition, availability, and cost. The materials used are: mild steel for shaft and machine stand; aluminium alloy for slicer plate, and hub; stainless steel for the knife; and brass for bushing.

CONSTRUCTION, TESTING AND COST ANALYSIS
CONSTRUCTION OF COMPONENT PARTS
The machine components were produced through the use of conventional machine tools. The machines used include lathe machine, milling machine and drilling machine.

OPERATIONAL SEQUENCE
It involves the procedures to be followed in order to put the machine into use.

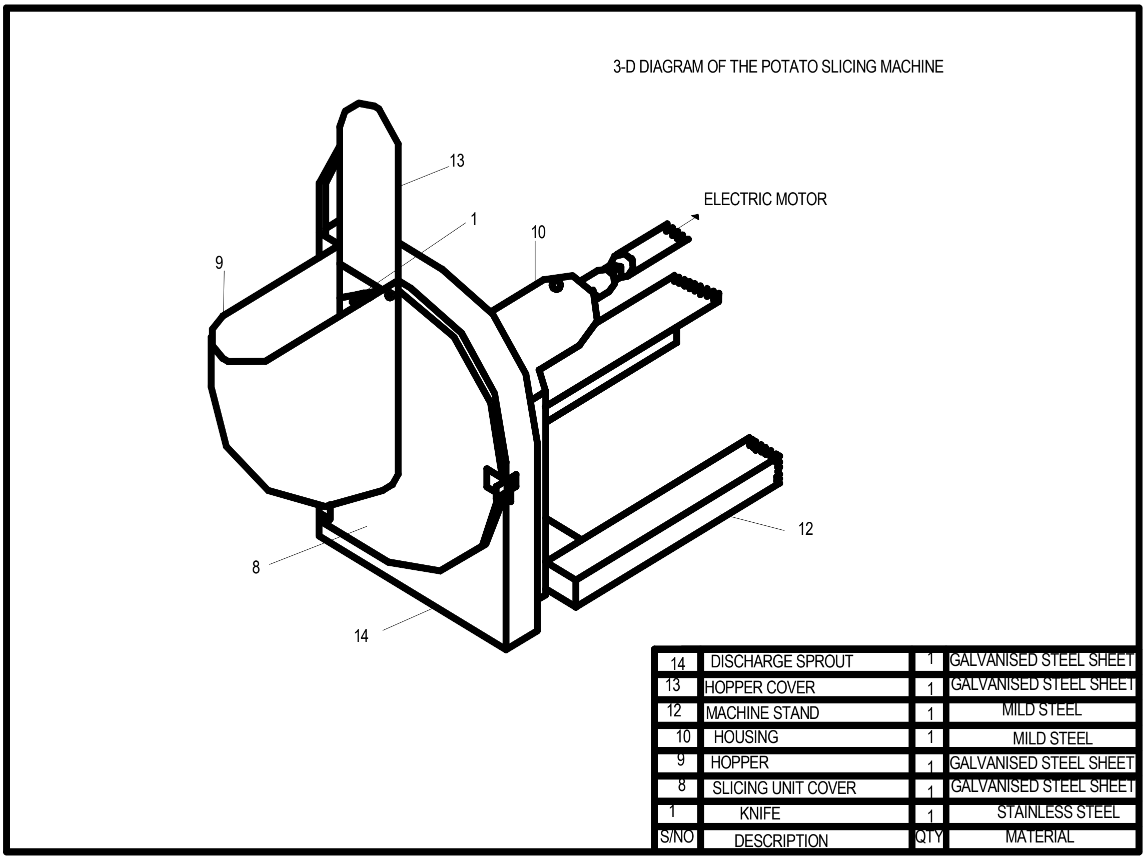
- i) Release the latch and open the cover/hoper
- ii) Using the brass and aluminium nuts adjust the knife in relation to slicer plate to set the aperture to the desired thickness of potato slice.
- iii) Close the cover and put the latch in place
- iv) Connect the electric motor to the power source
- v) Raise the cover plate, feed in the peeled potatoes into the hopper and replace the cover while slightly pressing it on the potatoes via the lever.
- vi) Put-on the power and immediately press the button of the capacitor and collect the sliced potatoes coming out of the sprout.

TESTING
On completion of the fabrication and assembly, the machine was tested for performance in terms of output and efficiency.

The output is measured in terms of mass processed per unit time.
The hopper of the machine was filled with tubers of potatoes and sliced. The time taken to slice the potatoes was noted.

After slicing, the potatoes were sorted into three groups: right thickness, wrong thickness and waste. Each of these were weighed and recorded.

This was done for each adjustment of blade for thickness. The efficiency was calculated based on those slices that satisfied the required thickness.



Output

Table 4.1 Machine Output

S/No.	Blade opening (mm)	Mass of slices (g)	Time taken (s)	Average loading times (s)	Total time taken (s)	mass/sec.	mass/min.
1	4	1200	16	12	28	42.9	2,574
2	7	1350	13	12	25	54	3,240
3	10	1250	10	12	22	56.8	3,408
						153.7	9,222

The average output of the machine is

9,222/3 = 3,074 g/min = 184Kg/hr

Efficiency

Table 4.2. Machine efficiency

S/N	Set thickness (mm)	Output Right thickness (g)	Output wrong thickness (g)	Wastage (g)	Total weight (g)
1	4	750	370	80	1200
2	7	900	386	64	1350
3	10	850	359	41	1250

Performance Efficiency of the machine = $\frac{weight\ of\ right\ size}{Total weight} \times 100$

Case 1 (4mm blade opening) = 62.5%
Case 2 (7mm blade opening) = 66.7%
Case 3 (10mm blade opening) = 68%

COST ANALYSIS

The total manufacturing cost will be the sum of the elemental costs.

Material cost	=	₦19, 400.00
Direct Labour costs	=	₦ 2,353.00
Overhead cost	=	₦ 3,529.50
		₦ 25,282.50

CONCLUSION

Potato slicing machine has been successfully developed and tested. The performance efficiency of the machine is 62.5% for 4mm blade opening, 66.7% for 7mm blade opening and 68% for 10mm opening. The total cost of producing the machine is Twenty Five Thousand, Two Hundred and Eighty Two thousand Naira only.

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