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Design of Power Transmission System and Dicer Blade of Potato Slicing Machine

DR. HTAY HTAY WIN[1], DR. MYINT THEIN[2], MG AUNT MIN THAW[3]
[1, 2, 3] Department of Mechanical Engineering, Mandalay Technological University

Abstract* - *Vegetable slicing machines are becoming more and more popular in this day and age. There are also so many types and sizes of various brand which can be found in local market for domestic use. But, there are small and medium fried potato businesses that are producing fried potato chips with a high capacity in Myanmar. Therefore, when the local fried potato businesses are slicing the raw potatoes, they use human workers for peeling and cutting. Even though the skillful workers are used, the processing time is still long. It should be faster for high production and also have human errors such as unequal thickness of potato chips, etc. To overcome the ineffective factors, the potato slicing machine which is intended for the local small and medium fried potato businesses will be an answer. In this research, the potato slicing machine is designed and constructed for the local fried potato business. The capacity of the machine is four kg/min. The 1.1kW motor is used for driving mechanism. The V-belt and V-grooved pulley are used for the power transmission system. The base frame material is cast iron and the cutting blade is also cast iron. The shaft material is mild steel. The efficiency of the machine is over 80%. The dimension is 40mm in length, 77mm in width and 96mm in height.

Indexed Terms -- Design, Power Transmission System, Blade, Potato, Slicing Machine

I. INTRODUCTION

Potato is a major food crop, grown in more than 100 countries in the world. According to Food Association Organization (FAO), potato is consumed by more than one billion people in the world. It is a high quality vegetable cum food crop and used in preparing more than 100 types of recipes. The protein content of potato has a high biological value than cereals and considered to be better than milk. Hence, potato is supplementing meat and milk products by lowering energy intake and also by reducing food cost.

Potato is a very rich source of starch. It contains about 80% water and 20% dry matter. Potato is popularly known as "the king of vegetable" in western countries, because it also contains phosphorus, calcium, iron and some vitamins. Apart from use of fresh potatoes for the purpose of making vegetables and gravy, they are dehydrated in the forms of slices, sticks, cubes or powder to impart better shelf life. Yet another popular use is to make wafers or chips that are why potato became popular food item not in home but also in hotels, canteens, restaurant, etc. During 1993-2020, demand for potato is expected to rise by 40 per cent worldwide. This indicates a clear opportunity to capture the huge domestic and international market of potato by producing value added potato product.

Potatoes are usually peeled and cut into different shapes like cubes, thin slices or rings to facilitate secondary processing and materials of construction, sharpness, rigidity of cutting tools and knife speed were effective parameters in cutting operations and strongly influences the energy required, production rate and final surface finish of the sliced potatoes. The quality of chips plays a vital role in the potato processing. Due to uneven thickness of the slices arising from improper tools a lot of wastage of vegetable is happening leading to loss of productivity and other miscellaneous damages to vegetable.

Therefore, potato slicing machines are becoming popular nowadays as an advanced processing method. Some of potato slicing machines are implemented as automated complete system which is set up with frying portion and seasoning portion.

II. POTATO SLICING MACHINE

The design and production of a machinery as part of the technological development of a country requires the acquisition of technology and development of capacity in three activities of design, fabrication, and engineering research and development. Engineering development and testing of machinery and equipment is a compliment to any design and manufacturing process. It is through such testing and subsequent development that operational problems of the machines produced locally can be investigated and solved and the quality of product maintained**.**

Potato Slicing Machines are simple and easy used units for making potato chips. They are available in a wide range of capacities and may operate to get the different forms of potato chips. But, it wisely needs to use specially engineered equipment such as designed blades. Main variations in quality are in casing design, rotating blade material, belt or chain quality, and drive equipment. The main purpose of potato slicing machine is produce potato chips uniformly and quickly.

The semi-automated potato slicing machine of 7kg/min capacity is design and developed. The main components of unit are

- Inlet hopper
- Discharge hopper
- Slicing wheel
- Power Transmission system

The design of various component of the unit is mainly based on the functional and structural strength. Different types of potato of size 5-7cm put into the hopper manually. Slicing wheel mounted on the shaft which is rotated by the electric motor with the help of belt pulley mechanism. When potatoes come in contact with cutting blade of slicing wheel and cut into thin slices of thickness 2mm approximately. Cutting involves principally the application of shearing force on potato with the help of a blade.

Hopper: The rectangular shape hollow box which is tapered from bottom is used for storage the potatoes. It has a circular opening at the bottom for passes the potatoes.

Slicing Wheel**:** A circular plate is used as a slicing wheel which has two cutting blades used to cut the potato. Blades are mounted on the wheel at an angle of 180 degree apart. The cutting edge of blade is sharp to reduce shearing force. It cuts two slices of potato in single revolution. The three dimensional drawing of rotating cutting disc is illustrated in Figure 1.

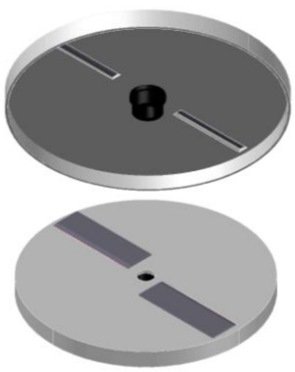

Figure 1. Isometric View of the Slicing Wheel

Power Transmission System: The main source of power transmission system is electric motor, one pulley is mounted on driven shaft. Driven shaft supported by two pedestal bearings on frame. Power is transmitted through electric motor by using V-belt form driving shaft to driven shaft. The components of power transmission system are Motor, Pulley V-belt, designed shaft and main frame.

III. THEORY BACKGROUND AND METHODS

A. Velocity Ratio of a Belt Drive

$$\textit{Velocity ratio} = \frac{N_2}{N_1} = \frac{d_1}{d_2} \qquad (1)$$

The peripheral velocity of the belt on the driving pulley,

$$v_1 = \frac{\pi d_1 N_1}{60} \qquad (2)$$

The peripheral velocity of the belt on the driven pulley,

$$v_2 = \frac{\pi d_2 N_2}{60} \qquad (3)$$

B. Length of an Open Belt

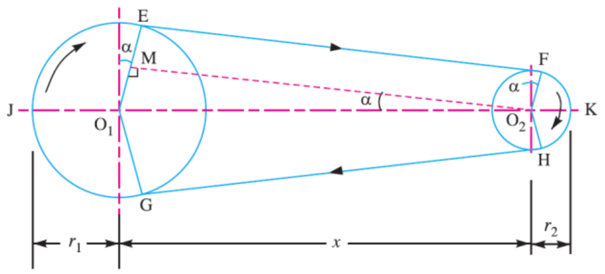

Figure 2. Open Belt Drive

The length of the belt L = Arc GJE+ EF+ Arc FKH+ HG

= 2 (Arc JE+ EF+ Arc FK)

$$= 2\left[\frac{\pi}{2}(r_1+r_2)+\alpha(r_1-r_2)+x-\frac{(r_1-r_2)^2}{2x}\right]$$

$$= \pi(r_1+r_2)+2\alpha(r_1-r_2)+2x-\frac{(r_1-r_2)^2}{x}$$

$$L = \frac{\pi}{2}(d_1+d_2)+2x+\frac{(d_1-d_2)^2}{4x} \qquad (4)$$

$$\text{Angle of contact } \theta = (180-2\alpha)\frac{\pi}{180}\text{ rad} \qquad (5)$$

C. Power Transmitted by a Belt

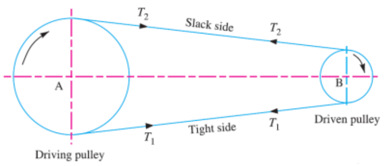

Figure 3. Power Transmission by a Belt

work done per second = $\left(T_1\text{-}T_2\right)v$ Nm/s (6)

Power transmitted = $\left(T_1\text{-}T_2\right)v$ Watt (7)

Torque exerted on the driving pulley = $\left(T_1\text{-}T_2\right)r_1$ (8)

Torque exerted on the driven pulley = $\left(T_1\text{-}T_2\right)r_2$ (9)

Cutting Force of the Blade

$F = ma,\ a = r\,\omega^2$

$F = mr\,\omega^2$ (10)

D. Stresses in a Flywheel Rim

The tensile stress in the rim due to the centrifugal force, assuming that the rim is unstrained by the arms, is determined in a similar way as a thin cylinder subjected to internal pressure.

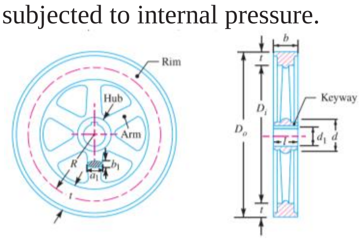

Figure 4. Flywheel

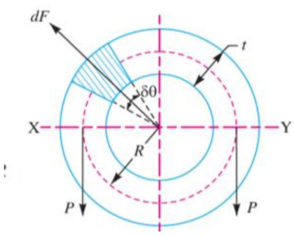

Figure 5. Cross-section of a Flywheel Rim

Centrifugal force on the element,

$dF = dm.\omega^2.R = \rho.A.R.\delta\theta.\omega^2.R$

Total vertical bursting force across the rim diameter

This vertical force is resisted by a force of 2P, such that

$= \rho.A.R^2.\omega^2\int_0^{\pi}\sin\theta d\theta$

$= \rho.A.R^2.\omega^2[-\cos\theta]_0^{\pi} = 2\rho.A.R^2.\omega^2$

$2P = 2\sigma_t \times A$

$\sigma_t = \rho.R^2.\omega^2 = \rho.v^2 a$ (11)

E. Tensile Bending Stress caused by Restraint of the Arms

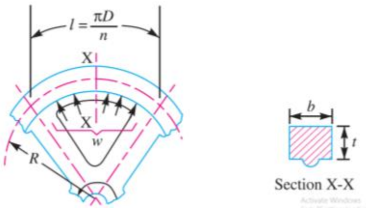

Figure 6. Portion of Flywheel

Bending stress,

$$\sigma_b = \frac{M}{Z} = \frac{b.t.\rho.\omega^2.R}{12}\left[\frac{2\pi R}{n}\right]^2 \times \frac{6}{b \times t^2} \quad (12)$$

$$= \frac{19.74\rho.\omega^2.R^3}{n^2.t} = \frac{19.74\rho.v^2.R}{n^2.t}$$

Now total stress in the rim,

$\sigma = \sigma_t + \sigma_b$ (13)

F. Stresses in Flywheel Arms

The following stresses are induced in the arms of a flywheel.

(a) Tensile stress due to centrifugal force acting on the rim.

(b)Bending stress due to the torque transmitted from the rim to the shaft or from the shaft to the rim.

(c)Shrinkage stresses due to unequal rate of cooling of casting.

(a)Tensile Stress due to the Centrifugal Force

Tensile stress in the arms,

$\sigma_{t1} = \frac{3}{4}\sigma_t = \frac{3}{4}\rho \times v^2$ (14)

(b) Bending Stress due to the Torque Transmitted

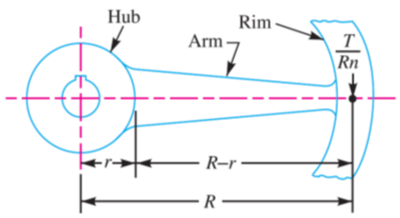

Figure 7. Components of Pulley

Bending Stress in arms

$\sigma_{b1} = \frac{M}{Z} = \frac{T}{R.n.Z}(R\text{-}r)$ (15)

Total tensile stress in the arms at the hub end,

$\sigma = \sigma_{t1} + \sigma_{b1}$ (16)

The bending stress due to the belt tensions,

$$\sigma_{b2} = \frac{(T_1 - T_2)(R - r)}{\frac{n}{2} \times Z} \quad (17)$$

Total bending stress in the arms at the hub end

$$\sigma_b = \sigma_{b1} + \sigma_{b2} \quad (18)$$

The total tensile stress in the arms at the hub end

$$\sigma = \sigma_{t1} + \sigma_{b1} + \sigma_{b2} \quad (19)$$

IV. DESIGN CALCULATION OF POWER TRANSMISSION SYSTEM

$$VR = \frac{d_2}{d_1} = \frac{235}{75} = 3$$

$$\frac{d_2}{d_1} = \frac{N_1}{N_2}$$

$$N_2 = \frac{N_1}{3} = \frac{1400}{3} = 466.67\text{rpm} = 467\text{rpm}$$

15g of potato per single revolution, therefore, capacity is 7kg/min.

The length of the belt

$$L = 2(400) + \frac{\pi}{2}(235 + 75) + \frac{(235-75)^2}{4(400)} = 1302.95\text{mm}$$

Table1. Result data of Transmission System

Sr No	Parameter	Symbol	Value	Unit
1	The Tight Side Belt Tension	T_1	271.9	N
2	The slack side Belt Tension	T_2	21.7	N
3	Required Power	P_{req}	485.12	Watt
4	Cutting Force of the Blade	F	1.6	kN
5	Bending Stress of Flywheel Rim	σ_t	0.089	MPa
6	Tensile Bending Stress of Restraint of the Arms	σ_b	0.86	MPa
7	Total Stress in the Rim	σ	0.95	MPa
8	Bending Stress due to Torque	σ_{b1}	29.4	MPa
9	Bending Stress due to Belt Tension	σ_{b2}	76.8	MPa
10	Total Tensile Stress in the Arms	σ	106.267	MPa

V. CONSTRUCTION AND PERFORMANCE TESTING

(i) Preparing the Required Equipment

Before construction, it is important to arrange the setting to start the process. It also needs to think what kind of materials is used for which portion, which method is used to join the raw materials, and how to assemble the whole system.

Motor Raw Materials and Equipment Frame

Figure 8. Preparation Process

Figure 8 shows Preparation process to make potato slicing machine by using local materials.

Figure 9 Potato Slicing Machine after Painting

(ii) Performance Testing of Potato Slicing Machine

A simple power operated machine for slicing of potatoes was fabricated using low cost locally available materials. It consists of solid round disc with two blades. Potato slices are made by the impact shearing force. Three different weights of raw potatoes are sliced for evaluating the machine performance. At first, 330g of raw potatoes are put into the slicing machine through the inlet hopper.

The raw potatoes are sliced within seven seconds. Therefore, the capacity of machine for first testing is 2.8 kg/min while the theoretical result is seven kg/min. The second testing is carried out with the raw potatoes weight of 390g in six seconds. In this time, the capacity increases to 3.9kg/min. The last testing is conducted within 5 seconds for slicing the raw potatoes weight of 360g and capacity is 4.3kg/min. Therefore, the capacity increases more and more with the increase of speed of pushing the potatoes into the slicing blade. It mainly depends on the feeding system of machine.

Table 2. Result Data of Performance Test

Sr No	Weight (g)	Time (s)	Capacity (kg/min Theoretical	Capacity (kg/min) Experime nt	Efficien cy
1	330	7	7	2.8	85%
2	345	5	7	4.1	79%
3	350	6	7	3.5	82%
4	360	5	7	4.3	88%
5	360	6	7	3.9	83%

VI. CONCLUSION AND DISSCUSION

In conclusion, the efficiency of the machine is over 80% according to the performance data result. The efficiency of the machine is changing with the pushing force of potatoes by feeding mechanism. The elapsed time is also changing with the feeding mechanism. Taking average value, the capacity of the machine is 3.5 kg/min.

The results and fabrication of this research has shown possibility of manufacturing a relatively cheap, easy to use and reliable machine for slicing vegetable which reduces human effort. The machine was safely operated, but it requires power for just the electric motor, thus the production of fumes is entirely eliminated.

The potato slices obtained can be used with slight additions as potato chips after drying which is a value added product and can be sold to obtain more profits. This machine has lot of scope for future. The maximum efficiency of the machine is 88%.

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