DESIGN CONSIDERATION AND METHODOLOGY FOR FABRICATION OF ELECTRICALLY OPERATED POTATO PEELING APPARATUS

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ABSTRACT
The design of the machine was based on the development and modification of the peeling tool of previous potato peeling machines and the peeling principle. Assumptions and references are taken for designing the Potato peeling machine is based on market research and survey. The design calculation of Potato peeling machine is done. For designing the Potato peeling machine, various design parameters are required such as speed of drum, design of pulley and belt, design of transmission shaft, etc. This paper shows all calculation for mechanized potato peeler.

Keywords: Design of V-Belt, Design of Pulley, Design of transmission shaft

I. INTRODUCTION

Potato is the only crop that can make an impact on the highly populated Indian nation for feeding the people. Potato (Solanum Tuberosum L.), the third most important staple crop in the world, is a widely consumed vegetable in India. Potato is a very rich source of starch. 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 hence that’s why potato became popular food item not in home but also in hotels, canteens, restaurant, etc. Hence peeling method of potato is point of interest.

The method of peeling is always key factor which decide its suitability for further utilization. compared the influence of peeling method on its composition of Peeling Potato [11]. Among the different peeling methods, mechanical peeling can attract the customer satisfaction because of its benefits. The mechanical peeling becomes so popular because they produced fresh peeled product. As view of customer became more important for food processing industries hence more researchers have showed interest towards mechanical peeling process.

The study of mechanical as well as physical properties of fruits and vegetable are very important. It can increase performance of food processor particularly peeler. Increasing the processing efficiency and decreasing losses of fruits and vegetables is a matter of interest for the food industries. Although each method has own benefits and limitations, but mechanical methods are preferred because of keeping edible portions of produce fresh and damage free [9].

Using abrasive or cutting tools are the most common ways for mechanical peeling of fruits and vegetables. The result of applying abrasive peelers is evenly peeling regardless uneven surfaces or irregular shape of produce. Despite high peeling production rate as the main advantage, loading sensitivity and high waste of edible portions are the main limitations. Peelers which apply cutting tools are lesser common than abrasive ones. Knifes, blades, and rotary cutters are the most common cutting tools for same. Rotary cutters are the only flexible one among cutting tools showing good access to different parts of uneven surfaces[8]. But during the process of mechanical abrasive peeling product is subjected to unwanted mechanical load and stresses. This unwanted load such as tension, compression, bending, torsion load, vibration, impact and so on is the main reason for bruising of fruits and vegetables during post harvest operation.[11].

Reducing harmful effect of unwanted loads and improving the effectiveness of unwanted loads can be achieved by knowledge of mechanical properties.
(shear strength, forces, and toughness) of the product and design parameters. Hence design consideration is very much important for positive performances. The requirement to develop new product and tool for peeling that can be mechanized and automated has led to versatile current peeling methods, machinery and equipments.

2. DESIGN CONSIDERATION

The following were put into consideration while designing the machine.
 i. Volume of production, kg/min.
 ii. Design analysis.
 iii. Material selection.
 iv. Fabrication/component analysis.
 v. Operation analysis.
 vi. Maintenance.
 vii. Cost Effectiveness
 viii. Able to peel different varieties, shapes and sizes of cassava;
 ix. Made from readily available materials;
 x. Reduce labour input in traditional method of peeling; and
 xi. High capacity compared to manual operations.

3. RESEARCH METHODOLOGY AND DESIGN PROCESS

3.1. Determination of power required to turn the abrasive lower plate.

The power required to peel the potato is nothing but amount of power required to turn the lower plate which was determined using the expression given by Rajput (2013) as shown in Equation (1).

\[ \text{Torque required} = F \times \text{radial distance} \]
\[ = (m \times g) \times r \]  \…………..(1)

Where:
\[ F = \text{force in N} \]
\[ T = \text{Torque in Nm} \]
\[ r = \text{Radius of the drum in m} \]
\[ g = \text{Acceleration due to gravity} \]
\[ N = \text{RPM of electric motor.} \]

\[ m = \text{mass of potato + mass of lower plate} \]

Based on design power, Electric motor is recommended by considering factor of safety.

3.2. Design of pulley and belt.

3.2.1. Determination of larger pulley diameter (Driven pulley)

Based on design power P, Belt is selected from design data book. Similarly diameter of smaller pulley is recommended with velocity ratio in the range between 3-5.

For single Belt Transmission:- one driver pulley and one driven pulley
\[ D_1 \times N_1 = D_2 \times N_2 \]

Where,
\[ D_1 = \text{Diameter of driving pulley in mm} \]
\[ N_1 = \text{Revolutions of driving pulley in rpm} \]
\[ D_2 = \text{Diameter of driven pulley in mm} \]
\[ N_2 = \text{Revolution of driven pulley in rpm} \]

Hence diameter of driven pulley can easily calculated using the relation
\[ \frac{N_1}{N_2} = \frac{D_2}{D_1} \]  \………….. (2)

3.2.2. Determination of approximate length of a V-belt

This is the length of the belt between the electric motor pulley and the peeling drum pulley.

\[ L = 2C + \frac{\pi(D_1+D_2)}{2} + \frac{(D_2-D_1)^2}{4C} \]  \………….. (3)

Where:
\[ L = \text{the length of the belt,} \]
C = center distance of the belt and D1 and D2 are diameters of electric motor and peeling drum pulleys
From Table – XV – 10 (DDB)
C = D1 + D2

3.2.3 Determination of angle of wrap for both pulley.

Angle of wrap is the external angle that the point of contact of the belt on each of the pulleys makes with the center of the pulley.

The angle of wrap for the driving pulley (\(\theta_1\)) and driven pulleys (\(\theta_2\)) determined with Equation (4) and (5) as expressed by Khurmi and Gupta (2012);

\[
\text{Angle of wrap of open belt in rad } \theta_1 = 180 + 2 \sin^{-1} \left( \frac{R - r}{c} \right) \times \frac{\pi}{180} \quad \text{.........(4)}
\]

\[
\theta_2 = 180 - 2 \sin^{-1} \left( \frac{R - r}{c} \right) \times \frac{\pi}{180} \quad \text{.........(5)}
\]

3.2.4. Determination of belt tension

The belt tension is the pulling force that arises as a result of the movement of the belt over the pulleys. The tension on the slack and tight belt was determined with Equation (6) as given by Kurmi and Gupta (2012);

\[
P = (T_1 - T_2) V \quad \text{.........................(6)}
\]

Where

\[
T_1 \text{ and } T_2 \text{ are tensions on the tight and slack sides respectively (N)}
\]

\[
V = \text{belt speed (m/s)} = \frac{\pi \times N \times D_1}{60}
\]

Using belt ratio for an open belt

\[
2.3 \log \left( \frac{T_1}{T_2} \right) = \mu \theta \quad \text{.........................(7)}
\]

Where

\[
\mu = \text{coefficient of friction between belt and pulley.}
\]

For C.I pulley and rubber belt, \(\mu = 0.30 \) ( Khurmi and Gupta)

Lesser value of belt tension ratio will govern the design.

3.2.5. Determination of number of strands.

Number of strands means number of belt required for drive system. The values will be decided by equation (8)

\[
\text{Number of strand } = \frac{\text{Design power}}{\text{Power rating per belt}} \quad \text{.........(8)}
\]

Power rating per belt, Watt is given by equation (9) from DDB From table – XV – 9 (DDB)

\[
(Power/Belt) = (F_W - F_C) \left[ \frac{\left[e^{(\mu \theta / \sin(A/2))} - 1\right]}{\left[e^{(\mu \theta / \sin(A/2))}\right]} \right] V_p
\]

Where,

\[
F_W = \text{Working load, N}
\]

\[
F_C = \text{Centrifugal Tension, N}
\]

\[
k_c = \text{Centrifugal Tension factor}
\]

From Table – XV – 8 (DDB)

\[
\mu = \text{Co-efficient of friction}
\]

From Table – XV – 10 (DDB)

\[
\alpha = \text{Cone angle} = 34^\circ
\]

3.2.6. Determination of total load on belt and pulley in dynamic condition.

The load on belt and pulley during dynamic condition is summation of initial tension, centrifugal force and maximum bending load on pulley. It is expressed by equation (10) from B.D. Shivalkar

From Table – XV – 9 (DDB)

\[
\text{Maximum total force, } F_b = T_1 + F_C + F_{b\text{max}} \quad \text{.........(10)}
\]

From Table – XV – 1 (DDB)

Initial Tension, \(T_i\), N is given by

\[
2(T_i)^{0.5} = (T_1)^{0.5} + (T_2)^{0.5}
\]

\[
F_C = \text{Centrifugal Tension in N}
\]

\[
k_c = \text{(} V_p/5 \text{)}^2
\]

\[
F_{b\text{max}} = k_b / D_1
\]

Where, \(k_b\) – Bending stress factor and \(D_1\) – smaller Pulley diameter in mm

From table – XV – 8 (DDB)

\[
k_b = 17.6 \times 10^3
\]

3.2.7 Design of smaller and larger Pulley

From table – XV – 7 (DDB)
Material of pulley – cast iron
Type of construction
Diameter below 150 mm – Web construction
Diameter above 150 mm – Arm construction

So, based on pulley diameter, therefore construction will be decided.

From Table – XV – 11 (DDB)

For Web construction

Example: Select Groove section – A

\[ \begin{align*}
    l_p & = 11 \text{ mm} \\
    h & = 8.7 \text{ mm} \\
    e & = 15 \pm 0.3 \text{ mm} \\
    D_p & = 75 \text{ mm} \\
    \alpha & = 34^\circ \\
\end{align*} \]

Width of pulley, \( w = (n-1) e + 2f \)
where, \( n \) – number of belt = 1

For Arm Construction

Number of arms
Diameter of hub, \( D_h = 1.5D_s + 25 \)
Length of hub, \( L_h = 1.5D_s \)

4. DETERMINATION OF PEELING DRUM SHAFT SIZE

Components mounted or integrated with shafts causes various stresses in the shaft design. The design analysis is to obtain shaft diameter that will ensure failure-free operation of the shaft under different loading condition. The diameter of solid shaft was determined as given by Rajput (2013) in Equation (11);

\[ d^3 = \frac{16}{nSs} \times \sqrt{(KbMb)^2 + (KtMt)^2} \] ………………(11)

Where

\( Mt = \) torsional force, Nm
\( Kb = \) combine shock and fatigue factor applied to bending moment = 1.5 (Khurmi and Gupta, 2012).
\( Kt = \) combine shock and fatigue factor applied to torsional moment = 1.0 (Khurmi and Gupta, 2012).
\( Ss = \) allowable shear stress for shaft with keyway is 35-40 MN/m² (Khurma and Gupta, 2012)
\( Mb = \) bending moment, Nm

4.1 Calculation of Bending Moment

Now considering the larger pulley is mounted on the drive shaft at some distance away from fixed end and shaft is cantilever type. On the pulley the self acted in downward direction and tension forces acted in horizontal direction.

On Vertical Plane

The loads acting on the shaft in vertical plane are the summation of weight of driven pulley and weight of potatoes.

\[ F_v = W_{dp} + W_p \]

Where

\( W_{dp} = \) weight of the pulley
\( W_p = \) average weight of the potatoes

\[ F_v = W_{dp} + W_p \]

Force Diagram in Vertical Plane

Bending moment in Vertical Plane is given by equation

\[ M_V = F_v \times b \]

Horizontal Plane

The load acting on shaft in horizontal plane are Tension on tight and slack side (T1+T2) only.
Fh = T1+T2 shown below

**Force Diagram in Vertical Plane**

Bending moment On Horizontal Plane

\[ M_H = F_h \times b \]

So, Resultant Bending Moment, \( M_R \)

\[ M_R = (M_V^2 + M_H^2)^{0.5} \]

\[ \vspace{0.5cm} \]

**4.2 Calculation of bending Moment**

Torque transmitted from driving pulley to driven pulley is nothing but design torque calculated as given by Rajput (2013)

\[ M_t = \frac{95509}{N} \], Nm………………..(13)

Where:

P = power of an electric motor in watt,

N = speed of rotation of selected electric motor pulley in rev/sec

The schematic diagram of Potato peeling machine is shown in figure 1 and characteristic details are given in table 1

**5. RESULT AND CONCLUSION**

The designs of various parts and parameters are taken into consideration and above values obtained successfully. These values are implemented of fabrication of same machine which is working successfully

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**Fig 1: Schematic diagram of potato peeler**

**Table 1: Technical characteristic of machine**

<table>
<thead>
<tr>
<th>Sr. no</th>
<th>Description</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Larger pulley diameter</td>
<td>250 mm</td>
</tr>
<tr>
<td>2</td>
<td>Smaller Pulley diameter</td>
<td>75 mm</td>
</tr>
<tr>
<td>3</td>
<td>Power required</td>
<td>0.8 Kw</td>
</tr>
<tr>
<td>4</td>
<td>Length of belt</td>
<td>1200mm</td>
</tr>
<tr>
<td>5</td>
<td>Shaft diameter</td>
<td>25 mm</td>
</tr>
<tr>
<td>6</td>
<td>Capacity of machine</td>
<td>10-15 kg</td>
</tr>
</tbody>
</table>

**REFERENCES**


