Design, Experimentation and Performance Testing of Innovative Potato Processor

Mr. Vijay P Talodhikar [1] Mr.P.A Potdukhe[2]
[1]*Research scholar, Rajiv Gandhi College of Engineering. Research & Technology. Chandrapur(M.S),442402*
[2.]*Professor in Rajiv Gandhi College of Engineering. Research & Technology.Chandrapur,(M.S), ,442402*
Correspondence .[1]*v.talodhikar@gmail.com., Mobile no.-8308831359,*

Abstract-The development of the potato peeling machine was based on the modification of previous potato peeler and the peeling principle. Assumptions and references are taken for designing the Potato peeling machine is based on market research and survey . literature survey reveal that food processing industries in India have launched massive expansion/ modernization programs with a view to adopt modern technology which is energy efficient, cost effective and environment friendly 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 modernizeds potato peeler. This proposed updation in potato peeler could alleviate the problems faced by conventional and traditional potato peeling methods which helps in boosting the processing and export of potato products.

Keywords: Potato peeler, Design of Belt, Design of larger and smaller Pulleys, Design of shaft

1. INTRODUCTION

Potato is the only crop that can make an impact on the highly populated Indian nation for feeding the people. The latest statistics published by World Potato Statistics | PotatoPro a one third of all potatoes is harvested in China and India. Globally the estimated potato production in year 2017 is 388,191,000 tonnes. The potato production in India stood second at 48,605,000 tonnes whereas China stood first with 99,205,600 tonnes. . As stated in report of Horticulture Division, Ministry of Agriculture, Government of India, New Delhi, the area and production of potato in the country during 2017-18 is estimated around 21.51 lakhs hactores and 485.29 lakhs MT respectively. 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..Fig 1 shows major constituent of Potato

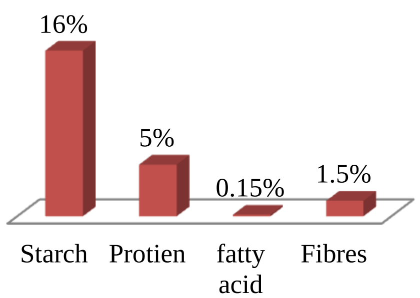

fIg. 1 The Major Constituent of potato

A ses occurs due to poor handling and lack of storage problem. The biggest opportunity before Indian is that there is enormous scope for increasing consumption of potato in almost all sectors including the rural sector which remains fairly unexposed to the multi-faceted use of potato. Food processing industries in India have launched massive expansion/ modernization programs with a view to adopt modern technology which is energy efficient, cost effective and environment friendly.

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.

Since different type of fruits have different shapes and sizes hence different machine are to process them. Peeling of food or vegetable is usually carried out by particular machine. [1]. Hence development in is very much required to promote timely large scale processing and to overcome unhygienic environment problems which resulted in the development of various types of peeling machines.

The method of peeling always play vital role which decide its suitability for further and future utilization. compared the influence of peeling method on its composition of Peeling Potato [5]. Potato peeling by hand or tool is always tedious and time consuming process as shown in fig. 2.

Fig.2: Potato peeling by hand tool

Among the different peeling methods, mechanical peeling can attract the customer satisfaction because of its benefits. The abrasive 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 [2].

Using abrasive or cutting tools are the most common ways for mechanical peeling of fruits and vegetables. The result of applying abrasives on inside surface of peelers produce even peeling regardless uneven surfaces or irregular shape of produce.. 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 [3]. 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.

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.

- Volume of production, kg/min.
- Design analysis.
- Material selection.
- Fabrication/component analysis.
- Operation analysis.
- Maintenance.
- Cost Effectiveness
- Able to peel different varieties, shapes and sizes of potato
- Made from readily available materials
- Reduce labour input in traditional method of peeling and
- 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 eq. "(1)".

But Torque required = F × radial distance

= (m × g) × r …………..(1)

Where:

F = force in N

T = Torque in Nm

r = Radius of the drum in m

g= Acceleration due to gravity

N= RPM of electric motor.

m= 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

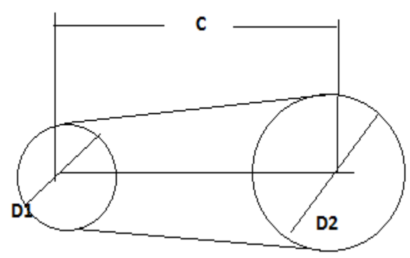

Fig.3 Schematic diagram of Pulley

Based on design power P, Selection of belt is done from design data book. The diameter of smaller pulley is recommended with velocity ratio in the range between 3 to 5.The Belt pulley arrangement is shown in Fig 3.

For single Belt Transmission:-one driver pulley and one driven pulley

D1×N1=D2×N2

Where,

D1 = Diameter of driving pulley in mm

N1 = Revolutions of driving pulley in rpm

D2 = Diameter of driven pulley in mm

N2 = Revolution of driven pulley in rpm

Hence diameter of driven pulley can easily calculated using the "eq.(2)".

$\frac{N1}{N2} = \frac{D2}{D1}$…………….. …………………….. (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 is given by "eq.(3)".

$L = 2C + \frac{\pi(D1+D2)}{2} + \frac{(D2-D1)^2}{4C}$ …………….. (3)

Where:

L = 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)
$C = D_1+D_2$

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 "eq. (4)" and "eq.(5)" as expressed by Khurmi and Gupta (2012).

Angle of wrap of open belt in rad

$\theta 1 = 180+2\sin^{-1}(\frac{R-r}{C}) \times \frac{\pi}{180}$ ………………(4)

$\theta 2 = 180-2\sin^{-1}(\frac{R-r}{C}) \times \frac{\pi}{180}$ ……………….…(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 "eq. (6)" as given by Kurmi and Gupta (2012).

$P=(T1-T2)V$ ………………………………..(6)

Where

P = belt power (W)

T1 and T2 are tensions on the tight and slack sides respectively (N

V = belt speed (m/s) = $\frac{\pi\times N\times D1}{60}$

Using belt ratio for an open belt

$2.3\log_e\left(\frac{T1}{T2}\right) = \mu\theta$…………………………….....(7)

Where

μ = coefficient of friction between belt and pulley.

For C.I pulley and rubber belt, μ= 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 "eq.(8)".

$\text{Number of strand} = \frac{\text{Design power}}{\text{Power rating per belt}}$……….(8)

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

$(\text{Power/Belt})=(F_W-F_C)\{[e^{(\mu\theta/\sin(\alpha/2))} - 1]/[e^{(\mu\theta/\sin(\alpha/2))}]\}V_P$ ……………………………………………………(9)

Where,

F_W = Working load, N

$F_W = w^2$

F_C = Centrifugal Tension, N

$F_C = k_c (V_P/5)^2$

k_c = Centrifugal Tension factor

From Table – XV – 8 (DDB)

μ = Co-efficient of friction

From Table – XV – 10 (DDB)

μ = 0.3

α = Cone angle = 34°

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 "eq .(10)" from B.D. Shivalkar.

From Table – XV – 9 (DDB)

Maximum total force, $F_1=T_i+F_C+F_{bmax}$…...............(10)

From Table – XV – 1 (DDB)

Initial Tension, T_i , N is given by $2(Ti)^{0.5} = (T1)^{0.5} + (T2)^{0.5}$

Fc = Centrifugal Tension in N

$F_C = k_c (V_P/5)^2$

Maximum bending load on smaller pulley.

$F_{bmax} = k_b / D1$

Where, k_b – Bending stress factor and

D1 – 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

l_p – 11 mm	b – 3.3 mm
h – 8.7 mm	e – 15±0.3 mm
D_P – 75 mm	α – 34°

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

Accessories mounted on 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 "eq(11)".

$d^3 = \frac{16}{\pi Ss} \times \sqrt{(KbMb)^2 + (KtMt)^2}$…………….…(11)

Where

Mt = torsional force, Nm

Kb = combine shock and fatigue factor applied to bending moment = 1.5 (Khurmi and Gupta, 2012).

Kt = total shock and fatigue index 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

Sr. no	Description	Specification
1	Larger pulley diameter	250 mm
2	Smaller Pulley diameter	75 mm
3	Power required	0.8 Kw
4	Length of belt	1200mm
5	Shaft diameter	30 mm
6	Capacity of machine	10-15 kg

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 shown in figure 4.

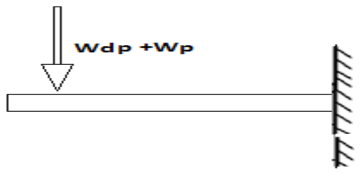

Fig 4 Force diagram of vertical plane

Fv = Wdp + Wp

Where

Wdp = Weight of the pulley

Wp = Average weight of

Bending moment in Vertical Plane is given by equation

$M_V = Fv \times b$

Horizontal Plane

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

Fh = T1+T2 shown in figure 5

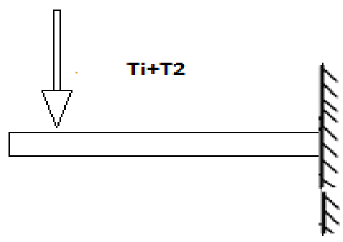

Fig 5 :Force diagram in horizontal plane

Bending moment On Horizontal Plane

$M_H = Fh \times b$

So, Resultant Bending Moment, M_R

$M_b = (M_V^2+M_H^2)^{0.5}$ …………………………..(12)

4.2 Calculation of bending Moment

Torque transmitted from driving pulley to driven pulley is nothing but design torque calculated as given by "eq(13)..

$Mt = \frac{95509}{N}$, Nm……………………………….(13)

Where

P = power of an electric motor in watt,

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

After making a design calculation table 1 shows the characteristic details.

Table 1: Technical characteristic of machine

The prototype fabricated Potato peeling machine is shown in figure 6 .

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Fig.6 Prototype Potato Peeler

The three dimensional view and top view of processor are shown in cad model figure 7 while peeled potato

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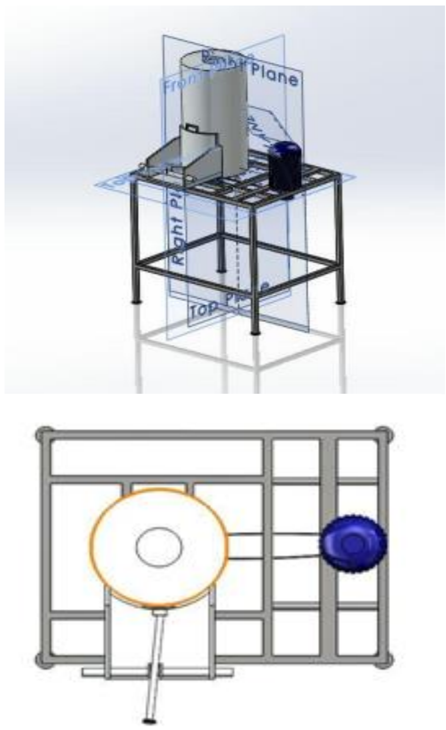

Fig 7: Cad Model of potato peeler

Fig: 8 Peeled Potato

Fig 9 Closed view of Peeled Potato

5. RESULT AND CONCLUSION

The designs of various parts and parameters are taken into consideration and values shown in table 1 are obtained successfully. These values are implemented for fabrication of same machine which is working successfully. From observation table it is cleared that at speed of 420 rpm, peeling efficiency was high and flesh loss is less.

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Appendix A:

Calculation and Farmulae:

1. Peeling Efficiency = $\frac{\text{Weight of peel removed by machine}}{\text{Total weight of peels}} \times 100$

$$\frac{W6 - W5}{W6} \times 100$$

2. % Weight of peels =$\frac{\text{Weight of peels}}{\text{Weight of unpeeled potato}} \times 100$

3. % Flesh loss of potato = $\frac{\text{Weight of the flesh removing by machine by machine}}{\text{Total flesh weight}}$

$$= \frac{W7 - W4}{W7} \times 100$$

Where,
W1 = Weight of unpeeled potato
W2 = Weight of potato after peeling with machine
W3 = Weigh of peels + flesh
W4 = Weight of potato after removing peels manuals
W5 = Weight of peels not peeled by machine
W6 = Assume weight of peels = 0.163× W1
W7 = Assume weight of potato flesh

Observation table 2:

Speed of rotation	**Duration of peeling (mins)**	**W1 (kg)**	**W2 (kg)**	**W3 (kg)**	**W4 (kg)**	**W5 (kg)**	**W6 (kg)**	**W7 (kg)**	**P.E. (%)**	**F.I. (%)**
592	5	4	3.5	0.5	3.3	0.2	0.65	3..35	69.23	1.5
592	5	4	3.7	0.3	3.45	0.28	0.65	3.5	57.05	2.28
592	5	5	4.4	0.55	4.28	0.25	0.81	4.5	69.32	2.73
592	5	6	5.4	0.6	5.1	0.30	0.97	5.3	69.07	3.7
								Mean	**64.27**	**4.89**
420	5	7	6.35	0.65	6.03	0.32	1.41	6.2	71.95	3.03
420	5	6.5	5.9	0.6	5.51	0.31	1.05	5.65	71.67	2.57
420	5	6	5.5	0.5	5.25	0.25	0.97	5.4	74.43	2.33
420	5	7.5	6.8	0.7	6.5	0.30	1.22	6.7	75.18	2.74
								Mean	**73.28**	**2.67**

Weight of potato (kg)	**Weight of peeled potato (kg)**	**Weight of peels (kg)**	**% weight of peels**
8	6.5	1.5	18.75%
7	5.8	1.2	17.14%
6.5	5.35	1.15	17.61%
7.5	6.2	1.3	17.33%
		Mean	**17.72%**