

Design and Performance Testing of Semi-Automatic Machine for Potato Peeler-Cutter

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ABSTRACT

In processing potatoes into sticks on a large scale, an equipment is needed that can facilitate the manufacturing process. Therefore, it is necessary to research the design of the potato peeler and cutter and test the performance of the tool. This study aims to determine the design and selection of materials, to determine the production process of potato peeler and cutter and to determine the effect of rotation on time and level of cleanliness of potatoes. This machine consists of several components, namely the frame, peeler tube, cutting tube, transmission unit and electric motor. The working mechanism of this tool is that the peeler disc which is moved by an electric motor rotates to push the potatoes, so that the rotation causes friction between the potatoes and the peeler tube which has a rough surface, this friction causes the potato skin to peel off and is then forwarded to the potato cutter tube with a propeller, which is driven by an electric motor so that the rotation pushes the potatoes into the knife so that the potatoes that pass through the peeler tube are cut into sticks. From the results of testing the tool obtained data on potatoes grade A with an average time of 2 minutes and a motor rotation of 170 rpm, capable of peeling 96.8% of potatoes with a weight loss of 3.2% of potatoes. For potatoes grade B with an average time of 2 minutes and a motor rotation of 170 rpm was capable of peeling 97% of potatoes with a weight loss of 3%, and the results of potato cuts with a cross sectional size of 6.9 × 6.9 mm.

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1. INTRODUCTION

Potato productivity in Indonesia, based on data from 2015-2019, grew by 3.02% (Kementerian Pertanian Republik Indonesia, 2019). Potato (*Solanum tuberosum* Linn.) is one of the root crops that have high carbohydrates, causing potatoes to be known as a substitute for rice, corn, and wheat (Wibowo, 2015). Potatoes have an important role in the human diet. Potato is the sixth food product in the world after sugarcane, labyrinth,

rice, wheat and milk (Mhetre *et al.*, 2021). The benefits of potatoes, among other things, are that they contribute nutrients to the diet including vitamin C, potassium, and dietary fiber. Research on animal and human have shown that potatoes and potato nutrition can have a positive impact on risk factors for chronic disease including blood pressure, blood lipids, and inflammation (Katherine, 2019). Potatoes are usually made into various types of food such as french fries, potato chips, soup, and other dishes. In the process of making food, potatoes need to be processed first, for example, peeled and cut into sticks or dice (Irwan *et al.*, 2021). Potatoes are served in a variety of ways, namely hot, soft, or crunchy. Usually also served as a side dish or complement for lunch or dinner. One of the serving methods for turning raw potatoes into a dish is french fries. Machines or tools used to cut potatoes must be able to produce uniform pieces of potato and maintain the quality of potatoes in the preparation process (Hoque, 2017; Kartika, 2013).

The potato cutting method for french fries can be done manually or automatically (Mishra *et al.*, 2013). For companies with large capital and more resources, the French fries production method is with a fully automatic machine capable of producing large quantities of French fries per day. However, for small companies and individual sellers, the most preferred method is still conventional, namely using manual human labor to produce french fries (Jarwo, 2002). In Indonesia, there are still many Small and Medium Enterprises (SMEs) that still use conventional methods in producing french fries. In the manual method, potatoes need to be peeled before being cut to a certain size. This method requires manpower to peel and cut potatoes, thus making this method time-consuming and labor-intensive (Kumar *et al.*, 2019). It also requires skilled manpower to reduce the time required in production. In the market, manual potato cutters for producing french fries come in various designs from the simplest to the almost complex ones (Wadagavi *et al.*, 2017). Preparation of raw potatoes before frying requires several steps that are time consuming if done manually (Zin *et al.*, 2021).

The design and modification of a semi-automatic potato peeler and cutter machine (Alfino *et al.*, 2020) was carried out by combining the peeling and cutting plates into one (Aldrianto & Sakti, 2015). The function of designing a cutting machine is to get more precise cutting results (Sugandi, 2017). The use of a machine as a potato cutting tool is an alternative in reducing processing costs (He *et al.*, 2013). A short potato peeler machine is needed to obtain high productivity (Kumat *et al.*, 2019; Inglel, 2020). In designing a potato cutting machine, it is necessary to continue with machine performance testing (Maharani *et al.*, 2021; Win *et al.*, 2019).

Hatwar (2016) stated the need to develop a semi-automatic machine capable of peeling and cutting potatoes into fried potato sticks. To achieve the objectives of this research, a semi-automatic machine is developed that is capable of peeling and cutting potatoes into the shape of sticks. This study aims to design and test a machine to peel and cut potatoes into sticks. The design is targeted to produce portable machines with low manufacturing costs and suitable for small and medium industries. The test was focused on small (grade A) and medium (grade B) potatoes.

2. MATERIALS AND METHODS

This research was conducted at the Production Process Laboratory of the Mechanical Engineering Study Program, Faculty of Engineering, Darma Persada University, Jakarta in August 2021. The materials needed for the research consist of several components

and materials that are processed in production according to the machine design. The components used are listed in Table 1.

Table 1. Materials and components used in designing potato peeler-cutter machines

No	Component	Materials	Detail
1	Outer tube	Stainless steel	Ø 459 mm x 520 mm x 0,5 mm
2	Peeling tube	Silicon carbide	Ø 439 mm x 520 mm x 10 mm
3	Tube lid	Stainless steel	Ø 468 mm x 10 mm x 0.5 mm
4	Inlet door	Stainless steel	100 mm x 100 mm
5	Hinge	Stainless	
6	Key	Stainless	
7	Output funnel	Stainless steel	120 mm x 100 mm
8	Hose	Fabrication	Ø 1/2 inch
9	Disk	Stainless plate	Ø 438 mm x 2 mm
10	Tube base plate	Stainless steel	Ø 459 mm x 520 mm x 0.5 mm
11	Water outlet	Stainless steel	Ø 50 x 15 cm
12	L stainless	Stainless	40 mm x 40 mm x 500 mm
13	Bearing holder	L Stainless	40 mm x 40 mm x 370 mm
14	Bearing	Stainless	Ø 19 mm
15	Speed control	Fabrication	
16	Single phase electric motor	Fabrication	1 hp 1400 rpm
17	Pulley	Aluminum	Ø 33 cm and Ø 5 cm
18	Belt	Canvas	A-44 and A-37
19	Bolt nut 8	Stainless	M8 x 30 mm
20	Bolt nut 10	Stainless	M10 x 50 mm

2.1. Machine Design

In this design stage, the calculation process is carried out to determine the size and ability of a component to accept working forces and moments (Wati et al., 2022). The design starts from calculating the volume of the tube so that it can include potatoes as needed, followed by calculating the required rotation speed (rpm), then calculating the pulley diameter to get the required rotation (rpm), and calculating the diameter of the shaft with a load of 5 kg and a rotation of 170 rpm. Other calculations include determining the length of the v-belt, the linear speed of the belt, the type of belt, then calculating the torque to determine the motor power and calculating the required motor power and designing the tool to get an efficient and effective product.

2.2. Machine Design Calculation

2.2.1. Peeler and Cutter Tube Speed

The rotation speed of the planned peeling tube with the size of the pulley can be calculated using Equation 1 (Suga, 2004):

$$\frac{N_2}{N_1} = \frac{d_1}{d_2} \quad (1)$$

With pulley diameter (d_1) of 35 mm and (d_2) 29 mm and rotation speed of drive pulley $N_1 = 1400$ rpm, it can be calculated that rotation speed of the driven pulley is $N_2 = 169$ rpm.

2.2.2. Torque

Torque (T) is the weight force (F) multiplied by the radius distance (r) perpendicular to the force. For gravity on the shaft is 50 N and a distance of 12.5 mm will produce a torque of 0.625 N.m. Therefore, the torque required for the pulley to peel and cut potatoes is 0.625 N.m.

2.2.3. Motor Power

Power on the motor is the power generated by the engine. This power requirement is generated by the torque and angular velocity using Equation 2. Using the previously used data for the rotating speed N_1 , we can calculate the motor power as 0.16 HP. Therefore, for the use of the motor on the machine using a motor with a size ¼ HP.

2.2.4. Motor Efficiency

$$P = \frac{T \times N_1}{5252} \quad (2)$$

The efficiency of an induction motor can be calculated by Equation 3:

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% = \frac{\tau_{load} \times \omega_m}{\sqrt{3} \times V \times I \times \cos\theta} \times 100\% \quad (3)$$

Using motor speed ω_m of 1400 rpm, the efficiency obtained from the calculation results is 56% for a voltage 220 V and current 6.3 A. This is categorized as low efficiency.

2.2.5. Tube Volume

The volume of the peeler tube with radius of 22 cm and height of 51 cm can be easily calculated as 0.07 m³ or 70 dm³. The peeler tube uses 304 stainless steel having a composition of 0.042% C, 1.19% Mn, 0.034% P, 0.03% S, 0.15% Si, 13.00% Cr, 1, 02% Ni and the rest is Fe. The material has a tensile strength of 580 MPa, a yield strength of 198 MPa, an elongation of 50% and a hardness of 87 HRB.

2.2.6. Shaft Diameter

The diameter of the shaft was determined by Equation 4.

$$d_s = \left[\frac{5.1}{\tau_a} \times Kt \times Cb \times T \right]^{1/3} \quad (4)$$

With motor power $P = \frac{1}{4} \text{ HP} = 0.18 \text{ kW}$ and $N = 1400 \text{ rpm}$, then torque T was calculated as:

$$T = \frac{60}{2\pi} \times 10^5 \times \frac{P}{N} = \frac{60}{2\pi} \times 10^5 \times \frac{0.18}{1400} = 125 (\text{kg} \cdot \text{mm})$$

For stainless steel S30C, $s_b = 48 \text{ (kg/mm}^2\text{)}$, $sf_1 = 6$, and $sf_2 = 2.0$ so that we have shear stress s_a as:

$$\tau_a = \frac{48}{6,0 \times 2,0} = 0,25 (\text{kg/mm}^2)$$

The correction factor K_t is taken according to the type of loading on the rotating shaft, so that the torsional moment is 1.5. The correction factor for flexural load C_b is 2.0. Using these values, we get shaft diameter to be 19.6 mm. The diameter of the shaft with a power of 0.186 kW is greater than 19.6 mm. In order to get a safe point the diameter of the shaft is added by 5 mm, which is a diameter of 25 mm. So the diameter of the shaft used is 25 mm. The axle uses ASTM A350 carbon steel material with the symbol S30C which has a tensile strength of 48 kg/mm^2 .

2.2.7. Bearing Size

Shaft uses hard steel, whereas bearing uses bronze. Based on calculation, the pressure obtained is 0.64 kg/mm^2 , less than the permissible pressure for the bearing, namely $(0.5\text{-}0.75) \text{ kg/mm}^2$. Therefore, using axial bearings with hard steel shafts and bronze bearings is safe.

2.2.8. V-Belt Size

To find out the length of the circular belt can be calculated based on [Khurmi et al. \(2005\)](#). With a distance of $x = 260 \text{ mm}$ and pulley size (d_1) 3.5 cm and (d_2) 29 cm, the V-belt size is obtained with a length of $956 \text{ mm} = 48 \text{ inches}$.

2.2.9. Belt Linear Speed

The magnitude of the circular velocity or linear velocity can use equation 5:

$$V = \frac{\pi \cdot d \cdot N}{60} \quad (5)$$

With pulley diameter (d_2) 29 mm and rotation speed of driven pulley $N_2 = 170 \text{ rpm}$, we can calculate the linear velocity of the belt as $V = 2.5 \text{ (m/s)}$. This linear speed of the driving pulley can be said to be safe, because the value of v is less than 30 m/s

2.3. Machine Construction

After calculating the design of the machine, the next process was machine construction using the following specifications:

1. The main frame used L-steel (30 mm x 30 mm x 3 mm).
2. The main tube used a stainless plate ($\varnothing 320 \text{ mm} \times 370 \text{ mm}$).
3. The rotating disk (carbon plate: $\varnothing 300 \text{ mm} \times 4 \text{ mm}$ and $125 \text{ mm} \times 30 \text{ mm} \times 60 \text{ mm}$).
4. The axle used solid steel ($\varnothing 25 \text{ mm} \times 3900 \text{ mm}$).
5. Potato outlet used stainless plate ($425.5 \text{ mm} \times 145 \text{ mm}$).
6. The water outlet used steel pipe ($\varnothing 50.8 \text{ mm} \times 170 \text{ mm}$).
7. The driving machine used an electric motor $\frac{1}{4} \text{ HP}$.
8. Bearing used a rolling bearing 19 mm.

9. Belt used V-belt size of a-44.

10. Pulleys had a size of $\varnothing 290$ mm and $\varnothing 50$ mm.

Figure 1 shows the design of the peeler-cutter machine. The process of making the machine started from the preparation of tools and materials according to the design that has been determined in the process of designing a potato peeler and cutter machine. Tools and materials that have been prepared previously according to the design were then continued into the fabrication process which consists of cutting the main frame, cutting plates for peeling tube and potato cutters. The joining processes used welding methods on machine frames and potato tubes using materials stainless steel which is expected not to corrode which will cause potato products to be unclean and unhealthy to be processed or consumed. Frame and plate tube were then connected and shaped according to the design, then they enter the assembly process to join the main frame, peeler and potato cutter tubes, and other components.

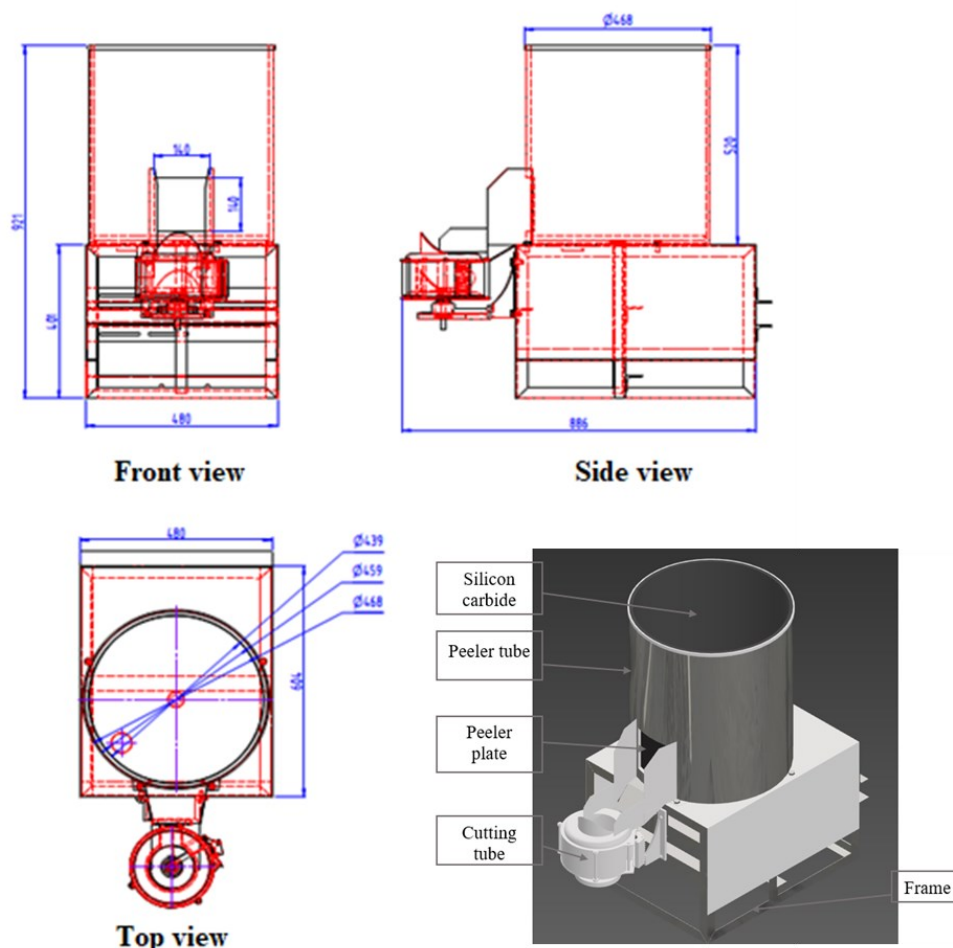


Figure 1. Design of potato peeler-cutter machine

2.4. Working Mechanism

Figure 1 shows the parts of a potato peeler and cutter machine. The working mechanism of this machine is that the peeler disk driven by an electric motor will rotate, push, and rotate the potatoes in the tube. The rotation causes friction between the potato and the peeler tube which has a rough surface. This friction causes the

potato skin to peel. The next process, the potato enters the cutting tool by means of a propeller driven by an electric motor so that the rotation pushes the potato into the cutting knives. The design of knife arrangement was presented in Figure 2. The cutting knives are from razor blades with a distance 7 mm. The knife frame uses a carbon steel plate that is coated with clear so it is not easy to corrode and acrylic to provide distance between the blades from one another. The cutting process will form a stick that has been designed with a size of 7 mm × 7 mm.

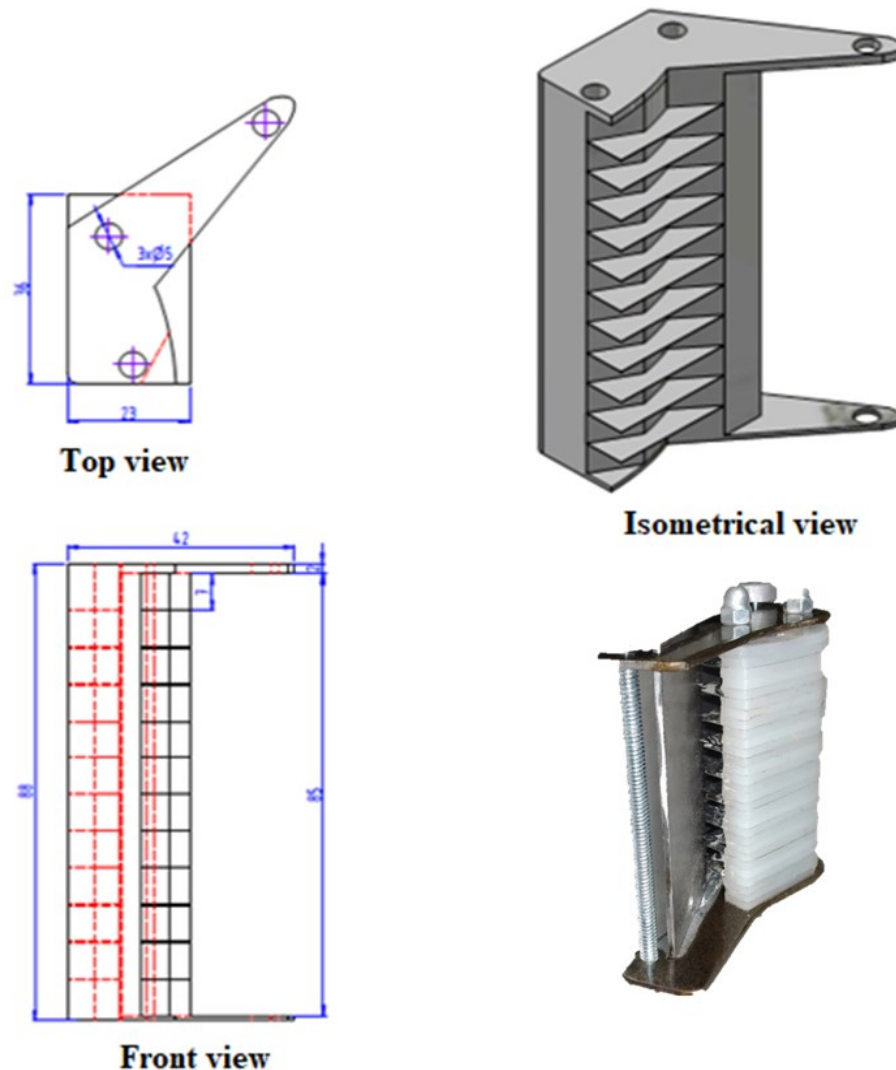


Figure 2. Design of knives arrangement for potato cutter

2.5. Machine Testing

The machine was tested using 2 types of potato, namely grade A and grade B. Grade grouping is determined by the size of potato. Potatoes of grade A have a larger size as compared to those of grade B. Each potato grade was tested 3 times with potato weight of 0.6 kg to evaluate the effect of rotation and time (Reka et al., 2015). During the testing process the engine speed was varied as 100, 140, 170 rpm. Parameters to be observed were average weight loss and stick dimension.

3. RESULTS AND DISCUSSION

3.1. Potato Peeler-Cutter

Figure 3 shows a photo of a semi-automatic potato peeler-cutter machine that is targeted to peel and cut potatoes into sticks at the same time. The machine consists of several components, namely the frame, peeler tube, cutting tube, transmission unit and electric motor. Important features of the machine include the dimensions of 886 mm × 482 mm × 921 mm, tube capacity 5 kg, machine weight 40 kg. The machine is equipped with a single phase electric motor 0.25 HP and 1400 rpm, the shaft size of 25 mm (diameter) and a height of 398 mm, the drive pulley of 35 mm and the driven pulley of 290 mm, and V-belt type A 44 and 48. The cutter tube is presented in Figure 4.

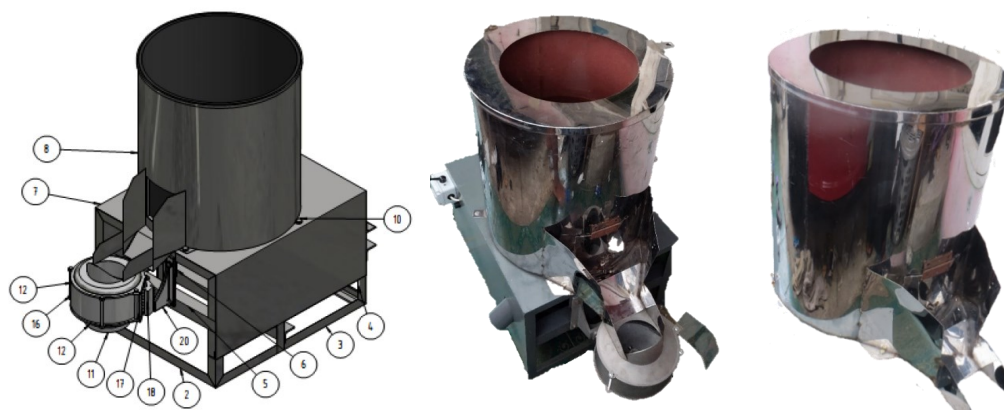


Figure 3. Design (left) and resulted peeler-cutter machine (center and right). The nomenclature numbered in the left figure refer to Table 1.

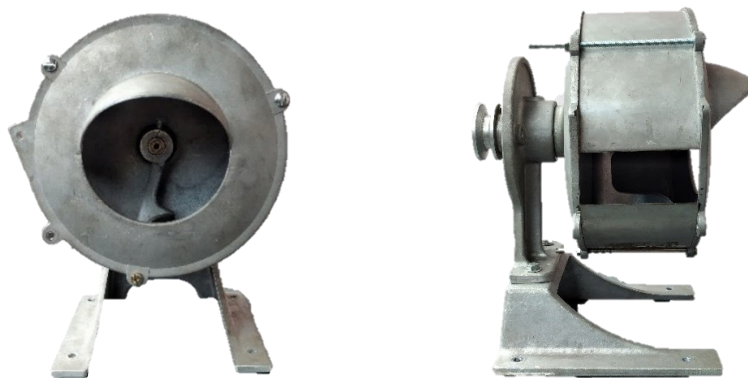


Figure 4. Cutter tube

The peeler tube serves to accommodate the potatoes to be peeled and the potatoes will be rotated by the disc. The potatoes will rub against the walls of the tube, causing them to peel. The peeler tube is made of 304 stainless steel material which makes the tube resistant to corrosion caused by the reaction of water. The stainless plate is rolled to form a cylindrical tube and then welded. Inside the tube there is silicon carbide which functions to peel potatoes. The tube is also given a door for the exit of potatoes with a size of 10 cm × 10 cm. Meanwhile, the cutting tube serves as a place for cutting peeled potatoes. The rotating potato cutter tube contains the propeller and makes the potatoes rub against the knife so as to make the potatoes cut

into 7 mm × 7 mm sticks with a length that adjusts to the size of the potato shape. Cutting tube using ASTM A384 material. With the manufacturing process by casting.

3.2. Frame Strength

The strength of the potato peeler-cutter frame was analyzed through a simulation using the von Mises stress and the result is presented in Figure 5. The stress of one of the post-processors is the result of the calculation of the stress-strain relationship in the object model, the strain is obtained from the deformation experienced by the model. The equivalent voltage used is the Von-Mises method. The following is an illustration of the results of the equivalent stress analysis. The maximum equivalent stress occurs in the welding section of the upper frame of 4092.57 MPa, then the minimum equivalent stress is 0 MPa. Based on the color of the simulation results (Figure 6), it indicates that the frame is still in a safe load.

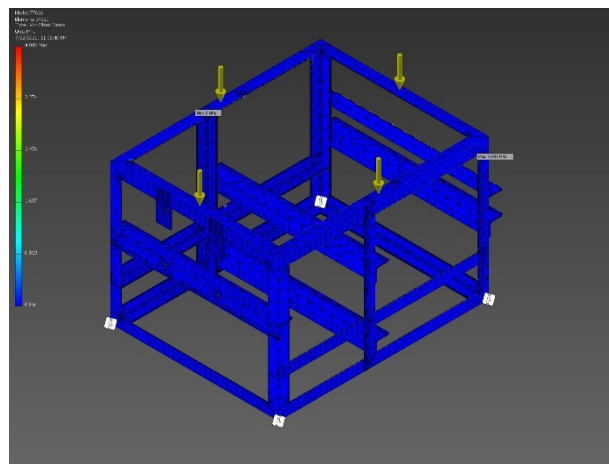


Figure 5. Result from simulation using Von Mises stress

3.3. Machine Performance

Data retrieval of machine performance testing results by adjusting the motor rotation variations on the results of peeling and cutting with weight parameters and peeling results and the shape of potato sticks. Table 2 and 3 show the results of machine performance testing using potatoes grade A and grade B, respectively. From Table 2, the results of machine testing using large grade A potatoes, we find that the peeling time decreases with machine speed. At 170 rpm it takes 1.35 min or a capacity of 27.8 kg/h with a weight loss of 0.025 kg. When the engine speed drops to 140 rpm, the time required for stripping is 2.10 min (capacity 19.1 kg/h) with a weight loss of 0.02 kg. When the rotation is lowered again to 100 rpm, the peeling time takes 3 min (capacity 13.9 kg/h) with a weight loss of 0.015 kg. The results of the peeling and the shape and size of the potato sticks were in accordance with the needs.

Table 2. Machine performance using potatoes grade A









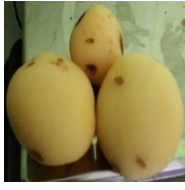



Speed (rpm)	Time (min)	Potato weight (kg)		Capacity (kg/h)	Peeled potato	Potato cuts
Initial	Final					
170	1.35	0.625	0.600	27.8		
140	2.10	0.670	0.650	19.1		
100	3.0	0.695	0.680	13.9		

Table 3. Machine performance using potatoes grade B

Speed (rpm)	Time (min)	Potato weight (kg)		Capacity (kg/h)	Peeled potato	Potato cuts
Initial	Final					
170	1.35	0.625	0.600	16.4		
140	2.10	0.670	0.650	9.0		
100	3.0	0.695	0.680	6.6		

From Table 3 the test results for grade B potatoes are smaller than grade A. Here we get results similar to the test using grade A potatoes, but the peeling time is slightly faster. At 170 rpm it takes 1.30 min (capacity 16.4 kg/h) for maximum results, with a weight loss of 0.02 kg. When the engine speed drops to 140 rpm, the stripping time

increases to 2 min (capacity 9.0 kg/h) with a weight loss of 0.008 kg. If the engine speed is lowered to 100 rpm, the stripping time increases to 2.50 min (capacity 6.6 kg/h) with a weight loss of 0.01. The peeling results and the size of the potato sticks were in line with expectations.

3.4. Discussion

The results of testing the operation of the potato stick peeler and cutter with a capacity of 5 kg using two types of potatoes, namely grade A and grade B potatoes showed different results. The peeling method using friction operated at a motor rotation speed of 170, 140, 100 rpm showed that the peeled potatoes and sticks were visually clean and met expectations. We can evaluate the performance of the machine based on the length of time cleaning and cutting on the variation of the motor speed and measure the weight of the potatoes before entering the machine and after leaving the machine. The results of the engine performance test show that the rotational speed of the motor affects the speed of the potato peeling process. The higher the rotational speed of the machine, the faster the stripping process so that the machine has a high capacity. For example, at a motor speed of 100 rpm, a potato peeler-cutter machine can finish peeling of 0.695 kg of potatoes grade A in 3 min which results in a working capacity of 13.9 kg/h. By increasing the motor speed to 170 rpm, the working capacity of the engine is increased to 27.8 kg/h. The machine test results also show that the size of the potato greatly affects the machine performance. When used for peeling grade B potatoes, the engine capacity is only 6.6 kg/h and 16.4 kg/h, respectively, at motor speeds of 100 and 170 rpm. This means that the large size of the potato produces a high capacity of the peeler-cutter machine compared to its use using small potatoes.

In a previous study reported that potato peeling can be said to be clean when in 1 kg of potatoes, the loss is 250 grams (25%). In grade A potatoes, the optimal average time was 5 minutes which was able to peel 97.5% potatoes with a weight loss of 1.5% and all skin surfaces were peeled off. For grade B potatoes with a motor speed of 150 rpm, it was found that 5 kg of potatoes could be completed in 5 minutes with a success factor of 100%, with a weight loss of 5%, and all skin surfaces were peeled off and the potatoes were clean (Edy, 2018). The test results explain that the higher the rotation, the quality of the results is not affected. However, there is an effect on the quantity of lost material where the increasing rpm rotation means the more the thickness of the potato decreases so that at a motor speed that is too high there will be a lot of wasted potatoes.

For the size of the potato sticks after going through the cutting process using a cutting knife, the average size according to the design. The design of the cutting blade as shown in Figure 2, there are 12 lined holes and 5 levels where the blade rotates on the axis. For each box the holes on the knife have been set the distance that is 7 mm wide and 7 mm high. From the results of the experiment, after going through the process of stripping the tube, the potatoes were then pushed into the cutting chamber and produced sticks with a cross-sectional size approaching an average of 7 mm × 7 mm. As for the length of the sticks, adjust the shape of each potato. In particular, the center of the potato is more precise when it can be cut in full, while the ends or the outer part of the peeled skin are less precise in adjusting the shape of the potato (Figures in Tables 2 and 3). The results of measuring the shape of potato sticks using a caliper have met the target average size, which is 6.9 mm or 98% for both grade A and

B potatoes. In practice, the use of tools adjusts to the shape and size of the potatoes produced for the cutting process.

4. CONCLUSIONS AND RECOMENDATION

Based on the testing of the potato peeler-cutter with a capacity of 5 kg, it was concluded that the potato peeler-cutter can operate according to the design, namely the dimensions of the tool 886 x 482 x 921 mm, capacity 5 kg, total machine weight 40 kg, 1 phase electric motor 1400 HP rpm, the shaft uses a diameter of 25 mm and a height of 398 mm, the dimensions of the drive pulley are 35 mm and the driven pulley is 290 mm, and uses a V-belt type A 44 and 48. The test results for grade A potatoes with an average time of 2 minutes and a motor rpm of 170 rpm, capable of peeling potatoes 96.8% with a weight loss of 3.2%, grade B potatoes with an average time of 2 minutes and a motor rpm of 170 rpm capable of peeling potatoes 97% with a weight loss of 3%. In using the machine, especially in the peeling process, it is necessary to pay attention to the processing time and the rotation of the peeler tube (maximum 3 minutes) for grade A and B potatoes or by visually seeing whether the potatoes have been peeled to the maximum, this is because the longer the peeling process will result in more loss of the potatoes.

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