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# Design and Testing of Rubber Seed Crusher


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**ABSTRACT**

Rubber seeds are one of the products from rubber plantations which are in large numbers but have not been utilized. The flesh of the seeds contains vegetable oil of 45.63% of rubber seeds and can be used as raw material for edible oil. The hard shell of rubber seeds can also be used, one of them being biobriquettes.This study aims to separate the rubber seed flesh from the shell with a mechanically designed crusher and separator of the rubber seed flesh from the rubber seed shell. This machine is designed and made using a single roller crusher as a rubber seed crusher and at the output there is a static sieve to separate the rubber seed shell and rubber seed flesh. The dimensions of this machine are 1310 mm × 500 mm × 600 mm. The results showed the effective capacity of 46.998%, with the percentage of seeds left behind by 17%. The yield of rubber seed flesh is 31.17%, the yield of rubber seed shell is 67% with losses of 1.84%. The power consumption, break event point and internal rate of return (IRR) of this machine are 7.43 kWh, 1.247,58 kg/year and 55.63%, respectively. The use of this machine is considered feasible due to its NPV > 0.

**Keywords:** design, roller, crusher, separator, rubber seed

## 1. Introduction

Rubber seeds are found in each fruit chamber. The number of seeds is usually three, sometimes six, according to the number of spaces. Large seed size with hard shell. The color is blackish brown with distinctive patterned spots (Self-help Spreading Team, 1992).

Rubber (*Hevea brasiliensis Muell. Arg*) is which one of agriculture product many have developing economic country. Except of latex product, rubber of plantation to production rubber seeds to optimum used not yet. As see oil content on rubber seed is very high 45.63% so the rubber seed oil has wide potential aplication. To obtain oil from rubber seed, there are two methods commonly used for oil extraction from rubber seeds, which are mechanical pressing and solvent extraction (Hakim and Mukhtadi, 2018).

Rubber seed shells are one of the many biomass that can be used as the main material for making briquettes. Biobriquettes are alternative fuels that are in the form of charcoal and have a higher density. Rubber seed shells generally contain 60 – 80% cellulose, 5 – 20% lignin. The rubber seed shell has a moisture content percentage of 14.3%, an ash content of 0.1% fiber and various carbon compounds of 85.6% (Selpiana et al, 2014).

Rubber seeds are also easily damaged, rubber seeds are not resistant to drought and do not have a dormancy period. In addition, if the moisture content is below 12% rubber seeds will die (Astawan et al, 2018). This causes the shelf life of seeds to be very short with the optimum storage temperature is 7 - 10°C, since at this temperature it has not undergone cell freezing (Nilasari 2012). If the rubber seeds are dead, then follow-up processing is very necessary to reduce the accumulation of rubber seed waste.

Until now, there are still few people who use rubber seeds. In addition, the management carried out is still carried out manually, especially in the process of separating seed flesh from the shell so that people are less interested in managing rubber seeds. For this reason, it is necessary to make a machine that can break and separate the rubber seed shell from the rubber seed meat which is carried out mechanically to be able to help rubber farmers manage rubber seeds to be more economically valuable so as to increase the income of rubber farmers.bes research background, previous studies and research objectives, which is no more than 20% of the total page.

This study aims to design and manufacture a rubber seed shell crusher and separator from the flesh, conduct tests to determine the performance of the machine and an economic analysis of the rubber seed shell crusher and separator from the rubber seed (*Hevea brasiliensis*.) flesh mechanically.

## 2. Materials and Methods

The rubber seed crusher and separator machine is designed and manufactured to break the rubber seeds and separate the pulp from the shell mechanically. With this machine, it is hoped that rubber farmers can take advantage of rubber seeds by reprocessing rubber seeds so that rubber seeds can be of economic value. This machine is operated very easily and only by one operator. Machine operation can be done at home and maintenance is also very simple. The implementation of testing activities on this machine starts from the rubber seeds that have been collected and then dried and cleaned. Then the machine is started and the rubber seeds are put into the hopper. The rubber seeds will enter the crushing chamber and be crushed by the crushing roller, then the broken seeds will enter the separation chamber. In the separation chamber, the separating roller will separate the flesh of the seeds from the shell.

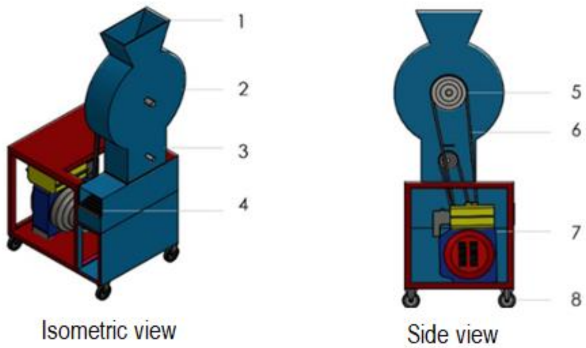


**Figure 1.** Schematic diagram of the overall structure of the seed crusher device: 1—hopper; 2—chrusher chamber; 3—separation chamber; 4—sieve device; 5—pulley; 6—v-belt; 7—electric motor; 8—wheel.

### *2.1 Functional Parts*

The functional part of this machine is the part that acts on the process of crushing rubber seeds and separating the rubber seed shell from the flesh. These functional parts include:

#### *2.1.1. Hopper*

The hopper serves as a place for the entry of raw materials before being broken down. The material used is an iron plate that has excellent resistance. The volume of the hopper can be determined using the trapezoidal prism volume equation.

#### *2.1.2. Crusher Roller*

The crusher roller serves as a rubber seed crusher. The roller used is a single roll crusher type where the main part is a cylindrical wheel that rotates as a crusher for the rubber seed shell and a plate as a holder. Before determining the type of material in the manufacture of rollers, the compressive strength value of rubber seeds is first determined. The measurement of the compressive strength value of rubber seeds is carried out in a manual way, namely by pressing the rubber seeds that are above the scales. Then it is seen the amount of energy required to crush the rubber seeds on the scales.

*2.1.3. Separator Roller*

The separator roller serves to separate the rubber seed shell that is still attached to the rubber seed flesh. This separator roller is tubular and designed using fins. The fin will later hit the broken rubber seed against the wall from the dividing chamber so that there is no lumpy part on each rubber seed.

*2.1.4. Sieve*

A sieve is a tool for separating the shell of rubber seeds from the flesh. The size of the sieve hole/mesh is 3 mesh (rough sieve). So that on the shell of the rubber seed will fall under the sieve to the reservoir and the rubber seed flesh will roll from the top of the sieve to the reservoir.

*2.1.5. Pulley*

Pulley is an engine element that functions as a connector for the rotation received from the electric motor then forwarded using a belt – V to the roller crusher and separator. The size of the pulley is determined using the following equation:

$$n_2 = \frac{n_1 \times D_1}{D_2} \tag{1}$$

Where,

$n_1$ = rotation of driven pulley (rpm)
$n_2$ = rotation of the drive pulley (rpm)
$D_1$ = diameter of the driven pulley (mm)
$D_2$ = diameter of the drive pulley (mm) (Sularso and Suga. 2004)

*2.1.6. V-Belt*

V-Belt is one of the connecting connectors made of rubber and has a trapezoidal cross section. V-Belt is used by winding a V-shaped pulley groove. To determine the belting length (L) can use Equation:

$$L = 2C + \frac{\pi}{2}\left(D_1 + D_2\right) + \frac{1}{4C}\left(D_2 - D_1\right)^2 \tag{2}$$

To determine the axis distance of the shaft used p the following equations :

$$C = \frac{b + \sqrt{b^2 - 8\left(D_2 - D_1\right)^2}}{8} \tag{3}$$

$$b = 2L - 3.14\left(D_2 - D_1\right) \tag{4}$$

Where,

L = length of belt circumference (mm)
C = shaft axis distance (mm) (Sularso and Suga. 2004)

*2.1.7. Electric Motor*

An electric motor is a device that can convert electrical energy into motion energy. This is influenced by 3 factors, namely the electricity used, the speed produced, and the amount of power (torque) based on the load (F). The determination of motor power is done manually, namely by winding the rope on the pulley attached to each roller, at the end of the rope, a pull scale is provided to get the weight of the roller pull when crushing rubber seeds. To determine the magnitude of the power of the supplied electric motor using the following equation:

$$HP = \frac{Tn}{63000} \tag{5}$$

Where,
T = torque (lb.in)
n = rotations per minute (rpm)

To determine the torque on the shaft can use the following equation:

$$T = F \times r \tag{6}$$

Where,
T = Torque (N.m)
F = Applied load (N)
r = Force arm (m) (Timothy and Wentzell, 2003)

*2.2 Manufacture of Structural Parts*

*2.2.1. Framework*
The framework of this machine is a support for all components and gives shape to the machine. It is also a buffer for other components of functional tools. The dimensions of the tool frame are adjusted to the capacity of the crusher and separator chambers. The design of the height of the tool frame is adjusted based on one of the principles of anthropometric design, namely the principle of designing products that can be operated between a certain range of human height sizes.

*2.2.2. Crusher chamber*
The crushing chamber serves as a place for crushing the shell of rubber seeds. In the densest crushing chamber, a cracking roller with a plate as a holder. The crushing chamber is designed in the form of a cylindrical tube that can follow the shape of the crushing roller.

*2.2.3. Separation chamber*
The separator chamber serves as a place for the separation of the rubber seed shell with the flesh. In this section there is a separator roller and also a sieve with a size of 3 mesh. The dimensions of the separator chamber are designed in the form of blocks.

Assembly is carried out to realize the machine to crush and separate the rubber seed flesh from the shell. Furthermore, machine testing is carried out to obtain information whether the machine can operate according to its function. To determine the success of the design, it is necessary to test with the following test parameters.

*2.2.4. Effective capacity of the machine*
The measurement of the effective capacity of the machine is carried out by dividing the weight of the rubber seed material against the time required by the following equation:

$$KEA = \frac{W_T}{T} \tag{7}$$

Where,
KEA = Effective capacity of the machine (kg/h)
$W_T$ = Total weight of rubber seeds processed (kg)
T = Processing time (hour)

When testing the machine, not all processed rubber seeds can be accommodated in the discharge line. There are seeds that are still left on the machine where the percentage of seeds left can be calculated by the following equation:

$$P_{BT} = \frac{W_{SL}}{W_T} \tag{8}$$

Where,
PBT = percentage of seed left in the machine (%)
WSL = weight of seed left in the machine (kg)

*2.2.5. Rubber seed yield*

Rubber seed yield is the percentage of rubber seed meat obtained by comparing it with the initial weight of the processed material. This can be obtained using the following equation:

$$R_Y = \frac{W_{DB}}{W_T} \times 100\% \quad (9)$$

Where,
$R_Y$ = Rubber seed meat percentage (%)
$W_{DB}$ = Rubber seed meat weight (kg)

*2.2.6. Electrical power consumption*

The consumption of electrical power when the machine is operating is measured by a wattmeter and then calculated by the following equation:

$$W = P \times T \quad (10)$$

Where,
W = electrical power consumption (kWh)
P = electrical power used (kW)

*2.3 Economic Analysis*

Economic analysis was carried out to determine the feasibility of the machine made in increasing the economic value of rubber seeds.

*2.3.1. Break Event Point*

The determination of the break-even point aims to determine the minimum production limit that must be achieved so that the managed business is still feasible. Calculations are carried out with the following equation:

$$S = \frac{F_C + P}{S_P - V_C} \quad (11)$$

Where,
S = Sales variabel (kg/year)
$F_C$ = Fixed cost (IDR/year)
P = Profit (IDR)
$S_P$ = Selling per unit (IDR /kg)
$V_C$ = Variable cash (IDR /kg)

*2.3.2. Net Present Value*

Net present value is the criterion used to determine the feasibility of the machine to be operated. Calculations can be done with the following equation:

$$NPV = PWB - PWC \quad (12)$$

Where,
NPV = net Present value (IDR)
PWB = present worth of benefit (IDR)
PWC = present worth of cost (IDR)

*2.3.3. Internal Rate of Return*

The internal rate of return calculation is carried out to determine the ability to recover the investment that has been issued. Calculations can be done with the following equation:

$$IRR = p\% + \frac{x}{x - y}(q\% - p\%) \quad (13)$$

Where,
p = the most attractive bank interest rate (%)
q = trial interest rate (> of p) (%)
X = NPV at p (IDR)
Y = NPV at q (IDR) (Giatman, 2011)

## 3. Results and Discussion

The frame serves as a support and holder for all machine components. The engine frame has a length of 600 mm, a width of 500 mm and a height of 400 mm using iron elbow with dimensions of 40 × 40 × 2 mm. Hopper, is a container before the rubber seeds are broken down. Hopper is made of iron plate with a thickness of 1.5 mm. The designed hopper capacity can accommodate 1 kg of rubber seeds. The dimensions of the hopper on the top base are 300 mm, the bottom base is 150 mm, the height is 140 mm and the prism height is 130 mm with a hopper volume of 3900 $cm^3$. Pulleys are used to transmit power and rotation from one shaft to another. The drive motor pulley has a diameter of 2.5 in, so using equation (2) the diameter of the crusher rotor pulley is 9 in and the separator rotor pulley is 7 in. The V-belt is used to transmit rotation and power from one pulley to another. Using equations (3) and (4), the length of the v-belt on the breaking roller is 61 in, and the separation roller is 42 in. The sieve is used in the process of separating the rubber seed shell from the rubber seed flesh. This sieve has a fixed gap that is balanced/unchanged (stationary). The sieve is made using concrete iron arranged vertically to the side with a distance of 1.1 cm between the irons with a length of 30 cm and a width of 14 cm. The crushing roller is used to crush the rubber ore which is fed through the hopper. The crushing roller is designed with a rotary roll system with a predetermined speed. A cylindrical crushing roller with a diameter of 300 mm and a tube width of 130 mm is mounted with concrete iron on the surface of the roller with a distance between the irons of 20 mm. The separation roller is used to separate the fragments of rubber seeds that are still lumpy from the results of the crushing roller. The separation roller is a cylindrical tube with a diameter of 100 mm and a width of 140 mm. An electric motor is used to convert electrical energy into mechanical energy. The mechanical energy produced by the electric motor is in the form of rotation of the motor. Based on the calculation using equation 1, the electric motor power requirement for the operation of the rubber seed crusher and separator is 1 HP with 1400 rpm rotation. To transmit power and rotation of the electric motor using a 2.5 in diameter pulley.

**Figure 2.** a) Built in overall machine design; b) seed flesh and cracked shell

The machine was designed to crush and separate the flesh of rubber seeds from the shell. The process starts from inserting rubber seeds in the hopper which then the seeds will fall into the crushing chamber in which there is a cracking roller. The roller rotates and carries the seeds towards the grinding wall so that the seeds grind and break. Between the roller and the wall, a gap the size of the rubber seed has been made so that the rubber seed shell can break without having to damage the rubber seed flesh. After passing through the crushing roller, the rubber seeds are carried through a small hole towards a separator roller. This separator roller serves to separate the rubber seed shell that is still attached to the rubber seed flesh. The separator roller is designed using fins and at different speeds than the crushing roller. The separator roller will blow the fallen rubber seed and blow it into the surrounding wall. Then the rubber seed will fall into a static sieve, where a hole has been provided that is smaller in size than the flesh of the rubber seed. So that what enters the hole is only the shell of the rubber seed. The rubber seed flesh will be accommodated in the seed meat reservoir while the shell will fall on the shell reservoir.

*3.1. Crushing force of rubber seed*

The measurement of the pressure force is intended to determine the amount of pressure needed to break the rubber seeds on the crushing roller. The seeds used for this crushing test are seeds that have just fallen from the tree with an average moisture content of 8%. The value of the crushing force of rubber seeds is shown in Table 1.

**Table 1**. Crushing force of rubber seeds

| Replication | Crushing force of rubber seeds | |
|---|---|---|
| | Kg | N |
| 1 | 24.70 | 242.31 |
| 2 | 25.40 | 249.17 |
| 3 | 24.60 | 241.33 |
| Average | 24.90 | 244.27 |

Table 1 above shows the differences in seed crushing force. This is due to the thickness of the seed shell, the size and the moisture content of the seed.

*3.2. Effective capacity*

Effective capacity testing aims to determine machine productivity per unit time. Determination of the effective capacity is done by comparing the weight of the rubber seed material to the time required to break the rubber seed. The test was carried out at 400 rpm (pulley diameter 9 in) splitting roller pulley and 514 rpm separation roller pulley (7 in diameter pulley). The effective capacity of the machine is presented in Table 2.

**Table 2**. Effective capacity of the machine

| Replication | Material weight (kg) | Time (hour) | Effective capacity (kg/h) |
|---|---|---|---|
| 1 | 2 | 0.04 | 47.73 |
| 2 | 2 | 0.05 | 39.21 |
| 3 | 2 | 0.04 | 54.05 |
| Average | 2 | 0.04 | 46.99 |

Table 2 above shows that from 2 kg of rubber seed weight which was processed with 3 repetitions, there were variations in the effective capacity. This is because the setting of rubber seeds that fall from the hopper to the crushing chamber is still manual. So that the size of the hole and the number of rubber seeds that fall into the crushing chamber varies. However,or further calculations, the effective capacity value used is the average value, which is 47 kg/hour.

*3.3. Losses*

Lasses is the percentage of seeds left in the machine or thrown from the yield reservoir because the size of the seeds is too large so that they do not pass through the separator sieve. The percentage of remaining seeds is the ratio between the weight of the seeds left behind or wasted and the initial input period of the material expressed in percent. The percentage losses of seeds is presented in Table 3 below.

**Table 3.** Percentage of losses

| Replication | Total weight (kg) | Weight of broken seeds (kg) | Weight of seeds left behind or wasted (kg) | *Losses* (%) |
|---|---|---|---|---|
| 1 | 2 | 1.92 | 0.08 | 4.00 |
| 2 | 2 | 1.51 | 0.49 | 24.50 |
| 3 | 2 | 1.55 | 0.45 | 22.50 |
| Average | 2 | 1.66 | 0.34 | 17.00 |

Table 3 shows that the average losses is 0.34 kg or 17%. This is caused by the snagging of seeds between the rotor and the walls of the chamber and the broken seeds do not pass between the filters so they cannot collect in the yield storage.

*3.4. Seed flesh*

Calculation of the flesh content of the rubber seeds is carried out to determine the percentage of the flesh of the rubber seeds which is broken by the machine in the unit weight of the processed material. The calculation results are presented in Table 4.

**Table 4.** Percentage of the seed flesh and seed shell

| Replication | Total weight (kg) | Seed flesh weight (kg) | Seed shell weight (kg) | Percentage of seed flesh (%) | Percentage of seed shell (%) |
|---|---|---|---|---|---|
| 1 | 2 | 0.55 | 1.45 | 27.50 | 72.50 |
| 2 | 2 | 0.69 | 1.31 | 34.75 | 65.25 |
| 3 | 2 | 0.82 | 1.82 | 40.76 | 59.24 |
| Average | 2 | 0.69 | 1.31 | 34.34 | 65.66 |

*3.5. Electric power consumption*

Measurement of electric power consumption is carried out using a wattmeter to determine the value of electric power consumption in one experiment. Electric power consumption aims to determine the amount of costs that must be incurred when using the machine. The value of electric power consumption is obtained by using Equation 12 which is presented in Table 5 below.

**Table 5.** Electric power consumption

| Replication | Time (second) | Electric power (Watt) | Electric consumption (kWh) |
|---|---|---|---|
| 1 | 150.84 | 313.30 | 7.48 |
| 2 | 183.60 | 316.70 | 6.21 |
| 3 | 133.20 | 318.40 | 8.61 |
| Average | 155.88 | 316.13 | 7.43 |

*3.6. Break event point (BEP)*

The break event point calculation is carried out to determine the minimum production limit that must be achieved and marketed so that the managed business is feasible to run. In this condition, the income earned is only sufficient to cover operational costs without profit. By using Equation 11, this machine can reach the break-even point when breaking rubber seeds of 1,247.575 kg/year.

*3.7. Net Present Value (NPV)*

Net present value is used to measure the feasibility of a business. In this case it is the feasibility of this machine as an investment to support production. From the calculations that have been done using Equation 12, the NPV value obtained is IDR 371,765,927,-/year with an attractive interest rate of 6%. NPV > 0, means the business is profitable and feasible to develop.

*3.8. Internal Rate of Return (IRR)*

Internal rate of return is used to predict the feasibility of long life of machine ownership at a certain level of profit. With equation 16, the IRR value obtained is 55.53%, which means that the business of breaking rubber seeds to produce vegetable oil from rubber seed flesh and biobriquettes from rubber seed shells is predicted to be feasible if borrowing capital at the bank at an interest rate of less than 55.53% per year. The higher the interest rate on the loan, the less profit will be obtained.

## 4. Conclusion

The design of the crusher and separator of the rubber seed flesh from the shell has a machine dimension of 1310 mm × 500 mm × 600 mm using an electric motor of 1440 rpm with a power of 1 HP. This machine has an average effective capacity of 47 kg/hour with an average percentage of losses by 17%. The average yield of rubber seed flesh obtained is 34.34%, then the average yield of rubber seed shell is 65.66%. The average electric power consumption obtained from the crusher and separator of rubber seeds is 7.43 kWh. The BEP value obtained is 1,247.58 kg/year, the NPV value is IDR 371,765,927,-/year and the IRR value is 55.53%.

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