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The Design of A Coffee Pulper Machine By Using Inventor Autocad Software

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ABSTRACT

Coffee is one of the favorite beverages enjoyed by people from all walks of life. The main challenge in the coffee bean peeling process in small and medium enterprises (SMEs) is that it is still done manually. The primary goal of creating this technological innovation is to assist workers in the production process by using appropriate technology, thereby improving the quality, effectiveness, and efficiency of their work. The design optimization and manufacturing process of the coffee pulper machine begins with literature studies, design and calculations, the fabrication of the machine, and ends with testing. The design is created using Inventor Autocad software. The coffee peeling machine measures 110 cm x 127 cm x 130 cm and is powered by a gasoline engine with an initial speed of 1800 rpm, which increases to 3600 rpm. It uses two pulleys with a ratio of 1:6, an A-75 V-belt, and a solid shaft with a diameter of 20 mm. The final result shows that the coffee pulper machine has a capacity of 610 kg per hour.

1 Introduction

The people's economy means that production is carried out by everyone, the benefits can be enjoyed by all, and it is under the supervision and leadership of community members [1]. In line with this definition, the Triple-Co concept elaborates on the principles of co-ownership, co-determination, and co-responsibility. Thus, all economic actors are involved in economic activities.

Kulon Progo is one of the regencies in the Special Region of Yogyakarta known for producing the highest yield of plantation crops. One of the plantation products in Kulon Progo is coffee. The total area of coffee plantations in Yogyakarta reaches 1,652.41 hectares. Kulon Progo contributes the largest coffee plantation area among other regencies in Yogyakarta, covering 1,422.51 hectares, or approximately 86% of the total coffee plantation area in the region [2]. One of the areas in Kulon Progo that produces coffee from plantation land is the Samigaluh District, specifically in Pagerharjo Village. In Samigaluh District, there are 22,065 people working in agriculture, fisheries, or livestock sectors. In Pagerharjo Village, 3,721 residents are employed in agriculture, fisheries, or livestock sectors.

Coffee is a favorite beverage among both the upper and lower classes, and is enjoyed by both men and women. Indonesia is the fourth largest coffee producing country after Brazil, Vietnam and Colombia, with a total production in 2017 of 10.8 million 60-kg bags [3]. Although coffee is currently a growing commodity, many challenges are faced by coffee entrepreneurs in

Pagerharjo in improving their businesses. This is due to the lack of supporting equipment that ensures the smooth operation of their businesses.

Pagerharjo is a village in the Samigaluh district, where the majority of its economic activities are supported by coffee cultivation and its processing. Due to the creative initiative of the youth, SMEs, and the local Women Farmers Group (KWT) in Pagerharjo, guided by the local government and Bumdesa Binangun Raharjo, a natural resource conservation project was carried out by planting 24,000 coffee trees in the village. Based on observations, the potential market size has not been matched by an increase in production capacity. Coffee fruit processing greatly affects the quality of the coffee produced.

One challenge faced is the process of removing the coffee skin, where the time and energy required are still too large, making the process inefficient [4]. The method of coffee bean processing in Pagerharjo is mostly still manual. This contrasts with the dry processing method, where after harvesting, the coffee beans are directly sun-dried without undergoing skin peeling for 12-14 days. This long drying period can potentially lead to mold growth, which can damage the coffee beans. Additionally, the quality of the skin removal process is not optimal, as many beans break during the manual peeling process [5]. These issues increase the time, labor, and cost involved in peeling, so to meet the high demand, the community needs technological innovation.

The appropriate technology to be developed and implemented in the community of Pagerharjo is a coffee skin peeling machine (pulper). The coffee fruit skin removal process (pulping process) is typically assisted by water and is carried out mechanically, either manually or using a 5 HP gasoline engine. The coffee bean skin peeling machine (pulper) is driven mechanically (with a gasoline engine) to accelerate the peeling process. The application of a perforated cylindrical knife that rotates on a shaft is expected to replace the function of the existing manual tools. This perforated cylindrical knife system can help maintain the quality of the coffee and improve the efficiency of the coffee bean peeling production. Coffee farmers need a pulper machine design that can automatically separate the coffee beans from the skins, is easy to operate, and has simple maintenance, so that the expected production targets can be achieved

2 Method

This research uses the Research and Development (R&D) approach, referring to the 4-D model (Four D Models) of Thiagarajan with modifications. In the Define phase, it was found that coffee bean processing in Pagerharjo Village requires the application of technology that can assist the community in increasing production capacity. Fundamentally, the people of Pagerharjo do not have technology for processing fresh coffee beans, as they have been drying the beans first before taking them to milling facilities to separate the coffee beans from the skin. Based on observations and interviews, it was also found that the geographical location of Pagerharjo, with its predominantly hilly terrain, experiences relatively frequent power disturbances. Therefore, the use of energy sources other than electricity needs to be considered. The people of Pagerharjo desire to process the coffee beans immediately after harvesting, with a capacity of more than 400 kg per hour. In general, the technology applied should be easy to maintain and safe to operate for the people of Pagerharjo, while also having a high productivity rate.

Based on the information obtained in the Define phase, the researcher then proceeded to the Design phase (Design) of the coffee pulper machine for the community of Pagerharjo. The selection of materials that are resistant to corrosion, machining techniques, the construction of a sturdy frame and drive mechanism, the choice of the main drive motor, operating system, and machine productivity were the key focuses of this phase. All activities in the Design phase were examined through relevant literature.

In the Develop phase (Development), the researcher carried out the process of manufacturing a prototype of the coffee pulper machine according to the results from the Design phase. The developed product, the coffee pulper machine, was then validated by an expert (expert appraisal) and underwent functional testing. The machine testing used the following indicators: (1) machine capacity, (2) component calculations, and (3) hopper capacity. Specific parameters for testing included: (1) the average size of the coffee fruit (length, thickness, and average width of the coffee fruit), (2) the density of the coffee fruit, (3) the percentage of peel removal per kilogram, and (4) the hopper capacity

The steps in this research are divided into four parts, which are:

a. Need and Assessment

This begins with an analysis of the needs in the field. Discussions take place between the researcher and coffee farmers in Pagerharjo.

b. Observation and Interviews

Through observation and interviews, it was found that the community needs a machine design that is easy to operate and maintain, yet has high performance.

c. Machine Design

The machine is designed using Autodesk Inventor software. This design produces working drawings. Based on the generated working drawings, the material specifications, tools used, and work steps can be identified.

d. Component Fabrication

This step involves creating working drawings for each component, resulting in the actual design based on the drawings created.

e. Literature Review

A literature review is conducted to supplement data or information as references based on previous research findings.

f. Machine Performance Calculation

The performance of the coffee skin peeling machine is calculated based on the data obtained in the field.

2.1 Research procedurs

This research is divided into several processes. The first process is the analysis process, which explains the stages of coffee fruit skin peeling. The next step is problem formulation, where the issues encountered during the analysis phase are identified. Following that is the design phase, which involves designing the coffee pulper machine using Autodesk Inventor software. The preparation of tools, materials, and work steps involves gathering the tools required for making holes, joining, measuring, and cutting. This stage also defines the work steps, such as the construction of the frame as the main support for the machine. The assembly phase is carried out to assemble all the components into a complete machine.

The performance testing phase is where the machine is tested using Robusta coffee as raw material. The evaluation phase assesses the results of the performance test to determine whether the machine meets expectations. If not, the machine will undergo improvements starting from the design; if it does meet expectations, the process moves to the next stage. The final stage is the machine finishing, which includes painting and shipping the machine.

2.2 The indicators observed

Experimental Materials (Coffee Fruit), including average length, thickness, and width of the coffee fruit, density of the coffee fruit, hopper capacity, percentage of peel removal per kilogram.

a. Coffee bean measurement

The average length, thickness, and width of a coffee bean (measured with a caliper).

b. Percentage of husking results per kilogram

The percentage of coffee yield per kilogram is determined through laboratory analysis.

c. Coffee density

$$\rho b = \frac{wb}{v} \tag{1}$$

Where:

$\rho b = coffee\ density\ (gram/cm^3$

$wb = mass\ of\ coffee\ (gram)$

$v = volume\ of\ chamber\ (m^3)$

d. Hopper capacity

The capacity of the hopper can be calculated using the following equation:

$$Hc = V \times \rho b \tag{2}$$

Where:

$Hc = \ Hopper\ capacity\ (gr)$

for the volume of a frustum:

$$V = \frac{1}{3} \times h \times (A + a + \sqrt{(A \times a)}) \tag{3}$$

Where:

$V = \ Volume\ of\ frustum\ (cm^3)$

$h = height\ of\ the\ frustum\ (cm)$

$A = area\ of\ the\ larger\ base(\ cm^2)$

$a = area\ of\ the\ smaller\ base\ (cm^2)$

3 Result and discussion

This section presents the findings of the research and provides an in-depth analysis of the results. It covers the performance of the developed coffee pulper machine based on the various parameters tested, including its capacity, efficiency in peeling, and its impact on coffee quality.

3.1 Design of the Coffee Pulper Machine

The machine was designed using Autodesk Inventor software, taking into account the needs of the local farmers and the technical requirements for processing coffee efficiently as shown in Figure 1. The coffee pulper machine operates when the gasoline engine is started, which then rotates the pulley. The rotation is transferred through the V-belt to the peeling cylinder's pulley attached to the shaft. As the peeling cylinder rotates, the shaft drives the gears, which in turn move the carrier. This allows the wet coffee fruit to be fed into the hopper. The coffee is carried by the rotation of the peeling cylinder, where the coffee fruit is squeezed between the cylinder and the plandes (pressing roller). After the coffee fruit is crushed and broken down, the beans and the skin naturally separate and exit through their respective openings.

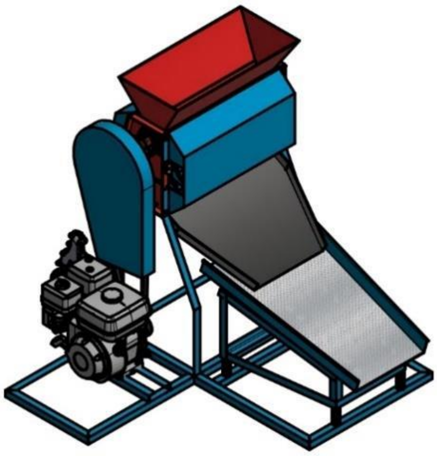

Figure 1. Coffee pulper machine design

The coffee pulper machine is composed of several key components as shown in Figures. 2, each designed to work together to efficiently peel the skin from coffee fruits while maintaining the quality of the beans.

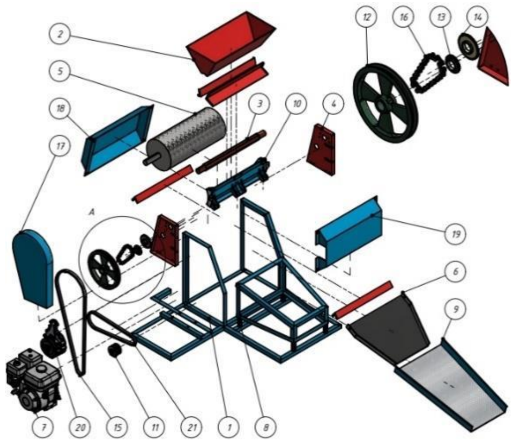

Figure 2. Coffee pulper machine components

Below are the main components involved in the design of the coffee pulper machine:

1. Main Frame

   Functions as the support for all components; this frame is made of 3x3 cm angle iron.

2. Hopper (collection bin)

   Functions as a container for the coffee beans to be peeled. Its prismatic shape facilitates the storage of a larger quantity of coffee fruit.

3. Carrier (coffee fruit feeder)

   Functions to direct the coffee fruit into the peeling cylinder. It has a star-like shape with 6 points, which helps guide the coffee in an orderly manner during the peeling process.

4. Peeling Frame

   Functions as the support for the peeling components; this frame is made of sheet metal.

5. Crusher/Peeling Cylinder

   Functions to peel the coffee fruit and separate the beans from the fruit's skin. It is in the shape of a perforated tube.

6. Outlet/Exit Channel

Functions as the exit path for the coffee beans after they have been peeled.

7. Drive Motor

The drive motor used in this coffee pulper machine is a gasoline engine with a power of 5.5 HP.

8. Vibration Motor

This motor is used to vibrate the sifter so that the sifter can automatically operate.

9. Sifter

The sifter in the coffee pulper machine is used to sort the coffee beans along with the coffee skin that comes out through the exit channel.

10. Pressing Roller

Functions as a press to push the coffee beans against the peeling cylinder. It is made of cast iron.

11. Motor Pulley

Functions as the connecting component that transmits the motor's rotation to the shaft.

12. Large Pulley

Functions as the connecting component that transmits the rotation of the shaft received from the drive motor.

13. Gear 1

A small gear with 15 teeth, it functions to transfer the rotation from the shaft of the cylinder to the carrier.

14. Gear 2

A gear with 30 teeth, it functions to receive rotation to drive the carrier.

15. V-Belt

A rubber V-belt with a trapezoidal cross-section, it functions to transmit power from one shaft to another.

16. Chain

Functions to transfer power from one shaft to another.

17. Pulley Cover

Functions as a protective cover for the transmission components.

18. Cylinder/Crusher Cover

Functions as a protective cover for the moving peeling cylinder components.

19. Plandes Cover

Functions as a protective cover for the plandes.

20. Water Pump

Functions to supply water as an assisting medium in the wet pulping process of coffee.

21. Belt Pump

This V-belt functions to transfer power from the drive motor to the water pump.

3.2 Shaft calculation

a. Transmitted Power from a Motor

The motor to be used in this study has a power of 5.5 HP, 3600 rpm. To convert it into kilowatts (kW), the following equation can be used:

$$Power\ (kW) = Power\ (HP) \times 0.7355 \tag{4}$$

So, the power of the motor is 4.043 kW.

b. Torque calculation

The torque calculation can be found by following this equation:

$$T = \frac{P \times 9550}{n} \tag{5}$$

Where:

$T =\ Torque\ (Nm)$

$P =\ motor\ power\ (kW)$

$n =\ motor\ speed\ (rpm)$

$V =\ Volume\ of\ frustum\ (cm^3)$

So, the torque is 10.76 Nm

3.3 Results of observation

a. Coffee bean

The measurement of the average coffee bean, including length, thickness, and width, aims to determine the ideal distance to be used for the gap between the hulling drum and the coffee hulling groove on the plender. Based on the results of caliper measurements with an accuracy of 0.02 mm, as presented in Table 1.

Table 1. The average size of the coffee bean.

	Length (mm)	Width (mm)	Thickness (mm)
Max	15.36	14.88	16.46
Min	6,66	6.26	8.36
Avg.	12.01	10.57	12.41

b. Coffee bean density

From the calculation results, it is known that with a 500 cm^3 measuring cup, the average number of coffee beans is 325. The weight of the coffee beans is 518.28 grams. Therefore, the density of the coffee beans is calculated to be 1.0365 grams/cm^3 or 1,036.5 kg/m^3.

c. The percentage of husking yield

The average husking yield measurement is conducted to determine the weight of the coffee beans after hulling and to determine the weight of the removed coffee husk. The results of the measurement serve as a comparison for theoretical capacity calculations. Based on the average measurement of the husking yield of coffee beans, it was found that 1 kg of coffee beans after hulling will become 675.80 grams or 67.58%.

3.4 Theoretical Machine Capacity

The theoretical capacity calculation of the machine is performed based on the following known data:

a. The assumption factor for the rolling of coffee beans in the hulling gap (Da) = 0.17.

b. Dimensional factor for one hulling cycle (Db) = 0.33

c. Efficiency of coffee bean lifting by the carrier = 70%

d. Number of coffee beans lifted by the carrier = 44 beans per trough

e. Number of troughs on the carrier = 6

f. Total revolutions = 128.57 rpm (N)

g. Efficiency due to friction, hulling, and other factors = 80%

The theoretical capacity of the coffee bean hulling machine can be calculated using the following equation:

$$Machine\ capacity = \frac{Da \times Db \times \eta \times \Sigma y \times \Sigma x \times N}{100} \tag{6}$$

$$Machine\ capacity = \frac{0.17 \times 0.33 \times 70 \times 44 \times 6 \times 128.57}{100}$$

$$Machine\ capacity = 726\ kg/h$$

Considering the friction, hulling, and other factors with an efficiency of 80%, the calculation is as follows:

$$\frac{762\ kg}{hour} \times 80\% = \frac{609.6kg}{hour}\ (\approx 610kg/h) \tag{7}$$

So, the machine theoretical capacity is 610 kg/h

4 Conclusion

Based on the calculations and analysis of the theoretical capacity of the coffee bean hulling machine, the following conclusions can be drawn:

a. Theoretical Capacity:

The machine's initial theoretical capacity, before adjusting for factors like friction and hulling efficiency, is 762 kg/hour.

b. Efficiency Adjustments

After considering the effect of friction, hulling, and other operational factors (with an efficiency of 80%), the effective processing capacity of the machine is reduced to 610 kg/hour.

c. Key Influencing Factors:

The efficiency of the lifting mechanism (70%) and overall operational losses due to friction and material processing have significant impacts on the machine's final output, reducing its theoretical capacity.

Practical Implications: The adjusted capacity of 610 kg/hour reflects more realistic processing expectations and will be crucial for setting operational targets, maintenance schedules, and assessing overall performance in a real-world setting

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Conflicts of Interest

The authors no conflict of interest.

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