Design and Development of Young Coconut Shell and Husks Shredder Machine

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Abstract. Young coconut shell and husk shredder machine is designed for shredding the husks after the process of coconut shell crushing. The main objective of this machine is to reduce coconut shell waste after the completion of harvest. The machine contains of two shafts of 25 blades per shafts (1st stage) and another two shafts of 30 blades per shaft (2nd stage) placed side by side in order to put pressure on the coconut shell and husk during the cutting process. At stage 1, which is the shredding stage, it has 2 shafts which both rotate in the opposite direction. The blades have bigger surface area, thick, hard-faced cutting surfaces and run in low rotation per minute (rpm) in order to crush the coconut shell and husk. At stage 2, which is the cutting stage, it consists of 2 shafts which rotate in the opposite direction and each shafts consist of 30 blades. The blades in stage 2 is thinner compared to the blades in stage 1, sharp cutting edge and the distance from each blades are closer to each other in order to cut and shred the coconut shell and husks into small, fine and desired size. Furthermore, the rotations of the blades are both in opposite directions toward each other which mean that the cutting process will consists pressure into the shell and husks. The output for the machine is able to produce 50 - 80 kg of young coconut shell and husks after the shredding process hourly. The machine uses electrical motor to reduce sound pollution. Besides that, a 1420 rpm motor is fitted to run the machine entirely which is equivalent to 1 Horsepower (Hp). The output power achieved is 544 kiloWatt hour (kWh) with an efficiency of 73%. Lastly, the objectives are achieved, that is to reduce young coconut shell and husks waste by converting to animal feeds.

1. Introduction
The young coconut shell and husk shredder machine is designed for shredding the husks as the end product after the process of coconut shell crushing. The main objective of the machine is to reduce young coconut shell waste after the completion of harvesting process. The machine is suitable to small farmers who can earn extra income besides farming by re-using the waste that was left behind. The targeted outcome from the shredding process is to able to obtain the crushed coconut shells into finer pieces in order to produce husks, activated carbon, kernel, or charcoal. First, the husks can be used for purposes such as mixing the soil around the plants in order to make the soil moist, or even made into coconut charcoal which would be helpful in improvising the soil quality which helps to raise the carbon dioxide content in the soil. The husks can be also used to produce pillows and mattresses [1]. The reason why the coconut shells are crushed into finer pieces is because of the wastages from the coconut shells can put into good use.
The coconut palm is one of the most useful tropical trees and is used for food, beverage, shelter, animal feed, and is grown industrially for the edible and highly saturated oil contained in the flesh of its fruits. The tree can survive 50 years without needing much attention and the fruits drop throughout the year. The nut has a smooth epidermis over a fibrous mesocarp (husk) that covers the hard endocarp (shell). A thin brown layer (testa) separates the shell from the endosperm (kernel, flesh, meat), which is approximately 1-2 cm thick. A cavity within the kernel contains the coconut water [2].

The husk and shells can be used for fuel and are a source of charcoal. Activated carbon manufactured from coconut shell is considered extremely effective for the removal of impurities. Coconut husk has high amount of lignin and cellulose, and that is why it has a high calorific value of 18.62MJ/kg. The chemical composition of coconut husks consists of cellulose, lignin, pyroligneous acid, gas, charcoal, tar, tannin, and potassium. The predominant use of coconut husks is in direct combustion in order to make charcoal, otherwise husks are simply thrown away. Coconut husk can be transformed into a value-added fuel source which can replace wood and other traditional fuel sources. In terms of the availability and costs of coconut husks, they have good potential for use in power plants [3].

Every year tones of coconut shell and husk are being produced, though very small portions are being used in the field of feedstock and energy production. The expansion of bio-composites has amplified industrial usage that would release the possibilities to minimize the wastage of renewable materials. It promotes a non-food-based market for agricultural industry [4].

Coconut husk and shells are an attractive biomass fuel and are also a good source of charcoal. The major advantage of using coconut biomass as a fuel is that coconut is a permanent crop and available round the year so there is constant whole year supply. Activated carbon manufactured from coconut shell is considered extremely effective for the removal of impurities in wastewater treatment processes. [5,6]

Coconut shell is an agricultural waste and is available in plentiful quantities throughout tropical countries worldwide. In many countries, coconut shell is subjected to open burning which contributes significantly to CO₂ and methane emissions. Coconut shell is widely used for making charcoal. The traditional pit method of production has a charcoal yield of 25–30% of the dry weight of shells used. The charcoal produced by this method is of variable quality, and often contaminated with extraneous matter and soil. The smoke evolved from pit method is not only a nuisance but also a health hazard.

This paper will present the design, analysis and testing of the fabricated machine to produce animal feeds from agro waste.

2. Methodology
The design of the machine is divided into two stages as shown in figure 1. The first stage is to cut the coconut shell and husks into smaller pieces. After that, the coconut shell and husks will fall into a container for the second stage process so that it can shred the coconut shell and husks into finest pieces as expected. Finally, the output of the finest piece of coconut shell and husks will drop into a container that was placed near the machine.
Figure 1. Design of working principles

Figure 2. Machine development

Figure 2 showed the final stage machine development of the coconut shell and husks shredder machine. The selection criteria were based on hardness, easy handling, weight, noise and cost.
3. Results and Discussions
To investigate the noise made by the machine, an acoustic dosimeter is used. By using the formula of Sound Pressure Level against Time, the noise from the machine was able to be calculated as shown in Table 1 below:

| Time (sec) | Noise (decibels) |
|-----------|------------------|
| 1         | 85.6             |
| 3         | 86.1             |
| 5         | 82.3             |
| 7         | 86.6             |
| 10        | 85.7             |

Sound Pressure Level (SPL) against Time

\[
\text{SPL} = 10 \times \log \left( \sum_{i=1}^{n} 10^{(\text{decibels}_i / 10)} \right) 
\]

\[
\text{SPL} = 10 \times \log \left[ 10^{(85.6/10)} + 10^{(86.1/10)} + 10^{(82.3/10)} + 10^{(86.6/10)} + 10^{(85.7/10)} \right] 
\]

\[
\text{SPL} = 10 \times \log \left[ 10^{8.56} + 10^{8.61} + 10^{8.23} + 10^{8.66} + 10^{8.57} \right] 
\]

\[
\text{SPL} = 92.5 \text{ dB} 
\]

Coconut shell and husks will drop into the machine opening and the designed blades will finish the cutting process. The rotation of the blades need to be calculated by using a formula to identify the speed or rotation of the blades needed. The power for the blades to crush the coconut shell and husks need to be calculated as the overall efficiency of the designed machine is important.

Given machine properties as below:
- Horsepower: 1 Hp
- Revolution per minute: 1420 rpm
- Voltage: 240V
- Frequency: 50Hz
- Current: 7.3 A

The machine consists of two pulleys which are driver and driven. The smaller pulley has a diameter of 0.15 m and the larger pulley has a diameter of 0.3 m. The length of belt between two pulleys is 1.3208 m.

Velocity, \( v = \frac{\pi DN}{60} \)  

\[
v = \frac{\pi (0.3)(1420)}{60} 
v = 22.305 \text{ m/s} 
\]
Weight of Motor = 15 Kg
Weight of Pulley = 2 Kg
Diameter of Small Pulley = 0.15 m
Diameter of Big Pulley = 0.30 m
Velocity, \( v = 22.305 \) m/s

Given:
\[ V = \frac{d}{t} \]  \hspace{1cm} (3)

Thus, Time, \( t = \frac{1.3208}{22.305} \)
\( t = 0.059 \) s

Given:
\[ a = \frac{v - u}{t} \]  \hspace{1cm} (4)

Thus, Acceleration, \( a = \frac{22.305 - 0}{0.059} \)
\( a = 378.06 \) m/s²
Force to Hold 2 kg pulley, \( P = M_L a + M_L g \)  
\( P = M_L (a + g) \)  
\( P = 2 (378.06 + 9.81) \)  
\( P = 775.74 \text{ N} \)

Coefficient of Friction
\( f = \mu R_N \)  
\( R_N = W \)  
\( f = P \)  
\( f = 775.74 \text{ N} \)

\[ 763.12 = \mu (19.62) \]  
\[ \mu = \frac{763.12}{19.62} \]  
\[ \mu = 0.0253 \]

Power Transmitted
Formula: \( P = (T_1 - T_2) V \)
\[ \frac{T_2}{T_1} = e^{\mu \theta} \]  
\[ \frac{T_2}{775.74} = e^{0.0253 \times 3.147} \]  
\[ T_2 = 1.083 \times 775.74 \]  
\[ T_2 = 751.37 \text{ N} \]

Hence, \( P = (775.74 - 751.37) \times 22.308 \)  
Power transmitted by machine = 543.65 \text{ W}\]

Efficiency of Motor:
\[ 1 \text{ Hp} = 746 \text{ watt} \]  
\[ \eta = \frac{P_{\text{out}}}{P_{\text{in}}} \times 100 \]  
\[ \eta = \frac{543.65}{746} \times 100 \]  
\[ \eta = 72.88\% \]

Power efficiency \( \simeq 73 \% \)

Unit of electrical power is kWh (S.I. unit) which is actually 1000 Watt per hour. That means if an equipment needed 1000 Watt to run for an hour, it will consume 1 unit of electricity. As 1 Hp is equal to 745.7 Watt, the mechanical output of the motor is 745.7 Watt (1 Hp) and the motor efficiency is 73 \%.
Power = 745.7 × \frac{73}{100} = 544.361 \text{ kWh}

Now, the electric power unit is calculated in kWh which means the total power need to run the motor is 1.775 kW for an hour. We need to calculate the power consumption for 24 hours, so that we need to substitute the values into equation below:

\[
\frac{\text{Power}}{\text{Watt/hour}} \times \text{time} = \frac{544.361}{1000} \times 24
\]

Power Consumption = 13.06 kWh

Overall, the results showed that the efficiency of motor was 73% and the noise was less than 93 dB so that it can prevent our eardrum from damage. Next, the size of cutting was found to be 3 cm² to 5 cm² respectively. The rpm of blades was at 800-1000 rpm, rpm of motor was at 1420 rpm while the rpm for pulley was at 500-700 rpm. Besides, the torque was 3.193 Nm and the power consumption after we have calculated is 13.06 kWh.

3.1 Stress Analysis

| Table 2 Stress Analysis Result of Shafts |
|----------------------------------------|
| Name | Minimum | Maximum |
| ---- | ------- | ------- |
| Volume | 1.802x10⁻³ m³ |  |
| Mass | 14.15 kg |  |
| 1st Principal Stress | -6212.7 MPa | 173587.9 MPa |
| 3rd Principal Stress | -1734.4 MPa | 16638.4 MPa |
| Displacement | 0 m | 9.6 m |

Figure 3 shows the 1st Principal Stress. The minimum value for the principal stress is -6212.7 MPa while the maximum stress is 17358.9 MPa. The shafts in the 1st principal stress shows normal when all the shafts, blades, housing and washers are jointed together.
Figure 4 shows the 3rd Principal Stress. The minimum value for the principal stress is -1734.4 MPa while the maximum stress is 16638.4 MPa. The shafts in the 3rd principal stress will run a little bit when all the shafts, blades, housing and washers are jointed together.

![3rd Principal Stress](image1.png)

**Figure 4.** 3rd Principal Stress

Figure 5 shows the displacement. The minimum value for the principal stress is 0 m while the maximum stress is 0.036 m. The displacement shows normal when all the shafts, blades, housing and washers are jointed together.

![Displacement](image2.png)

**Figure 5.** Displacement

4. Conclusions
The machine constructed is able to shred and cut 50 - 80 kg of young coconut shell and husk hourly. This machine is designed to produce animal feed from agro waste. The size of animal feed shredded and cut is range from 2 - 6 cm. Experimentally, cows has been constantly feeds for Three days at a cow farm at Tambun, Perak shows with good sign of eating without any harm.
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