Test Performance and Economic Analysis of Straw Chopper Machine

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Abstract. The usage of rice straw as an alternative basic compost fertilizer is needed. Rice straw processing into compost fertilizer through stage chopper. Chopper is the size reducing stage that it is easily decomposed. The chopper processing can be done by using straw chop machine. This research aims for performance test and economic analysis. Research use descriptive analysis. The results of performance test of straw chop machine have actual capacity is 103.32±12.068 kg/h, engine efficiency is 79.59%, power requirement with load and without load are 1.1±0.067 HP and 0.698±0.109 HP, specific load 7.94 W/kg, chopper yield is 94.33±0.97%, the percentage of chopper chunks is 83.55±0.04%, engine noise level 76.6±0.5 dB, and vibration level on the framework, hopper and chopper cylinder are 18±4.9 mm/s², 53.94±1.3 mm/s² and 21.6±4.6 mm/s². Based on the result of economic analysis of rice straw chop machine have the basic cost is Rp.46,159,621. with gross income Rp.55,792,800./year. The breakeven point has been reached when the machine has chopped 41,078 kg of rice straw. This rice straw chopper machine has met the economic feasibility criteria of NPV>0 that is Rp.52,821,891. BC Ratio>1 with value is 1.17. IRR value> MARR interest rate (9%) with IRR 102%.

1. Introduction
Rice straw is a waste of agricultural products that can easily be encountered. Most farmers only consider rice straw as a waste that has no economic value. Only a small portion of straw is used by farmers while the rest is left or even burned on the ground directly [1].

Straw has a variety of benefits that can improve the welfare of farmers. In many countries (including China, Korea, and Japan), these wastes are used for compost, animal feed, mulch for vegetables and fruits, household fuels, craft materials, rooftops, and place of mushroom growing [1]. According to [2], national rice production in 2015 reached 75.40 million tons. While in West Java, in the same year rice production reached 11.39 million tons. Based on rice production data, the amount of straw that can be produced in Indonesia is estimated to reach 113.1 million tons, while for West Java area is estimated to reach 17.1 million tons.

The production of agricultural waste, especially rice straw in Indonesia is quite large as previously described. Therefore, it is very important for the community, especially farmers to develop and utilize the existence of such waste in order to provide greater benefits. People, especially farmers, must open their horizons to the utilization of the agricultural wastes they produce. Utilization of waste has been widely applied by the community to household wastes and other organic wastes. However, there are still few farmers who utilize rice straw waste to the maximum. Straw has many benefits that can be developed, among others as fuel, animal feed, cage or barn floor, packing of agricultural materials (eg eggs), building materials (roofs, walls, floors), mulch, and handicrafts.

Most of the farmers do the burning of rice straw produced after harvest without seeing the great benefits of the straw itself. The burning of this straw aims to accelerate the preparation or processing of the soil for the next planting period. However, the burning of straw can result in some nutrients being lost, especially volatile nutrients and other nutrients that are not available on the soil.
To overcome this, one way of utilizing the right rice straw for farmers is to use it as a raw material for composting. In the process of making straw into compost, of course, the process of enumeration of straw into smaller sizes. It is necessary to expand the contact surface of the material with microorganisms. The smaller the size of the raw materials used, the process of material decomposition will be faster. The process of enumeration of straw is of course not be done manually so it requires a simple mechanical tool capable of producing rice straw reproduce.

Agricultural Machinery and Equipment Laboratory, Department of Agricultural Engineering and Biosystem of Padjadjaran University has developed rice straw machine. However, the machine has not been specifically tested in terms of performance or economic analysis. Performance testing and economic analysis of the engine is necessary to know the quality, quantity, and efficiency of the machine work made. In addition, this test can also provide information on the deficiencies and advantages of the machine. Therefore, research on performance test and economic analysis of rice straw machine has been made.

The purpose of this research is to test the performance of rice straw enactment machine which include: theoretical capacity, actual capacity, machine efficiency, actual power requirement, specific power, reedmen enumeration, percentage of length of enumeration, noise, vibration, and physical work load.

This research was also conducted to determine the economic feasibility analysis on rice straw enumerator which includes calculation of fixed cost, variable cost, Break Even Point, Pay Back Period, Net Present Value, Benefit Cost Ratio, and Internal Rate of Return.

2. Methodology

This research was conducted in September 2017 until January 2018. This research took place in Agricultural Machinery and Equipment Workshop, Faculty of Agricultural Industrial Technology, Padjadjaran University. The research method used is descriptive analysis method. Descriptive analysis is doing measurement, observation and calculation of structural components and performance / functional machine [3]. The data obtained then analyzed so as to get an idea of the performance of straw chopper machine which in the end can provide an image of the feasibility of the machine. The research can be seen in Figure 1.
3. Tools and materials
The tools and materials used for this research are:

3.1. Tools.
Tools used are clamp meter, tachometer, vibration meter, soundlevel meter, laptop, meter, stopwatch, scales.

3.2. Material
The material used in this research is rice straw as much as 250 kg.

4. Research stages
The research stages explanation as follows:

4.1. Performance Test
Engine performance tests are performed to evaluate engine capabilities while operating. The performance test parameters to be tested are: a. theoretical capacity; b. actual capacity; c. engine efficiency; d. actual power requirements; e. specific energy; f. rendemen enumeration; g. percentage of length of count; h. noise levels, and vibrations. Performance test is conducted based on [4] standard test of Chopper Machine of Organic Fertilizer Raw Material - Quality Requirement and Test Method. Testing is done with 5 repetitions for each repetition requiring ± 50 kg of rice straw.

4.2. Economic Analysis
To find out the economic feasibility of straw chopper machine is done calculation of economic analysis. Economic analysis is done is to calculate the cost component of the series of rice straw enumeration process. The stage of economic analysis of straw chopper machine includes: a. calculation of basic costs; b. the amount of acceptance; c. determination of business break-even point; and D. economic feasibility analysis by using Net Cash Value Method (NPV), Method of Benefit and Cost Ratio (BCR), and Method of Return on Capital (IRR).
4.3. Data Calculation

The data calculation is done by using equation of formula as follows:

4.3.1. Theoretical Capacity [5].

\[ K_t = \frac{\rho_j \times L_t \times A_t \times \lambda_k \times N_c}{6 \times 10^3} \]  \hspace{1cm} (1)

- \( K_t \) = Theoretical capacity of machine (kg/h)
- \( \rho_j \) = Density of straw cage (kg/m³)
- \( N_c \) = Rotating speed of enumerator cylinder (rpm)
- \( A_t \) = Area of enumeration area (m²)
- \( L_t \) = The length of the theoretical slice (m)
- \( \lambda_k \) = Number of blades

4.3.2. Actual Capacity.

\[ K_a = \left( \frac{M_{bc}}{T_p} \right) \times 3600 \]  \hspace{1cm} (2)

- \( K_a \) = Actual capacity of enumeration (kg/h)
- \( M_{bc} \) = The total mass of material that comes out within a certain time (kg)
- \( T_p \) = Time specified to accommodate material (s)

4.3.3. Machine Efficiency.

\[ \eta = \frac{K_a}{K_t} \]  \hspace{1cm} (3)

- \( \eta \) = Machine efficiency
- \( K_a \) = Actual capacity (kg/h)
- \( K_t \) = Theoretical capacity (kg/h)

4.3.4. Theoretical Power Requirement.

\[ P_t = \frac{2\pi \times M_t \times N_m}{60} \]  \hspace{1cm} (4)

- \( P_t \) = The required power of the electric motor (W)
- \( M_t \) = torque moment (Nm)
- \( N_m \) = Round on motor fuel shaft (rpm)

4.3.5. Specific Power.

\[ P_{sp} = \frac{P_a}{K_a} \]  \hspace{1cm} (5)

- \( P_{sp} \) = Specific power of enumeration (kW/kg)
- \( P_a \) = Actual power of enumeration (kW)
- \( K_a \) = Actual capacity of machine (kg)

4.3.6. Rendemen Enumeration.

\[ R_p = \frac{M_{bo}}{M_{bi}} \]  \hspace{1cm} (6)

- \( R_p \) = Rendemen Enumeration
- \( M_{bo} \) = Mass of paddy rice straw out (kg)
- \( M_{bi} \) = Mass of incoming rice straw (kg)

4.3.7. Percentage Length of Haystack.

\[ P_{pk} = \left( \frac{M_{c1}}{M_{c1} + M_{c2}} \right) \times 100\% \]  \hspace{1cm} (7)

- \( P_{pk} \) = Percentage of length of haystack (%)
- \( M_{c1} \) = Straw pulp mass less than 50 mm (kg)
- \( M_{c2} \) = Straw pulp mass more than 50 mm (kg)

4.3.8. Fixed Cost.

\[ B_T = D + H + M + I + L \]  \hspace{1cm} (8)

- \( B_T \) = Fixed cost (Rp/year)
- \( D \) = Depreciation Cost (Rp)
H = Place or building cost (Rp)
M = Cost of repair and maintenance (Rp)
I = Tax expense (Rp)
L = Capital interest (Rp)

4.3.9. Biaya Variabel.

\[ BV = Bop + Bl \]  

\( BV \) = Variable cost (Rp/h)
\( Bop \) = Operator fee (Rp/h)
\( Bl \) = Electricity cost (Rp/h)

4.3.10. Break Even Point (BEP).

\[ BEP = \frac{BT}{(HP - BV)} \]  

\( BEP \) = Business break-even point (kg)
\( HP \) = Product price (Rp)

4.3.11. Payback Period (PBP).

\[ PBP = \frac{Total Investasi}{Keuntungan} \]  

\( PBP \) = Payback Period (year)

4.3.12. Net Present Value (NPV).

\[ NPV = \sum PV \text{ income} - \sum PV \text{ spending} \]  

\( NPV \) = Net Present Value

4.3.13. Benefit Cost Ratio (BCR).

\[ BCR = \frac{(\sum PV \text{ income})}{(\sum PV \text{ spending})} \geq 1 \]  

\( BCR \) = Benefit cost ratio

4.3.14. Rate of Return on Capital (IRR).

\[ IRR = i1 - \left( \frac{NPV1 \times (i2 - i1)}{(NPV2 - NPV1)} \right) \]  

\( IRR \) = rate of return on capital
\( i1 \) = 1st interest rate
\( NPV1 \) = Net Present Value at 1st interest rate
\( i2 \) = 2nd interest rate
\( NPV2 \) = Net Present Value at the 2nd interest rate

5. Result and discussion

5.1. Physical Characteristics of Rice Straw

Characteristic testing aims to determine the physical characteristics of paddy straw to be chopped. Characteristics of the materials used affects the results of rice straw enumeration. Testing of material characteristics include measurement of water content, bulk density, length and diameter of rice straw. Based on the result of the test, it was found that the water content of wet straw base was 74.28 ± 1.068%, straw density of 160.57 ± 2.04 kg / m3, average straw length 689 ± 59.3 mm. diameter in rice straw 1.2 ± 0.3 mm, and outer diameter of 3.2 ± 0.6 mm. Measurement of moisture content of the substance before the enumeration is to determine the suitability of the water content of the material to be used for standard enumeration. Bulk density measurements are used to calculate the capacity of the chamber, theoretical capacity, and theoretical driving power requirements.

5.2. Performance Test Engine

Performance test is to find out how big the work of machine in quantity and quality. The engine performance test covers the actual engine capacity aspect, engine efficiency, rendemen enumeration,
actual power requirements, specific power, percentage of length of churn, physical workload, vibration level, and noise level. Testing is done based on [4] about Choper Machine Organic Fertilizer Raw Material - Quality and Test Requirements. Prior to the test, the calculation of power and engine capacity theoretically. The theoretical capacity of the straw chop machine is 129.8 kg/h can be seen in Appendix 4. Based on the calculation data in Appendix 7, the magnitude of the theoretical power without load is 0.7 horse power [HP] while the theoretical power when there is a load that is 2.03 HP.

Based on the results of performance test, the rice straw machine has an actual capacity of 103.32 ± 1.068 kg/h, the machine efficiency is 79.59%, the engine power requirement when there is load and no load 1.1 ± 0.067 HP and 0.698 ± 0.109 HP , specific power of 7.94 W/kg, yield of 94.33 ± 0.97% counting, percentage of length of length 83.55 ± 0.04%, machine noise level at 76.6 ± 0.5 dB, and vibration level at frame, hopper and process i.e. 18 ± 4.9 mm /s², 53.94 ± 1.3 mm /s² and 21.86 ± 4.6 mm/s².

The specification of the performance test results can be determined by comparing the test standard with the results obtained through measurement and calculation. If the result meets, it will be known how well this machine enumerates. Parameters tested to find out the specification of straw chopper performance test can be seen in Table 1.

Table 1. Specification of Straw Counter Test Results

| Parameter               | Test Standard          | Test Result          | Terms            | Information |
|-------------------------|------------------------|----------------------|------------------|-------------|
| Actual Capacity         | Class A with capacity <500 kg/h | 103.32 kg/h         | Test results <Terms of test | conform     |
| Round knife blade       | 1200-1300 rpm          | 1243 rpm             | -                | conform     |
| Engine efficiency       | 80%                    | 79.59%               | Test results >Terms of test | un conform  |
| Rendemen Enumeration    | 65%                    | 94.33%               | Test results >Terms of test | conform     |
| Percentage length of count | 80%                   | 83.55%               | Test results >Terms of test | conform     |
| Noise level             | 90 dB                  | 76.6 dB              | Test results <Terms of test | conform     |
| Level of vibration      | ≤ 4.5 mm/s            | 47.48 mm/s           | Test results <Terms of test | un conform  |

5.3. Economic Analysis

Economic analysis is conducted to determine the level of investment profit of rice straw enumerator machine when the machine is used for enumeration. Economic analysis includes the calculation of basic cost (fixed cost and variable cost), break even analysis, and economic feasibility analysis including Net Present Value, Internal Rate of Return, Benefit and Cost (Benefit Cost Ratio Analysis), as well as the Method of Payback Period (Pay Back Period Analysis).

Based on economic analysis of rice straw machine is feasible to be operated with the application in the field in accordance with the calculation data. The amount of basic cost Rp. 46,159,621,- with annual gross revenue of Rp. 55,792,800,-. The break point of the straw enumeration was reached when the machine had chopped 41,078 kg of rice straw. This paddy straw machine has met the economic feasibility criteria of NPV> 0 that is Rp. 52,821,891,-. The magnitude of BC Ratio> 1 with value 1.17. IRR value> MARR interest rate (9%) with IRR 102%.

Economic feasibility analysis is used to determine whether the investment of rice straw enumerator machine is profitable or not. This can be seen from the calculation of NPV, BC Ratio, IRR, and payback period. Criteria of economic feasibility include if NPV> 0, BC Ratio> 1, IRR> MARR interest rate [6].
Of the three criteria are compared with the calculation results of economic feasibility analysis of the machine Table 2.

| Parameter     | Requirement       | The Calculation Results | Information |
|---------------|-------------------|-------------------------|-------------|
| NPV           | NPV > 0           | 52,821,891              | Feasible    |
| BC Ratio      | BC Ratio > 1      | 1.17                    | Feasible    |
| IRR           | IRR > interest rate MARR | 102%                     | Feasible    |
| Pay Back Period | Fast is better     | 0.93 year               | Feasible    |

6. Conclusion

Based on the results of performance test, the rice straw machine has an actual capacity of 103.32 ± 1.068 kg / hour, the machine efficiency is 79.59%, the engine power requirement when there is load and no load 1.1 ± 0.067 HP and 0.698 ± 0.109 HP , specific power of 7.94 W / kg, yield of 94.33 ± 0.97% counting, percentage of length of length 83.55 ± 0.04%, machine noise level 76.6 ± 0.5 dB, and vibration level at frame, hopper and process ie 18 ± 4.9 mm/s2, 53.94 ± 1.3 mm/s2 and 21.86 ± 4.6 mm/s2. Overall performance of this jrami counter machine is good enough.

Based on economic analysis of rice straw machine is feasible to be operated with the application in the field in accordance with the calculation data. The amount of basic cost Rp. 46,159,621,- with annual gross revenue of Rp. 55,792,800,-. The break point of the straw enumeration was reached when the machine had chopped 41,078 kg of rice straw. This paddy straw machine has met the economic feasibility criteria of NPV> 0 that is Rp. 52,821,891,-. The magnitude of BC Ratio> 1 with value 1.17. IRR value> MARR interest rate (9%) with IRR 102%.

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