International Journal on Advanced Science Engineering Information Technology

Vol.8 (2018) No. 5
ISSN: 2088-5334

Designing of Straw Chopper Machine for Compost Production

Wahyu Sugandi[#], Zaida[*], Asep Yusuf[#], Ahmad Thoriq[#], Ade Kramadibrata[#]

[#] Department of Agriculture and Biosystem Engineering, Universitas Padjadjaran
Jl. Raya Bandung-Sumedang Km 21 Jatinangor, Sumedang, Indonesia
sugandiwahyu@gmail.com

**Department of Food Industrial Technology, Universitas Padjadjaran*
Jl. Raya Bandung-Sumedang Km 21 Jatinangor, Sumedang, Indonesia
zd.zaida9@gmail.com

***Abstract*—Amount of straw wastes in Ciparay, Bandung, West Java Indonesia reaches 10-12 tons.ha^{-1} but its has not been well managed, after harvested, the remaining unused straw is abandoned on the ground and is eventually burned. In the long run, this straw burning will be very disadvantageous to farmers, especially in terms of the environmental impacts on rice paddy including decreasing soil fertility, killing soil biota, damaging soil physical properties and wasting energy. One of alternatives to utilize rice straw able to provide added value is utilizing its waste as a material to make compost on the condition that the straw is already chopped into a size of 5-10 cm according to SNI standards. Therefore, a study on rice straw chopping technology based on the composting requirements is required. The aim of this study is to design a prototype of rice straw chopper with capacity 100 kg.hr^{-1}. The method used in this research is engineering design with observation of the reasearch, design criteria, functional and structural design, figure design, technical analysis, prototyping of rice straw chopper, machine functional and performance test. The measurement results of rice straw characteristics show that the average length, diameter, bulk density and moisture content of rice straw are 708 mm, 4 mm, 160.6 kg.m^{-3} and 34.6% wet basis. This straw chopper design were produces a prototype with a dimension of 1040 mm (length) x 1000 mm (height) x 465 mm (width) with a power source generator using 5.5 HP gasoline motor. The result of functional test of the straw chopper shows that the actual capacity of this straw chopper is 100.32 kg.hr^{-1}.**

***Keywords*— rice straw; straw chopper machine; compost; compost production.**

I. INTRODUCTION

Indonesia is an agrarian country whose people work on agriculture one of which is rice. According to the data of Central Statistical, Indonesia's national rice production reaches 75.56 million tons with the amount of straw produced is approximately 113.3 million tons. Ciparay is one of the areas in Bandung and many of the citizens work as rice farmers. According to the chair person of Sugih Tani farmer group in 2017, the area of rice paddy in Ciparay is ±100 ha with rice production per ha reaching 7 - 8 tons and the amount of the straw possibly produced is estimated to reach 10-12 tons. Basically, the amount of the straw produced is not optimally by farmers because its waste after harvested is abandoned on the ground, sometimes used as animal feed, or burned as shown on Figure 1.

In the long run, this practice (straw burning) will be very disadvantageous at least in two aspects, i.e. land degradation and energy wastage [2]. Straw burning will kill soil biota in layers so that it can cause damage to soil physical properties and soil fertility.

Fig. 1 Straw burning after rice threshing [1]

Some nutrients are lost, especially volatile one, as well as other nutrients that may become unavailable to plants

[3].This nutrient loss without any replenishment of these elements into the soil will lead to an imbalance of the nutrient balance that will decrease the soil fertility level and lead to a decrease of crop production and productivity [4].The process of nutrient loss due to straw burning is shown on Figure 2.

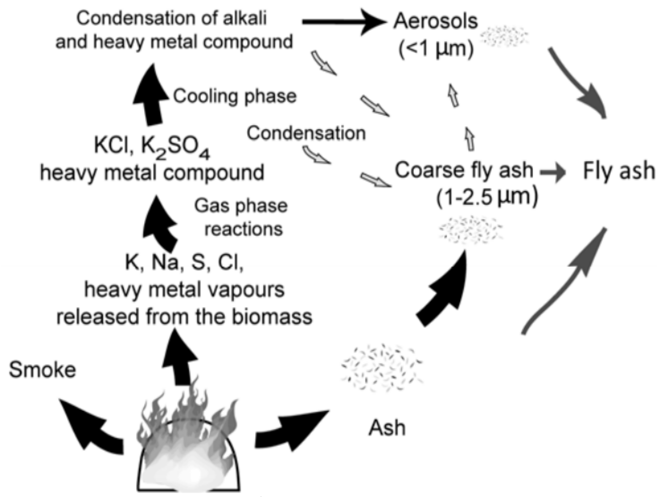

Fig. 2 The mechanism of nutrient loss through the rice straw burning

When the rice straw is being burned, it will produce smoke, ash carried by the wind, and heavy metal vapors released from biomass such as Potassium (K), Sodium (Na), Sulphur (S), and Chlorine (Cl). Furthermore, these heavy metals will enter into the gas reaction phase where they react into potassium chlorate (KCl) and potassium sulphate (K2SO4) compounds. The KCl and K2SO4 compounds then enter the cooling phase and condensate into very small-sized particles (aerosols) that is below 1 µm, and then will be carried by the wind as ash [5].

Straw processing requires so much time, labour, and additional work that it is necessary to find alternatives in order that the straw can be utilized by the farmers. Moreover, one of the alternatives to utilize rice straw is making compost. Rice straw is known to contain K and Si in sufficient quantities. Therefore, the needs of K and Si in large quantities can be obtained from rice straw [6].

Solution, it can be concluded that the straw utilization as compost raw material can provide added value, especially for rice farmers. However, one of the requirements to obtain a good compost is that the straw must be first chopped into a smaller size (size reduction) [5].This size reduction is done in order to simplify the decomposition process of rice straw into compost. Due to the large quantity of rice straw in Ciparay, Bandung, it is necessary to design of rice straw chopper.

II. Materials and Method

This study uses engineering design method, namely, making a design irregularly so that there is a new contribution both in process and form (Figure 3).

In detail, step of the research stages in Figure 3 can be described as follows:

1. Problem Identification: conducting an observation on problems arising in rice farmer group in Ciparay, providing solutions especially in terms of the utilization of straw waste during harvesting season. And conducting a study and research intensively in relation to the rice straw copper engineering.

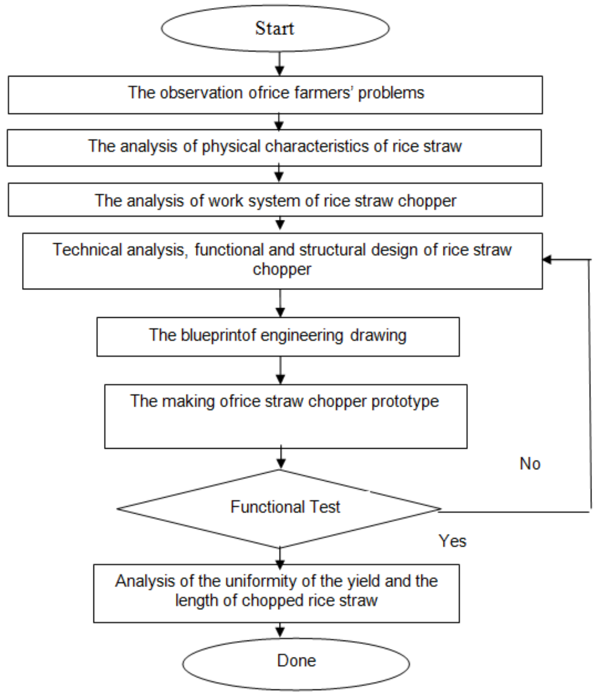

Fig 3 The research stages of rice straw chopper engineering

2. Design Criteria: Determining a chopping mechanism suitable to be applied to the chopper [7] , in the hope that the length of the chopping process result will meet SNI standard, namely 5-10 cm. and Studying the Rice Straw Characteristics: carrying out a measurement of the dimension, bulk density and moisture content of the rice straw as the basis for designing the chopper.
3. Functional Design: The functional design is emphasized on the machine functionalities as a whole and the produced output. Meanwhile, this functional design consists of the mechanism analysis of the chopping blades, the chopping blade holder cylinder, the machine construction analysis, the transmission system analysis, the chopping power analysis, and the rice straw chopper ergonomic and anthropometrics analysis.
4. Structural Design and Technical Analysis: Structural design is an important stage determining the final chopper design because in which the hoper position, the chopping blades, the blade holder cylinder, the engine frame, the driving motor holder and the discharge hole are assembled into a unified form and placed in accordance with the original functions and design. Meanwhile, technical analysis is more about the calculation of shaft, pegs, bearings, chopping blade dimension, cutting angles, chopping blade cylinder, frame, weld and lathe.
5. The Blue Print Figure of Machine Design. The whole process of structural design of straw chopper will be presented in 2D and 3D using AutoCAD.
6. The Manufacturing of Rice Straw chopper. After figure design was made perfectly, the next step is making and assembling the rice straw chopper.

7. Machine Functional Test: Machine functional test will be done to determine the function of rice straw chopper when it operates. Has the chopper functioned according to the initial planning. If not, a more detail design study will be done.

A. *Technical Analysis*

Technical analysis considered in this chopper includes the force requirement, shaft analysis, pin analysis, SPI analysis, bearing analysis, transmission unit analysis, frame strength analysis and weld strength analysis[8]. Technical analysis examines the strength of the material of each chopper component by performing dimensional measurements, theoretical calculations and direct observations when the machine operates.

B. *The Requirement of Driving Force*

Force requirement analysis is required to determine the amount of energy or force required by a machine when starting the chopping process from the beginning of the ingredient input to the end of the chopping process. The force generated when the machine is being operated comes from the movement of the machine transmission along with the other machine components interconnected each other and the combustion process converting chemical energy into mechanical energy, that drive the chopping blades in the chopping chamber.

The requirement of force to drive the work mechanism of the chopping is calculated by the following equation[15]:

$$P_t = \frac{2\pi \times M_t \times n_c}{60} \tag{1}$$

Whereas P_t as theoretical power (W); nc as rotational speed of chopping cylinder (rpm) and M_t as torque moment (Nm). To generate theoretical power, the value of chopping cylinder's torque moment can be calculated by the following equation [5], [10]:

$$M_t = F_t \times r_c \tag{2}$$

Whereas Mt is torque moment (Nm); Ft as tangential force (N) and rc as the radius of chopping cylinder (m). The Tangential force (F_t) is calculated by the following equation [5]:

$$F_t = m_s \times g \tag{3}$$

With, F_t is tangential force (N); m_s is the mass of chopping cylinder (kg); and g is gravitational acceleration ($m.s^{-2}$). To generate the driving force with load, the total mass of the load has to be calculated on the chopping chamber using the equation as follows [11]:

$$m_{jrc} = V_{rc} \times \rho_j \tag{4}$$

Whereas, m_{jrc} is the mass of straw stored in the chopping chamber (kg); V_{rc} as the volume of the chopping chamber (m3); and ρ_j as straw density ($kg.m^{-3}$)

C. *Transmission Unit Analysis*

This rice straw chopper uses belt and pulley as its transmission units. The transmission comparison in belt-pulley transmission system can be calculated by the equation as follows [15]:

$$\frac{n_m}{n_c} = \frac{D_p}{d_p} \tag{5}$$

Note:

nm = rotational speed of driving motor (rpm)
nc = rotational speed of chopping cylinder (rpm)
dp = diameter of driving motor's pulley (mm)
Dp = diameter of chopping cylinder's pulley (mm)

The length of belt used can be calculated by the equation as follows [12], [13]:

$$L_b = 2C_p + \frac{\pi}{2}(D_p + d_p) + \frac{1}{4C_p}(D_p - d_p)^2 \tag{6}$$

Note:

L_b = length of the belt (mm)
C_p = distance between pulley center (mm)
D_p = diameter of chopping cylinder's pulley (mm)
d_p = diameter of driving motor's pulley (mm)

The mass of the belt can be calculated by the equation as follows[16]:

$$m_b = \rho_b \times A_b \times L_b \tag{7}$$

Note:

m_{ob} = mass of the belt (kg)
A_b = cross-sectional area of the belt (m^2)
ρ_b = belt density ($kg.m^{-3}$)
L_b = length of the belt (m)

The linear speed can be calculated by the following equation[14]:

$$v = \omega \times r_p \tag{8}$$

Whereas, v is the linear speed ($m.s^{-1}$); r_p as the radius of driving motor's pulley (m); and ω is the angular velocity ($rad.s^{-1}$)

III. RESULTS AND DISCUSSION

A. *Problem Identification*

The potential area of rice paddy in Ciparay is ±100 ha with rice production per ha reaching 7 - 8 tons and the amount of the straw possibly produced is estimated to reach 10-12 tons. Basically, the amount of the straw produced is not optimally by farmers because its waste after harvested is abandoned on the ground

B. *The Physical Characteristics of Rice Straw*

The measurement results of rice straw characteristics show that the average length, diameter, bulk density and moisture content of rice straw are 708 mm, 4 mm, 160 $kg.m^{-3}$ and 34.6% wet basis.

C. *Design Criteria*

1. The capacity of the designed cropper is 100 kg hr^{-1}
2. The chopping mechanism uses a hammer mill and stationary blades installed at the entrance with chopping blades spinning radials
3. 14 pieces of slicing blades are used in this chopper and

attached to the chopping cylinder.
4. The slicing machine used is 5.5 HP gasoline driving motor that it can produce straw with length less than 5 cm, meeting SNI standard.
5. The machine is designed to be easy to overhaul for easy maintenance.

D. Functional Design

The main function of this straw chopper is to chop straw into a desired size. To fulfill the main function, supporting function is required, namely by using hoper and chopping blades. Relating to the function of rice straw pusher and strainer, the rice straw has to be put in the hoper and in the process of chopping the rice straw, it requires the cylinder and the chopping blades attached to the cylinder so that the rice straw can be chopped into the desired size as shown in Figure 4.

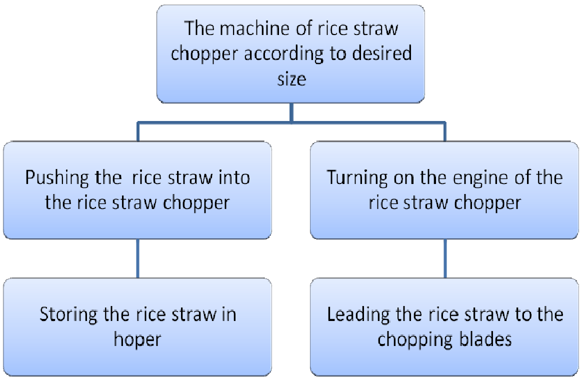

Fig. 4 The Scheme of Functional Design

E. Structural Design

The design of rice straw chopper with gasoline driving motor is divided into 4 parts, namely the design of the chopper, the gasoline engine holder framework (Figure 5), the chopping cylinder cover, and the chopping cylinder design. After the design of these four units has been completed, these units will be assembled and merged into a rice straw chopper so that it can chop rice straw into certain desired.

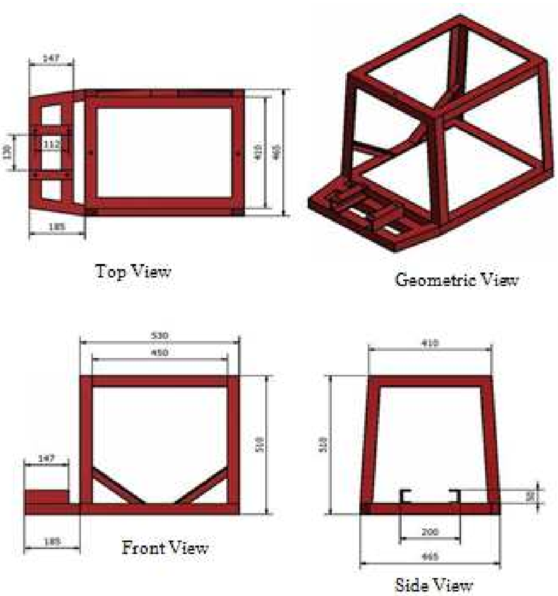

Fig. 5 The frame and gasoline motor holder

F. The Design of the Chopping Cylinder Cover Unit

The chopping cylinder cover unit is made for safety reason and as a stationary blade when the chopping blades are spinning. The cover unit can be closed and opened using a hinge so that if the rice straw piles, it can be cleaned. The material used is made of bent iron plate as shown on Figure 6.

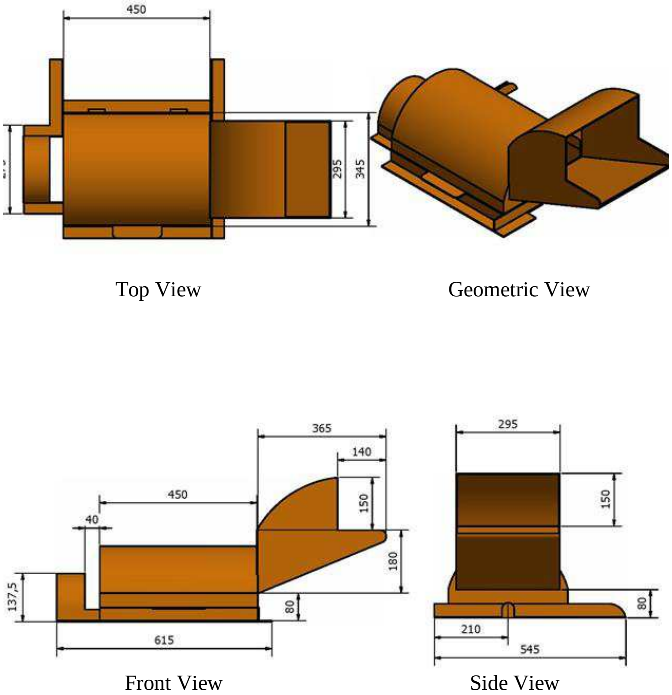

Fig. 6 The Cover of Chopping cylinder unit

G. The Design of Chopping Blades Cylinder Unit

The chopping cylinder unit is made to chop the rice straw into the desired length, namely less than 5 cm. The number of blades used is 21 pieces in total with a minimum rotational speed, 250 rpm that can be set on the gas pedal of the gasoline motor. The larger the rpm value, the smaller the length. At the end of the blade is installed a fan to move the chopped rice straw resulted to the output hole. The design of the chopping cylinder unit is presented on Figure 7

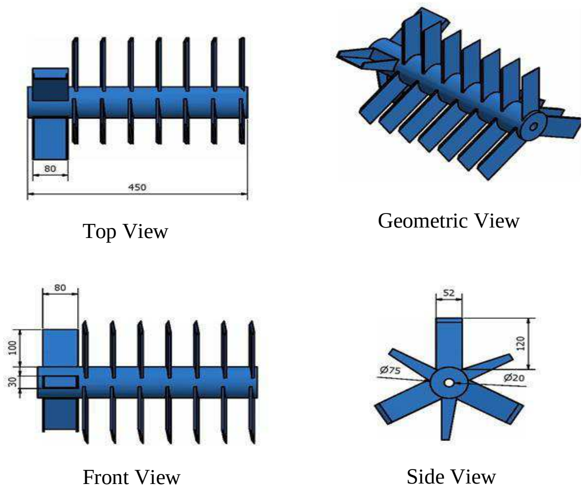

Fig. 7 Chopping Cylinder Unit

In general, the process of chopping rice straw is as follows (Figure 8). The chopper machine consists of four main parts : material insertion hole (hopper), engine frame, slicing cylinder and material discharge hole.

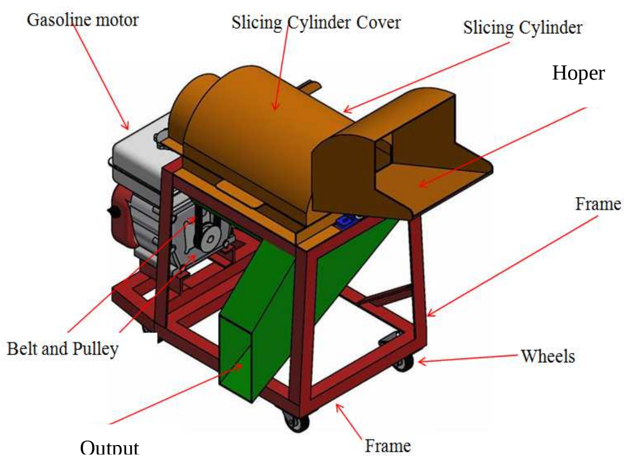

Fig. 8 The Mechanism of rice straw chopper

H. The Manufacture of Rice Straw Chopper

The rice straw chopper is manufactured after the calculation of figure design and technical analysis have been completed. Each component is assembled and arranged in accordance with the figure design made. As for the making of the frame, it is made of iron elbow 3 to make it able to withstand the load when the machine operates. The load includes motor gasoline, chopping cylinder, cylinder cover and hoper. A wheel is installed to the frame so that the machine can move easily from one place to another place. The manufacture of rice straw chopper can be seen on Figure 9 (a. measurement of angle, b. welding process).

a. Measurement of angle b. Welding Process

Fig. 9 The Manufacture of Rice Straw Chopper

Finally, by following the rules to design machines especially agricultural one, the enumerator machine can be assembled and tested functionally. Furthermore, functional and performance tests are done to ensure whether the machine has been successfully made in accordance with the initial design or still requires some improvements. If the result is fine, then the performance will be done. Structurally, the sugarcane litter chopper can be seen on Figure 10.

Based on the measurement result, the actual capacity of this straw chopper is 100.32 $kg.hr^{-1}$, with the length of the piece less than 5 cm as shown on the following figure 11.

Front View Side View

Fig. 10 The Prototype of Rice Straw Chopper

Fig. 11 Chopped Rice Straw

IV. Conclusions

The measurement results of rice straw physical characteristics show that the average length, diameter, bulk density and moisture content of rice straw are 708 mm, 4 mm, 160 $kg.m^{-3}$ and 34.6% wet basis. The result of functional test of the straw chopper shows that the actual capacity of this machine is 100.32 $kg.hr^{-1}$. The machine prototype of this chopper is divided into 4 parts namely hoper, cylinder cover, chopper cylinder, and frame. This straw chopper has a dimension of 1040 mm (length) x 1000 mm (height) x 465 mm (width).

Acknowledgment

We would like to thank to Rector Universitas Padjadjaran for research funding. This research was provided by Hibah Internal Unpad Grant No. 855/UN6.3.1/PL/2017.

References

[1] A. Trivedi et al., “Sustainable bio-energy production models for eradicating open fi eld burning of paddy straw in Punjab , India,” Energy, vol. 127, pp. 310–317, 2017.

[2] S. K. Lohan et al., “Burning issues of paddy residue management in north-west states of India,” Renew. Sustain. Energy Rev., vol. 81, no. June 2017, pp. 693–706, 2018.

[3] J. Idrovo-novillo, I. Gavilanes-terán, M. Angeles, and C. Paredes, "Composting as a method to recycle renewable plant resources back to the ornamental plant industry : Agronomic and economic assessment of composts," Process Saf. Environ. Prot., vol. 116, pp. 388–395, 2018.

[4] Ó. J. Sánchez, D. A. Ospina, and S. Montoya, "Compost supplementation with nutrients and microorganisms in composting process," vol. 69, no. 26, pp. 136–153, 2017.

[5] J. Tong, S. Xu, D. Chen, and M. Li, "Design of a Bionic Blade for Vegetable Chopper," J. Bionic Eng., vol. 14, no. 1, pp. 163–171, 2017.

[6] H. Blanco-canqui, C. A. Francis, and T. D. Galusha, "Does organic farming accumulate carbon in deeper soil pro fi les in the long term ?," Geoderma, vol. 288, pp. 213–221, 2017.

[7] S. Talapatra, M. Shakil, P. K. Mondal, M. S. Islam, and S. Islam, "Implementation of Product Design Tools for the Development of an Automated Vegetable Chopper," Technol. Invest., vol. 5, no. 01, p. 1, 2014.

[8] A. Hafezalkotob, A. Hami-Dindar, N. Rabie, and A. Hafezalkotob, "A decision support system for agricultural machines and equipment selection: A case study on olive harvester machines," Comput. Electron. Agric., vol. 148, no. November 2017, pp. 207–216, 2018.

[9] N. K. Pleshanov, "Neutron bandpass limiting chopper," Nucl. Inst. Methods Phys. Res. A, vol. 872, pp. 139–143, 2017.

[10] B. X. Han and M. P. Stockli, "Model of a SNS electrostatic LEBT with a near-ground beam chopper," in AIP Conference Proceedings, 2009, vol. 1097, pp. 395–401.

[11] L. Luo, I. Baran, S. Rusinkiewicz, and W. Matusik, "Chopper," ACM Trans. Graph., vol. 31, no. 6, p. 1, 2012.

[12] L. Tóth and Y. P. Tsividis, "Generalization of the principle of Chopper stabilization," IEEE Trans. Circuits Syst. I Fundam. Theory Appl., vol. 50, no. 8, pp. 975–983, 2003.

[13] X. Gao and Y. Guan, "Handaxes and the Pick-Chopper Industry of Pleistocene China," Quat. Int., pp. 1–9, 2017.

[14] S. M. Mathur and P. Singh, "Development and performance evaluation of a water hyacinth chopper cum crusher," Biosyst. Eng., vol. 88, no. 4, pp. 411–418, 2004.

[15] Khurmi, R.S. (2002). Strength of Materials. Ram Nagar, New Delhi: S Chand & Company Ltd.

[16] Srivastava. (1993). Engineering Prinsiple of Agricultural Machine. ASAE Textbook Number 6. American Society of Agricultural Engineers.