Conceptual Design Portable Chopper Machine for Palm Oil Frond : Laws of Classical Mechanics and CAD Approach

Ramayanti Bulan, Safrizal, T. Saiful Bahri

Abstract— A portable chopper machine is required for handling palm frond waste. Engineering design analysis required before manufacturing process. It will produces a conceptual design from portable chopper machine. Computer Aided Design (CAD) in modern engineering has been used as one of the methods in the analysis of engineering design. The aim of this research is to design of conceptual portable chopper machine for palm oil frond through laws of classical mechanics and CAD approach. Design analysis used the laws of classical mechanics. Engineering drawing and load static simulation of portable chopper machine used CAD SolidWorks software. Static simulation was conducted to know the strength or the ability of material to receive the load, its can support engineering design analysis. The results show that the minimum shaft diameter is 34.56 mm. The length, width and thickness chopper blade is 120 mm, 40 mm, 4.55 mm, respectively. The power needed of portable chopper machine is 13.16 hp. The result of the load static simulation consist of maximum stress value, yield strength and displacement value on the index bar. The maximum stress on the index bar used to evaluate the design is secured.

Index Terms— Conceptual design, computer aided design, portable chopper machine, load static simulation, SolidWorks.

1 Introduction

Palm oil plantations in addition to producing fresh fruit bunches (FFB), it's also produce waste in the form of palm frond or palm stems. The palm stems waste can be utilized as organic fertilizer. One of the machines required for the produced of organic fertilizer made from palm stem is the chopper machine. Area of oil palm plantations in indonesia (11.6 milion ha (2016) [1]) require chopper machine that have high mobility (portable).

Computer aided design (CAD) is used as the methods in the analysis of engineering design [2]. CAD based designing approaches give more effective, efficient labor costs and its can minimize errors in manufacturing processes[3]. Static simulation based on CAD was conducted to know the strength or the ability of material to receive the load. The conceptual design of chopper machine is drwan with SolidWorks software. The law classical mechanics approach was conducted to know the minimum shaft diameter and dimension of chopper blade. The aim of this paper is to design of conceptual portable chopper machine through laws of classical mechanics and CAD approach.

2 Research Method

The methodology of this research took care of the design analysis of the portable chopper machine (laws of classical mechanics and CAD approach), material selection for each component designed and engineering drawings of the portable chopper machine.

- *Ramayanty Bulan is a senior lecture in Agricultural Engineering Departements, Faculty of Agriculture, University of syiah kuala, Indonesia, PH: 0852-6122-5616. E-mail: Ramayantybulan@gmail.com*
- *Safrizal is currently pursuing doctoral degree program of Agricultural Engineering, Bogor Agricultural University, Indonesia*
- *T. Saiful Bahri is currently pursuing doctoral degree program in Bogor Agricultural University, Indonesia*

2.1 Research Prosedure

The research begins with a review of former research on the characteristics of palm frond. The physical and mechanical properties (Table 1) of the palm stem are used to determine mechanism of the portable chopper machine. The laws of classical mechanics are used to analyze the dimensions of the chopper blade, the dimensions of the machine shaft and power needed. The result of analysis are verified using the static simulation based on CAD to obtain visual design quality. The component that have the right design criteria are then drawing to become the conceptual design of a portable chopper machine. The research procedure is shown in Figure 1.

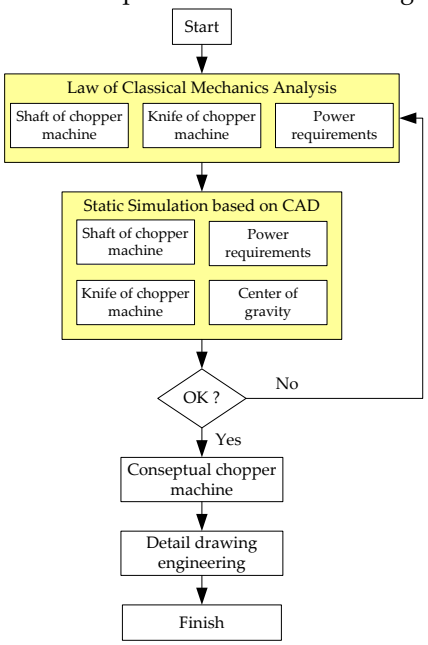

Fig. 1 The diagram of research procedure

Table 1 Some physical dan mechanical propertise palm frond

Parameter	Size	Unit	Source
Weight of leaf sandfrond	5.7 – 8.3	kg	[4], [5]
Width of frond area cutting	15 – 20	cm	[5]
Area of cutting frond section	41.25 – 62	cm^2	[4], [5]
Length of per leaf	7.0 – 9.0	m	[5], [6]
Amount of leaves	200 – 320	Leaf	[5], [6]
Friction coeficient	0.39	-	[5]
Cutting Force	5.25 – 7.90	N/cm^2	[7]

2.3 Laws of Classical Mechanics Analysis

Analysis to determine the dimension (thickness) of the chopper blade is using laws of classical mechanics approach [8], [9]. Resultan forces will be determine the maximum bending moment (M, N.mm) on the chopper knife (Figure 2). The maximum bending moment is then used to calculate the cross section modulus (Z, mm^3) using Equation 1. The type of blade used is carbon steel sheet (SS) 1023 with tensile strength (σ_i) 425 Mpa. Model of the chooper knife is a rectangle. The thickness of the counting blade (b, mm) is determined by Equation 2.

$$Z = \frac{M}{\sigma_i} = \frac{F \cdot R}{\sigma_i} \quad (1)$$

$$b = \left(\frac{6Z}{h}\right)^{1/2} \quad (2)$$

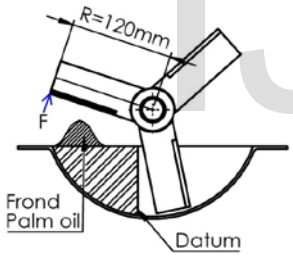

Fig. 2 Mechanism of portable chopper machine

The analysis for determining the shaft diameter of the portable chopper machine using laws of classical mechanics [4]. The maximum bending moment (M, N.mm) is determined by the resultant forces on the machine shaft. Equation 1 is used to calculate the cross-sectional modulus (Z, mm^3). The type of shaft material used is carbon steel sheet (SS) 1023 with tensile strength (σ_i) 425 Mpa. The diameter of machine shaft (d, mm) is determined using Equation 3.

$$d = \left(\frac{32Z}{\pi}\right)^{1/3} \quad (3)$$

The required power of palm frond chopper machine (P, Watt) is determined using Equation 4 [8]. The power requirement of chopper machine is based on the maximum engine rotation speed (n) of diesel that is 2400 rpm. Cutting force of palm frond (TP, N/cm^2) is used as the force to be achieved by the machine (F, N).

$$P = \frac{2\pi n R F}{60} \quad (4)$$

2.4 Load Static Simulation

Static simulation was conducted to know the strength or the ability of material to receive the load, its can support engineering design analysis. Its drawn with Solidworks software helped. Solidworks is one of CAD software to create engineering drawing and do some simulation. One of simulation can be done by solidworks is load static simulation. The design has been analyzed and right in accordance with the engineering design criteria then its called the conceptual design. After that, its generate in the form of detailed engineering drawings. Table 2 is used as material characteristic in FEM simulation.

Table 2 Material characteristics carbon steel sheet (SS) 1023

Characteristics	Size	Unit
Elastis modulus	2.045×10^{11}	N/m^2
Poisson's ratio	0.29	-
Tensile strength	4.250×10^8	N/m^2
Yield strength	2.827×10^8	N/m^2
Mass density	7858	kg/m^3
Hardenign factor	0.85	-

3 Results and Discussions

3.1 Construction Portable Chopper Machine

The construction of the chopper blades is shown in Figure 3. Portable chopper machine is use impact cutting method with engine rotation speed at 2400 rpm. The engine rotation speed of portable chopper machine was suggested by Persson i.e 20 - 40 m/s [10]. It is a good cutting for impact cutting method. The count of knives in a circle is 3 units. Feeding rate portable chopper machine based on research of Bulan is 0.5 m/s [4]. Chopped palm frond will be shredded to a size of ≤ 0.5 mmm. The chopped coefficient of chopper machine is 85%. The requirement analysis of the portable chopper machine knife is presented in Table 3.

Table 3 Construction of portable chopper machine blade

Parameter	Size	Unit	Equation
Amount cutting knife (A_c)	1176.47	cutting/ second	$A_c = \frac{V \times 10^3}{S_c \times K_c}$
Total blade choper machine (T_c)	30	unit	$T_c = \frac{A_c \times 60}{n}$
Total blade choper machine in line (T_s)	10	unit	$T_s = \frac{T_c}{A_n}$

Total of blade in portable chopper machine is 30 units with revolutions at 0.33 clockwise. The blade is consists of 10 blade in rows with 3 blade every single circle. Spacing of thr blade in a row is 25 mm. The length of the blade is 120 mm with a width of 40 mm. The thickness of the blade is above 4.55 mm with the material of Carbon steel sheet (SS) 1023. The blade is made with angle 45° and length 80 mm. Length of shaft machine is 270 mm.

The result of load stress simulation on the chopping blade is shown in Figure 4. The simulation results show that the

stress that occurs in the chopping blade is in the range of 10.1 kPa to 110 Mpa (Table 4). These results indicate that the chopper blade design is within safe limits for the Carbon steel sheet (SS) 1023 type material which modulus elastic 205 Gpa and tensile strength 425 Mpa. The maximum strain and displacement occurring in the chopper knives is also at a very low level at 4.2×10^{-4} and 0.4 mm, respectively. At the end of the blade is a plate mounted plate that serves as a blower with the number of plate 4 units. The length, width and thickness of the plate is 95 mm, 50 mm, 2 mm, respectively.

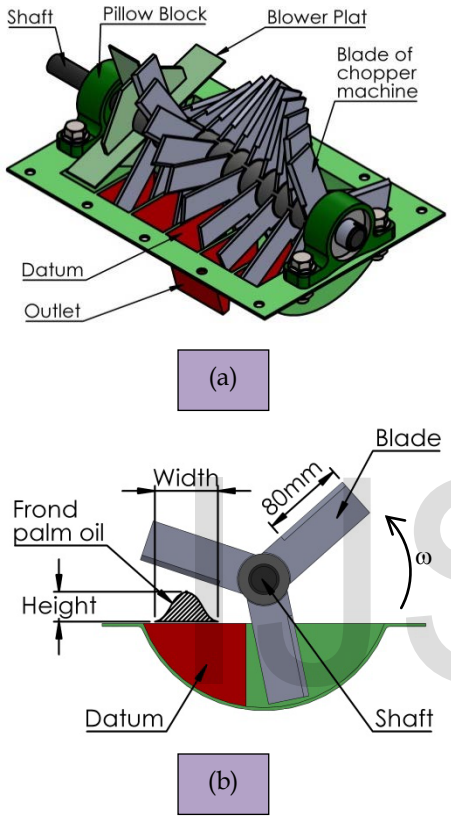

Fig. 3 Construction of portable chopper machine (a) isometric view (b) Section front view

Table 4 Simulasi result blade of portable chopper machine

Parameter	Type	Min	Max	Unit
Strain (Figure 4a)	ESTRN: Equivalent Strain	2.15×10^{-8}	4.20×10^{-4}	-
Stress (Figure 4b)	VON: von Mises Stress	1.01×10^{4}	1.10×10^{8}	N/m²
Displacement (Figure 4c)	URES: Resultant Displacement	0	0.40	mm

The classical mechanics law approach indicates that the minimum diameter of shaft chopper is above 34.56 mm using carbon steel sheet (SS) 1023 material. The resultant force in the shaft is 9765 N. The resultant force is the total force acting on the blade of the chopper. The result of load stress simulation on chopper shaft is shown in Figure 5. The simulation result shows that the stress maximum that occurs on the chopper shaft 171 Mpa (Table 5). These results indicate that the design of the chopper shaft is within safe limits for the carbon steel sheet (SS) 1023 type material which modulus elastic 205 Gpa and tensile strength 425 Mpa. The maximum strain and displacement occurring on the counter shaft is very low level at 7.85×10^{-4} and 0.46 mm, respectively.

Table 5 Simulasi result shaft of portable chopper machine

Parameter	Type	Min	Max	Unit
Strain (Figure 5a)	ESTRN: Equivalent Strain	3.6×10^{-11}	7.85×10^{-4}	-
Stress (Figure 5b)	VON: von Mises Stress	0	1.71×10^{8}	N/m²
Displacement (Figure 5c)	URES: Resultant Displacement	0	0.46	mm

3.2 Power Requirement

The results of the analysis show that the portable chopper machine needed power of 13.16 hp with engine rotation speed at 2400 rpm. The greatest power is used to pass the cutting style of palm stem. The rotating speed of the chopper with the blade radius 120 mm will be produce a linear velocity of 30.14 m/s. This is in accordance with the cutting method suggested by Persson [10] which states that the cutting impact cutting method requires a linear velocity of 20-40 m/s.

3.3 Center of gravity

Center of gravity of the portable chopper machine in the coordinates of X, Y, Z is -432 mm, -146 mm, 0 mm, respectively. The value is based on the distance from the center of point drawing. Determination of center of gravity using Solidworks software. The center of gravity result is shown in Figure 6. Center of gravity of chopper machine on X axis inclined to front. This enables the chopper to be more easily to move. Center of gravity on the Y axis shows that the portable chopper machine is stable to stand while operating. This is because the center of gravity on the Z axis tends to lower. Center of gravity on the Z axis tends to be right in the center of the simentris of the portable chopper machine. This indicates that it will be stable during operation.

3.4 Conseptual Design Portable Chopper Machine

The conceptual design of the portable chopper machine has been successfully designed (Figure 6). it has length, width and height of 880 mm, 572 mm, 919 mm, respectively. Conceptual design of a portable chopper machine uses five wheels. One wheel works for steering and 4 wheels that function to withstand the load of the chopper machine. It aims to support the mobility of the portable chopper machine in order to reach all area of the oil palm plantation.

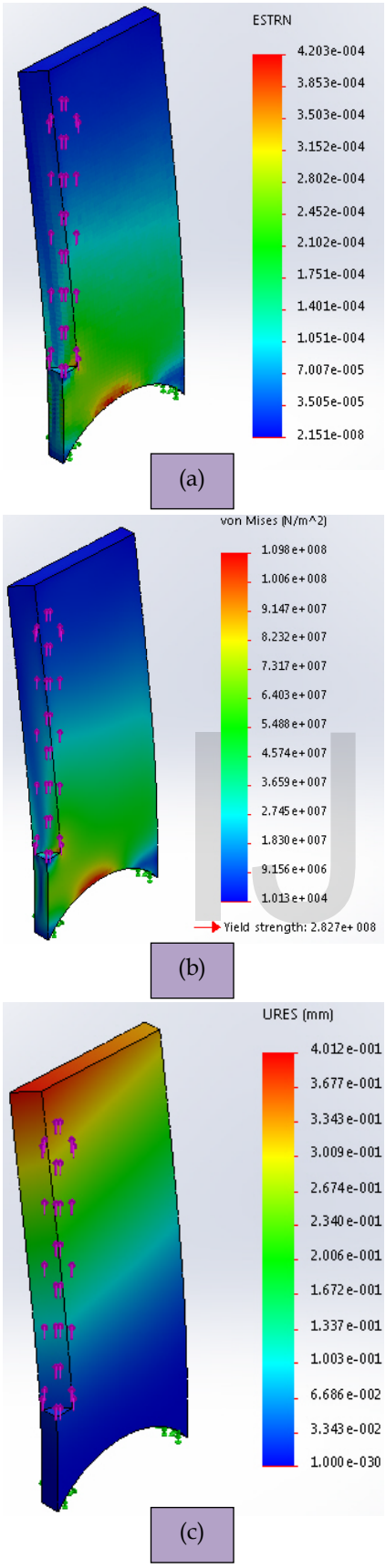

Fig. 4 Load static simulation display on the blade (a) strain analysis (b)stress analysis (c) displacement analysis

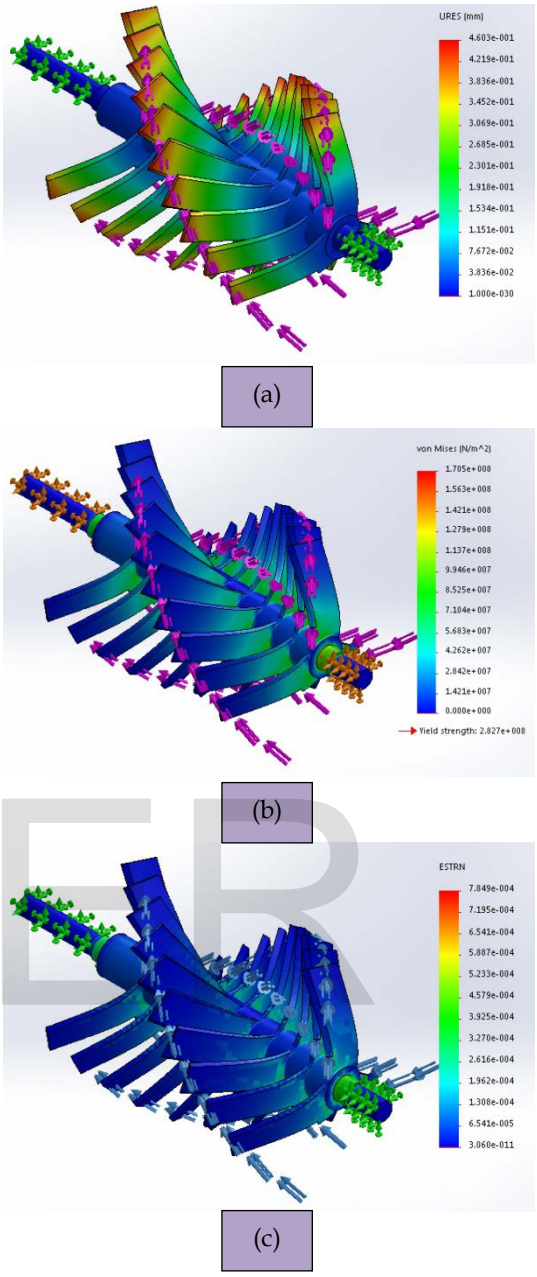

Fig. 5 Load static simulation display on the shaft (a) strain analysis (b) stress analysis (c) displacement analysis

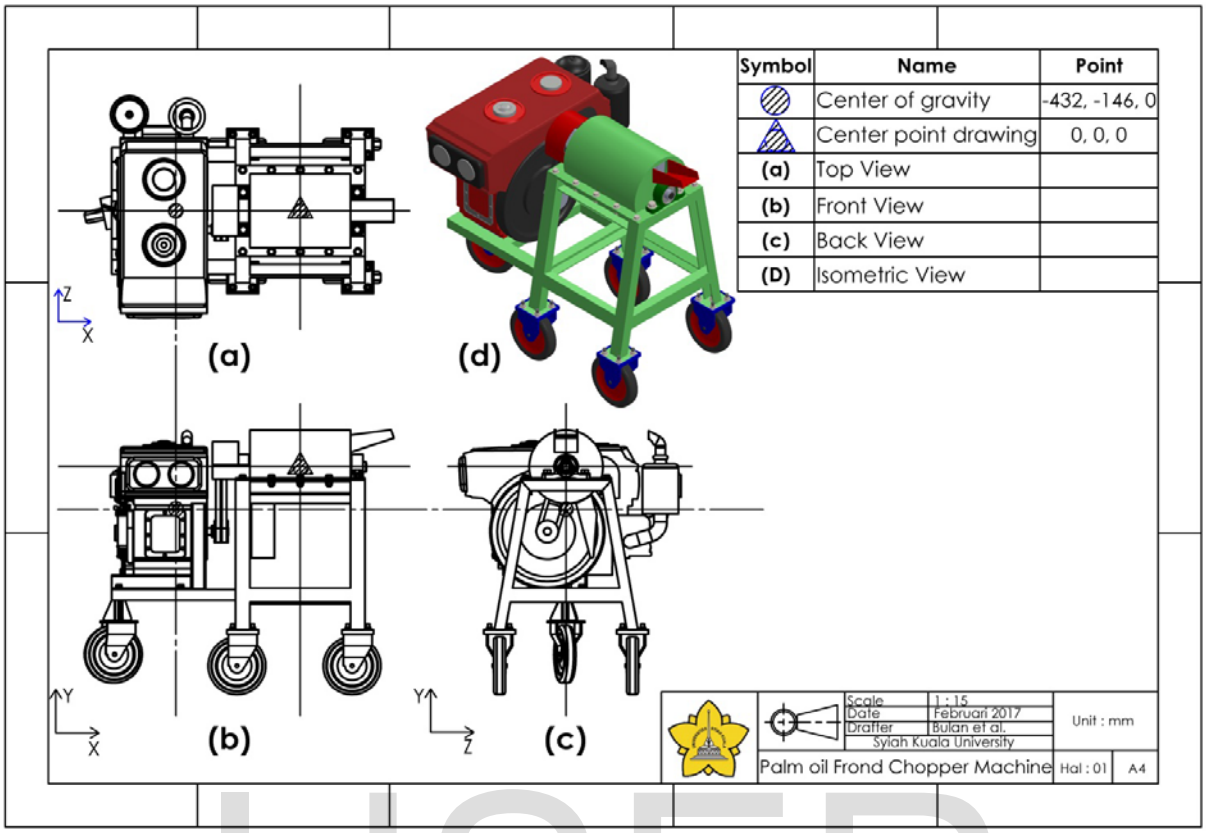

Fig. 6 Conceptual design and center of gravity from palm frond portable chopper machine

4 Conclusion

1. The engineering analysis of the chopper blade obtained the length, width and thickness is 120 mm, 40 mm, 4.55 mm, respectively. The total blade portable chopper machine is 30 pieces with 3 pieces per circle and 10 row.
2. The shaft portable chopper machine using the type of material carbon steel sheet (SS) 1023 with a minimum diameter above 34.56 mm.
3. Power recruitment portable chopper machine is 13.16 hp with engine rotation speed at 2400 rpm.
4. Center of gravity analysis shows that the portable chopper machine has a good stability to operate because the center of gravity is at a safe level.

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Nomenclature :

CAD	: Computer aided design
M	: Bending moment (N.mm)
Z	: cross section modulus (mm^3)
σ_i	: Tensile strength (Mpa)
SS	: Steel sheet
b	: Thickness blade (mm)
F	: Force (N)
R	: Radius (mm)
h	: Height (mm)
d	: Diameter (mm)
π	: Phi (3.14)
P	: Power (watt)
TP	: Cutting Force (N/cm^2)
n	: Rotary speed (rpm)
A_c	: Amount cutting knife
V	: Linear speed (m/s)
S_c	: Chopped dimension (mm)
K_c	: chopped coefficient (%)
T_c	: Total blade portable chopper machine
T_s	: Total blade portable chopper machine in line
A_n	: Total blade chopper per cycle
X, Y, Z	: Cartesian coordinate