Calculation and Design of Transmission System in the Design of Empty Palm Oil Fruit Bunches Chopper Machine with a Capacity of 100 Kg/Hour

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***Abstract*– The waste of empty palm fruit bunches (EFB) as compost material and as fiber material needs to go through a decomposition and chopping process to simplify the processing process. The empty palm fruit bunches (EFB) chopping machine has now been developed in various regions using various types of transmission, propulsion, and various models. The design of chopping machines is also increasingly diverse in line with the increasing market demand for processed products from empty palm fruit bunches (EFB). Based on these conditions, an appropriate transmission system is needed to lighten the workload of the machine, increase production yields, and save production costs. From the results of the research, it was found that the empty palm fruit bunches chopping machine with a total capacity of 100 kg/hour was tested. The machine is driven by an electric motor with a power of 4 kW and a rotational speed of 1440 rpm, which is transmitted using a pulley and belt open drive transmission system. The power from the machine is transmitted to the cutting section to chop the empty palm fruit bunches well.**

***Keywords*– Chopping, Empty palm fruit bunches, Transmission,**

I. INTRODUCTION

Palm oil plant (Elaeis guineensis Jacq) is one of the plants that produce vegetable oil with the highest consumption figures among other vegetable oil-producing plants. Indonesia is one of the largest producers of oil palm in the world, with the demand for palm oil consumption increasing every year. This has led to an increase in the amount of waste from palm oil processing and other related products. One of the most significant types of solid waste produced from palm oil processing is the Empty Fruit Bunch of Oil Palm (EFB). Based on the data obtained from processing one ton of fresh fruit bunches, approximately 220-230kg of EFB can be produced [1]. One of the products derived from utilizing EFB is the organic compost raw material [2]. Before further processing, the large-sized EFB, with a maximum diameter of around 25 cm and a length between 25 cm and 30 cm, needs to go through the shredding process to reduce its size. To be easily processed into compost, its dimensions should be reduced to at least 0.5 - 1 cm or even better if it becomes as soft as sawdust before undergoing further processing into compost. In this research, the Industrial Engineering Department of ITS (Sepuluh Nopember Institute of Technology) collaborates with the Chemical Engineering Department - ITS and their partner, the IKM East Java, to design and create a machine for shredding the Empty Fruit Bunch of Oil Palm to maximize the production process of high-quality organic compost. The shredding machine is required to have a capacity of 100 kg/hour as requested by the partner, IKM East Java. Therefore, a mechanism for the Empty Fruit Bunch shredding machine needs to be developed.

The empty fruit bunches of the oil palm chopper machine work by feeding the empty fruit bunches of oil palm through a funnel or hopper, which are then shredded by rotating cutting blades powered by a driving motor. One of the previous studies conducted by [3] resulted in a circular blade-type empty fruit bunches of oil palm chopper machine with a shredded size of an average length of 8 cm. Another research by [4] produced a unit of device that untangles the empty fruit bunches of oil palm into fibers. Although the machine's working system is suitable, the shredding results from both previous studies are still not optimal in terms of size. The transmission system in the empty fruit bunches of oil palm chopper machine is almost similar to the research conducted by [5] regarding the transmission of plastic waste chopper machine, as well as the study by [6] about the design and construction of corn cob chopper machine, both of which use a belt and pulley transmission system (open belt drive) to transmit rotation from the motor to drive the cutting blades. The presence of this chopper machine can save time, cost, and energy in the process of making oil palm compost compared to manual shredding. Additionally, the empty fruit bunches of the oil palm chopper machine also help shorten the time in the process of organic composting.

Based on the description above, a study will be conducted regarding the calculation and planning of transmission system components to be used for the empty fruit bunches of oil palm chopper machine, capable of

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processing 100 kg of EFB per hour, with shredding results as previously explained. This research will encompass the calculation and planning of shaft components, pins, belts, and pulleys, as well as bearings. The research will commence with a literature review and observation of various models and types of empty fruit bunches of oil palm chopper machines, as well as several other material chopper machines. Observations will be made regarding plantations and a direct assessment of the conditions of empty fruit bunches of oil palm in plantation areas, coupled with a study based on relevant literature or similar research. The equipment manufacturing process will be guided and directed by the supervising instructor and coordinated with experts based on calculation and design results. This process aims to understand the components of the machine and the factors influencing the shredding process, ultimately determining the design and planning of the machine. Based on this planning design, a machine sketch design will be created, which will then be used for the calculation and design of the transmission system for the EFB chopper machine with a capacity of 100 kg per hour. The calculation and design results will yield machine drawings, types, and specifications of components to be used, complete with their dimensions. Subsequently, the procurement of transmission system components will be carried out according to the planned requirements, which will then be assembled for the empty fruit bunches of the oil palm chopper machine. Once the machine is assembled, testing will be conducted to determine if the machine can achieve the specified capacity parameters, and the results of these tests will serve as a reference for determining the final specifications and capacity of the machine.

In this research, the partner desires an empty fruit bunches of oil palm chopper machine capable of processing 100 kg of EFB per hour. Considering the size and characteristics of the empty fruit bunches of oil palm, a suitable transmission system will be required to transmit power from the driving motor to the cutting blades or shredding component. The transmission system in the chopper machine will undoubtedly involve the determination and selection of shafts, pins, bearings, pulleys, belts, and several other factors that will affect the transmission and shredding of the empty fruit bunches of oil palm. Design considerations and calculations for the machine components must be detailed, starting from the type, type, size, and even the durability and lifespan of the components used. This will result in a transmission system specification that is suitable for the empty fruit bunches of oil palm chopper machine capable of achieving a capacity of 100 kg per hour, and economically affordable as well.

II. METHOD

Observations were conducted to obtain an overview of the equipment assembly process in the workshop located in Kenjeran Surabaya, as well as to directly assess the conditions and characteristics of the empty fruit bunches of oil palm in Pare. Based on the observation results, it was found that there is a high demand for organic fertilizer made from empty fruit bunches of oil palm waste. To meet this demand, the chopper machine needs to work with a large workload. However, a machine with a high workload requires a suitable transmission system to ensure that the overall power and energy required can be transmitted optimally.

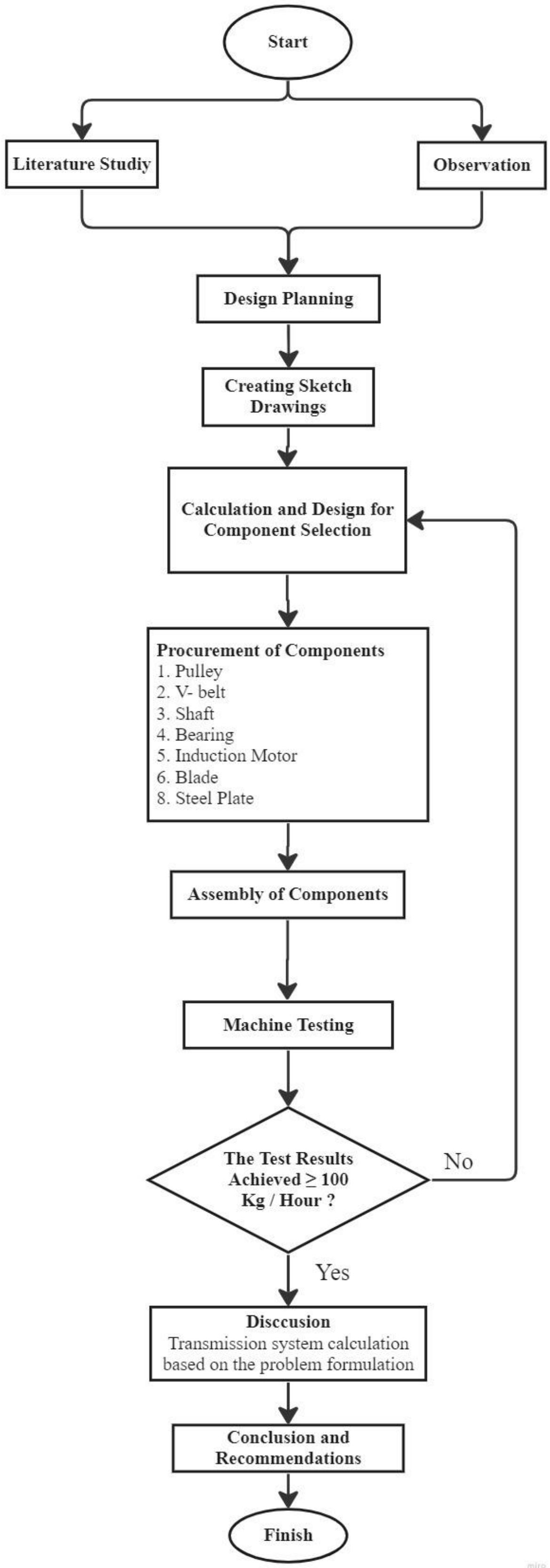

Figure 1. Flowchart

Several references can assist in the research process. The literature study was conducted by searching sources related to Empty Fruit Bunch of Oil Palm and its utilization, as well as literature study on various shredders, cutters, and crushers for comparison with the machine to be created.

The design variables of the form and structure of the machine to be created are determined, as well as specific factors and conditions that are considered to accommodate the components of the shredder machine. This includes design parameters, design criteria, and experimental design of the empty fruit bunches of oil palm chopper machine. Based on these considerations, calculations, and design can be carried out regarding the type and model of electric motor to be used, along with shafts, bearings, and all transmission system components that will be used in the 100 kg/hour capacity empty fruit bunches of oil palm chopper machine.

The procurement of several components that match the specifications of the empty fruit bunches of the oil palm chopper machine, obtained from the calculations and planning, is followed by the assembly process of the machine components. After that, the machine testing will be conducted, focusing on the total capacity of the machine achieved within a specific period. This testing aims to determine the overall capacity of the empty fruit bunches of the oil palm chopper machine.

III. RESULTS AND DISCUSSION

A. Design Concept

In the design process of the empty oil palm bunches chopper machine, the form and structure will accommodate machine components, including design parameters, design criteria, and experimental design of the empty oil palm bunches chopper machine.

1) Design Parameters
   The operation, performance, cost level, and redundancy of the empty oil palm bunches chopper machine, as designed according to the requirements.
2) Design Criteria
   Explicitly, the achievements that must be attained by the design and construction of the empty oil palm bunches chopper machine to be deemed successful. In the recommendation and feasibility report, particularly concerning design and decision criteria.
3) Experimental Design
   The experimental design will explain a systematic and efficient method that allows others to study the relationship between multiple input variables (also known as factors) and the main output variable (also known as response) of the empty oil palm bunches chopper machine.

B. Transmission System Planning

The transmission system of the 100 Kg/Hour capacity empty oil palm bunches chopper machine uses an open belt drive mechanism as like the transmission system in the study of [7]. In this mechanism consists of several components, including pulleys, belts, shafts, pins, and an electric motor. The existing transmission system will transfer the speed from the electric motor to the cutting components. The mechanism in this transmission system starts with the activation of the electric motor, where its speed is transmitted to pulley 1, which then uses a V-belt to transfer it to pulley 2 and drive the shaft through the pulley. Subsequently, the connected cutting blade on the shaft will rotate and chop the empty oil palm bunches of materials fed through the hopper input.

C. Design Power and Torque

Based on the research and calculations of power and force, the driving electric motor has a power (P) of 4 kW and a motor speed (n1) of 1440 rpm, with a planned power (Pd) of 3.18 kW, and a cutting shaft speed (n2) of 720 rpm, resulting in a design Torque (Mt) of 2705.56 kgf. mm, based on the formula equation from [8]

$$Mt = 974000 \frac{P_d}{n_1} \quad (1)$$

$$Mt = 2705.56\ kgf.mm \quad (2)$$

D. Selection of Belt Type.

Selection of belt type. The selection of the belt type can be determined based on the planned power and the number of rotations that occur on the smallest pulley. The following data is obtained:
Engine speed without load (n1): 1440 rpm
Chopper rotation speed (n2): 720 rpm

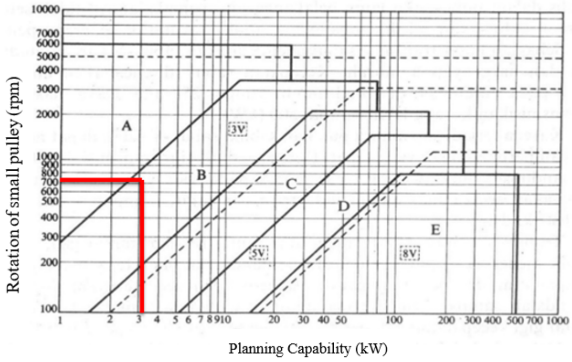

Figure 2. Selection Belt Type Diagram

Based on the V-belt selection diagram [9] it is determined that the appropriate belt type to be used is Type B with the following V-Belt dimensions: Width (b) = 17 mm, Height (h) = 11 mm, Area (A) = 1.38 cm^2 = 14 mm.

Using the dimensions data from pulley 1 (the driving pulley) diameter of each pulley. Based on "Table 2.2 Minimum Driving Pulley Diameter" [9] it is known that the recommended minimum diameter for the driving pulley is 145 mm. Based on the availability of pulley components in the market, a driving pulley with a diameter close to 10 inches or 152.4 mm is selected. The diameter of the cutting pulley is obtained to be 304.76 mm. based on the formula equation from [8] Based on the availability of components in the market, a driving pulley with a diameter of 12 inches or 304.8 mm is selected.

$$\frac{n_1}{n_2} = \frac{d_2}{d_1} \quad (3)$$

$$d_2 = 304.76\ mm \quad (4)$$

Considering the dimensions and size of the selected cutting pulley components: Type: B-2, Size: 12 inches, and Shaft hole diameter: 65 mm

Based on [9] the calculation result, a V-belt with a length of 1848.17 mm is obtained. Considering the material availability in the market, a V-belt with a size close to it is selected, which is V-belt Type B-74 with a length of 74 inches or 1879.6 mm.

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) + \frac{1}{4C}(D_2 - D_1)^2 \quad (5)$$

$$L = 1848.17\ mm \quad (6)$$

E. Shaft Planning

The shaft of the empty oil palm bunches chopper machine is typically made from a material that possesses several advantages, such as good strength, hardness, and toughness. Alloy steel is usually employed when additional strength and hardness are required, while high carbon steel can offer a good combination of strength and lower cost. For the design of this empty oil palm bunches chopper machine, the shaft material selected is Carbon steel ST60.

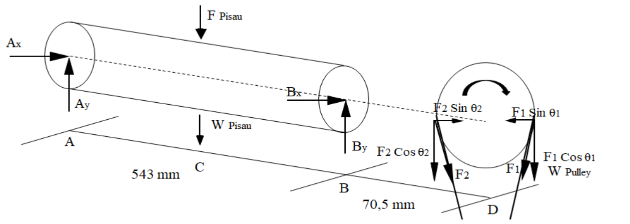

Figure 3. Free Body Diagram of Shaft

Based on the free body diagram of the shaft (Figure 3), it is known that the magnitude of forces on the shaft is FAh = 2.31 kgf, FAv = 17 kgf, FBh = 20.06 kgf, and FBv = 72.43 kgf. The moments acting

As well as the minimum shaft diameter size (ds) obtained, which is 14.62 mm using the equation [8] (this size is used as a minimum reference for selecting the shaft diameter).

$$ds \geq \sqrt[6]{\frac{(16^2 Mb^2 + 16^2 Mt^2)}{\pi^2 \left(\frac{ks.\sigma yp}{sf}\right)^2}} \quad (7)$$

$$ds \geq 14.62\ mm \quad (8)$$

Based on the requirements and availability of shaft material, a shaft diameter of 65 mm is selected to be used, and also it can be known that the bearing inner diameter is 65 mm.

F. Bearing Design

Based on the shaft diameter of 65 mm, so that the bearing inner diameter will be used for is 65 mm. Based on the direction of the load supported by this bearing, which is perpendicular to the axis, a radial-type bearing is chosen. Considering the availability of components and the magnitude of the applied force and equivalent loads, a bearing of the Ball Bearing type 6013 is selected in accordance with the requirements.

$$P = (X.V.Fr + Y.Fa) \quad (9)$$

$$P = 75.16\ kgf \quad (10)$$

G. Dowel Design

Based on the previous calculations, a shaft diameter of 65 mm or 2.6 inches has been determined. According to the 'Standard Square and Flat Key Size Table' [9], the dimensional size can be determined based on the selected type of key. The chosen key type is the Flat Key, taking into consideration several important aspects: ease of installation, safety and strength, resistance to rotation, compact design, and affordability. Therefore, based on the data from the standard square and flat key size table and the selection of the key material (ASTM Class 40).

The key to be used can be determined with the following specifications Flat Key Type, and Material Type ASTM Class 40

Shaft Diameter (inclusive)	Square Type		Flat Type		Tolerance		Stock Length, L		
	Maximum Width, W	Height at Large End, H*	Maximum Width, W	Height at Large End, H*	On Width	On Height	Minimum	Maximum	Advancing by Increments of
1/2 - 9/16	1/8	1/8	1/8	3/32	−0.0020	+0.0020	1/2	2	1/4
5/8 - 7/8	3/16	3/16	3/16	1/8	−0.0020	+0.0020	3/4	3	3/8
15/16-1 1/4	1/4	1/4	1/4	3/16	−0.0020	+0.0020	1	4	1/2
1 5/16-1 3/8	5/16	5/16	5/16	1/4	−0.0020	+0.0020	1 1/4	5 1/4	5/8†
1 7/16-1 3/4	3/8	3/8	3/8	1/4	−0.0020	+0.0020	1 1/2	6	3/4
1 13/16-2 1/4	1/2	1/2	1/2	3/8	−0.0025	+0.0025	2	8	1
2 5/16-2 3/4	5/8	5/8	5/8	7/16	−0.0025	+0.0025	2 1/2	10	1 1/4
2 7/8 -3 1/4	3/4	3/4	3/4	1/2	−0.0025	+0.0025	3	12	1 1/2
3 3/8 -3 3/4	7/8	7/8	7/8	5/8	−0.0030	+0.0030	3 1/2	14	1 3/4
3 7/8 -4 1/2	1	1	1	3/4	−0.0030	+0.0030	4	16	2
4 3/4 -5 1/2	1 1/4	1 1/4	1 1/4	7/8	−0.0030	+0.0030	5	20	2 1/2
5 3/4 -6	1 1/2	1 1/2	1 1/2	1	−0.0030	+0.0030	6	24	3

SOURCE: ASME: ANSI Standard B17.1-1967.

*This height of the key is measured at the distance W, equal to the width of the key, from the large end.

†4 1/2 in. length instead of 4 3/8 in.

Figure 4. Standard Square and Flat Key Size Table

According to the standard square and flat key size table and the diameter of the shaft, it is known that the dimensions of the dowel with

(W) Width: 0.63 inches or 15.88 mm
(h) Height: 0.44 inches or 11.11 mm
(L) Length: 2.5 – 10 inches or 63.5 – 254 mm

Calculating the capacity of the palm oil empty fruit bunch (EFB) chopping machine was carried out to determine the machine's ability to shred EFB accurately and in accordance with actual operational productivity. Based on the results of machine trials carried out, the following results were obtained:

TABLE 1.
TRIAL RESULT

No	Trial Period	Results
1	10 min	16.12 Kg
2	10 min	17.20 Kg
3	10 min	15.23 Kg
Total	**30 min**	**48.55 Kg**

$$Q = \frac{Total\ production}{total\ production\ time} \quad (11)$$

$$Q = 96.72\ Kg\ /Hour \quad (12)$$

IV. CONCLUSION

The conclusion from the trials that have been carried out is that the capacity of the oil palm empty fruit bunch (EFB) chopping machine is 96.72 Kg/Hour. This result was influenced by shredded material that came out through the gap between the hopper connection and the engine cover and the partially damp EFB conditions. These factors also cause uprooted material to scatter around the machine and contribute to surrounding air pollution, regarding the shredded output in fine fiber, empty palm fruit bunches with lengths varying from 1 mm to 10 mm. These fibers are suitable for further processing into organic fertilizer.

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