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# PALM FRESH FRUIT BUNCH THRESHING MACHINE DESIGN

J. B. Samon
Laboratory of Mechanics, Materials and Photonic, Department of Mechanical Engineering, National Advanced School of Agro-Industrial Sciences, the University of Ngaoundere, Cameroon
E-Mail: jboscosamon@gmail.com

## ABSTRACT

In the view of obtaining a small-scale palm oil mill in rural areas with probably no electrical energy, the major bottleneck in some small-scale palm oil processing industries is the stripping (separation) of palm fruits from bunches. Therefore, it is very important to have an efficient small threshing machine. This paper depicts the design of a palm bunch threshing machine which requires less human effort and very efficient. We selected Functional analysis tools (to express our need, show the relationship between our machine and its environment, and to express the logical relationship between the functions of the machine), geometric dimensioning to determine the various sizes of each component of our threshing machine and CAD software in 3D computer modelling and simulation of our palm bunch threshing machine. At the end, we obtained a design plan of an efficient threshing which requires less human effort and adapted to the rural environment.

**Keywords:** palm oil, palm bunch threshing machine, functional analysis, CAD software, geometric dimensioning.

## 1. INTRODUCTION

It is generally agreed that the Oil Palm *(Elaeisguineensis)* originated in the tropical rain forest region of West Africa. The main belt runs through the southern latitudes of Cameroon, Côte d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, Togo and into the equatorial region of Angola and the Congo. Processing oil palm fruits for edible oil has been practiced in Africa for thousands of years, and the oil produced, highly coloured and flavoured, is an essential ingredient in much of the traditional West African cuisine. The traditional process is simple, but tedious and inefficient. We have 4 principal palm oil production methods which are the traditional methods, small-scale mechanical units (processing units handling up to 2 tonnes of Fresh Fruit Bunches (FFB) per hour), medium-scale mills (3 to 8 tonnes FFB per hour) and large industrial mills (3 and 8 tonnes FFB per hour).

In Cameroon, major Agro-industries involved in palm oil production are: SOCAPALM (25,000 ha), C.D.C (15,000 ha), PAMOL (10,000 ha), SPFS (7,000 ha) and SAFACAM (4,000 ha). They contribute up to 80% of the total edible oil needs. Steps and various procedures the palm fruits are processed into palm oil as illustrate in Figure-1.

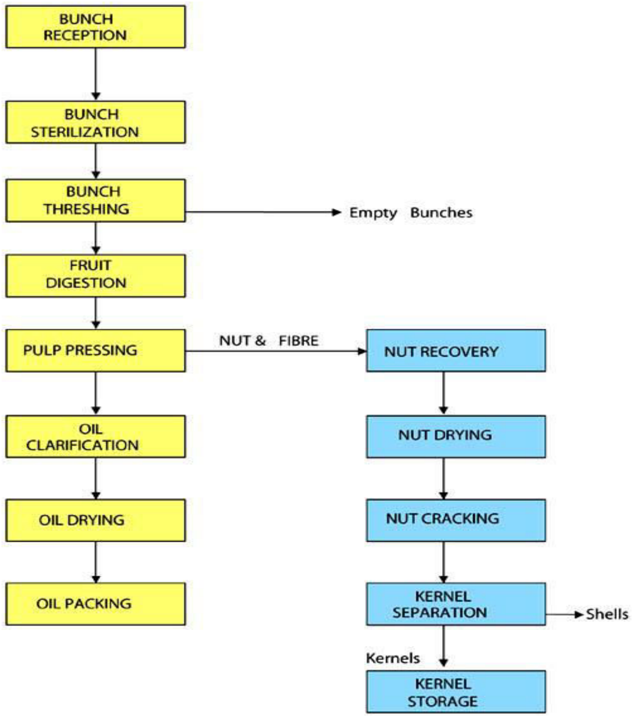


**Figure-1.** Palm oil process in the palm oil mills (Kwasi, 2002).

In the production of palm oil, the separation of palm fruit from bunches is a key determinant step be it in large scale production mills or in traditional producers of palm oil. Talking about traditional threshing process in Cameroon, the transformation of FFBs to CPO involves a number of activities. After harvesting, the FFBs are transported to the palm oil mill, allowed to ferment for an average of 5-7 days before FFBs are shredded into pieces. The major operating activities at the mills include splitting (cutting) and/ or chopping (shredding) of FFBs, stripping to separate fruits from bunches, selecting and sieving of stripped nuts using wreck and mesh wires respectively, loading and boiling of nuts, crushing of boiled nuts

VOL. 17, NO. 10, MAY 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences



pressing and clarifying the red palm oil. Of these, only digestion and pressing are either fully or partially mechanized. Splitting/Chopping of FFBs: This process involves the use of an axe or cutlass and it is usually performed by men due to the strength required. Splitting is usually done on bare ground. Splitting or chopping results in fruit bruises that lead to reaction within the oil cells thereby increasing the free fatty acid (FFA) content of the oil. In order to limit this reaction within the oil cells, FFB should be handled with care (Ngando *et al*. 2011). Storage of cut/chopped bunches: After chopping/ cutting of the FFBs, they are stored in heaps for 5-7 days to facilitate easy loosening or removal of fruits from spikelet. This method of storage facilitates the wilting of the tissue connecting the fruit to the bunch/spikelet, thereby causing the fruit to easily detach from the bunch/spikelet during stripping. The fermentation process further increases the FFA content. Poor and lengthy storage of fruits lead to a considerable increase in FFA that affects the quality of palm oil produced from the loose nuts (Corley *et al.* 2003; Owolarafe *et al*. 2008; Ngando *et al.* 2011). Where quality control methods are applied in processing, it is recommended that palm fruits should be processed within 48 hours after harvesting. This is to stop the action of lypolytic enzymes and prevent the production of FFA (Kwasi, 2002). The field survey revealed that these fruits were stored for some days prior to processing due to the many reasons. The difficulty in the detaching of fruits from the bunch immediately after harvesting to prepare for boiling. The fruit storage is believed to increase oil content as the mesocarp of the fruits becomes soft and easier to press after storage and fermentation. This perception is in contrast to the findings of Badmus (1991) and Tan *et al*. (2009) who consider that the fermentation process results in low quality oil and increases FFA levels. The fruit storage is also believed to reduce the moisture content of the fruits, consequently leading to a lower quantity of palm-oil mill effluent. Stripping of cut bunches:

After softening of the fruits, these bunches are stripped using sticks or the blunt edge of a cutlass to remove any nut that is still attached to the bunch. Stripping is mostly done by men and the average cost per ton of FFB is 4628 USD.

In this study, we will concentrate our efforts on how to improve the traditional methods of production of palm oil by the conception of a bunch thresher that will help us facilitate and boost the production rate by increasing the amount of separated fruits from bunches. To attain our objectives, our studies will be based on two main sections namely; methods and results respectively and finally a conclusion and perspectives.

## 2. METHODOLOGY

### 2.1 Materials Used

The operation of detaching the grains from the spikes, panicles, ear heads, cobs or pods is known as threshing. Threshing can be achieved by: stripping action, rubbing action and impact action. Threshing is the process of loosening the edible part of grain (or other crop) from the straw to which it is attached. It is the step-in grain preparation after reaping. Threshing does not remove the bran from the grain. Threshing may be done by beating the grain using a flail on a threshing floor. Concave (drum): Cylinder and concave together makes the threshing unit.

It separates the grain from the crop and removes grain from the straw. Concave is provided in the thresher to hold the fed crop inside the threshing chamber and allows only grain and small amount of chaff to pass through it.

From Tables 1 and 2, we can see the different mechanical and physical properties of the palm bunch and palm fruits in terms of their varieties and the ideal composition of palm fruit bunch (Carrere, 2010; Minarni *et al.* 2017; Owolarafe *et al*. 2007). The structure of palm fruit is illustrated in the Figure-2.

**Table-1.** Physical and mechanical properties of palm fruits (Owolarafe *et al.* 2007).

| Properties | Dura variety | Tenera variety |
|---|---|---|
| Length, mm | 30.25 (±5.07) | 35.96 (±4.08) |
| Width, mm | 19.94 (±2.64) | 20.15 (±3.79) |
| Thickness, mm | 15.66 (±2.25) | 17.11 (±1.91) |
| Sphericity, % | 70.67 (±9.27) | 64.23 (±6.58) |
| Aspect ratio, % | 67.78 (±15.29) | 56.77 (±9.47) |
| Fruit mass, g | 7.66 (±2.04) | 8.50 (±2.00) |
| True density, kg/m3 | 1112.50 (±52.60) | 995.70 (±26.99) |
| Bulk density, kg/m3 | 659.40 (±21.74) | 611.04 (±27.79) |
| Density ratio, % | 59.33 (±2.21) | 61.45 (±4.01) |
| Porosity, % | 40.67 (±2.21) | 38.55 (±4.01) |

**Table-2.** Ideal composition of palm fruit bunch.

| Bunch weight | 23-27 kg |
|---|---|
| Fruit/bunch | 60-65 % |
| Oil/bunch | 21-23 % |
| Kernel/bunch | 5-7 % |
| Mesocarp/bunch | 44-46 % |
| Mesocarp/fruit | 71-76 % |
| Kernel/fruit | 21-22 |
| Shell/fruit | 10-11 |

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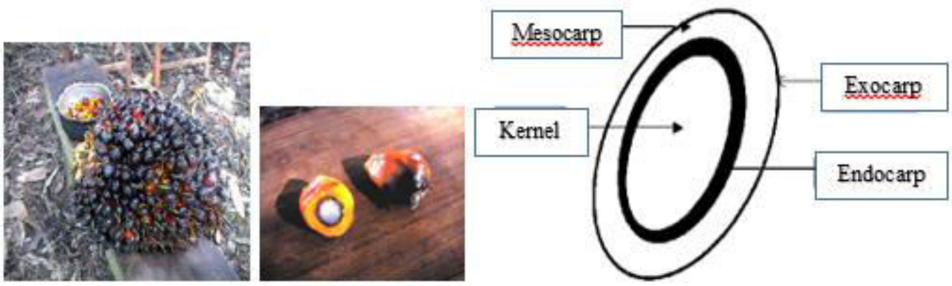


**Figure-2.** Structure of palm fruits.

### 2.2 Methods Implemented

The main method use here is functional analysis technic, which is one of the design method. It is also used to explain the workings of a complex system (Evrard *et al.* 2017). Three mains steps were used for designing the machine as illustrate the Figure-3.

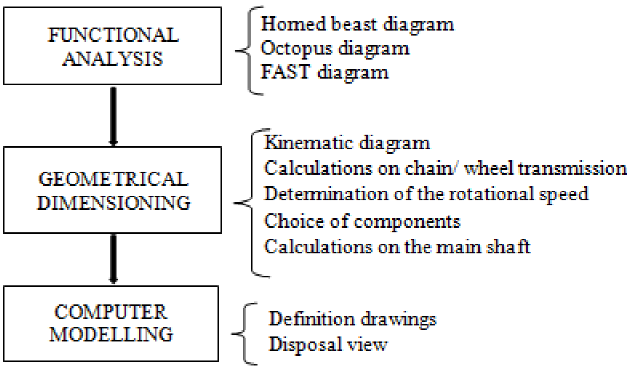


**Figure-3.** Methodology of machine dimensioning and design.

Horned beast diagram is a functional analysis tool who is aimed at defining the requirements (needs) by answering to some important questions. The purpose of the Octopus Diagram is to illustrate the associations of a system and the elements of its environment. These associations are actions of the system and/or one of these environmental elements. The diagram gives the idea about the palm fruit bunch thresher and function parameters and functional constraints related to it. Functional Analysis System Technique (FAST) is a technique to develop a graphical representation showing the logical relationships between the functions of a project, product, process or service based on the questions 'How' and 'why' (Figure-4).

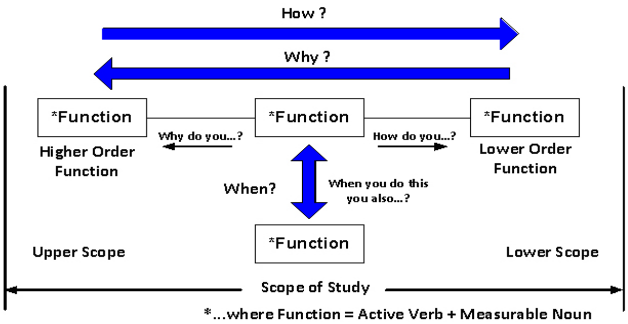


**Figure-4.** Example of a FAST diagram.

### 2.3 Geometric Dimensioning

Here we determine the couple necessary to put the main shaft into rotation so that we can be able to make a choice on the characteristics and type of motor to use. To help us make a choice we will calculate the rotational speed necessary to thresh bunches (rotational speed which will permit bunches to undergo much impacts in the drum).

We are going to determine the rpm so that the FFB undergoes much impact in the rotating drum. We will do so by using the following hypothesis. We assume that the bunch is undergoing circular rotatory motion inside the drum, there exist a centripetal force $F_c$ of the bunch who is directed towards the center of the drum who increases with increase in rpm.

$$F_c = \frac{mv^2}{r} = mr\omega^2 \tag{1}$$

With: ω the angular velocity in rads/s, $\omega = \frac{\pi N}{30}$
Where N is in rpm, r the radius of the drum in mm, m the mass of the bunch in kg. When the rpm is very high, the centripetal force is also high and therefore bunches will stick to the rotating drum and there will be little or no impact between the bunch and the drum and therefore reducing the threshing efficiency.

Now for the bunch to undergo much impact, we let the centripetal force be less than the weight of the bunch $W_B$ and we can therefore determine the rpm for which

$$F_c < W_B \tag{2}$$

VOL. 17, NO. 10, MAY 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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We should also determine the dimensions of the main transmission shaft and the maximum weight it can support and we will simulate the final model on Solid Works.

We will use the two steps in dimensioning the main shaft: the presentation and diagram of external forces and moments applied on the main shaft (representation in free body diagram of the external actions on the main shaft), then the system being in equilibrium we will use the following fundamental statics law and the end the diagram of internal efforts (forces)

$$\begin{cases} \sum \overrightarrow{F_{ext}} = 0 \\ \sum \overrightarrow{M(F_{ext})} = 0 \end{cases} \tag{3}$$

The system we choose for the couple transmission from the engine is the chain/wheel system because it is more adapted for high couple transmissions. To dimension this system, we carry out the following calculations as depicted in Figure-5.

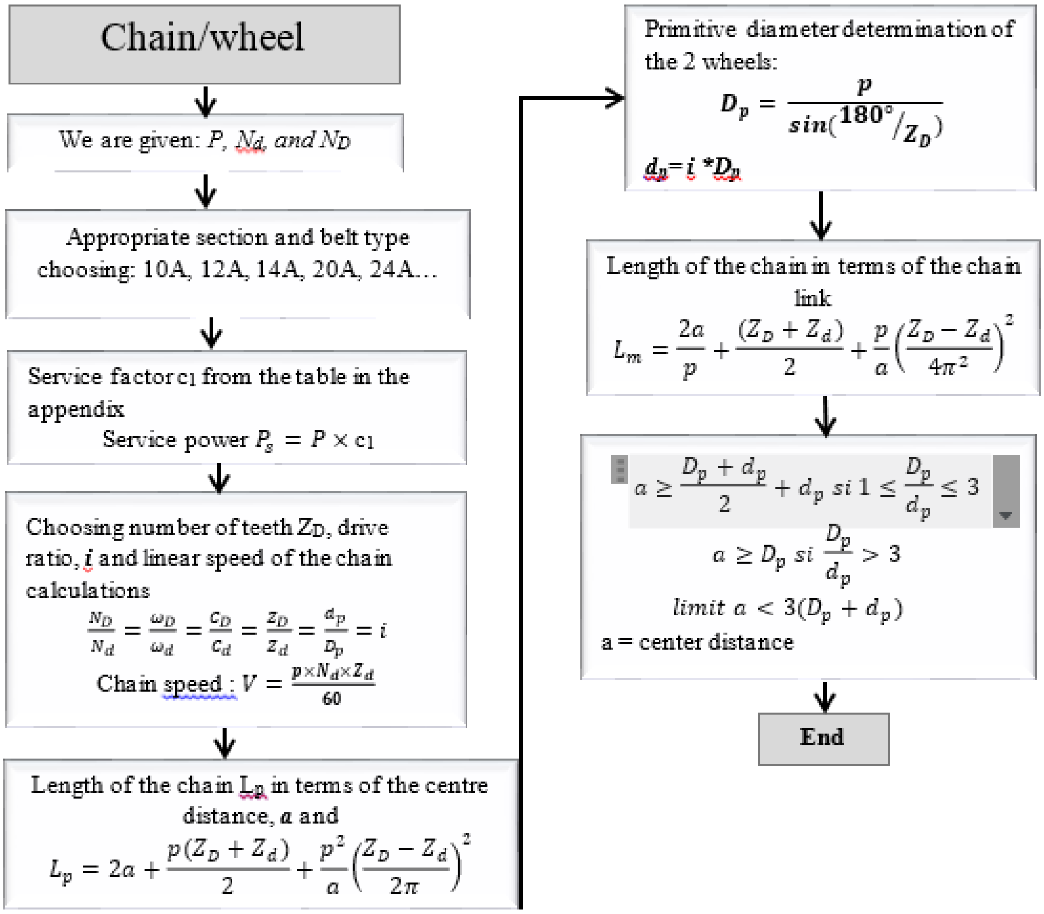


**Figure-5.** Methodology to size the pulley/belt transmission system.

Our bunch threshing machine is supposed to be driven by thermal engine coupled with a gearbox to reduce the rotational velocity (rpm) and increase the torque produced by the thermal engine which therefore drives the main shaft and therefore the threshing process is achieved. This choice is based on the criteria on choosing the useful power and torque, the rotational velocity of receptor (the output of the gear box), the input energy (electrical or fuel), the variable or constant velocity and the dynamic performance. The reference ($GX\ 3\ N\ 025\ R\ 04\ 00$) shows the characteristic sample for choosing a standard gearbox with low clearance GX, engine size 3, type of Normal N and reduced R clearances, reduction ration of 025, gear reducer of 04 and normal shaft 00 (AUDIN, 2020).

## 3. RESULTS

### 3.1 Functional Analysis Tools

We answer the following questions for applying the horned beast diagram as shown in Figure-6: What is the product? (Fresh Fruit Bunch threshing/stripping machine), Who is the beneficiary of the product? (local palm oil producers), What for? (separating fresh palm fruits from their bunches) and The machine interacts with? (palm fresh fruit bunch).

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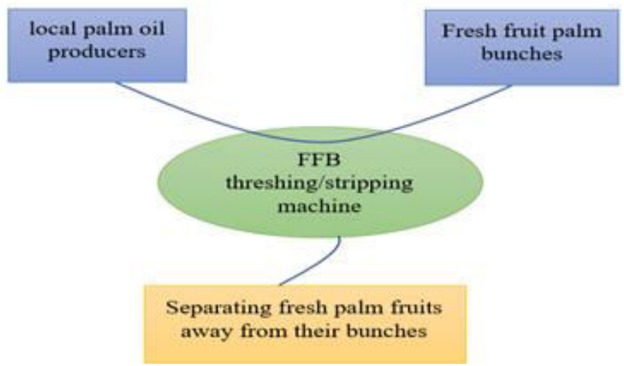


**Figure-6.** Horned beast diagram of a FFB thresher.

From our Octopus diagram we have obtained 2 function parameters (FP) and 7 function constraints (FC) as shown in Figure-7, where:

**FP1:** Able to separate fresh palm fruits from their bunches

**FC1:** The machine should be easy to use or manipulated

**FC2:** The machine should be able to function with a multiple types of engine

**FC3:** easy to be mounted and dismounted for maintenance purpose

**FC4:** The inlet should permit the bunch pass through

**FC5:** It should have less weight possible and should not affect the stripped (separated) fruits.

**FC6:** Occupy lesser space possible to thresh many bunches.

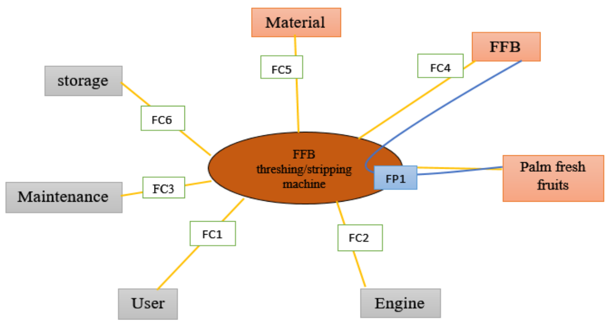


**Figure-7.** Octopus diagram of a FFB thresher.

We will elaborate the FAST diagram (Figure-8) of the function parameter *FP1* of a FFB threshing machine.

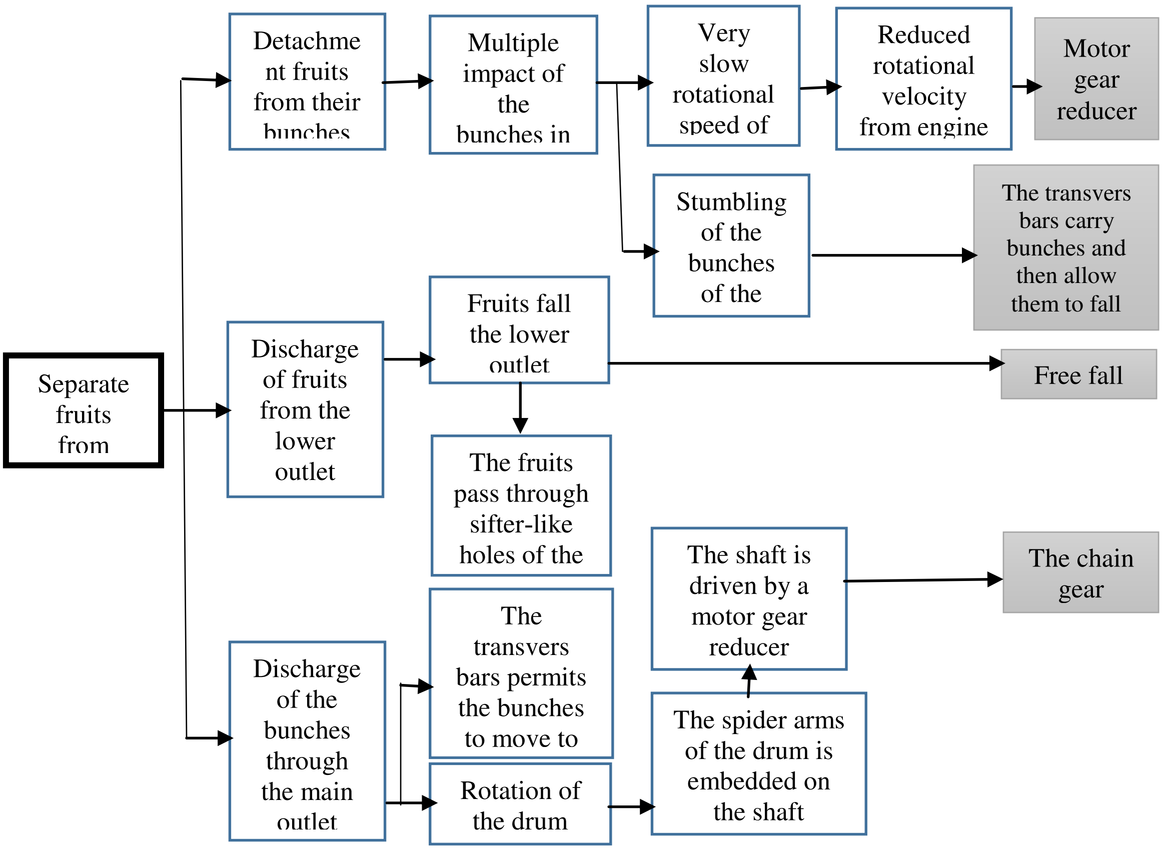


**Figure-8.** FAST diagram of a FFB threshing machine.

VOL. 17, NO. 10, MAY 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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### 3.2 Determining RPM of the Drum and the Dimensioning of the Main Shaft

The determination of the rpm of the drum is through this condition $F_c < W_B$, $mr\left(\frac{\pi N}{30}\right)^2 < \boldsymbol{W_B}$; $N < \sqrt{\frac{30^2 \times W_B}{mr\pi^2}}$; $N < \sqrt{\frac{30^2 \times m \times g}{mr\pi^2}}$. It is given: We take g = 10m/s$^2$, $W_B$ = 500N, r = 800mm = 0.8m, m = 50kg. After computing we found N < 33.76 rpm. But for the proper threshing of the bunch, we will choose to thresh with an rpm of 30, so, N=30rpm.

The Figure-9 depicts the free body diagram of the main shaft.

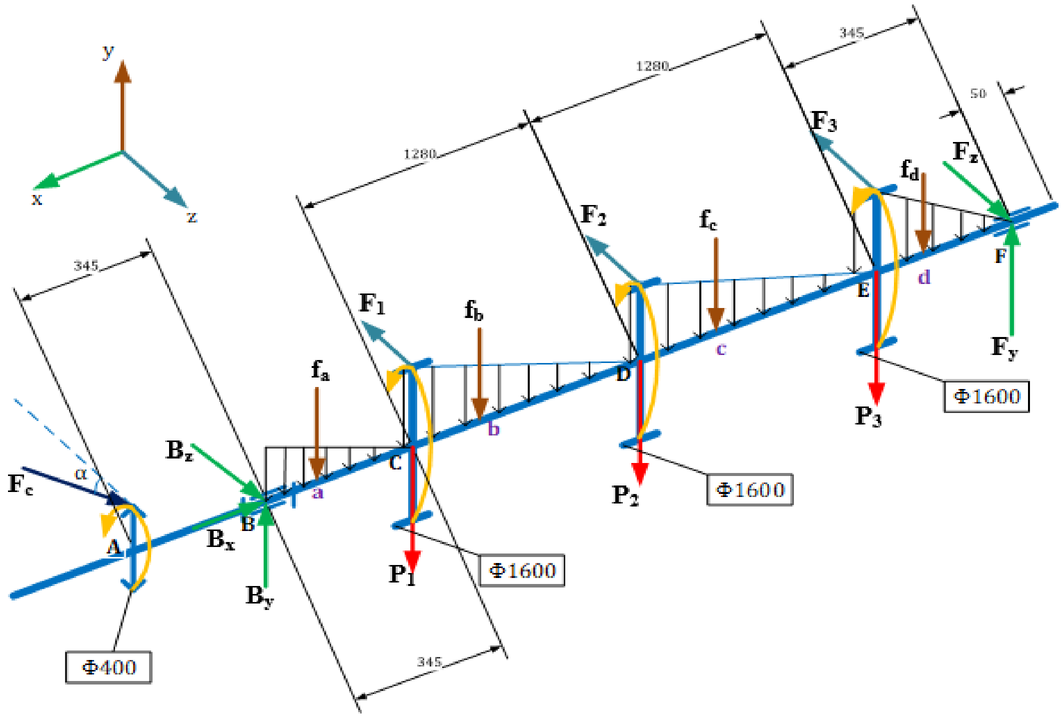


**Figure-9.** Free body diagram of the main shaft.

We have to determine the reaction forces at the supports; B and F and the resistive couple on the shaft created by the tension on the belt Fc and by applying the fundamental law of statics. Having this, we have to calculate the diameter of the main shaft will be done by studying all the solicitations that are applied on it. The two main solicitations for our shaft is bending + torsion. For bending and torsion, the maximum normal and shear stresses are respectively given at the equations 3 and 4.

$$\sigma_{\max} = \frac{Mf}{Iz} * \mathrm{v} \tag{4}$$

$$\tau_{\max} = \frac{Mt}{Io} * \mathrm{v} \tag{5}$$

And the admissible stress for these combined solicitations with respect to the material type of the main shaft which is stainless steel is:

$$\tau_{\text{Admissible}} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} \tag{6}$$

This admissible stress is from the theory of appropriate maximum shear stress (Fachon, 1996).

For a circular section transmission shaft, v = d/2, $I_0 = 2I_z = \pi d^4/32$

$$\tau_{\text{adm}} = \sqrt{\left(\frac{M_f}{2Iz}v\right)^2 + \left(\frac{M_T}{Io}v\right)^2} = \frac{16}{\pi d^3}\sqrt{M_T^2 + M_f^2} \tag{7}$$

And therefore, we can deduce the diameter d of the transmission shaft;

$$\mathrm{d} = \left(\frac{16}{\pi * \tau_{adm}}\sqrt{M_T^2 + M_f^2}\right)^{\frac{1}{3}} \tag{8}$$

Where the torsional moment $M_T = C_U$ (the couple transmitted by the motor gear reducer), $M_f$ = the maximum bending moment during on the internal actions of the main shaft which is usually obtained by studying the internal efforts supported by the material. And $\tau_{\text{adm}}$ = practical slip resistance = $\frac{1}{2}$elastique limit. Since we are dealing with stainless steel, the elastic limit is 200MPa and therefore, $\tau_{adm} = 100MPa$

$M_T = C_U$, but we know that $C_M$ is the couple needed to put the shaft in to rotational motion due to the chain/wheel system. So, $C_U$ = 13600 Nm and therefore, $M_T$ = 13600 Nm

To calculate the bending moment, we will make 5cuts on the shaft and calculate the internal efforts. After

VOL. 17, NO. 10, MAY 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences



making four fictive cuts on the shaft, we have the maximum bending moment,

$M_f$ = 6553074.125Nmm. And the diameter of the shaft d is $d = 91.61mm$. But for our study, we will take d = 100mm

From the need expressed, we will use an electrical engine. Now we are going to determine the characteristics (*power, couple and rpm)* of the engine required for the proper functioning of our machine. From that we will choose the type of motor gear reducer which will be used to reduce the rpm of the engine to a low rpm of the machine. We are looking for the characteristics of the engine in figure 10 (Denis, 2020).

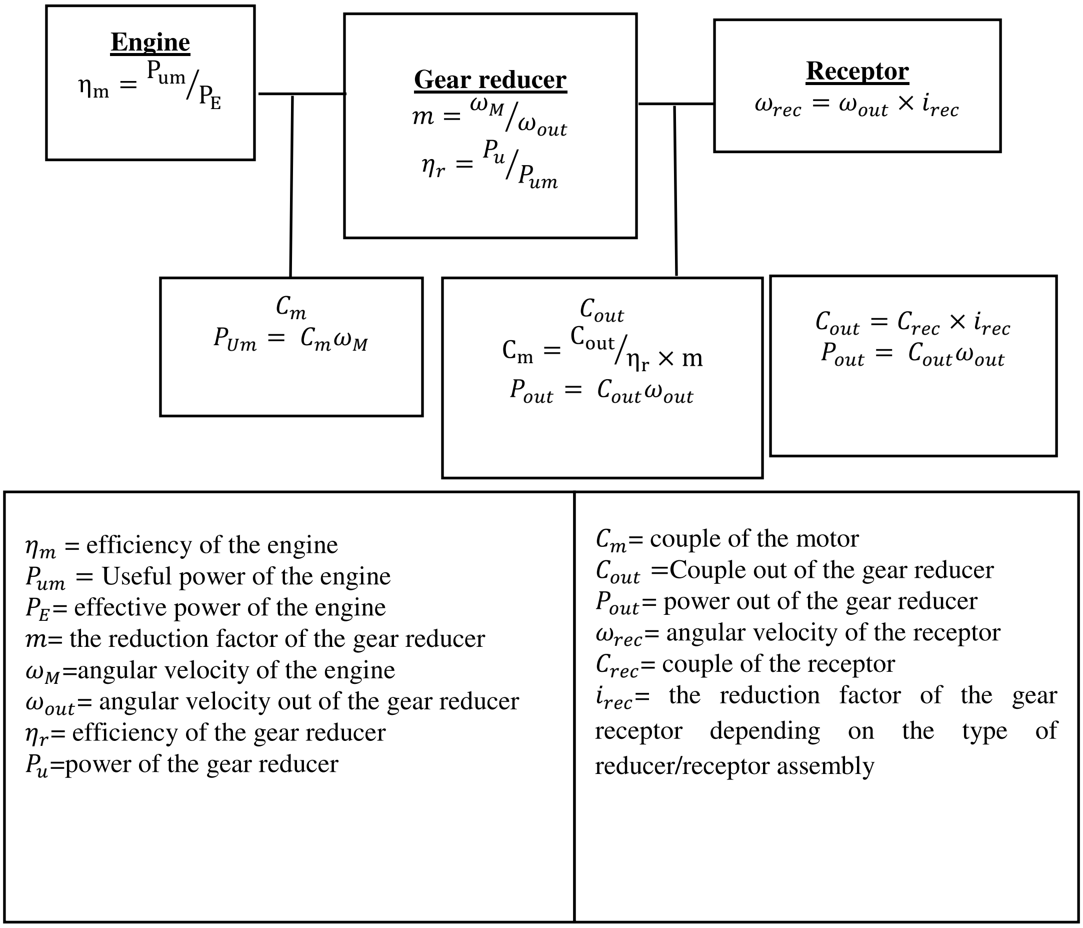


**Figure-10.** Characteristic of the engine.

Given these data: $C_{rec} = C_u = 13600kNmm$, $i_{rec} = 0.5$, $\omega_{rec} = \frac{\pi N_D}{30} = 3.14rads/s$, $\omega_{out} = {\omega_{rec}}/{0.5} = 6.28\, rads/s$, the drive ratio of the gear reducer $m = 75$, the efficiency, $\eta_r = 92\%$,$C_{out} = 6800kNmm$ and $P_{out} = 42.704kW$, we find $C_m = {6800}/{0.92 \times 75} = 98.55kNmm$, $\omega_M = \omega_{out} \times m = 6.28 \times 75 = 471rads/s$, $P_{Um} = 98.55kNmm \times 471rads/s = 46.417kW$, $N_M = {\omega_M \times 30}/{\pi} = {471 \times 30}/{3.14} = 4500rpm$. The Characteristics of the thermal engine are $P_{Um} = 46.417kW$, $N_M = 4500rpm$. For our machine, we choose the gear reducer with the following characteristics:$GX$ 8 $N$ 075 $R$ 09 01

3.3 Presentation of the 3D machine model

The drawings were done on Solid Works 2016, 64×bit edition. This drawing illustrates the bunch threshing machine together with all its components and quantities Figures 11 and 12.

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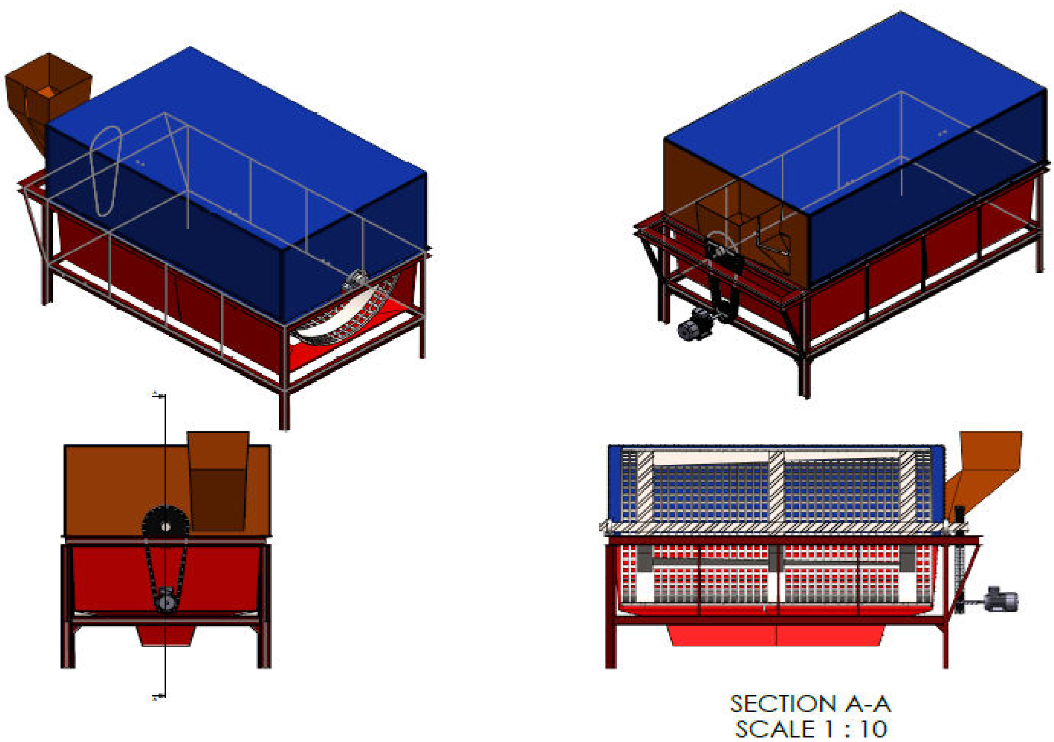
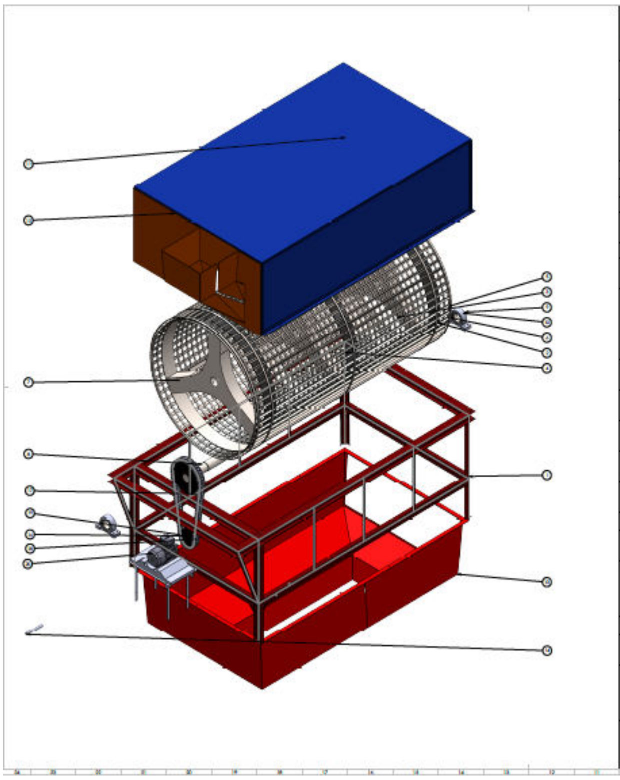



**Figure-11.** 3D model of palm bunch threshing machine.



| No. ARTICLE | motor support | DESCRIPTION | QTE |
|---|---|---|---|
| 1 | support block good one prime | | 1 |
| 2 | main circles | | 4 |
| 3 | spider arm | | 4 |
| 4 | t-shaped bars | | 58 |
| 5 | inner thin circles | | 32 |
| 6 | thinner circles | | 7 |
| 7 | bars inside drum | | 3 |
| 8 | main shaft sim | | 1 |
| 9 | palier frame | | 2 |
| 10 | AFBMA 20.1 - 40-100 - Full,DE,AC,Full_68 | | 2 |
| 11 | top support | | 1 |
| 12 | INLET2 | | 1 |
| 13 | fruit outlet | | 1 |
| 14 | motor shaft | | 1 |
| 15 | chain path | | 1 |
| 16 | sprocket motor | | 1 |
| 17 | sprocket | | 1 |
| 18 | part 2 inner chain new version | | 68 |
| 19 | first part chain | | 34 |
| 20 | 70382194 | | 1 |
| 21 | motor support^Assembly machine1 | | 1 |
| 22 | motor frame^Assembly machine1 | | 1 |

**Figure-12.** Exploded view of palm bunch threshing machine.

**4. CONCLUSION AND PERSPECTIVES**

The aim here was to design a palm bunch threshing machine which requires less human effort and very efficient for small size enterprise. We selected Functional analysis tools (to express our need, show the relationship between our machine and its environment, and to express the logical relationship between the functions of the machine), geometric dimensioning to determine the various sizes of each component of our threshing machine and CAD software in 3D computer

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modelling of our palm bunch threshing machine. We end this step by obtaining the design plan of an efficient threshing, which requires less human effort and adapted to the rural environment. A fabrication analysis of the machine could also be made so as to calculate its fabrication cost,

**REFERENCES**

Audin. 2020. GX Servomoteur, - 7 bis rue de Tinqueux - 51100 Reims - France (Web : http : www.audin.fr - Email : info@audin.fr). 2020

Badmus GA. 1991. NIFOR Automated Small Scale Oil Palm Fruit Processing Equipment its need, development and cost effectiveness: Proceedings 1991 International. Oil Palm Conference Chemistry and technology. In Basiron Y, et al, ed. Palm Oil Res. Inst. Malaysia, Kuala Lumpur [13.4.4], 20-31.

Carrere R. 2010. Oil palm in Africa: Past, present and future scenarios: World Rainforest Movement Series on tree plantations 15. December, Montevide

Corley RHV and Tinker PB. 2003. The Oil Palm. 4th Ed. John Wiley and sons, Hoboken, New Jersey, USA. 541 p.

Denis Rabasté. 2020. Principes et caractéristiques des principaux moteurs électriques, IUFM Aix Marseille, http://www.sciences-et-techniques.sitew.fr/fs/Root/ctlvo-V_moteur_simpl_1_.pdf .

Evrard H., S. Buisine and R. Duchamp. 2006. Assessment of the Respective Benefits of 'Axiomatic Design and New Products Design Method' for the Design of a Biomechanical Simulator. in Proc. ICAD2006, 4th of International Conf. on Axiomatic Design, Firenze.

Fachon Jean-Louis, Guide Mécanique: Science et technologie industrielle, Edition Nathan, p. 481 (Current 380), 1996.

Kwasi Poku. 2002. Small-scale palm oil processing in Africa, foodandagriculture organization of the united nations rome, 2002, fao agricultural services bulletin, 148, ISSN 1010-1365

Minarni S., Roni S., Rasmiana P. and Arian T. S. 2007. Analysis of Physical Properties of Oil Palm Fresh Fruit Bunches Using Image J. Applied Science and Technology, 1(1), 2017 http://www.estech.org.

Ngando EGF, Mpondo MEA, Dikotto EEL and Koona P. 2011. Assessment of the quality of crude palm oil from smallholders in Cameroon. Journal of Stored Products and Postharvest Research. 2(3): 52-58.

Owolarafe O.K. *et al*. 2007. Journal of Food Engineering 78 (2007) 1228-1232.

Owolarafe OK. Taiwo EA and Oko OO. 2008. Effect of processing conditions on yield and quality of hydraulically expressed palm oil. International Agro-Physics. 22(4): 349-352.

Tan C, Ghazali HM, Kuntom A, Tan C and Ariffin AA. 2009. Extraction and physiochemical properties of low free fatty acid properties crude palm oil. Food Chemistry. 113: 645-650.

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**Appendix 1.** Service factor $c_1$(https://www.scribd.com/document/479340480/1484-pdf)

| Driven unit | Driving unit / Motor | | | | | |
|---|---|---|---|---|---|---|
| | AC motors, single- and three-phase with star-delta start. DC shunt-wound motors. Multiple cylinder internal combustion engines. | | | AC motors, single- and three-phase, series wound, slip-ring motors with direct start. DC motors, series and compound wound. Single cylinder internal combustion engines | | |
| | Number of operating hours per 24 hours | | | Number of operating hours per 24 hours | | |
| | Up to 10 | Over 10 to 16 | Over 16 | Up to 10 | Over 10 to 16 | Over 16 |
| Agitators for liquids. Small centrifugal blowers. Fans up to 7.5 kW. Light-duty conveyors. | 1.0 | 1.1 | 1.2 | 1.1 | 1.2 | 1.3 |
| Belt conveyors for sand, grain, etc. Dough mixers. Fans over 7.5 kW. Generators. Washing machines. Machine tools. Punching, pressing and shearing machines. Printing machines. Positive displacement rotary pumps. Vibrating and rotary screens | 1.1 | 1.2 | 1.3 | 1.2 | 1.3 | 1.4 |
| Brick-making machinery. Bucket elevator. Piston compressors. Screw conveyors. Hammer mills. Hollanders. Piston pumps. Positive displacement blowers. Crushers. Woodworking machinery. Textile machinery | 1.2 | 1.3 | 1.4 | 1.4 | 1.5 | 1.6 |
| Gyratory and jaw-roll crushers. Mills (ball/rod). Hoists (heavy loads). Rolling mills, calendars etc. for the rubber and plastics industries. | 1.3 | 1.4 | 1.5 | 1.5 | 1.6 | 1,8 |