DESIGN AND FABRICATION OF PALM KERNEL SHELL CRACKING MACHINE

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A PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF ENGINEERING (B.ENG) IN THE DEPARTMENT OF PRODUCTION ENGINEERING UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA.

SEPTEMBER, 2023

CERTIFICATION

This is to certify that this project was done by Nnamani Izuchukwu Samuel, with Matriculation number ENG1704475 of the DEPARTMENT OF PRODUCTION ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN, BENIN CITY, as part of requirement for the award of the Bachelor of Engineering (B.Eng) Degree.

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PROF. R.O. EDOKPIA Head Of Department	Date

DEDICATION

This project work is dedicated God Almighty, the creator of all things.

ACKNOWLEDGMENTS

First and foremost, I extend my gratitude to the Almighty for His unwavering guidance, protection, and wisdom, which enabled me to successfully complete this project.

I would like to express my sincere appreciation to my supervisor, Prof. J.A. Akpobi, for his invaluable guidance and support throughout the entirety of this endeavor. Sir, your assistance has been instrumental, and I am deeply thankful for it.

Special thanks to the H.O.D, Prof. R.O. Edokpai, Dr. O.O. Ogbeide, Prof. J.A Akpobi, Dr. E. Ebojoh, Dr. E.M. Etuk, Engr. O.I. Ihenyen, Dr. C.E. Etin-Osa, my course advisor who has always been there for us and other staff not mentioned for the knowledge they shared with me in my five years of study at the University of Benin.

I also wish to convey my profound thanks to my family for their unwavering support and encouragement throughout this journey. Your support has been a constant source of strength and motivation.

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ABSTRACT

This project centers on devising a cost-efficient and highly productive solution for the palm oil industry, with a specific focus on alleviating the labor-intensive palm kernel cracking process. The proposed machine incorporates cutting-edge design principles and advanced materials to elevate its performance and reliability. By subjecting the project to rigorous engineering analysis and prototyping, the primary objective is to attain the utmost efficiency in kernel cracking while concurrently minimizing waste and energy consumption. Furthermore, the design prioritizes safety, environmental consciousness, and scalability.

The successful execution of this project holds the potential to transform the palm oil industry by simplifying the kernel extraction procedure, ultimately ushering in heightened productivity and sustainability within the sector.

CHAPTER ONE

1.0 INTRODUCTION

Palm kernel and cracked shells are valuable farm products in Nigeria. They have diverse applications in industries like soap production, cosmetics, livestock feeds, medicine, foundry, civil work, and energy production.

Local farmers in southern Nigeria face challenges in cracking palm kernels efficiently and separating the shells without much effort and time, at an affordable cost.

This project aims to address these issues by designing and constructing an improved palm kernel cracker and separator. The goal is to enhance output efficiency and ensure complete separation of the cracked kernels from the shells.

1.1 PROBLEM STATEMENT

Production of Palm kernel oil from palm kernel nuts is a delicate and labor-intensive process. Traditional methods used in rural areas involve a lot of hard work and can be hazardous. People manually cracking the nuts risk accidentally hitting their fingers with the impact stone. To address these challenges, the palm kernel cracking machine is designed to be power-driven, increasing efficiency, reducing accidents, and minimizing the time required for the process.

1.2 AIM

We aim to create an affordable and user-friendly machine using locally available materials. This machine will be specifically designed to cater to the needs of rural dwellers, ensuring comfort and effective usage.

1.3 OBJECTIVES

We aim to design a palm kernel cracking and separating machine that reduces maintenance costs and separation time. The machine will be easy and safe to operate, requiring no special skills. The research outcomes will contribute to the sustainability analysis of palm kernel machines and have various benefits, including serving as teaching aids, promoting economic development, and creating job opportunities for Nigerian farmers.

1.4 SIGNIFICANCE OF THE PROJECT

This project aims to help local palm kernel businesses and medium-scale industries by providing them with a convenient, affordable, and easily accessible method of cracking palm nuts. Currently, many of them still rely on manual cracking due to the high cost or unavailability of machines. Our goal is to offer a solution that addresses these challenges and improves their operations.

1.5 SCOPE OF THE PROJECT

The palm kernel cracker and separator are primarily employed by local farmers and medium-scale industries, serving those with palm nut quantities not surpassing 1000kg per day.

1.6 JUSTIFICATION OF THE PROJECT

In many parts of Nigeria, palm nuts are cracked manually using stone arrangements and the mortar and pestle method. These techniques have been used for a long time at the village level. The initial approach includes placing approximately six nuts on a level surface and employing another stone as a hammer to crack them. Women and children are majorly employed to carry out this task, but it can be tiring and time-consuming. Additionally, there are health hazards associated with this process, and winnowing is required to remove the fiber still attached to the nuts.

The new palm kernel cracking machine is powered and designed to increase efficiency, reduce accidents, and save time during the process.

CHAPTER TWO

2.0 LITERATURE REVIEW

This chapter involves review of the literature that is important to this work. It critically considers some concepts such as conceptual framework, principle and element of design, historical development of tools and machines, types of agricultural machines.

2.1 THE CONCEPTUAL FRAMEWORK

This study is grounded in the conceptual framework encompassing the ideas of engineering, design, and construction. Engineering, as defined here, involves the practical application of scientific principles and mathematics to address various challenges. While scientists and inventors contribute innovations, it is the role of engineers to implement these discoveries in the real world.

The term "engineering" spans diverse fields and skills, making engineers integral as scientists, inventors, designers, and builders. They enhance human capabilities, ensuring safety, and improving lives. Engineers undergo training to be resourceful, creative, knowledgeable, and proficient in tasks such as;

a. esigning engineering projects, supervising construction,
b. Creating electrical and electronics components,
c. Developing new products and production techniques,
d. Managing resources effectively.

The concept of design has been interpreted in various ways by different scholars. According to Homsby (2001), design involves the art or process of determining the appearance or functionality of something through plans and models. It can also refer to a drawing or plan used for manufacturing. Linbeck (1990) defines design as the process of inventing or planning physical things with a new organization or form in response to a specific function. He emphasizes creativity in planning to address particular needs, emphasizing the original treatment of problems.

Simpson (1992) underscores the importance of creativity in design, stating that an individual demonstrates creativity when adopting, modifying, or altering ideas to meet specific needs. He rejects the notion that creativity in design involves copying or replicating others' work, emphasizing the need for originality and genuine innovation.

2.2 PRINCIPLES AND ELEMENTS OF DESIGN

In every design process, the goal is not only to develop a functional product but also one that has aesthetic appeal (Linbeck, 1990). To fulfill this objective, the design process should adhere to specific principles or elements. Linbeck (1990) categorizes these principles into three groups: functional, material, and visual requirements.

2.3 MATERIAL REQUIREMENT

Welch (1998) emphasized that a designer should possess a thorough understanding of the characteristics and constraints of various materials to effectively choose the most suitable ones. For example, the designer should be knowledgeable about which metals can undergo bending, folding, forming, soldering, welding, riveting, and gluing.

2.4 VISUAL REQUIREMENT

Linbeck (1990) emphasized the necessity for a product to possess an attractive visual appeal for the observer. He underscored that meeting this requirement involves careful consideration of the visual arrangement of design elements, including lines, shapes, textures, and colors. According to Welch (1998), human beings generally respond more favorably to aesthetically pleasing objects rather than unattractive ones. Given the subjective nature of beauty, where one person's idea of beauty may not align with another's, the designer must be mindful that visual requirements entail achieving proper balance, correct proportion, harmonious colors and textures, and a well-defined form.

2.5 HISTORICAL DEVELOPMENT OF TOOLS AND MACHINES

Miller (1995) proposed that man's initial attempt at tool-making might have involved imitation, where he observed and mimicked animals in activities like catching fish, building houses, or cracking nuts. It became evident to him, however, that his physical abilities in these tasks were imperfect, leading him to invent tools to enhance his efficiency. Initially, aesthetics might not have been a significant consideration for these rudimentary tools; functionality took precedence. Additionally, he faced limitations in materials, initially working with only stone, wood, bone, and leather.

Building on this idea, Hindbeck (1990) highlighted that the earliest tools were primitive and multipurpose, aiding early humans in securing basic necessities. For instance, prehistoric humans used stones in their natural, crude forms to assist in cutting, shaping, and clubbing.

2.6 RELATIVE ADVANTAGES OF MACHINES OVER HUMAN POWER

The following are the advantages of machines over human power

(i) Machines perform work that are heavier and delicate.

(ii) Machines make better use of natural forces, for instance, man is able to send messages to several miles, flies through the air, generates electricity from windfall and water flow.

(iii) Machines undergo faster and more accurate work.

(iv) Cost reduction in production leading to cheaper goods.

(v) Machine widen the scope of employment thereby creating more job opportunities.

2.7 PALM KERNEL CULTIVATION AND PROCESSING

Nigeria possesses a predominantly flat terrain with 71.2 million hectares of arable land, much of which is suitable for two-season plantations annually. The country's soil and climate conditions are conducive to cultivating a variety of agricultural crops, particularly tropical and subtropical economic crops. Notably, the coastal belt in Nigeria, spanning a depth of 100-150 miles, supports the growth of oil palm, extending inland for approximately 450 miles along the valleys of the Niger and Benue rivers. Oil palm cultivation has become a staple and stable crop ingrained in the way of life and cultural practices for millions of Nigerians.

2.7.1 Oil Palm Processing (Palm nuts cracking and shelling) In Nigeria

There exists a substantial and sustainable market for palm kernel nuts in Nigeria, serving as the primary raw materials for producing palm kernel oil and palm kernel cake. The palm kernel transformation into oil involves a multi-step process, including nut cracking, shell-kernel separation, washing, cleaning, kernel milling, and kernel oil extraction. Among these, nut cracking and shelling are particularly critical in the palm kernel oil industry.

Crucial to the quality of kernel oil, cracking palm nuts to release the kernels can be achieved through two prevalent methods: the manual (traditional) approach and the mechanical method. The traditional method involves hand-cracking nuts using stones and manually separating kernels from shells, proving to be labor-intensive and time-consuming, with relatively low efficiency to meet industry demands.

Mechanical methods, on the other hand, involve either the impact of the nuts against a hard surface or the application of direct mechanical pressure to crush, cut, or shear through the shell. The palm nut cracking machine, based on hurling nuts at high speed against a stationary hard surface, includes two common types: the roller cracker and the centrifugal impact cracker.

The roller cracker operates by cracking nuts between two fluted rollers moving in opposite directions, although its efficiency is reduced due to varying nut sizes. The centrifugal impact cracker utilizes centrifugal force to flap palm kernel nuts against a stationary hard surface, employing shock to shear, crush, or cut through the shell.

Following the cracking process, the separation of palm kernel and shell occurs. Two prevalent techniques for separation are the wet and dry methods. The wet method utilizes a liquid medium to separate constituents based on specific gravities, requiring subsequent sterilization and drying of recovered kernels. In contrast, the dry method does not involve a liquid medium. Kernels recovered through the wet method undergo sterilization and a 14-16 hour re-drying process in silos to eliminate moisture absorbed during separation.

Figure 2.1: Kamel Seed/Nut

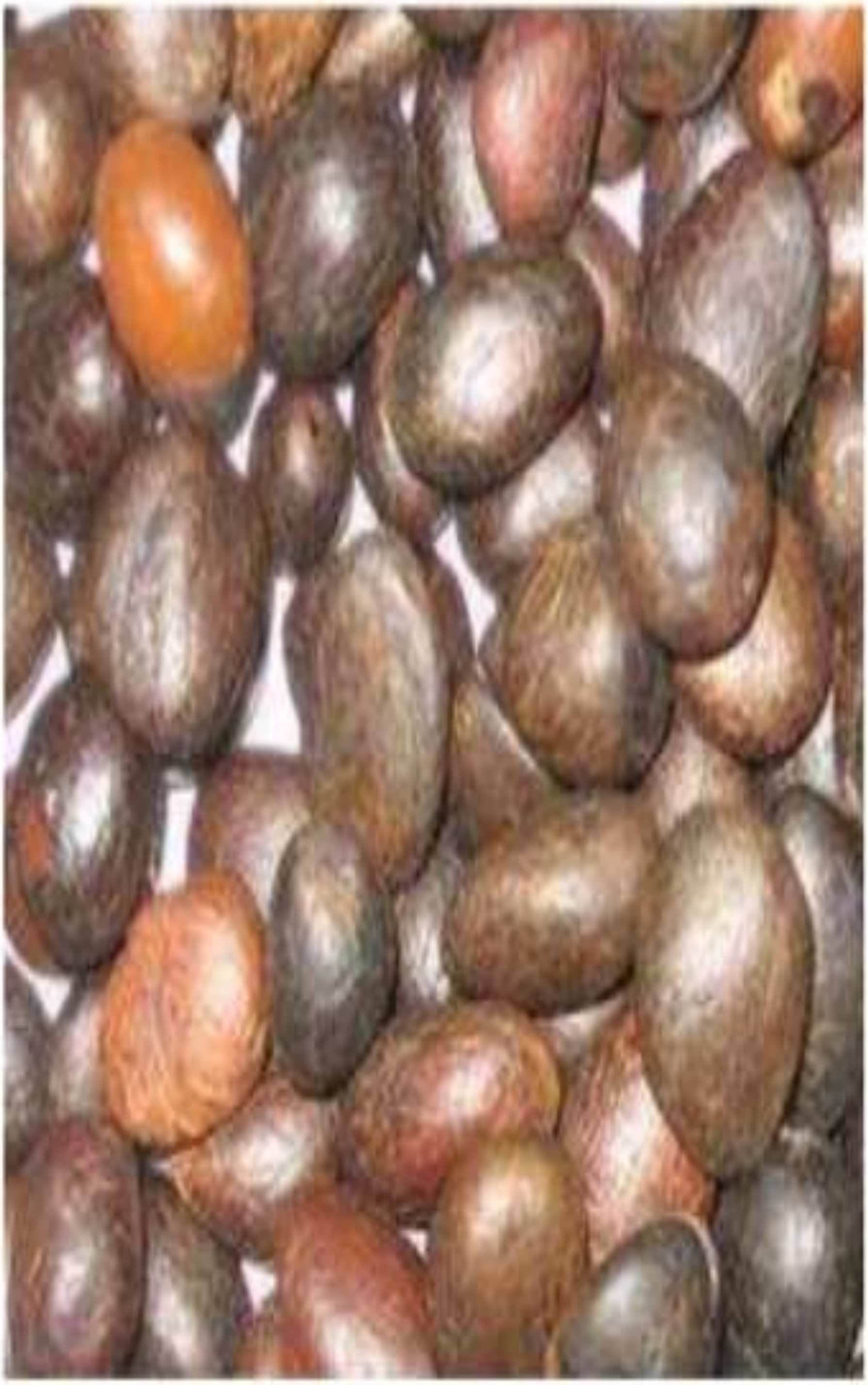

Figure 2.2: Palm Kanel

2.7.2 Mechanical Extraction of Palm Kernel Oil

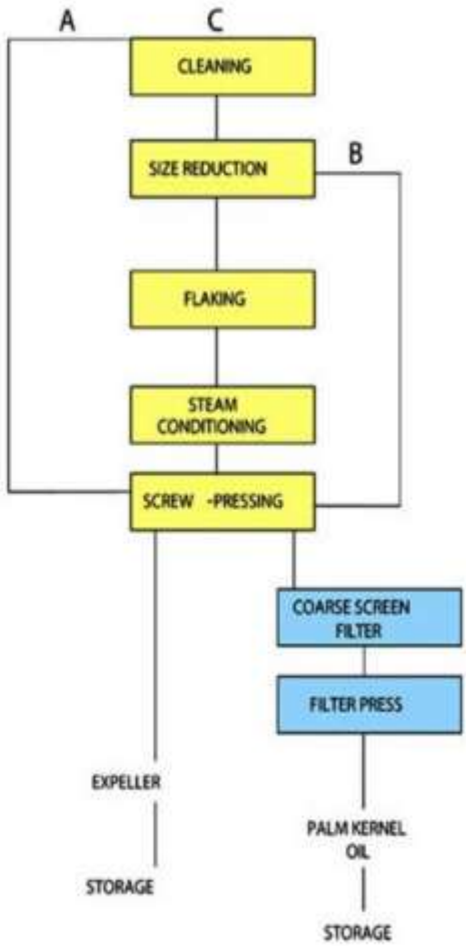

Figure 2.3: Showing the Mechanical Extraction of Palm Kernel Oil

Line A is designated for the direct screw-processing of kernels without any pre-treatment, while Line B is intended for screw-pressing after partial kernel pre-treatment. Line C, on the other hand, is designed for screw-pressing after complete pre-treatment of the kernels.

2.8 ECONOMIC IMPORTANCE OF PALM KERNEL PRODUCTION IN NIGERIA

Before the commencement of crude oil production in Nigeria, the primary focus of the country was agriculture, with a significant emphasis on palm crude oil production. Despite this historical reliance, Nigeria's palm crude oil production and exportation are currently ranked fourth globally. The production of palm crude oil is a crucial component of the nation's economy for various reasons, with a key factor being the substantial employment generated within this sub-sector. The economic importance of palm kernel production includes:

(1) It contributes to alleviating poverty, closely tied to the fact that a significant portion of the country's agricultural activities occurs in rural areas, where the majority of the impoverished population resides. As a result, a well-established palm crude oil sub-sector holds substantial potential for reducing poverty. It creates job opportunities

(2) It serves as an avenue for foreign exchange and thus enhance growth and development.

The design and fabrication of efficient and cost-effective machines for agricultural processes play a crucial role in improving productivity and reducing labor-intensive operations. In the context of palm oil production, the cracking of palm kernel shells is a critical step to extract the valuable kernel within. This literature review aims to explore the existing research and advancements related to the design and fabrication of palm kernel shell cracking machine

2.9 REVIEW OF LITERATURE:

Design and Development of a Palm Kernel Nut and Shell Separating Machine (Ahmed et al., 2017):: This study presented the design and fabrication of a palm kernel nut and shell separating machine. The machine utilized a roller and perforated plate system to crack the palm kernel shells, followed by a pneumatic system to separate the cracked shells from the kernel. The results showed improved efficiency and reduced labor requirements compared to traditional manual methods.

Development of Palm Kernel Shell Cracker (Agarry et al., 2019): Agarry and colleagues developed a palm kernel shell cracker using a rotary nut cracking system. The machine incorporated a rotating drum with adjustable paddles to crack the shells, followed by a sieving mechanism to separate the cracked shells from the kernels. The study reported a high cracking efficiency and recommended further optimization for large-scale applications.

Design and Fabrication of a Motorized Palm Kernel Shelling Machine (Adeboye et al., 2020): Adeboye et al. presented the design and fabrication of a motorized palm kernel shelling machine that integrated mechanical and pneumatic systems. The machine employed a rotating drum with protruding spikes to crack the palm kernel shells, followed by a pneumatic separator to separate the cracked shells from the kernels. The results indicated improved efficiency and reduced processing time compared to manual methods.

Assessment of the Efficiency of a Palm Kernel Cracking Machine (Oduwole et al., 2021): This study evaluated the performance of a palm kernel cracking machine that utilized impact forces to crack the shells. The machine employed a rotor with rotating blades and a perforated screen to crack and separate the shells from the kernels. The evaluation revealed high cracking efficiency, minimal kernel breakage, and a reduction in labor-intensive processes

2.10 SUMMARY OF REVIEWED LITERATURE

The literature examination reveals that throughout history, humans have consistently crafted tools and machines to meet their evolving needs. The process of design adapts alongside advancements in technical knowledge, material requisites, and aesthetic preferences. Moreover, the literature indicates that the utilization of machines has the potential to enhance agricultural productivity.

The literature showed that Nigeria cultivates and processes palm kernel and the methods that is being used for its processing. It has also shown that the traditional method for processing palm kernel is labour- intensive, time consuming and also has inadequate efficiency to satisfy the increasing demands of the expanding industry. This study however intends to close the gap by focusing on the design and construction of palm kernel cracking machine.

CHAPTER THREE

METHODOLOGY

3.0 METHODOLOGY

This section aims to outline the methodology employed during the course of the study periods.

3.1 MATERIAL SELECTION

The overall characteristics of any material used in the construction of an engineering component are influenced by its chemical composition, its atomic and molecular arrangement forming crystals, grains, and solid structures, as well as the manufacturing processes and treatments applied to achieve its final form and condition. When selecting a material for a specific engineering application, various properties such as strength, machinability, corrosion resistance, electrical characteristics, thermal conductivity, melting point, etc., must be taken into account. Often, a trade-off between these properties is necessary, and the choice of material typically involves a compromise.

In this study, the fundamental requirements for selecting materials for machine components were addressed. While the final decision usually requires a compromise, the criteria can be broadly categorized as service, fabrication, and economic requirements. The selection of construction materials was based on factors like availability, durability, and procurement costs, with the aim of minimizing the overall production cost of the machine. Angle Iron (Mild-steel) was chosen for constructing the base unit, including the stands and cross members. The design process critically examined various material properties to ensure suitability for the intended purpose.

i. Mechanical Strength: This encompasses the toughness and corrosion resistance attributes of the materials to be employed, and this consideration should be contingent upon the specific service requirements.

ii. Cost: The overall cost of a material includes expenses related to raw materials, fabrication, installation, and potential replacements due to failures. Failure to account for costs may result in unforeseen expenditures during repairs or replacements, leading to economic damage and production losses.

iii. Service Requirements: These encompass factors such as dimensional stability, strength, and toughness, among others.

iv. Design: In material selection, design is intricately linked to strength and ductility. However, there are instances where seeking an alternative material prompts feasible design modifications that can offer greater advantages than altering the alloy composition.

v. Availability: Regardless of a material's advantages, if it is not readily accessible, it is impractical to base a design on it. This includes both the cost-effective availability of the material and its availability in the desired form.

vi. Fabricability: Fabricability is closely tied to availability. The proper selection of material for a specific task poses one of the engineer's most challenging tasks. An engineer must be capable of choosing the optimal combination of material properties at the lowest cost without compromising quality, favoring materials that are easy to fabricate.

vii. Ductility: Ductility, in relation to strength, is often achieved at the expense of strength during the cold working of metals. Nevertheless, the greater the ductility achievable without a significant loss in strength, the better. Simultaneously, a substantial level of ductility is essential for fabrication through rolling and mechanical working processes.

3.2 DESIGN CONSIDERATIONS

To achieve a satisfactory design for the palm kernel shell cracking machine, it is essential to carefully address the factors of workability, durability, and reliability concerning its components. Workability pertains to ensuring that the machine's components meet the design specifications and can be seamlessly integrated into an operationally feasible unit. Durability guarantees the continuous operation of the machine throughout its design life without experiencing material or component failures, while reliability ensures that the machine performs in accordance with the specified design requirements. In summary, the design considerations for the palm kernel shell cracking machine included:

- Assessing the stress imposed on the shaft during torsion.
- Evaluating the strength and rigidity of the shaft when transmitting power under various operating and loading conditions.
- Determining the power to be transmitted to the shaft through the electric motor.
- Ensuring the machine's reliability, durability, and safety during use.
- Choosing manufacturing processes that facilitate low-cost production.
- Considering the machine's versatility, portability, and ease of maintenance.

3.3 DESIGN PROCEDURE

In the initial design phase of the machine, various factors were taken into account before arriving at the most suitable material selection. These designs addressed many of the areas where previous challenges had been encountered. Multiple designs were generated and criticized for deficiencies related to various factors. Some of these factors include:

1. Avoidance of excessive mechanisms to prevent the machine from becoming unwieldy. The paramount importance is placed on ensuring the versatility of its movement or mechanism.
2. Simplification of the design to ensure that the transmitted motion is logical and to restrict damage that might occur if the machine were subjected to a high load.

3.4 DESIGN FEATURES

To ensure the machine's efficient and optimal performance, the following criteria were taken into account:

(i) The design and construction were simplified to minimize costs, making it affordable for a wide range of users.

(ii) The power requirement for operating the machine was minimized to enable it to be powered by a petrol engine.

(iii) The machine was designed for use in any palm kernel-producing rural area, emphasizing mobility.

(iv) Component parts were designed to be highly replaceable in the event of damage.

3.5 MACHINE DESCRIPTIONS AND OPERATION

The palm kernel processing machine is composed of five primary units: the in-feed unit, the cracking unit, the discharge outlet, and the drive unit.

3.5.1 The cracking unit

The cracking chamber is configured as a hollow cylindrical tube with a rectangular (channel-shaped) structure. The cylinder has dimensions of 375 × 400mm for its minor and major diameters, respectively, and a length of 175mm. At the back surface, the cracking chamber is drilled with an 80mm diameter to allow the driving shaft to pass through to the core of the chamber via the ball bearing. The cracking process involves the impact force applied to the kernels by beaters striking against the walls of the cracking chamber. This impact force is generated by the kinetic energy of the hammer through the rotary motion of the motor. As each kernel nut is introduced into the cracking chamber, it is impacted against the chamber walls by the high velocity of the hammer, effectively loosening each kernel seed from its shell covering. The cracking unit is constructed from mild steel.

3.5.2 Machine Components

The Hopper

The hopper, constructed from 1.4 mm gauge mild steel sheet metal, takes the form of a truncated square base pyramid. It is linked to the conveying channel that directs the flow towards the cracking chamber. The hopper serves as the receptacle for the dried, non-fibrous palm kernel shells intended for cracking. Its design facilitates a steady and controlled introduction of palm kernel shells into the cracking chamber through the neck, facilitating the cracking process.

3.5.2.1 Power Transmission Shaft

The power transmission shaft, constructed from mild steel, features one end that is step turned to dimensions Ø29 mm x 85 mm, providing accommodation for the two bearings. The shaft has a total length of 600 mm and a diameter of 35 mm.

3.5.2.2 Bearing and the Bearing Housing

The power transmission shaft, constructed from mild steel, features one end that is step turned to dimensions Ø29 mm x 85 mm, providing accommodation for the two bearings. The shaft has a total length of 600 mm and a diameter of 35 mm.

3.5.2.3 Pulley

This unit facilitates the transfer of power from the shaft of the electric motor (prime mover) to the shaft of the cracking mechanism through two V-belts. It includes a smaller pulley with a diameter of 60 mm, connected to the prime mover's shaft, and a larger pulley with a diameter of 85 mm, connected to the cracking machine's shaft.

3.6 DESIGN CONCEPT AND CALCULATIONS

The machine was designed to accommodate the diverse physical characteristics of various palm kernel varieties (Dura and Tenera). This includes considerations for different sizes of palm kernel nuts obtained from local sampling, as well as the characteristics of the shell and kernel, the weight of the palm kernel, and the coefficient of friction for both the shell and kernel in relation to carbon steel. To ensure optimal performance, various palm kernel nuts were randomly selected and measured, revealing average diameter sizes ranging from 11.0 to 25.0 mm and shell thickness sizes ranging from 0.8 to 2.7 mm, before the fabrication of the machine.

3.6.1 Design Analysis

3.6.2 The Feeder

This structure, shaped like a pyramidal frustum, functions as a feed hopper, facilitating the gradual and smooth introduction of aggregate material into the separating medium for processing. The design specifications are outlined below:

12.7 *mm* standard ply wood board was used for the hopper.Top dimension length is 642 *mm*

Breadth = 530 *mm*

Bottom dimension = length = 242 *mm*

Breadth = 130 *mm*

Centre height = 500 *mm*

Slant height = 539 *mm*

For rectangular base

Length = 242 *mm*

Breadth = 130 *mm*

Frame work channel:

Mild steel channel

Thickness: 2.5 mm

Size = 25.4 x 25.4 mm

3.6.3 Electric Motor

The electric motor serves as the primary driving force, linking various moving components of the machine through a combination of drives and pulleys. The motorselected for this design is a 3HP electric motor.

The Power transmitted by the belt drive from the electric motor,

P= (T_1-T_2) V

Where,

$$V = \frac{\pi D n N n}{60}$$

$$V = \frac{\pi x 125 x 10^{-3} x 1400}{60} = 9.16 m/s$$

Substituting;

P= (355.725 - 122.9) ×9.16

P= 232.825x9.16 = 2132.667 W

P = 2132.667 W

3.6.4 Pulleys:

The suggested choice for the pulley in this machine is mild steel. The decision to opt for mild steel materials is grounded in their relatively lighter weight compared to cast iron pulleys, along with higher strength and durability, reducing the likelihood of failure or breakage. The size of the pulley is determined by its pitch diameter in a drive combination of pulleys operating at a specified speed, calculated as follows:

$\underline{Dn} = \underline{Rr}$

$Dr \quad Rn$

Determining pulley size

The size of the pulley is determined by its pitch diameter in a drive configuration of pulleys operating at a designated speed, the pitch diameter could be calculated from the following basic relationship:

Where Dn = The required pitch diameter of the driven pulley

Dr = Pitch Diameter of the driver pulley

Nn = Rotational Speed of the driven pulley

Nr = Rotational Speed of the driver pulley.

Assuming a driver pulley diameter of 125mm with a high motor rotational speed of 2880 rev/min was selected.

Also, a cast-iron driven pulley of 240mm diameter was selected.

Therefore, the rotational speed of the driven pulley and hence the shaft mounted on it willbe.

$$Nn = \frac{Dr.Nr}{Dn} = \frac{125 \times 2880}{240} rev/min$$

Nn = 1500rev / min

3.6.5 Beater design

Mass of beater = 4 kg

Weight of beater = (4x10)N = 4N

Weight of 1 beater = $\underline{4N}$ = 2N

2

Mass of nuts per hour = 800kg per hour

= $\underline{850}$ kg/ sce =

3600

0.2222kg /s

Weight of nuts per second = (0.222x10) N = 2.

3.6.6 The shafting design

The rotating element responsible for the palm kernel nut cracking process is the shaft, crafted from a mild steel rod. Shaft design considerations revolve around strength, rigidity, and stiffness. The radius of gyration (k) is determined, treating the cracking impeller and tube as a rectangular cross-section. The choice of mild steel is justified by its high torsion strength, resistance to wear, and cost-effectiveness, as highlighted by Khurmi and Gupta in 2007.

The vertical loading configuration for first shaft is shown in Figure 1 with P_1= 6508.78 N,P_2 = 433.91 N, A_V = 7048.18 N (up), B_V= 105.49 N (down)

Figure 3.1: Vertical loading configuration for shaft I

The shear force diagram based on this loading is shown in Figure 2.

Figure 3.2: Vertical shear Force Diagram for shaft I

The vertical bending moment for shaft I is shown bekow

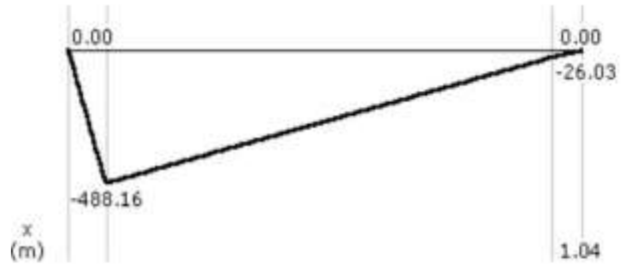

Figure 3.3: Vertical bending moment diagram for shaft I

The horizontal loading on the shaft I is shown in Figure 4 with P_1 = 11.34 N, P_2 = 81.07 N

A_H = 6.9 (up), B_H = 85.51 N (up).

Figure 3.4: Horizontal loading configuration for shaft I

The corresponding shear force diagram is shown in Figure 5 below

Figure 3.5: Horizontal shear force diagram for shaft I

The bending moment diagram for horizontal loading is shown in Figure 6 below,

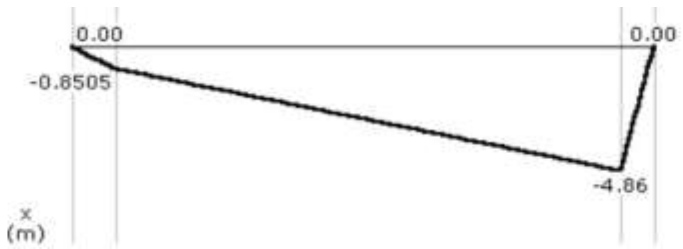

Figure 3.6: Horizontal bending moment diagram for shaft I

From Figures 4 and 6, the maximum bending moment for shaft I is

M b (max) = $\sqrt{(488.16)\ 2\ +\ (0.85)2}$ = 488.16mm

$d^3 = \frac{16}{\pi \times Ss}\sqrt{(k_b M_b)^2 + (K_1 M_1)^2}$

Where:

S_S= Maximum shear stress (N/m)

M_1= Torsional moment (N/m)

M_b= Combine shocks and factors applied to bending moment (N/m)

k_1 =or for bending and torsional moment respectively [N/m]

For a belt drive

Torsional moment M_1 =7.05Nm

Bending Moment M_b = 11.67Nm

Shock and fatigue factor s applied to bending moment Mb = 1.5Shock and fatigue factor applied to Torsional moment M_1 = 1.

Allowable stress=S_S =40 x 106 N/m2

From above formula considering the factor of safety of 1.5d=20.09mm

Therefore, the minimum shaft diameter suitable for transmitting this drive is 20 mm, making the chosen 20 mm shaft diameter in the design appropriate. Considering the cracking impeller and tube as a rectangular cross-section, the radius of gyration (k) is determined. The motor (prime mover) operates at a speed of 1420 rpm with a pulley size of 145 mm. To meet the required speed of the shaft, which is 400 rpm,

D_r = 145 *mm*, R_r = 1420 *rpm*, R_n = 400 *rpm*

Diameter of pulley I, D_n = 515 *mm*

Diameter of pulley I, D_n = 515 *mm*

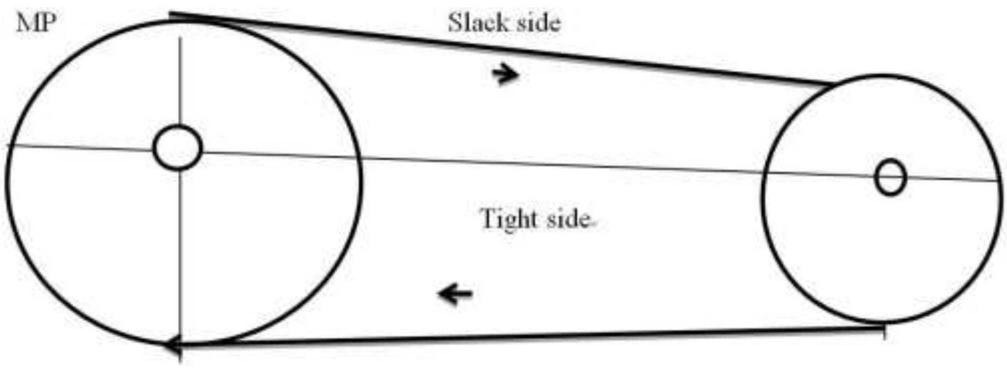

Figure 3.7: Tight and slack sides of belt tension

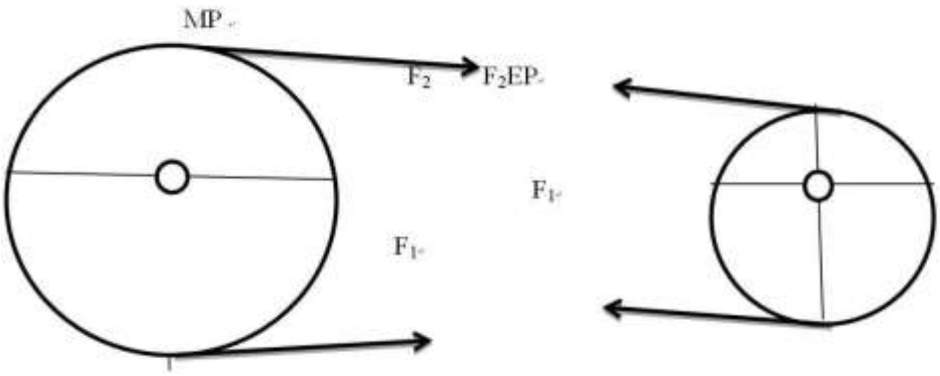

Figure 3.8: Impacted forces by the belt

3.6.7 Selection of the belt, size, length and pulley size

The approach to selecting the belt involves evaluating each belt's thickness in terms of power capacity per unit length and width at various velocities, chosen from standard tables. These values are then divided into the required power and multiplied by service factors to determine the necessary belt width. The choice of belt is influenced by factors such as the nature of the load it carries, the type of driving unit, horsepower rating, the speed of the driver and driven units, and the plant layout. In the case of the 2 HP prime mover operating at a speed of 1400 r/min, a V-belt was chosen. A V-belt is characterized by an endless, flexible belt that transmits power by contacting and gripping the pulleys.

The use of the V-belt is employed in this design owing to the following reasons

a. It reduces vibration.

b. It possesses the capability to absorb shock during machine startups.

c. The operation of the belt and pulley is characterized by a quiet and relatively low noise level.

d. Installation and removal are straightforward and uncomplicated.

e. It offers an extended lifespan, ranging from 3 to 5 years, resulting in low maintenance costs.

f. The drive is highly efficient, as the slip between the belt and pulley groove is minimal.

g. The V-belt allows operation in either direction, with the tight side positioned at the top or bottom, and the center-line may be horizontal, vertical, or inclined.

h. The V-belt drive contributes to compactness due to the small distance between the centers of pulleys.

The following are put into consideration in the selection of the V-belt (A-type).

C = Centre Distance between driver and driven pulleys.

Dr= Diameter of Driver Pulley.

Dn = Diameter of Driven Pulley.

P= Power to be transmitted.

Nr = Rotational Speed of the driver shaft

N = Rotational Speed of the driven shaft

α_1 = Angle of wrap for driver pulley

α_2 = Angle of wrap for driven pulley

b= Belt width

t = Belt thickness

Allowable stress for rubber betting 1-1.7MPa.

T_1 = Tension on the tight side of the belt

T_2 = Tension on the slack side of the belt

L= Length of belt.

For the machine deigned to satisfactorily crack palm-kernel shells,

C = 448mm

$r = \frac{Dr}{2} = \frac{125}{2} = 62.5\ mm$

$R = \frac{Dn}{2} = \frac{240}{2} = 120.0\ mm$

The Length of belt is calculated from

$L=4[C^2 + (R-r)^2]^{1/2} + \pi (R+r)$

$L=4[448^2 + (120-62.5)^2]^{1/2} + \pi (120 + 62.5)$

$L=4[448^2 + 57.5^2]^{1/2} + \pi (182.5)$

$L=4[20401025]^{1/2} + 573.341$

$L=4[452.674] + 573.341$

$L=1806.7 + 573.341$

L= 2380.04mm

L= 2.38m

3.6.8 Determination of Angle of Wraps

From $\sin \beta = \frac{R-r}{C}$

The angle of wraps, α_1 and α_2 are obtained as follows:

$\alpha_1 = 180^0 - 2 \text{ Sin}^{-1} \left(\frac{R-r}{C}\right)$

$= 180^0 - 2 \text{ Sin}^{-1} \left(\frac{120-62.5}{448}\right)$

$= 180^0 - 2 \text{ Sin}^{-1} \left(\frac{575}{448}\right)$

$= 180^0 - 2 \text{ Sin}^{-1} (0.1283)$

=180° - 2 Sin- (575)

=180 - 2 Sin (0.1283)

$\alpha_1 = 180^0 - 2(7.374)$

$= 180 - 14.75^0$

$\alpha_1 = 165.25°$

Also, $\alpha_2 = 180^0 - 2 \text{ Sin}^{-1} \left(\frac{R-r}{C}\right) = 180^0 - 2 \text{ Sin}^{-1} \left(\frac{120-62.5}{C}\right)$

=180°+ 14.75°

α_2 =194.75"

3.6.9 Determination of Tension on Tight Side of Belt, T_1

Knowing the values of width and thickness of the V- belt, T; can be determined by usingthe expression.

T_1 = Required Cross-sectional area of belt x Maximum stress in belt.

Cross-Sectional Area = Width x thickness

= b x t

$= 9.3mm \times 10.2mm$

$= 94.86mm^2 = 94.86 \times 10^{-6} m^2$

Maximum Stress in belt is taken as 1.5×10^6 N/m^2

For a factor of safety of 2.5

$T_1 = (94.86 \times 10^{-6} \times 1.5 \times 10^6 \times 2.5)$ N

$T_1 = (142.29 \times 2.5) = 355.72$ N

3.7 DESIGN FOR PULLEY

For the drive of this machine, the V-belt class B type (17 × 1325) was selected. The choice for the width of pulley grooves (w) adhered to the recommendation that the pulley width should be approximately 25% greater than the width of the belt, as suggested by Ndukwu and Asoegwu in 2000. The design details of the pulley are illustrated in Figure 1.

$w = t + (25\%\ of\ t)(mm)$Where;

w =width of the pulley,

t = width of the V- belt

For Machine and Engine pulleys

w = 17 + (25% × 17) = 21.25 mm

3.7.1 Speed ratio

The speed ratio and the pulley diameters were designed using formula:

$$\frac{N_1}{N_2} = \frac{D}{d}$$

N_1 = speed of engine pulley (r/min.)

N_2 = speed of machine pulley (r/min.)

D = diameter of the larger pulley (Machine) (mm)

d = diameter of the smaller pulley (Engine pulley) (mm)

3.7.2 For the Pulleys;

Maximum engine speed $N1$ = 2400 r/min

Diameter of the engine pulley d = 110 mm

Maximum machine speed $N2$ = to be determined

Diameter of the machine pulley D = 250 mm

$$N_2 = \frac{2500 \times 110}{250} = 1100 r/m$$

Bearing selection

In assumptions of these parameters where: number of rows of balls (i), Number of balls perrow (Z) = 10,

Diameter of balls (D) = 10 mm,

Radial load factor (f0) = 12.3,

Nominal angle of contact (α) = 20 °

The basic static radial load rating for roller bearing (Co) was calculated as shown as,

Co = fo iZD

2 cosα = 12.3 × 1 × 10 × 102 cos 20 =11558.22

For a bore of 30 mm and outer diameter 72 mm, with corresponding width of 19 mm, the corresponding roller bearing number selected was 306 (Khurmi and Gupta, 2006).

Mainframe: This supports the entirety of the machine structure and is composed of a rectangular box constructed from channels. Bored holes are strategically positioned to facilitate the attachment of screws for securing the cover (body). Specifications for the mainframe are as follows:

Mild steel Channel ofWidth = 900 mm Length = 2140 mm Thickness = 3.5mm Height = 1200 mm

Cross sectional dimension = (40 x 40) mm^2

3.8 WORKING PRINCIPLE

The palm nuts are introduced into the machine through the hopper, and its slanting design facilitates the smooth movement of kernels during the feeding process. As the nuts are fed from the hopper at a moderate speed, they make an impact with the beater. The resulting cracked kernels and shells then pass into the cracking drum and exit through the outlet at the bottom part of the cracking drum, which is connected to the supporting frame and equipped with the first screen.

The cracked kernels, with an observed average size of 11mm, along with cracked shells smaller than 12mm, fall through the first separating screen (sieve). This sieve is designed with holes of 12mm, allowing it to retain cracked shells larger than 12mm, as well as a few kernels larger than 11mm. The second filter, designed with holes of 10mm, retains 90% of kernels and filters out nearly all cracked shells with a size of 10mm and less than 10mm that fall onto it from the first sieve. The kernels will be remove or collectedfrom the second screen while, the cracked shells will also be remove from the first screen and underneath the second screen.

The working mechanism typically follows the following steps;

1. Feeding: Palm kernels are fed into the machine through the hopper.
2. Cracking: The machine applies force by impact to crack the hard outer shell of the palm kernels by the help of a beater (hammer)
3. Collection: The external palm kernels are collected in a separate container for further processing
4. Shell Disposal

3.9 ASSEMBLY OF PARTS

Once all the components were manufactured, the assembly of the machine followed a series of steps:

1. The drive shaft, featuring the pulley and two bearings, was welded to the rectangular frame channel using a manual arc welding machine.
2. The shaft, along with the welded cracking rectangular frame and the flywheel, was then affixed at the two bearing casing points to the bearing support stand initially welded to the supporting base.
3. The hopper was also welded and secured to the frame.
4. The subsequent step involved installing the cracking basket inside the bucket mounted on the frame at the top part of the supporting base, using bolts and nuts to allow for cracking.
5. The hammer was then attached to the shaft, which was mounted on the bearing, using bolts and nuts in a manner that facilitates the smooth flow of palm nuts from the hopper through a centralized hole in the cracking into the rectangular channel.
6. The electric motor was mounted on the rectangular frame, a pulley was connected to the motor shaft, and a belt was attached and connected to the pulley.

CHAPTER FOUR

PERFORMANCE TEST EVALUATION AND RESULT

4.1 PERFORMANCE TEST

Upon completing the fabrication and assembly of all machine components, a series of tests were conducted to assess the efficiency of the newly developed machine. Three distinct tests were performed using sample sizes of 100, 100, and 200 palm kernels. Each sample was introduced into the hopper through the flow channel, feeding into the cracking chamber at a consistent and moderate machine speed. The recorded results were then used to calculate machine performance efficiency, percentage cracked efficiency, and mechanical damage kernel efficiency.

The primary focus for the optimal performance of the designed and constructed palm kernel cracking unit lies in the cracking efficiency and kernel breakage factor of the machine. This involves finding a compromise between achieving high cracking efficiency and maintaining a low kernel breakage factor or ratio.

To evaluate the throughput of the machine, 100 palm nuts were weighed and fed into the hopper. The cracker operated at a constant speed of 1845 rpm, a modification from the speed of the electric motor reported in previous studies (Koya, 2006; Antia et al., 2014). The cracking period was recorded for each operation, and this procedure was replicated for each sample from three trays corresponding to different sizes.

The findings revealed that the total number of cracked palm kernel nuts increased with the shaft speed, while the number of uncracked nuts decreased. Additionally, partially cracked palm kernel nuts were observed to be 2.75% at 800 rpm and 1.75% at the highest speed of 1800 rpm. The lowest percentage of unbroken kernels (1.50%) was noted at a shaft speed of 1600 rpm, while the highest percentage of broken nuts (3.25%) was observed at the maximum shaft speed of 2400 rpm.

4.2 RESULTS

Table 4.1: Shows the performance tests for the developed palm kernel nuts cracking machine, with minimum speed of 800 rpm and highest speed of 2400 rpm

Number of palm kernel nuts (4Reps)	Shaft speed (rev/min)	Cracking time taken (s)	Un-cracked nuts (%)	Partially cracked nuts (%)	Un-broken kernels (%)	broken kernels (%)
85	400	64	2.52	2.72	93.22	1.72
85	600	44	2.12	2.31	93.24	1.54
85	1400	33	1.52	1.43	92.18	2.65
85	1800	21	1.34	1.21	93.44	2.31

Table 2 displays the cracking time and throughput of the newly developed machine. The cracking time in seconds decreased from 64 to 20 seconds as the shaft speed increased from 800 to 2400 revolutions per minute. Through experimental testing with the designed machine, it was observed that the throughput capacity increased from 11.5625 to 37.000 g/s, correlating with the rise in shaft speed from 400 to 1800 rpm.

Table 4.2: Showing the cracking time and the throughput of the developed machine

No of palm kernel nuts (4 Rep)	Mass of kernels (g)	Shaft speed (rpm)	Cracking time (s)	Throughput (g/s)
85	218	400	64	11.5625
85	347	500	44	16.7955
85	421	1300	33	22.4546
85	423	1600	21	35.1429
85	482	1800	20	37.0000

The graph in Figure 4.1 illustrates machine efficiencies in relation to shaft speed. Notably, both performance efficiency and overall efficiency reached their peak values at a speed of 1600 rpm, registering at 94.75% and 93.329%, respectively. Simultaneously, cracking efficiency demonstrated an increasing trend, rising from 97.5% to 99% as the shaft speed increased. The percentages of broken nuts were recorded as 1.75%, 1.5%, 1.5%, 2.5%, and 3.25% at speeds of 800, 1200, 1600, 2000, and 2400 rpm, respectively, with an average of 2.1%.

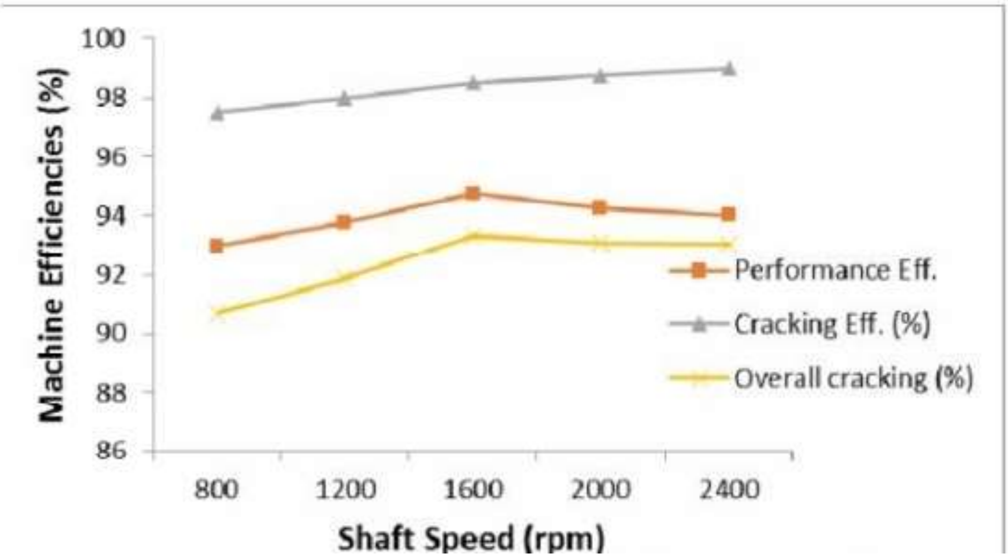

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Figure 4.1 Graph of machine efficiencies against shaft speed

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This separator effectively separates kernels from shells following the cracking and fiber separation processes. The developed machine holds significant potential for profitable entrepreneurial ventures, particularly for small-scale stakeholders in the palm oil and related industry who may find imported dry type separators financially burdensome. The applicability of this innovation extends to the processing of nuts and shells sharing similar characteristics with palm kernels. This advancement has the capacity to greatly enhance the burgeoning kernel industry and the agricultural sector of the nation.

The fabrication of the modified palm kernel cracker was executed successfully, and its overall efficiency surpassed that of the conventional model. It eliminates the need for manually separating kernels from cracked shells, aligning with the project's objectives. Importantly, mass production of the machine could substantially reduce production costs. This research resulted in the development and construction of a locally sourced Palm Kernel Nut-Cracking machine, proving to be a cost-effective alternative to foreign counterparts. The machine is particularly economical for establishing small-scale industries, especially in developing countries like Nigeria.

Considering the present level of technology and acknowledging the challenges and long hours associated with traditional palm kernel cracking methods, the utilization of this locally designed palm kernel cracker has the potential to address existing problems. This, in turn, will contribute to the increased production of palm kernel oil, palm kernels, and palm kernel seeds, thereby improving the standard of living for users. To ensure the machine's maximum performance and a prolonged service life, proper maintenance and operations are crucial. This includes preventing the machine from coming into contact with water or rainfall, regular lubrication of bearings, and the tightening of any loose bolts and nuts before each operation. Additionally, operating the machine on level ground is recommended to prevent excessive vibration.

5.2 RECOMMENDATIONS

The following recommendations are made for the developed palm kernel cracking and separating machine.

1. The design consideration should minimize noise and vibration by using a low-noise bearing.
2. The design should be made in order to regulate the number of nuts going into the cracking chamber.
3. For any future investigations into this machine, it is recommended to integrate a palm kernel and seed separator.
4. The design should incorporate a palm kernel nut regulator at the hopper's opening to the cracking chamber, constructed to control the number of nuts entering the cracking chamber.
5. The machine's attractiveness to entrepreneurs, particularly in the large-scale kernel production sector, would significantly increase with automation. This is highly advised.
6. Enhancing the recovery rate of shell pieces that adhere to the belt surface and improving the machine's efficiency can be achieved by introducing a scraper unit at the discharge end.

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