ISSN No:-2456-2165

Design, Development and Performance Evaluation of an Improved Palm Kernel Oil (PKO) Expeller

Ochonogor Ashibudike Destiny[1]; Harold Omon Okereke[2]; Edokpayi Evans Efosa[3]
Department of Production Engineering, University of Benin, Edo State, Nigeria

Atonuje Onujoghene Ephraim[4]
Department of Computer Science
Delta State University Abraka, Nigeria

EngrOfomaja Nelson Iguemedere[5]; Engr Gospel Akaroro Usiwoma[6]
Delta State School of Marine Technology, Burutu, Nigeria

Abstract:- A palm kernel oil expeller was designed and developed for efficient and effective separation of palm kernel oil and kernel cake respectively. It was designed and developed to remove drudgery and increase oil recovery efficiency and in turn increase the quality of the palm kernel cake which is used as feed for animals. For optimal operation and performance of the machine, material selection was an integral part of the design process, a careful selection of materials was given priority attention. The machine's components, including the hopper, expelling chamber, shaft, and adjustable choke mechanism, underwent design and development processes involving techniques like cutting, welding, drilling, bending, and boring. Powered by a 20hp electric motor, the machine boasts a nominal input capacity of around 380kg/hr.The regulation of clearance between the barrel and the adjustable cone (choke mechanism) plays a crucial role in controlling the thickness and dryness of the pressed cake. Leveraging this choke mechanism allows for an extraction efficiency of approximately 95%. Notably, the machine's design facilitates the processing of cold palm kernel seeds without the need for pre-treatment.The breaking and cooking operations are seamlessly executed by the screw shaft within the barrel of the unit, showcasing the machine's efficiency in handling palm kernel seeds throughout the processing stages.The machine is simple and can easily be operated and maintained by rural farmers.

I. INTRODUCTION

The oil palm stands out as a crucial cash crop in tropical regions. Its primary derivatives, palm oil and palm kernel oil (P.K.O), play integral roles in various industries. Palm oil is derived from the succulent flesh of the palm fruit, while palm kernel oil is extracted from the tough kernel within the fruit. Extracting oil from the resilient palm kernel proves to be a more intricate and less efficient process compared to obtaining palm oil from the pulpy flesh. Both palm oil and palm kernel oil serve as vital raw materials in the production of diverse products such as margarine, candles, epoxy resins, soaps, detergents, lubricants, pomades, cosmetics, and more. Additionally, the palm kernel cake, a byproduct obtained during the extraction of palm kernel oil, is employed as an additive in the manufacturing of livestock feed. This cake serves as a significant protein source crucial for the proper growth and development of livestock (P.E. Amiolemhen and J.A. Eseigbe, 2019). kernel oil and palm kernel cake. These components enhance the palatability of various food brands when used in conjunction. Palm kernel oil, the second most consumed lauric acid group, is derived from the dried kernels of the oil palm fruit, scientifically known as Elaeisguineensis. The lauric oils extracted from palm kernel hold considerable importance in the global oleochemical industry, primarily due to the crucial role of the lauric fraction in soap and detergent manufacturing. Furthermore, palm kernel oil can be modified for use as a non-petroleum-based alternative fuel (FAO 2017). In 2011, Nigeria ranked as the third-largest producer of palm fruit, boasting approximately 2.3 million hectares (5.7×106 acres) under cultivation. Up until 1934, Nigeria held the distinction of being the world's largest producer of palm fruit. Both small- and large-scale producers actively contribute to the industry's growth (FAO 2011). The primary method for extracting edible oils from oil seeds is mechanical pressing, a process commonly employed in the industry (Mrema and McNulty, 1985). This method ensures the extraction of a non-contaminated, protein-rich, low-fat cake at a relatively low cost. However, mechanical presses exhibit lower extraction efficiencies, leaving about 8 to 14% of the available oil in the cake unextracted (Srikantha, 1980). An estimated annual value of US $57 million worth of edible oil is left in the deoiled cake due to these inefficiencies. In contrast, solvent extraction methods achieve extraction efficiencies exceeding 98%, but they are more complex and expensive (Bargale, 1997). Continuous efforts to improve the oil extraction efficiency of screw presses have been underway, emphasizing the optimization of key process variables. These variables include applied pressure, pressing temperature, and moisture conditioning of the fed samples, as highlighted by Ohlson in 1992. The ongoing research and development in this area aim to enhance the overall performance and effectiveness of screw presses in oil extraction processes.Well-maintained and skillfully handled expellers, according to Weiss (1983), can process significant volumes of oil per day, reducing the oil content of meal. Khan and Hanna (1983) designed a screw press that ruptures oil cells under pressure, expelling oil through slots between cage lining bores. The capacity of a screw press depends on the size of the cage holding the product (UNIFEM, 1987). Small power-driven expellers requiring about 8 hp can

ISSN No:-2456-2165

process varying amounts of raw materials per hour, depending on the type of expeller (KH, 1985). High oil content nuts and seeds, such as palm kernels with 47-56% oil content, are suitable candidates for small-scale extraction. Edible oils produced through mechanical extraction methods typically require no further refining, bleaching, or deodorizing. Improvements in mechanical extraction equipment and techniques, particularly through power conditioning, have shown potential to increase oil recovery for various seeds. Efforts are ongoing to enhance the performance of oil expellers through modifications, improved design, and optimization, aiming to develop more efficient mechanical screw presses that can compete globally and contribute to increased vegetable oil production in developing countries. Various designs of palm kernel oil expeller in the past have been saddled with the problem of accelerated shaft wear, thus increasing the maintenance and operating cost of the machine as the shaft will have to be replaced after very few months of usage. The extraction efficiency of the existing local design is also low, thus having an adverse effect on the quality of cake which is a source of protein in livestock feed. Palm kernel oil expeller is also imported to the country from some of our trade partners like Germany, Malaysia e.t.c with more advanced technology thus having a negative effect on our gross domestic product. These imported P.K.O expeller's also experience accelerated shaft wear as stated above and lacks certain important local content. This project work expresses the need to develop indigenous capacity for rational design and development of an efficient and effective P.K.O expeller in Nigeria.

II. LITERATURE REVIEW

A. *Genesis of the Problem*

Various methods are employed for extracting oil from oilseeds, including those from olive, palm fruit, shea butter, coconut, and more. The traditional Ghani method, originating from India, is commonly used for crushing oil from mustard and sesame seeds, coconut, and groundnuts (Achaya, K.T. Ghani, 1993). However, this extraction process is slow and may not be sustainable in the long run (Ibrahim, A., 2015).Oil plate presses, often utilized for expressing oil from palm fruit, are influenced by the intensity of pressure application (Adesina, B.S., and Bankole, Y.O., 2013). Solvent extraction, another method, is capital-intensive, and the quality of oil obtained is considered inferior to that obtained through mechanical extraction methods (Sodeifian, G., and Ansari, K., 2011).Oil expellers, on the other hand, are widely used for crushing oil from various lipid feedstocks. They are known for being easy to operate, versatile with different oilseeds, less complex, and cost-effective to maintain (Farm Energy, 2017). Omobuwajo et al. (1997) delved into the temperature distribution and heat generation in the barrel of the oil expeller, emphasizing the need for a careful study of the thermal influence of the oil expeller.Researchers such as Khan and Hanna (1983) have highlighted that extraction factors like pressing time, temperature, pressure, and moisture content of the seed significantly impact oil yield during the extraction process. According to William et al. (2008), an increase in temperature and a decrease in moisture content tend to enhance the rate of oil extraction. Isobee et al. (1992) reported an impressive over 93% efficiency in terms of oil recovery from a screw press fabricated for untreated sunflower seeds. These studies collectively contribute to the ongoing efforts to optimize oil extraction methods and improve efficiency in the oilseed processing industry. The literature on oil extraction methods is extensive, with several studies focusing on different seeds and expeller designs. Tunde-Akintunde (2001) reported a temperature range of 70-80 ℃ for extracting oil from soybean seed expeller. Ajibola et al. (1989) achieved an extraction efficiency of 64% for palm kernel seed. Akinoso et al. (2009) investigated the effects of feeding rate, compressive stress, and speed of operation on an oil expeller, with compressive stress found to be the most influential factor on oil yield. Martins et al. (2013) developed a low-cost expeller for extracting oil from Castor and Jatropha seeds, incorporating designs to control pressure drag and compression ratio. Samuel and Alabi (2012) emphasized the importance of laboratory tests and analysis to enhance the productivity of palm kernel oil mills. Olaniyan et al. (2012) designed a portable screw expeller for soybean and palm kernel oil, reporting high oil yield and extraction efficiency. Onto et al. (2011) found that oil extracted from oil expellers exhibited superior quality compared to solvent extraction. Akerele and Ejiko (2015) achieved a 72.94% extraction efficiency for a horizontal expeller designed for groundnut oil. Bahadar et al. (2013) simulated pressure distribution inside the barrel of a screw press. Odewale et al. (2017) fabricated a U-shaped screw jack for oil extraction, with minimal extraction loss.While existing literature extensively covers expellers for various seeds, such as groundnut, sunflower, jatropha, and rice bran, there is a notable gap in research on palm kernel oil expellers. This study aims not only to fabricate a screw expeller for palm kernel oil but also to improve the material of construction, manufacturing methods, and overall efficiency. The research will delve into various palm kernel extraction methods, providing a comprehensive analysis of the existing techniques in the context of palm kernel oil extraction.

B. *Extraction methods*

The methods of extracting palm kernel oil from palm kernel seeds are grouped into three, namely : the traditional methods, the mechanical methods and the chemical methods (FAO, 2017)**.**

➢ *Traditional methods*

- **Traditional roasting method:** This method relies on heating palm kernels to rupture the oil glands. Palm kernels are placed in a clay pot and heated using burning wood. At a certain high temperature, oil is released from the seeds and then collected
- **Traditional pressure methods:** The traditional pressure methods include the following:
- **Hand Pressing:** Crushed seeds are wrapped in cloths and

✓ Then hand-pressed to squeeze out the oil.
✓ Stone and lever pressing: Crushed kernels are pressed to release oil using devices operated by stones and levers.

- ✓ The mortar is fixed to the ground, and the pestle is inserted to crush the kernels through pressure and friction. The pestle is typically driven by one or a pair of animals. Oil in the kernels runs out through a hole at the bottom of the mortar.
- ✓ Traditional aqueous method: Crushed or ground kernels are boiled in water to release oil, which floats on the water surface. The palm kernel oil on the surface is collected with a mug into another pot. The water content of the recovered oil is then removed by heating.

These traditional methods highlight the diverse ways in which palm kernel oil extraction has been historically carried out. Each method utilizes different principles, tools, and techniques to extract oil from palm kernels, reflecting the ingenuity and resourcefulness of traditional oil extraction practices.

- ➢ *Solvent or chemical extraction methods*

In the solvent extraction method of oil extraction, ground kernels undergo treatment with a solvent, which washes or dissolves the oil out of the ground kernel material. The pure oil is subsequently obtained through the evaporation of the solvent. The solvent extraction process can be broken down into three primary unit operations: kernel pre-treatment, oil extraction, and solvent recovery from the oil and meal, respectively. While solvent extraction is a viable option for high-capacity mills in large-scale operations, it is generally not recommended for small enterprises (Poku, K. 2002).

- ➢ *Mechanical methods*

Mechanical extraction comprises several processes. As shown in Fig. 1 below, the three main steps are:

- Kernel pre-treatment
- Screw-pressing
- Oil clarification.

In these methods of mechanical extraction, mechanical compressive forces are used to separate palm kernel oil from solid palm kernels under permitting conditions. The mechanical methods of palm kernel oil extraction include the following:

III. HYDRAULIC PRESSING METHOD

This method applies Blaise Pascal's principle of pressure, which states that pressure applied to a confined fluid is transmitted equally in all directions. In the context of oil extraction, a hydraulic press is utilized, where a hydraulically operated piston or ram is employed to press oil out from ground kernels. In modern hydraulic presses designed for oil extraction, there is typically a stack of horizontal boxes. Each box contains a batch of ground kernel particles wrapped in a cloth. The stack of boxes is compressed by the hydraulic ram, and as a result of the applied pressure, oil is expelled through openings in each box. This process efficiently harnesses hydraulic pressure to extract oil from the ground kernels, demonstrating the practical application of Pascal's principle in the field of oil extraction.

- ➢ *Screw Press methods*

The screw press consists of a series of continuous worms built on a steel shaft that rotate within a perforated housing (e.g a pipe) and operates against a restricted opening. The movement of the palm kernels being processed is made possible by the worm flights. The conditioned kernels are fed into the housing through a hopper and are forced along as the screw rotates, crushing and heating up the mass. The crushing and heating of the mass of palm kernel, facilitates oil extraction (Obetta, S. E. 2003).

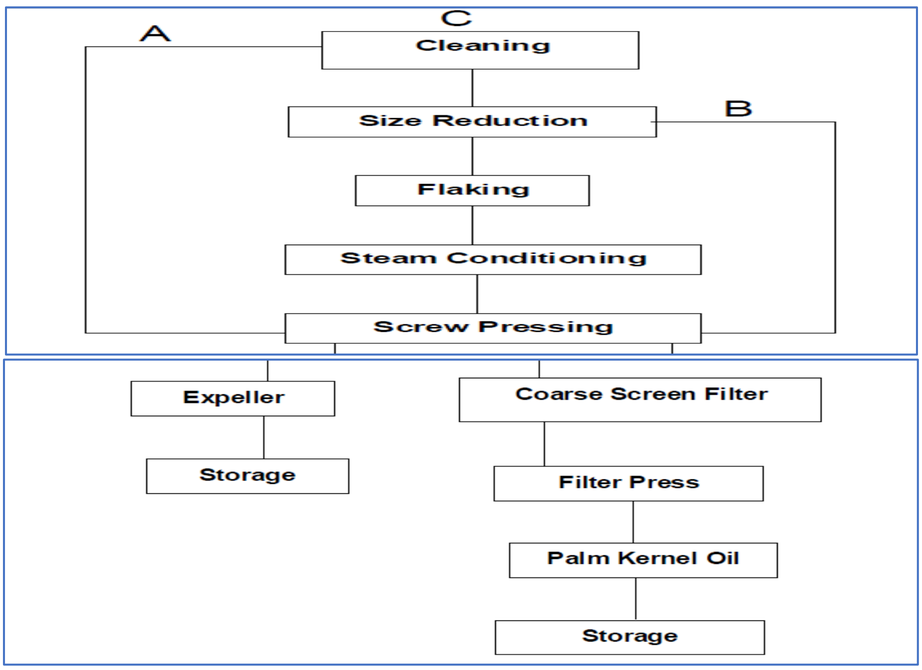


Fig. 1: Mechanical extraction of palm kernel oil by screw press method (Adapted from FAO Agriculture Service Bulletin).

ISSN No:-2456-2165

Line (A) is dedicated to direct screw-pressing without any prior kernel pre-treatment. In contrast, Line (B) involves partial kernel pre-treatment before progressing to screw-pressing. Finally, Line (C) is designed for a comprehensive pre-treatment of the kernels, followed by the subsequent screw-pressing stage. This categorization illustrates varying levels of preparation and treatment applied to the kernels in each processing line, allowing for a nuanced approach to the overall extraction process

C. Kernel pre-treatment

The extraction of palm kernel oil involves a crucial pre-treatment process, as highlighted by Poku, K. (2002). The key steps in the pre-treatment include:

The extraction of palm kernel oil involves a crucial pre-treatment process, as highlighted by Poku, K. (2002). The key steps in the pre-treatment include:

➢ *Cleaning of Kernels:*

Vibrating screens are employed to sieve out foreign materials such as sand, stones, or any undesirable substances. Magnetic separation is used to remove metal debris.

➢ *Breaking Kernels:*

A breaker rolls, swinging hammer, or a combination of both is utilized to break the kernels into small fragments. This process increases the surface area of the kernels, facilitating subsequent flaking.

➢ *Flaking:*

The kernel fragments are then subjected to flaking in a roller mill. A large roller mill, consisting of up to five vertically mounted rollers, is used. Each roller revolves at a speed of 200-300 rpm.

The thickness of kernel cakes is progressively reduced as they travel from one roller to another, initiating the rupturing of cell walls.

The kernel flakes exiting the bottom nip have a thickness ranging from 0.25 mm to 0.4 mm.

➢ *Steam Conditioning in a Stack Cooker:*

The flakes are moved to a stack cooker for steam conditioning.

Steam conditioning serves several purposes, including adjusting the moisture content of the meal to an optimum level, rupturing cell walls (initiated by rolling), coagulating the protein in the meal to facilitate separation of oil from protein materials, and reducing the viscosity of the oil.

The meal flows through compartments in series, from the top compartment to the bottom (fifth compartment).

Mechanical stirrers agitate the meal at each stage.

Steam trays heat the cookers, and live steam may be injected into each compartment as needed.

Important factors in this process include retention time, temperature, and moisture content.

Typically, in palm kernel processing, the meals are cooked to a moisture content of 3 percent at a temperature of 104-110°C.

This pre-treatment process is essential for ensuring the quality of the extracted palm kernel oil and for preventing damage to the screw-press during the extraction process. It also contributes to the efficient separation of oil from protein materials.

➢ *Screw-pressing*

The cooked meal undergoes the next stage in the extraction process by being fed into the screw-press. The screw-press consists of an interrupted helical thread (worm) that revolves within a stationary perforated cylinder referred to as the cage or barrel. The meal is propelled through the barrel by the action of the revolving worms.

As the meal progresses through the barrel, the volume axially displaced by the worm diminishes from the feeding end to the discharge end. This compression process squeezes the meal, facilitating the extraction of oil. The expelled oil drains through the perforations in the lining bars of the barrel, while the de-oiled cake is discharged through an annular orifice.

To prevent extreme temperatures that could potentially damage the quality of the oil and cake, the worm-shaft is consistently cooled with circulating water. Additionally, the barrel is externally cooled by recycling some cooled oil. This cooling mechanism helps maintain optimal conditions for the extraction process and ensures the quality of both the extracted oil and the residual cake.

➢ *Oil clarification*

The oil extracted from the press contains a certain quantity of 'fines and foots,' necessitating a removal process. This removal step is crucial to enhance the quality and purity of the expelled oil, ensuring that it meets desired standards for consumption or further processing. The oil is directed to a reservoir and is then either pumped to a decanter or a revolving coarse screen to eliminate a substantial portion of solid impurities. Following this, the oil undergoes filtration in a filter press to eliminate any remaining solids and fines, ensuring the production of clear oil before storage.The cakes expelled from the presses are transported for either bagging or bulk storage.

It's worth noting that not all crushers utilize the same procedure for the mechanical extraction of kernel oil. There are three variations:

- Direct Screw-Pressing:

Some mills crush the kernels directly in the presses without any pre-treatment. Double pressing is usually required to ensure efficient oil extraction.

The screw-presses used are typically less than 10 tons per unit per day.

- Partial Pre-Treatment:

Kernels are initially broken down into smaller fragments by grinding before screw-pressing.

In some cases, cooking is also carried out as part of the pre-treatment.

- Complete Pre-Treatment:

The full pre-treatment processes, as described earlier, are carried out before screw-pressing. Plants with larger capacities (50-500 tons per day) often opt for complete pre-treatment, and the equipment is usually imported from Europe.

These variations in the extraction process allow for flexibility in the choice of methods based on the scale of the operation and the desired quality of the extracted oil.

D. Comparison of extraction methods

The comparison of palm kernel oil extraction methods reveals that traditional methods like roasting, hot water floatation, and pressure applications are more laborious, time-consuming, and less effective. On the other hand, modern methods such as solvent extraction and mechanical press (expeller) are more efficient. However, solvent extraction is relatively expensive and poses fire explosion hazards, making it unsuitable for small and medium-scale farmers, who are the majority of oil processors in developing countries like Nigeria. As a result, most commercial palm kernel oil extractions in Nigeria are conducted with mechanical screw presses or expellers.

Other differences include:

- Traditional Roasting Method:

Produces black-colored palm kernel oil.

- *Traditional Pressure Methods:*

Exert low pressures and often extract not more than 20 to 25% of the inherent oil.

- *Chemical Method (Solvent Extraction):*

Efficient and leaves only about 1% oil in the cake.

Capital and volume-intensive, requiring extra skills, making it unsuitable for small-scale processors.

- *Continuous Screw Press (Expeller):*

Compact machine with a high initial cost outlay.

Requires minimal skill for operation.Low labor requirements, and maintenance problems are low when properly handled. Can operate at capacities ranging from 3 tons to 1000 tons per day.Fast wear of the worm flight and housing if friction is not reduced.n Power consumption is usually high.The proposed design aims to address specific issues related to the wear of the housing and worm flight by employing proper material selection and design procedures. This indicates a focus on improving the efficiency and durability of the continuous screw press for palm kernel oil extraction.

E. Problems facing indigenous design and manufacture of palm kernel oil expeller in Nigeria

The indigenous design and manufacture of palm kernel oil expellers in Nigeria face several challenges, including:

- *Inadequate Screw Press Design Information:*

Lack of comprehensive information for adaptive, empirical, rational, and optimum designs.Limited or no established theories for screw pressing of palm kernel oil expression.Insufficient knowledge about the effects of screw geometry on press performance.Absence of suitable expressions for predicting torque requirements and pressure in palm kernel oil screw presses. Limited data on the effects of screw pressing and kernel conditions on palm kernel oil quality and yield.

Almost nonexistent mathematical modeling of screw pressing for palm kernel oil extraction, leading to trial-and-error methods for press development.

- *Unavailability of Suitable Construction Materials Locally:*

Lack of locally produced rust-free aluminum and stainless steel.Non-availability of strong and tough metals and alloys suitable for various components like shafts, pins, gears, screw threads, and axles.Absence of materials like Nickel-Chrome Steel, Chrome-Vanadium steel, and Manganese alloy steel in the local market.Limited availability of strong construction steel in Nigeria, with mild steel being the strongest locally produced.Absence of key materials such as chilled cast iron or cast steel for manufacturing high-profile pulleys.Lack of locally produced reinforced fibers for manufacturing power transmission belts.Limited availability of case-hardened steels like 10C4 and 14C6 for gears, worms, etc., which are crucial components in screw presses.These challenges contribute to the reliance on imported materials, increasing the cost of production and limiting the scalability and affordability of palm kernel oil expellers in Nigeria. Addressing these issues would require a coordinated effort in research, funding, and institutional support for the local design and manufacture of efficient and cost-effective palm kernel oil expellers.

F. Palm Kernel Oil

Palm kernel oil is a consumable plant oil extracted from the kernel of the palm fruit (Hartley, 1997). This semi-solid oil exhibits higher saturation levels compared to palm oil and is comparable to coconut oil in its characteristics. It remains in a semi-solid state under non-temperature conditions.Palm kernel oil exhibits excellent stability at elevated cooking temperatures, making it particularly well-suited for commercial cooking applications. Notably, it boasts an extended shelf life, surpassing that of many other vegetable oils. Additionally, this oil is rich in lauric acid, as highlighted by Poku in 2002, adding to its nutritional profile and versatility in various culinary uses.Palm kernel oil is cholesterol-free and devoid of trans fatty acids. Similar to coconut oil, it is abundant in lauric fatty acids (CHO), making it well-suited for the production of soaps, washing powders, and various personal care products. This versatility stems from its composition and properties, contributing to its use in diverse industrial and personal care applications. Lauric acid helps in quick lathering. A good soap must contain 15% laurate for good lathering, while soap made for sea water usage virtually must be based at 100% laurate (Bachmann, 2005). The palm kernel oil is highly different from palm oil. The two oils from the same fruit are entirely different in fatty acid composition and properties. Palm kernel is an important bio product from oil palm mill/processing. Plant palm kernel constitutes about 45% - 48% by weight of oil in which properties and characteristics are quite different from palm oil rather resembles coconut oil (Gbasonuzo et al. 2012). The major fatty acid (lauric (C) accounts for about 48% of the fatty acid composition. Other constituents of palm kernel oil include 16% nuriatic acid (C) and 15% oleic acid (C). Palm kernel oil is used in manufacturing both edible and non-edible products and has a great use both in the food industry and non-food industry (Oyinlala et al. 2004). Food usage of palm kernel oil is more saturated and can be regenerated into a wide range of products for the food industries. It can be used alone or in a blend with other oils for the manufacture of cocobutter substances, confectionary fats, biscuit dough's, filling cream, cake icing, and table margarine (Bredeson, 1983). Palm kernel oil is known to confer special attractive physical features and aroma to bakers of bread and other bakery products. It is also used in making chocolate and some other related food products. It is used in home cooking for different types of food. Palm kernel oil can be directly combined with petrol diesel or used in making biodiesel for diesel engines. Locally, Africans utilize the oil to fuel indigenous lamps for lighting in rural communities without electricity (Shaver, 2005). It is employed in the production of various non-edible items such as soap, detergent, candles, cosmetics, creams, glues, lubricants for machines, plastics, drilling mud for the petroleum industry, printing inks, rubbers, pharmaceuticals, and more (Butcher, 2005). The palm kernel oil production process involves the selection of quality palm-kernel-nuts, crushing them with a nut-crusher, heating the seeds using a mechanical seed fryer to activate the oil molecules, and subsequently transferring the heated-crushed nuts to the oil press. The oil pressing machine then presses the heated seeds, expelling the oil through the oil exit chamber and simultaneously releasing the cake through the cake exit chamber (Oyinlala et al., 2004). The crude oil is collected in a drum of high capacity or overhead tanks and then allowed to settle. Since the sludge (sediments) or residue is denser than the oil, it settles below the oil. Then the oil can be collected over the residues and undergoes further purification to remove impurities and get a brighter color. Lack of skilled manpower, inadequate provision of machines, and poor technology have affected a lot of food and raw material processing in Nigeria, especially in southeastern Nigeria. Palm kernel oil is one of the widely used raw materials for many industries in Nigeria. It is used extensively in the country and requires attention from policymakers to enhance, equip, and encourage raw material (palm kernel oil) producers and processors.

G. *Quality indicators*

According to Adeeko, K. A. and Ajibola, O. O. (1988) and Fasina, O. O. and Ajibola, O. O. (1988), characteristics such as iodine value, free fatty acids, peroxide value, viscosity, thiobarbituric acid value, saponification value, refractive index, color, specific gravity, etc., are used in evaluating the quality of vegetable oils. The free fatty acid serves as a valuable indicator of the extent of degradation through hydrolysis. Meanwhile, the peroxide value functions as a measure of active oxygen in 1kg of oil, effectively gauging the stability of the oil. The thiobarbituric acid value serves as a secondary oxidation test, employed to identify the initial stages of lipid oxidation. Meanwhile, the iodine value reflects the degree of unsaturation in the oil, and the saponification value indicates the average molecular weight of the mixed triglycerides present in the oil. In commercial transactions, free fatty acid and peroxide values are frequently regarded as crucial quality parameters for vegetable oils. High levels of F.F.A. are associated with degradation by hydrolysis and high refining losses. It should be less than 5% (UNIDO, 1977). High peroxides are associated with rancidity development, and the value should not be more than 10 for fresh oil (Pearson, D. 1970).

IV. METHODOLOGY

A. *Material Selection*

In the early stages of the design process, it becomes evident that multiple materials can fulfill a specific function. The selection process involves a rational measurement of crucial properties to make an informed choice among the available materials.

For optimal operation and performance of the machine, material selection was an integral part of the design process, a careful selection of materials was given priority attention.

Material selection plays a very important role in machine design. When selecting a material or component to perform a particular operation, it is expected to know its mode of failure. Material selection is not only influenced by this also the cost of the materials also has to be considered.

Successful selection of materials depends on the ability to satisfy the mechanical properties and factors. The best materials is the one which serve the desired objective at the minimum cost .The following are some of the most important factors that should be considered when selecting materials in machine design.

- Durability of the materials
- Availability of the materials
- Ability to withstand corrosion
- Malleability
- Conductivity
- Cost
- Ease of use
- Mechanical Strength and Rigidity

B. *Properties of some Materials Selected*

Based on the composition and mechanical properties the following materials were selected

Mild Steel [0.08 – 0.25%C]

Mild steel has high tensile strength of 400-450 MN/M2, good weldability, it is tougher than wrought iron. Mild steel constitutes about 75% of the materials used in the design of the palm kernel oil expeller machine. Because of it goods ductility, mild steel is readily formed into intricate shapes.

C. Construction / Fabrication

The palm kernel oil expeller machine is composed of the following essential parts:

- Pulleys
- Mild steel angle bar
- Mild steel U channel
- Angle bar
- Gearbox
- Belt
- Keys
- Mild steel shaft
- Spline hub
- Mild steel square rods
- Bearings
- Mild steel plate
- Bolts and Nuts
- Electric Motor
- Electrodes
- Grinding discs

The fabrication of the various components was accomplished using diverse fabrication techniques, including cutting, welding (both arc welding and gas welding), drilling, bending, and casting.

D. Finishing

Appearance and finishing of machine accounts for the effective sales of the machine. The beauty of a machine is an important factor and depends on good finishing.

Everything that is in view for appreciable periods of time whether in public or in the home, should be made to look as attractive as possible. All metal were cut and tested for squareness, filed to finish where necessary.

E. Installing and Operating Guideline

The following points should be looked into during the installation of the machine:

- Machine should be installed on a level ground.
- Machine should be installed at a well ventilated spot.
- Machine should be installed near a source of light.
- The machine should be observed carefully before operation
- Plug wire to socket and switch on the power supply.

F. Care and Maintenance

- Change the belt when weak due to expansion
- Clean machine after use each day
- Avoid leaving the un-extracted palm kernel nuts in hopper after use of machine
- Ensure that the bolts on machine are tight.

After a rigorous approach to the design calculations which gave the required results for the various components in chapter three, it is observed that the palm kernel oil expelling machine will be able to compete favorably with it's contemporaries, with minimum cost and increased efficiency of about 95%.

V. DESIGN CALCULATIONS

A. Determination of Drive Power

According to American Society of Agricultural Engineers (ASAE) 1989, the crushing strength of palm-kernel under compressive load, δc = 1.042N/mm2 while , the force acting on the worm shaft due to action of the palm kernel, F = 2.11697N, Area of contact between a spherical palm kernel and the worm shaft is given by;

$$A_x = \frac{HdD}{2(H+d)} \quad , \quad mm^2$$

But,

$$\delta_c = \frac{F}{A} \, , \frac{N}{mm^2}$$

$$\delta_c = \frac{2(H+d)F}{HdD} \quad , N/mm^2$$

Hence, the load on the worm screw is:

$$F = \frac{HdD\,\delta_c}{2(H+d)} \quad , \qquad N$$

Where,
A = Area of contact between kernel and screw, mm2
H = Average diameter of kernel, mm
D = Approximate deformation of kernel, mm
d = Radius of crushing shaft, mm
F = Crushing load at crushing point, mm
R = Average radius of sample, mm

$\delta_c =$ Stress at Crushing point, N/mm2

When H = 5mm, D = 1mm
T = FLn

Where,
T = Torque developed on the shaft, nm
L = Length of shaft, mm
N = Number of thread on shaft

According to ASAE, where T = 6600Nm for a sudden surge.
Power (P) = Tω = fLnω
Where, ω = Angular velocity of the worm shaft

$$\omega = \frac{2\pi N}{60} \quad , \quad rads$$

N = shaft speed, rpm

B. *Design of Keys*

In the considered design, the torque transmission from the diesel engine to the screw shaft through the gearbox is characterized by both vibratory and heavy forces. To address this, taper keys were employed in accordance with BS4235: Part 1; 1972 standards.

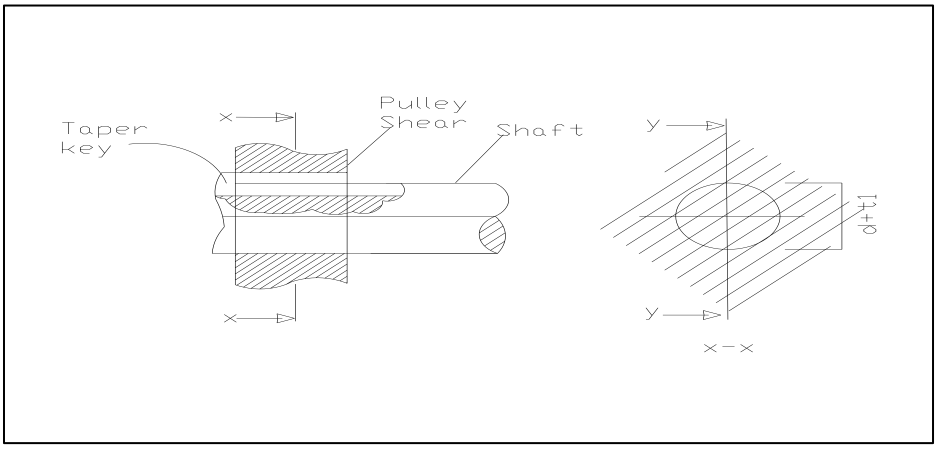


Fig. 2: Shows a section of the taper.

Fig. 2, A section of hub assembly, showing the taper key.

Given that the diameter of both the engine shaft and the input gearbox shaft exceeds 22mm, the design choice for rectangular taper keys was made. This decision aligns with the specifications outlined in BS4235: Part 1; 1972, and further details can be found in pertinent texts, such as "Engineering Drawing with Worked Examples" (3rd edition) by M.A. Parker and F. Pickup.

➢ *Design Analysis*

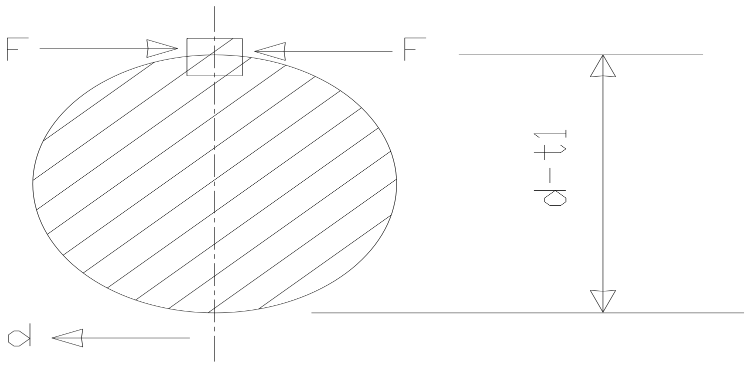


Fig. 3: Analysis of stresses in the taper key

By taking moment about the shaft axis, we have;

$$F = \frac{2M_t}{d_{shaft}}$$

- **Assumptions:**

The force, F is tangential to the surface of the shaft.

The stress along the length of the key is uniformly distributed.

These assumptions lead to the following formulae;

$$\tau = \frac{F}{l_d b}$$

$$\rightarrow \tau = \frac{2M_t}{d_{shaft} l_d b} \text{ on the key sides and}$$

$$\delta_{bear} = \delta_{compressive} = \frac{F}{(h - t_i) l_d}$$

$$\rightarrow \delta_{bear} = \frac{2M_t}{(h - t_i) l_d d_{shaft}} \text{ , on the key sides}$$

Due to the wider width than depth of the rectangular taper key, it is prone to failure in compression rather than shear.

Therefore, the governing equation for the limiting condition is:

$$\delta_{bear} = \frac{2M_t}{(h - t_i)l_d d_{shaft}} \leq [\delta_{bear}]allowable$$

Where,
Mt = Torque transmitted (N/mm)
dshaft = Shaft diameter (mm)
$l_d =$ Effective design length of key (mm) and $4b \leq l_d \leq 16b$ (where b = width of key)
$t_i =$ Depth of key (mm)
h = Height of key in hub (mm)
$\delta_{bear} =$ Bearing stress, N/mm2
$\tau =$ Shear stress, N/mm2

For steel hubs [δ_{bear}] allowable is taken as 70mpa or 70N/mm2.

$$\delta_{shaft} = \frac{2 \times 598636.58}{5 \times 110 \times 60}$$

$$\rightarrow \delta_{bear} = 36.28 \text{N/mm2}$$

Since $\delta_{bear} \leq [\delta_{bear}]allowable$,

therefore the design is satisfactory from standpoint of bearing pressure.

C. *Shaft Design*

➢ *Design of Shaft*

In designing the shaft using ductile materials and adhering to strength considerations, the approach follows the maximum shear theory of failure. Applying the ASME code equation for designing a transmitting solid shaft under both torsion and bending, the expression is:

$$d^4 = \frac{16}{n\tau_{all}}\sqrt{(K_b M_b)^2 + (k_t M_t)^2}$$

Where,
d = Shaft diameter, m
K_t = Combined shock and fatigue factor applied to torsional moment
M_t = Torque on shaft or torsional moment, Nm
M_b = Bending moment on shaft, Nm

But,

$$\tau_{all} = \frac{0.5\delta_y}{N}$$

Where,
τ_{all} = Allowable shear stress, N/mm2
N = factor of safety
$\delta_y =$ Ultimate yield strength of shaft materials, N/m2

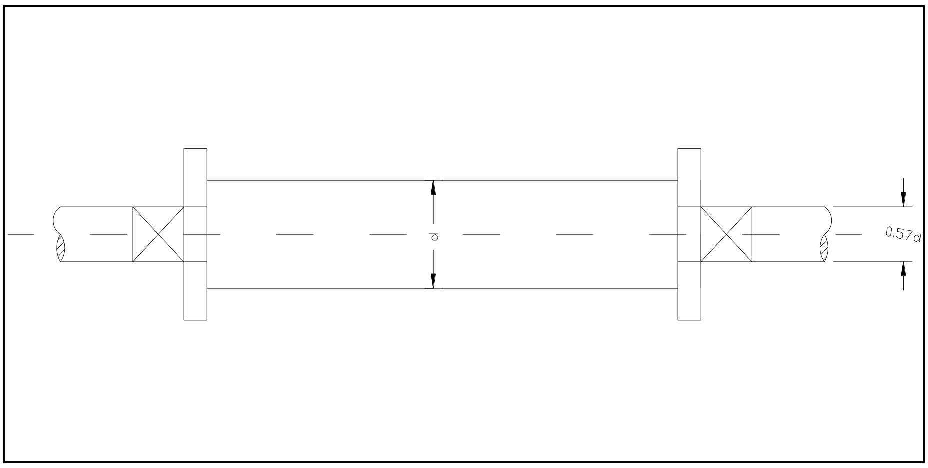


Fig. 4: A sketch of the shaft

➢ *Calculation of Bending Moment Assumptions*

- Vertical loads on shaft are mainly due to weights of palm kernel seeds, screw on shaft and cone on shaft.
- **NB:** A fully charged or loaded Barrel was assumed to hold about 1500 kernel seeds on average (that is about 22.5N)
- Weight of worm on shaft was assumed 22.7N
- Weight of cone on shaft was assumed 104.0N
- Hence, a total vertical load on shaft used is 149.2N.
- W, was assumed to be located mid-way between the shaft supports (i.e. the bearings)
- The distance between the bearings was assumed to be, l = 700mm
- Hence, we have the followings diagrams:

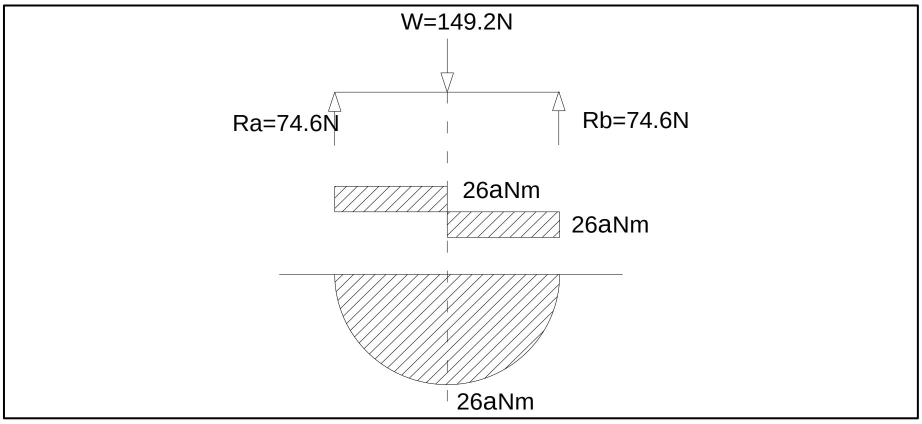


Fig. 5: Force diagram, Shear Force diagram and bending moment diagram.

Bending moment, M_b = 26.11Nm.

$$M_t = \frac{Power\ (P)}{Angular\ velocity, \omega}$$

- *Calculation of Torsional Moment*

Power, P = 20hp = 20 X0.746kW = 14.92Kw

Angular velocity, ω is given as:

$$\omega = \frac{2\pi N}{60}$$

$$\therefore \omega = \frac{2 \times \pi \times 48}{60}$$

$$M_t = \frac{20 \times 746 \times 60}{2 \times \pi \times 48} = 2968.23$$

$$\rightarrow M_t = 2968Nm$$

For a medium carbon steel shaft

$$\delta_y = $$ 480MN/m2

Taking a factor of safety, N = 4, we have;

$$\tau_{all} = \frac{0.5\delta_y}{N}$$

$$= \frac{0.5 \times 480}{4} = \frac{60MN}{m^2}$$

$$\therefore \tau_{all} = 60MN/$$

$$\therefore \tau_{all} = 60MN/m^2$$

Hence,

$$d_{shaft}^3 = \frac{20}{\pi \times 60 \times 10^6}\sqrt{(2.0 \times 25.74)^2(20 \times 2968)^2}$$

$$d_{shaft}^3 = 0.00062985m^3$$

$$d_{shaft} = 0.08571938$$

$$\rightarrow d_{shaft} = 85.7mm$$

$$Use, \quad d_{shaft} = 86mm \approx 90mm$$

This value is taken because of the availability of the 90mm shaft over the 70mm shaft, and also the cost of purchase which was also considered due to this, it is very obvious that with the 90mm shaft the factor of safety is increased.

VI. CALCULATION OF ANGULAR DEFLECTION OF SHAFT

The design of shaft for torsional rigidity was based on the permissible angle of twist, α. The amount of permissible angle of twist depends on the particular applications and varies from about 0.3 degree per metre for machine tool shaft to about 3 degree per metre for line shafting. That is 0.3°/m ≤ α ≤ 3°/m

But,

$$\propto = \frac{584M_t l}{Gd^4}$$

Where, M_t = 2968Nm, l = 0.7m, G = 80x109N/m2 and d = 0.09m

$$\therefore \alpha = \frac{584 \times 2968 \times 0.7}{80 \times 10^9 \times (0.090)^4}$$

$$\alpha = 0.23° \frac{}{m}$$

Since α = 0.23°/m < 3.0 °/m, therefore the design is satisfactory based on torsional rigidity.

➢ *Calculation of Lateral Deflection of Shaft*

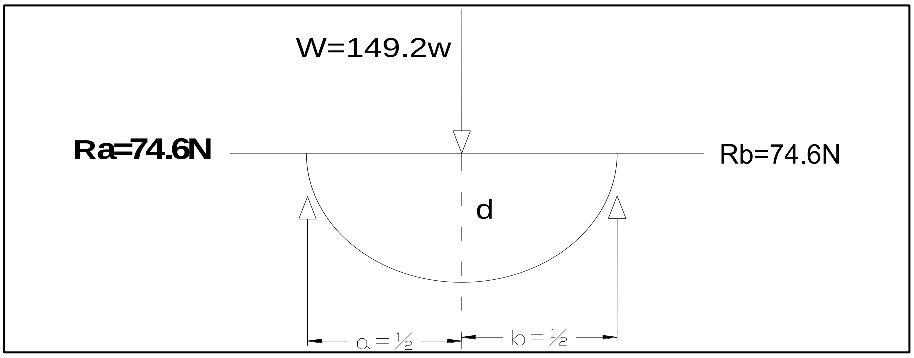


Fig. 6: Deflection of shaft

The deflection at any point for a simply supported shaft of length, l in which W is at distances, a = $\frac{1}{2}$ and b = $\frac{1}{2}$ from the bearings support is:

$$\delta = \frac{Wx}{48EI}(31 - 4x^2)$$

$$At\ x = 0, \quad \delta = 0; \quad hence\ \delta_{min}\ occurs\ at\ point\ A$$

$$At\ x = \frac{1}{2}, \quad \delta = \frac{Wl^3}{24EI}, \quad hence\ \delta_{max} = \frac{Wl^3}{24EI}\ occurs\ at\ x = \frac{1}{2}$$

Given:

$$W = 149.2N, l = 0.7m, E = 207 \times \frac{10^9 N}{m^2}$$

$$I = \frac{\pi d^4}{64} = \frac{\pi \times (0.090)^4}{64} = 3.22 \times 10^{-6} m$$

$$\therefore\ \delta_{max} = \frac{Wl^3}{24EI} = \frac{149.2 \times 0.7^3}{24 \times 207 \times 10^9 \times 3.22 \times 10^{-6}}$$

$$\delta_{max} = 0.00000320m$$

$$\delta_{max} = \frac{0.00320mm}{0.7m} = \frac{0.0046mm}{m}$$

But, $\delta_{max} \leq [\delta]allowable$

$$where\ [\delta]allowable = 0.086mm/m$$

= Allowable lateral deflection for machinery shafting.

$$Since\ \delta_{max} < [\delta]allowable,$$

the design is deemed satisfactory when evaluated against lateral deflection criteria**.**

➢ *Calculation of Critical Speed Of Shaft*

Using Rayleigh-Ritz Equation, the critical speed of a shaft may be calculated by:

$$W_c = \frac{60}{2\pi}\sqrt{\frac{g}{\delta}}$$

Where, $W_c =$ critical speed, rpm =?

$$g = \frac{9.81m}{s^2}, \quad and$$

$$\delta = \delta_{max} = 0.00000320mm$$

$$\therefore\ W_c = \frac{60}{2\pi}\sqrt{\frac{9.81}{0.00000320}} = 16{,}719.8rpm$$

$$\rightarrow W_c \approx 16{,}720rpm$$

$$W_c = 16{,}720rpm$$

Obtained critical speed is significantly greater than the specified value of n3 = 48rpm, the design can be considered satisfactory based on critical speed analysis.

D. Design of Screw on Shaft

The shaft is tasked with supporting a screw on its surface to facilitate the crushing and conveying operations of the kernel seeds. In this design, a square thread made from a 12.5 x 12.5mm mild steel rod was chosen for the screw. This decision was made for practical reasons, opting for mild steel due to the availability of the rod and cost considerations compared to machining high carbon steel.However, a notable drawback of this choice is the need for periodic replacement of the screw on the shaft due to wear. Test results indicate that the screw's lifespan is approximately 12-18 months

➢ *Analysis of Forces on the Screw Shaft*

The forces generated by the torque, Mt on the screw shaft in the Barrel are:

F_t = Tangential force (or transmitted load)
F_a = Axial force (or thrust load)
F_r = Radial force

Nevertheless, Fr = 0 because the pressure angle of a square thread is zero.

Hence, the forces in the barrel due to the torque, M_t are:

F_t = Tangential force

F_a = Axial force (or thrust load), and these forces are shown in figure 9 below.

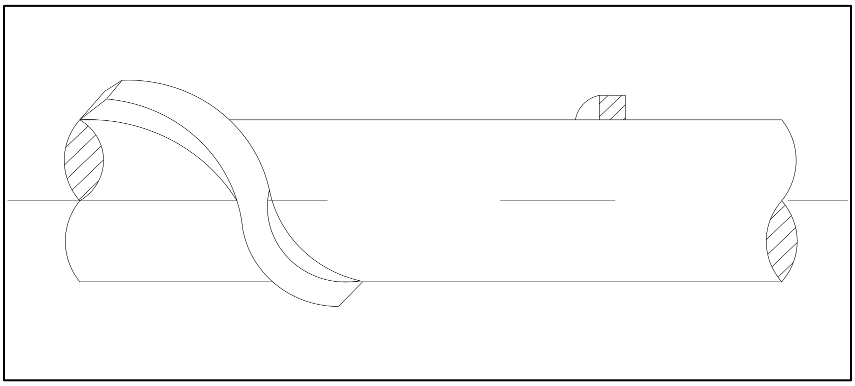


Fig. 7: Forces in the Barrel

From Fig. 3.9, the moment of the force F_t about the shaft axis is;

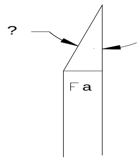
$$F_t \frac{d_m}{2} = M_t$$

$$\therefore F_t = \frac{2M_t}{d_m} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.i$$

From figure 9 we have

hen

$$\therefore R = F_t[\sin\emptyset + \cos(90° - 2\emptyset)]$$



$$\therefore F_a = F_t \tan\emptyset \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots ii$$

Moreover, resolving F_r and F_a, Perpendicular to the screw thread, we have

$$R = F_a \cos\emptyset + F_t \cos(90° - 2\emptyset)$$

$$= F_t[\tan\emptyset \cos\emptyset + \cos(90° - 2\emptyset)]$$

➢ *Determination of the Pitch of the Screw*

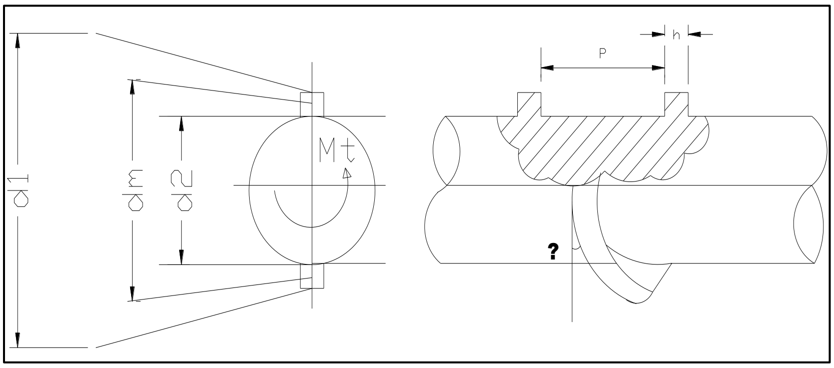


Fig. 8: An enlarged detail of the screw shaft

Where, we assumed screw size = 12.5mm square

shaft diameter, d_{shaft}=75mm

Mean circle diameter, $d_m = d_{shaft} + h$ =87.5m

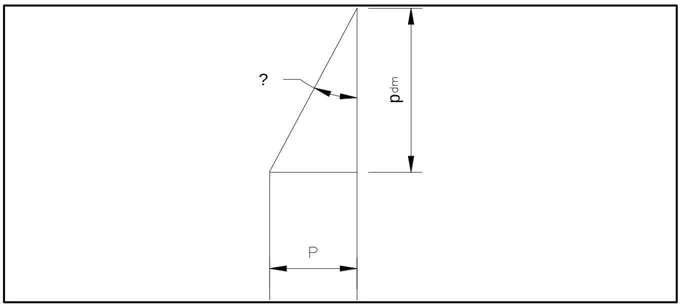
International diameter of barrel, $d_1 = d_{shaft} + 2h$ = 100mm

Pitch of screw (P) =?

$$and\ helix\ angle\ \emptyset = ?$$

From Fig. 7, we have:

ISSN No:-2456-2165



Hence,

$$\tan\emptyset = \frac{P}{\pi d_m} \quad \text{..iii}$$

Standard or full pitch of screw flight is equal to its diameter with helix angle (ϕ) of 17° and 40mm - (Plant Engineering Handbook edited by Stainiar (1959) pp. 28155-28157).

Using the pitch of the screw to mean circle diameter, we have:

P = d_m = 87.5mm

From equation (ii) we have

$$\tan\emptyset = \frac{P}{\pi d_m}$$

$$\emptyset = \tan^{-1}\left(\frac{87.5}{\pi \times 87.5}\right) = 17.67°$$

$$\therefore\ \emptyset \approx 17.7°$$

➢ *Calculation of the Forces on the Screw Shaft*

Given that M_t = 2968Nm, h = 12.5mm, p = d_m =87.5mm and ϕ = 17.7°, then:

$$F_t = \frac{2M_t}{d_m} = \frac{2 \times 2968}{87.5 \times 10^{-3}}$$

$$\therefore\ F_t = 67840N$$

$$F_a = F_t \tan\emptyset = 67840 \tan 17.7°$$

$$\therefore F_a = 21650.51N, and$$

$$R = F_t[\sin\emptyset + \cos(90° - 2\emptyset)]$$

$$= 67840[\sin 17.7° + \cos(90° - 35.4°)]$$

$$= 67840(0.30403 + 0.57928)$$

$$\therefore R = 59923.83N$$

➢ *Stresses in the Thread of the Screw Shaft*

The stresses in the thread of the screw shaft result from the combined effect of the axial force, F_a and tangential force, F_t on the thread.

This combine effect is represented by force R perpendicular to the screw thread.

- **Assmptions:** Stresses in the thread are estimated by considering the thread to be a shaft cantilever beam projecting from the root cylinder. The beam width is the length of thermal (measured at mean radius) subjected to the load, R. The load, R is presumed concentrated at the mean radius of the thread i.e. at one half of the thread depth, h.

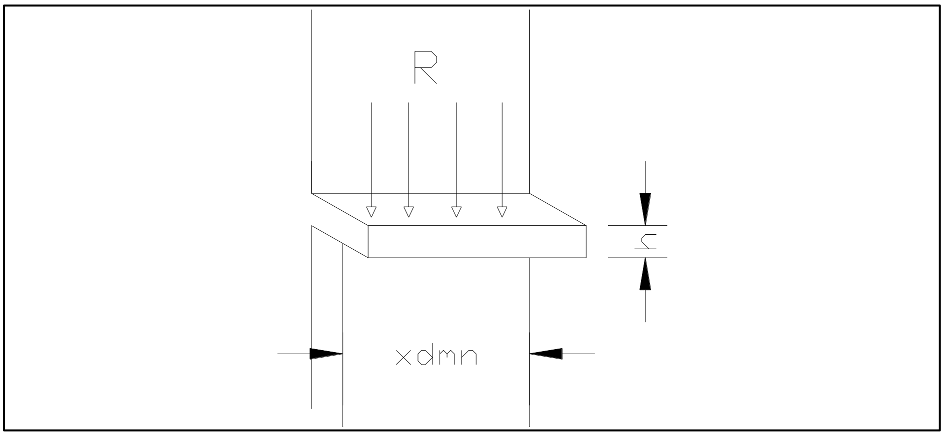


Fig. 9: Stresses in the thread of the screw shaft

From the figure above, the bending stress, δ_b at the root of the thread is:

$$\delta_b = \frac{2R}{\pi n d_m h} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots iv$$

In addition, the mean transverse shear is:

$$\tau_s = \frac{R}{\pi n d_m h} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots v$$

Since $\delta_b \geq \tau_s$, then

The maximum pressure in the barrel P is equal to the bending stress, δ_b in the thread.

$$P = \delta_b = \frac{2R}{\pi n d_m h} \leq [\delta_{bear}]$$

……………………………vi

Where, n = Number of pitches of the screw thread, and P = Pressure in the barrel

- *Determination of the Number of Pitches of the Threads on the Shaft*

By experiment he crushing pressure of the seeds was found to be;

$$\delta_c = 6.57MN/m^2$$

The bending stress at the root of the screw thread is he stress imposed on it by the crushed kernel seeds because of the movement of the screw shaft.

Therefore, for the kernel seeds to be crushed at all, the bending stress must at least be equal to the crushing stress.

That is,

$$\delta_b \geq \delta_c$$

Also, the maximum bending stress δ_b imposed on the kernel seeds must not exceed the safety (allowable) stress in the screw thread.

That is

$$\delta_b \leq \delta_{all} \text{ ,where } \delta_{all}$$
$$= max.\, safety\ pressure\ the\ screw\ thread\ can\ bear$$

Hence, the limiting equation is;

$$\delta_c \leq \delta_b \leq \delta_{all} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots vi$$

Given that $\delta_{all} = 8.0MN/m^2$, for steel screw thread on steel shaft, and applying equation (vi) we have;

$$\delta_c \leq \delta_b$$

$$\delta_c = \frac{2R}{\pi n d_m h}$$

$$\rightarrow n = \frac{2R}{\pi \delta_c d_m h} \leq \frac{2 \times 59923.83}{\pi \times 6.57 \times 87.5 \times 12.5}$$

$$n \leq 5.31$$
$$\therefore n = 5$$

Also, $\delta_b = \delta_{all}$

$$\frac{2R}{\pi d_m h d_{all}} \leq \delta_{all}$$

$$n \geq \frac{2R}{\pi \delta_m h d_{all}} = \frac{2 \times 59923.83}{\pi \times 87.5 \times 10^{-3} \times 12.5 \times 10^{-3} \times 8 \times 10^6}$$

$$\therefore n = 4.46$$

$$n \approx 5$$

Hence, the required number of screw pitches on the shaft is n = 5

- *Determination of the Maximum Pressure in the Barrel*

Since, n = 5, then, the maximum pressure (P) in the barrel is:

$$P = \delta_b = \frac{2R}{\pi n d_m h}$$

$$= \frac{2 \times 59923.83}{\pi \times 5 \times 87.5 \times 10^{-3} \times 12.5 \times 10^{-3}}$$

$$P = 6.97N/mm^2$$

$$\therefore P \approx 7.0N/mm^2$$

E. Design of Choke Mechanism

The choke mechanism comprises an internally threaded adjustable cone and a hand wheel designed to turn the cone along the externally threaded section of the worm-shaft.This cone is the choke, an adjustable pressure orifice at the end of the barrel constricting the discharge of dryness or wetness of the "pressed cake". Its adjustable nature enables it to be used with wide range of power source from diesel to various electric motors power input.

➢ *Determination of Thread Parameters on the Cone and Screw Shaft*

The screw employed in this design features a square thread, cut internally on the cone and externally on the shaft, ensuring a precise fit and effective operation. Square threading is selected in preference to other forms of threading because of:

It's ability to perform optimally in a dirty environment (such as the case that exists in the briquettes molding environment).

It requires shorter hub length than other forms of threading.

In the design of the choke mechanism for geometry and strength, the parameters given below were obtained by; assuming that:

The pressed cake exerts pressure on the cone surface, half its total length.

The pressure exerted by the pressed cake on the cone surface is the maximum pressure in the barrel.

This pressure is less or equal to the allowable pressure in the screw threads.

With this cone, an extraction efficiency of about 95% was achieved by having a cone clearance of between 3mm and 5mm from the barrel.

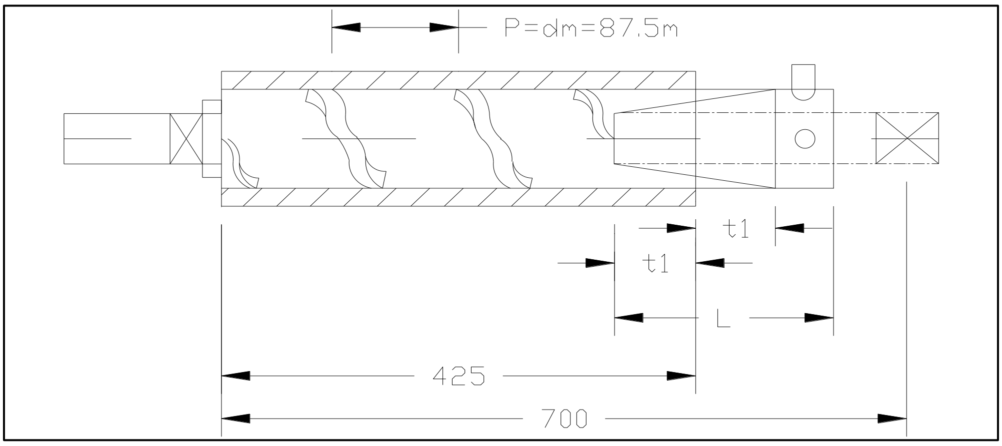


Fig. 10: The choke mechanism

F. Coupling Design

The type of coupling used in this project is the rigid flange coupling, since the shaft speed is low and there is an accurate rigid axial alignment.

The screw shaft cannot be welded to the flange because of the need to change the screw, after sometimes (usually about 18months) on the shaft. Hence, a means to hold the shaft to the flange has to be designed. This was done by locking the hub of the flange to the shaft with bolts.

➢ *Design of Flange Coupling*

The design of the flange diameter and the web thickness, considering both geometric and strength requirements, adheres to the specifications outlined in BS449.

The pitch circle diameter and the flange diameter of the coupling is design based on the following assumptions:

The bolts are initially tightened by hand, achieving finger tightness. Subsequently, the load is transferred from one-half of the coupling to the other through a uniform shear stress in the shank of the bolt. The shaft is subjected to shock and fatigue.

The bolts are uniformly arranged in the flange on bolt circle diameter.

And the final resultsare:
Pitch circle diameter = 125mm
Flange diameter = 200mm

The bolt diameter was calculated by equating the resistance to shear by N bolts (where N = 6 for pitch circle diameter between 160 and 300mm), with the shaft torque modified by shock and fatigue. And the bolt specification is: M12 x 1.5 x 60.

The minimum thickness of flange web was calculated by assuming that the flange bolts are finger-tight and the bolts are pressed against the web. This resulted in web thickness of 8.33mm. However, the thickness of web used is 15mm.

➢ *Design of Flange Hub*

The diameter and the hub thickness were calculated in accordance with BS449, which establishes the relationship between the hub and shaft.

Conversely, the calculation of the diameter of the locking pins (bolts), the determination of the number of bolts, and the length of the hub were performed under the assumption that the allowable bending stress between the shaft and bolts would be less than or equal to the allowable bending stress within the materials of the shaft/hub. The results obtained are:

Hub diameter = 90mm
Hub thickness = 20mm
Bolts specification is: M16 x 2.5 x 120
Hub length = 105mm

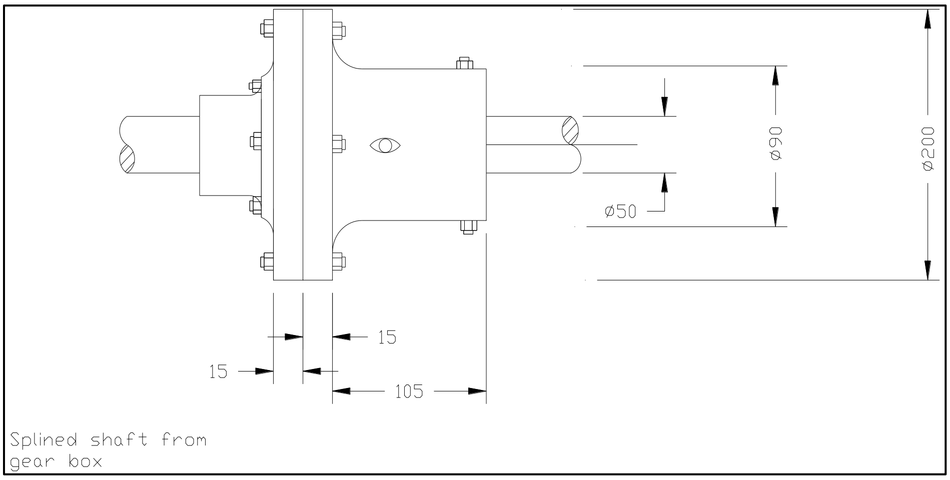


Fig. 11: Coupling Design

G. Design of Barrel

The interior of the barrel is intentionally designed to enhance friction between the kernel seeds and the barrel walls when the shaft is in rotation. This design aims to minimize slippage and rotation of the "meal" (pressed cake) along with the shaft. As a result, the barrel is not typically constructed as a plain cylinder, as this would allow for a high degree of free rotation of the "meal" with the shaft. Instead, the barrel is commonly divided into two halves to facilitate ease of maintenance.

➢ *Design of Barrel Thickness*

In determining the thickness of the barrel the following assumptions were considered:

- The barrel is considered a thick cylinder and hence, radial and longitudinal stresses are negligible.
- The pressure generated by the kernel inside the barrel is assumed to be uniformly distributed within the barrel.
- No external pressure is acting o the barrel.
- The barrel is made of ductile material.
- The temperature generated within the barrel is low, so that thermal stress generated within it is negligible.

By equating the force due to the pressed cake pressure with the force resisting the bursting of the barrel, applying the maximum theory of failure, we have:

Barrel thickness = 12.5mm
Barrel thickness = 130mm

H. Design of Barrel Arms Thickness and Width

Since the barrel is split into two halves, bolts are then needed to lock them together. The diameter of this bolts were calculated assuming that the force due to the pressed cake pressure with the force resisting the bursting of the barrel. This resulted in bolts specification of: **M12 x 2.0 x 70**. The thicknesses of the barrel arms were calculated y assuming that the shearing of the barrel arms will occur. The barrel arm thickness calculated is 12.5mm. The widths of the barrel arms were calculated in accordance with BS449.

The results are:
Upper barrel arm width = 80mm
Lower barrel arm width = 130mm

The diameter of the bolts required to lock the lower barrel arm to the framework were determined by assuming that the axial force in the barrel will tend to shear the bolts.

Hence, equating this axial force with the resistance by N bolts (N = 8) to shear, we have:

Bolts specification is: **M10 x 1.5 x 45.**

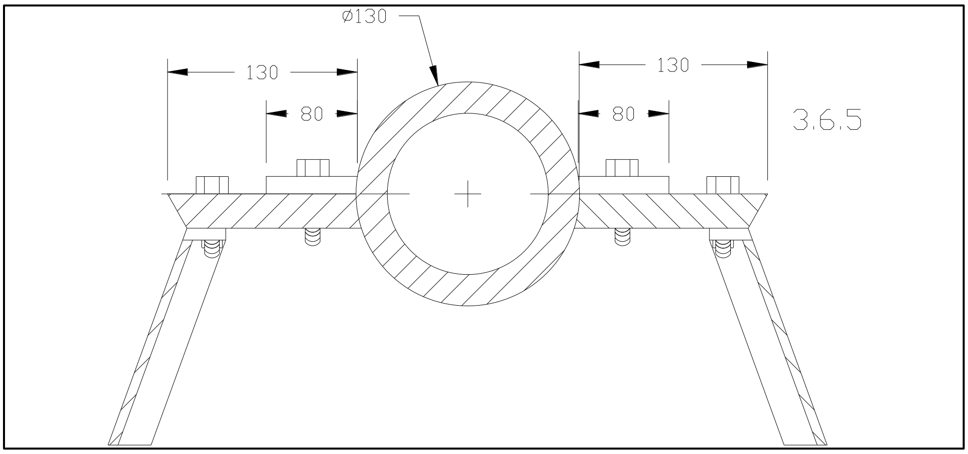


Fig. 12: Design of barrel

I. *Selection of Bearings*

Each type of bearing possesses unique properties that render it particularly suitable for specific applications. The selection of bearings is based on their type and size, ensuring optimal performance and efficiency in diverse operational contexts.

➢ *Selection of Bearing Type*

To select a certain bearing type several factors: must be considered and assessed relative to each other.

These factors include:
Available space
Loads (magnitude direction and type(s) of load)
Flexibility
Speed
Precision
Noise
Axial displacement
Ease of mounting and dismounting
Cost of purchase

After due consideration of the above listed factors, tapered-roller bearing were selected.

➢ *Selection of Bearing Size*

The choice of bearing size for a given application is determined by evaluating its load-carrying capacity in relation to the anticipated loads, as well as the specified requirements for life and reliability. The design calculations for selecting the appropriate bearing size were conducted by referencing the SKF General Catalogue from the year 1987. In accordance with the reference catalogue, the series 32310 pillow bearing with a bore of 50mm was chosen. The determination of the overall radial load involved considering the loads on the shaft and the cantilever load imposed on the shaft by the coupling. This selection process ensures that the chosen bearing is appropriately sized to handle the combined radial loads associated with the specific application. Also, the rated life of the more heavily loaded bearing at the support near the choke mechanism was determined.

The rated life for the series 32310 tapered-roller bearing at this support was determined to be Lh = 15,129.33 hours. This value represents the expected operating life of the bearing under the specified conditions and loads.

But from the reference catalogue, the basic rating life for a crushing working for 10hours or less is between 10,000 and 25,000 hours.

Hence, the bearing selected for use is very adequate.

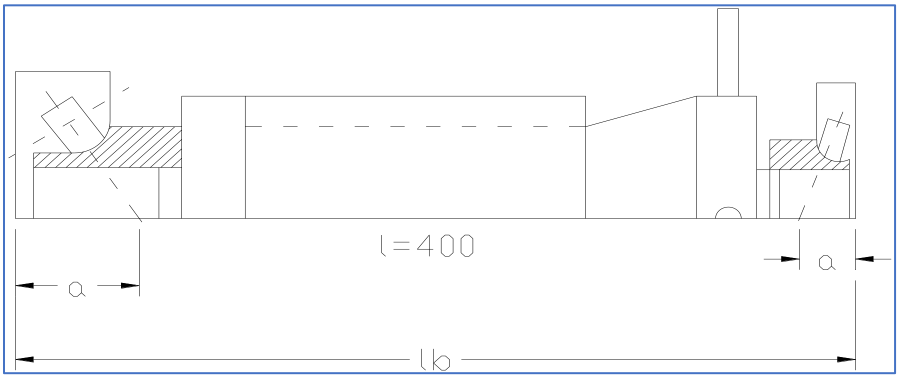


Fig. 13: Selection of bearing

J. *Design of Foundation Bolts and Foundation Platform*

➢ *Design of Foundation Bolts*

The diameter of the foundation bolts, employed to secure the machine to the foundation platform, was calculated with the assumption that the bolts would fail in shear under the influence of the axial force in the barrel. This axial force tends to displace the machine along the foundation platform.The presence of frictional force between the machine framework and the foundation platform was considered. By equating the resistance provided by N bolts (where N = 4) with the axial forces reduced by the frictional force between the machine framework and the foundation platform, it was determined that the foundation bolt diameter should be 10mm. This calculation ensures that the bolts can effectively withstand the axial forces while accounting for the frictional forces in the system.

➢ *Design of Foundation Block*

The foundation block was designed to contain suitably the oscillations arising from the motion of the machine.

In accordance with one rule of thumbs given by Nuovopignone, 1988, Italy:

The weight of the foundation block is specified to be either 4 or 5 times the weight of the machine alone. Given that the weight of the machine is 276kg and assuming the density of concrete to be 1500kg/m³, with the length of the foundation block being 1800mm and the width being 1200mm, the calculation yields a required depth of the foundation (D) that must be greater than or equal to 426mm to accommodate the specified conditions. This ensures the necessary stability and support for the machine and foundation system.

K. *Description of The Newly Developed Palm Kernel Oil Expeller Machine*

The Palm kernel oil expeller machine consists of:

The framework of outline dimension 1320mm long x 800mm high x 800mm wide; bolted to the foundation platform.

The palm kernel oil expeller machine comprises two pulleys - one with a 132mm diameter connected to the engine shaft and another with a 400mm diameter at the gearbox input shaft. A gearbox with a maximum speed ratio of 5:1 is incorporated for power transmission. A rigid flange coupling connects the gearbox to the screw-shaft, which is 1000mm in length and has a diameter of 90mm. This robust configuration ensures efficient and reliable operation during the extraction process. A barrel with two arms 130mm wide, length 425mm and diameter (100mm internal and 130mm external).

The choke mechanism screwed to the screw-shaft at the end of the barrel.

Two, 32310 series tapered roller bearings, located at the two ends of the shaft.

A hopper with shut off slides, mounted on the barrel at its beginning, and

Two trays underneath the barrel, one to collect palm kernel oil and the other to collect the pressed cake.

VII. DISCUSSION OF RESULTS

The development of this machine is in response to a growing demand for a straightforward, small-capacity screw press suitable for village/cottage industry or on-farm applications. Its design allows for the processing of cold palm kernel seeds without the need for pre-treatment. The breaking and cooking operations are efficiently carried out by the screw shaft's action within the barrel of the unit.The machine boasts a nominal input capacity of approximately 380kg/hr when powered by a 20hp electric motor. Kernels are introduced into the screw press through a hopper affixed to the barrel, featuring a shut-off slide for control.Within the cylindrical barrel, as the screw shaft rotates, the kernels undergo crushing against the barrel walls and are simultaneously conveyed towards the far end of the screw-shaft. At this point, a steel adjustable choke mechanism engages, pressing the crushed kernels against the barrel wall to extract the kernel oil. The extracted kernel oil flows out through small screens or drainage slots at the bottom of the barrel into an oil tray, while the resulting "pressed cake" discharges from the cone section into another tray.By adjusting the clearance between the barrel and the adjustable cone (choke mechanism), precise control over the thickness and dryness of the pressed cake is achieved. This choke mechanism allows for an extraction efficiency of approximately 95%, showcasing the machine's effectiveness in the oil extraction process.

VIII. CONCLUSION AND RECOMMENDATION

The observations/findings and studies carried out on the various methods of palm kernel oil expelling revealed the advantages inherent in the design concept adopted in this project fabrication. Such advantages include effective and efficient palm kernel oil extraction, cost reduction relative to those imported from developed countries, ease of manufacture and easy source of components locally, non – complexity of design and assembly of machine, easy accessibility to parts with regards to maintenance and repair works, low capital involvement with regards to being affordable to related small scale establishment.

Moreover other advantage that makes this machine design unique is the ease of expelling with effective performance and high efficiency even without heating the palm fruit. This does not produce good results in other similar machines which require that the palm fruit be heated before efficient expelling can be achieved.

The addition of the regulating or the control unit is a feature that creates room for the control of the quantity of palm kernel oil to be expelled at a time.

Indeed, by finely adjusting the clearance between the barrel and the adjustable cone, also known as the choke mechanism, precise control is exerted over both the thickness and dryness of the pressed cake. This regulation ensures that the extraction process is optimized, allowing for a tailored output of pressed cake with desired characteristics. The choke mechanism helps to increase the efficiency of extraction alongside with the action of the worm.

Further the enclosure of the shaft inside the barrel on which the spring is welded ease the maintenance of the unit. The shaft can be easily removed from the barrel when the spring(worm) is worn out which in this case do not wear out easily and when it does it is replaced with a new spring (worm) welded to it.

Finally with the concept adopted in the design of the PKO expeller, safety was taken into consideration thereby making the machine user-friendly thus preventing hazards.

A. Conclusion

The design and development of a palm kernel oil expelling machine encompass the construction of essential components such as the hopper, expelling chamber, and the careful selection of the shaft and gear motor, among other vital parts. The assembly process is designed to be straightforward and distinctive, facilitating efficient palm kernel oil expelling. The key element in this process is the worm, carried on the rotating shaft and enclosed by the barrel. This setup ensures optimal performance in extracting palm kernel oil while simultaneously prioritizing ease of maintenance for the entire machine.The designed and development of palm-kernel oil expeller, on proper assembling could effectively and efficiently extract oil form palm kernel with an efficiency of about 95%.

This model hopefully could be a boost to the Nigerian kernel industry and agricultural sector when patronized by foreign investors and other users and further developed. This therefore could improve the nation’s economic status in the ever growing international kernel market. It would also enhance the establishment of small scale industries to process the palm kernel seeds provided by our large oil-palm plantations thereby creating and increasing employment opportunities.

B. Recommendation

Possible ways of improving on this machine include the automation of the whole process and the introduction of features to enhance oil recovery from the palm kernel seed. This would increase oil yield of bothsmall and large scale kernel production sector thereby making oil available for various utilization and also making quality palm kernel cake available for the livestock industry.

Also the design can be improved by introducing another similar expelling barrel in line with the previous expelling barrel on the same shaft so as to increase turn out rate of the entire system.

Among other ways, the expelling machine can be provided with wheels to permit its movement from one location to another where it is to be used, the provision of dampers is also necessary to reduce machine vibrations.

ISSN No:-2456-2165

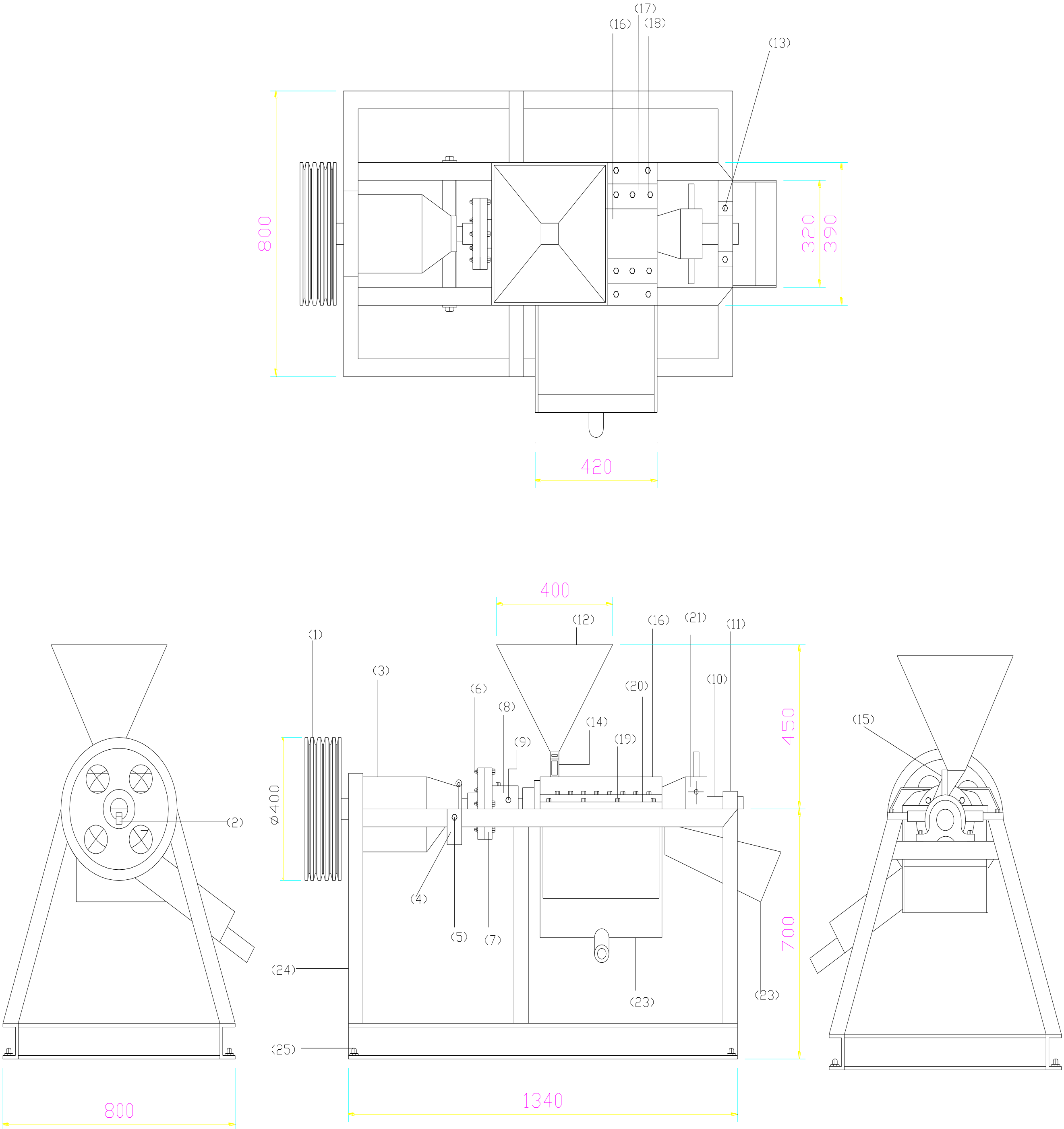


Fig. 14: Orthographic Projection Of The Palm Kernel Oil Expeller Machine

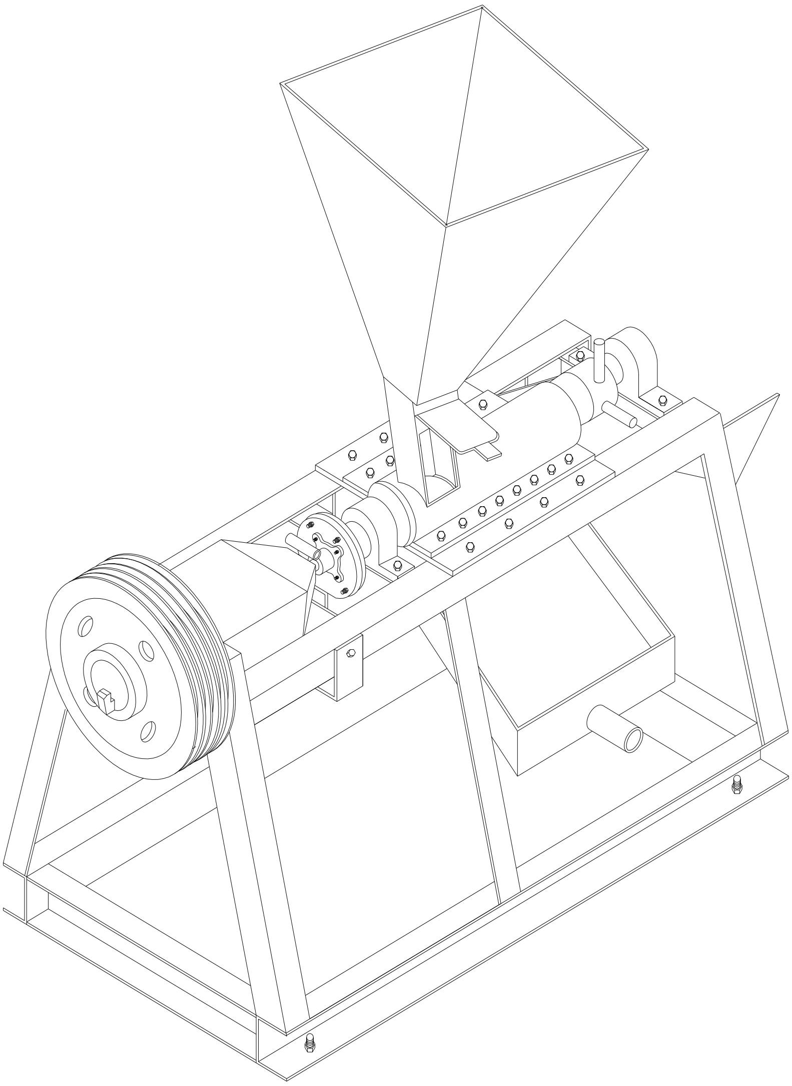


Fig. 15: Isometric Projection Of The Palm Kernel Oil Expeller

Fig. 16: Pictorial view of barrel, foundation bolts and gear motor sit

Fig. 17: Pictorial view showing the foundation coupling along with components of the upper chamber

Fig. 18: Pictorial view of the hopper, flange and gear motor sit during construction

Fig. 19: Pictorial view of the bearing, adjustable cone and barrel during construction

Fig. 20: Pictorial view of the gear motor used for the construction process.

REFERENCES

[1]. Achaya, K.T. Ghani: A traditional method of oil processing in India, 1993 www.fao.org/docrep/t4660t/t4660t0b.htm, Accessed on 30 December, 2017.
[2]. Adeeko, K. A. and Ajibola, O. O., 1988, "Processing Factors affecting Yield
[3]. and Quality of Mechanically Expressed Groundnut Oil," Proceedings of CIGR Inter-sections Symposium, NSAE, Nigeria. p. 59-69.
[4]. Adesina, B.S., and Bankole, Y.O. Effects of particle size, applied pressure and pressing time on the yield of oil expressed from Almond seed. Nigerian Food Journal, Volume 31, (2013), pp. 93-105.
[5]. Ajibola, O.O. A study of some factors affecting the hydraulic pressing of palm kernel. Journal of Food Science and Technology, Volume 26, (1989), pp. 213 – 217
[6]. Akerele, O. V and Ejiko, S. O. Design and construction of groundnut oil expeller. International Journal of Engineering and Computer Science. Volume 4, (2015), pp. 12529-12538.
[7]. Akinoso, R., Raji, A. O., and Igbeka, J. C. Effects of compressive stress, feeding rate and speed of rotation on palm kernel oil yield. Journal of Food Engineering, Volume 93, (2009), pp. 427-430.
[8]. Amiolemhen P. E and J. A. Eseigbe (2019). Design and Fabrication of a palm oil kernel. NIJOTECH
[9]. Bachmann J. (2005). Oilseed Processing for Small-Scale Producers. National Sustainable Agriculture Information Service. Bredeson DK. (1983). Mechanical Oil Extraction. Journal of the American Oil Chemists' Society. 60;(2): 211-213.
[10]. Bahadar, A., Khan, M. B., and Mehran, T. Design and development of an efficient screw press expeller for oil expression from Jatropha curcas seeds: A computational flow dynamics study of expeller for performance analysis. Industrial & Engineering Chemistry Research, Volume 52, (2013), 2123-2129.
[11]. Bamgboye, A. I. and Adejumo, A. D. Development of a sunflower oil expeller. Agricultural Engineering International: CIGR Journal, (2007).
[12]. Butcher D. (2005). Pedal Powered Generator. David Butcher's Personal Page. Shaver M. (2005). Bicycle Powered Generator. Matt Shaver's Home Page. http://attra.ncat.org/attra-pub/oilseed.htmlhttp://www.losgatos.ca.us/davidbu/pedgen.htmlhttp://users.erols.com/mshaver/bikegen.
[13]. de Conto, L. C., Gragnani, M. A. L., Maus, D., Ambiel, H. C. I., Chiu, M. C., Grimaldi, R., and Gonçalves, L. A. G. Characterization of crude watermelon seed oil by two different extractions methods. Journal of the American Oil Chemists' Society, Volume 88, (2011), pp. 1709-1714.
[14]. Dehulled Sunflower Seed. Journal American Oil Chemistry Society, Volume .69, (1992), pp. 884-889.
[15]. Dietz, H. M., 1987, "Detoxification of Rape Seed and Rape and Meal With Special Reference to Brassica Comprestris Varieties," Ph.D Thesis, University of Reading, U.K. p.46.
[16]. Farm Energy: Mechanical Extration Processing Technology for Biodiesel-eXtension., http: //www.knecom[.com/oil-mill-plant/oil-pressing, ccessed on 31 November, 2017
[17]. Fasina, O. O. and Ajibola, O. O., 1988, "Mechanical Expression of Oil fromConophor Nut (TetracarpidiumConophorum)," Proceedings of CIGR Intersectionssymposium, NSAE, Nigeria. p. 1-58.
[18]. Hartley CWS. (1997). The Oil Palm. New York: John Wiley & Sons, Intermediate Technology Development Group, Principles of Oil Extraction, Technical Briefs, Intermediate Technology Development Group [Online].
[19]. Hartely, C. W. S. (1967). "The Oil Palm". 2nd Edition. Longman Group Ltd. London.
[20]. Khan, L. M., and M. A. Hanna. Expression of oil from oilseeds - a review. Journal of Agricultural Engineering Research, Volume 28, (1983), pp. 495-503.
[21]. Khurmi, R. S. and Gupta, J. K., 2005, A Textbook of Machine Design. Eurasia
[22]. Manta, I. H., and Ajisegiri, A. O. Design and fabrication of a cottage groundnut oil Expeller. Journal of Humanities, Science and Technology (JOHSAT),

Niger State Polytechnic, Zungeru, Volume 2, (2007), pp. 131-136.

[23]. Martins, K., Pires, H., Viana, L. G., Lídia, S. P. M., Silva, L. E. M. D., and Rodrigues, J. R. P. Development of a prototype of screw press for the collection of oil from seeds of castor and jatropha. In 13th Brazilian Congress of Thermal Sciences and Engineering, Uberlandia, MG, Brazil, (2010).

[24]. Nmanu Aki (Palm Kernel Oil) Using Complete Pretreatment Process : Proceedings of the World Congress on Engineering and Computer Science 2012 Vol II.WCECS 2012, October 24-26, 2012, San Francisco, USA.

[25]. Obetta, S. E. 2003, "Development of a Hot-water Palm Kernel Oil Extraction System," Ph. D Thesis, University of Nigeria, Nsukka

[26]. Odewale, M.M., Sunmonu, M.O., Oyeniyi, S.K., Adesoye, O.A., and Ikubanni, P.P. Development of U-channel screw jack for vegetable oil extraction. Nigerian Journal of Technology, Volume 36, (2017), pp. 979-986.

[27]. Olaniyan, A. M., Yusuf, K. A., Wahab, A. L., and Afolayan, K. O. Design, development and testing of a screw press expeller for palm kernel and soybean oil extraction. In Post-Harvest, Food and Process Engineering. International Conference of Agricultural Engineering-CIGR-AgEng 2012: agriculture and engineering for a healthier life, Valencia, Spain, 8-12 July 2012. CIGR-EurAgEng, (2012).

[28]. Olatunde, O. B., Ajav, E. A. and Fatukasi, S. O. Design and Fabrication of Groundnut (Arachis Hypogaea) Roaster cum Expeller. International Journal of Science and Technology, Volume 3, (2014), pp. 177-184.

[29]. Olayanju, T. M. A., Akinoso, R. and Oyeku, O. M., 2004, An Investigation into the Machine Parameters of Some Vegetable Oil Expellers," Proceedings of NIAE. 26: 387-390.

[30]. Omobuwajo, T. O., Ige, M. T., and Ajayi, O. A. Heat transfer between the pressing chamber and the oil and oilcake streams during screw expeller processing of palm kernel seeds. Journal of food engineering, Volume 3, (1997), pp. 1-7

[31]. Oyinlala A, Ojo A, Adekoya LO. (2004). Development of a laboratory model screw press for peanut oil expression. Journal of Food Engineering. 64(2): 217-227

[32]. Oyinlala A, Ojo A, Adekoya LO. (2004). Development of a laboratory model screw press for peanut oil expression. Journal of Food Engineering. 64(2): 217-227.http://www.itdg.org/docs/technical_information_service/oil_extraction.pdf

[33]. Pearson, D. 1970, "The Chemical Analysis of Food," Churchill, London.

[34]. Poku K. (2002). Small Scale Palm Oil Processing in Africa. Rome: Food and Agriculture Organization of the United Nations,

[35]. Pradhan, R. C., Mishra, S., Naik, S. N., Bhatnagar, N. and Vijay, V. K. Oil expression from Jatropha seeds using a screw press expeller. Biosystems engineering, Volume 109, (2011), pp. 158-166

[36]. Pub. House (PVT) Ltd., India. Poku K. (2002). Small Scale Palm Oil Processing in Africa. Rome: Food and Agriculture Organization of the United Nations,

[37]. Reeves, James B.; Weihrauch, John L; Consumer and Food Economics Institute (1979). Composition of foods: fats and oils. Agriculture handbook 8-4. Washington, D.C.: U.S. Dept. of Agriculture, Science and Education Administration. p. 4. OCLC 5301713.

[38]. Samuel, O.D., and Alabi, A.G.F. Problems and solutions involved in oil processing from palm kernel seeds. The Pacific Journal of Science and Technology, Volume 13, (2012), pp. 372-383.

[39]. Sayasoobthorn, S., Kaewueng, S. and Patharasathapornkul, P Rice bran oil extraction by screw press method: Optimum operating settings, oil extraction level and press cake appearance. Rice Science, Volume 19, (2012), pp. 75-78.

[40]. Smith, R. L. and Kraybell, H. R. 1972, "Soybean Oil Quality and Yield as Affected by Conditions of Expression," J. Ind. Eng. Chemistry. 55, 334.

[41]. Sodeifian, G., and Ansari, K. Optimization of FerulagoAngulata oil extraction with supercritical carbon dioxide. The Journal of Supercritical Fluids, Volume57 (2011), pp. 38-43

[42]. Tunde-Akintunde, T. Y., Akintunde, B. O., and Igbeka, J. C. Effects of processing factors on yield and quality of mechanically expressed soybean oil. Journal of Engineering Technology, Volume 1, (2001), pp. 39-45.

[43]. 42. UNIDO, 1977, "Guideline for the Establishment and Operation of Vegetable Oil Factories" United Nations Publications, United Nations. New York. P. 14.

[44]. 43. V. O. N., 1987, "Palm Kernel Oil and Cake". Pamphlet of Vegetable Oils Nig. Ltd. (V. O. N.), Ikeja, Nigeria.