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Design and Fabrication of a Palm Fruit Digester

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***Abstract* – This work presents the design and fabrication of a palm fruit digester. The need for a more efficient process for extracting palm oil has made researchers sought for a palm fruit digester that can carry out the extraction process without breaking its nuts or having low belt drive. Hence, for an efficient palm oil extraction system, a proper design that can guarantee capacity and efficiency is fabricated. Critical studies have shown that horizontal digesters are efficient but are usually accompanied by low belt drive, while on the other hand, the vertical digester are also efficient but breaks up nut when breaking up oil bearing cells. In order to increase the efficiency of the extraction process, the use of belt is eliminated and replaced with direct coupling. The design made use of Autodesk inventor professional software to produce the CAD model of the machine. From the design analysis, the machine frame has a bending value of 1.742e^{-02}mm and with the displacement value of 1.742e^{-02}mm while the average performance of the machine determined was 485.25 Kg/h and 78.74%, for the throughout and efficiency respectively.**

***K*eywords—Palm fruit, palm fruit digester, palm oil extraction, palm fruit processing and palm oil.**

I. INTRODUCTION

The oil palm fruit (Elaesis guineensis) is a member of the family of (Arecaceae). The plant contains up to 400 species, each fruit is a drupe, with a fibrous and oily mesocarp and a stony endocarp or shell, the shell encloses one seed or kernel. The ripe fruit is bright red except for the top which may be dark brown or black. All the fruit of an inflorescence make up a bunch. There are three naturally occurring forms of the palm oil fruit termed Dura, tenera and pisifera. The Dura form has a thick endocarp (up to ¼ inch) such that the mesocarp occupies only 35 – 65% of the fruit. The tenera form has a thin endocarp (up to 1/8 inch) and is 55 – 95% mesocarp. Yield and fruit weight are higher in dura and lower in tenera although tenera produces fruit with higher oil content but less kernel oil when compared to the dura variety. The endocarp is absent in the pisifera form, they lack seed entirely. Pisifera are undesirable from a commercial stand point since they have low yield and are vigorous, however, they are extremely important in breeding, (Agbonkhese et al, 2018).

The crop is often referred to as a crop of multiple values, which underscores its economic importance. The demand for domestic and industrial application of palm oil has continued to increase. It is estimated that for every Nigerian household of five, about two liters of palm oil are consumed weekly for cooking. Nevertheless, palm oil a product extract of palm fruit is an essential multipurpose raw material for both food and non-food industries. Palm oil is used in the manufacturing of margarine, soap, candle, base for lipstick, waxes and polish bases in a condense form, confectionary, pharmaceuticals, tin plating, lubricant, biodiesel, fat spread, ice cream, coffee whiteners, whipping creams, fatty acids free formulation, palm-based cheese, micro-encapsulated, filled milk, mayonnaise and sealed dressings, red oil/olefin Also, with the growing population of Nigeria, an increase in the number of families, and communities, there will be an increase demand and compensating consumption rate in the country for oil palm products, most especially the red oil for daily cooking and consumption. Thus, a local technology that can be used to process the fruit will be paramount. Such technology will help to reduce the rate at which local and industrial batch users will use in handling the material (drudgery) for palm oil processing. It will also help to achieve increase in productivity as the time and energy it will take for palm oil to be locally processed can be reduce twice the rate using mechanical means, (Oghenevwaire, 2019).

The major process in the oil palm process is the palm fruit digestion. According to (Agbonkhese et al, 2018.), Digestion is the process of releasing the palm oil in the fruit through the rupture or breaking down of the oil bearing cells. Digestion and oil extraction are the most tedious and essential operations in traditional palm fruit processing. Therefore, early efforts concentrated on these tasks. The digester machine commonly used consists of a cylindrical vessel fitted with a central rotating shaft carrying a number of beater (stirring) arms. Through the action of the rotating beater arms by a prime mover, usually a fuel, diesel engine or an electric motor, the fruit is pounded. Digester comes in two categories and these are vertical and horizontal digesters. The vertical digester consists of the hopper, digester barrel, Bearings, main shaft, Beaters arms, discharge end, worm gear, wheel gear and the prime mover. The vertical digester's barrel carries the hopper and the shaft assembly which lies in the central position of the barrel. The shaft assembly is made up of shaft with six beater arms which are arranged at specific angle and distance strongly welded to the shaft in the horizontal position. The shaft carrying the worm gear and the pulley are placed in the horizontal position. The worm and wheel gear arrangement are to enable the direction of motion to be changed from horizontal plane to vertical plane. The digester works on rotary impact principle. More so, in the horizontal digester, digestion is done by the beater arms which also convey the macerated oil palm fruits from the digester posterior end to the exterior end conveyor automatically due – screw – arrangement of the beater arms.

Horizontal digester has higher efficiency due to its ability to break up all oil-bearing cells and ability to not break a nut in the process, but is usually accompanied by low belt drive efficiency due to slippage and improper design of the pulley system, which is a result of the length while the vertical digester has more efficient pulley system but it breaks up nut when breaking up all oil-bearing cells. Thus, this study focused on design and optimization of palm fruit digester machine.

II. LITERATURE REVIEW

Over the years, the need for oil extraction from palm fruit has led to invention of several palm fruit digesters available today, this includes both horizontal and vertical type digesters. Hence the trend of consistent research works has characterized the progressive development of the palm fruit digester. This machine consists of the feeder (Inlet Channel), Digester Drum, Stirrer, Frame, Cover, Outlet and Prime mover. This narrows down the cause of this study to optimizing the breaking up of nuts in the digester and obtaining an optimal production of good quality oil which offer the most favorable efficiencies at minimum cost.

In relations to palm fruit and palm oil, the study of the effect of processing conditions on yield and quality of hydraulically expressed palm oil, Owolarafe et al., (2008) concluded that increase in digestion time and expression pressure increased the solid impurity at all sterilization times. Yeow et al., (2010) investigated the application of microwave moisture sensor for determination of oil palm fruit ripeness which proved to be effective in calculating the complex relative permittivity from the measured reflection coefficient between 1 GHz and 5 GHz. Also, an evaluation of color models for Palm Oil Fresh Fruit bunch ripeness classification carried out by Sabri (2018), concluded that YCbCr and YUV color models produced the highest ripeness classification for palm oil fresh fruit bunch and further study on palm oil fresh fruit bunch ripeness grading identification using color features by Sabri et al., (2017), concluded that color moment features handle illumination changes better than color histogram and color correlogram. Onu et al., (2021) researched on the comparative analysis of the level of engagement in palm oil processing among rural households in Southeast Nigeria, the research recommended that State and Federal Government should gear up efforts in providing basic infrastructure in the study area so that the efficiency of processing of oil palm products can be guaranteed. Anyaoha et al., (2018) experimented on evaluating oil palm fresh fruit bunch processing in Nigeria, the study concluded that the monetary value of lost crude palm oil per 1000 kg of fresh fruit bunch processed in the industrial route is more than the labor cost of processing 1000 kg of FFB in the small-scale route.

In relations to palm fruit digesters, Agbonkhese et al., (2018) designed and fabricated a vertical palm fruit digester with locally sourced materials with the performance test evaluation showing that the machine has a capacity of 740kg/h with an efficiency of 92.31%. An investigation on the development of motorized oil palm fruit rotary digester by Asoiro and Udo (2013) recommended that manufacturers should take up this innovation of the motorized oil palm fruit rotary digester and implement it in the mass processing of red oil palm fruit for export, domestic and industrial uses.

III. METHODOLOGY

Description of the designed palm fruit digester:

The palm fruit digester is comprised of the following components; (1) The feeder (Inlet Channel), (2) Digester Drum, (3) Stirrer, (4) Frame, (5) Cover, (6) Outlet, (7) Prime mover (8) Sieve. The overall height of the palm fruit digester is 1250mm, width of 720mm and length of 450mm. The digester drum has a height 600 mm and diameter 450 mm. The feeder has a height of 190mm, width of 150mm and length of 150mm. the frame has a height of 908mm, width of 370mm and length of 370mm. the sieve has a diameter of 430mm. the stirrer has a height of 450mm, daometer of 30mm and a sweep clearance of 5mm.

Table 1: Materials used for the palm fruit digester.

S/N	NAME	MATERIAL USED
1.	The feeder (Inlet Channel)	Stainless steel (Sheet metal)
2.	Digester drum	Stainless steel (Sheet metal)
3.	Stirrer	Mild steel
4.	Sieve	Stainless steel (Sheet metal)
5.	Frame	Mild steel
6.	Cover	Stainless steel (Sheet metal)
7.	Outlet	Stainless steel (Sheet metal)
8.	Prime mover	Electrical Motor

PRINCIPLE OF OPERATION

The primary rotation of the electric motor is essential for the powering of the palm fruit digester. The feeder allows the introduction of cooked palm fruit to the system. The stirrer rotates in a clockwise direction. The motion of the stirrer causes friction between the palm fruit and the drum containing it hence, breaking up all oil-bearing cells of the palm fruit. The sieve allows only the passage of the extracted oil through to the outlet.

DESIGN CONSIDERATIONS

The consideration for the design is to attain light weight with high rigidity, easy installation such as assembly, disassembly and operation, and cost reduction and also to achieve efficient extraction with high throughput.

DESIGN APPROACH

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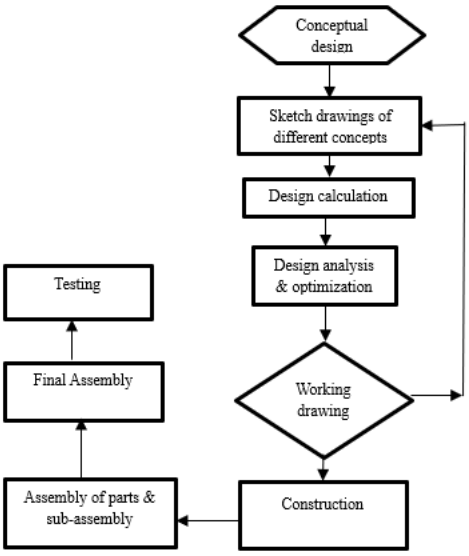

Fig 2: The design approach for palm fruit digester

DESIGN OF MACHINE COMPONENTS

The Feeder (inlet channel)

The feeder or the inlet channel is the channel which allows the cooked palm fruits to go into the digester drum for processing. However, the feeder is not only meant for the cooked palm fruits, but also it acts as a channel for pouring in water for the washing of the processed palm fruits.

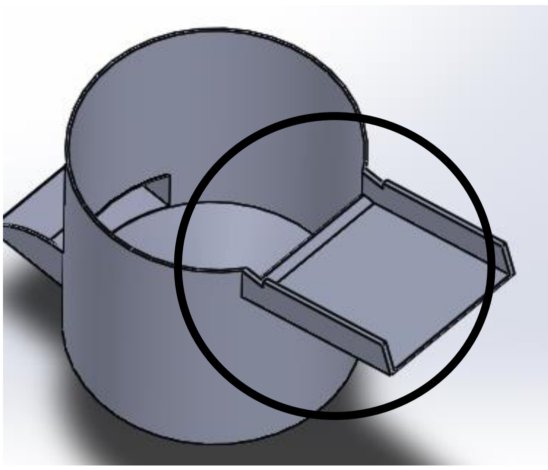

Fig. 2: The pictorial view of the Feeder

However, various sheet metal materials were considered for the design; Aluminum sheet metal, Stainless sheet metal and Mild steel sheet metal. Stainless steel was preferred over other materials because it has high corrosion resistance, allowing it to be used in all types of environments. Even at elevated temperatures and pressures it is resistance to fire and heat. Low alloyed grades resist corrosion in atmospheric conditions and highly alloyed grades can resist corrosion in most acids, alkaline solutions, and chloride bearing environment.

Table 2: Properties of Engineering Materials for the feeder

Material	Corrosion value (mm/y)	Strength value (MPa)				Machinability value	Weldability value	Cost (₦)
		Yield strength	Tensile strength	Compression strength	Fatigue strength			
Aluminum sheet metal	0.00768	276	310	30-280	96.5	5	3	15000
Stainless sheet metal	0.05-2	215	510	170-310	103-104	2	4	60000
Mild steel sheet metal	-	250	450	250	270	3	5	30000

Digester drum

The digester drum is a cylindrical contain where the processing activities of the palm fruit is carried out.

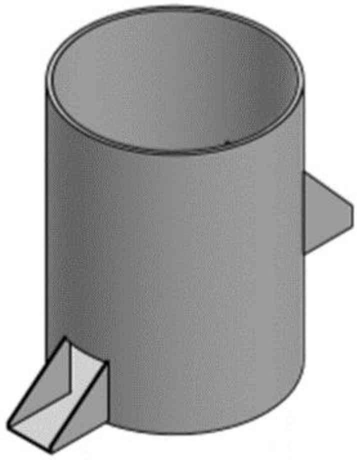

Fig. 3: The pictorial view of the Digester drum

Determination of The Volume of The Drum

The volume of the drum is given by:

$V = \pi r^2 H$ …………………………… (Eq. 3.1)

Where:

V = Volume of the drum

H = Height of the drum

r = radius of the drum

Stirrer

The component which is made up of shaft and a group of blades. The function of the stirrer is to process the cooked palm fruit into oil by rotating it around the walls of the digester drum. Apart from the processing function of the stirrer, it also helps in the collection of the chaff and channeling it to the discharge outlet.

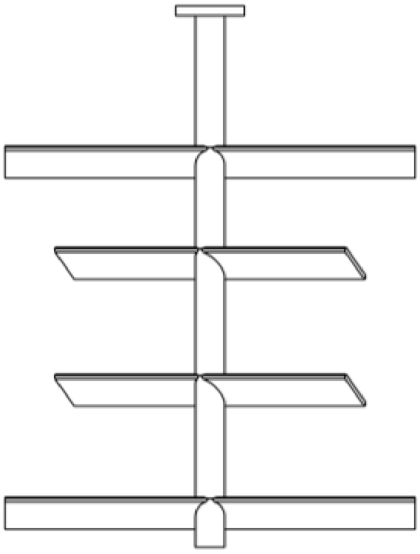

Fig. 4: pictorial view of the stirrer

Table 3: specification of stirrer

Diameter	30mm
Height	570 mm
Sweep clearance (mm)	5mm
Number of blades	8
Specification	Circular/ flat bar
Material	SAE- 950A Alloy mild steel

Sieve

The component separates the palm fruit chaff from the extracted oil.

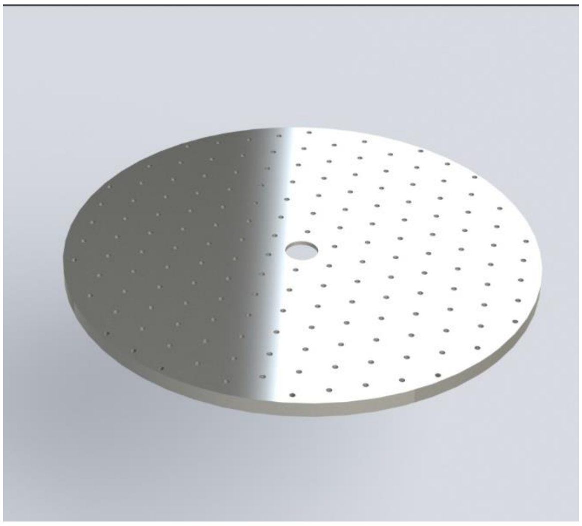

Fig 5: pictorial view of sieve

Frame

For the framing structure, mild steel – 45x45x 5mm was selected because of its unique characteristics like machinable, weldable, affordable and anti-corrosion.

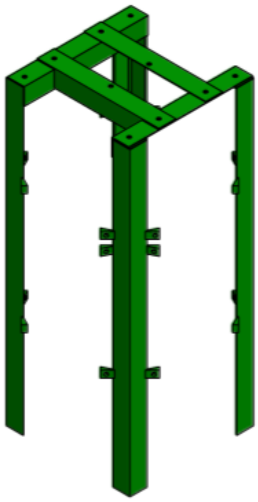

Fig 5: 3D CAD model of framework

Table 4: Specification for Structural Framework

Length (mm)	370
Width (mm)	370
Height (mm)	908
Frame specification (mm)	60x60x4
Weight (kg)	17.47
Material	SAE- 950A Alloy mild steel

Rigidity of the frame

This is the measure of the resistance offered by an elastic body to deformation. It is calculated using the expression: $k = F/\delta$

Where K = Stiffness (Rigidity) (N\m)

F = Total force on the frame (N)

δ = maximum deflection on the frame (m)

The component channels the removal of fluid and chaff from the system. the system was designed with two outlet channels. The conical channel was designed for discharging the oil while the other outlet channel is for the chaff discharge.

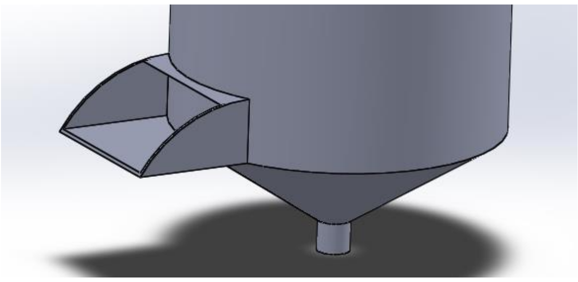

Fig. 6: The CAD drawing view of the outlet channels

Prime Mover

Prime mover is a system that generates the rotary motion. The YL7124 geared-electrical motor of 1.5Hp was utilized.

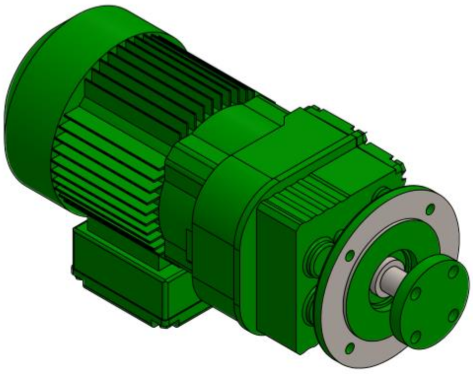

Fig. 7: The CAD drawing view of motor

Table 5: Specification of Electric motor

Motor parameter	Unit	Value
Model number	-	YL7124
Type	-	Geared motor
Number of poles	-	4
Casing protection	-	Closed type
Number of stators	-	Single -phased
Speed	-	Low
Application	-	Industrial
Voltage	V	230
Frame	-	63- 132M
Housing material	-	Cast iron, aluminum, steel, stainless
Bearing	-	SKF, NSK, NTN, C&U, NF
Capacitor	µF	400
Speed	rpm	500-1440

Determination of The Required Power

According to Oghenevwaire et al., (2019), they stated that in accordance with the American Society of Agricultural Engineers (ASAE), the rupture strength of palm fruit sterilized at 100°C under atmospheric pressure for a period of 45 minutes is 1.082N/mm^2. However, rupture force can be determined using the equation stated below:

$$S_R = \frac{F_R}{A_M} \quad \text{.................................. (Eq. 3.2)}$$

Where:
S_R = rupture strength
A_M = area of palm fruit mesocarp (mm^2)
F_R = rupture force (N)

Assuming that the palm fruit is a sphere, the area can be determined as follows:

$$A_M = 4\pi R_m^2 \quad \text{................................ (Eq. 3.3)}$$

COMPLETE PALM FRUIT DIGESTER DESIGN

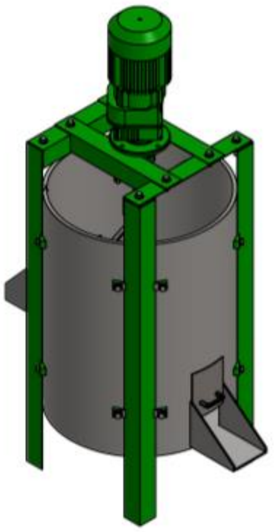

Fig 8: complete palm fruit digester

Fig 9: exploded view of palm fruit digester

Fig 10: sectioned view of palm fruit digester

Determination of Machine Torque

Torque transmitted per digester arm can be determine using the formula reported by Oghenevwaire et al., (2019)

$$(T_d) = F_R \times L_D \quad \text{........................ (Eq. 3.4)}$$

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Where:
L_D = The Length of the Digester arm
However, total torque in the digester
T = Td x N................................ (Eq. 3.5)
Where:
N = Number of digester arm
Fr = mω2Ld .... (Eq. 3.6)

The angular speed can be determined by:

$$\omega = \sqrt{\frac{F_R}{mLD}} \quad \text{............................. (Eq. 3.7)}$$

$$F_R = mg \quad \text{............................... (Eq. 3.8)}$$

$$M = \frac{FR}{g} \quad \text{.................................. (Eq. 3.9)}$$

However,

$$\omega = \sqrt{\frac{g}{LD}} \quad \text{............................... (Eq. 3.10)}$$

Therefore, $P_d = T\omega$ .... (Eq. 3.11)
Where:
Pd = Power required by the digester
T = Torque
ω = Angular speed

Determination of Machine Shaft Diameter

Determination of the shaft diameter is necessary to ensure a satisfactory strength and rigidity when the shaft is transmitting power under various operating and loading conditions. This was obtained using the conventional formula reported by Khurmi and Gupta (2005)

$$D^3 = \frac{16}{\pi S_a}\sqrt{(K_b M_b)^2 (K_t M_t)^2} \quad \text{......... (Eq. 3.12)}$$

Where;
Mb = the bending moment,
Mt = the torsional moment,
Kb = the combined shock and fatigue factor applied to bending moment,
Kt = the combined shock and fatigue factor applied to torsional moment;
Sa = the allowable stress.

Critical Speed of The Shaft

Critical speed of the shaft plays a vital role in the determination of the efficiency of the machine. Thus, the critical speed of the machine was determined as reported by Khurmi and (Gupta 2005)

$$\omega s = \sqrt{\frac{48\varepsilon l}{mL}} \quad \text{............................. (Eq. 3.13)}$$

Where,
ω = the critical speed of the shaft,
ε = the modulus of elasticity of steel,
m = the mass of the shaft,
L = The length of the shaft

Torsional Deflection of The Shaft

This was calculated to know the angle of deviation of the shaft in degrees and to make sure this angle of deviation is at its minimum as reported by Khurmi and (Gupta 2005)

$$\alpha = \frac{584\tau L}{D^4 G} \quad \text{............................. (Eq. 3.14)}$$

α = Angular shaft deflection in degrees,
L = Length of the shaft,
G = modulus of elasticity of steel,
$D = 2.26\times4\sqrt{\tau}$

Determination of The Power Required to Drive the Shaft

It is important to note the amount of power required to drive the shaft. Thus, it was calculated as reported by Khurmi and (Gupta 2005)

$$P = \frac{2\pi NT}{60} \quad \text{.................... (Eq. 3.15)}$$

$$T = \frac{\pi}{16} \times \tau \times d^3 \quad \text{.................... (Eq. 3.16)}$$

Where;
P = the Power,
T = the Torque,
τ = the Shear stress of the shaft,
D = the diameter of the shaft.

Bearing reaction on the shaft (R1)

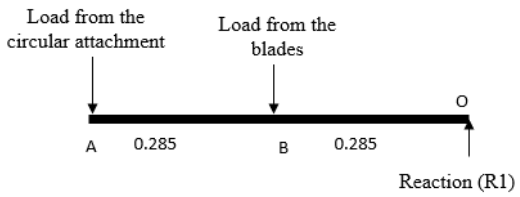

Fig 10: The Free body diagram of the system

From the evaluation of the forces, determination of the bearing reactions, maximum bending moments (Mmax) and others stress analysis of the shaft were performed using inventor professional software (educational license) and are shown in the figures below:

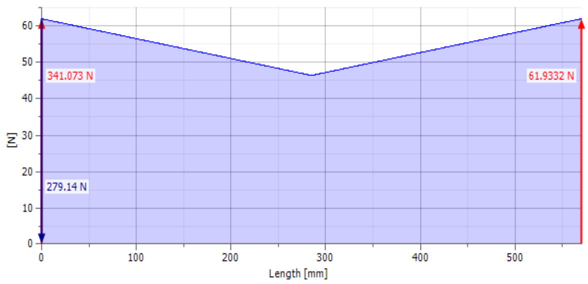

Fig 11: Shear force diagram

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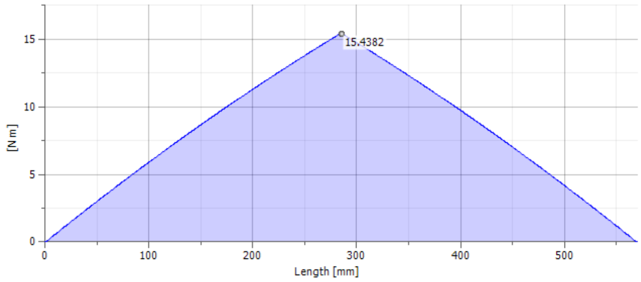

Fig 12: Bending moment diagram

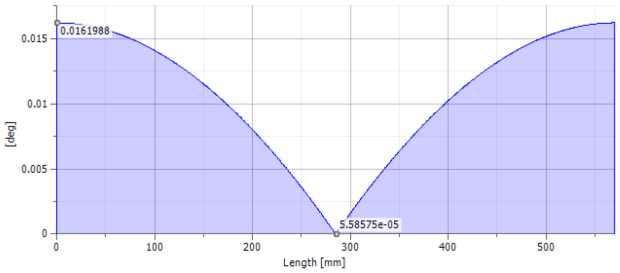

Fig 13: Deflection

FABRICATION APPROACH

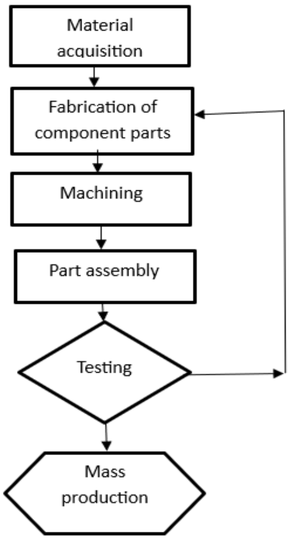

Fig 14: The fabrication approach for palm fruit digester.

Manufacturing processes, equipment and tool.

Table 6: The manufacturing process each of the sub-assembly part

S/N	Sub-part	Manufacturing process
1	Drum/outlet zones	• Cutting • Folding • Welding
2	Frame	• Making • Cutting • Welding
3	Shaft	• Cutting • Shaping • Forging • boring
4	Arms	• Cutting • Welding
5	Outlet cover	• Cutting • Welding
6	Sieve	• Cutting • Folding • Welding

Table 7: Equipment and tools used

S/N	Production process	Equipment	Tools	Consumables
1	Measurement		Tape rule, Steel rule, Vennier callipers	
2	Marking		Centre punch, Divider, Try square, hammer	Engineering Chalk
3	Cutting	Oxy-acetylene set, hand cutting machine	Cutting disc, Cutting blades	Saw blades, oxy-Acetylene, cutting disc
4	Drilling	Vertical drilling machine, lathe machine	Drill bits, coolants	
5	Folding	Folding machine	Stakes, anvil, mallet, hammer	
6	Rolling	Cylindrical rolling machine	Hammer, mallet	
7	Welding	Arc welding machine	Hand gloves, welding shield, chipping hammer	Stainless steel electrodes*, carbon steel electrodes**

Fig 15: Assembling the machine fabricated parts

Fig 16: Locally fabricated Palm Fruit Digester

RESULTS

FEA result (Stress-stress value)

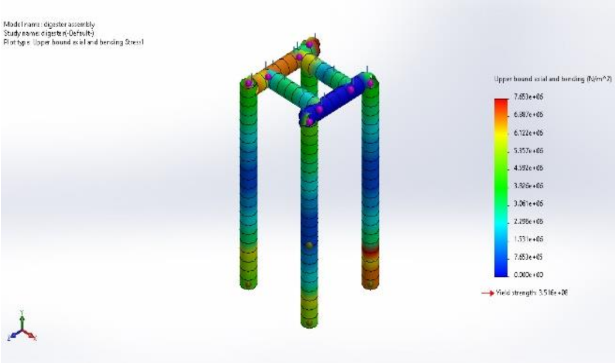

Fig 17: Stress- strain analysis of the frame structure

Fig 17 shows that the frame begins to bend at the bending value of 7.653e^{+06}N/m^2, also the yield value of the frame was at 3.516e^{+06}N/m^2.

FEA result (Displacement value)

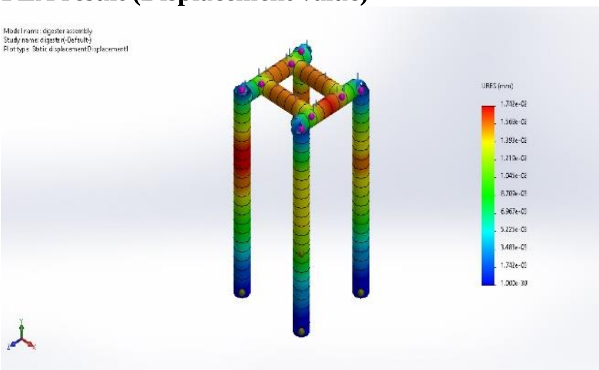

Fig 18: displacement analysis of frame structure

Fig. 18 shows that the maximum displacement value of the frame during analysis is 1.742e^{-02}mm.

Table 8: Technical specification of the machine

S/N	Design entity	Unit	Value
1	Angular speed	Rad/sec	8.67
2	Machine power	hp	2
3	Mass of the shaft	Kg	3.167
4	Number of blades	-	8
5	Shaft diameter	mm	30
6	Shaft length	mm	570
7	Shaft speed	RPM	760
8	Tangential force acting on the blades	N	42.81
9	Torque	N-m	18.84
10	Volume	m^3	95.44
11	Weight of the blades	N	50

IV. CONCLUSION

This research presented design and optimization of palm fruit digester machine. The machine was optimally design bringing in mind the best engineering design practices. Furthermore, the machine was successfully fabricated. The following were the conclusion of the data gotten from the experiment:

- Decrease in the motor speed, increases the efficiency of the digestion, and also decreases in the throughout
- An increase in the motor speed substantially increases the throughout, but brings about decrease in the efficiency
- The average performance result was 485.25 Kg/h and 78.74%, for the throughout and efficiency respectively
- The frame has a bending value of 1.742e-02mm and with the displacement value of 1.742e-02mm

V. RECOMMENDATION

Further study should be done on other component parts like the arms, the configuration of the arms, the geometry of the digester, etc., to investigate if it can increase the performance of the machine.

VI. REFERENCES

[1] Agbonkhese, Kingsley A, Omoikholo, frank, & Okojie, Godwin. (2018). Design and fabrication of a vertical palm fruit digester. 7(1), 7. http://dx.doi.org/10.24327/ijcar.2018
[2] Anyaoha, K., Sakrabani, R., & Patchigolla, K. (2017). Evaluating oil palm fresh fruit bunch processing in Nigeria.
[3] Asoiro, U, & Udo, U. C. (2013). Development of motorized oil palm fruit rotary digester. 32, 8.
[4] Palm oil processing. (n.d.). Retrieved May 4, 2022, from https://www.fao.org/3/y4355e/ y4355e04.htm
[5] IPROJECT, F. Y. R. P. T. & M. I. P. & D. | iproject from. (n.d.). Design and fabrication of a palm fruit digester. Mechanical Engineering. Retrieved May 3, 2022, from https://iproject.com.ng
[6] Nur Jannah Md Zain & Wan Nurshazelin Wan Shahidan. (2018). Maximization of Palm Fruit Planted Area Using a Goal Programming Approach. 3(3).
[7] Nurbaity Sabri, Zaidah Ibrahim, & Dino Isa. (2018). Evaluation of Color Models for Palm Oil Fresh Fruit Bunch Ripeness Classification. 11(2), 9. https://doi.org/10. 11591/ijeecs.v11.i2.pp549-557
[8] Nwankwojike, B. N., Odukwe, A. O., & Agunwamba, J. C. (2011). Modification of sequence of unit operations in mechanized palm fruit processing. 30(3).
[9] Nze, E. O., Nzeakor, F., & Egbosionu, C. (2017). A-Comparative-Analysis-of-Palm-Fruit-Processing-and-Palm-Oil-Marketing-in-Anambra-State-Nigeria.pdf. 1.
[10] O.K. Owolarafe, E.A. Taiwo, & O.O. Oke. (2008). Effect of processing conditions on yield and quality of hydraulically expressed palm oil. 22, 4.
[11] Oghenevwaire, I. S. (2019). Design and Fabrication of a Motorized Oil Palm Fruit Rotary Digester Machine. American Journal of Engineering Research, 11.
[12] Oil palm | Description, Uses, Cultivation, Environmental Impacts, & Facts | Britannica. (n.d.). Retrieved May 4, 2022, from https://www.britannica.com/plant/oil-palm
[13] Onu, S. E., Ekwe, K., & Onuekwusi, G. (2021). Comparative Analysis of the Level of Engagement in Palm Oil Processing Among Rural Households in Southeast Nigeria. 25.
[14] Pradeep, P. & Edwin Raja Dhas, J. (2015). Characterization of chemical and physical properties of palm fibers. 2(4). https://doi.org/10.5121/msej.2015.2401
[15] Red Palm Fruit. (n.d.). Retrieved May 4, 2022, from https://specialtyproduce.com /produce/Red_Palm_Fruit_9147.php
[16] Sabri, N., Ibrahim, Z., & Jamil, N. (2017). Palm oil fresh fruit bunch ripeness grading identification using color features. http://dx.doi.org/10.4314/jfas.v9i4s.3
[17] Saturday, A., Peter, O. O., Ojo, O. I., Saturday, E., & Amos, A. O. (2017). Design and Development of a Continues Palm Nuts Digesting Machine. 20.
[18] Vida, B., Edward, K., & Gifty, S. (2021). The Impact of Different Drying Techniques on the Physicochemical and Quality Characteristics of Oil Palm Fruit Mesocarp (Elaeis guineensis). 6.
[19] You Kok Yeow, Zulkifly Abbas, & Kaida Khalid. (2010). Application of Microwave Moisture Sensor for Determination of Oil Palm Fruit Ripeness. 10(1). https://doi.org/10.2478/v10048-010-0002-x
[20] Yunus, R. (n.d.). Modelling and Simulation of Heat and Mass Transfer in Oil Palm Fruit Digestion Process. 9.