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Design of Pyrolyzer for the Production of Fuel Oil Using Palm Kernel Shells

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ABSTRACT

Design of pyrolyzer to process 1000kg/day of palm kernel shells (PKS) to fuel oil, water and char was carried out. The PKS was collected from different geographical locations, identified and authenticated before it was washed, sun dried and crushed to a standard grade of 425 µm. The PKS was later pyrolysed in the reactor from 400 - 450^oC. The fuel oil product was passed through a condenser submerged in ice bath for cooling to 10^oC. The products were assumed to be a parallel first order irreversible reaction. Rate constants (k_{oil}, k_{water}, and k_{char}) and overall constants k were calculated from the laboratory pyrolysis results and were used to obtain the reactor volume which lead to the determination of the height and diameter of reactor. The thickness of reactor shell was calculated using standard design equations from literature and laboratory data. The heat required for pyrolysis of 1000kg/day of palm kernel shell was obtained from scale up of heat requirement obtained from laboratory results. The lagging thickness was determined through equations of heat transfer resistances across the reactor cross section. The volume of reactor required to pyrolyse 1000kg/day was 107.143m^3, the decomposition reaction constant K_{oil} of the fuel oil was 1.153x10^{-4}min^{-1} while the overall constant K was 3.17x10^{4}min^{-1}. The energy required to pyrolyse the PKS was 14025kJh^{-1} while the product temperature and the atmospheric temperature were 723K and 378K, respectively. Total heat transfer resistances across the reactor cross section were found to be between 2.798x10^{-6} K/W and 2.51 x 10^{-4} K/W.

KEYWORDS: Pyrolyzer, Design, Palm kernel shells-dura-and-tenera, fuel Oil, Reaction constants.

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1. INTRODUCTION

The high energy demand and globalization in the industrialized world intensify the need to adapt to a rapid increase in climate change. This involves strategies that would encourage conservation and alternative energy sources (Cunningham & Cunningham, 2006). One such strategy could be seen in the pyrolysis model for biomass (like the palm kernel shells *etc.*) pyrolysis in the batch reactor. Pyrolysis is a thermo-chemical decomposition of organic material at elevated temperatures in the absence of oxygen. The word pyrolysis is coined from Greek language with word pyro meaning “fire” and lysis “separating” (Kalyana *et al.,* 2005). There are number of benefits when using biomass residues as fuel instead of using fossil fuels (Song *et al.,* 2004; Tasi, *et al.,* 2007; Natthaya, 2013). Biomass fuels do not create any rise in the amount of greenhouse gas in the atmosphere biomass contains almost no Sulphur, thus the combustion of the biomass creates hardly any sulfur acid. The ash is normally alkaline.

Using biomass residues as fuel often solve waste disposal problem and create instead an income for the waste producer or user (Ashok, 2008; Camila *et al*., 2013; Acikgoz, & Okockar, 2004). There is problem of insufficient energy source and the need for an alternative, less expensive and renewable

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energy source. Also, there is need to convert the land pollution caused by Palm Kernel Shells to energy source by using the shells which is a waste after the removal of palm kernel nut. One of the byproducts of pyrolysis of biomass (PKS) which is the char can be converted to activated carbon and used for a lot of industrial and domestic purposes (Ademiluyi & Alex, 2016b; Ademiluyi, & Nze, 2016c). Development of Design data for PKS pyrolysis will encourage local fabrication of this reactor and reduced the cost of importation of the reactors.

The objectives of the research are to obtain kinetic data and use the data to design a batch pyrolyzer for the production of production of bio-fuel and char from 1000kg of Palm Kernel Shells per day.

2 MATERIALS AND METHODS

A Materials/ Parameters required for the Design of Pyrolyzer

i. Palm Kernel Shells (Dura & Tenera specie PKS)
ii. laboratory scale pyrolyzer
iii. High temperature Thermometer
iv. Burner
v. Bomb calorimeter
vi. Mass Spectrophotometer
vii. Material of construction; stainless steel internal, mild steel external
viii. Lagging material; glass wool

B Input Parameters

i. Density of PKS kg/m^3
ii. Mass of PKS
iii. Input temperature T_i
iv. Initial concentration C_{A0}
v. Conversion X_{AO}
vi. Heat capacity C_P
vii. Input quantity of heat Q
viii. Conversion Rate r_A
ix. Input time
x. Atmospheric temperature
xi. Thermal conductivity of lagging material
xii. Outside resistance
xiii. Film heat transfer coefficient

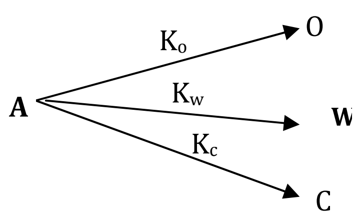
C Output parameters for design of pyrolyzer

i. Height
ii. Diameter
iii. Volume
iv. Heat Required
v. Internal Temperature (T_{ai})
vi. Outside Temperature T_{out}
vii. Stainless steel thickness for (ℓmm) internal
viii. Mild Steel Thickness (ℓmm) for external
ix. Rate constant K_O for Oil
x. Rate constant K_W for water
xi. Rate constant K_C for Char
xii. Overall Rate constant K
xiii. Internal Resistance R_1 for Hot Air
xiv. Resistance R_2 for internal Stainless Steel Material
xv. Resistance R_3 for the Insulating Material thickness
xvi. Resistance R_4 for Mild Steel
xvii. Resistance R_5 for the Air Surrounding the Reactor

2.1 Design Equations for Batch Pyrolyzer of Palm Kernel Shell

2.1.1. Kinetic Model for Pyrolysis of Palm Kernel Shell

Let: Palm kernel shells be denoted as A
Fuel Oil denoted as O
Water denoted as W
Bio char denoted as C



The design was based on the use of 1000kg/day of palm kernel shells to produce oil, water and char. The products were assumed to be a parallel first order

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irreversible reaction. Rate constants (K_o, K_w, and K_c) for oil, water and char and overall constants K were calculated from the laboratory pyrolysis results and were used to obtain the reactor volume which lead to the determination of the height and diameter of reactor. The thicknesses of reactor shells were calculated using standard design equations from literature and laboratory data. The heat required for pyrolysis of 1000kg/day of palm kernel shell was obtained from scale up of heat requirement obtained from laboratory results.

The lagging thickness was determined through equations of heat transfer resistances across the reactor cross section (R_1 for the resistance of the internal hot air within the reactor, R_2 is for the internal stainless steel reactor thickness, R_3 resistance of the insulating material (glass wool) thickness, R_4 resistance of mild steel lagging cover and R_5 for the resistance of surrounding air).

Rate Equation

The rate of pyrolysis of PKS can be related to a batch reactor as (Octave, 2007):

$$r_A = \frac{dC_A}{dt} = (-k_o - k_w - k_c)\, C_A \quad (1)$$

$$-r_A = (k_o + k_w + k_c)\, C_A \quad (2)$$

$$-r_o = \frac{dC_O}{dt} = (k_o)\, C_A \quad (3)$$

$$-r_w = \frac{dC_W}{dt} = (k_w)\, C_A \quad (4)$$

$$-r_c = \frac{dC_C}{dt} = (k_C)\, C_A \quad (5)$$

The overall constant k

$$k = (k_o + k_w + k_c)\, C_A \quad (6)$$

For overall constant k,

$$-r_A = \frac{dC_A}{dt} = kC_A \quad (7)$$

$$-r_A = \ln C_A \Big|_{C_{Ao}}^{C_A} = kt \quad (8)$$

Rearrange and integrate using boundary conditions gives

$$-r_A = \ln C_A \Big|_{C_{Ao}}^{C_A} = kt \quad (9)$$

$$-r_A = \ln\left({C_A}/{C_{A0}}\right) = kt$$

$$r_A = \ln \frac{C_{A0}(1 - X_A)}{C_{A0}} = kt$$

When $C_A = C_{A0}(1 - X_A)$ (10)

$$\Rightarrow \quad r_A = -\ln(1 - X_A) = kt \quad (11)$$

Assume the Decomposition Reaction to be Parallel 1st Order and is Irreversible

When $r_A = \frac{dC_A}{dt} = (-k_o - k_w - k_c)\, C_A$

To calculate K_O, rate of pyrolysis shell r_A is given as

Also in term of PKS Converted

$$r_A = \frac{dC_A}{dt} = (+k_o + k_w + k_c)\, C_A \quad (12)$$

$$r_A = -\ln(1 - x_A) = kt \quad (13)$$

Conversion of PKS to obtain fractional conversion X_{Ao} of oil.

$$-\ln(1 - x_{Ao}) = k_o\, t \quad (14)$$

2.1.2 Determination of Reaction Constants k_O, k_W, k_C and Overall Reaction Constant, k

When time of conversion is t in seconds

$$k_o = -\ln(1 - x_{Ao})\frac{1}{t} \quad (15)$$

b) Conversion of PKS to obtain fractional conversion X_{Aw} of water

$$-\ln(1 - x_{Aw}) = k_w\, t \quad (16)$$

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$k_w = -\ln(1 - x_{Aw})\frac{1}{t}$

Where $K_w = rate\ constant\ k\ for\ water$

$-\ln(1 - x_{Aw}) = k_w t$ (17)

c) Conversion of PKS to obtain fractional conversion X_{Ac} of Char

$-\ln(1 - x_{Ac}) = k_c t$ (18)

For k_c = rate constant k for char

$-\ln(1 - x_A) = k_c t$

$k_c = -\ln(1 - x_{Ac})\frac{1}{t}$ (19)

$k = (k_0 + k_w + k_c)$ (20)

$K_0 = Reaction\ constant\ for\ oil\ (s^{-1})$

$K_w = Reaction\ constant\ for\ water\ (s^{-1})$

$K_c = Reaction\ constant\ for\ char\ (s^{-1})$

K = Overall constant for the decomposition reaction (s^{-1})

$$V = \pi r^2 h \Rightarrow h = \frac{V}{\pi r^2} \quad (21)$$

$$V = \pi r^2 h \Rightarrow h = \frac{V}{\pi r^2} \quad (21a)$$

$$h = \frac{N_{A0}}{\pi r^2 t} \int_0^{XA} \frac{\partial x_A}{-r_A} \quad (21b)$$

Volume of the reactor rearranging equation 21a and 21b give

$$V = \frac{N_{A0}}{t}\int_0^{x_A}\frac{dx_A}{(-r_A)} \quad (22)$$

$$V = \frac{N_{A0}}{t}\int_0^{x_A}\frac{dx_A}{KC_A)} \quad (23)$$

Relationship betweeh diameter D to height H of reactor as specified from Chemical Engineers handbook are into ratio 1 to 2 (Perry, 2008).

so that

h = 2D

D = 0.5h (24)

$$\frac{\pi D^2}{4}h = V \quad (25)$$

$$h = \frac{V X 4}{\pi D^2} = \frac{V X 4}{(0.5h)^2 X \pi} \quad (26)$$

$$h = \frac{4V}{\pi D^2} \quad (27)$$

2.1.3 Determination of Pyrolyzer Reactor Thickness

Pyrolyser reactor thickness was computed using equation 29.

$$\ell = \frac{P_i D_i}{2Jf - P_i} \quad (28)$$

(Coulson & Richardson, 2013)

Design Temp was 450°C (Obtain from pyrolysis experiment). Typical design stress for stainless steel at 450°C was obtained from Sinnot and Galvin (2013). Also design pressure, was taken as 10% above operating of pressure. A corrosion allowance of 2mm should be used.

2.1.4 Determination of Thickness of the Reactor insulator Cover Cylinder.

Diameter of the insulator reactor cover Cylinder (D_S) = Diameter of the internal stainless steel (D_i) + 2(thickness of the steel plate (t_s) +2(thickness of the insulated (t_{insl}) + 2 (thickness of the external mild steel cover (t_{ms}) . i.e.

$D_s = D_i + 2t_s + 2t_{insl} + 2t_{ms}$ (29)

2.1.5 Thickness of the reactor insulator covers Cylinder

$\lambda = \frac{P_i D_s \times 1000}{2Jf - P_i}$ + corrosion allowance (Coulson & Richardson, 2013) (30)

where P_i, = design pressure

Design temperature 450°C,

Design stress (*f*) = 100N/mm² (Sinnolt, & Galvin, 2013).

Corrosion allowance of 2mm was used.

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2.1.6 Determination of the Lagging Thickness of the Reactor

To calculate the thickness of the insulating material, Heat lost by reactor to surrounding is

$Q = (T_{ai} - T_{atm})/R_T$ (31)

The total resistance R_T = Resistance of products in reactor + Resistance of stainless-steel reactor + Resistance of insulation (glass wool) + Resistance of stainless-steel cylinder covering insulator + Resistance of air at surrounding of reactor as developed by Ademiluyi (2016a) for design of lagging for rotary dryers.

$R_T = R_1+R_2+R_3+R_4+R_5$ (K/W) (32)

$R_T =$

$$\frac{1}{(h_{va} * 2 * 3.142 * (D/2) * L} + \frac{In(r_2/r_1)}{(2*3.142*L*k_{sd})} + \frac{In(r_3/r_2)}{(2*3.142**L*k_{ins})} + \frac{In(r_4/r_3)}{(2*3.142*L*k_{sc})} + \frac{1}{(h_{out}*2*3.142*(t_{isl}+D/2+t_d+t_{sc})*L} \quad (33)$$

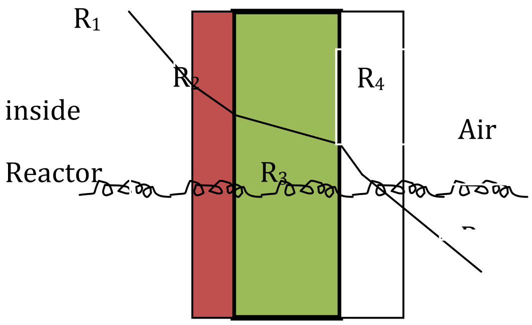

Fig 1: Reactor, insulator and resistances

Rate of heat lost from reactor = rate of heat lost to the atmosphere.

$$Q = \frac{T_{ai} - T_{atm}}{R_T} = Q = \frac{T_{os} - T_{atm}}{R_5} \quad (34)$$

Where h_{out} is heat transfer coefficient for air outside dryer was taken as 15W/m^{2}K.

T_{ai} = inlet air temperature of dryer

T_{atm} = atmospheric temperature

T_{os} = temperature of the outside surface and π =3.142

$$\text{Hence} \quad R_T = R_5 \frac{T_{ai} - T_{am}}{T_{os} - T_{atm}} \quad (35)$$

The thickness of insulation t_{isl} , was then obtained by combining equation 33 and 34 choosing values of from t_{isl} from (0.03-0.3m until equation 33 balance 34.

2.1.6 Determination of the Energy Required to Pyrolyse Palm Kernel Shells

The energy required to pyrolyse Palm Kernel Shells was calculated from equation (36).

$Q = MC\Delta T$ (36)

where Q = Quantity of Heat

M = Mass of the Shell = 1000kg

C = Specific Capacity of Palm Kernel Shell (kJ/kgK) = 1.98kJ/kgK

(Fono *et al*, 2013)

ΔT =Temperature Change (K)

2.1.7 Lagging/Insulating material of Pyrolyzer

Glass wool was recommended as lagging for pyrolyser.

2.1.8 Materials of Construction for Batch Reactor Type Pyrolyzer

Stainless steel material was recommended for construction of reactor to avoid contamination of fuel oil and mild steel as lagging cover to reduce cost of fabrication of material.

2.1.9 Pyrolysis of Palm Kernel Shells

In order to obtain data and other parameters for the design of pyrolyzer to process 1000 kg/day of PKS, fuel oil was produced in laboratory scale using palm kernel shells of different species in order to identify palm kernel shells with the highest fuel oil yield. Five hundred grams 500g, 1000g and 1500g of fresh samples of Tenera and Dura species of palm kernel shells obtained from Osun, Imo and Rivers States, were washed and dried. It was transferred to cellophane bags

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and sealed. The samples were crushed using crusher to a particle size of 425µm dried and later poured serially and separately into the reactor through the hopper. The hopper was properly sealed to avoid leakages before switching on the heater. The shells were pyrolysed until the product temperature rise to 400°C, the reaction time and temperature were taken as the reaction progresses further to 450C . The fuel oil produced was cooled using condensers.

3. RESULTS AND DISCUSSION

3.1.1 Product Temperature of Palm Kernel Shells Specie Collected from Different locations with Respect to Pyrolysis Time

Figure 2 shows a comparable pyrolysis temperature of Tenera PKS collected from Osun and Omagwa from 0 to 55mins while Dura PKS showed a distinct and lowest pyrolysis temperature up to 55 minutes. At 58mins, the temperature of Dura was comparable to that of Tenera PKS collected from Omagwa while the Tenera from Omagwa revealed a comparable pyrolyzed temperature of 350 °C at 66 minutes to Osun type and remained constant at the climax temperature of 350 °C. The close pyrolysis temperature of Osun and Omagwa Tenera shell implied that they can be a substitute to each other. These results also show that location of planting same kernel type did not affect the pyrolysis temperature. The pyrolysis of Dura Palm Kernel differs slightly from Tenera palm shell.

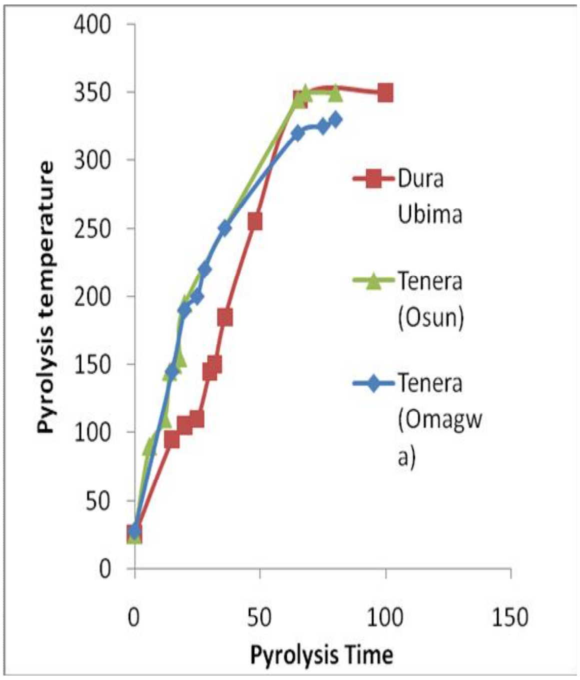

Fig 2: Product temperature during pyrolysis of palm kernel shells collected from different location with pyrolysis time using different palm kernel shells.

3.1.2 Volume of Liquid Produced

Fig 3 shows the volume of liquid produced during pyrolysis by different Palm Kernel Shells with respect to time. Tenera (Osun) kernel shell showed sharp increase in production of liquid at 10 minutes before it reduced at increasing rate after 20 mins (Fig. 3). Dura and Tenera PKS from Umuagwo showed a close comparable volume of liquid at 28 mins and Dura PKS maintained this volume up to 40 mins before reaching climax of about 500 ml while the volume of liquid obtained Tenera (Umuagwo) was increased at lower rate before reaching the climax at 80 mins as shown in Figure 3. The volume of liquid produced was in this order; Dura (Ubima) > Tenera (Umagwa) > Tenera (Osun) at 80 mins. Since Dura gave the highest volume of oil within 60 mins out of the three palm kernel shells investigated, it was therefore considered as the best and this fuel oil subjected for further analysis

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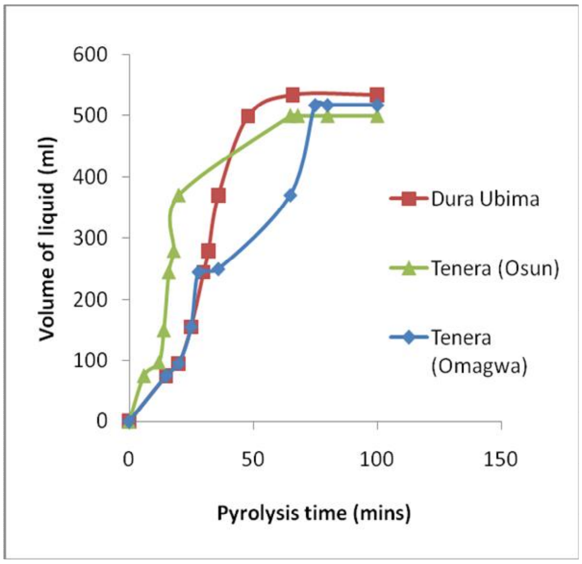

Fig 3: Volume of liquid produced during pyrolysis by different palm kernel shells with respect to time.

3.1.3 Variation of Product Temperature and Pyrolysis Time on the Quantity of Palm Kernel Shells (Dura)

The product temperature increases with increase in pyrolysis time as shown in Fig 4. Pyrolysis temperature of Dura at 500g showed an increase temperature that rose to 400^0C which was attained in less than 60mins and was distinct from that of Dura PKS 1000 and 1500g with pyrolysis temperature of 275 and 220^0C respectively. Pyrolysis temperature of Dura at 500 g showed an increase temperature that rose to 400 °C which was attained in less than 60 mins and was distinct from that of 1000g and 1500g with pyrolysis temperature of 275 and 220 °C, respectively (Fig.4). This result shows that the pyrolysis time and product temperature is characterized by the quantity of PKS pyrolysed.

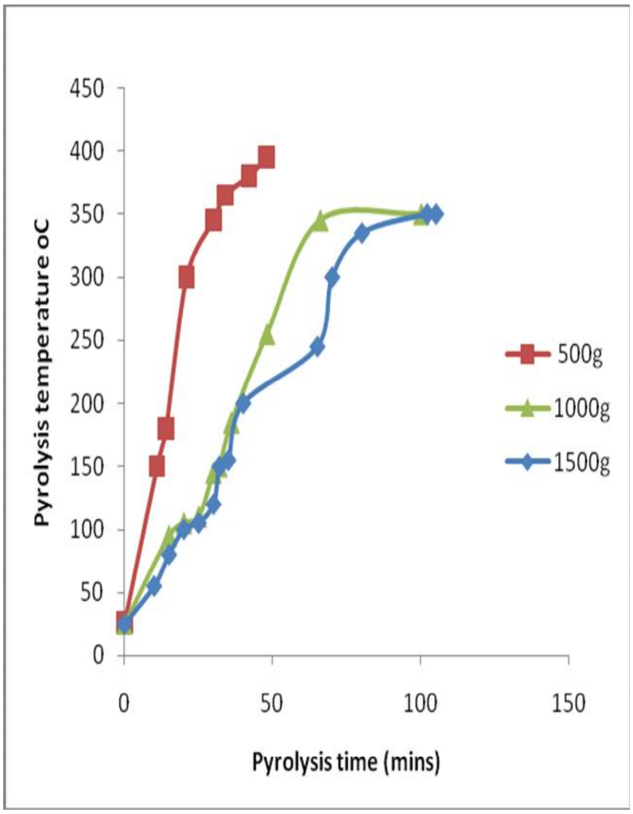

Fig 4: Variation of product temperature and pyrolysis time on the quantity of palm kernel shell (Dura)

3.1.4 Variation of Volume of Liquid Produced with Respect to Pyrolysis Time and the Quantity of Palm Kernel Shells (Dura)

Fig. 5 shows the variation of liquid fuel produced with respect to pyrolysis time using different quantity of Dura palm kernel shell. The volume of liquid fuel produced increased with increase in pyrolysis time. As expected, the volume of liquid produce increase with increase in mass of Palm Kernel Shell and pyrolysis time/

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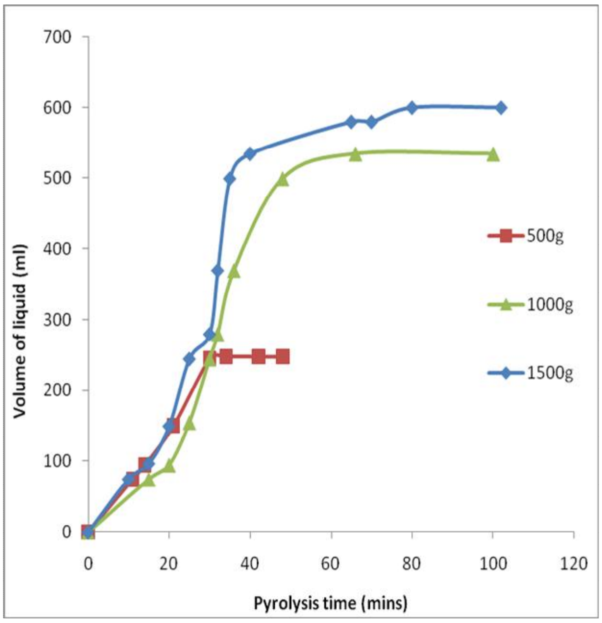

Fig 5 Variation of volume of liquid produced with respect to pyrolysis time and the quantity of palm kernel shells (Dura)

3.1.5 Percentage Product Yield of Products from Palm Kernel Shells.

Table 1 shows the yield of char, oil and water during the pyrolysis of different mass of Dura PKS. Pyrolysis products showed increased char, oil and water with respect to increased masses of (500, 1000 and 1500g) Palm Kernel Shells while the percentage fuel oil yield was reduced with increase in the mass of PKS. In respect to mass of fuel oil, water and charcoal produced, it was worthwhile using 1000 g in this experiment since the percentage product was at highest value in this gram. Moreover, Table 1 showed that increase in mass did not affect the fuel yield and % water content obtained after separating the fuel oil from the liquid obtained during pyrolysis. The % non-condensable gases were small in comparison with other by products.

Table 1 Percentage yield of products from pyrolysis of palm kernel shells

Mass of PKS (g)	Fuel yield (%)	Water content (%)	Char yield (%)	Non condensable gas (%)
500	28.90	43.20	27.00	0.90
1000	36.65	41.02	22.21	0.08
1500	36.65	40.09	23,10	0.26
1000000	36.75	40.08	22.99	0.10

3.1.6. Specification of Design of pyrolyser

The reactor was designed to process 1000kg/day. The reaction stoichiometry, material and energy balances were prepared to specify the input quantity and to know the expected output products.

The data obtained from Table 1 were used to obtained the conversion of char, oil and water and from the kinetics/mathematical model developed in section 3 the rate constants were obained further from pyrolysis of 1000kg/day of palm kernel shells. A computer program was written for this design and scale up using some dimensionless factors and constants obtained from literature to design batch reactor-pyrolyzer of 1000kg/day to process Palm Kernel Shells. Data obtained at laboratory scale, and data obtained from literature and other parameters mentioned in section 3, were also used to obtain the height, diameter and volume of the reactor. Table 3 shows the final specifications of pyrolyzer for 1000kg/day of Palm Kernel Shells.

Table 2: Final design specifications of pyrolyzer for 1000kg/day capacity size of palm kernel shells

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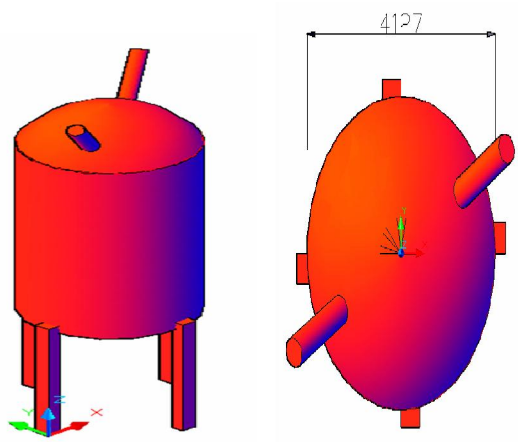
Specifiations of the Reactor	Dimension	Unit
Height	8.15402	m
Diameter	4.07701	m
Volume	107.1429	m^3
Heat Required for pyrolysis	14,025	kJ/hr
Internal Temperature (T_{ai})	723	K
Outside Temperature T_{out}	378	K
Stainless steel thickness (ℓmm)for internal	5	mm
Mild Steel Thickness(ℓmm) for external	5	mm
Constant K_O for Oil	1.53×10^{-4}	s^{-1}
Overall Constant K	3.17×10^{-4}	s^{-1}
Lagging Insulating Thickness thickness	0.10	m
Thickness of cover Plate	5	mm
Lagging Material Material of Construction	-	glass wool
internal Resistance R_1 for Hot Air	2.51×10^{-4}	K/W
Resistance R_2 for internal Stainless Steel Material	2.798×10^{-6}	K/W
Resistance R_3 for the Insulating Material thickness	2.3194×10^{-3}	K/W
Resistance R_4 for Mild Steel Thickness	1.904×10^{-4}	K/W
Resistance R_5 for the Air Surrounding the Reactor	6.0265×10^{-4}	K/W
Total resistance R_T across the reactor thickness	3.578×10^{-3}	K/W

The volume of the reactor was found to be $107.1429m^3$,the height of the reactor was obtained to be 8.15402m, the diameter was calculated to be 4.07713m while the lagging thickness for conserving the heat was found to be 0.10m. The cross-sectional view, the first angle autographic view, the exploded view and the 3d model of the complete pyrolyzer batch reactor design are shown in Figures 6.

The materials of construction for this design was obtained from literature to be stainless with internal of 0.005m thickness, glass wool for insulating/lagging material and mild steel of 0.005m thickness for covering of lagging externally



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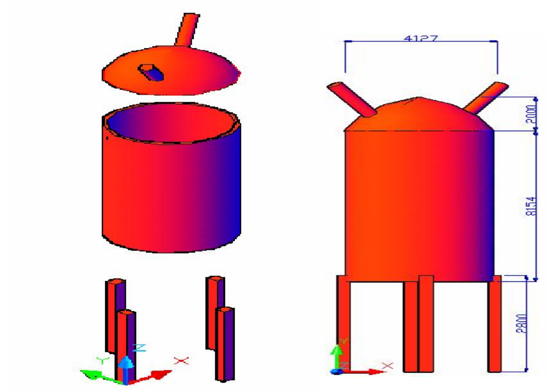

Fig 6: 3D and first angle autographic view of the batch reactor for PKS.

4. CONCLUSION

The Design of pyrolyser for pyrolysis of palm kernel shells was investigated. The quantity of PKS pyrolysed affects the pyrolysis temperature and time. The volume of reactor required to pyrolyse 1000kg/day of palm kernel shells was found to be 107.143m^3. The thickness of reactor was 5mm and material of construction of stainless steel and the lagging thickness of 0.1m. The height of the reactor was found to be 8.15403m with the diameter of 4.0771m. The decomposition reaction constant k_{oil} of the fuel oil obtained was determined to be $1.153 \times 10^{-4} s^{-1}$ and the overall constant k was calculated to be $3.17 \times 10^{4} s^{-1}$. Energy requires to pyrolyse the PKS was 841500kJ. The reactor temperature was 723K while the outside temperature was 378K. Total heat transfer resistances R_1, R_2. R_3, R_4, and R_5 across the reactor cross section were found to be; 2.51×10^{-4} K/W, 2.798×10^{-6} K/W, 2.3194×10^{-3} K/W, 1.904×10^{-4} K/W and 6.026×10^{-3} K/W, 1.904×10^{-3} K/W, 1.904×10^{-4} K/W and 6.026×10^{-3} K/W respectively The results obtained from this work can be used to scale up design of pyrolyser for production of fuel oil from palm kernel shells.

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REFERENCES

Acikgoz, C., Onayio, A. & Okockar O. M. (2004). Fast Pyrolysis of Linseed: Product Yields and Compositions. *Bioresource Technology,*71 (2), 417 – 429.

Ademiluyi, F. T. (2016a). Development of Software for Design and Construction of Rotary Dryer for Drying Ground Cassava. *An International Journal of Engineering Technology,* 6 (8), 261-264.

Ademiluy, F.T **&** Alex, A. (2016b). Batch Adsorption Kinetics of Zinc Ions Using Activated Carbon from Waste Nigerian *Bamboo International Journal of Engineering and Applied Sciences* 3(1) 95-99.

Ademiluyi, F. T & Nze, J. C. (2016c) Sorption Characteristics for Multiple Adsorption of Heavy Metal Ions Using Activated Carbons from Nigerian Bamboo. *Journal of Materials Science and Chemical Engineering*, 4(4) 39-48.

Ademiluyi, T. & Adebayo, T.A. (2007). Fuel Oil from Pyrolysis of Waste Polyethylene Sachets *Journal of Applied Sciences and Environmental Management.* 71(2), 21-26.

Ademiluyi, T., & Akpan, C. (2007). Preliminary Evaluation of Fuel Oil Produced from Pyrolysis of Waste Water Sachets, *Journal of Applied Sciences and Environmental Management,* 11 (3), 127-131.

Ashok, P. (2008). *Handbook of Plant-Based Biofuels.* U.S.A: CRC Press Taylor & Francis Group.

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Camila, S., Canabarro, N. & Chayene, G. (2013). Thermochemical Process for Biofuels Production from Biomass. United Kingdom: Licensee Chemistry Central ltd.

Cunningham, M. A. & Cunningham, W. P. (2006). *Principles of Environmental Science Enquiry and Applications* (3rd Edition). New York: McGraw-Hill Science/Engineering.

Fono-Tamo, R. S & Koya, O. A. (2013) Characterisation of Pulverised Palm Kernel Shell for Sustainable Waste Diversification. *International Journal of Scientific & Engineering Research*, 4, 4- 6.

Kalyana, C..P, David, A. R.& Shuguang D (2005). Silver Nanoparticles from Ultrasonic Spray. Pyrolysis of Aqueous Silver *Nitrate Aerosol Science & Technology,* 39:1010 – 1014.

Natthaya, P., & Chaiyot, T. (2013). Product Characterization and Kinetics of Biomass Pyrolysis in a Three-Zone Free-Fall Reactor. *International Journal of Chemical Engineering*. 20(14),1-10.

Octave, L. (2007). *Chemical Reaction Engineering*. (3rd Ed.), John Willey & Sons (Asia) Pte Ltd, Singapore.

Perry, R. H., & Green, D.W. (2008). *Perry's Chemical Engineer's Handbook*, New York: McGraw Hill, Professional Publishing.

Octave, L. (2007). *Chemical Reaction Engineering*. Singapore, (3rd Ed.) Singapore: John Willey & Sons (Asia) Pte Ltd.

Sinnolt, R. K. & Galvin, T. (2013). *Coulson and Richardson's Chemical Engineering Design.* New York: John Willey & Sons Inc.

Song, Y. L, Tsai, S. C, Chen C.Y, Tseno, T.K, Tsai C.S, Chen, J. W. & Tao T.D. (2004). Ultrasonic Spray Pyrolysis for Synthesis of Spherical Zirconia Particles. *Journal of the American Ceramic Society*, 87(10), 1864-1879.

Tasi, W.T., Lee, M. K & Chang, Y. M, (2007). Fast Pyrolysis of Rice Husk: Product yields and Compositions. *Bioresource Technology*. 981, 22 – 28.

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