

Original Research Article

Performance and Thermal Efficiency Parametric Design of an Energy Efficient Rotary Furnace

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Abstract: A review of works on rotary furnace was handled and this provokes ingenuity in this paper to consider all parameters necessary to design and developed an energy efficient rotary furnace. High insulation bricks, low speed of rotation, fuel type and its calorific value, flame stability and flame length, burner type, geometry of the rotary drum, recuperation and absence of pulsating flow nature from blower due to power fluctuation are all considered for the design of an energy efficient rotary furnace.

Keywords: design, operating parametric factors, thermal efficiency and performance, energy efficient rotary furnace.

INTRODUCTION

Rotary furnaces are good examples of fuel-fired furnace. Rotary furnaces should be harnessed because they form bases for melting of scraps of iron or steel and aluminum recycling. The sizes vary based on demand. They could form back bone of local foundries and manufacturing for a techno-economic purposes in developing nations like Nigeria. Basically, a furnace is a brick-lined chamber, capable of holding/conveying the material to be treated, to which heat is applied by one of various means so as to achieve the required final results [1]. Quite a large number of rotary furnaces are found to perform below the expected capacity, most especially in terms of thermal efficiency, mainly because of non-standardization of designs and more often than not, non-inclusion of a heat exchanger [2]. This paper therefor found it necessary determine most parametric factors as the operating conditions that can favour the achievement of an energy efficient rotary furnace. A great deal of heat energy is lost during the operation of rotary furnaces. This paper focuses on the parameters that can improve the thermal efficiency and performance of the rotary furnace. Maximum heat utilization in the rotary furnace is favoured through its shape orientation, rotatory speed, insulation, recuperation, flame length and flame stabilization, type of fuel used and non-pulsating flow of air from the centrifugal blower.

ENERGY EFFICIENT ROTARY FURNACE

An energy efficient rotary furnace should ensure that the heat flow to the surface of scraps of metals is at its maximum and that it can be absorbed completely. These factors considered are such that:

- a. The geometric orientation should influence
 - I. Vigorous circulation: - hot air stream and gases in the furnace chamber should be made to circulate vigorously, mainly under the action of air fuel jets from burners.
 - II. complete combustion:- Fuel should be burned completely and combustion should occur within the furnace space where possible.
 - III. Pressure difference:- The design of a pressure conditions in the furnace should be such as to minimize the contact of furnace atmosphere with the surroundings [3].
- b. Fuel type, burner type and flame utilization
 - I. The temperature difference between the heating medium and heated surfaces should be as high as possible.
 - II. The furnace should be supplied with heat extensively with the maximum heat utilization within the furnace space.

DESIGN

Methodology

The design was detailed following the design considerations. The design was done with CAD using solid works 2013 and certain assumptions are made in the design calculations and analysis.

Design Considerations

Following the frame work of this paper , the design considerations are; High insulation bricks ,low speed of rotation, fuel type and its calorific value, flame stability and flame length, burner type, geometry of the rotary drum, recuperation and absence of pulsating flow nature from blower due to power fluctuation.

Assumptions

1. Linings: the bricks are assumed to be isotropic and made from locally sourced red clay.
2. No pulsating flow: steady flow of gases, flame etc.
3. Steady speed of rotation: low but steady speed of rotation
4. Heat transfer mode: The assumption made in heat transfer modes which has major influence on the thermal efficiency and performance of the furnace are;
 - a. The heat flow transferred from the gases to furnace lining by convection is taken to be equal the heat flow given up by the lining to the surrounding. This last assumption makes it possible to regard the lining as adiabatic relative to the radiant flux falling onto it [1].
 - b. The temperature and radiation characteristics of the gases in the furnace surfaces are taken to be constant over the whole furnace volume
 - c. The temperature in various parts of metal surface is assumed to be constant and uniform.

ANALYSIS

Geometry

The geometry of the rotary furnace is investigated to affect the flow of hot air stream, gases and their vigorous circulation in the furnace chamber. This goes a long way to affecting the heating and thermal capacity of the furnace. The shape configuration manages the heat loss by minimizing flow rate of these gases through pressure gradient across the entire volume of the rotary drum. The geometry described by two cones and a cylinder that is the heart of the rotary drum where melting takes place. the inlet cone where firing nozzle is positioned, determined the spread of the flame, circulation of hot gases since it is a diverging cone, hence it is called the megaphone with reduced speed to build up pressure.it is determined in the work of Asha Saturday *et al* [4] to be longer than the exit cone whose function is to reduce pressure and increase flow velocities described with sharp slant sides. The ratio of inlet and exit cones length are dependent on the volumetric diameter of the cylinder (melting chamber) or belly

$$0.65 \leq \frac{L_{exit}}{L_{inlet}} \geq 0.58 \quad (1)$$

L_{exit} =exit or exhaust cone length, L_{inlet} is the inlet cone length(mega phone) [4].

Insulation

Lining the internal walls of the furnaces thermal facilities becomes important to save and reduce the influence of the thermal stress and pressure loads from these restrained components. Lining also prevents the shell from melting and conserve heat for the primary function of melting of the scraps. The performance of lining like the local red clay depends on its particle size that affects the density, the level of compression force, firing temperature and resident time during the brick manufacturing process and its thickness

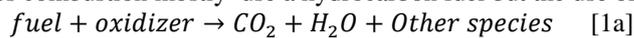
Fuel And Fuel Type

Depending on many factors, certain types of fuels are preferred for certain geographic locations due to cost and availability considerations. Fuels also vary depending on the application. Gaseous fuels — particularly natural gas — are commonly used in most industrial heating applications in the U.S. In Europe, natural gas is also commonly used, along with light fuel oil. In Asia and South America, heavy fuel oils are generally preferred although the use of gaseous fuels is on the rise. In Nigeria, most foundry operation are heated using condemned oils or diesel, for reason of cost effectiveness and it availability. Fuel choice has an important influence on the heat transfer from a flame. In general, solid fuels like coal and liquid fuels like oil produce very luminous flames that contain sooth particles that radiate like blackbodies to the heat load. Gaseous fuels like natural gas often produce nonluminous flames because they burn so cleanly and completely, without producing sooth particles. A fuel like hydrogen is completely nonluminous, as there is no carbon available to

produce soot. In cases, where highly radiant flames are required, a luminous flame is preferred. In cases where convection heat transfer is preferred, a nonluminous flame may be preferred in order to minimize the possibility of contaminating the heat load with soot particles from a luminous flame. Where natural gas is the preferred fuel and highly radiant flames are desired, new technologies are being developed to produce more luminous flames. Therefore, the fuel itself has a significant impact on the heat transfer mechanisms between the flame and the load. The heat value of the fuel is a factor besides its availability. The waste liquids are fed through the burner, which is powered by a traditional fuel such as natural gas or oil. The waste liquids often have very low heating values and are difficult to combust without auxiliary fuel. This further complicates the burner design where the waste liquid must be vaporized and combusted concurrently with the normal fuel used in the burner.

Combustion And Its Chemistry

Combustion is said to be the controlled release of heat and energy from the chemical reaction between a fuel and an oxidizer. This is contrary to a fire or explosion which are usually uncontrolled and undesirable. The industrial processes combustion mostly use a hydrocarbon fuel but the use of coal in some furnaces like copula type.



The “other species” depends on what oxidizer is used and what is the ratio of the fuel to oxidizer. 79% N₂ by volume is normally carried through in the combustion process. The exhaust gas composition is very important in determining the heat transfer in the system.

Unburned hydrocarbons in the exhaust indicate that the fuel was not fully combusted and therefore not all of the available heat was released. High excess O₂ levels in the exhaust usually indicate that too much oxidizer was supplied. The excess oxidizer carries sensible energy out the exhaust, which again means that some of the available heat of the fuel was not fully utilized to heat the load.

Recuperative Air and Fuel Preheat Temperature

Heat is recovered to improve the overall thermal efficiency of the process to reduce operating costs. The recovered heat is most commonly used to preheat the incoming combustion air and is sometimes used to preheat the incoming fuel. Preheating either the air or the fuel affects the composition of the combustion products. This recuperative process is geared to enhance and maximize heating ,thermal efficiency and performance of the furnace .it is a heat exchanger for of design where air is drafted through an outer concentric duct and hot flues escaping through the inner pipe.

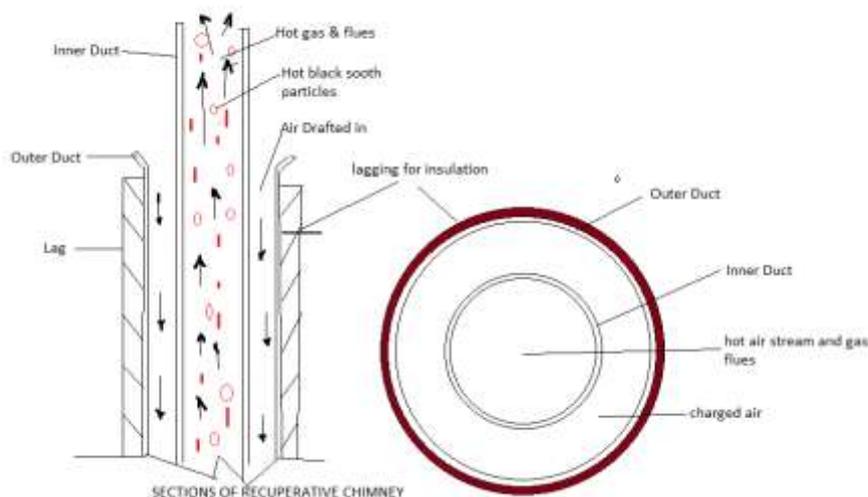


Fig-1: Section of a recuperative chimney

A recuperator is a low- to medium-temperature continuous heat exchanger that uses the sensible energy from hot combustion products to preheat the incoming combustion air. The temperatures ranges are up to 1300°F, or 700°C. These heat exchangers are commonly counter flow, where the highest temperatures for both the combustion products and the combustion air are at one end of the exchanger with the coldest temperatures at the other end. Lower temperature

recuperators are normally made of metal, while higher temperature recuperators may be made of ceramics. Recuperators are typically used in lower temperature applications because of the limitations of the metals used to construct these heat exchangers.

Burner

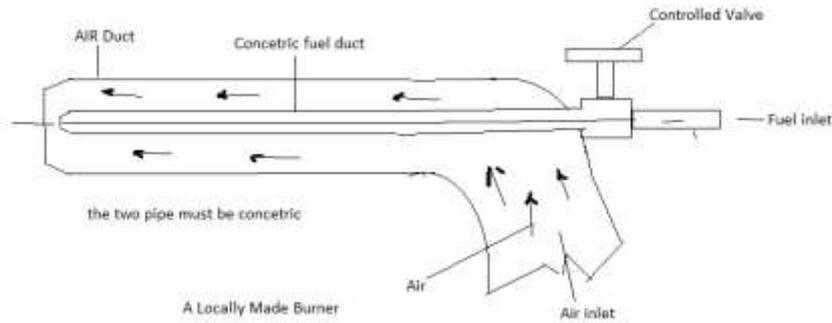


Fig-2: A Sketch Of A Burner

The burner is the device used to combust the fuel, with an oxidizer to convert the chemical energy in the fuel into thermal energy. A given combustion system may have a single burner or multiple burners, depending on the size and type of the application. There are many types of burner designs that exist due to the wide variety of fuels, oxidizers, combustion chamber geometries, environmental regulations, thermal input sizes, and heat transfer. The heat from the burner radiates in all directions and is efficiently absorbed by the load. However, the cylindrical geometry has some limitations concerning size and load type that make its uses limited to certain applications such as melting scrap aluminum or producing cement clinker. The majority of industrial burners use air for combustion

Burner Design Consideration and type

The design factors to consider in burners designs are, certain types of fuels are preferred for certain geographic locations due to cost and availability considerations, the staging or mixing. burners types are simply shown at a glance diagrammatically as given

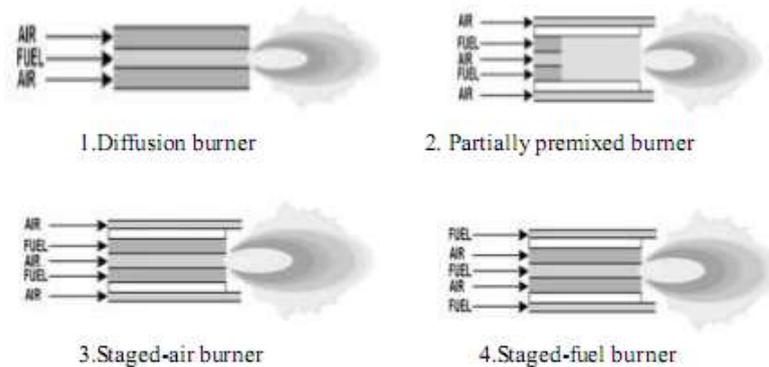
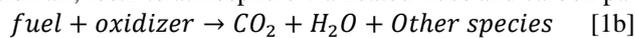


Fig-3: Type of burners

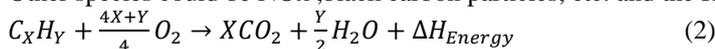
KINETICS IN THE DESIGN

i. Heat Generation

Heat release Q_g during combustion is a sum of the heat required to melt the metal scraps, absorbed by lining, preheating combustion air, lostn to atmosphere via heated flues and carbon particles and to lagging. From combustion



Other species could be NOx ,black carbon particles, etc. and the Heat Energy released. For hydrocarbon fuel



ΔH_{Energy} = the energy generated

if the energy generated is the quantity of heat required Q_g that is the heat released

$$Q_g = Q_{melt} + Q_{rad} + Q_{ins} + Q_{car} + Q_{rec} + Q_{lag} + Q_{atm} \quad (3)$$

ii. HEAT ENERGY ANALYSIS

a. Q_{melt} this is the heat required to melt scraps of metal with M mass

$$Q_{melt} = MC_{Pm}\Delta T + ML \quad (4)$$

b. Q_{rad} is the Heat of exothermic reactions, which is the heat liberated through oxidation of metal. 5652KJ/kg

$$Q_{rad} = 5652 \times M \times x\% \text{ of oxidation lost of the iron} \quad (5)$$

where M = mass of the scraps (kg)

this should be noted that it a heat generated in addition to the original heat generation by combustion since it is exothermic.

c. Q_{rec} as the recuperative heating

$$Q_{rec} = \dot{m}C_{Pa}T_aV_a n_f \quad (6)$$

\dot{m} is the flow rate (Kg/hr), T_a is temperature of preheated air ($^{\circ}C$), C_{Pa} = specific heat capacity of air at T_a (KJ/m³ $^{\circ}C$), n_f is the air excess factor, V_a is quantity of air theoretically required to burn a unit of fuel (m³/kg).

d. Part of the recuperative air is used to preheat the incoming fuel in the burner which improves its atomization and closer to gaseous state

hence the heat becomes

$$Q_{fuel} = \dot{m}C_{Pf}T_f \quad (7)$$

C_{Pf} is the specific heat capacity of preheated fuel (KJ/kgK), T_f is temperature of preheated fuel (K).

e. Q_{atm} is the LOST to atmosphere by waste gases and carbon particles

$$Q_{atm} = \dot{m}C_{Pg}V_gT_g \quad (8)$$

C_{Pg} = mean specific heat of waste gases (KJ/m³ $^{\circ}C$), V_g = quantity of the waste gases in a unit mass of the fuel (m³/kg), T_g = temperature of the waste gases ($^{\circ}C$).

f. Heat losses by conduction through the lining is the insulation heat absorbed by the bricks Q_{ins}

$$Q_{ins} = \frac{\pi K_L(r_{is}+r_{ib})(T_{ib}-T_{is})(L_c+L_{sl})}{r_{is}-r_{ib}} \quad (9)$$

K_b = thermal conductivity of the bricks lining (W/mK), r_{is} = junction radius = internal radius of the shell without the lining (m), r_{ib} = internal radius of the shell with the lining (m), T_{is} = average temperature in the furnace (K), T_{ib} = outside (surface) temperature of the shell (K), T_0 = room temperature (K), L_c = length of the cylindrical shell (m), L_{sl} = slant length of the conical frustum (m)

g. Average Temperature Difference in the furnace chamber

Using the logarithmic mean temperature difference (LMTD) approach (Kern 1984)

$$\Delta t_{avCHAMBER} = \frac{(t_f^{in}-t_g^{in})-(t_g^{out}-t_{am}^{out})}{\ln\left[\frac{t_f^{in}-t_g^{in}}{t_g^{out}-t_{am}^{out}}\right]} \quad (10)$$

h. Average Temperature Difference in the Recuperator

logarithmic mean temperature difference (LMTD) approach(Kern 1984) still in use here

$$\Delta t_{avRECUPERATOR} = \frac{(t_g^{in}-t_{am}^{in})-(t_g^{out}-t_{am}^{out})}{\ln\left[\frac{t_g^{in}-t_{am}^{in}}{t_g^{out}-t_{am}^{out}}\right]} \quad (11)$$

i. Waste Heat

This is the unaccounted energy wastes and are minimal base on the recuperator. These comprised the heat from fumes of coating of the scraps, carbon particles, and flue gases and infiltration between the furnace and the recuperative sprout.

Heat losses by radiation through exhaust end of the chimney of the furnace

$$Q_{EX} = \epsilon_0 (T_{av\ CHAMBER}/100)^4 A \theta t_{op} \tag{12}$$

ϵ_0 = emissivity of a black body = 50768 W/m²K⁴

A = surface area of open door (m²)

θ = diaphragming coefficient ≈ 0.67

t_{op} = time of melting operation (h)

j. Convection

Convection heat transfer is caused by fluid motion past a material, where the fluid is either at a higher or lower temperature than the material. In industrial combustion applications, the fluid is usually at a higher temperature than the medium it is heating. At least one person has argued that convection is not actually a separate mode of heat transfer, but that it is a subset of conduction because the energy must still conduct from the fluid to the material. This may true on a microscopic scale in the boundary layer next to the material, convection is a fundamentally different process from conduction and is treated here as such, which is the convention in standard heat transfer texts. Forced convection is often a very important mode of heat transfer in industrial combustion systems.

Forced convection

Forced convection heat transfer occurs when a fluid is at or over a medium (liquid or solid)

$$q = hA(T_f - T_m) \tag{13}$$

where q is the heat flux to the medium (kW), his the convective heat transfer coefficient W/m²-K, A is the surface area of the medium in contact with the moving fluid, T_f is the fluid temperature (K), and T_m is the temperature (K) of the Lining of the furnace

Forced Convection from Flames

In most conventional furnace heating processes, forced convection is only a small fraction of the total heat transfer to the scraps. Most of the heating emanates from the radiation from the hot refractory walls (linings). However, in flame impingement, with no furnace enclosure, forced convection may be 70% to 90% of the total heat flux [5, 6]. For flame temperatures up to about 2600°F (1700K), forced convection is the dominant mechanism in flame impingement heat transfer [7]. For low-temperature flames, as is common in air/fuel combustion systems, forced convection has generally been the only mechanism considered. In highly dissociated oxygen/fuel flames, a large fraction of the heat release is from exothermic reactions from radiations. Laminar flames have been used in many flame impingement studies [8-18]. Sibulkin developed a semi analytical solution for the heat transfer for laminar flow, normal to the stagnation point of an axisymmetric, blunt-nosed target [18];

$$q_s'' = 0.763(\beta_s, \rho_e, \mu_e)^{0.5} Pr_e^{-0.6} C_{Pe} (T_e - T_w) \tag{14}$$

But the Turbulent flames have also been commonly used [19-22]. A typical example of an empirical equation, incorporating the turbulence intensity Tu, was given by Hustad [22] as Turbulent flames have also been commonly used [19-22]. A typical example of an empirical equation, incorporating the turbulence intensity Tu, was given by Hustad [22]

$$q_s'' = \frac{k_e}{d_b} \left\{ 0.41 Re_{b,e}^{0.6} Pr_e^{0.35} Tu^{0.15} \left(\frac{Pr_e}{Pr_w} \right)^{0.25} \right\} (T_e - T_w) \tag{15}$$

k. Radiation

Thermal radiation is one of the most significant heat transfer mechanisms in industrial furnaces, radiation is a unique method of heat transfer as no medium is required for energy transport — it can be transmitted through a vacuum . Radiation is simply the transmission of energy by electromagnetic waves, which are characterized by their wavelength or frequency governed by:

$$\lambda = \frac{c}{\nu} \tag{16}$$

Where, λ is the wavelength, c is the speed of light, and ν is the frequency.

The radiation can be absorbed, reflected, transmitted, or some combination of these three which is most often .
 $\alpha + \rho + \tau = 1$ (17)

where α is the absorptivity of the medium, ρ is the reflectivity, and τ is the transmissivity, For most solid materials, the transmissivity is low except for materials like glass and plastics. The reflectivity of most solids is low, unless they are highly polished (e.g., new stainless steel). For liquids, the transmissivity may be significant, especially for fluids with high water contents. For most gases, the transmissivity is generally very high with negligible absorptance and reflectance. These radiative properties are extremely important in determining how much radiation will be transferred to and from a medium. This is further complicated by the fact that these radiative properties may be functions of wavelength, angle of incidence, surface condition, and thickness. There are three common forms of radiation heat transfer in industrial heating applications: (a) radiation from a solid surface, (b) radiation from a gaseous medium (usually referred to as nonluminous radiation), and (c) radiation from particles in a gaseous medium (usually referred to as luminous radiation)

$$q_1 = \sigma A \epsilon_f T_f^4 \tag{18}$$

where σ is the Stefan–Boltzmann constant (see Eq. 18), ϵ_f is the average flame emissivity, A is the area radiating, and T_f is the average absolute flame temperature . the radiation from the flame with a hot blackbody background (furnace wall) is measured:

$$q_2 = \sigma A \epsilon_f T_f^4 + \sigma A (1 - \alpha_f) T_w^4 \tag{19}$$

where α_f is the average flame absorptivity and T_w is the average wall temperature. Finally, the radiation from the hot blackbody background (furnace wall) is measured immediately after the flame is extinguished:

$$q_3 = \sigma A T_w^4 \tag{20}$$

The flame is assumed to be a gray body so that:

$$\alpha_f = \epsilon_f \tag{21}$$

From the above equations, the flame emissivity ϵ_f

$$\epsilon_f = 1 - \left(\frac{q_2 - q_1}{q_3} \right) \tag{22}$$

flame temperature T_f

$$T_f = \left(\frac{q_1}{\sigma A \epsilon_f} \right)^{1/4} \tag{23}$$

Lowes and Newall [23] agued that there are shortcomings with this approach because:

- i. The absorptivity of the flame is not equal to the emissivity unless the blackbody source is at the flame temperature.
- ii. The emissivities obtained assume a gray body, which is normally not strictly true.
- iii. Soot particles in the flame can cause radiation scattering, which may give high absorptivity values

The radiation from the flame was then the difference between that total radiation and the wall:

$$q_{rad,total} = K q_{rad,walls} + q_{rad,flame} \tag{24}$$

Emissivity of most materials surfaces is a function of temperature

Radiation Between Surfaces

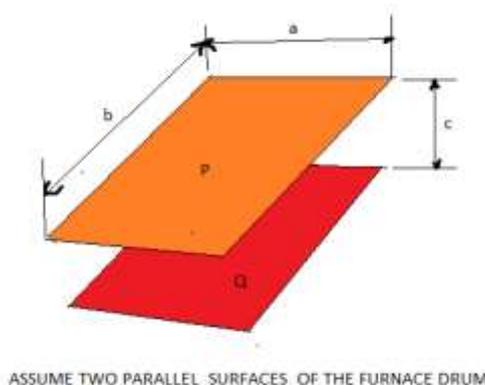


Fig-4: Radiative surfaces

The net radiant heat transfer from one surface to another can be calculated from:

$$q_{P \leftrightarrow Q} = \sigma A_P F_{P \rightarrow Q} (T_P^4 - T_Q^4) = \sigma A_Q F_{Q \rightarrow P} (T_P^4 - T_Q^4) \quad (25)$$

where $q_{P \leftrightarrow Q}$ is the net energy transferred between surfaces 1 and 2, $F_{i \rightarrow j}$ is the view factor or radiation shape factor, which is the diffuse radiation leaving surface i and received at surface j , and due to the reciprocity theory. From the definition of the view factor as the fraction of the total energy radiated by surface Q which is intercepted by surface P , an enclosed surface i gives the identity, then it becomes

$$\sum_K F_{i,j} = 1 \quad (26)$$

where the surfaces j are all the other surfaces which enclose surface i

$$A_P F_{P \rightarrow Q} = A_Q F_{Q \rightarrow P} \quad (27)$$

The view factor between two identical, parallel, directly opposed rectangle is described by the equation

$$F_{P \rightarrow Q} = F_{Q \rightarrow P} = \frac{2}{\pi XY} \left\{ \ln \sqrt{\frac{(1+X^2)(1+Y^2)}{1+X^2+Y^2}} + X\sqrt{1+Y^2} \tan^{-1} \frac{X}{\sqrt{1+Y^2}} + Y\sqrt{1+X^2} \tan^{-1} \frac{Y}{\sqrt{1+X^2}} - X \tan^{-1} X - Y \tan^{-1} Y \right\} \quad (28)$$

where $X = a/c$, $Y = b/c$, $a =$ length of the rectangles, $b =$ width of the rectangles, and $c =$ spacing between the parallel plates surfaces. The value calculated is traced out from the view factors tables that will be used for further calculation.

1. Recuperation

Preheating the air and the fuel become vital for effective combustion and heating. The design and analysis of a recuperative chimney is thoughtful for heating maximization and loss reduction. Consider the following assumptions, that no infiltration in the recuperator to assume it is air tight, and that 5% of the heat escaping from the exhaust end of the furnace into the recuperative chimney is lost to atmosphere

$$(1 - 0.05)V_g(C_{Pg}^{in}T_g^{in} - C_{Pg}^f T_g^f) = V_a(C_{Pa}^f T_a^f - C_{Pa}^{in} T_a^{in}) \quad (29)$$

$V_g =$ Volume of exhaust gases, $C_{Pg}^{in} =$ specific heat capacity of the inlet exhaust gases, $T_g^{in} =$ inlet exhaust gases temperature, $C_{Pg}^f =$ final specific heat capacity of the gases at exit of the chimney plume of the air., $C_{Pa}^f =$ final specific heat capacity of the air at entrance of the blower to the burner, $T_a^f =$ final temperature of the air at entrance of the blower to the burner, $C_{Pa}^{in} =$ specific heat capacity of the air at inlet of the top of the chimney, T_a^{in} is temperature of inlet air, $T_g^f =$ final temperature of exhaust gases at exit of the chimney., $V_a =$ velocity of the air at inlet of the top of the chimney.

This govern the heat exchange between the incoming air and the exhaust gases. Only at the inlet sprout of the chimney is lagged with clay and the external duct is lagged with 10mm thick clay, at box there are heat exchanging tubes with pressure drop.

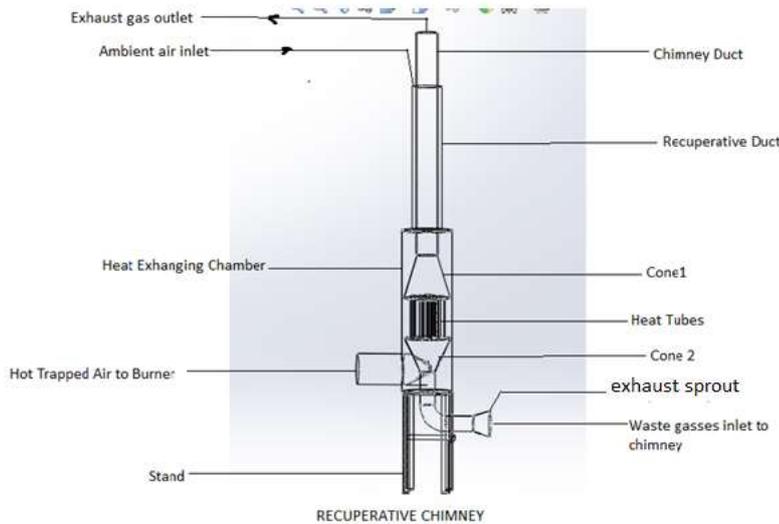


Fig-5: Recuperative chimney

Volume of the Chimney

Longer pipe

Volume of a cylinder V_c

$$V_c = \pi r^2 h \tag{30}$$

Volume of 10 heat tubes

$$V_{ht} = \pi r_{ht}^2 h_{ht} \tag{31}$$

Volume of the cones

$$V_{con} = \frac{1}{3} \pi r_{con}^2 h_{con} \tag{32}$$

the frusta rule should be followed since both cones are truncated

External Shell

Two cylinders are involved

The inner volume the shell considering the two

$$V_T = \pi(r_B^2 h_B - r_A^2 h_A) \tag{33}$$

The volume of the heated or recuperative air is approximately

inner volume of the external shell – volume of the chimney enclosed by it

The intensity of radiative heat transfer to this volume of air is a function of the temperature of the external chimney surface area, the total surface area of the chimney exposed to this air and the material thermal conductivity as well as its thickness. The amount of heat energy possessed by this air is a function of all previously mentioned and the ambient conditions of the air.

J. Other Factors

The speed of rotation is a prevalent factor that can affect the resident time under normal conditions assuming other factors are perfect. Low speed are seem to be favourable for improve resident time as it promote effective melting. Non-pulsating flow as it affects the stability of flame should be avoided by ensuring and guarding against voltage fluctuation and unbalance impellers of the centrifugal blower.

MODELS

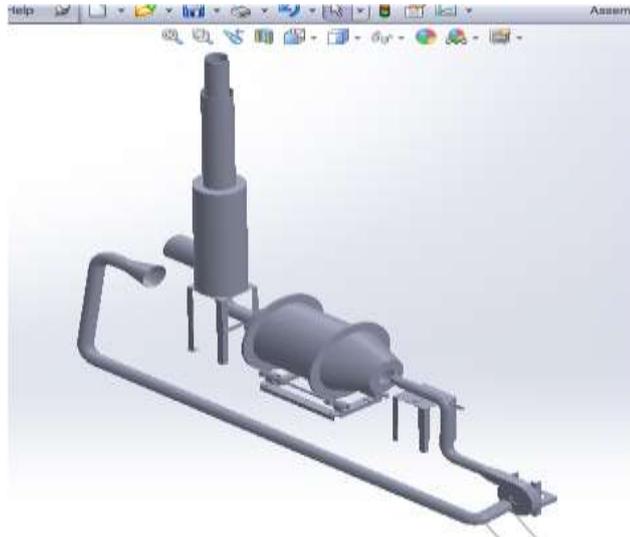


Fig-6: 3-D (Isometric) View

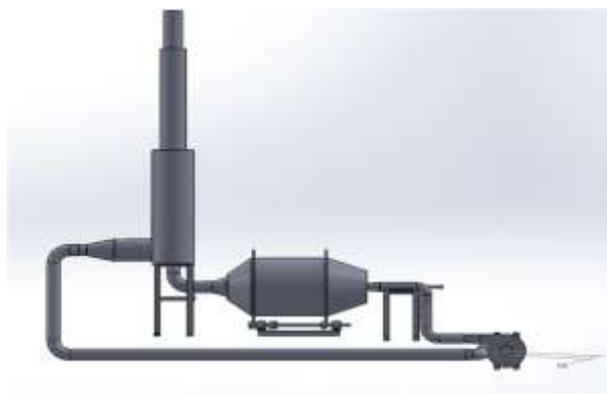


Fig-7: 2-D view of the solid form of rotary furnace

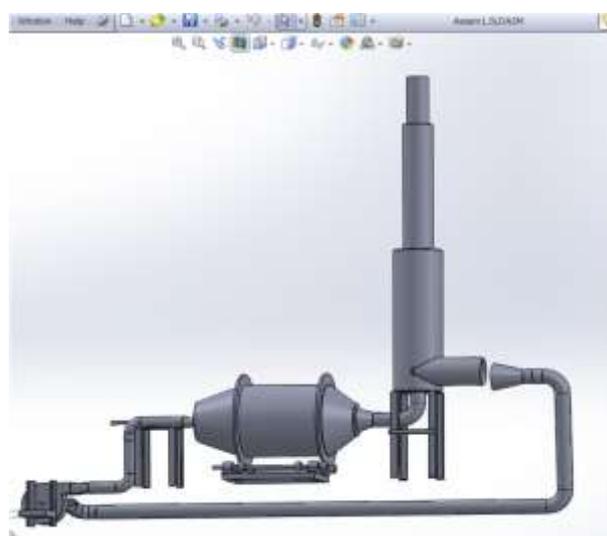


Fig-8: Left side of the model

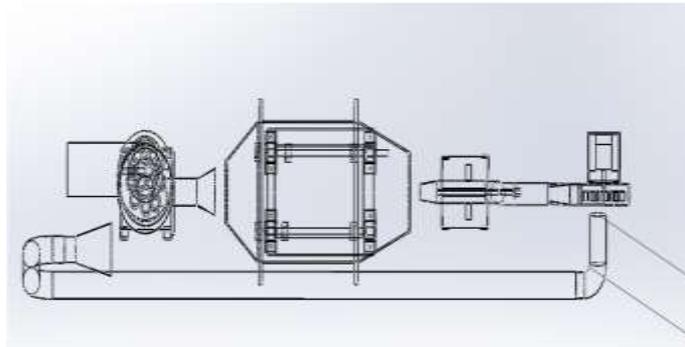


Fig-9: Top view

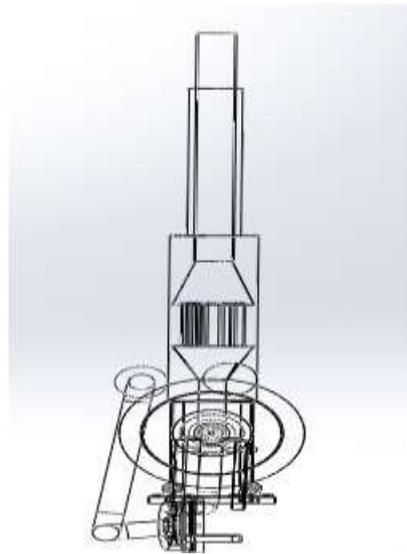


Fig-10: Front View

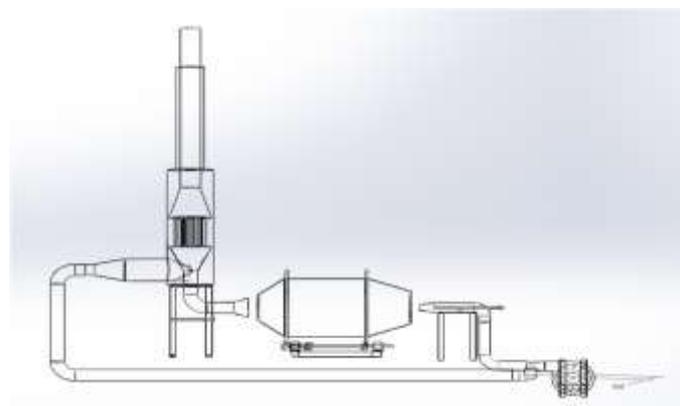


Fig-11: Side View

DISCUSSION

Rotary furnace like other furnaces need to be lagged or insulated with clay, bricks or fibre glass when available and necessary, this there for shield the shell and other metal parts from effect of severe thermal environment under their restrained condition that could lead to deformation of the shell. Hence proper insulation helps to improve thermal efficiency and performance of the furnace and keep the useful life of the furnace. All external hot air conducting ducts should be lagged externally to prevent and minimize heat loss. Infiltrations should be checked and all leakages should be blocked with clay or metal when applicable.

CONCLUSION

Rotary furnace designs are necessary to encourage manufacturing and production of component of machine units to improve industrialization in developing techno-economic countries like Nigeria. Rotary furnace offers a saving grace towards reproduction of worn out, or broken parts from machines and other production components for retail and large scale production, there by encouraging technological growth and economic development. Enhancing the operating parameters that will improve thermal efficiency and performance, reduce resident time, reduce cost of production through enhancement of fuel consumption and improve quality of materials produced from rotary furnace will promote the use of rotary furnaces as a preference to others.

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