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DESIGN AND TESTING OF A CUPOLA FURNACE FOR MICHAEL OKPARA UNIVERSITY OF AGRICULTURE, UMUDIKE

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Abstract

The need to recycle and productively reuse the abundant scrap metals in the country led to this paper. The task therein focused on a design aimed at the modification and re-fabrication of an existing cupola furnace in-situ at the Engineering Workshop of Michael Okpara University of Agriculture, Umudike (MOUAU) in Abia State, Nigeria. From the design, 0.00129m^3/s volume of air supplied to the cupola furnace with an available volumetric capacity of 0.01378m^3 at the rate of 32963.58W/m^2 produced an estimated melting heat of 89113.5KJ/hr with a melting rate of 123kg/hr for the complete combustion of the fuel utilizing a mass of charge of material of 123kg. These parameters as compared for the already existing cupola at the Workshop gave the volume of air supplied as 0.000257m^3/s at the rate of 285973.05W/m^2 with the melting rate capacity of 67952.25kJ/hr and a melting rate of 101.2kg/hr, respectively. Consequently, the fuel analysis performed showed that the stoichiometric air/fuel ratio obtained was 11.39, while the efficiency of the cupola furnace was calculated as 67% against the 50.02% value of the already existing one in-situ at the Workshop. This represents an increase of about 16.98% in efficiency from the already existing and modified cupola used as standard for the present study. It is thus recommended that this novelty design be used as a foundation for building bigger furnaces and for the sensitisation of students' awareness in foundry technology and practices.

Keywords: furnace lining, refractory materials, critical radius of insulation, furnace fuel, heat transfer, cupola zones

1. Introduction

In a bid to recycle and reuse the abundantly available scrap metal materials available in Nigeria, developing a cupola furnace has been seen as a means to harnessing the optimal production of the output of the plant. Therefore, the purpose and focus of this work are to enunciate steps leading to the designing, modifying, testing and updating the cupola furnace presently located in MOUAU Engineering Workshop. This paper thus will assist the country especially undergraduate engineering students and foundry technologists in a noble bid of improving their foundry technology and practices at all levels. To actualize this quest, a cue was taken from the work of Nwaogu [1] and other best practices of what obtains from literature in several industrialized countries of the world.

Steel is the bed rock of technological development of any nation of which Nigeria is not an exception. A look at the history of some industrialized countries like Japan, China and Europe reveals their extensive use of foundry technology. Metalwork has contributed enormously to technological advancement. On the contrary, a closer study of the fabrication industries in Nigeria reveals that the concept of design are greatly hampered due to the unavailability of metal smelting and melting industries where the desired metallic properties can be fixed in to the base iron to obtain the desired properties. Indeed, Nigeria cannot realize her vision to join the industrialized countries by the year 2020 without developing her iron melting and casting capabilities. In a bid to achieve this, great efforts are made by some researchers [2, 3, 18] among others in Nigeria to harness the potentials of engineering foundry materials available for the production of different machine component parts and allied products. Hence, there is dire need to develop efficient and eco-

Table 1: Average properties of some solid fuels.

S/N	Poperties	Value	Wood	Peat	Lignite	Bituminous Coal	Charcoal
1	Moisture content as found	%	25-50	90	50	2	-
2	Moisture content at firing	%	10-15	15-20	15	2	2
3	Volatile matters	%	80	65	50	30	10
4	Fixed carbon	%	20	30	45	65	89
5	Ash	%	Trace	5	5	5	1
Chemical Analysis							
6	Carbon, C	%	50.0	57.5	70.0	86.0	93.0
7	Hydrogen, H	%	6.0	5.5	5.0	5.5	2.5
8	Oxygen, O	%	43.0	35.0	23.00	6.0	3.0
9	Nitrogen (N) + Sulphur (S)	%	1.0	2.0	2.0	2.5	1.5
Calorific Value							
10	Dry fuel (Cal/g)	Gross	4450	5000	6400	8600	8300
		Net	4130	4710	6140	8310	8170
11	Normal fuel (Cal/g)	Gross	3780	3800	5170	8000	8050
		Net	3420	3460	4870	7720	7910

Source [6]

nomically viable cupola furnace. This will also move the nation to another level in the area of environmental degradation by harnessing and putting to gainful use the abundant scrap metals littered all over the nation.

2. Materials and Methods

An old cupola furnace in MOUAU Engineering Workshop was used as the basis for this work. The modifications made include: designing of a more durable and suitable lining using refractory bricks, incorporation of a drop bottom, charging door, spark arrester and thus increasing the efficiency of the furnace. The outermost part of the cupola furnace was made of a 6mm thick metal plate rolled into a cylindrical shape with a diameter of 380mm and a height of 1480mm, respectively. For easy lining, it was divided into two parts: the upper segment and the lower segment. The latter had an air box through which air is blasted into the furnace with the help of a centrifugal blower mounted 2.5m away from the furnace. On this lower part is located the slag and tap hole through which slag and molten metal were tapped respectively. The furnace was lined with a 6mm thick heat resistant refractory bricks fueled alternatively by charcoal with a heating value of 29600kJ/kg instead of coke. The furnace was designed to a capacity of 123kg as the mass of charge of materials utilizable.

The fabricated cupola furnace as observed during experimentation proved to be more efficient, productive and reliable. The technical and operational characteristics were at optimum and economical since its ease of operation and maintenance are simple.The aspects and/or materials considered for the redesign, modification and fabrication of the cupola are as follows:

2.1. Charcoal

This is an amorphous form of carbon, made by enclosing billets in a resort and exposing them to a red heat for about four to five hours. It burns with pale blue flame at a high temperature and has a calorific/heating value of about 29600kJ/kg [4, 5]. Charcoal is usually produced by slow pyrolysis (the heating of wood or other substances in the absence of oxygen). The resulting soft, brittle, lightweight, black, porous material resembles coal. By comparison, charcoal burns at an intense temperature of up to 2700℃ as opposed to the melting point of cast iron of approximately 1200 to 1550℃ [6]. It is also an excellent reducing fuel for the production of cast iron and has been used in that way since Roman times. Charcoal by far as Henrik [6] reported, is a superior fuel to coke since it burns hotter and has no sulfur.

The choice of using charcoal than coke for the design was necessitated by the fact that charcoal is more readily available and abundant. Grossly, it has high calorific/energy/heating value (HCV) greater than coke [4,5]. Other parameters considered for the selection of charcoal as different from coke are as examined and documented by Savastru [7]. The average properties of charcoal and other solid fuels are as given in table 1.

2.2. The furnace

Figure 1 shows the schematic overview of different components of the cupola furnace, while figure 2 presents the sectional view of the system as discussed briefly.

2.2.1. The shell and the cylindrical shell

The metallic cylindrical shell was designed to a diameter of 380mm with a total height of 1480mm. This was divided into two segments (upper and lower) for

Table 2: Material contents of insulation used.

S/N	Material	Mass (kg) (Mixture)	Thermal conductivity (W/mK)	Temperature (℃)
1	Processed kaolin	3.00	0.034	30
2	Nsu clay	3.00	0.221	20
3	Nafuta clay	3.00	0.220	20
4	Cotton wool/saw dust	1.00	0.064	300
5	Refractory clay	1.5	1.035	450

Source [9]

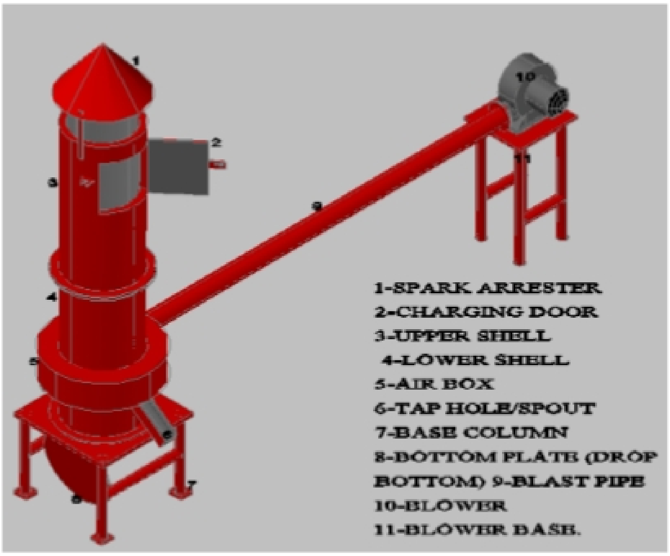

Figure 1: A 3-D description of the fabricated cupola furnace.

easy lining. Conversely, the cylindrical shell used for the cupola furnace is made of heat resistant nickel steel. A steel of 0.6mm thick metal plate was selected for this purpose because of the high temperature at which the furnace is going to be fired.

2.2.2. The refractory lining

The insulation materials and the refractory bricks used were locally sourced from Project Development Institute (PRODA) Enugu [8]. The material contents of the insulation used and their properties are as presented in table 2, while the composition of the insulation bricks (refractory bricks) used are depicted in table 3, and composed of a mixture of fire clay, Nsu clay and grog materials, respectively [9]. A mixture of Nsu clay (Nzu) collected from Agbaghara in Mbano L.G.A. of Imo State according to Ugwu and Ojobor [9] was used because of its plasticity which helps to bind other clays together. Also, the choice of using fire clay for the mixture was made because of the refractoriness too since it is more plastic than Kaolin. Although kaolin (china clay) as reported [9] is the best refractory clay type in existence because it will not soften below 1750℃, they possess little plasticity due to their

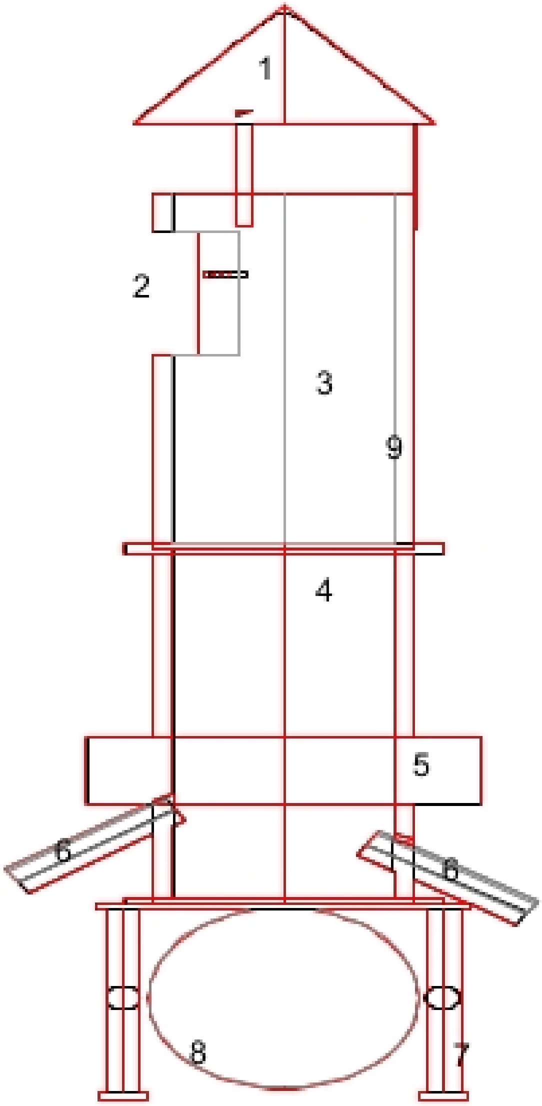

Figure 2: Sectional view of the cupola furnace. (1 – Spark arrester; 2 – Charging door; 3 – Upper shell; 4 - Lower shell; 5 – Air box; 6 – Tap/slag hole; 7 – Base column; 8 – Drop bottom; 9 – Refractory bricks.)

Table 3: Composition of insulation bricks.

S/N	Material	Weight (kg)
1	Fire clay	30
2	Nsu clay	13
3	Grog	55
Total		100

Source [9]

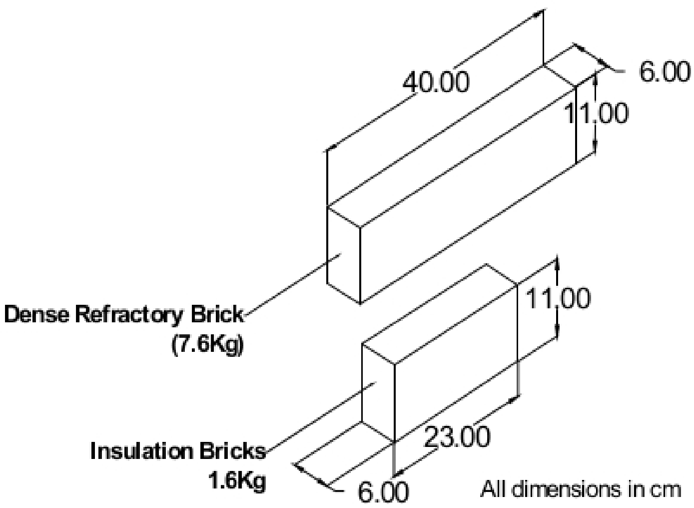

Figure 3: Refractory bricks.

large clay particles. Another material used was grog; which is burnt clay. Based on these, the bricks were consequently formed, cut to the designed shapes and sizes and then fired to the required temperature.

Two types of refractory bricks as shown in figure 3 were employed in the fabrication of this furnace, namely: dense refractory bricks and insulating bricks (less dense). The former weighs 7.6kg with a dimension of (40 × 6 × 11) cm and lined on the melting zone, while the latter weighs 1.6kg with a dimension of (23 × 6 × 11) cm in length, width and height, respectively; and lined on the upper section. Moreso, a mixture of cement, silica and china clay was used as binder to hold the bricks securely to the walls of the shell.

3. Design Considerations and Analyses

3.1. Furnace design

Selection criteria such as portability, use of low floor space, ability to explain the working conditions, and the cost implication, etc of cupola furnace for fabrication according to Nwaogu [1] are based on number rating. Cupolas are rated by number from 0 to 12, and their capacities are designated as melting rates measured in kilogram per hour (kg/hr). In this regard, size 2 cupola was chosen with a designed melting rate of 123kg/hr for fabrication. It was designed to operate at a temperature of 1600℃ since the melting temperature of cast iron is about 1530℃ [1]. Other furnace design parameters considered are described as follows:

3.2. Heat transfer by conduction

Conduction as the transfer of heat from one part of a substance to another part of the substance or from one part of a substance to another in physical contact with it without appreciable displacement of the molecules forming the substance [10, 11], basically described the situation of the refractory bricks inside the furnace and the walls of the furnace cylindrical shell. This is governed by Fourier's law of heat conduction which states that the rate of flow of heat through a simple homogeneous solid is directly proportional to the area of the section at right angles to the direction of heat flow, and to change of temperature with respect to the length of the path of the heat flow [10, 11, 12, 13]. Mathematically, this is represented as:

$$Q = -KA\frac{dt}{dx} \tag{1}$$

where: K = thermal conductivity of the body; Q = heat flow through a body per unit time (W); A = surface area of heat flow through the body (m^2); dt = temperature difference of the faces of block of thickness through which heat flows (℃ or °F); and dx = thickness of the body in the direction of flow (m), respectively. However, the negative sign of K is to take care of the decreasing temperature along with the direction of increasing thickness. Since the temperature gradient is always negative along positive x-direction, the value of Q thus becomes positive.

Hence, from equation 1, the thermal conductivity of the material and the thickness or area of insulation required for the furnace wall were determined using [10]:

$$K = \frac{Q}{A} \times \frac{dx}{dt} \tag{2}$$

In-view of equation 2, the thermal conductivity of the materials adopted for this cupola design was carefully considered and selected [11].

3.3. Heat transfer by radiation

Radiation as the transfer of heat through space or matter by means other than conduction and convection, are electromagnetic in nature. Since all bodies radiate heat, the radial heat transfer of the cupola designed, was considered. Thus, from equation 1 [14], $Q \propto A\frac{dt}{dx}$; hence:

$$Q = -K_b \times A_b\frac{dt}{dx} \tag{3}$$

where: $A = 2\pi XL$ = the cross sectional area of the furnace shell (m^2). Therefore:

$$Qdx = -K_b \times 2\pi XLdT$$

$$\frac{dX}{X} = -K_b\frac{2\pi LdT}{Q}$$

$$\int_{X_1}^{X_2}\frac{dX}{X} = \frac{-2\pi LK_b}{Q}\int_{T_1}^{T_2}\frac{dT}{T}$$

$$\ln X_2 - \ln X_1 = \frac{2\pi LK_b}{Q}[T_1 - T_2]$$

$$\therefore T_1 - T_2 = \frac{\ln\left[\frac{X_2}{X_1}\right]}{\frac{2\pi LK_b}{Q}} \tag{4}$$

where: $T_1 - T_2$ = temperature distribution in the refractory lining; Q = quantity of heat conducted through the walls; X_1 = internal radius of the cylindrical refractory lining; X_2 = external radius of the cylindrical refractory lining; L = length of the cylindrical shell; K_b = thermal conductivity of the refractory lining (bricks); as: T_1 and T_2 = interface temperatures between the refractory bricks and the metal shell, respectively; dt = temperature difference of the faces of the bricks of thickness, dx through which the heat flows (℃); and dx = thickness of the refractory bricks in the direction of flow (m), respectively.

3.4. Heat conduction through the metal shell

In the cupola designed, provision was made to determine the heat conduction through the refractory lining and that through the metallic cylindrical shell. If T_1 = the temperature on the furnace side, T_2 = the temperature between the refractory bricks and the metallic shell, and T_3 = the temperature on the outermost shell, respectively; based on [14]:

$$T_1 - T_3 = (T_1 - T_2) + (T_2 - T_3) \tag{5}$$

But from equation 4,

$$T_1 - T_2 = \frac{\ln\left[\frac{X_2}{X_1}\right]}{\frac{2\pi LK_b}{Q}}$$

Similarly,

$$T_2 - T_3 = \frac{\ln\left[\frac{X_3}{X_2}\right]}{\frac{2\pi LK_s}{Q}} \tag{6}$$

Substituting equations 4 and 6 into 5 gives:

$$T_1 - T_3 = \frac{Q}{2\pi L}\left[\frac{\ln\left[\frac{X_2}{X_1}\right]}{K_b} + \frac{\ln\left[\frac{X_3}{X_2}\right]}{K_s}\right] \tag{7}$$

Thus:

$$Q = \frac{2\pi L(T_1 - T_3)}{\frac{\ln\left[\frac{X_2}{X_1}\right]}{K_b} + \frac{\ln\left[\frac{X_3}{X_2}\right]}{K_s}} \tag{8}$$

Hence, equation 8 establishes the quantity of heat conducted or transferred from the furnace side to the outside shell of the furnace; as: K_s = the thermal conductivity of the metallic shell (steel).

3.5. Refractory thickness of furnace wall

From equation 4:

$$\ln\left[\frac{X_2}{X_1}\right] = \frac{2\pi LK_b}{Q}[T_1 - T_2]$$

$$\ln X_2 - \ln X_1 = \frac{2\pi LK_b}{Q}[T_1 - T_2]$$

Since, X_2 (external radius of the cylindrical refractory lining) is at a lower temperature regime than X_1 (internal radius of the cylindrical refractory lining), it implies that:

$$-\ln X_2 + \ln X_1 = \frac{-2\pi LK_b}{Q}[T_1 - T_2]$$

Hence:

$$\ln X_1 = \frac{-2\pi LK_b}{Q}[T_1 - T_2] + \ln X_2$$

$$\therefore X_1 = e^{\frac{-2\pi LK_b}{Q}[T_1 - T_2] + \ln X_2} \tag{9}$$

3.6. Outside temperature of the furnace

This corresponds to the outside temperature of the cylindrical metallic shell (T_3). Recalling equation 7:

$$T_1 - T_3 = \frac{Q}{2\pi L}\left[\frac{\ln\left[\frac{X_2}{X_1}\right]}{K_b} + \frac{\ln\left[\frac{X_3}{X_2}\right]}{K_s}\right]$$

Thus:

$$T_3 = T_1 - \frac{Q}{2\pi L}\left[\frac{\ln\left[\frac{X_2}{X_1}\right]}{K_b} + \frac{\ln\left[\frac{X_3}{X_2}\right]}{K_s}\right] \tag{10}$$

3.7. The blower

The blower for the cupola as a form of a heat pump used in circulating air through the system, consists of a rotating wheel (impeller) surrounded by a stationary member (the housing). Air was fed into the fan by induced draft, while they were exhausted from the fan through forced draft convention.

For this design, an electrically powered centrifugal blower was selected over axial, due to its obvious advantages [15]. The specifications of the blower are given as in table 4, while its schematic diagram is shown in figure 4, respectively.

3.8. Analysis of air flow through the furnace

Air flows from the impeller opening through the 6mm diameter ducts into the furnace. The volume of air supplied (V_{AS}) was calculated using: Volume flow rate, $V_{AS} = Av$,

$$\therefore V_{AS} = \frac{\pi d^2 V}{4} \text{ or } \frac{\pi L^2 V}{4} \tag{11}$$

where: A = area of furnace (refractory bricks) exposed to heat flow (m^2), and v = velocity of air or rated speed of blower (m/s), respectively.

Table 4: Blower specifications.

S/N	Parameters	Quantity/units
1	Number of blades	12
2	Rated speed	2900rpm
3	Volume flow rate	$7.5m^3/min$
4	Rated voltage	220V
5	Pressure	1200Pa
6	Rated current	250A
7	Diameter of discharge pipe	6mm (0.006m)

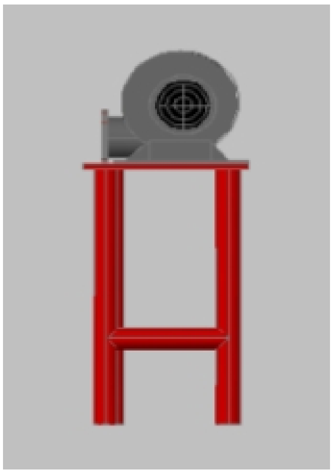

Figure 4: Centrifugal blower.

4. Results and Discussions

4.1. The mass of charge of material

The mass of charge of material (M_{CM}) was obtained from the Available furnace volume (V_{AF}) given by:

$$V_{AF} = \pi r^2 h \tag{12}$$

where: the internal furnace radius, r = 77mm (0.077m), and the metallic shell height, h = 740mm (0.74m), respectively. Hence: $V_{AF} = 0.01378\text{m}^3$.

Mass of charge of material = Density of material × Available furnace volume. Mathematically:

$$M_{CM} = \rho_{CS} \times V_{AF} \tag{13}$$

$\therefore M_{CM} = 8908 \times 0.01378 = 122.75\text{kg} \approx 123\text{kg}$ (for design purposes). Where: $\rho_{CS} = 8908\text{kg/m}^3$ for high heat resistant nickel steel material [16].

4.2. Rate of heat transfer through the furnace wall

The schematic representation of the heat conduction through the cross-sectional view of the composite furnace walls is as shown in figure 5. From Rajput [10], the heat transmitted or conducted through the

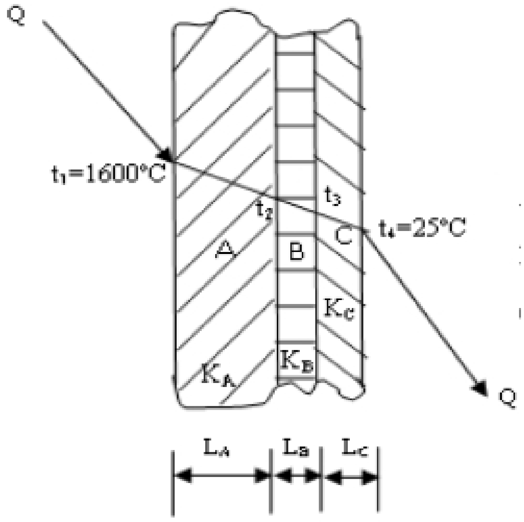

Figure 5: Heat conduction through the furnace. A = Refractory brick (L = 0.006m, K = 0.138W/m°C); B = Binder (mortar: L = 0.002m, K = 0.48W/m°C); C = Metal shell (L = 0.006m, K = 45W/m°C)

furnace walls is given as:

$$Q = \frac{A(t_1 - t_4)}{\frac{L_A}{K_A} + \frac{L_B}{K_B} + \frac{L_C}{K_C}} = \frac{(t_1 - t_4)}{\frac{L_A}{K_A A} + \frac{L_B}{K_B A} + \frac{L_C}{K_C A}}$$
$$Q = \frac{(t_1 - t_4)}{R_{th-A} + R_{th-B} + R_{th-C}} \tag{14}$$

Thus: $Q = 32963.58\text{W/m}^2$

4.3. Critical radius of insulation or wall thickness

According to the principle of Edward [9], the Critical radius, r_C, of insulation for a furnace wall is given by:

$$r_C = \frac{k}{h} \tag{15}$$

where: k = thermal conductivity of the refractory clay material at 450°C = 1.035W/mK (table 2), and h = heat transfer coefficient = $15\text{W/m}^2\text{K}$ [8], respectively. Hence, the critical radius of insulation for the furnace wall, r_C was calculated as: $r_C = \frac{1.035}{15} = 0.069\text{m}$ (69mm). However, the critical radius, r_C of 70mm was taken for the design to ensure adequate factor of safety.

4.4. Volume of air supplied

From table 4 and applying equation 11, $V_{AS} = Av = \frac{\pi L^2 V}{4}$. But $A = \frac{\pi D^2}{4} = \pi \frac{0.006^2}{4} = 0.000028274\text{m}^2$ and $v = \pi \times 0.30 \times \frac{2900}{60} = 45.55\text{m/s}$ $\therefore V_{AS} = 0.00129\text{m}^3/\text{s}$

4.5. Fuel analysis

From table 1, the composition by mass of charcoal is: carbon, C = 93%, hydrogen, H = 2.5%, oxygen, O = 3.0% and nitrogen, N = 1.5% with little traces of sulphur, respectively. The stoichiometric air/fuel ratio is calculated thus:

Let the equivalent formula for the fuel sample = $C_aH_bO_cN_dS_e$. But the percentage composition of nitrogen and sulphur from the table is 1.5%. For this design consideration, it was however assumed that the mass of sulphur in the fuel composition was minimal. Therefore, the percentage of nitrogen in the composition was assumed to be 1%, while that of sulphur was taken to be 0.5%, respectively. Thus, on the basis of 100kg of the fuel (charcoal as in table 1), the composition by mass gives:
C: 12a = 93; a = 7.75
H: 1b = 2.5; b = 2.5
O: 16c = 3.0; c = 0.188
N: 14d = 1; d = 0.071; and
S: 32e = 0.5; e = 0.016, respectively.

Hence, the formula of the fuel sample = $C_{7.75}H_{2.5}O_{0.188}N_{0.071}S_{0.016}$. Then, the combustion equation for the fuel sample is written as:

$$C_{7.75}H_{2.5}O_{0.188}N_{0.071}S_{0.016} + xO_2 + x\frac{79}{21}N_2 \longrightarrow pCO_2 + qH_2O + rSO_2 + sN_2 \quad (16)$$

Balancing the equation yields:
C: 7.75 = p; p = 7.75
H: 2.5 = 2q; q = 1.25
S: 0.016 = r; r = 0.016
O: 0.188 + $2x$ = 2p + q + 2r = 2(7.75) + 1.25 + 2(0.016)
0.188 + $2x$ = 15.5 + 1.25 + 0.032 = 16.782
$2x$ = 16.782 - 0.188 = 16.594
$\therefore \frac{16.594}{2} = 8.297$
N: 0.071 + $2 \times \frac{79}{21}$ = 2S = 0.071 + $2(3.762)x$
0.071 + 2(3.762)(8.297) = 2S = 0.071 + 62.427 = 62.498
$\therefore$ S = $\frac{62.498}{2}$ = 31.249. Hence, the balanced combustion equation now becomes:

$$C_{7.75}H_{2.5}O_{0.188}N_{0.071}S_{0.016} + 8.297O_2 + 8.297\frac{79}{21}N_2 \longrightarrow 7.75CO_2 + 1.25H_2O + 0.016SO_2 + 31.249N_2$$

Thus, the Stoichiometric air/fuel (A/F) ratio required = $\frac{8.297(32)+8.297(\frac{79}{21})28}{100} = 11.39$.

4.6. Quantity of heat required for melting, Q_m

According to Krivandin [17], the quantity of heat required for melting/combustion of the fuel is described by:

$$Q_m = C_m \times T_m \times G_m \text{ or } C_m \times (T_2 - T_1) \times G_m \quad (17)$$

Table 5: Cost analysis for the modification of the cupola.

S/N	Material Description	Cost (₦)
1	Fire Bricks	15,500.00
2	580 × 700 Cylindrical Shell	3,500.00
3	Fireclay and cement	2,500.00
4	Welding Electrode	1,000.00
5	Base Plate and $\frac{3}{4}'$ pipe for stand	4,000.00
6	Paint	1,000.00
7	Bolts and nuts/washers	900.00
8	Charcoal	2,500.00
	Total	30,900.00

where: C_m = specific heat of cast iron = 0.46KJ/Kg°K [19], T_m = temperature difference, T_1 = 25℃ or 298K (assumed room/ambient temperature), T_2 = 1600℃ or 1873K (furnace inner temperature) and G_m = furnace melting (cupola) capacity taken at 123kg/hr = 0.0278kg/s. Thus:

$$Q_m = 0.46 \times (1873 - 298) \times 123 = 89113.5\text{kJ/hr}$$

4.7. Efficiency/Output of the cupola

According to [19], the efficiency of the cupola is given by:

Efficiency = (Quantity of heat required for melting− Calorific value of the fuel)/(Quantity of heat required for melting) × 100

Mathematically,

$$\epsilon = \frac{Q_m - C_{vf}}{Q_m} \times 100 = 66.78\% \approx 67\% \quad (18)$$

Where: the heating/calorific value of the fuel (charcoal) used = 29600KJ/Kg [4, 5]. The value of the cupola efficiency as calculated (67%) conformed to the literature value of 50 to 70% [17], which according to the source, varies within the limits; and can be increased by the use of preheated air. Also, the calculated value represents an increase of about 16.98% in efficiency from the existing and modified cupola efficiency of 50.02% in-situ at the MOUAU Engineering workshop.

4.8. Financial cost analysis

Considering quality and cost effectiveness during material selection and procurement, the cost for the modification and fabrication of this cupola furnace is as tabulated in table 5.

However, because some other miscellaneous expenses in terms of labour and transportation were not accounted for during the fabrication, a 30% overhead was included in the material procurement which brought the grand total cost to forty thousand, one hundred and seventy (₦40, 170.00) naira, only.

5. Conclusion and Recommendations

5.1. Conclusion

A design that could lead to the production of larger cupola furnace has been accomplished through this research. This design also led to the production of a model-type cupola that could be used as a demonstration model in foundry technology in tertiary institutions. Cue was taken from an obsolete cupola furnace in MOUAU Mechanical Engineering Workshop for design and modification. More so, the produced cupola could further assist manufacturers who wish to build larger furnaces for commercial application with reduced cost implication. Furthermore, the fabricated cupola as modified during test running proved to be more economical having the optimum technical and operational characteristics in the areas of its productivity, efficiency, reliability, simplicity, ease of operation and maintainability.

5.2. Recommendations

From the study conducted, these recommendations were proffered:

- That the design should be adopted towards increasing students awareness and interest in foundry technology and practices.
- The iron rolling organisations and allied industries, universities and research institutes should use the enunciaton of this design as a basis for further improvement to metal smelting processes.

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