International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Design and Construction of an Electric Kiln For Low Temperature Applications

Idowu Oluwatuase Idowu[1], Sanya Olajide Tunmilayo[2]

Department of Glass and Ceramic Technology, Federal Polytechnic Ado Ekiti, P.M.B. Ado Ekiti, Ekiti State

Abstract: ***A low cost electric kiln was designed and fabricated for low temperature applications. The newly fabricated kiln was made using materials and technologies sourced locally. The kiln consists of kiln chamber, heating elements, a variable thermostat and lagging materials of insulating bricks and fibre glass. The production cost of the electric kiln is twenty-five thousand naira compare with imported ones that cost within the range of thirty-five thousand naira and forty-four thousand naira excluding importation and transportation charges.***

Keywords: Construction, Design, Electric kiln, Lagging materials, Low temperature applications

1. Introduction

Ceramics are inorganic, non-metallic materials that are processed and/or used at elevated temperatures. Many ceramics are resistance to abrasion, heat, corrosion and are generally chemically inert. Though ceramics are hard brittle materials that cannot withstand tension compared to the metals, they can sustain very large compressive load at high temperatures. They are widely used as sanitary wares, low and high voltage insulator, refractories for industries furnace and nuclear applications as fuel elements, fuel containers and moderator (Rajput, 2010).

Ceramics are processed at high temperatures so chemical and physical reactions will occur to permanently alter the unfired body. These reactions take place within a thermally insulated chamber, a type of *oven*, that produces temperatures sufficient to complete some process, such as hardening, drying, or chemical changes known as a kiln (A. Wikimedia Project, 2015). Kilns may be classified according to heat source as fuel fired kiln, solar kiln, and electric kiln. An electric kiln can be described as a non-fuelled powered kiln, that depend on radiant heat produced by the conversion of electrical energy to heat energy in heating elements(Olsen, 2001). Electric kilns use nowadays, often used elements made of special high temperature alloy of iron-aluminium-chrome. This alloy can withstand very high temperature (up to about 1015℃ {2400℉}) (Lewicki, 2014). Electric kiln manufacturers usually wired most kilns for 240 volt or 208 volt power systems for residential setting and industrial building respectively (Peterson, 2014). Most electric kilns being used in the country for firing serious ceramic operations are often imported from China, Australia and United States of America and so on. Importation of these products is a serious capital flight on the economy of our nation where unemployment is a major challenge. Also, in location where there is steady supply of electricity at reduced cost, electric kiln is a preferred choice of firing ceramic wares since it incurs no extra cost on fuels such as butane gas and kerosene and it environmental-friendly. This present study is aim at designing and fabricating a cost effective locally made electric kilns for low temperature firing of ceramic wares.

2. Research Methodology

2.1 Research Materials

The materials used to fabricate the electric kiln includes: 1.5mm flat mild steel sheet, angle bar of 2.54cm thickness. The electrical components (2000 watts capacity heating elements, 1.5mm wire, switch, thermostat, and ceramic connectors) were sourced from Lagos, Nigeria. Mortar to bind the insulating bricks was formed from kaolin clay (sourced from Isan-Ekiti, Nigeria), ball clay (sourced from Isan-Ekiti, Nigeria), grog and sodium silicate.

2.2 Design Calculations

Kiln Capacity (Volume)
The volume of a flat top kiln, V_k, was calculated using Eq. 1.(Ward, 2015).

$$V_K = w \times h \times d \quad \text{Eq. 1}$$

Where: V_K= interior volume of the electric kiln
w= width of the electric kiln
h= height of the electric kiln
d= depth of the electric kiln

$$\therefore V_k = 0.26 \times 0.25 \times 0.11 = 0.007{,}15\ m^3\ (0.25\ \text{ft}^3)$$

Cross-Sectional Area of the Kiln's Heating Chamber
The interior cross sectional area of the kiln was computed using Eq. 2:

$$Area = Length \times Width \quad \text{Eq. 2}$$

$$Surface\ Area = 26 \times 11 = 286\ cm^2$$

$$Surface\ Area = 25 \times 11 = 275\ cm^2$$

Element Surface Load
The surface load of an element estimates the wear or deterioration during a given period of time and it measured in watts per square centimetre (W/sq. cm) (Olsen, 2001).

$$Element\ surface\ load = \frac{Power}{Surface\ area} \quad Eq.3$$

$$Element\ surface\ load = \frac{2000}{286} = 6.993\ W/sq.cm$$

Electric Kiln Power (Kilowatts) Requirement

The required power for power (in kilowatts) of the electric kiln is a function the kiln's volume temperature and the time required to reach the temperature (Olsen, 2001). Kiln voltage depends on the local power voltage. The voltage supply is 240V in Ado-Ekiti State, Nigeria. 1.8KW is the recommended electric kiln power for kiln capacity below $0.028m^3$ (1 $ft.^3$). The rate of the resistance element used is 2KW.

Thus:

$$P = IV \quad Eq.4$$

Where: P = Power, I = current, V = voltage

Voltage is = 240V and Power is 2000 watts

$$Current = \frac{2000}{240} = 8.33 \; amps$$

Resistance of the Electric Kiln Element (R)

Resistance is given according to ohms as:

$$R = \frac{V}{I} \quad Eq.5$$

Where V= voltage and I = current

Therefore;

$$R = \frac{240}{8.33} = 28.8\Omega$$

2.3 Description of Components

Kiln Cover

The cover of the kiln is a movable flat roof construction. It is made up of insulating bricks, fibre glass lining, a stand and a metallic cover. Row of bricks were arranged on the stand and held tie together by bolts. The kiln cover was fabricated from mild steel sheet, of 610mm x 610mm, bent 90mm from each end to seal up the kiln jacket. A 2.5 mm diameter drilled hole near the centre of the kiln's floor serves as the chimney.

Kiln Wall

The kiln jacket was fabricated from a 1.5mm mild steel to produce a cuboid of 430mm x430mm x23mm as the dimension of the length, the width and height respectively. The jacket serves as a protective wall that seal up the kiln lagging.

Kiln Stand

The kiln stand was made up of 25 x 25 mm mild steel angle bar. The angle bars were cut and welded together to form a support for the base of the kiln with 430 x 430 x75 mm as the length, width and length. Insulating bricks are arranged on the stand.

Resistance Heating Element

The heating element used for the construction of the kiln is manufactured by Kenton incorporated with capacity of 2000watts, eight elements pieces were installed in the size grooves and connected to an electric power source.

Refractory Linings

A layer of insulating bricks with dimension of 250mm x 120mm x 60 mm followed by 10mm layer of fibre glass were used for lining the electric kiln.

Mortar Paste

Mortar paste was composed from admixture of ball clay, grog, kaolin sodium silicate and water. It was used to bind the bricks together while constructing kiln's wall, base and cover. The composition of the constituents of the mortar is shown in Table 1.

Table 1: Composition of the Mortar

Ball Clay	Grog	Kaolin	Sodium Silicate	Water
15kg	30kg	40kg	$50cm^3$	$2000cm^3$

2.4 Material Selections

Table 2 shows the materials selected for the design and fabrication of the electric kiln. The materials selections for this research work were mild steel and insulating brick. The reason for choice of mild steel is its corrosion resistant property, strength durability and cost effectiveness. The bill of engineering measurement and evaluation including the cost analysis of fabricating the electric kiln and the cost of imported kiln with similar heating capacities were shown in table 3 and table 4 respectively.

Table 2: Kiln part names, materials selection and quantity

S/N	Part Names	Materials	Quantity
1	Top Cover	Mild Steel	1
2	Kiln Door	Mild Steel	1
3	Kiln Stand	Angle Bar	4
4	Kiln Wall	Mild steel and fibre glass	
5	Kiln door	Mild steel and insulating brick	1
6	Insulating materials	Insulating brick and fibre glass	
7	Thermostat	Bi-metal	1
8	Electrical wire	Cable	4
9	Connector	Ceramic connector	8
10	Heating elements	Nickel-chrome alloy	8
11	Nuts	Iron	16

Table 3: Bill of engineering measurement and evaluation (BEME)

S/N	Items	Unit Price (N)	Quantity	Amount (N)	Amount ($)
1	Angle bar iron	1000		1000	5.1
2	Mild steel flat sheet	4500		4500	22.9
3	Mortar (Kaolin, Grog, Sodium silicate etc)	1000		1000	5.1
4	Sodium Silicate	150	2 litres	300	1.6
5	2KW Heating element resistance	250	8	2000	10.2
6	Thermostat	1000	2	2000	10.2
7	Ceramic connector	300	8	1800	9.2
8	AutoCAD drawing charges	3000		2400	12.2
9	Fabrication and electrical installation fees	5000		5000	25.5
10	Transport, typing expenses and Miscellaneous	5000		5000	25.5
	Total			25,000	127.5

1US Dollar equals 196.5 Nigerian Naira.(Central Bank of Nigeria, 2015)

Table 4: Cost analysis of imported kilns

S/N	Types of Kiln	Cost dollar ($)	Cost naira (₦)
1	Paragon Quick fire 6 Kiln	182.50	35,861.25
2	Kiln for PMC metal clay jewellery fusing enamelling and ceramic	200.00	39,300.00
3	Electric kiln for ceramics and other projects	225.00	44,212.50

1US Dollar equals 196.5 Nigerian Naira.(Central Bank of Nigeria, 2015) (eBay Incorporation, 2015).

3. Conclusions

The materials used to fabricate the portable electric kiln were sourced locally. The construction design is simple and provided avenue for easy maintenance and replacement of heating elements and further modification on the kiln. This kiln is simple to operate, cheap to maintain and can be used to fire small dimension ceramic wares and glass pieces up to 800℃.

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Design Drawing

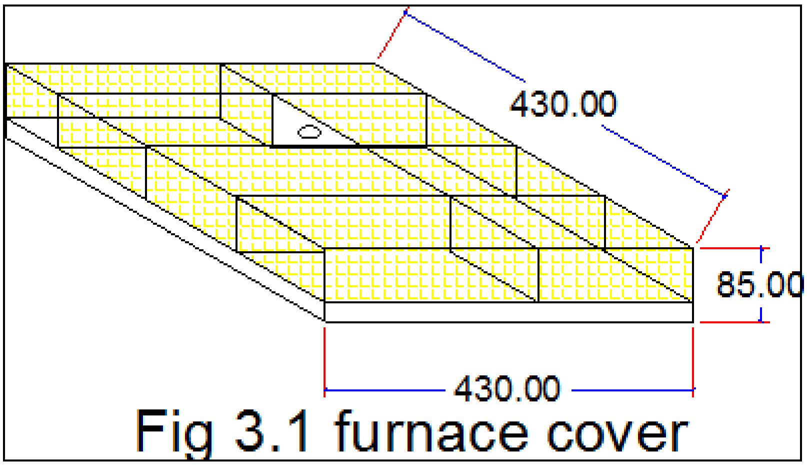

Figure 1: Isometric drawing of the electric kiln roof

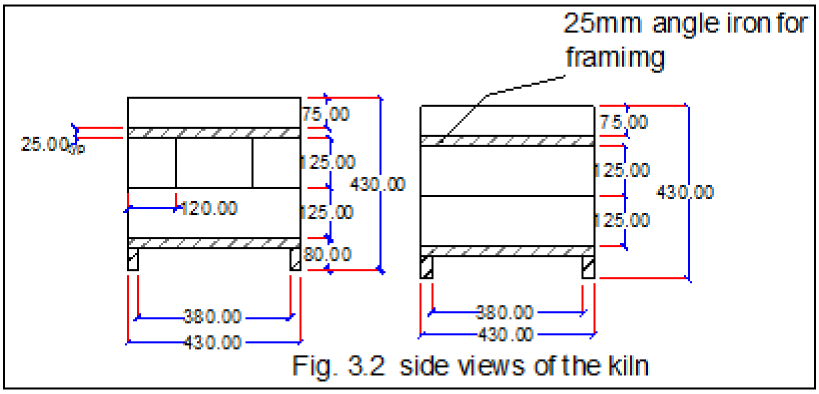

Figure 2: Orthographic view of electric kiln

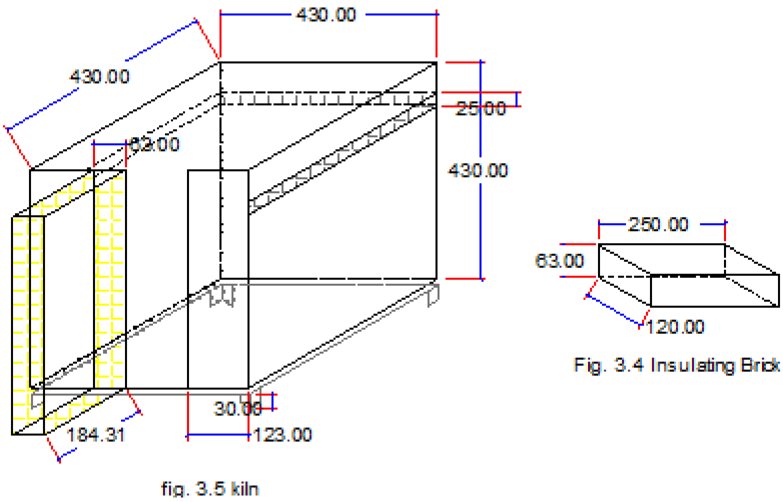

Figure 3: Isometric view of the Electric kiln without the kiln roof