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A Reactor Plant for Activated Carbon Production

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Abstract: **Annealing furnaces have normally been adapted for the production of activated carbon causing ingression of oxidizing fumes and subsequent damage of heating elements. In view of these, the objective of this work was to develop a reactor specifically for the production of activated carbon. A reactor plant of 0.8kg capacity was designed and constructed using locally source material. Galvanised steel plate and aluminosilicate bricks were selected as reactor shell material and refractory material respectively. The reactor has an efficiency of 80% ,with a thermal stress and strain of 166.9MP and 5.6 respectively. Validation of activated carbon quality from reactor was carried out using chemical activation. Very good activated carbons were produced at the selected operating conditions.**

***Keywords*: Activated carbon, chemical activation, , reactor ,thermal stress.**

1. INTRODUCTION

A furnace is an apparatus in which heat is generated and transferred directly or indirectly to a molten or solid mass for the purpose of effecting a physical, chemical or metallurgical change in the mass , (Atanda et la 2014) . Furnace is isolated from the surrounding by an insulated wall and is used to transfer heat to the material to be melted or heat treated within the furnace.. Ideally, all heat added to the furnaces should be used to heat the charge, load or stock. In practice, however, a lot of heat is lost in several ways. The losses include energy conversion losses, furnace wall losses, furnace opening losses and the likes. In order to prevent these losses, refractory materials are used in lining the furnace , (Atanda et la 2014) .Activated carbon is a microcrystalline form of carbon with very high porosity and surface area. It is a form of carbon that has been processed to make it extremely porous and thus to have a very large surface area available for adsorption or chemical reactions. (Odesola & Daramola, 2009). Activated carbons with highly developed surface area are widely used in a variety of industries for applications which include separation/purification of liquids and gases, removal of toxic substances, as catalysts and catalyst support (Moon and Shim, 2006; Fuente et al., 2001). With the development of technology, the applications of activated carbons keep expanding, with newer applications such as super-capacitors, electrodes, gas storage, and so on (Yuan and Zhang, 2006; Oda and Nakagawa, 2003; Biloé et al., 2002) Because activated carbons have well-developed pore structures and high internal surface area, they have been employed in a wide number of applications on an industrial scale, including technologies for the purification of gases; the removal of organic pollutants from water (i.e., purification of drinking water and wastewater); used as a catalyst or a catalyst support in the catalytic processes and used as electrode materials in electrochemical devices and processes over the last few decades (Gurrath et al., 2000; Henning and Sch¨ afer, 1993; Mazyck and Cannon, 2000;Walker and Weatherley, 2000). Thus an activated carbon has played an important role in the chemical, pharmaceutical and food industries. Various carbonaceous materials such as coal, lignite, nutshells, wood, and peat are used in the production of commercial activated carbon. However, abundance and availability of agricultural by-products make them good sources of raw materials for activated

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carbons. Harvesting and processing of various agricultural crops result in considerable quantities of agricultural by-products

Although several types of furnaces are described in the literature, three are most commonly used by producers of activated carbon.

i. Rotary Kilns

ii. Multiple hearth furnaces

iii. Fluidized bed furnaces

2. METHODOLOGY

MATERIALS:

The materials used include:

Refractory bricks ,Heating element, Heat sensor, Refractory binder, nitrogen gas , Galvanized steel plate 50mm diameter,r galvanized pipe, coconut shells, Potassium hydroxide pellets, fired bricks plate, gas regulator, gas hose, and electric wires.

Principle of Design:

For a constant temperature of the furnace, the electric power must equal the rate of heat losses to the surroundings by convection and radiation. Heat flows by conduction from inside tube to the outer shell through the refractory thickness. From the outside shell, heat is lost partly by radiation.

HEAT TRNSFER IN THE FURNACE:

The equation for conductive heat transfer through flat furnace wall with multiple layers is given by $\frac{T_1 - T_3}{\frac{X_A}{K_A\ A} + \frac{X_B}{K_B\ A}} = Q$……………………..(1)

T_i = Temperature of interfaces

Xi = Wall thickness

K_i = Coefficient of thermal conductivity

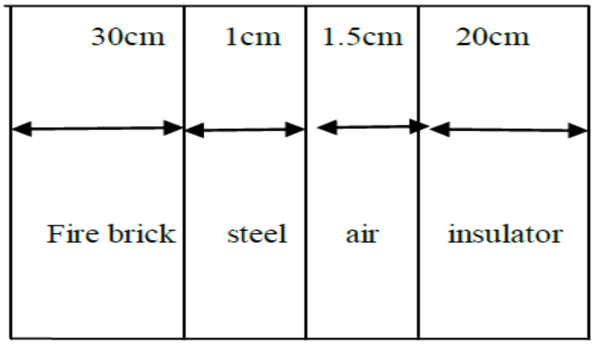

Figure 1 Schematic Diagram of furnace wall

The amount of heat transmitted through composite wall of the furnace per unit area is

$$\frac{Q}{A} = \frac{T_1 - T_3}{\frac{X_A}{K_A} + \frac{X_B}{K_B}} \text{…………… (2)}$$

$$\frac{Q}{A} = \frac{1473 - 303}{\frac{0.3}{1.63} + \frac{0.01}{16.9} + \frac{0.015}{0.0457} + \frac{0.2}{0.26}}$$

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$\frac{Q}{A} = \frac{1170}{0.184+0.0006+0.328+0.769}$

$\frac{Q}{A} = \frac{1170}{1.2816}$

$\frac{Q}{A}$ = 912.92watt/K.m^2

The heat loss through the walls of the furnace is 912.92watt/K.m^2

Temperature drop at the interface

$= \frac{temperature\ drop\ over\ A}{total\ temperature\ drop} = \frac{resistance\ of\ A}{total\ resistance}$ …………… (3)

$= \frac{\Delta t_1}{\Delta T} = \frac{r_A}{R_T}$

Temperature drop at fire bricks and steel interface

$= \frac{\Delta t_1}{1170} = \frac{0.1846}{1.2816}$

$\Delta t_1 = \frac{1170 \times 0.1846}{1.2816}$

$= \Delta t_1 = 168.5K$

Temperature drop at fire bricks and steel interface

$= 1473 - 168.5$

=1304.5K

$\cong 1305K$

Temperature at air /insulator interface

$= \frac{\Delta t_2}{1170} = \frac{0.328}{1.2816}$

$\Delta t_2 = \frac{1170 \times 0.328}{1.2816}$

$= \Delta t_2 = 299.4K$

Temperature at air /insulator interface

$= 1305 - 299.4$

=1005.6K

$\cong 1006K$

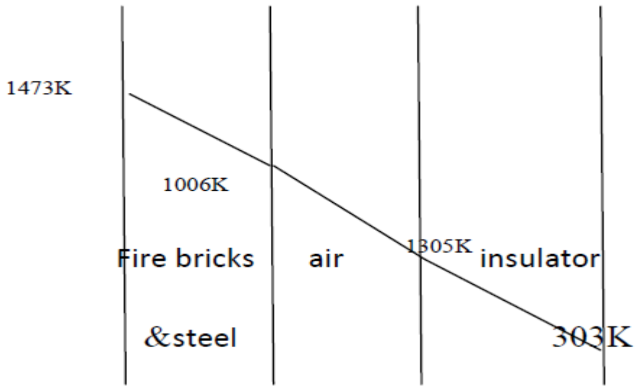

Figure 2 Furnace temperatures Profile

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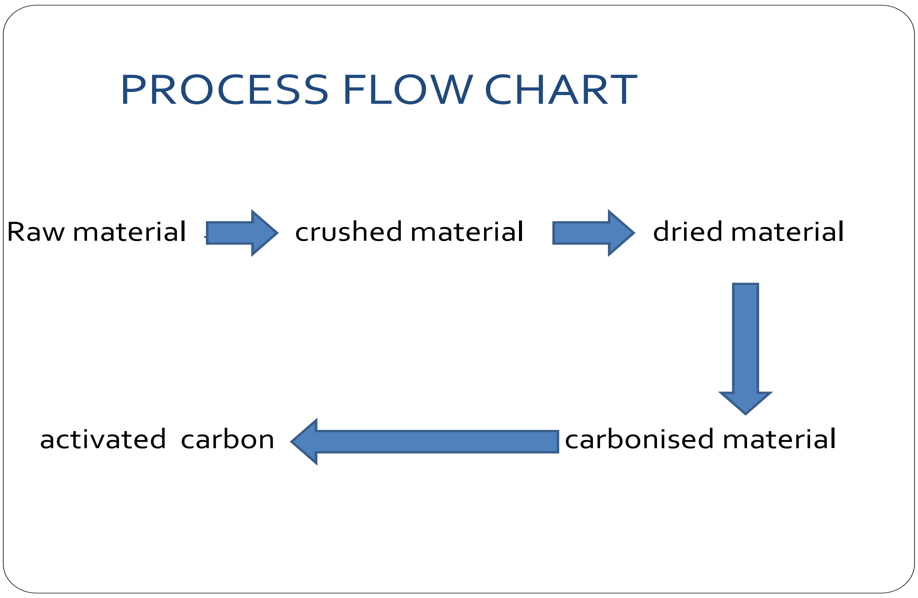

Figure 3 PROCESS FLOW DIAGRAM

3. RESULT

Figure 4 REACTOR

THERMAL EFFICIENCY:

Table 1 Reactor Thermal Efficiency

Voltage (volts)	Resistance (ohms)	Time(min)	**Heat input** (Q_I) $\frac{V^2}{R \times 4186.8}T$	Heat loss (Q_{loss})	$\frac{(Q_i - Q_{loss})}{Q_i}\%$
240	20	218.25	9007.7	912.92	89

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THERMAL STRESS AND THERMAL STRAIN:

Table 2 Thermal Stress and Thermal Strain of Reactor

Young modulus (E) GPa	Coefficient of expansion ($\propto$) 10^{-6} /°F	Temperature change (ΔT) °F	Thermal stress ($\sigma = E \propto \Delta T$) MPa	Thermal Strain ($e = \propto \Delta T$) 10^{-3}
300	8.1	687	166.9	5.6

4. DISCUSSION

Thermal Efficiency:

Thermal efficiency of the furnace using is 80%. This indicates that the furnace is highly efficient. There are a number of factors that contributed to this high value; one is the multilayer of the furnace wall ,this tends to reduce the heat loss unlike a single layer lining , second is the air gap between the inner refractory lining and the outer; air being a poor thermal conductor tends to reduce heat loss from furnace wall, equally important is the choice of the material used the outer insulation; fiber it has a very low thermal conductivity value of (0.26)

Thermal Stress:

The thermal stress developed in the wall of the furnace as a result of uniform temperature is 166.9MPa. In order to accommodate this stress in the furnace wall, aluminosilicate bricks were selected as the inner refractory material because of its high thermal resistance (260MPa) and strength coupled with its low coefficient of linear expansion. This will prevent cracking and eliminate built in barriers while acting as expansion relief

Thermal Strain:

The thermal strain in the refractory is 5.6x 10^{-3}, to accommodate this aluminosilicate bricks were selected because of its low coefficient of thermal expansion.

5. CONCLUSION

A reactor with 80% efficiency was developed, suitable for both chemical and physical methods of producing activated carbon**.**

The reactor was used to produce activated carbon from coconut shells

The quality of the produced activated carbon shows no disparity from literature.

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