Design and Construction of Heat Treatment Furnace Using Ant Hill

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Abstract
A heat treatment furnace using anthill has been designed and fabricated. Developing our local content in the production of heat treatment furnaces will be a major boost in the bid to take a prominent position in foundry and metallurgical engineering. It will contribute to checking the excess waste on the foreign scarce resources spent on the importation of heat treatment and crucible furnaces. Growing our technology is very important to promoting us into global recognition as producers instead of our unfortunate consuming nature which our nation is known for. The developed furnace has volume and height of $0.037m^3$ and 0.188m respectively. It worked well when tested for about five hours.. It had an efficiency of 91.3%
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1. Introduction

The art of making equipment using metals is an agelong practice that has made existence of man worthwhile. Before the advent of modern civilization , the practice of foundry has been a bit visible in a not large scale as it is predominately these days (Cui & Roven, 2015). The rural dwellers initially made hole in the earth to act as oven and used charcoal as fuel to produce heat that can melt metals. The practice which was observed for a long time gave rise to the production of metallic pots, plates, cups , farm machineries such as cutlass, hoes, spades and spoons etc. Historically, the Nok culture has been involved in the production of components even before 2000 A.D. The ancient Benin kingdom is reputed for the production of metal and bronze casting. This act of casting made the people popular globally (Yang,2003).

But, the advent of modern engineering as brought a total turn around to the hitherto crude way of producing metallic components. Nowadays, automobile engine components can be formed with ease by using crucible and heat treatment furnaces (Tsushima-Naka,2010). Accurate and precise manufacturing of automobile equipment are broadly done with the aid of foundry engineering. Generally, all sectors of engineering basically depend on the use of foundry engineering for the production of their metallic products. Foundry practice spans from the production of metallic kitchen cups to the casting major tank farms for the storage of petroleum products.

Heat treatment furnace is an equipment often used to heat treat and melt metals. It utilizes is heat treatment ability to alter and add mechanical properties in metals. This was essentially lacking in the past were effort was channeled to just main blank production of metallic components (Haydar,2018). The use of Heat treatment furnace has even paved way for the use of metallic composites which is noted for improvement of the components quality. The equipment has been developed by researchers in the past. (Major &Aliemeke,2021) produced a 50kg Charcoal crucible furnace for the production of metallic components. The work utilized charcoal as its source of fuel for firing the crucible furnace. Its major short coming was that it was not geared towards influencing the mechanical and physical properties of the parent metal as inherent in a modern heat treatment furnace. A heat treatment furnace that fires on black oil fluid was designed by Golorunnishola, *et al* (2019). The furnace, which has a capacity of 100kg was developed to melt aluminium alloys and ferrous metals. It sustains a thermal capacity of about 1350ºC. This is a departure from what is obtained from small foundries where furnace mass and thermal capacity is not more than 20kg and 800ºC.In the same vein a mini heat treatment furnace was designed by Oyewole and Olawale, (2011). The furnace has a capacity of 5kg and could entertain a thermal load of about 1200ºC.

It has become imperative to develop our local content in the production of heat treatment furnaces. This will go a long way to checking the excess waste on the foreign scarce resources spent on the importation of heat treatment and crucible furnaces (Sani,2015). Developing our technology is key to launching us into global recognition as producers instead of holistic consuming nature which African nations are known for. Advanced democracies and world powers shot into global dominance by developing their local content using their local technology.

This study is focused on developing a locally constructed heat treatment furnace using anthill that has the ability of influencing the physical and mechanical properties of aluminum alloys and ferrous metals.

2. Materials and Methods

The heat treatment furnace was constructed with anthill, fire bricks, tungsten metal as the heating element, 4mm thick mild steel plates, 2mm thick angle bar and electrical sockets, wires and circuit breakers (Jain, 2007). In getting an appropriate design for the heat treatment furnace, some important parameters such as furnace drum diameter, heating capacity, working pressure, wall thickness height of combustion chambers, change in volume of chamber and change in length of the treatment chamber will be adequately determined.

2.1 Design Specification

The design specifications used in this study are listed in this section
The height of drum =0.5m
Radius of drum=0.25
Mass of specimen=100kg
Density of aluminum=2710Kg/m^3

2.2 Determination of Heat treatment Furnace drum volume

The furnace volume was determined by using equation (1) obtained from Khurmi, & Gupta, (2005)

$$V_d = \frac{M}{\rho} \quad (1)$$

Where V_d=volume of the furnace drum
M=mass of 100kg (capacity of drum)
ρ=density taken to be 2710Kg/m^3.

$$V_d = \frac{100}{2710} = 0.037m^3$$

The volumetric capacity was determined to be 0.037m^3

2.3 Determination of the furnace height

The determination of furnace drum was determined using equation (2)

$$V_d = \pi R^2 h_d \quad (2)$$

Where V_d=volume of the furnace drum
R=radius of drum
h_d =height of drum

$$0.037 = \pi \times . 0.25^2 \times h_d$$

The furnace height was determined to be 0.188m.

2.4 Determination of the heat transferred across the furnace wall

The heat transferred across the furnace wall was determined by equation (3) obtained from Sharma & Aggarwal, (2012).

$$Q_f = \frac{A(T_2 - T_1)}{\frac{L_A}{K_A} + \frac{L_B}{K_B} + \frac{L_C}{K_C}} \quad (3)$$

Where Q_f=Heat transferred
T_2= maximum temperature of the furnace, 1250°C
T_1=ambient temperature, 27°C
A= area of bricks
L_A= thickness of P.O.P taken to be 200mm
L_B=Thickness of mortar , 100mm
L_C=thickness of metal sheet ,4mm
K_A=conductivity for P.O.P. 0.1185W/m°C
K_B=conductivity for mortar, 0.48W/m°C
K_C=conductivity for metal sheet. 50.5W/m°C

$$\frac{Q_f}{A} = \frac{(1250 - 27)}{\frac{0.2}{0.1185} + \frac{0.1}{0.48} + \frac{0.04}{50.5}} = 644.7 \, {}^{W}/_{m^2}$$

The rate of heat transfer was determined to be 6.44W/m^2.

2.5 Determination of the heat treatment efficiency

The efficiency of the furnace was determined using equation (4)

$$Efficiency = \frac{Heat\ output}{heat\ input} \times 100\% \quad (4)$$

The heat input is regarded as the electrical energy applied as shown in equation (5)

$$heat\ input = IVT \qquad (5)$$

where I=current in amperes

V=Voltage in volts(220 volt)

T=time in seconds(5 hours)

$$heat\ input = 15 \times 220 \times 5 \times 3600 = 59400000\, Joules$$

The heat output is the heat required to raise the temperature of aluminium alloy and that responsible for change of state of aluminum alloy

The heat required to raise the temperature was 50×0.907×(1250-27)=55463.05Kj

$$Efficiency = \frac{55463.05}{59400} \times 100\% = 93.33\%$$

The efficiency of the heat treatment furnace was determined to be 93.33%.

3. Results and discussion

The summary of obtained results and the graphical modeling of the furnace is presented in this section. Also, presented is the working principle and conclusion of the study.

3.1 Summary of the parameters

The summary of the calculated parameters is shown in Table 1.

Table 1: Summary of parameters

S/N	Parameters	Designed value
1	volumetric capacity	0.037m^3
2	furnace height	0.188m
3	rate of heat transfer	6.44W/m^2
4	Efficiency	93.33%
5	Heat input	59000Kj

3.2 Modeling of the Heat treatment furnace

The graphical modeling of the heat treatment furnace was done using AutoCAD software. The orthographic and isometric drawings are shown in Figures 1, 2 and 3 respectively

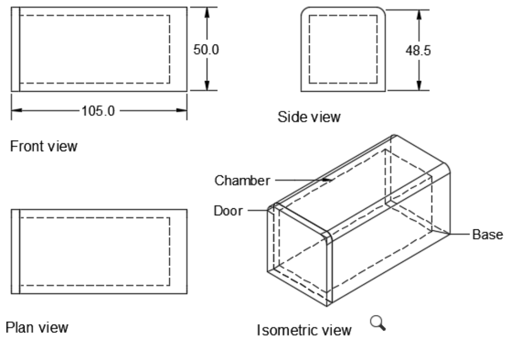
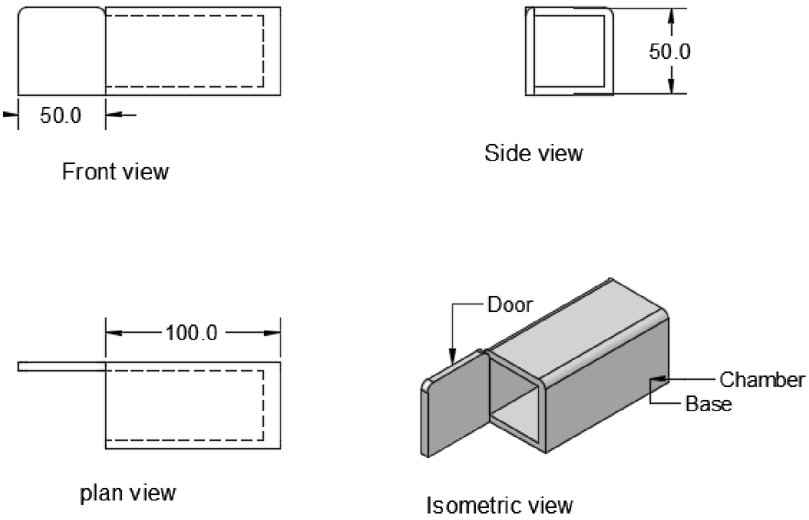


Fig. 1: Orthographic view of the closed constructed Furnace



Fig, 2: Orthographic view of the opened heat treatment furnace

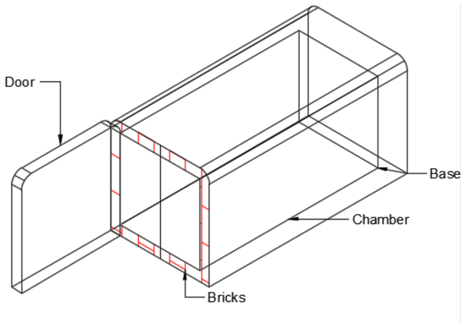


Fig. 3 : Isometric view of the Heat treatment furnace

3.3 Construction of the heat treatment furnace.

The heat treatment furnace was constructed with the values obtained from the designed calculations. The proper marking out was done to allow for adequate placement of the various components. The bricks were constructed using ant hill sand and mortar. A proper aligning of the furnace walls was done using the manufactured bricks (Upadhye & Keswani, 2012). Also, sodium silicate and kaolin were used as binding agent to promote cohesion between the bricks and furnace background. The furnace cover was also constructed using a metal base lined with bricks. The constructed heat treatment furnace is shown in Figure 4.

Fig. 4: The Constructed Heat Treatment Furnace

3.4 Working Principle of the furnace

The furnace is electrically powered through metallic tungsten heating element. The specimen aluminium alloy is placed in the combustion chamber which is charged up with the heat from the powered tungsten element (Sharma,2009). The placed specimen is heat treated across a temperature range of 0ºC to 750ºC. Also along the line the mechanical and physical properties are altered to suit a particular mecahinical and metallurgical function.

4. Conclusion

Developing our local content in the production of heat treatment furnaces will be a major boost in the quest to take a prominent position in foundry and metallurgical engineering. It will contribute to checking the excess waste on the foreign scarce resources spent on the importation of heat treatment and crucible furnaces. Developing our technology is very important to promoting us into global recognition as producers instead of the consuming nature which our nation is known for. The developed furnace has volume and height of $0.037m^3$ and 0.188m respectively.

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