BERKELEY PUBLICATION AND RESEARCH INTERNATIONAL
03.28.2022
Journal of African Research & Sustainability Studies Vol. 19 No.2

DEVELOPMENT AND TESTING OF HEAT TREATMENT FURNACE

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ABSTRACT

A heat treatment furnace which incorporates an alarm system had been designed and fabricate with its performance evaluated in this work. Most of the materials used for its design and production were locally sourced in Nigeria. Some design considerations, assumptions and designs were made before the actual work started. Mild steel plates and bars were the major metallic structural materials used. They were joined together by manual arc welding process, use of nuts and belts, screws etc. Refractory bricks and fiber glass were used to line the furnace for the purpose of insulation in order to have good heat retaining capacity inside the chamber of the furnace and minimize heat loss to the surrounding. A digital temperature and time control/monitor unit was also produced and electrically connected to the furnace to monitor and read the

Introduction:

Mechanical Properties of Engineering materials, especially metals and their alloys is dependent on their microstructures. Alteration of any of the properties implies an alternation of the material's microstructure. This change in the microstructure of a material is achieved chiefly through heat treatment. Heat treatment had been defined as the controlled heating and cooling operation applied to metals and alloys in solid states so to obtain the desired properties (*Herring, D.H.2016*).Heat treating is a process whereby the mechanical properties of metal are

ISSN: 1213-4977

temperature of the furnace via a thermocouple. The programmed soaking temperature is displayed digitally on the screen provided on the control unit. After assembly, the performance of the furnace was evaluated and it was observed that it has a tolerance of ±2.00c at a maximum temperature of 10050c in 70 minutes which translates to efficiencies of 83.75% in terms of maximum temperature reached and 71.8% in terms of heating rate based on design values of 12000c maximum temperature and 14.350C/min heating rate.

Keywords: *furnace, microstructure, temperature, refractory, heat ,*

altered deliberately by controlled heating and cooling of the metals. As a result, heat treatment involves thermal cycling between heating and cooling, which most metals and their alloys can be subjected to. Though most metals can be heat treated, the degree of response to the thermal cycling differs from one metal to another. One of the major reasons why steels show versatility is due to allotropic nature of the iron component which imparts a wide range of mechanical properties. A Furnace is a device used for high temperature heating. The name derives from Latin word formax [*Gorge, E.T, (2007*] which means oven. The heat energy required in a furnace may be supplied by fuel combustion or electricity. The heat treatment furnace is a heating chamber designed with a refractory material that retains heat that is measurable as well as controllable. Heat treating is Heat treatment impacts improves mechanical properties, such as hardness, tensile strength, impact energy, and the reduction of residual stresses [*Godwin O.C"*].

MATERIALS AND METHODS

Methodology

This chapter describes and discusses the materials, equipment and general techniques used in the design, construction and testing of an electrical heat treatment furnace which include:

(1) Setting the furnace specifications: A furnace of 3.5kW heating capacity was aimed to fabricate. It must be capable to heat metals to about 1200 ^{0}C. It enables the furnace to be useful to melt metals whose melting temperatures fall less than 1200 ^{0}C. Further, it has to be able to hold the melt at a set temperature for required amount of time. It must accommodate different sizes of crucibles for melting various quantities.

Heat Generated

Quality of heat generated from the industrial heating element was evaluated as 1548.39 J/s using a combination of Joule-Lenz's law and 0hms law given by Okeke and Anyakoha (1989) as

$$E = \frac{V^2}{R}$$

$Where\ E = ElectricaL\ Energy$

$t = time(s)$

$R = Resistance\ (\Omega)$

V = Voltage (V)

Temperature attained

Temperature of the brick wall inside the furnace (T_b) was evaluated form Newton's law of cooling as 1148.390c using equation ………………(2)

$Q = H_{air}A_b(T_{air-}\ T_b) \ldots \ldots \ldots \ldots \ldots 2$

$Where: Q\ =\ Quality\ of\ heat\ generated$

$Hair\ =\ Convective\ heat\ coefficient\ of\ air$

$Ab\ =\ Surface\ area\ of\ the\ bricks\ wall\ in\ the\ heatingChamber.$

Temperature of the outside brick wall before the fibre glass (Ts) was calculated as 956.130C using Fourier's law using equation ……..……..(3)

$Q = K_bA_b\frac{T_b - T_s}{dx}$…………………… (3)

$Where: Kb\ =\ thermal\ conductivity\ of\ brick\ (1.28\ w/mk)$

$(Marks\ Handbook)$

$dx = thickness\ of\ the\ brick\ wall.$
$Ab = As = surface\ area\ of\ brick$

Temperature of the space occupied by fibre glass (Tf) was also determined to be 31.300C using furrier's equations:

$Q = K_f A_f \frac{T_s - T_f}{dx}$……………………..(4)

$Where: Kf = thermal\ conductivity\ of\ fibre\ glass$ $(0.0436\ w/mk)$
$Af = Surface\ area\ of\ the\ space\ occupied\ by\ the\ fibre\ glass$
$dx = thickness\ of\ the\ fibre\ glass$

The temperature of the external wall casing (Te) also utilizes the Fourier's equation for its evaluation as 30.710C using equation ……..(5)

$Q = K_e e \frac{T_f - T_e}{dx}$……………(5)

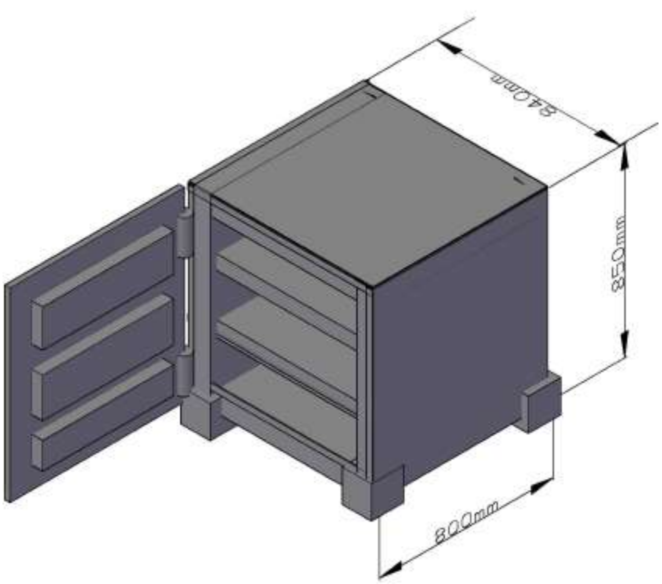
$Where: Ke = thermal\ conductivity\ of\ steel$ $(21W/mk)$
$Ae = Surface\ area\ of\ the\ mild\ steel$
$dx = thickness\ of\ the\ mild\ steel$

The fact that the human body temperature ranges from 35^0C to 43^0C. Hence, from the temperature of the furnace casing being 30.71^oC makes it very safe for the operation during heat treatment.

FABRICATION PROCEDURE

The casing was made form a 7mm thick flat sheet of mild steel in combination with angle steel bar 5mm thick measuring 98mm x 98mm. After measuring, marking out, and cutting to size as indicated in the design, all the pieces were joined together using manual metal are welding, nut and both, screw etc process, to produce the casing. Initially, the top was left open to allow for the laying of fibre glass and bricks. Also at the two opposite end of the sides, 150 x 150mm opening was provided for the door (front) and for the space where the electrical wires and thermocouple can pass through (back) After the casing was ready, it was lined with two refractory materials – fibre glass and refractory bricks. The bricks were laid side by side to each other and were bonded by a mortar made by mixing a refractory cement and water to paste using the standard ratios. Laying of the brick continued until the surface of the heating chamber was formed. The heating chamber formed a square-end cuboid shape of 150 x 150 x 400mm. A gap of 20mm was left opened between the metal plate and the wall brick, which was filed with fibre glass to improve the insulation. The assembled furnace was allowed to dry naturally as any breach or cracks observed were repaired as the mortar dries. Since mortar contracts and cracks during drying, the need to properly repair became imperative in order to enhance the working efficiency and the life span of the furnace [53]. After drying for about 10 days, the control (temperature and time) unit and the heating elements were electrically connected for the functionality of the furnace. The thermocouple is placed in the heating chamber of the furnace to read the temperature and it is connected to the temperature controller. Ac power source is connected to the system through an industrial switch.

A view of the Designed furnace.



RESULTS AND DISCUSSION

The assembled furnace was allowed to dry naturally as any breach or cracks observed were repaired as the mortar dries. Since mortar contracts and cracks during drying, the need to properly repair became imperative in order to enhance the working efficiency and the life span of the furnace . After drying for about 10 days, the control (temperature and time) unit and the heating elements were electrically connected for the functionality of the furnace. The furnace was heated to a temperature of 900^0 c without any specimen to dry it up. Next stage of heating was done with a sample of prepared metal. First of all, the specimens was set aside as received, the remaining test specimens were normalized; that is to say they were heated in the furnace at 880 °c, then the temperature[880] was maintained for 30minutes after which it was allowed to cool down in air[quenching in air].a set of the specimen was set aside again as normalized specimen.

The Electric heat treatment furnace was evaluated to ascertain its performance by heat treating mild steel with the following dimension: length 150mm and diameter 50mm at the range of temperature 35◦ - 1200◦ over a period of 2000 seconds. The results obtained were tabulated as indicated in Table 1 and graphically in Figure 2 . It was observed that the temperature of the furnace was maintained at 1200 degrees over a period exceeding 2000seconds and this shows that the furnace was designed to attain a maximum temperature of 1200

After normalizing, the specimens were heated to 880°c and then quenched in the a quenching medium [SAE, and water]. The specimens were experimented for the three tests[tensile, impact and hardness]

OBSERVATION AND TABLE 1 for impact test

S/NO	SAMPLE SPECIMEN	IMPACT ENERGY IN JOULES
1	SAE	94.50
2	Water	13.17
3	Normalized sample	91.80
4	As received sample	76.95

Time (seconds)	Temperature (Degree)
0	30
40	180
135	350
260	550
600	800
1100	1100
1550	1250
1900	1300

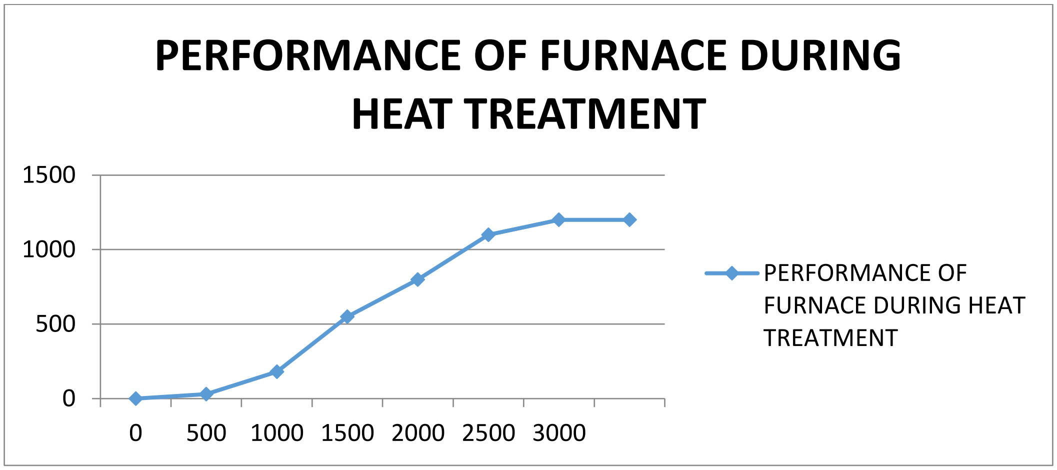


Fig 4. Graph of Temperature(°c) Against Time(seconds)

EFFICIENCY IN TERMS OF MAXIMUM TEMPERATURE AND HEATING RATE

The designed maximum temperature is 12000C to be attained in 1 hour. This translates to a heating rate of 200C/mms. While the maximum temperature reached in use is 10050C in 70 minutes. This translates to a heating rate of 14.360C/mms.

Therefore, efficiency in terms of:

(i) Maximum temperature is

$$Efficiecy = 1 - \left(\frac{1200 - 1005}{1200}\right) = 0.8375, = 83.75\%.$$

Heating rate is given as

$$Efficiency = 1 - \left(\frac{20 - 14.36}{20}\right) = 0.718, = 71.8\%$$

CONCLUSION

The design and fabrication of a heat treatment furnace has been successfully completed. The manufactured furnace is cheap when compared to the ones imported from Overseas because most of the materials were locally sourced. It has an efficiency of 83.75% and 71.8% based on design values in terms of attainment of maximum temperature and heating rate respectively. It had also shown high level of tolerance of ± 2.00C at temperatures below 1005^0C. The manufactured furnace also has good heat retention capacity, which makes it very safe for use.

Based on heating up to a temperature of 1005^{0}C, the furnace can be used to heat treat both ferrous and nonferrous metals and alloys in order to alter their microstructure and enhance their properties for the needed application in service. Hence, this furnace is highly recommended for use. Furthermore, in order to reduce the dead weight of the furnace, the future models should use light sheet metal for the casing and substitute more fiber glass for bricks.

The furnace was constructed putting into consideration; its temperature attainment, capacity of metals it can hold, the depth/surface area to be heat treated, operators safety, space to be occupied in the workshop floor, cost restrictions, availability of the materials used, its maintainability and portability.

The furnace was tested for heat treatment processes such as annealing, normalizing, case hardening and quenching, the results obtained shows that the microstrucrural and Mechanical properties of the tested specimen were changed after heat treatment**..**

Finally, the actualization and realization of this project is a boost to the development of local manpower capacity in Nigeria and also to advance the reliability of engineering materials in service

RECOMMENDATIONS

The purpose of this project is a boost to the development of local manpower capacity in Nigeria and also to advance the reliability of engineering materials in service. It is therefore recommended that local sourced materials for industrial production should be encouraged, this will reduce the overdependence on imported machine parts.

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