American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-9, Issue-7, pp-62-70
www.ajer.org
Research Paper Open Access

Development of a High-Efficiency Crucible Furnace for Melting 30kg Non-Ferrous Metal Scraps

Rasheed Olatunde Azeez[1*], Abdulmumuni Bashiru[2], Oyebola Olufemi[3], Osunseyi Timothy Olakunle[4], and Akinjogbin Oludele[5]
[1, 2, 3, 4 & 5]Department of Mechanical Engineering Technology, Federal Polytechnic Ede, Osun State, Nigeria
Corresponding Author: Rasheed Olatunde Azeez

ABSTRACT :*A crucible furnace is an equipment used in the foundry workshop or industry for melting metals for casting operations. They are the oldest type of melting furnaces used for melting and holding small batches of non-ferrous alloys for which a refractory crucible filled with metal is heated through the crucible wall. This paper focuses on the development of a 30-kilogram capacity diesel-fired crucible furnace used to melt aluminium metal. Drawings were produced to aid the fabrication of the furnace using a mild steel sheet while the other components needed for the fabrication were selected based on functionality, durability, availability of local materials, and cost. The test was carried out on the furnace to evaluate the performance and the results obtained showed that it took the furnace* $150\, mins$ *to completely melt*$30kg$ *of aluminum scrap between* $620^0C - 700^0C$ *using* $3.4\, litres$ *of diesel fuel. The developed crucible furnace has a fast heating rate, efficient fuel economy as it is capable of consuming fuel less than* $1.36\, litres/hr$*, the heating rate is* $77.3°C/min$*, melting rate of* $0.2\, kg/min$ *and heating efficiency of* 27.6%*which is quite impressive when compared with the conventional crucible furnace of* 28% *maximum efficiency. Thus, the overall efficiency of the developed furnace is 98.6%. The result above proved that the fabricated crucible furnace was effective, reliable, economical, environmentally friendly, has no side effect to the operator, easy to move from one place to another, useful in small scale, rural and urban foundry industries, can provide employment opportunities for Nigerian youth and useful in conducting practical in foundry workshop in any tertiary institution. The furnace can melt* $30kg$ *of aluminium scrap of automobiles, used cans, kitchen utensils between* $620^0C - 700^0C$*, and other metals for which the melting point is above* 700^0C *and below* 1500^0C*.*
KEYWORDS: *Aluminium scrap, Crucible furnace, Heating efficiency, Heating rate, Melting temperature.*

Date of Submission: 18-06-2020 Date of acceptance: 06-07-2020

I. INTRODUCTION

As it were before when humans were smelting ores of lead and tin but didn't need much more heat than it would require cooking their food and as time pass by, the need for something more than wood flame fires became apparent [16].

Knowledge of furnace technology is very important when working in a foundry. Metals normally melt at very high temperatures and required different types of furnaces for various applications.

In metal casting, the heat required to be exerted on the metal to reach its melting point is done through the furnaces. A furnace is equipment used to melt metals in its initial stages of the metallurgical process. There are different types of furnace used in melting such as Induction furnaces commonly used in foundries and capable of producing sixty-five tons of steel at each charge, crucible furnaces made of refractory materials such as ceramic to handle high temperatures, cupola furnaces made of long chimney-like furnaces filled with coal-coke and additives and lit for which metal is added directly to the furnace and lastly the electric arc furnaces which use electrodes to run an electrical current through the metal inside the furnace [3]. Furnace design for melting in foundries is done in a particular way to consume less heat and fuel as possible to melt the metal [12].

Crucible is the most basic form of the metal furnace that can handle the very high temperature. They are often made of ceramic and can be placed directly into the heat source/fire and filled with metal and additives. Jewellery makers and hobbyists still use crucible furnaces as well as some non-ferrous foundries, or those doing very small batch work [16].

Crucible furnaces are classified as a small capacity furnace used for melting small applications or holding furnaces. The metal is placed or poured into a ceramic crucible which is contained in a circular furnace that is fired by a gas burner or heated by electric elements. The heating fuel is typically coke, oil, gas, or electricity for which the gas-fired crucible style furnaces offer the advantage of a high-volume melt capacity per square foot of floor space required. They are perhaps the most flexible of all furnace styles, less affected by frequent cycling; they offer faster start-ups and temperature recovery [15].

The recycling on non -metal, especially, Aluminium recycling is one of the most profitable businesses in Nigeria and the world at large. Its popularity can be attributed to the fact that it takes lesser amounts of energy to aluminium scrap through the recycling process if compare to its ore and ferrous metals. It is therefore necessary to harness the available source of energy that will encourage and support the productivity of small and medium enterprises involved in the aluminium recycling business in Nigeria [5].

Foundry technology is practiced in urban and rural areas in Nigeria where the local foundry man digs a hole on the ground to take the shape of an oven using coal or charcoal as fuel and uses clay or metal pot as the crucible [11]. The availability of oil-fired crucible furnaces to the foundry and manufacturing process is very limited not minding its importance, and when available most of them are imported which is costing the country a huge sum of foreign exchange. The foundry workers were having problems working with a local type of crucible furnaces, such as high fuel consumption, high labour and material cost, the excessive time required for operation, air pollution during operation, and excessive heat loss in the system [11]. Other difficulties normally experienced by the foundry industries include lack of stable electrical power supply, high cost of importation of foreign furnaces, raw materials, etc. which had resulted to low production output, loss of man-hours, high cost of production, and in most cases, loss of jobs resulting in the closure of most of the industries.

It is estimated that Nigeria has about one hundred and sixty (160) foundries for which some are functional while others are in deplorable conditions; this drastically reduces the capacity of the industries to meet less than 5% of their demand for machine components and mechanical parts [14].

To address these challenges, a diesel-fired crucible furnace was developed that is capable of melting $30kg$ of automobiles aluminum scrap, used cans, kitchen utensils, from 660^0C to 700^0C and other metals for which the melting point is above 700^0C and below 1500^0C.

The fabrication of a diesel-fired crucible furnace is quite significant because of its high efficiency, accuracy, and ease in operation for melting metals in foundry workshop or industries. The furnace will contribute immensely to converting the scrap metal into useful products, lead to the development of indigenous technology especially in the production industries, improve working conditions of the foundry workers and encourage youths to venture into the foundry work.

II. RELATED WORK

Crucible is a ceramic or metal container for which metals or other materials are melted or subjected to a very high temperature. Crucible furnaces are one of the oldest and simplest types of melting units used in the foundry. This type of furnace makes use of a refractory crucible that contains the metal charge and heated via conduction of heat through the walls of the crucible. The furnace source of heating is mainly fuel from coke, oil, gas, or electricity. Crucible furnaces are typically classified according to the method of removing the metal from the crucible such as bale-out furnaces, where molten metal is ladled from the crucible; tilting furnaces, where the metal is poured directly from the furnace; and lift-out furnaces, where the crucible can be removed from the furnace and used as a ladle [1].

Researchers had worked on the crucible furnaces in the past, and their contributions are described below; [7] developed a Mini Electric Arc Furnace that can melt 5kg of steel/cast iron scraps, using locally produced Soderberg electrodes. The result shows that 60 minutes was required to heat the furnace between 1150°C – 1400°C and 95 minutes required to melt the first charge of 2kg with a melting rate of 21.05g/minute. [10], worked on a diesel-fired heat-treatment furnace using locally sourced materials to replace electrically powered heating elements which are not reliable due to lack of electricity supply in Nigeria. He observed that the furnace has a fast heating rate of 61.24°C /min at a pre-set temperature of 900°C resulting in less than 1.41litre/hr fuel consumption. [4], carried out performance evaluation on the charcoal-fired furnace for recycling aluminium scraps. The result shows that the efficiency of the furnace was 11.5% which is low due to the large quantity of energy wasted because the furnace is an open type. [17], carried out an investigation on the use of kerosene crucible furnace and attained 750^0C. They discovered that though, the temperature was sufficient for melting aluminium metal but inadequate for melting other non-ferrous metals.

[11], also developed a charcoal-fired crucible furnace for melting aluminium. The furnace is accessible to the local small scale foundry craftsmen but produces smoke that polluted the environment and addresses the problem experienced by a local foundry in the melting of metals. [2], improved on the crude method of melting using local foundry operators through the design and construction of the gas-fired type of crucible furnace. It was discovered that gas as a source of energy supply has dangerous implications and less common than coal or

charcoal type. But, the gas furnace is normally used in large and not small scale foundry industries because of the complication of its operation. [9], improved on the gas-fired crucible furnace through the design of a coal-fired crucible furnace. It was discovered that charcoal remains the most available fuel as coal is not available in many parts of the country. [8], designed an electrically powered stationary pot crucible furnace for pyrolysis and discovered the benefits of electrically power furnaces but its cost of operation was exorbitant. [6], design and construct an oil-fired crucible furnace that focused on ensuring a high heating efficiency for melting aluminium scrap, while effectively minimizing heat losses, and maximizing heat generation.

Thus, from the previous research on crucible furnace, there is a need to developed a furnace that can be fired with readily available fuel(especially, waste oil), has less maintenance and operating cost, economical when compared to the imported one, consume less fuel, and very efficient. These are the major gap that the fabricated diesel-fired crucible furnace aimed to address and to reduce the challenges faced by local foundry operators and businesses in Nigeria.

III. MATERIALS AND METHODS

A. Materials and Specification

Table 1: Material Specification of the Crucible Furnace

Materials	Specification	Quantity	Rate (N)	Amount (N)
Mild steel sheet	2438mm by 1219mm	2	14000	28,000
Mild steel rod	200mm by 300mm diameter	1	5000	5000
Mild steel angle iron	200mm by 300mm diameter	4	7500	30000
Refractory Black: silicon sand (sodium silicate + kaolin)	Durax	1 bag	25,000	25,000
Centrifugal blower	Single-phase	1	47,000	47,000
Purchase of Fabrication Materials	cutting, welding, grinding, painting & assembly	-	-	8000
Transportation	-	-	-	5000
Miscellaneous	AutoCAD drawing, Typing work, and others	-	-	6000
Total				**154,000**

B. Engineering Requirement for Material Choice

The main consideration for the for choosing the materials required for fabrication of crucible furnace;

- *Weldability*: The ability of the material to be welded
- *Toughness:* The ability of the material to withstand shock and absorb energy due to impact;
- *Fatigue:* The ability of the material to withstand cyclic stresses
- *Ductility:* The ability for the material to be drawn into wire
- *Durability:* The ability to stay strong and in good condition over a long period
- *Availability:* The state of the material readily accessible

Other reasons for selecting the materials above are as a result of high melting temperature and tensile strength, ability to resist heat and pressure and supply steady volume of air at efficient pressure

C. Machine Fabrication

The machine was fabricated based on the design specification. The construction was carried out with locally sourced materials to reduce the cost of production to meet the design objective. Each of the components was designed and fabricated following the due fabrication process as shown in figure 1. This entails marking and cutting out the required shape and dimension, welding of the parts to form the components, and surface finishing improving on the aesthetics.

- *Marking Out and Cutting:* This is the first fabrication stage which involved the marking and cutting out of the required dimension of 1417mm by 500mm from the mild steel for the furnace casing and a hole of diameter 70mm was marked out and cut on the point 353mm by 151mm on the plate. The furnace base was also cut from the steel plate to produce a circular sheet plate of diameter 450mm
- *Rolling and welding Process*: This process was used to produce the casing of the furnace by rolling the cut sheet metal in a rolling mill to produce a cylindrical housing for the furnace frame of diameter 450mm and height 456mm. The sheet metal that was rolled is welded to the required shape while the burner part is also welded to the furnace casing
- *Refractory lining*: Furnace refractory lining was made by mixing the refractory cement (Durax) with sodium silicate Na_2SiO_2 in the proportion of 1 Litre of Na_2SiO_2 to a bag of Durax of weight 25kg. Then, the blended mixture was thoroughly used in lining the furnace through three stages below;

  Flooring: The flooring was done by making the surface of the furnace base wet through a mixture of water and sodium silicate before pouring a very thin layer of 2mm thick refractory mixture. Before arranging the fire bricks into the furnace base, the mixture of the Castable refractory and sodium silicate are poured on it and allowed to set

The setting of bricks: The wall was also damped with sodium silicate before the surface is plastered with the mixture of the refractory cement and sodium silicate to form a layer of 10mm thickness before the 60mm thick bricks were glued to the first layer while it is still wet before a final layer

Drying: The furnace body is dried and fired for rigid cohesion

- *Furnace cover and stand*: The fabrication of the cover was based on the internal diameter of the furnace and a cover of a diameter of 376mm and a height of 150mmwas made from steel rim using purely the same mixture of Durax and sodium silicate with a hole in the rim which serves as the exhaust. The furnace cover support was fabricated from steel plate cut out to a dimension of 1166mm by 150mm

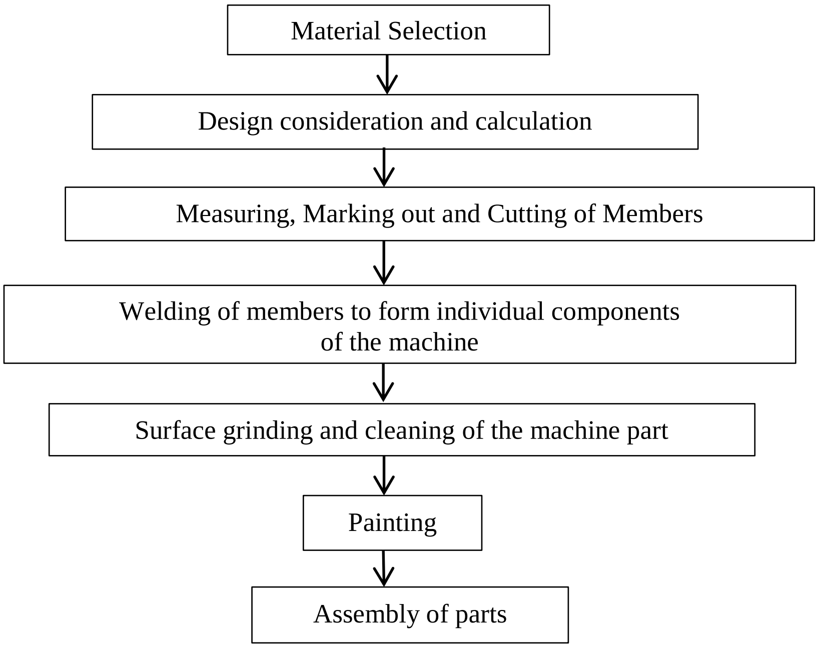


Fig. 1. Flowchart of Fabrication Processes

D. Working operation

Fig. 2. Fabricated Crucible Furnace

- Starting the furnace; The furnace is first pre-heated by coke/coal to introduce heat into the furnace, the electric the blower is then switched on to supply air into the furnace and then the fuel supply valve is opened to supply fuel (diesel) into the furnace to complete the combustion reaction in the furnace
- Scrap aluminium was measured to be 30 kg
- All the 30kg of aluminium was broken to small pieces and it was kept aside
- The amount of fuel used was measured in litre before supplying into the fuel tank

- The coke/coal was pre-heated in the furnace combustion chamber
- The crucible was placed inside the furnace
- The aluminium was fed into the crucible at an interval of 3 kilograms at given time intervals
- The blower was switch on to blow air into the combustion chamber
- The fuel supply valve was open to generate the required heat for melting of the aluminium
- The aluminium scrap was fed 3kg each at a given interval of time to melt completely until it reached 30kg
- The slag was removed from the melted aluminium (liquid)
- The aluminium was allowed to melt completely up to the pouring temperature and appropriate tong was used to fetch the molten metal from the crucible for casting.
- The molten metal was poured into the sand or clay mould for casting of the desired shape and allowed to solidify.

IV. RESULTS AND DISCUSSION

A. *Result*

After fabrication, the system was tested to determine the time required to completely melt the aluminium scrap while taken the temperature readings at regular intervals using pyrometer and stopwatch to monitor the time taken for 3kg of aluminium to melt completely. The test was conducted on the furnace to determine the time taken to raise the temperature of the melting aluminium to 660^0C using three (3) different ways such as; a no-load test of the furnace /empty furnace test, furnace with a load of 30kg at once and continuous method of melting 30kg of aluminium metal at 3Kg interval each. The results obtained are shown below;

Table 2: Result of the Test Carried Out On the Fabricated Crucible Furnace

Material **Aluminium**

Mass (kg)	Temperature drop after change $T_1(^0C)$	Melting Temperature $T_2(^0C)$	Temperature difference $(T_2 - T_1)$ (^0C)	Time is taken to raise temperature to the melting point after the charge (min)	Holding time for complete melting of aluminium (min)	Total time is taken (min)	Heating rate $(^0C$ /min)
3	26	660	634	23	4	27	23.5
6	546	660	114	17	4	21	5.4
9	553	660	107	13	6	19	5.6
12	558	660	102	9	6	15	6.8
15	563	660	97	7	6	13	7.5
18	570	660	90	6	6	12	7.5
21	588	660	72	5	6	11	6.5
24	600	660	60	4	6	10	5.0
27	605	660	55	3	8	11	5.0
30	610	660	50	3	8	11	4.5
Total				**90**	**60**	**150**	**77.3**

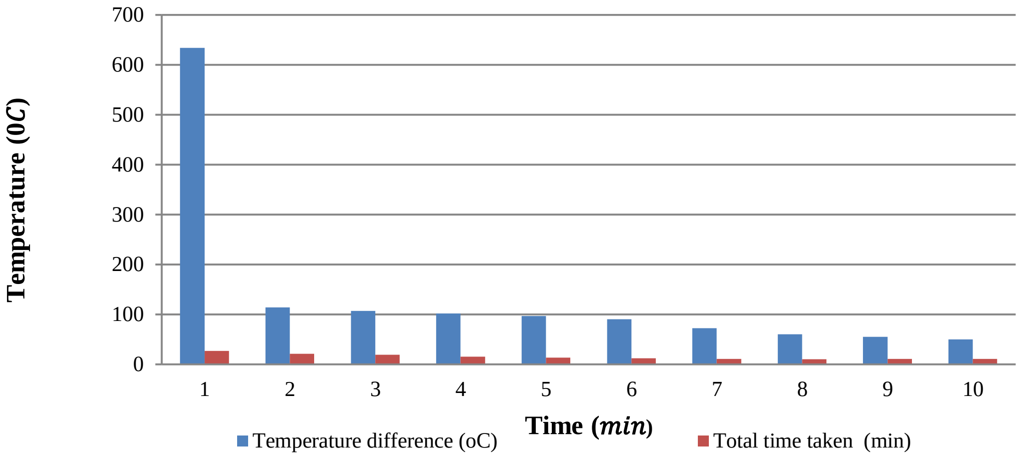


Fig. 3. Temperature time graph for continuous loading of 30kg of aluminium scrap

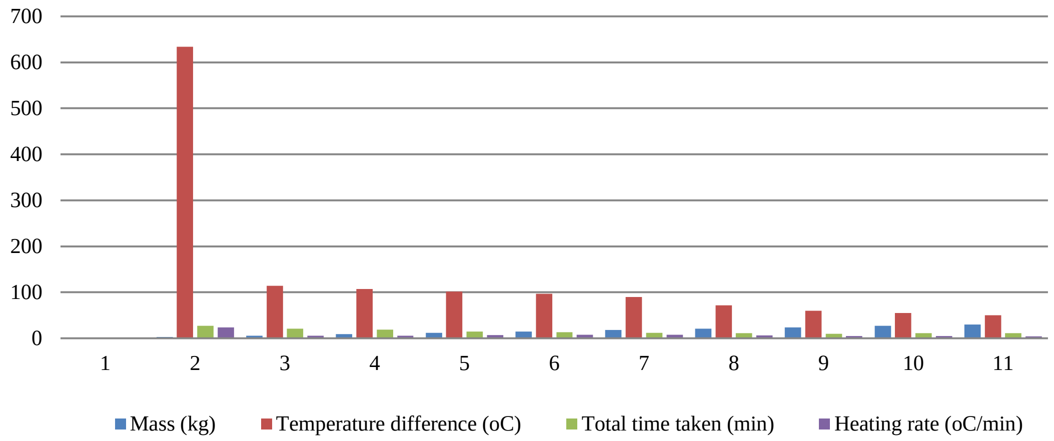


Fig. 4. Comparison of the Mass of the Aluminium, Temperature, Time and Heating Rate of the Furnace Graph

B. Performance Evaluation

The furnace parameter and the result obtained as shown in table 4 above are;

The ambient temperature (T_a) = 26°C, The melting temperature of the aluminium (T_m) = 660°C, Furnace Maximum Design Temperature (T_d) = 700°C, Total mass of charge (Kilogram) =30kg, Total time is taken to melt charge (minutes) =150minutes, Mass of the aluminium metal (m) = 30Kg, Specific heat capacity of the solid aluminium (C_{ps}) = $0.91KJ/kgK$, Specific heat capacity of the molten aluminium C_{pm}) = $1.18KJ/KgK$, Latent heat of fusion of aluminium (L) = $321KJ/kg$

The melting rate of the furnace can be determined below;

$$Melting\ Rate = \frac{Total\ mass\ of\ charge\ (Kilogram)}{Total\ time\ taken\ to\ melt\ charge\ (minutes)} \quad (1)$$

$$Melting\ Rate = \frac{30}{150} = 0.2\ kg/min$$

The efficiency of the crucible furnace when melting aluminium can be determined by;

Then the theoretical energy content to melt 30Kg of aluminium metal at 660°C when assuming its initial temperature at standard temperature and pressure of 26°C is calculated below:

Temperature rise to melting point $(\Delta\theta) = T_m - T_a$ (2)

$(\Delta\theta) = 660 - 26 = 634°C$

Energy content required to raise the temperature of the metal to the melting point (Q_S) as given by [13];

$Q_S = mC_{ps}\Delta\theta$ (3)

$Q_S = 30 \times 0.91 \times 634 = 17308.2\ KJ$

Temperature rise to reach the superheated stage

$(\Delta\theta) = T_d - T_m$ (4)

$(\Delta\theta) = 700 - 660 = 40°C$

Energy content required to superheat (Q_h);

$Q_m = mC_{pm}\Delta\theta$ (5)

$Q_m = 30 \times 1.18 \times 40 = 1416\ KJ$

Energy content required to change metal from solid to liquid (Q_L);

$Q_L = mL$ (6)

$Q_L = 30 \times 321 = 9630\ KJ$

Then, the total energy content of Aluminium (Q_T) can be determined by adding the energies above, thus;

$Q_T = Q_s + Q_m + Q_L$ (7)

$Q_T = 17308.2 + 1416 + 9630 = 28354.2\ KJ$

This means that the Heat required in melting the aluminum (Theoretical Energy) = $28354.2\ KJ$

The total amount of energy consumed in the furnace can be determined;

Recall; that the energy content of the fuel is rated as $139000KJ/gallon$ (8)

We know that; $1\ gallon = 4.6\ litres\ (British\ Standard)$

This implies that the energy content of the fuel is $\frac{139000}{4.6} = 30217.39\ KJ$

From the test carried out, the amount of fuel used to melt the $30kg$ of aluminium metal is $3.4litres$

Therefore, the total amount of energy used by the furnace $= 3.4 \times 30217.39 = 102739.126\ KJ$

This means that the heat used by the furnace (experimental heat energy) $= 102739.126\ KJ$
The efficiency of crucible furnaces ranges from a low 3.5% to a high 28%, the common commercial average being around 15%. The efficiency of the crucible furnace when melting aluminium metal is calculated as follows

$$Heating\ Efficiency\ (\eta) = \frac{Heat\ required\ to\ melt\ the\ aluminium}{heat\ used\ to\ melt\ the\ aluminium} \times 100\% = \frac{Heat\ energy\ theor}{etical\ heat\ energy\ experimental} \times 100\% \quad (9)$$

$$Heating\ Efficiency\ (\eta) = \frac{28354.2}{102739.126} \times 100\% = 27.6\%$$

The efficiency of the furnace increases with increased volume or mass of metal, this implies that the higher the melting capacity, the higher the efficiency.

C. Discussion

The result obtained from the three (3) tests carried out on the furnace, showed that;
For the No-load test/Empty Furnace Test (furnace tested without loading the aluminum); the temperature of the crucible rose from room temperature of 26^0C to 660^0C in $30\ minutes$, and it consumed $0.75\ litre$ of fuel.

For load test (furnace tested with a load of $30kg$ of aluminium); a load of $30kg$ of aluminium was put into the crucible furnace at once and it was observed that the crucible temperature rose to the melting point of 660^0C in 60min and it was maintained and held for 10 minutes while steering to ensure it melt completely, this test consumed 1.5 litres of fuel and the total time taken for melting of 30kg of aluminium at once was $70\ minutes$.

Lastly, for the continuous method of melting process was undergone to determine the time taken to melt 3 kilograms of aluminium and holding time for steering the molten aluminium to ensure complete melting of aluminium Table 2, Figure 3 and Figure 4 above shows the trend of the temperature rise and drop in the crucible while adding 3 kilograms of aluminium gradually into the crucible and the temperature dropped to a certain level before it rose back to 660^0C, the graph further shows the holding time required for every 3 kilograms of aluminium to melts and the heating rate. After adding $3\ kilograms$ of aluminium and continue firing the furnace to reach the melting point, the temperature drop when an additional $3\ kilogram$ of aluminium was added. This shows that the temperature decreases as the number of aluminium increases while the holding time decreases.
Time taken to raise the temperature from 26^0C to 660^0C was $90mins$ and the holding time for the aluminium to melt completely melted was $60mins$, therefore, the total time taken for melting of $30kg$ of aluminium at once was 150minutes and consumes $3.4\ litres$ of fuel.

From the performance evaluation above, the heating rate is $77.3°C/min$, melting rate of$0.2\ kg/min$, and the efficiency of the furnace 27.6%, which falls within the efficiency range of conventional furnace. This is very significant because most of the heat generated in the furnace was used in the melting of the metal.

V. CONCLUSION

The diesel-fired crucible furnace was fabricated to melt aluminium scraps with specific objectives of achieving high melting efficiency by effectively minimizing heat losses, and maximizing heat generation through the use of available local materials with good insulating properties for the refractory wall. The crucible inside the hearth was loaded with scraps from aluminium roofing sheets offcuts and canned drinks. Then it was heated for about 10 minutes and the aluminium scraps melted completely indicating that the forge can attain temperatures ranging from $620°c\ to\ 700°c$ which is the melting temperature range of aluminium. The successful melting of the aluminium scrap by the forge shows that the research objectives were successful. The material used for the development of the crucible furnace where all procured locally to encourage indigenous industries and encourage further research.

The developed crucible furnace has a fast heating rate, efficient in fuel economy as it is capable of consuming less than $1.36\ litres/hr$, can melt 30kg aluminium scraps in 150 minutes, the heating rate is $77.3°C/min$, melting rate of $0.2\ kg/min$ and efficiency of the furnace were calculated to 27.6%and the overall efficiency of the developed furnace is 98.6%. This is quite impressive when compared with the maximum efficiency of 28% obtainable from the conventional crucible furnace.
It was also observed that the furnace has a good heat-retaining capacity, can be easily maintained and safe to use. Digital pyrometer was used to measure the melting point of aluminium between temperature ranges of $620°c\ to\ 700°c$and can also be used to melt other materials with a melting point up to$1500°c$.

From the result above, it can be concluded that the crucible furnace can be effectively used in melting non-ferrous metal such as aluminium scrap of automobiles, used cans and kitchen utensils using sand casting moulds. This fabrication will contribute immensely in assisting local foundry industries, it is economical and time-saving during operation when compared to foreign ones, and it is suitable for use in small scale foundries and in conducting practical in tertiary institutions.

In developing countries like Nigeria, where the level of unemployment is high and job opportunities are very scarce, it is very important not to allow the few operating foundry industries and workshops to close down. Hence the fabricated furnace can conveniently replace the conventional imported crucible furnace as a means of improving the Nigerian local production, provide an alternative means for the foundry industry, provide employment opportunities, and saves a lot of foreign currencies used in importing the equipment to the country.

REFERENCES

[1]. AtlasFoundry Company Inc: http://www.atlasfdry.com/cruciblefurnaces.htm, 2018.

[2]. A.J. Komolafe, "Design and construction of a gas-fired crucible type furnace", Undergraduate Project, Department of Mechanical Engineering, ABU Zaria, 1992.

[3]. Amelt, "four different types of foundry furnaces", Amelt corporation Canada: https://www.amelt.com/blog/bring-the-heat-4-different-types-of-foundry-furnaces/, 2019.

[4]. A. O. Ighodalo, G. Akue, E. Enaboifo, J. Oyedoh, “Performance Evaluation of the Local Charcoal-Fired Furnace for Recycling Aluminium,” Journal of Emerging Trends in Engineering and Applied Sciences, vol. 2, no. 3, pp. 448-450, 2011.

[5]. B.C. Chukwudi and M.B. Ogunedo," Design and Development of a Gas-Fired Reverberatory Furnace", because of Huge Gas Reserves in Nigeria, Pacific Journal of Science and Technology, 8 (1), pp.13-21, 2017.

[6]. C. C. Beneth and B. O. Martins, “Design and Construction of an Oil Fired Crucible Furnace,” International Journal ofResearch and Review, vol. 5, no. 2, pp. 67-74, 2018.

[7]. F.A. Oyawale and D.O. Olawale, “Design and Prototype Construction of a Mini-Electric Arc Furnace”, the Pacific Journal of Science and Technology, 8(1) pp. 12-16, 2011.

[8]. I. F. Titiladunayo and O. P. Fapetu, “Selection of Appropriate Clay for Furnace Lining in a Pyrolysis Process,” Journalof Emerging Trends in Engineering and Applied Sciences, vol. 2, no. 6, pp. 938 – 945, 2011.

[9]. J. D. Folayan. "Design of coal-fired crucible type furnace," Undergraduate Project, Department of Mechanical Engineering, ABU Zaria, 2014.

[10]. K. K. Alaneme and S. O. Olanrewaju, “Design and Construction of a Diesel Fired Heat Treatment Furnace,” Journalof Minerals & Materials Characterization & Engineering, vol. 9, no. 7, pp. 581-591, 2010.

[11]. M.S. Garba, "Design, construction and testing of charcoal-fired crucible furnace for melting of 10kg of aluminium", Undergraduate Project, Department of Mechanical Engineering, ABU Zaria, 2015.

[12]. Pacific die casting, “Three main types of melting furnaces used in metal casting”, Tecate Mexico and Commerce, California, ISO 9001, 2015 certified.

[13]. R.S. Kurmi and J.K. Gupta, “Text Book of Machine Design”, Eurasia publishing Home (PVT), New Delhi, 2010.

[14]. S. O. Adeosun and L. O. Osoba, “Foundry Industry; A Tool for Technological Advancement in Nigeria,” In Proceedings of Nigeria Metallurgical Society Conference, Federal University of Technology, Akure, pp. 1, 2008.

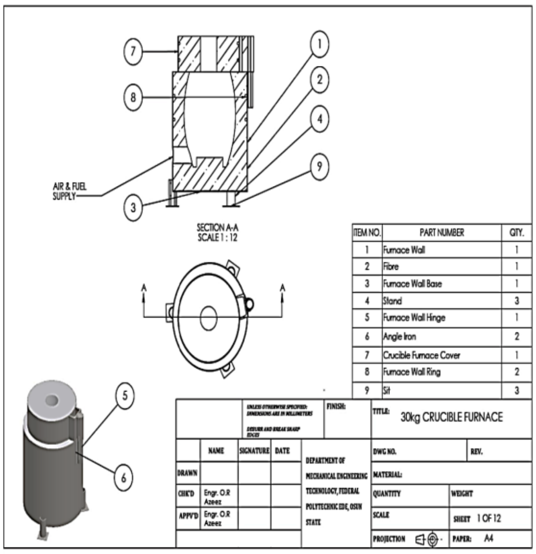
[15]. SilcarbRecrytalized Private Limited: https://www.silcarb.com/industrial-furnaces/crucible-type-aluminium-melting-furnaces.php, 2019.

[16]. Tony Williams, “What is the Melting Process Like in a Foundry”, Foundry Website by WIlliamsMarketingSystems.com, 2019.

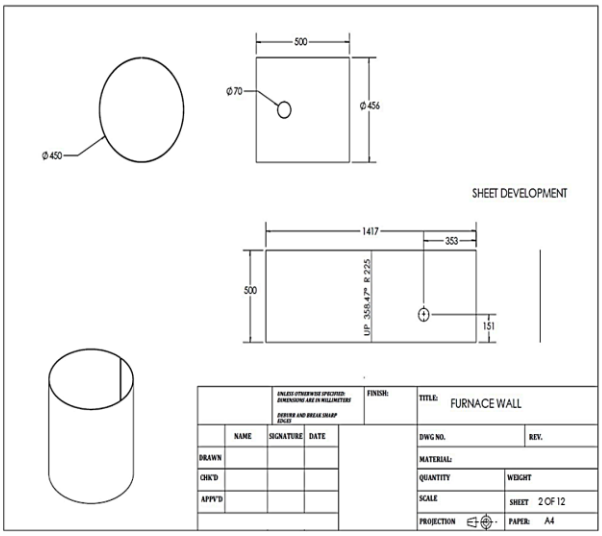
[17]. Y. Toshikazu and M. Ryoya, “The Production of Kerosene Burning Crucible Furnace and a Lesson in Casting Aluminium,” JJSTE, vol. 40, no. 22, 2012.

APPENDIX

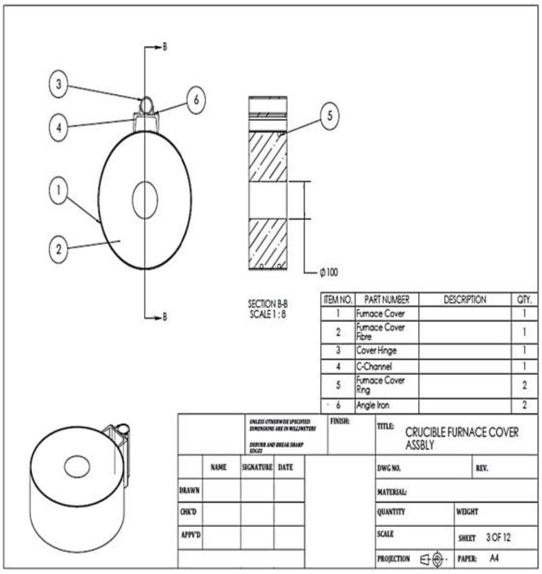
APPENDIX A: Orthographic and Assembly view of the crucible furnace



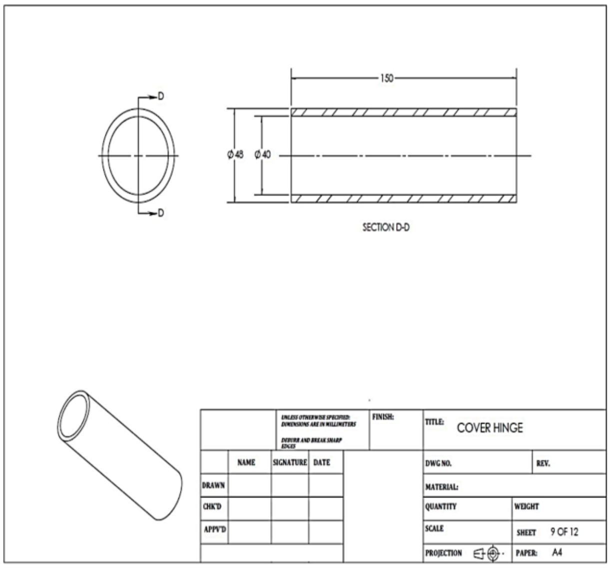
APPENDIX B: Orthographic view of the furnace wall



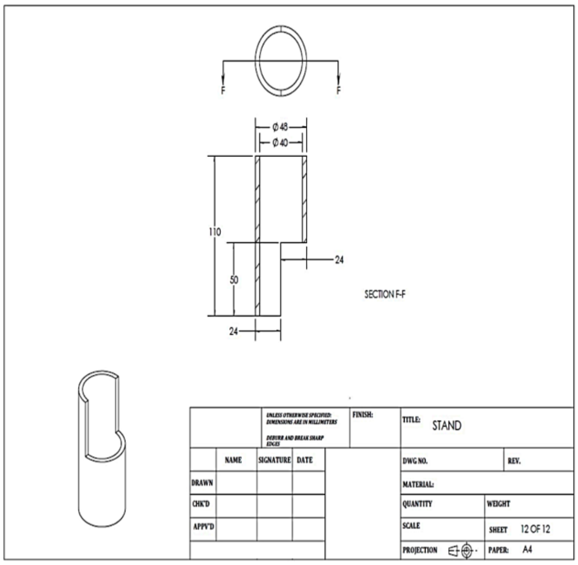
APPENDIX C: Orthographic and sectional view of the crucible furnace cover assembly



APPENDIX D: Orthographic view of the cover hinge



APPENDIX E: Sectional view of the furnace stands



APPENDIX F: Sectional view of the furnace wall ring