Global Scientific JOURNALS
GSJ: Volume 8, Issue 6, June 2020, Online: ISSN 2320-9186
www.globalscientificjournal.com

Development and Testing of Rotary Furnace fired with used Engine oil for Foundry Industries in Nigeria

Adewuyi R. A.[1], Adefidipe E.R.[2], and Ukachi P.A[1]
[1]*Department of Mechanical Engineering, The federal polytechnic Ado-Ekiti, Ekiti State,*
[2]*Olusegun Obasanjo Centre for Engineering Innovation (OOCEI), The Federal Polytechnic, Ado Ekiti.*
Corresponding Author: **reuben1178@yahoo.com**

ABSTRACT
The technological advancement of any nation is influenced by the extent to which its waste products can be harnessed and converted to useful products and services. The production of machine parts in foundry industries has become a general practice. This work deals with performance evaluation of a 500kg rotary furnace fired with used engine oil. Performance evaluation of a 500kg rotary furnace was carried out to determine its efficiency. Towards this objective, measurements were taken and the quantity of used engine oil, 170liters was used to fire the rotary furnace while melting 300kg of cast iron and its corresponding melting time which was 2hrs30 minutes measured with the use of stopwatch and melting point 1260 ºC measured with a Datalogger with type K thermocouples –3 channel–LU-MTM-380SD and temperature controller (rex-c900). The k-type thermocouples connected to the temperature controller senses the rise in temperature in the furnace thereby indicate the same on the temperature controller. The energy used was determined and the efficiency calculated. The heat generated in the furnace was calculated to be 4179620KJ And the efficiency of the rotary furnace was calculated to be 85%. Above all, in this paper, the rotary furnace was used to melt and the performance of the 500kg rotary furnace was evaluated to know its efficiency and the duration of time it to melt 300kg of cast iron and the liters of used engine oil used to melt 300kg of cast iron was determined.
Keywords: *Used engine oil, rotary furnace,* efficiency, *melting heat, the* heat generated.

1.0 INTRODUCTION

Casting is the best and effective technique used for manufacturing products especially intricate Components. The important accessory for casting is the furnace. The furnace is used to melt the metal. There are many types of furnaces available in the present-day market. These include Tilting furnace, Rotary furnace which are used to melt the scrap metal or normal metal and then mold that molten metal into the required product shape (Jain, 2014). A perfect furnace is one that reduces the wastage of material, reduces the cost of manufacturing, and thereby reduces the cost of production. Considering these aspects, a simple and least expensive tilting rotary furnace is designed and developed. The rotary furnace is one of the suitable furnaces for the production of cast iron at low cost. However, conventional furnaces for producing cast iron are induction furnaces of different types, electric arc furnaces, and cupola furnaces. Due to difficulty in operating air furnaces producing low carbon, malleable cast iron, and as a result of wasteful in fuel, the rotary furnace was designed. Casting is one of the oldest metals processing, in which difficult shapes that cannot be fabricated can be made easily using the casting process. In casting, scrap metal can be converted to wealth. The scrap is being melted; the molten metal is poured into the mould, to produce new shapes to be used for mechanical operation (Adeyemi, *et al.*, 2014).

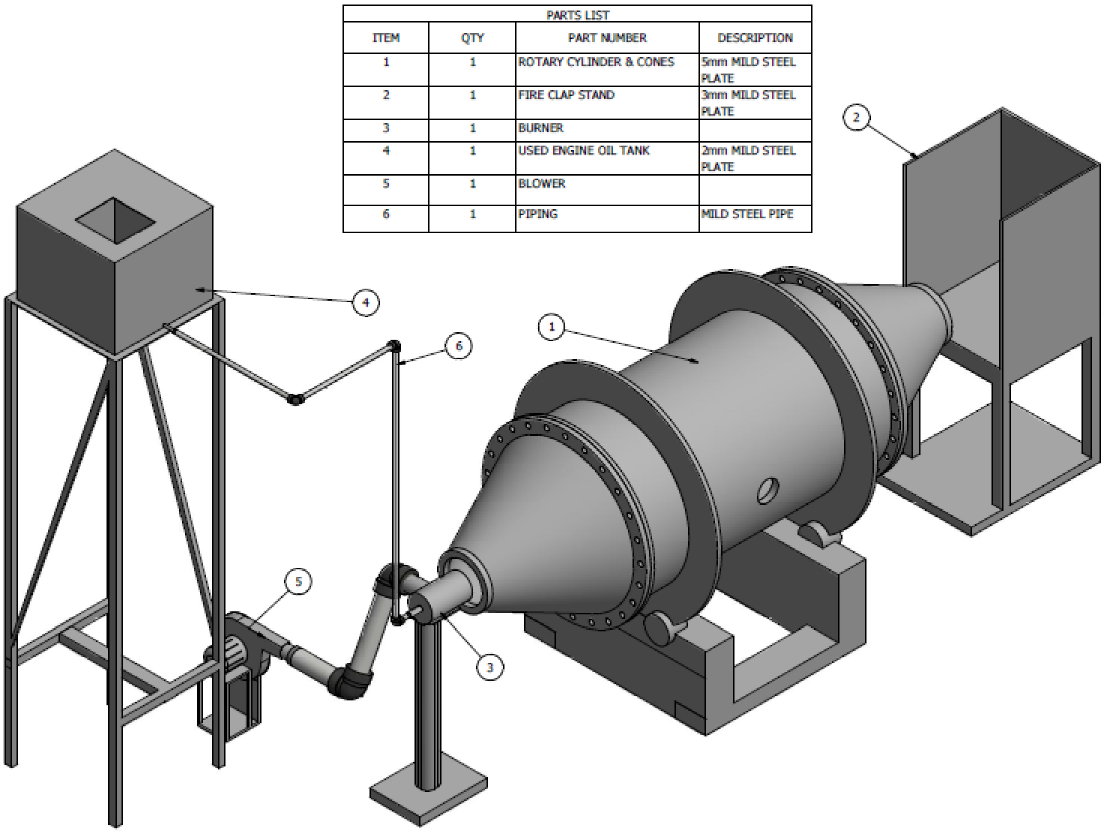
The rotary furnace is in the form of a metallic cylinder with the conical shape on both ends. Mild steel plate is used for the construction of the conical shell and its thickness varies depending upon the capacity of the furnace. This shell is rotated on its axis at 1-2rpm. For this purpose, tires (also called riding rings) are fitted on the shell. These are fabricated from mild steel squares or round rod, machined to a smooth finish. These tires ride on four-steel rollers which are again machined finely. These rollers are fitted on a robust mild steel structural frame to base support for strong rigidity (Olalere *et al.,* 2015).

The shell is lined inside with refractory bricks, refractory cement mixed with Sodium silicate content. Conical ends of the furnace are open on both sides. The furnace is charged with raw cast iron material alongside with additives from the front end (Hago & Al-Rawas, 2008). The other end is provided with a movable stand on which a burner is mounted. The burner can be a conventional one or a fully automatic one depending upon the fuel used. At the other end, an exhaust block lined with refractory bricks is provided. A tapping hole is provided at the center of the shell from where molten metal is discharged. Flue gases generated are sucked from the exhaust block side of the furnace (Zhou, et al., 2005). The rotary furnace is made up of the following main components: Rotating Cylinder; The cylindrical vessel is made of steel with truncated cone heads solidly bolted on the outside as presented in Figure 1.0. Inside the rotating cylinder and in contact with the steel there were refractory materials. The cylinder is rotated via an electrical gear motor, bearings, and supports arrangement, all controlled by a variable frequency switch. Tilting system (for tilting rotary furnaces): The whole complex is assembled on a special base structural steel. Gas Hood and Burner: The burner is generally located on the refractory lined door. The door was connected to the rotating support via a heavy fabricated arm and vertical pivoting assembly. High-speed air is provided by a centrifugal blower fan. This is combined with engine oil, to atomize the oil and exhaust collection hood is provided to collect the exhaust gases from the furnace. The hood is located above the exhaust block.

(Kardas, 2012) worked on the evaluation of the efficiency of working time of equipment in a blast furnace. OEE (Overall equipment effectiveness) and PAMC (plant and machine control) analysis which was used to assess and identify factors that had a great effect on the efficiency of the blast furnace under study. The level of efficiency is influenced by many factors. [1] Situation on the steel market in Poland and the world: changes in demand for steel products cause changes in the volume of production of pig iron, which affects the efficiency of the blast furnaces department. [2] Demand for raw materials: changes in demand for raw materials on the market often cause a situation when steel plants are forced to order raw materials which are low quality, what affects the quantity and quality of produced pig iron and quantity of slag. [3] Work organization of blast furnace - to maintain continuity of production and equipment in proper condition, the company accepted the rule that while two blast furnaces work, the third undergoes renovation.

(Jain, 2014) Experimentally Investigated Effect of Flame Temperature on Performance of Rotary Furnace. The natural sources of energy coal, oil, gas, etc. are depleting fast. His study deals with the importance of an LDO fired rotary furnace for ferrous foundries. The experimental investigations revealed that by reducing the excess air to 10 % and using a preheated air of 2000 °C not only the fuel consumption was drastically reduced but also the melting rate was considerably increased.

It has been observed that the major problem in the oil-fired furnace is non-uniform flame distribution, oxidation of metal, scale formation, carbon loss of metals, and emission of pollutants. Oil-fired furnaces have low productivity and long start-up time. To avoid these problems the rotary furnace should be used. By using the rotary furnace the productivity may be increased and production cost may be reduced. The oil-fired rotary furnace is usually used for melting waste cast iron for the production of parts e.g. block engine, cylinder head.



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	ROTARY CYLINDER & CONES	5mm MILD STEEL PLATE
2	1	FIRE CLAP STAND	3mm MILD STEEL PLATE
3	1	BURNER	
4	1	USED ENGINE OIL TANK	2mm MILD STEEL PLATE
5	1	BLOWER	
6	1	PIPING	MILD STEEL PIPE

Figure 1 A 3-D description of the fabricated Rotary furnace.

2.0 MATERIALS AND METHODS

a) MATERIALS

The cast iron weighing 300kg was purchased from different mechanic workshops in Ado-Ekiti. Foundry sand was collected in the nearby sand deposit, rotary furnace, used engine oil. Digital camera and grinding machine, Datalogger with type K thermocouples –3 channel–LU-MTM-380SD, thermocouple (Input Type Range of 1769^{0}C)

b) METHODS

Used engine oil of 170 liters was poured into the tank; the used oil is fired using a pilot burner. The pilot burner is more efficient than other burners; the pilot burner is lit with a push-button ignites. The pilot burner is located at the front of the furnace chamber, the combustion chamber was conical in shape both the front and the end, this enables the uniform heating of the metal inside the rotary furnace. The temperature inside the melting chamber was monitored through a Datalogger with type K thermocouples –3 channel–LU-MTM-380SD to measure the rise in temperature during the firing and the cooling of the process. A thermocouple (Input Type Range of 1769^{0}C) produces a temperature-dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature, of the system while connected to the temperature Data-logger. The k-type thermocouples connected to the temperature controller senses the rise in temperature in the furnace thereby indicate the same on the temperature controller.

Then the blower was connected to the burner which is located at the conical shell entrance of the furnace these atomize the oil and fired the furnace. Firstly the room temperature of the rotary furnace was noted which was 30.7ºC. The furnace was first preheated for 1hour to the temperature of about 356ºC, to enhance the quick melting of the cast iron, the burner was put off in other to charge the cast iron into the furnace. Cast iron of 300kg was charged into the furnace within 10 minutes which reduced the temperature of the furnace to 349ºC.

Thereafter, the burner was on and firing of the metal started the temperature was measured as it rises when it was exact 1hour 30 minutes the furnace was rotated at an angle 360 degree both clockwise and anti-clockwise to enhanced equal melting of the cast iron, the gear motor was used to control the furnace chamber. The rotation of the furnace was done in every 15 to 20 minutes when the cast iron was still melting, when it remains 30 minutes before the molten metal is to be discharged, Flux were dropped into the furnace about 1hour later to allow the pure metal to be separated from the slag easily. Some minutes later, the molten metal is tapped. When the cast iron finally melts, the burner was put off, and ladle was put under the rotary furnace, the molten metal was discharged into the ladle exactly 2hours 30 minutes and it was poured into the mould as shown in plate 2.0: The cast iron melted in the rotary furnace at the melting point of 1260^0C.

3.0 PERFORMANCE EVALUATION CALCULATIONS

The speed of the blower = 3000 revolution /minute

HEAT

Q=mc (T_2-T_1)

Q= Heat energy transfer (in joule)

m= the mass of liquid being heated (kg)

c= the specific heat capacity of the liquid (kj/kg)

Change in Temperature= is the change of the liquid state temperature (^{0}C)

m= 170 Liters = 170kg, c= 20 kj/kg, T_2= 1260 T_1= 30.7

Q= 170 x 20 (1260-30.7)

Q= 3,400 x 1,229.3

Q= 4179620 KJ

$$Melting\ Rate = \frac{\text{The total mass of charged (kg)}}{\text{Total time is taken to melt charged (Mins)}}$$

$$= \frac{300\,\text{kg of cast iron}}{150\,\text{minutes}} = \frac{300}{150} = 2\text{kg/mins.}$$

Quantity of Heat Required for Melting

$Q_m = C_m * T_m * G_m$ (Krivandin, 1980)

Where

C_m = specific heat capacity of cast iron = 0.46kj/kg

T_m = temperature difference (T2-T1) = 1260̊C-30.7̊C

G_m = rotary furnace capacity = 500kg

Hence the quantity of heat required for melting is calculated as

$Q_m = 0.46 \times (1260 - 30.7) \times 500$

$Q_m = 0.46 \times 1229.3 \times 500$

Q_m = 282739kj/mins

Actual efficiency/ output of the rotary furnace :

$$\text{Efficiency} = \frac{\text{Quantity of heat required for melting} - \text{calorific Value of oil used}}{\text{Quantity of heat required for melting}} \times 100$$ (Ugwua & Ogbonnayab, March, 2013)

Mathematically

$$\varepsilon = \frac{Qm - Cvf}{Qm} \times 100$$

Where the calorific value of oil = 42100kj/kg

$$\varepsilon = \frac{282739 - 42100}{282739} \times 100 = 85\%$$

4.0 RESULT AND DISCUSSION

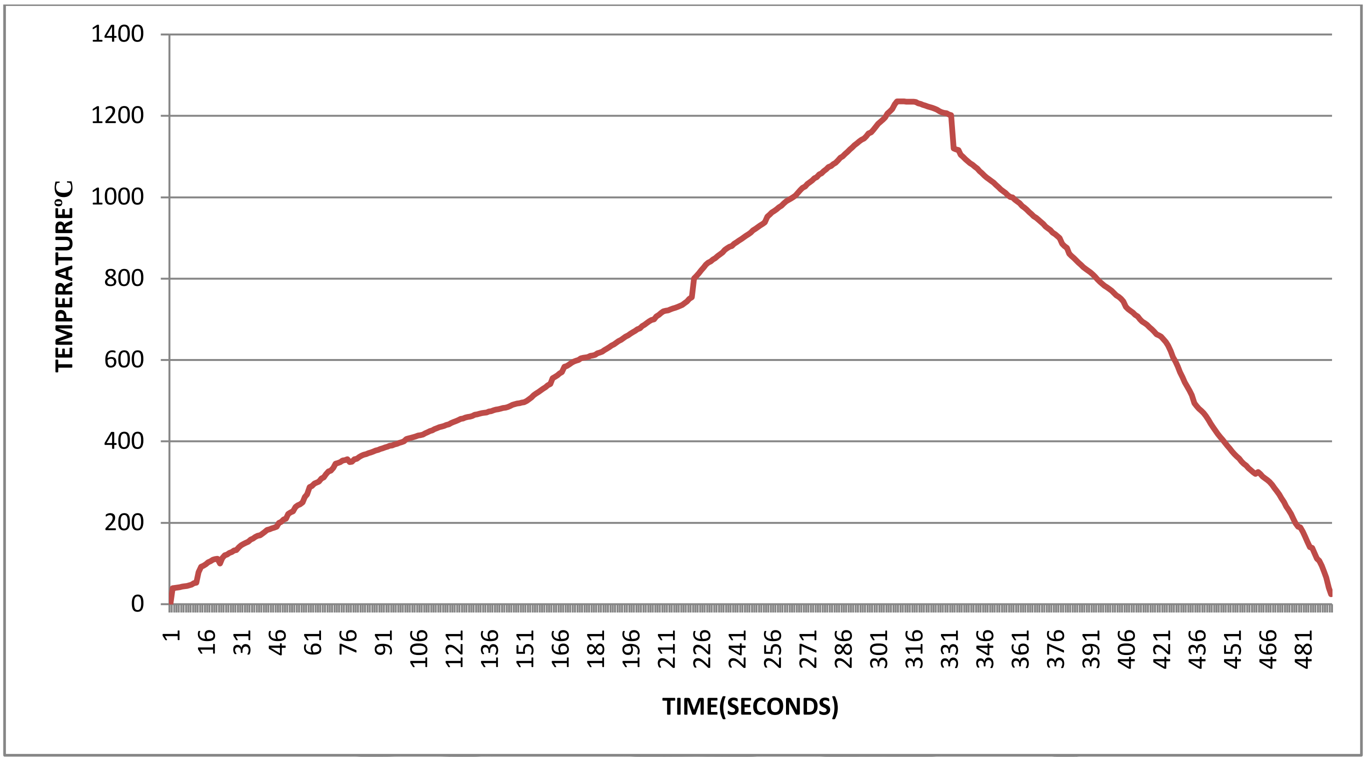


Figure 2.0: Melting and Cooling(Melting Point against Time).

Figure 1, shows the actual time for the rotary furnace of 500kg capacity to melt 300kg of cast iron which was 2hrs:30 minutes, also shows the used engine oil used to fire 300kg of cast iron was 170 liters. This graph also shows the temperature at which the cast iron was melted which were 1260˚C, it also shows the time taken for it cool down the furnace after the molten metal has been discharged which was about 6hrs. This graph shows the melting rate at which the 300kg of cast iron that was charged into the 500kg rotary furnace, including the time taken for it to reach the melting point (1260˚C) the time was 2hrs:30minutes. This figure also shows the cooling rate of the rotary furnace after the molten metal has been discharging against the time in five minutes interval for the rotary furnace to cool down to its room temperature. (Hago & Al-Rawas, 2008)

5.0 CONCLUSION.

On completion and testing, it was observed that the furnace has a fast heating rate (65.24^{0}C/min to attain a pre-set temperature of 1260^{0}C); and very good fuel economy consuming 170 liters in 2hrs:30minutes. It was also observed that the furnace has good heat retaining capacity; can be easily maintained and is safe for use. The melting rate and thermal efficiency improved significantly as a result of heat generated in the furnace which reduced the melting time.

Having carried out the performance evaluation of the fabricated 500kg rotary furnace capacity, it could also be ascertained from the stated parameters used that the rotary furnace has 85% efficiency with heat generated in the furnace calculated to be 417962KJ and could be effectively used to melt cast iron especially in converting waste to wealth.

Plate 1: Rotary furnace at a preheating stage.

Plate 2: Tapping of molten cast iron.

REFERENCE

[4] Olalere, A.A. Dahunsi, O.A. Akintunde, M.A., and Tanimola, M.O. (2015) "Development of crucible furnace Fired with Spent Engine Oil using Locally Sourced Materials", International Journal of innovation and Applied Studies ISSN 2028-9324 Vol. 13 pp. 281-288

[5] Jena, S. and Ravastngadi, S.T. (1992) "Commissioning and Operating an Induction Furnace at Zimasco (KweKwe Division) to Melt High carbon Ferrochromium", IFACON 6; Proceedings of the 6th International Ferroalloys Congress, Cape Town, Volume1, Johannesburg, SAIMM, Pages 113-118

[6]Karl-Heinz Funken, Martin Roeb, Peter Schwarzboezl, and HeikoWarnecke, et al (2001) "Aluminum Remelting using Directly Solar- Heated Rotary Kilns", Journal of Solar Energy Engineering, Vol. 123

[7] Hago, A.W. and-Rawas, A.A. et al (2008) "Design of a Rotary Kiln for Production of Sarooj", The Journal of Engineering Research,
Vol. 5, No.1, 55-61.

[8]**Sweleng, D.T (2013)** "Low-cement chrome-oxide-free castable for use in iron making rotary kilns", The Journal of The Southern AfricanInstitute of Mining and Metallurgy, Volume 113 page 651 – 658

[9] Nikolas Kantiranis,(2004) "Re-Cycling of sugar-ash: a raw feed material for rotary kilns", Waste Management, Volume 24, Issue 10, page 999 – 1004

[10] **UweKussel, Dirk Abel, Matthias Schumacher, and Martin Weng, (2009)**"Modeling of Rotary Kilns and Application to Limestone Calcination", Proceedings 7th Modelica Conference, Como, Italy, Sep. 20-22,

[11]Ortiz, O. A. Martínez, N. D. Mengual, C. A. andAballaym, P. M. (2007) "Optimal operation profit of a pilot rotary kiln for charcoal activation", Latin American Applied Research, 37:207-213

[12] Nihar P Bara (2013), "Finite Element Analysis of Induction Furnace For Optimum Heat Transfer", International Journal of Innovative Research in Science, Engineering and Technology
Vol. 2, Issue 5, Pages 1313-1319

[13] CCMA and Technikon (2001).Metal melting efficiency Project. California Cast Metal Association and Technikon. California Energy Commission Report U.S.A.

[14] **Abubakre O. K. (2001):** Development of Aluminum Based Metal Matrix Particulate Composites (MMPC) Reinforced with Alumina, Silica, and Mill Scale. Unpublished Ph.D. Thesis, Submitted to the Mechanical Engineering Department, Federal University of Technology, Minna, Nigeria.

[15] Alaneme K. K. and Olanrewaju S. O. (2010): Design of a Diesel Fired Heat-Treatment Furnace, Journal of Minerals and Materials Characterization and Engineering. Vol. 9, no.7, pp. 581-591.

[16] Babalola P. O., Inegbenebor A. O. and Bolu C. A. (2012): Design and Construction of Tilting Furnace for Producing Aluminium Matrix Composites, Presented at the International Conference on Clean Technology and Engineering Management (ICCEM), Mechanical Engineering, Covenant University, Ota, Nigeria. 12th - 15th November, pp. 260 - 271.

[17]Bello S. (2004): Design and Construction of a Gas Fired Crucible Furnace, Unpublished Master Degree Thesis Submitted to the Mechanical Engineering Department, Ambrose Ali University, Ekpoma, Nigeria.

[18]**Titiladunayo I. F. and Fapetu O. P. (2011):** Selection of Appropriate Clay for Furnace Lining in a Pyrolysis Process, Journal of Emerging Trends in Engineering and Applied Sciences. Vol. 2, no. 6, pp. 938 – 945.

[19] Attila Biro and Arpad B. Palotas, (2007)"Complex designing of Industrial Furnaces", 8th International Conference Heat Engines and Environmental Protection Hotel Uni, Balatonfüred, Hungary, 28-30

[20] Bazzani, N. (2004): The advantage of Rotating, FoundryTrade Journal, Vol. 178, No, 3611, pp, 8-9.

[21] Olorunshola, A.A.G., Anjorin, S. A. and Akintunde, M. A. (2016). Performance evaluation of erythrophleum suaveolens charcoal-fired cupola furnace, international journal of scientific and engineering research, (IJSER), Vol.7, Issue 1, pp. 833-842.

[22] Olorunshola, A.A.G., and Akintunde, M. A. (2013). Characterizing erythrophleum suaveolens charcoal as a viable Alternative fuel to coke in iron melting in Nigeria. IOSR JOURNAL of mechanical and civil engineering (IOSR-JMCE), Vol. 10, Issue 3, pp. 6-11.

[23]Olorunshola, A.A.G., Anjorin, S. A. (2015). Design, Construction, and Testing of an erythrophleum suaveolens charcoal-fired cupola furnace for foundry Industries in Nigeria, Scientia agriculture, Vol. 12, No. 1, pp. 1-12.