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Original Research Article

Comparative Analysis of Refractories for the Lining of a Non-Ferrous Metal Crucible Furnace

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Abstract: This paper examined the effect of heat on refractories used for the lining of the wall of crucible furnace; the refractories are bricks, zirconia and alumina. Knowledge based software such as Creo-element/Pro5.0 and ANSYS workbench 14.0 were employed for the modeling and steady state thermal analysis of the furnace. A temperature of 35^{0}C was used as initial temperature of preheating and a temperature of 800^{0}C as the pouring temperature. Maximum heat flux of bricks, zirconia and alumina were found to be 4.9967*10^{-8} W/m^2, 6.5999*10^{-6} W/m^2 and 6.6098*10^{-6} W/m^2 respectively, and the maximum directional heat flux of bricks, zirconia and alumina were found to be 1.0019*10^{-8}W/m^2, 1.2572*10^{-6} W/m^2 and 1.34*10^{-6} W/m^2 respectively. Comparatively, it was observed that, thermal loading was high in zirconia and low in alumina.
Keywords: Furnace, Crucible, Non-Ferrous, Metal and Refractory

INTRODUCTION

A furnace is an apparatus in which heat is liberated and transferred directly to solid or fluid charge mass, for the purpose of effecting a physical or chemical change, through cycle involving temperature in excess. There exist various classifications of furnaces based on the purpose and energy source. In the early nineteenth century, the phenomenon of crucible furnace was applied to the experimental melting of non-ferrous metals.

S.O. Adeosun *et al.* [1], reported that in the production of mineral resources, the melting of metals has become one of the tremendous industrial practices in the forefront. This is because metals are versatile elements whose fields of applications are very wide in human lives. Of all metals, iron production has developed substantially, such that different types of furnaces ranging from blast furnaces, open-hearth furnaces, to converters and electric furnaces for steel production are in use today worldwide. Ajaokuta Steel Company and Delta Steel Company are examples of steel making companies in Nigeria that use these types of furnaces. Aluminum being the most abundant metallic element, forming about 8% of the solid portion of the earth's crust, is rarely available as rich ores. Hence most countries are dependent on supplies of it being imported. Nigeria, for instance, uses aluminum in all aspects of human endeavor be it transportation, machine components, cooking utensils alloying etc. these components display a marked decrease in performance level after some years of service and have to be discarded.

The re-melting of these scraps product of aluminum will go a long way to enhance the availability of the product without over reliance on the foreign market, and thereby improving the foreign reserve. Similarly, the acquisition of melting equipment for this purpose has also become a very difficult thing such that there is a need to look inward for fabrication of some vital components for our technological growth. It is in view of this, that different methods of melting aluminum are being used in the country, such as crucible furnaces, either on industrial or local small scale. Therefore, Crucible furnace is a furnace used for melting non-ferrous metals.

J. Olenyi *et al* [2], studied the design and thermal analysis of crucible furnace for non – ferrous metal. In their study, they analyzed the heat flow in the crucible furnace during melting operation of the scraps in the crucible pot of the furnace. From the analysis, the maximum total heat flux was 1275200w/m2 which was found inside the region of the furnace and a minimum of 3.9833e-12W/m² at cold outer region of the furnace, also the positive heat flux of 835740w/m^2 inside the system and heat loss to the surrounding of 761420w/m2 were obtained at point of heat supply channel.

I. S. Asibeluo *et al* [3], designed a 50-kilogram capacity Cast-iron crucible furnace that is fired with diesel fuel. The furnace drum has an overall combustion capacity of 0.1404m3. It is fitted with a chimney to allow for the easy escape of combustion gases. The air blower discharge air into the furnace at the rate of 0.3m^3/s with an air/fuel ratio of 400:1. The cast-iron crucible furnace is designed to consume 4 gallons of diesel fuel with a rating of 139000kj/gallon which is required to completely melt 50-kilogram of cast iron over a period of 90min. The designed operation temperature range of the cast–iron crucible furnace is 13000C to 14000C.

I.S. Asibeluo [4] carried out thermal analysis of induction furnace, the mock-up induction furnace was modeled in COMSOL Multiphysics. Prior to that the induction heating Interface algorithm under the Heat Transfer Module of COMSOL Multiphysics was validated with the experimental data. The results of the study shown that the temperature of the crucible rises to 1500^{O}C in 2 hours of heating time at frequency of 8 kHz and current of 400 A. The conditions were favorable for melting of copper (melting point = 1085 °C) in the crucible.

MATERIALS

Three refractories were used for the investigation of this study. The refractories are bricks, zirconia and alumina.

Table 1: Thermal properties of the refractories under investigation

Materials Properties	Bricks	Zirconia	Alumina
Density	1600kg/m^3	5900 kg/m^3	3800 kg/m^3
Melting point	927 °C	2550 °C	2000 °C
Maximum service temperature	927°C	1200°C	1080 °C
Thermal conductivity	0.46 W/m.°C	2 W/m.°C	26 W/m.°C
Specific heat capacity	750 J/kg.°C	480 J/kg.°C	790 J/kg.°C
Thermal expansion coefficient	5*10^{-6} strain/°C	1.05*10^{-5} strain/°C	7*10^{-6} strain/°C

Source: Granta CES Edu Pack (2011)

METHODOLOGY

The crucible furnace was modeled using Creo element/Pro 5.0, and thereafter, the model was imported into ANYS workbench 14.0 for analysis. The thermal properties of each of the refractories were configured in the engineering data. While in the Model, the configured thermal properties were assigned to the geometry, and an initial temperature of 35^{0}C for preheating for analysis setting was chosen, because, to avoid the effect of thermal shock. The set up was also done to determine the response of the analysis from the imposed boundary conditions. A mesh having statistics of Nodes and Elements of 57546 and 10726 respectively were achieved. A temperature of 800^{0}C was used as the pouring temperature for the non-ferrous metal.

RESULTS

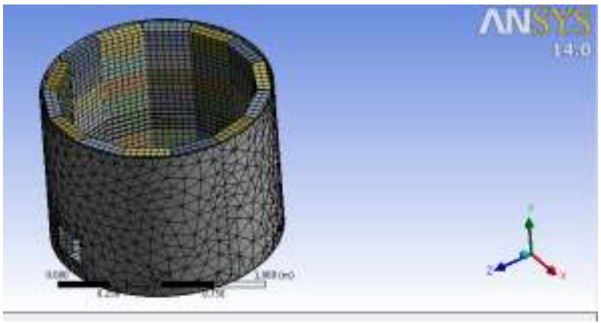

Figure 1: Mesh of the Furnace

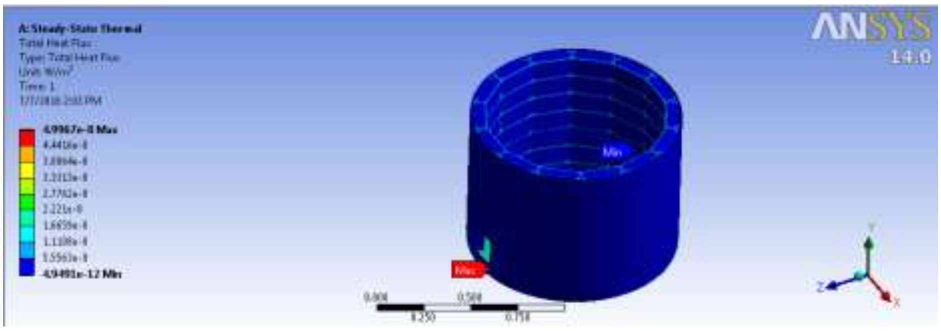

Figure 2A: Total Heat Flux Of The Bricks Analysis

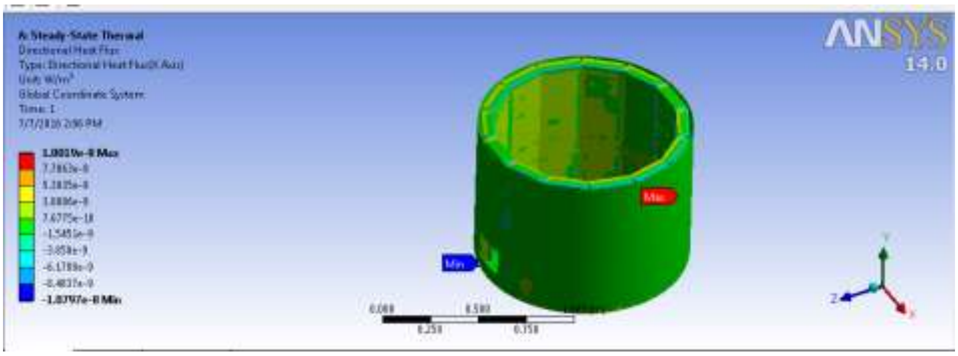

Figure 2B: Directional Heat Flux Of The Bricks Analysis

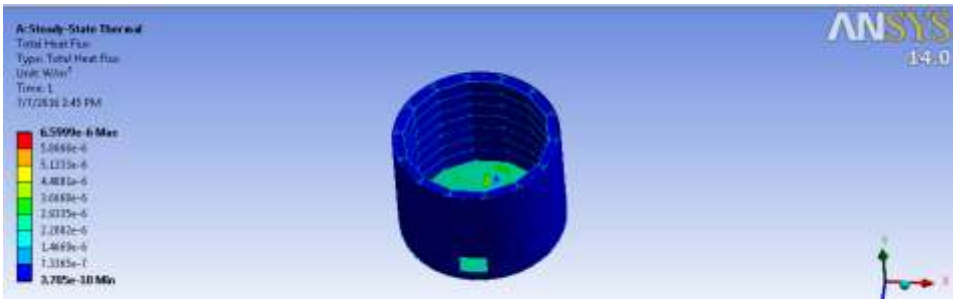

Figure 3A: Total Heat Flux of the Zirconia Analysis

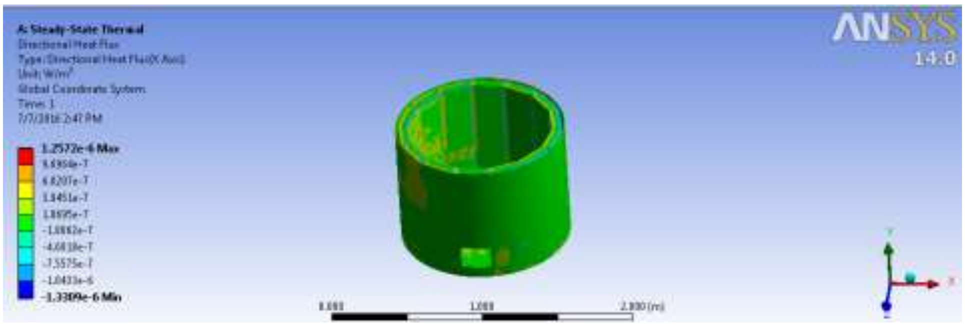

Figure 3B: Directional Heat Flux of The Zirconia Analysis

Alumina

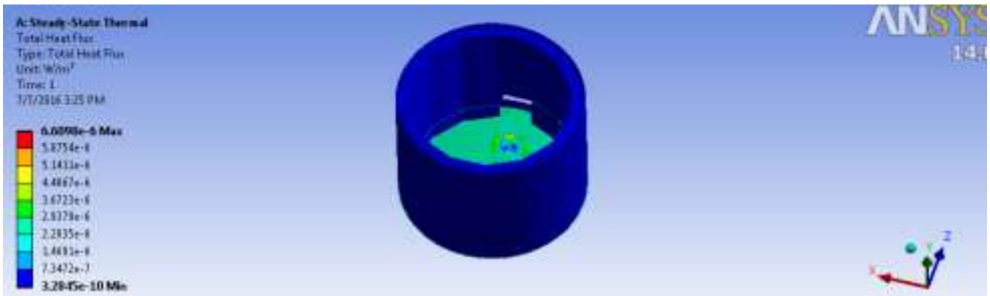

Figure 4A: Total Heat Flux of the Alumina Analysis

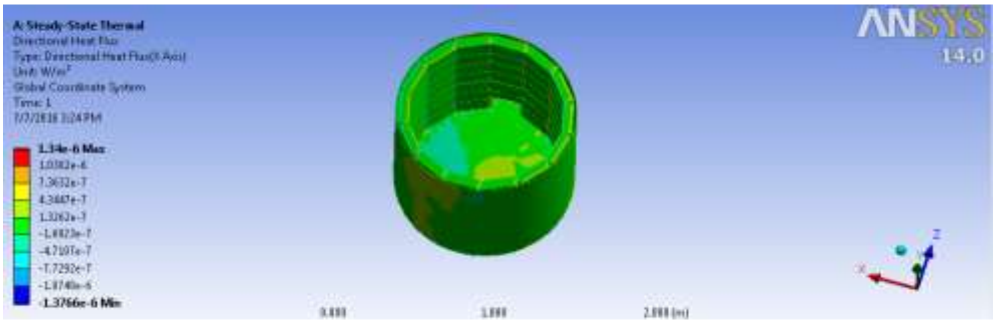

Figure 4B: Directional Heat Flux of the Alumina analysis

Table 2: The Maximum and Minimum Heat Flux and Directional Heat Flux of Bricks, Zirconia and Alumina from the Analysis

S/N	Parameters	Bricks	Zirconia	Alumina
1	Maximum Total heat flux	$4.9967*10^{-8}$	$6.5999*10^{-6}$	$6.6098*10^{-6}$
2	Minimum Total heat flux	$4.9491*10^{-12}$	$3.705*10^{-10}$	$3.2845*10^{-10}$
3	Maximum Directional heat flux	$1.0019*10^{-8}$	$1.2572*10^{-6}$	$1.34*10^{-6}$
4	Minimum Directional heat flux	$-1.079*10^{-8}$	$-1.3309*10^{-6}$	$-1.3766*10^{-6}$

DISCUSSION

From the steady state thermal analysis results, it was observed that the maximum heat flux of bricks, zirconia and alumina were found to be $4.9967*10^{-8}$ W/m^2, $6.5999*10^{-6}$ W/m^2 and $6.6098*10^{-6}$ W/m^2 respectively, and the maximum directional heat flux of bricks, zirconia and alumina were found to be $1.0019*10^{-8}$W/m^2, $1.2572*10^{-6}$ W/m^2 and $1.34*10^{-6}$ W/m^2 respectively. Comparatively, it was observed that, thermal loading was high in zirconia and low in alumina. This is an indication that, the higher the specific heat capacity and thermal expansion coefficient of refractories, the lesser their thermal loads and vice versa. Hence, alumina will exhibit low thermal load and would be durable and suitable for the lining of the wall of the crucible furnace for non-ferrous metal application.

CONCLUSION

Detailed steady state thermal analysis with ANSYS workbench 14.0 has been carried out on the crucible furnace. The thermal properties of the refractories were carefully selected using Granta CES Edu pack (2011). From the results of the analysis, maximum heat flux of bricks, zirconia and alumina were found to be $4.9967*10^{-8}$ W/m^2, $6.5999*10^{-6}$ W/m^2 and $6.6098*10^{-6}$ W/m^2 respectively, and the maximum directional heat flux of bricks, zirconia and alumina were found to be $1.0019*10^{-8}$W/m^2, $1.2572*10^{-6}$ W/m^2 and $1.34*10^{-6}$ W/m^2 respectively. Comparatively, it was observed that, thermal loading was high in zirconia and low in alumina. This connotes that, decrease in the thermal properties of the refractories, increases the thermal load of refractories material.

REFERENCES

1. Adeosun SO, Osoba LO; Foundry Industry; A Tool for Technological Advancement in Nigeria. Proceedings of Nigeria Metallurgical Society Conference. October/November at Federal University of Technology, Akure. Pg. 1. conference Proceedings. Kaduna Polytechnic, Kaduna, Nigeria, 2008.

2. Olenyi J, Oghenekaro P, Joseph M, Sheidu SO; Design and Thermal Analysis of Crucible Furnace for Non – ferrous Metal, Journal of Information Engineering and Applications, 2016; 6(3).
3. Asibeluo IS, Ogwor OE; Design of a 50-Kilogram Capacity Cast Iron Crucible Furnace Using locally available Materials. International Journal of Research in Engineering and Technology, 2015; 4(3):525-531.
4. Asibeluo IS; Fundametals of Foundry Technology and Forging Operations, Second edition. Published by Cee Emmy Ventures Agbor, Delta State, Nigeria, 2015.