Evaluation of Heat Losses from a 300 kg Capacity Cupola Furnace

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Abstract— *The efficiency of any foundry largely depends on the efficiency of the melting process, This in turn depend on the maximum utilization of heat generated in the furnace by reducing heat losses. This paper discuss the various forms of heat losses in a cupola furnace,, reasons for the losses and ways to reduce it. Minimized heat loss will reduce losses in melting, reduce slag formation and increase the combustion efficiency of coke and overall productivity and improve the quality and Mechanical properties of cast iron using Cupola.*

Significance of paper *The efficiency of any foundry largely rides on the efficiency of the melting process a multi-step operation where the metal is heated, treated, alloyed, and transported into die or mold cavities to form a casting, this can only be achieved if the heat generated is maximally utilized in melting process and heat losses is greatly reduced.*

This paper emphasis on method of reducing heat lost.

Keywords— heat losses, cupola, refractory, furnace, efficiency.

I. INTRODUCTION

Since the discovery of the earth's minerals, metal casting has played an important role in society. An integral part of every technological advance, casting have allowed us to build equipment to feed our people, fight for defense, build infrastructures and manufacture cars, trains, air planes e.t.cThe production of melting metal to make casting has traditionally been an art of form, an expression of human creativity carried out for both aesthetic and practical reasons [V. A. Knvandin, B.L. Markov(1980}].. The objective of metal casting has been to produce useful implements for human consumption as well as beautiful works of art. It is clear on examination of ancient art of casting, as well as modern industrial castings that their production requires significant skills as well as technological know how.

The ancient artisan used traditions and learned skills passed down through the ages, as well as experience to produce acceptable castings. The modern producer of industrial castings make use of these same skills, but supplements them with understanding of the fundamentals principles of fluid flow, heat transfer, thermodynamics and metallurgical micro structural development [McGraw-Hill Encyclopedia of Science and technology 5th edition 1998].

Metal casting remains all basically essential industry, as necessary to space vehicles as it was to mankind's very first machines. As science is applied more and more, so the skill, education and pay of foundry men goes up and ever up, increasing in turn the total wealth of the world Dr (C.O.Nwajagu (1984)). There is no better example of true creation of national wealth than the work of foundry man. He takes a raw material and through both art and science, creates a product that add direct value to our society's ever progressing way of life. All these contributions of foundry work towards better way of life, cannot be achieved without the most important or the backbone of the foundry itself, this is nothing but a foundry furnace, which takes in a solid raw materials and transformed it into a molten iron of desired pouring temperature through the application of heat generated by the healing elements or fossil fuel. Known as the original recycler, the foundry industry through proper utilization of heat generated inside the foundry furnace, gives a new useful life to as many as 15 million tons of scrap metal each year that would otherwise be rendered useless.[V. A. Knvandin, B.L. Markov(1980}]

The metal casting process is the simplest, most direct route to a near net-shape product, and often the least expensive. This process in its fundamental form requires a mold cavity of the desired shape and molten metal to pour into the mold cavity. Human beings have been producing castings for thousand of years, most often pouring metals into molds made of sand.

Casting serves as the most universal of all known methods of shaping metal. Through casting, a wide range of size or products can be obtained. There is little weight or size limitation upon castings; the only restriction is imposed by the supply of molten metal and the means of lifting and handling the output. Components of few grams as well as those weighing many tons can be produced by casting. In 1966, a unique steel casting of length 11.2 metres and weight 257000 kilograms was produced, some year in the former USSR, a horizontally stamping machine weighing 270,000 kilogrames was produced [Dr C.O.Nwajagu (1984)]. Casting is applied both in batch and in mass production of objects with simple as well as intricate shape.

II. METHODOLOGY

The construction and testing of foundry cupola furnace was conducted at the faculty of Technology, Bayero university, Kano. It was test run twice and the experimental results was used to analyse the various heat losses.

The various heat losses in cupola operation are:

a. Heat lost through the wall by conduction and convention.
b. Heat lost by slag
c. Heat from the mechanical incompleteness of combustion.
d. Heat lost through the flue gases
e. Heat lost by radiation through open door of the furnace
f. Loss of the heat accumulated in the linings
g. Heat losses due to unaccounted losses

(1)Heat lost through conduction

Fourier's law of heat conduction states that the rate of flow of heat through a simple homogeneous solid is directly proportional to the area of the section at right angles to the direction of heat flow, and to change of temperature with respect to the length of the path of the heat flow Mathematically, this is represented as:

$$Q = -KA\frac{\delta t}{\delta r}$$

(2.1) Heat lost by slag

Qs = Ms Cs ΔTs $Q_S = M_s C_s \Delta T$

Where,

M_s = Mass of the slag = 15% of the charge for optimum Performance

C_s = specific heat capacity of the slag

ΔTs = temperature change

Since the preheat temperature is expected to elevate to 400^0c,

Ms = 15% of 350 = 52.5kg/h

Cs = 0.224 KJ/Kgk

ΔTs = 1400 – 400 = 1000^0C

1400^0C is the maximum temperature attained in the furnace

(2.2)Heat lost from incomplete combustion

This term implies various losses of fuel, for instance mechanical losses in combustion of solid fuel are usually 5 percent, and therefore,

$$Q_{mc} = 0..05 M_f . HCV$$

Where, M_f = mass of fuel

HCV= Higher calorific value of the fuel

(2.3) Heat lost through the flue gases

This is the heat carried away by the flue gases.

It is given as:

$$Q_f = M_f V C T \text{ (KJ/h)}$$

Where

V_g = Specific volume of the mixture of waste gases

C = Specific heat capacity of the mixture of waste gases

T = Temperature of the waste gases

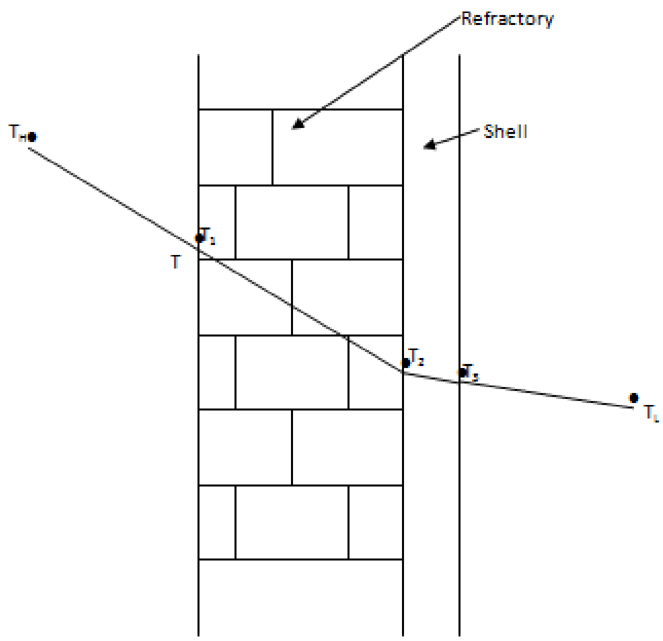
(2.4) **Heat losses by radiation through open door of the furnace**

This heat lost by radiation when the charging door is open for recharging, and it is given as:

$$Q = \sigma[\frac{T}{100}]^4 dAU, where$$

$\sigma = stefan\ Boltzman\ constant, (5.67\ x10^{-8} Wm^{-2} k^{-2})$

(2.5) **Loss of the heat accumulated in the lining**



This is part of the heat generated that is absorbed by the linings, it is obtained as thus:

From

$$Q\alpha\ A\frac{\delta t}{\delta x}$$

$$hence\ Q = -KXA\frac{\delta t}{\delta x}$$

$$where\ A = 2\pi XL$$

$$= crossectional\ area\ of\ the\ furnace\ shell.$$

$$Q\delta x = -kX2\pi XL\delta t\delta T,$$

$$\frac{\delta x}{x} = -k\int_{x_1}^{x_2}\frac{\delta X}{X},$$

$$\int_{x_1}^{x_2}\frac{\delta X}{X} = \frac{-2\pi L\delta T}{Q}\int_{T_1}^{T_2}\frac{\delta T}{T},$$

$$LnX_2 - LnX_1 = \frac{2\pi LK}{Q}[T_1 - T_2]$$

$$T_1 - T_2 = \frac{LnX_2 - LnX_1}{\frac{2\pi LK}{Q}}$$

$$T_1 - T_2 = heat\ lost\ to\ the\ refractory\ lining.$$

(2.7) Unaccounted heat losses

This is the differences between the total quantity of heat generated from the coke and the sum heat utilized in the furnace and heat losses. It is usually 10 to 15 percent of the total heat generated. [Institute of Indian Foundry men,(2006)]

The total heat generated from the fuel is obtained from the product of mass of the fuel used and it calorific value.

The heat utilized in the furnace is obtained from the differences between total heat generated and total heat losses.

Therefore efficiency of the furnace is given as thus:

Efficiency of the furnace = $\frac{Heat\ utilised\ in\ the\ furnace}{Gross\ calorific\ value\ of\ coke}$

Table. 1:Processes Preheating

EXPERIMENT	CAST IRON SCRAPS(Kg)	COKE (Kg)	LIMESTONE (Kg)	STEEL SCRAPS(Kg)	SILICON (Kg)	TIME BEFORE TAPPING(min)
1	50	7	2	3	0.3	6
2	50	6	2	3	0.3	8
3	50	4	2	4	0.4	16

Table.2: Results

CHARGING	MASS OF SLAG (Kg)	MASS OF MOLTEN IRON (Kg)
FIRST CHARGE	8	43
SECOND CHARGE	7	48
THIRD CHARGE	4	48.5

From the above result obtained it is observed that the melting rate increased with increase in time of operation.

The values in table 1 and table 2 were used to obtain the calculated values for the various heat losses as shown below.

Table.3: Values for Heat losses

HEAT LOSSES	EXP 1	EXP 2
Heat lost through conduction(kJ/h)	4113	4113
Heat lost by slag(kJ/h)	11760	11362
Heat lost from incomplete combustion(kJ/h)	75000	72010
Heat lost through the flue gases(kJ/h)	627	627
Heat losses by radiation through furnace door(kJ/h)	1379.27	1375.27
Loss of the heat accumulated in the lining (kJ/h)	261261	261261
Unaccounted heat losses(kJ/h)	60874.95	60874.95
The total heat losses (kJ/h)	405833.82	405833.82
The total heat generated from the fuel(kJ/h)	1500000	1500,000
The heat utilized in the furnace (kJ/h)	1094,000.17	1094,000.17
Efficiency of the furnace (kJ/h)	0.729	0.729

III. DISCUSSIONS

Reduction in the quantity of slag was observed after the introduction of silicon to the charges and this enhanced a reduction in heat lost through slag, Melting rate increases with an increase in time of production and combustion rate also increases leading to low heat lost. Heat lost through flue gas was very low because cupola works with the principle of counter flow, the charges flow in opposite direction to the flow of heat,, this enables a maximum absorption of heat by the charges before the flue gas escapes. From the table 3 the total heat losses was obtained by the summation of all heat lost and then subtracted from total quantity of heat generated, this gives us the quantity of heat utilized in the furnace.

IV. CONCLUSION

Maximum heat lost was recorded from heat accumulated in the refractory lining, this often observed in most cupola furnace lined with poor refractory materials. It is recommended that a high alumina refractory be adopted in the furnace design, High alumina refractory has low conductivity, withstand high temperature and chemical action of molten metals. Progress in metallurgy have accelerated the development of a new type high alumina refractory which we are to put into consideration in our future furnace design.

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