Development of a High Efficient of Manual Furnace Blower of The Local Charcoal-Fired Furnace for Aluminium Recycling

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Abstract- The charcoal-fired furnace is usually used for Aluminium recycling for the production of cooking utensils in local small-scale Aluminium recycling industries. The performance of such a furnace and manual operated blower was carried out to determine the efficiency and energy consumption in the cause of electrical power failure. Towards this objective, measurements were taken of the quantity of charcoal used for different melts and their corresponding melting times and temperatures. The wheel gear speed ratio of 1:16 was calculated, the energy used was determined and the efficiency calculated. The efficiency obtained for the furnace and the manual-operated blower was 11.6%. The value was obtained as a result of variable atmospheric conditions, non-uniform speed, and the open nature of the environment and the furnace.

Indexed Terms- Aluminium recycling, Charcoal-fired, Furnace blower, Wheel gear, efficiency.

I. INTRODUCTION

Aluminium is a silver-white metal obtained from bauxite, a rock composed of more than 50% aluminium hydroxides formed by weathering in tropical regions. Aluminium is the earth's third most abundant element (after oxygen and silicon) and the most abundant metal in the earth's crust (8% by mass). Aluminium-bearing compounds have been used by man from the earliest times. Pottery was made from clays rich in hydrated silicate of aluminium and at one point in history aluminium was so valuable that rulers and the wealthy preferred cutlery made from aluminium instead of gold. In other words, aluminium is produced each year than all other nonferrous metals combined.

Aluminium scrap has considerable market value because the energy needed for primary production is stored, to a large extent, in the metal itself and, consequently, in the scrap too (Adeolu, *et al*, 2017, Ighodalo, *et al,* .2011). Therefore, the energy needed to melt aluminium scrap is only a fraction of that required for primary aluminium production. Furthermore, it can be recycled again and again without loss of its inherent properties since its atomic structure is not altered during melting.

Today the Aluminium industry is made up of three basic categories of production, which are Primary, Secondary, and Tertiary production of Aluminium. The primary production of Aluminium involves the preparation of high purity Alumina from Bauxite by the Bayer process (Faith, 1973). Aluminium ingots are currently being obtained from importation since ALSCON Nigeria's primary producer is presently not functioning. The ingots produced from the primary producers are used by the secondary producers in the rolling mills to produce plates and sheets, corrugated sheets, circles, container sheets, foils, rods and wires, seamless tubes, etc. The secondary producers in Nigeria are the aluminium rolling mills such as in Sango-Ota and the first Aluminium in Port-Harcourt. The tertiary producers purchase Aluminium products from the secondary producers for various applications such as building, machine, and automobile components, cooking and packaging wares, etc (Abed, 2013 and Ajuwa, 1998). Examples of such tertiary producers in Nigeria are Oluwalogbon Aluminium (Iseyin town), Agbajelola Aluminium forging works (Saki town), Fati Aluminium port production (Saki town), Alidu port making (Saki town), Abejiwaye ornament and forging works (Saki town) Aimasiko Aluminium port production (Lanlate town), Extrusion company Ltd (Lagos), etc.

Within this tertiary group is a subset that is primarily involved with the recycling of Aluminium scraps for the production of local cooking pots (popularly called Koko Irin or Aperin in South West Nigeria), frying pans, and spoons of various sizes in small scale Aluminium casting foundries. Such large-sized cooking pots are used for cooking during special occasions such as weddings, burials, and local restaurants. Such enterprises may be run by a family unit employing four to six persons in casting the various cooking utensils and can thus be categorized as small-scale enterprises. The furnaces used in such small-scale enterprises are usually solid fuel (charcoal) fired and are locally fabricated. They employ sand casting which is considered one of the most versatile methods for producing small quantities of castings (Overview, 2008). An example of such an enterprise is Abejiwaye ornament and forging works and Aimasiko Aluminium port production located in Saki and Lanlate town, Oyo State, Nigeria. This paper aims to carry out an approach to improving manually operated furnace blower by using a gear drive centrifugal blower to determine the working efficiency and to reduce energy-consuming.

II. MATERIALS AND METHODS

Aimasiko Aluminum pot production, Lanlate, Oyo State, is involved in the production of local cooking accessories such as pots, frying pans, and spoons of various sizes using Aluminium scraps. The Aluminum scraps were obtained from suppliers at a rate between one hundred and one hundred and fifty naira per kilogram of Aluminum scrap, depending on the location. This scrap is not pre-treated or cut to specific sizes. Samples of about 30 kg – 50 kg of Aluminium scraps, depending on the size and thickness are required to produce a local cooking pot of 20 - 40 gallons, and 25 kg in weight, the difference accounting for dirt and impurities in the scrap. Melting of the Aluminium scrap is carried out in a local melting furnace. A schematic setup of the manually geared blower of the local charcoal-fired furnace for molten Aluminium is shown in Figure 1.

The local furnace consists of a cast-iron crucible which is heated by charcoal placed on the combustion chamber. The combustion chamber is lined with red clay which serves as the refractory material and is in abundant supply in this area. Strong effective heating is generated by the manual blowing of the furnace. This is achieved by a combination of wheel gears, pedal, fan and a duct system that directs the air to the combustion chamber. The blowing of air aids the combustion of charcoal. The wheel gear and pedal which rotates the fan (blower) manually through a gear mesh drive can also be operated by an electric motor and potable gasoline machine.

The first step in the production of molten Aluminium from scraps is by charging the furnace (open top) crucible. The charcoal is ignited and strong heating is achieved through the wheel gear speed Figure1. (One revolution of the drive gear is equal to sixteen revolutions of driven gear) by bottom blowing of air through the duct does the melting of the Aluminum scraps. During the melting of the scraps, impurities slags core collected on top of the molten Aluminum which is skimmed off at different time intervals. After each skimming, additional Aluminium scraps are charged into the furnace crucible, while skimming is stopped when the maximum amount of pure molten aluminium remains in the crucible. The crucible of molten Aluminium is moved manually with metal tongs to be poured into moulds for casting into pots and other kitchen accessories.

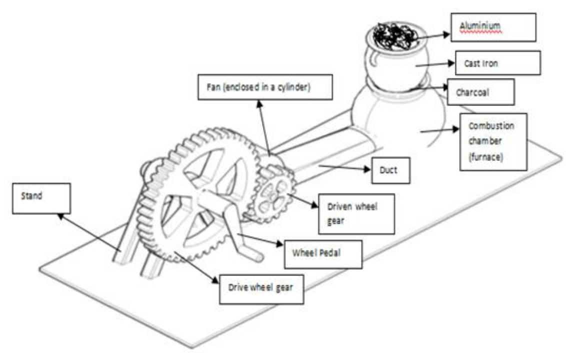

Figure 1: Constructed manual geared blower for the local charcoal-fired furnace for melting

III. PERFORMANCE EVALUATION OF MANUAL GEARED BLOWER OF LOCAL CHARCOAL-FIRED FURNACE

Records were taken at Aimasiko Aluminium port production while the analysis was done at Adeseun Ogundoyin Polytechnic, Eruwa. The procedure is as follows; 3.5kg of charcoal was measured with a weighing scale and was loaded into the furnace chamber. The cast-iron pot was placed on top of the furnace which served as the crucible and 3.5kg of Aluminium scraps were measured into the crucible pot.

The charcoal was ignited with kerosene and matches to start the fire. The pedal attached to the gear wheel was then pressed on and the air from the blower kept the charcoal burning. The quantity of charcoal used, time of melting and the temperature of melting were recorded. A k-type thermocouple connected to temperature readout with a temperature range of 0 to 1400ºC was used for temperature measurement and the time of melting was taken using a stopwatch. The same procedure was carried out for different weights of aluminium samples 3.5kg, 5kg, 7kg, 10kg, 12kg and 15kg, respectively.

IV. RESULTS AND DISCUSSION

The results obtained are shown in Table 1.

Table 1: Result of Aluminium Melting using a manual geared blower for the local charcoal-fired furnace

Mass of Aluminium (kg)	Mass of charcoal (kg)	Time (mins)	Temp-erature (^{0}C)
3.5	3.0	12	683
5.0	4.7	17	685
7.0	6.0	20	687
10	8.0	23	698
12	13	27	711
15	13	31	713

Table 2: Energy produced for melting aluminium scrap using the manual geared Blower

Mass of Aluminium (kg)	Mass of charcoal (kg)	Time (mins)	Tempe rature (^{0}C)	Energy (MJ)
3.5	3.5	12	683	72.3
5.0	4.7	17	685	77.1
7.0	6.0	20	687	81.7
10	8.0	23	698	89.7
12	13	27	711	93.4
15	13	31	713	98.3

It was observed from Table 2 that as the weight of aluminium melted increases the time and temperature of melting also increases so also the energy used. 17kg of coal cost Two thousand and one hundred Nigerian Naira (about four American dollars)

Evaluation of the Energy Spent on Melting Aluminium with the Charcoal-Fired Furnace blower
The temperature value for redwood charcoal ranges from733 K to 1214 K = 30.5 MJ/kg (USDA, 1974).

Energy = Calorific value x weight of charcoal used
From the above energy expression, Table 2 is obtained for energy used.

Using the values in Table 2,

$$\text{Average energy} = \frac{512.5}{6} = 85.4 \text{ MJ}$$

$$\text{Average weight of Aluminium} = \frac{52.5}{6} = 8.8 \text{ kg}$$

Average energy used per kg of Aluminium =

$$\frac{\text{Average energy}}{\text{Average weight of Aluminium}} = \frac{85.4}{8.8} = 9.7 \text{ MJ/kg}$$

The theoretical amount of energy required to melt one tonne of Aluminium and raise its temperature to 730 ºC is approximately 1120 MJ (Ramsell, 1998), therefore energy required to melt 1 kg of Aluminium is,

$$\text{Energy required} = \frac{1120}{1000} = 1.12 \text{ MJ/kg}$$

Therefore,

$$\text{Efficiency of the furnace} = \frac{\text{Energy required}}{\text{Energy used}} = \frac{1.12}{9.7} \times 100 = 11.6\%$$

This efficiency value is lower when compared with gas-fired crucible furnaces which are also used for smaller melts and have efficiency as low as 12% (METALS Advisor, 2008). Typical gas-fired. Reverberatory furnaces have melting efficiencies in the range of 25 % to 28 % (CCMA and Technikon, 2001; BEE, 2005, Katerina, et al, 2016).

CONCLUSION

The efficiency obtained for the local charcoal-fired furnace and the manual geared operated blower was

11.6%. The value was obtained as a result of variable atmospheric conditions, non-uniform speed and the open nature of the environment and the furnace. The melting temperature was attained in a short time producing quick melting this is due to the wheel gear working principle (speed increaser), direct contact of the coal embers with the crucible and also due to the low quantities melted.

Speed increaser gear used helps reduce energy consumption since stirring of the bath takes place with the doors closed. Experience has shown that a 15% reduction in energy consumption is realistic and that a 25% to 30% improvement is achievable depending on the furnace and operation-specific variables.

Melt rate increases substantially with forced circulation. Cycle time reductions of 50% to 25% have been observed inside well furnaces when a local manual pump is used.

The furnace efficiency can be improved through modification of the furnace by adopting a closed arrangement.

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