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Performance Evaluation 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 towards production of cooking utensils in local small scale Aluminium recycling industries. The performance of such a furnace and manual operated blower was carried out in order to determine the efficiency and energy consumption in the cause of electricity power failure. Towards this objective, measurements were taken of the quantity of charcoal used for different melts and their corresponding melting period and temperatures. The wheel gear speed ratio of 1:8 was calculated, the energy used was determined and the efficiency calculated. The efficiency obtained for the furnace and the manual operated blower was 10.7%. The value obtained is as a result of variable atmospheric condition, non-uniform speed and open nature of the environment and the furnace. The melting temperature was attained in a short time producing quick melting this is due to wheel gear working principle (speed increaser), direct contact of the coal embers with the crucible and also due to the low quantities melted The furnace can be improved by adopting a closed arrangement.

1. 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 (Juris, 2016 and Shakhashiri, 2015). 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 by aluminium instead of gold. In other word, 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 (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 over and over without loss of its inherent properties since its atomic structure is not altered during melting.

Today 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 (John, 2016 and 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 in Sango-Ota and 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 (Lumley, 2011 and Ajuwa, 1998). Examples of such tertiary producers in Nigeria are Oluwalogbon Aluminium (Iseyin town), Agbajelola Aluminium Forging Works (Saki town), Fati Aluminium Pot Production (Saki town), Alidu Pot Making (Saki town), Abejiwaye ornament and Forging Works (Saki town), Aimasiko Aluminium port production (Lanlate town), 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 Yoruba land), 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 marriages, burials and other ceremonies and for 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 as one of the most versatile methods for producing small quantities of castings (Overview, 2008). An example of such enterprise are Abejiwaye Ornament and Forging Works and Aimasiko Aluminium Pot Production located in Saki and Lanlate towns, respectively, Oyo state, Nigeria. The aim of this paper is to carry out an approach to improve manual furnace blower efficiency using gear drive centrifugal blower and to reduce energy consumption.

2. METHODOLOGY

Materials and Production

Aimasiko Aluminium Pot Production Lanlate, Oyo State, is involved in the production of local cooking accessories like, pots, frying pans and spoons of various sizes using aluminium scraps. The aluminium scraps are obtained from suppliers at a rate of ₦100 - ₦150 per kilogram of aluminium scrap, depending on the location. This scrap is not pre-treated or cut to specific sizes. About 30kg - 45kg of aluminium scrap, depending on the size and thickness is required to produce a local cooking pot of 20 - 35 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 set up of the manual geared blower of the local charcoal fired furnace for melting aluminium is presented in Figure 1. The local furnace consists of a cast iron crucible which is heated by charcoal placed in 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 obtained by manual blowing of the furnace. This is achieved by a combination of wheel gears, pedal, fan and a duct system which directs the air to the combustion chamber. Blowing of air aids the combustion of the charcoal. The wheel gear and pedal which rotates the fan (blower) manually through a gear mesh drive can also be operated by electric motor and portable gasoline machine.

Furnace and Crucible Operations

The first step in the production of molten aluminium from scraps is by charging of the furnace (open top) crucible. The charcoal is ignited and strong heating is achieved through the wheel gear speed (As presented in Figure 1). (One revolution of drive gear equal to eight revolution of driven gear) by bottom blowing of air through the duct does commences melting of the aluminium scraps. During melting of the scraps, impurities float on top of the molten aluminium which are skimmed off at different time intervals. After each skimming, additional aluminium scraps are charged into the furnace crucible, 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 their covers with other kitchen accessories. There is always an excess of molten aluminium in the crucible to which is added the next batch of aluminium scraps to be melted.

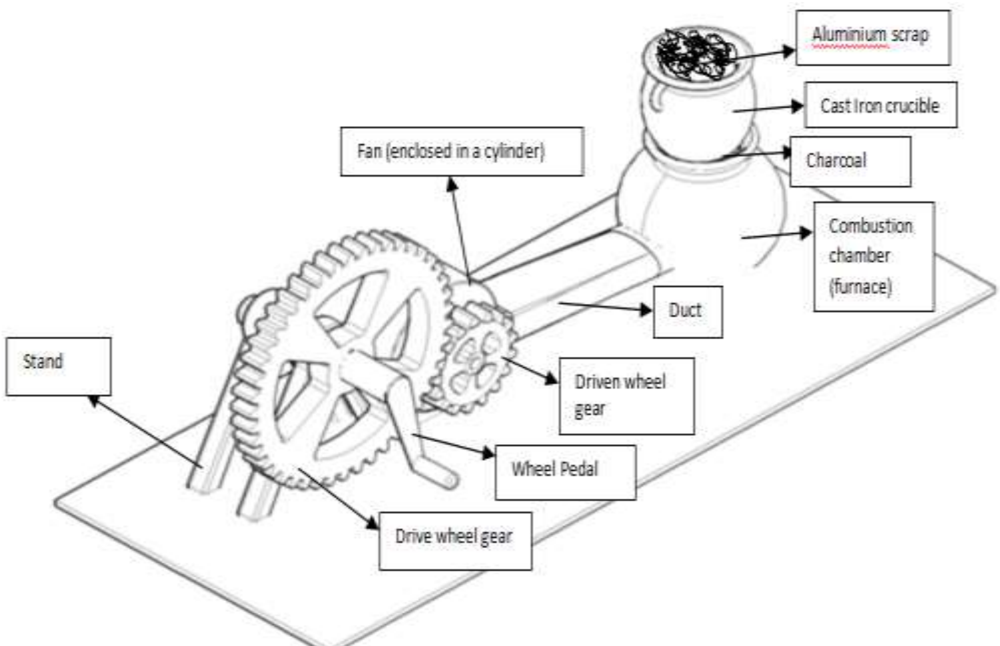

Figure 1: Manual geared blower for the local charcoal fired furnace for melting Aluminium

Performance Evaluation of Manual Geared Blower of Local Charcoal Fired Furnace

Measurements were taken at Aimasiko Aluminium Pot Production while the analysis was done at The Ibarapa Polytechnic Ibadan, Eruwa. The test procedure is as follows; 2.5kg of charcoal was measured with a weighing scale and was loaded into the furnace chamber. The cast iron crucible was placed on top of the furnace which served as the crucible and 2.5kg of aluminium scraps was measured into the crucible.

The charcoal was ignited with kerosene and matches to start up 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, duration of melting and the temperature of melting were recorded as shown in Table 1. A k-type thermocouple connected to temperature readout with a temperature range of 0 to 1400ºC was used for temperature measurement and time of melting was taken using a stopwatch. The same procedure was carried out for different weights of aluminium scraps (2.5kg, 5kg, 7kg, 10kg, 12kg and 15kg) and the quantity of charcoal used, duration of melting and the temperature of melting were also recorded in each production.

3. RESULTS AND DISCUSSION

Table 1 presents the result of aluminium melting using manual geared blower for the local charcoal-fired furnace while Table 2 shows the energy produced for melting aluminium scrap using manual geared blower. Table 1 reveals that as the weight of the charcoal in the local charcoal fired furnace increases so also the time and temperature increases in aluminium melting process. It was observed that the differences in the melting temperature occurred due to the atmospheric effects and open nature of the local charcoal fired furnace. 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. The cost of 17kg of coal was N2100.

Table 1: Result of Aluminium Melting Using Manual Geared Blower for the Local Charcoal-Fired Furnace

Mass of Aluminium (kg)	Mass of charcoal (kg)	Time (mins)	Temperature (^{0} C)
2.5	2.5	17	680
5	2.7	22	684
7	3.0	26	689
10	3.2	29	701
12	3.3	32	713
15	3.5	34	718

Table 2: Energy Produced for Melting Aluminium Scrap Using Manual Geared Blower

Mass of Aluminium (kg)	Mass of charcoal (kg)	Time (mins)	Temperature (^{0} C)	Energy (MJ)
2.5	2.5	17	680	76.3
5	2.7	22	684	82.4
7	3.0	26	689	91.5
10	3.2	29	701	97.6
12	3.3	32	713	100.7
15	3.5	34	718	106.8

Evaluation of the Energy Spent on Melting Aluminium with the Charcoal-Fired Furnace blower

The higher heating value for redwood charcoal for the temperature range 733 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 spent.

Using the values (as presented in Table 2),

$$\text{Average energy } = \frac{555.3}{6} = 92.6\ MJ$$

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

$$\text{Average energy used per kg of Aluminium } = \frac{\text{Average energy}}{\text{Average weight of Aluminium}} = \frac{92.6}{8.8}$$

$$= 10.6\ MJ/kg$$

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,

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

$$\text{Therefore, Efficiency of the furnace} = \frac{\text{Energy required}}{\text{Energy used}} = \frac{1.12}{10.6} \times 100 = 10.7\%$$

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 25 to 28% (CCMA and Technikon, 2001; BEE, 2005).

4. CONCLUSION

The efficiency obtained for the local charcoal fired furnace and the manual geared operated blower was 10.7%. The value obtained is as a result of variable atmospheric condition, non-uniform speed and open nature of the environment and the furnace. The melting temperature was attained in a short time producing quick melting, this is due to 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 furnace and operation specific variables. Melt rate increases substantially with forced circulation. Cycle time reductions of 50% to 25% have been observed in side 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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