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THE USE OF RENEWABLE ENERGY TO PRODUCE AIR BLOWER IN CHARCOAL FURNACE FOR ALUMINUM RECYCLING

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Abstract: *The charcoal-fired furnace is typically used in local recycling enterprises to produce cooking utensils from recycled Aluminum. Nearly all local foundries in Nigeria use manually run blowers to supply air for charcoal combustion and to melt metals. This has demonstrated how many man-hours are needed to operate the blower. This becomes difficult with low enterprise's productivity. In order to boost production, it is vital to discover simpler means of providing the energy needed for combustion. This study involves designing and building a solar-powered blower. To achieve this goal, measurements of amount of charcoal for melting of Aluminum and Zinc with their related melting times were made. Manual air blowers and those driven by solar energy have similar principle of operation. According to performance data from the manually operated air blower, melting 5kg of Aluminum and 5kg of Zinc takes about 69 minutes and 44 minutes on average, respectively. On the other hand, melting 5kg of Aluminum and 5kg of Zinc takes the solar-powered blower about 31 minutes and 18 minutes, respectively. The solar-enabled air blower melts quicker than the manually operated air blower. It was also discovered that the Solar-enabled air blower also avoids challenging task of providing energy for melting and lowers cost of melting.*

Keywords: *Aluminum, recycling, solar-powered furnace, air blower, charcoal furnace.*

1. Introduction

Aluminum is a silvery-white, Bauxite-derived metal found by weathering in tropical regions, the Bauxite rock is made up of over 50% Aluminum hydroxides. By 8% composition by mass, it is the most abundant metal available on the earth crust, and third most abundant metal after Silicon and Oxygen (Adeolu, Daniyan, Babalola, Okojie, & Aderoba, 2017). In the earliest times, man is known to have used Aluminum-bearing compounds for so many reasons. History has a record that clay rich in hydrated silicate of Aluminum were used to make pottery. The demand for Aluminum was so enormous that the wealthy and the ruling class sometimes demanded Aluminum in place of Gold. Aluminum is mostly produced on yearly bases than every other non-ferrous metal put together. Both Adeolu, *et al.*, (2017); Ighodalo, Akue, Enaboifo and Oyedoh, (2011) opined that Aluminum scraps has significant market value since the amount of energy needed for primary production is stored in the metal scraps itself known as minuscule (Garba 2015). Aluminum has been reused or recycled many times without loss of its molecular arrangement because its atomic matrix is unaltered when undergoing the process of melting.

Basically, Aluminum production entails the primary, secondary and the tertiary production stages. At primary stage, Aluminum production involves using Bayer Process to obtain Alumina of high purity from Bauxite, (Faith, 1973). Due to current unavailability of the principal producer in Nigeria, ALSCON, Aluminum ingots are currently imported. Secondary producers employ the ingots made by the primary producers to make container sheets, seamless tubes, plates and sheets, corrugated sheets, and wires and many others in rolling mills. Rolling mills for Aluminum, including those in Sango-Ota and Port-Harcourt, are Nigeria's secondary producers. Products made of Aluminum are bought by tertiary manufacturers from secondary producers for use in a variety of applications, including building, machine, vehicle components and packaging supplies, etc (Ajuwa, 1998).

Oluwalogbon Aluminum (Iseyin town), Agbajelola Aluminum Forging Works (Saki town), Fati Aluminum Port Production (Saki town), Alidu Port Making (Saki town), Abejiwaye Ornament and Forging Works (Saki town), Aimasiko Aluminium Port Production (Lanlate town), Extrusion Company Limited, Lagos, etc. are a few examples of such tertiary producers in Nigeria. A subset of this tertiary group is principally engaged in the recycling of Aluminum scraps for the production of small-scale Aluminum casting foundries, local frying pans, spoons of various sizes, and cooking pots (often known as Koko Irin or Aperin in South West Nigeria). Such sizable cooking pots are employed for unique occasions including weddings, funerals, and neighborhood eateries. These businesses, which employ four to six people to cast various cooking utensils and may be owned by a family unit, fall under the category of small-scale businesses. Such small-scale businesses typically use locally manufactured, solid fuel (charcoal) fueled furnaces. They use one of the best adaptable techniques of making small numbers of castings, like sand casting (Osarenmwinda, 2015). Abejiwaye Ornament and Forging Works and Aimasiko Aluminium Port Production, located in Saki and Lanlate town, Oyo State, Nigeria, are two examples of such a business.

2.0 REVIEW OF LITERATURES

It is important to remember that a country's ability to capture and transform its essential mineral resources, like Aluminum, into the necessary completed products, determines how far it can advance technologically (Osarenmwinda, 2015). The components for a nation's industrial development are the production and processing of metals. Metal casting is widely utilized metal processing procedures both in production and in processing of metals. Metal melting, which frequently requires supplying air into the boiler to achieve combustion, is at the heart of foundry processes. According to Okechukwu, Dauda, Enebe, Oloyede and Nwagu, (2013), visits to local charcoal foundries in Nigeria during familiarization missions revealed that numerous man-hours are lost during firing because one worker is devoted to operating the rotary blower, reducing the energy needed by this worker for casting and invariably lowering the labor productivity of the company. According to Adefemi, Ilesanmi, Simeon, Favour and Adeyemi (2017), melting and extraction, which are often done in a boiler, have emerged as the crucial industrial activities when using mineral resources such as metals for processing. A boiler is a piece of machinery used to melt metals for casting. The reason for heating a material, how heat is transferred to the material, how the furnace is fired, and how materials are handled inside the furnace are the typical categories used to classify furnaces. Local small-scale Aluminum casting foundries typically recycle Aluminum using the charcoal-fired boiler to create cooking utensils (Ighodalo et al., 2011).

Metal melting, which frequently requires supplying air into the boiler to achieve combustion, is at the heart of foundry processes. Pneumatic systems, bellow systems, engine-driven blowers, hand-driven blowers and motor-driven blowers are some ways to feed air to metallurgical furnaces (Okechukwu et al., 2013). Air blower, sometimes known as centrifugal fan, is frequently employed in HVAC systems or for exhaust purposes. The "centrifugal fan," and "blower," are widely used interchangeably to describe mechanical devices used to move gases or air. Due to their versatility and widespread use in various industrial applications, centrifugal blowers are quite popular (Jayapragasan & Manojkumar, 2015). According to Oyelami, Olaniyan, Iliya, and Idowu, (2008), the design basis for a blower is essentially identical to the design of a centrifugal pump, with exception that the blower operates on air whereas the word "centrifugal pump" is frequently linked with liquids for its operation. A centrifugal fan moves air despite resistance from ducts, dampers, and other components by increasing the volume of the air stream using the kinetic energy of the impeller. Because centrifugal fans provide a relatively constant airflow when operating at a constant fan speed, they are known as constant displacement or constant volume devices. Therefore, an air blower is a device that accelerates driving energy to the outer rim of an impeller, converting it to kinetic energy in a fluid. It consists of a spinning set of vanes (blades) to manipulate the air. The rotor and impeller are part of the hub and blades' rotating assembly. The blower’s design follows a near general principle to the design of a centrifugal pump in almost all significant ways, with the exception that "centrifugal pump" is frequently linked to liquids as its working fluid (Oyelami et al., 2008). The gasoline or air enters from the side of the fan wheel, spins 90 degrees, and accelerates owing to force as it passes over the fan blades and out of the fan housing (Abed, 2013).

The high cost of fossil fuels and Nigeria's unstable power supply made this study necessary for foundry applications. Because there is no power source for electric motor-driven blowers, fossil fuel-fired motorized blowers are expensive to fuel, and hand-driven blowers are exhausting, there is a need to provide a different system of blowing charcoal foundries. Furnace that is fired by charcoal is typically utilized in nearby small-scale Aluminum casting foundries to recycle Aluminum into the production of cooking utensils. Through designing and constructing a solar-powered air blower, with ways of delivering air for the operation of a charcoal-burning crucible furnace for melting metals, this study aims to solve the aforementioned problems, hopefully resolving all of them.

2.1 Centrifugal Blowers

Blowers speed up the flow of air or gasoline through impellers that have been carefully manufactured. They are typically used to transmit, chill, ventilate, aspirate, etc., by allowing the flow of air or gas. Low inlet pressure and high exhaust pressure are characteristics of a blower. The kinetic energy of the blades increases the air pressure at the outflow. Centrifugal blowers use high-speed blades or impellers to move air and/or other gases. They offer numerous blade orientations, including radial curves that face both forward and backward. Centrifugal blowers' flow will drop proportionately when speed decreases, according to the fan’s affinity restrictions.

Radial Fans: As a result of their high static pressure and capacity to handle substantially polluted air streams, radial fans are industrial workhorses. They are also well suited for high temperatures and medium blade tip speeds. The blades are not curved and are often utilized for cooling in tiny exhaust systems.

Forward-curve fans: Function at lower temperatures and are utilized in hygienic settings. They function best when moving huge amounts of air against low pressures. The blade's design in this instance is curved

Backward-inclined fans: More effective than forward-curved fans are backward-inclined fans. Due to the fact that fluctuations in static pressure do not overload the motor, reverse-inclined fans are also known as "non-over loading" fans. In this case, the blades rotate at a far faster rate than forward-curved blades. The flat blades turn anticlockwise to the rotational axis. For tasks requiring high-static pressure, it is ideal.

3.0 MATERIALS AND METHODOLOGY

3.1 Design of Blower

In the design, *U* represents the velocity through which a fluid must flow to move through a blower at a specific location on the rotating impeller. The flow entering the impeller has a radial component of motion rather than a tangential one because the blower has lower entrance guiding vanes. The air's absolute speed as it travels through the impeller is also given by *V*. The angle produced by *Vr* and *U* extended is known as β , whereas the angle formed by the line perpendicular to the impeller vane and the line pointing in the vane's direction is known as $\check{\alpha}$.

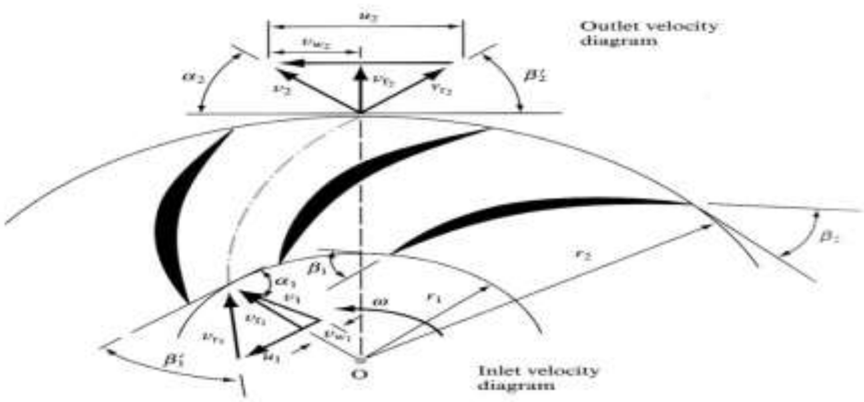

Figure 1. velocity diagrams showing Inlet and Outlet of the impeller (Kothandaraman and Rudramoorthy,2007)

Garba, (2015) asserted that a fan has to feed a furnace with minimum of 22.28 kg/s (0.0223 m^3/s) air for a 1kg of wood charcoal to be completely burnt. In this design, the blower's air flow rate is set at 0.0223 m^3/s (the least amount of air needed to completely burn 5kg of wood charcoal). Based on the flow rate and rotational speed, the impeller is designed. According to Okechukwu et al. (2013), the impeller-shaft can rotate at 2000 revolutions per minute since charcoal does not need plenty air to glow and the distance that the air must travel via the inlet pipe.

According to the ASME code, the internal diameter to exterior diameter ratio ranges from 0.4 to 0.7, according to the best performance criterion (Ibrahim, Abdullahi. & Pindiga., 2019).

Hence, $$0.5 < \frac{D1}{D2} < 0.8 \quad (1)$$

To design the ration of $\frac{DI}{D2} = 0.45$ (2)

We have the number of blades, (C), to achieve maximum efficiency in accordance with ASME Code, as follows:

$$C = \frac{8.5 \sin \beta_2}{1 - \frac{D1}{D2}} \quad (3)$$

Where β_2 = vane's outlet angle = $20^o < \beta_2 < 90^o$, for this design, β_2 is taken as 45^o.

The number used by the impellers,

C = 6 the impeller Area (A)

$$A = \frac{\pi d^2}{4} \quad (4)$$

$$A = \frac{\pi 0.19^2}{4}$$

$$A = 0.03m^2$$

Equation 5 and equation 6 are used, respectively, to calculate the impeller inlet and outlet speeds.

$$U_1 = \frac{\pi D_1 N_1}{60} \qquad (5)$$

$$U_2 = \frac{\pi D_2 N_2}{60} \qquad (6)$$

$$U_1 = \frac{3.14 \text{ X } 0.086 \text{ X } 2000}{60}$$

$$U_1 = 9m/s$$

$$U_2 = \frac{3.14 \text{ X } 0.019 \text{ X } 2000}{60}$$

$$U_2 = 20m/s$$

$$V_1 = V_{r1} = U_1 \tan \beta_2 \qquad (7)$$

$$V_2 = V_{r2} = U_2 \tan \beta_2 \qquad (8)$$

$$V_2 = \frac{V_{f2}}{\sin \beta_2}$$

$$V_2 = \frac{1}{\sin 30}$$

$$V_2 = 2m/s$$

$$V_{W2} = \sqrt{V_2^2} - V_1^2$$

$$V_{W2} = \sqrt{3.8^2} - 2.02^2$$

V_{W2} = 3.18m/s

$V_{r2} = \frac{1}{\sin 45} = 1.14 m/s$

$V_{r2} = \frac{2.20}{\sin 29} = 4.45 m/s$

Equation 9 display the quantity of air discharged (Q), and it is determined as follows:

$$Q = 2\pi r_1 b_1 V r_1 \qquad (9)$$

$$= \rho g Q H \qquad (10)$$

Pi = 1.166 x 9.81 x 0.022 x 2

P = 0.5kW

Pi = 500W

From equation 11, we can calculate torque as:

Torque (T)

$$T = \frac{P_i}{w} \qquad (11)$$

$T = \frac{500}{2 \ x \ \pi \ \text{x} \ 2000}$

T= 0.04N-mm

For shafts with keyways for allowance, Choure (2017) stated that the maximum permitted shear stress is 42MPa, and the shaft diameter (ds) can be computed using equation 12.

$$ds = \sqrt[3]{\frac{16\ X\ T}{\pi\ \mathrm{X}\ \int s}} \tag{12}$$

$$ds = \sqrt[3]{\frac{16\ X\ 0.04}{3.14\ \mathrm{X}\ 42}} \quad = \ 0.17m$$

Using experimental results from Sani, Kantiok and Atiku, (2016), we can use the ASME Code described in 13 to determine the breadth of the blade.

$$W = \frac{6(\frac{D_1}{2})}{C+1} \tag{13}$$

$$W = \frac{6(\frac{0.086}{2})}{6+1}$$

$$W = \ 0.037m$$

Efficiency (η) for the blower is shown below:

$$\eta = \frac{P_o}{P_i} \tag{14}$$

$$Pi = T\omega \tag{15}$$

$$Pi = 0.04 \text{ x } 2\text{x } \pi \text{ x } 2000$$

$$P = 0.5024kW$$

$$\eta = 0.500.5024$$

$$\eta = 99.5\%$$

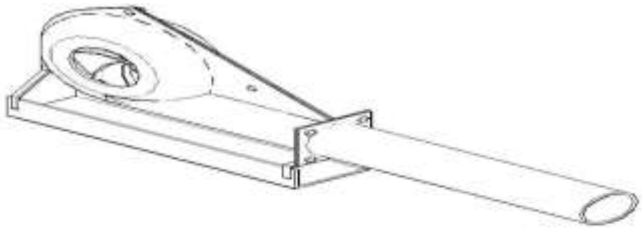

Figure 2. Diagram depicting the blower

3.2 System Integration and Sizing for Solar Power

According to Abdul Kadir (2014), integrating solar power as an alternative energy production employing photovoltaic systems can increase productivity rate, which will aid the industry by speeding up production and eliminating or reducing the weariness felt by the local foundry workers. Depending on the manner of production and the characteristics of photovoltaic system (PVS), the idea of integrating solar photovoltaic systems into the production industry will have an impact. According to Begovic (2001), the PVS is deemed valuable if it fits the basic requirements for the system operating perspective. Daly and Sorrison (2001) further argued that PVS' influence on the quality of power is dependent on its interaction with the DG unit's size, the utility system, amount of generation corresponding to load at the interconnection point, and PVS's overall capacity in relation to the system.

Location is a decisive factor when sizing and designing a solar energy power system due to the fact that solar energy's performance is dependent on its geographical location. In Damaturu, Nigeria, solar radiation of high intensity amounts to 6.176 kW/m2/day, and the average sunshine hour for the region is approximately 9 hours per day, indicating the semi-arid region of Northern Nigeria's solar energy potential (Muhammad, Ngala, Shodiya, & Shuwa, 2016). Eseosa & William (2017) theorized that for the PV module's optimal tilt angle in continuous tilt direction to increase irradiation and to maintain matching conditions for all sites, Damaturu's maximum tilt degree is given 11.9.

Capacity of PV W_P panel needed is given below:

$$= \frac{\textit{Power rating of the blower}}{\textit{Sunshine hours per day x tilt angle x deviation cell tempt. x looses}}$$

$$Capacity\ of\ PV\ Wp\ panel\ needed = \frac{502.4 \text{ x } 6}{9 \text{ x } 11.9 \text{ x } 0.49 \text{ x } 0.7}$$

= 82.0573

$Number\ of\ PV\ Panels\ needed = One\ 100\ Wp\ Module$

The battery must make-up for non-concurrent supply of energy, including consumption. The capacity of the battery is measured in amp hours (Ah). Consequently, the following expression will be used to compute the required battery capacity.

For the battery Capacity (Ah):

$$= \frac{\textit{Total Watt – appliances used hours per day x autonomy days}}{\textit{0.85 x 0.6 x battery voltage(nominal)}}$$

Appliances used in total = (1DC Motor x 502.4 Wx 6 hours) =3014.4 Watt

Battery voltage (Nominal) = 12V

Days of autonomy = 1 days

$$\text{Battery Capacity (Ah)} = \frac{3014.4 \times 1}{(0.85 \times 0.6 \times 12)}$$

= 492.55 Ah

The total required ampere-hours is 492.55, hence the battery must be rated 12 V 500 Ah for a day's autonomy.

4.0 RESULT AND DISCUSSIONS

The constructed blower is seen in **Figure 3.**

Figure 3. Construction of a Solar-Powered Blower

To evaluate the performance of the manufactured blower, we compare its performance to that of a manually operated air blower. **Tables. 1** and **2** display the test results for the two air blowers. 5kg of charcoal was used to melt 5kg of Aluminum and 5kg of charcoal was used to melt 5kg of Zinc. When using the blower (manually driven) to deliver air for ignition and burning of the charcoal for melting, only 3.8kg and 0.83kg of the measured 5kg of charcoal were sufficient to melt 5kg of Aluminum and Zinc, respectively. The manually operated blower required approximately 69 and 44 minutes to melt 5kg of Aluminum and Zinc at temperatures of 694.39°C and 431.01°C, respectively. Using a solar-powered air blower at an average atmospheric temperature of 37 °C, it takes 31 and 18 minutes to melt 5kg of Aluminum and zinc at melting temperatures of 775.8 °C and 425.7 °C, respectively.

Table 1. Performance assessment of air blower operated manually

Materials/Metals used	Aluminium	Zinc
Ambient/atmospheric temperature	34.3°C	36.5°C
Aluminum quantity by weight	5 kg	5 kg
Charcoal quantity by weight	2.9 kg	0.84 kg
Temperature of melted metal	698.39°C	442.1°C
Duration	69 minutes	44 minutes

Table 2. Performance assessment of solar-powered air blower

Materials/Metals used	Aluminium	Zinc
Ambient/atmospheric temperature	36.1°C	38.2°C
Aluminum quantity by weight	5 kg	5 kg
Charcoal quantity by weight	2.8 kg	1.2 kg
Temperature of melted metal	775.8°C	425.7°C
Duration	31 mins.	18 mis.

5.0 FINDINGS AND CONCLUSION

A SOLAR-POWERED AIR BLOWER FOR A CHARCOAL-FIRED FURNACE WAS DESIGNED AND CONSTRUCTED, AND ITS PERFORMANCE WAS EVALUATED AND COMPARED WITH THAT OF A TRADITIONAL AND MANUALLY DRIVEN AIR BLOWER. IT WAS DESIGNED TO IMPROVE AIR VELOCITY FOR THE IGNITING OF CHARCOAL. THE PHOTOVOLTAIC SYSTEM SUPPLIED THE NECESSARY ENERGY TO START THE BLOWER. IN ADDITION, THE DC BATTERY WAS UTILIZED TO PROVIDE DIRECT CURRENT ELECTRICAL ENERGY FROM THE PHOTOVOLTAIC PANELS DURING OFF-PEAK HOURS. THE STUDY RESULTS INDICATED THAT THE SOLAR-POWERED BLOWER PRODUCES AIR MORE QUICKLY AND MORE EFFECTIVELY. THE SOLAR-POWERED AIR BLOWER REQUIRES APPROXIMATELY 31 MINUTES AND 18 MINUTES TO MELT 5KG OF ALUMINUM AND 5KG OF ZINC RESPECTIVELY, WHILE THE MANUAL BLOWER REQUIRED APPROXIMATELY 69 MINUTES AND 44 MINUTES FOR THE SAME 5KG OF ALUMINUM AND 5KG. THIS FURTHER DEMONSTRATES THAT SOLAR-POWERED AIR BLOWERS ARE MORE EFFICIENT AND REQUIRE LESS TIME TO MELT ALUMINUM AND ZINC WHEN COMPARED TO MANUALLY OPERATED AIR BLOWERS. IT ALSO ELIMINATED THE LABORIOUS ASPECT OF ACQUIRING ENERGY FOR MELTING, AS WELL AS THE LENGTHY DURATION TYPICALLY ASSOCIATED WITH MELTING PROCESSES.

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