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Design and Development of an Engine-Driven Blower for Charcoal Furnaces

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ABSTRACT

Towards providing an alternative source of air-supply for charcoal furnaces, instilling ergonomics in charcoal foundries and increasing the productivity of small foundry enterprises, an engine-driven blower has been designed, developed and tested. Pro-Engineer software was used in geometric modeling, analysis and assembling of the parts. The impeller-shaft subassembly was converted to an equivalent shaft of equal mass and predetermined diameter. Design analysis yielded the torque and power requirement of the impeller-shaft assembly which were used to select GX-160 Engine. Cost of the blower can be reduced by lowering the frame height and attaching the impeller to the engine shaft. Also, the design methodology can be used in designing blowers for other applications.

Keywords: Foundry, Engine-driven blower, Charcoal fired furnaces, Ergonomics, Productivity

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I. INTRODUCTION

Production of metals has dominated known manufacturing processes. These techniques include: casting, forging, machining, welding, rolling, etc. Casting or founding remains the bedrock upon which the other techniques depend on. 'Casting' means the pouring of molten metal into a mould, where solidification occurs [7]. At the core of the foundry processes is the melting of metals, which often involves the supply of air into the furnace to achieve combustion. Methods of supplying air to metallurgical furnaces include: pneumatic system, bellow system, hand-driven blowers, motor-driven blowers and engine-driven blowers. The reluctance in the use of charcoal furnace by small foundry enterprises is a direct result of lack of reliable economical means of supplying air to the furnace. Charcoal fired furnaces are one of the cheapest furnaces which have metamorphosed from bellow through manual rotary blower to electric motor-driven bower systems. The unreliable power supply in Nigeria for electric motor-driven blowers and the fatigue associated with the hand-driven blowers necessitated the thought of providing an alternative blowing system for charcoal foundries. The charcoal fired furnace is usually used for aluminium recycling towards production of cooking utensils in local small scale aluminium casting foundries [2].

Familiarization trips to local charcoal foundries in Nigeria showed that much man-hours are wasted during firing as one labourer is dedicated to driving the rotary blower. This reduces the energy required by this employee for casting and invariably lowers the labour productivity of the enterprise. The reliance on manual blowers for air supply in small foundries in Nigeria is due to the epileptic power supply for energizing electric motor-driven blowers. The scope and objectives of ergonomics is "designing for human use and optimising working and living conditions" [10]. Productivity may be defined as the optimum utilization of all the resources of organization: men, money, materials, machinery, energy, space and technology, etc. Output per employee per hour, in all phases must be maximized. The manufacturing enterprise must constantly strive for higher productivity. Two of the major resources that should be optimally planned are: human resources and equipment [8]. Hence, the need for an alternative source of air supply that will increase the convenience of use, enhance safety, reduce stress and fatigue, improve quality of work life and increase productivity through ergonomical supply of air in charcoal foundries cannot be overemphasized.

The objectives of this project include:

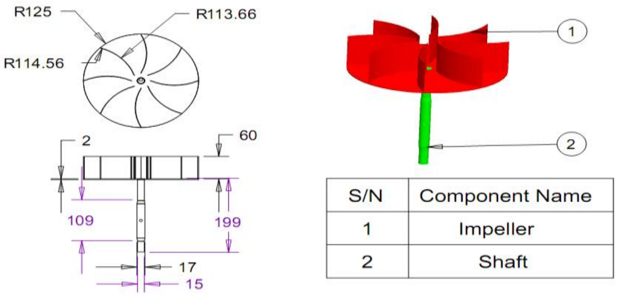
(i) To develop an alternative source of air-supply to charcoal furnaces;
(ii) To instill ergonomics in charcoal foundries;
(iii) To develop a simple method of selecting engines for engine-driven blowers;
(iv) To increase the productivity of small foundry enterprises.

II. METHODOLOGY

The method of engine selection was based on the following conditions: (i) Mass of the impeller-shaft subassembly can be converted to an equivalent shaft of equal mass; (ii) The angle of twist of the impeller-shaft assembly equals 1^0; (iii) Equivalent torque of the impeller-shaft subassembly should be less than the engine torque; (iv) Power required by the impeller-shaft subassembly is less than the power output of the engine to be selected; (v) The same size of pulley is used on the impeller shaft and the engine shaft to ensure minimal deviation from the engine torque and speed.

2.1 Geometric modeling and analysis of the impeller-shaft subassembly

Pro-engineer software was used in drawing, assembling and determining the mass properties of the impeller-shaft subassembly as follows:



S/N	Component Name
1	Impeller
2	Shaft

Fig.1: 2D and 3D geometric models of the impeller-shaft subassembly

An impeller is a wheel (or rotor) with a series of backward curved vanes or blades [6]. A shaft is a rotational member, usually of circular cross section, used to transmit power or motion. It provides the axis of rotation, or oscillation, of elements such as gears, pulleys, flywheels, cranks, sprockets, and the like and controls the geometry of their motion [9].

Table1: Mass properties of the impeller-shaft subassembly

Parameters	Values/Units
VOLUME	1.8340908e+05 MM^3
SURFACE AREA	2.1435932e+05 MM^2
AVERAGE DENSITY	7.8500000e-09 TONNE / MM^3
MASS	1.4397613e-03 TONNE

Result of the analysis in Pro-Engineer software showed that the mass of the impeller-shaft subassembly equals 1.44kg, approximately. Notice that, the average density of the subassembly equals 7850kg/m^3 [1], because they are made of steel.

2.2 Conversion of the impeller-shaft subassembly to an equivalent shaft

Let the mass of the impeller-shaft subassembly, m = 1.44kg; Diameter of the equivalent shaft, d = 0.015m; Density of steel, $\ell = 7850\text{kg/m}^3$ [1]; Volume of the impeller-shaft subassembly, $V = 1.834 \times 10^{-4}\text{m}^3$; Equivalent length of the shaft of equal mass as that of the impeller-shaft subassembly, L =?

Let the volume of the cylindrical equivalent shaft, $V = \frac{\pi d^2 L}{4}$ [1] …………………………………………… (1)

L can be determined from equation (1) using Excel spreadsheet as shown in table2:

Table2: Determination of the equivalent length in Excel spreadsheet

d (m)	d^2 (m^2)	V (m^3)	L =4V/πd^2 (m)
0.015	0.000225	0.0001834	1.03769715

Hence, the equivalent length, L, is approximately 1m.

2.3 Determination of the twisting moment of the impeller-shaft subassembly

The torque or twisting moment of the equivalent shaft is given by the equation

$$T = \frac{G\theta J}{L} \quad [3] \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Where, θ is the angle of twist (radian); G is the modulus of rigidity (N/m^2); L is the equivalent length of the impeller-shaft subassembly; J is polar moment of inertia of the impeller-shaft subassembly (m^4). Let $\theta = 1^0 = \pi/180 = 0.0175$ (rad.), Modulus of rigidity of steel, G = 8.0 × 10^4 N/mm^2 = 8.0 x 10^{-2} N/m2 [4], L = 1m.

$$J = \frac{\pi}{32} d^4 \quad [3] \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

$$J = \frac{\pi}{32}(0.015)^4 = 4.97 \text{ x } 10^{-9} \text{ m}^4$$

Substituting the values of G, θ, J, and L into eqn. (2), yields

T = 8.0 x 10^{10} x 0.0175 x 4.97 x 10^{-9}/1 = 6.96Nm.

2.4 Power transmitted by the impeller-shaft subassembly

The power, P_t, transmitted by the impeller-shaft subassembly can be determined from the expression

$$P_t = \frac{2\pi NT}{60} \quad [4] \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$

Considering the fact that charcoal does not require much air to glow and the length of travel of the air via the inlet pipe, we use the revolution per minute (RPM) of the impeller-shaft assembly, N = 2000 RPM.
Substituting the values of N and T into equation (4), gives
P_t = 2 × π × 2000 × 6.96/60 = 1457.70W

2.5 Power required to drive the impeller-shaft subassembly

Using a power tolerance of 500W, the power, P_r, required to drive the impeller-shaft subassembly can calculated as follows: $P_r = P_t + 500$ = 1457.70 + 500 = 1957.70W
But, one horse-power (hp) equals 746watts, hence, P_r= 1957.70/746 = 2.62hp.

2.6 Selection of the engine for driving the impeller-shaft subassembly

Notice that, the torque exerted by the belt on the driver pulley = ($T_1 - T_2$) r_1 [5], equals the torque exerted on the follower pulley = ($T_1 - T_2$) r_2 [5], because the same size of pulley was used as driver and follower. Where T_1 (N) and T_2 (N) are the tensions in the tight side and slack side, respectively; r_1 (m) and r_2 (m) are the radii of the driver and follower pulleys, respectively.

Selection of the engine was based on torque, power required, RPM and fuel consumption. GX-160 engine was selected based the parameters shown in table3 below:

Table 3: Engine selection parameters

Parameter	Impeller-Shaft Subassembly	GX-160 Engine
Torque(Nm)	6.96	10.80
RPM	2000	2500
Power(hp)	2.62	5.5

The fuel consumption of the engine as specified by the manufacturer is 290g/hp-hr.

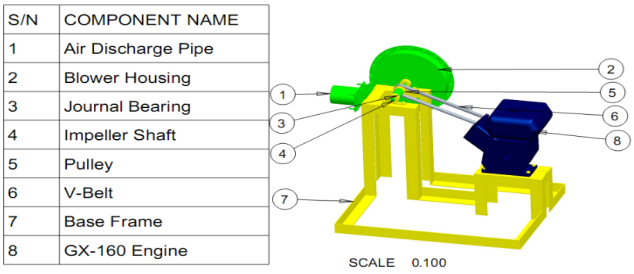
2.7 Development of the engine-driven blower

The blower was developed with locally available materials and driven by 5.5hp GX-160 engine. Equipment and tools used during the development processes include: Measuring tape, scriber, plywood and nails as compass, try square, punch, hammer, ruler, vice, hacksaw, filing machine, diesel engine, arc welding machine, spanner, screw driver and razor blade. Due to the unavailability of small journal bearings, bearing housings were improvised for the bearings. Table3 shows the lists of materials and development processes used in making the engine-driven blower.

Table4: Materials used and development processes for parts/subassemblies

S/N	Parts/ Subassembly	Materials Used	Development Processes
1	Impeller Housing and Cover	2mm-Mild Steel Sheet, M8-Bolts and Nuts, Paper Gasket and Blue Gum	Marking, Cutting, Welding, Filing, Gluing and Fastening
2	Impeller-Shaft	2mm-Mild Steel Sheet, ø20mm-Ribbed Steel Bar	Marking, Cutting, Welding and Filing
3	Discharge Pipe and Holder	Same as in 1 above	Same as in 1 above
4	Base Frame	45mm × 3mm-Angle Iron	Same as in 2 above
5	Blower-Base Frame	M8-Bolts and Nuts, Improvised Journal Bearing	Marking, Drilling, Welding and Fastening

2.8 Drawings and pictures of the developed engine-driven blower



S/N	COMPONENT NAME
1	Air Discharge Pipe
2	Blower Housing
3	Journal Bearing
4	Impeller Shaft
5	Pulley
6	V-Belt
7	Base Frame
8	GX-160 Engine

Fig. 2: Trimetric drawing of the engine-driven blower in Pro-Engineer software

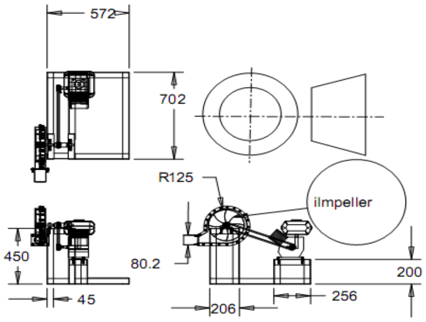
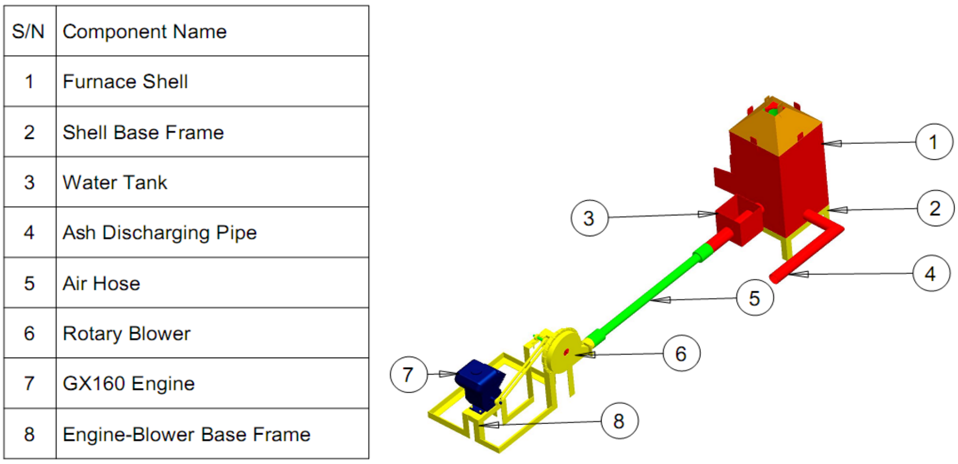


Fig. 3: Third angle projection of the engine-driven blower



S/N	Component Name
1	Furnace Shell
2	Shell Base Frame
3	Water Tank
4	Ash Discharging Pipe
5	Air Hose
6	Rotary Blower
7	GX160 Engine
8	Engine-Blower Base Frame

Fig. 4: Isomeric drawing of the blower-charcoal furnace assembly in Pro-Engineer software

Fig. 5: Engine-driven blower being tested with an improvised charcoal fired furnace

Fig. 6: Picture showing molten aluminium and water-cooled air inlet pipe

III. RESULTS AND DISCUSSION

3.1 Results

On completion of the development stage of the engine-driven blower, a charcoal furnace was constructed to ascertain the functionality of the blower. Additionally, light melting aluminium scraps from can drinks and heavy melting aluminium scraps from cars and motorcycle were used to test run the blower. Production of aluminium pulleys was achieved using the blower, also. The results of the firing process are as shown in table4.

Table5: Results of the firing tests and production carried out with the engine-driven blower

Firing No.	Quantity of Aluminium Scrap Melted (kg)	Firing Time (min)
1	4.0	40
2	2.5	20
3	11.0	55

While firing no. 1 was carried out with light melting scraps, firing no. 2 and 3 were achieved with heavy melting aluminium scraps.

3.2 Discussion

The firing time per kilogram of melted aluminium decreased from 10min./kg, through 8min./kg to 5min./kg for firing no. 1, 2 and 3, respectively. The high firing time per kilogram recorded in firing no.1 can be attributed to the time spent in removing excessive slag generated by the aluminium cans from the furnace. Firing no.2 was a test run carried out with heavy melting aluminium scrap, while firing no. 3 represents actual production with the blower. A difference of 3min/kg between firing no.3 and 2 can be ascribed to the high temperature of the furnace achieved from the first melting down, which lowers the time for the melting of subsequent scraps.

IV. CONCLUSION

Considering the outcome of the design calculations, engines of capacity 2.62hp and above can be used to drive the impeller-shaft subassembly. Benefits of the use of the developed engine-driven blower include: reduction in the energy expended in driving the blower as the alternative air supplier can work faster and longer with low maintenance cost. The heat conducted to the blower was reduced with a water tank that cools the air inlet pipe and a long insulating hose to minimize metal to metal heat conduction to the blower. Though, the method adopted in this paper seeks to simplify the design method of selecting engines for engine-driven blowers, it can be used in the design of blowers for other applications. It is pertinent to discharge the water in the tank via the tap when it starts boiling and replace it before firing continues. However, the cooling water did not boil during the highest firing period of 55 minutes. Also, the hose should be removed after firing to prevent it from melting by convectional heat backflow from the furnace. The developed blower can sufficiently supply the amount of air required to keep the charcoal glowing and melt non-ferrous metals. More so, the discharge rate can be varied by adjusting the engine throttle.

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