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Research Article

SOLAR POWERED MULTI-PURPOSE CHARCOAL STOVE

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Abstract

In developing economies of the world, cooking had traditionally been done using firewood as fuel, regardless of its associated health implications such as respiratory and heart diseases, lung cancer and eye irritations. Despite these difficulties, wood fuel had remained popular even amongst developed nations. In Nigeria, the use of wood fuel still thrives well in our rural communities for large families, groups during parties etc., because of ack of access to modern cooking fuels. Nevertheless, though charcoal fuel might not offer the same level of convenience as gas or other cooking fuels, its smoke flavour stands out above all others. The dry, white-hot heat of charcoal sears found quickly, creating a crusty, caramelized exterior and smoky flavour when used for grilling meat for example. In this project, we aim at designing and producing an ozone friendly solar powered charcoal cooking stove capable of producing a regulated heat output, that, when extended, can melt low specific heat metals such as aluminum and copper.

Keywords: Charcoal-powered stove, radiation shield, low specific heat capacity, waist-high brick, and mortar unit.

INTRODUCTION

Over the years cooking has been done in the open, on grounds and on low masonry constructions with massive amount of heat loss and air pollution. Waist-high brick-and-motor units and their chimneys appeared in the Middle Ages for cooking to enable cooks to avoid kneeling and sitting. around fire to be able to attend to what they cook. Then cooking was done on cauldrons hung above the fire or placed on trivets. Simple heat control was effected by placing the caldrons higher or lower above the fire. Francois Covilles, about the 18th century attempted to limit heat loss which was a major handicap with the waist-high brick-and-mutter until by a masonry construction with several fire holes on a perforated iron plate. Further improvement on head efficiency was later made by hanging the cooking pots centered around the holes through a top iron plate. Later the Chinese and Japanese (about 3rd and 6th century) introduced the clay stoves which enclosed the fire completely. The introduction of clay around the fire made heat concentration, hence efficiency most probable. For an optimum performance, a charcoal stove requires a large upstream of pulling air (and potentially heat) out through a chimney to prevent air and smoke from spilling back into the system, thus causing discomfort to the user. The Rumford stove (1969), (believed to have been invented by Benjamin Thompson) used one fire to heat several pots that were also hung on holes so that they could be heated from the side holes as well. To each hole was a heat regulator. This stove, although not suitable for domestic use, proved useful in large canteens or coffle kitchens. Further works by Benjamin Thompson led to the reduction of size of iron stove and the regulation of air in-flow into the system to allow only the needed air for complete combustion. Modern wood and charcoal stoves incorporate systems which aid complete combustion. Catalytic converters which help gaseous and smoke particles not completely burnt to combust are installed in expensive wood and charcoal stoves.

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Other models designed to produce complete combustion and hence improve efficiency use designs which include firebox installation, large baffle to produce longer, hotter gas flow path, pre-heating the air prior to it entering the combustion chamber and the use of radiation shields under the combustion chamber. The use of gas as a source of energy in cooking is rising in developing countries that have the resources and yet unaffordable for nations that do not have them. Other forms of stoves are powered by gas or electricity. James Sharp, an English man was the first to patent a gas stove in 1826 but the Swedish Nobel Prize winner Gustaf Dalen made the most notable improvement in gas-powered stove in 1922. His stove has stood as the most efficient design and the most sort after kitchen "most have" in certain circles despite the enormous price tag. Thomas Ahearn (2009) invented the electric cooking stove; the electric stove technology has evolved from successive generations into the emergence of resistance heating coil (which heated iron hotplates) with glass ceramic cook tops. The use of electric stoves in developing countries is not popular partly because most villages and towns are not connected to the power grid and partly because many cannot afford the cost of this clean energy source. Charcoal stoves are by all accounts popular because of the availability of charcoal. In this work, we design and construct an environmentally friendly multi-purpose stove most targeted for use in areas located off the electricity grid. The stove incorporated a solar panel to generate a dc source that will power a fan motor necessary to produce an upstream of hot air and heat unto whatever sits on the stove. This will also minimize smoke discomfort to the user. Clay and ceramic are used and lined up with funnel-like metal hopper to concentrate heat and improve energy efficiency. Since the project is aimed for use in an off-the-grid location, the solar system, which is fitted with battery illuminates this environment with bulbs made of light emitting diodes. DC phone charger pots are also provided to charge the users phone and ensures that the user stays in communication with friends and family 24/7. The benefits of the solar powered charcoal stove are many. A bank of resistive potentiometric regulators is incorporated to generate a regulated heat output, from as low as 25^0C to 600^0C onto the cooking vessel. This enables various kinds of cooking and grilling to be done on the stove. Moreover, the heat regulator can be adjusted to very high resistive values to produce as much as $600^0 C$, enough to melt low specific heat metals like aluminum. The storage battery can be used to store charges for use during the night times. Nevertheless, for a higher energy output and a longer lasting hour of use, even in dark times, the number of storage batteries and the number of solar panels could be increased, though with a few challenges which were taken care of.

MATERIALS AND METHODS

First, the structural materials were fabricated from the following materials.

i) $12.7mm$ angle iron metal
ii) $2.5mm$ plane metal sheet
iii) $50.8mm$ steel pipe
iv) Electrodes, cutter, file, and paint.

To date, various methods have been developed and introduced in the process of making charcoal stoves. We recommend that recycled sheets of steel be employed in making the multipurpose wood stove as we have an abundance of these littered all over the place. This will even help in cleaning up our environment.

Step 1

Four pieces of the angle iron were cut to $45.72cm$ to serve the height of the stove. Eight pieces of the same material were cut to $50.8cm$ to brace the up and bottom of the height of the stove as shown in Figure 1

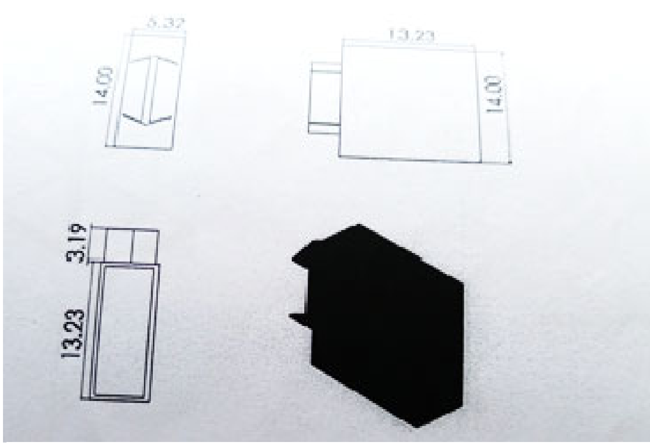

Figure 1. The Drawing showing the Stove Skeleton

Step 2

Four pieces of metal sheets were cut for the construction of the hopper each having a dimension of $35.5cm$. The four pieces of metal sheet would be welded together to form the hopper. A hollo metal pipe structure of $63.5cm$ covered the bottom of the hopper from where the charcoal ash was collected. This also serves as an air inlet to the stove and is mounted 50 cm from the base of the hopper. Four metal sheets of dimensions $130mm$ were welded together to form a cube-like shape and is attached to the hopper to serve as an ash collector.

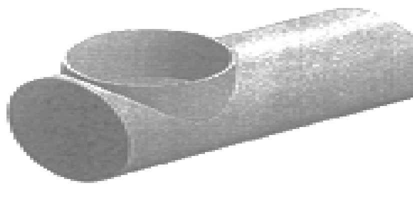

Figure 2. Skeleton of the Hopper

Step 3

Four pieces of triangular shaped metal whose dimensions are shown are welded to the top of the brace to serve as the utensil carrier.

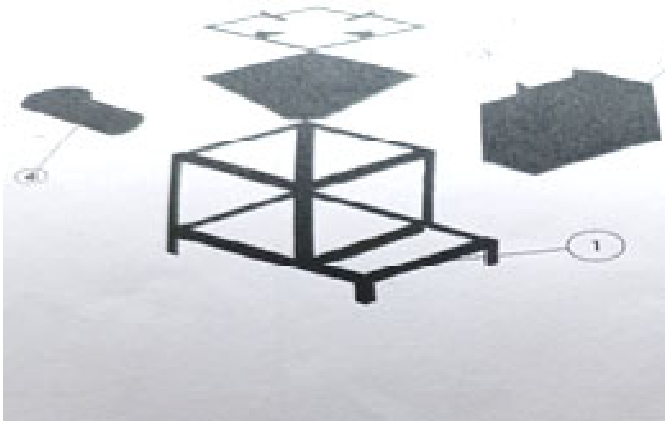

Figure 3. The Cooker Base

Step 4

The DC motor stand was constructed with four pieces of angle bars of $7.62cm$ in thickness and metal sheets of $35.5cm$ by $50.8cm$ dimension. This box houses the DC motor and is as shown in Figure 4. Also, within the box housing the DC motor is the circuit for the solar panel design. The novelty of this design is in the section with the inclusion of the solar panel that traps the sun's energy during the day and stores the energy for usage at dark hours.

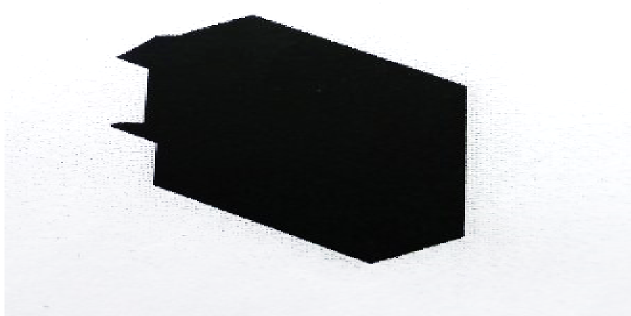

Figure 4. DC Motor Housing

The high-power Light Emitting Diodes are powered from the energy stored in the lead-acid battery, and because the capacity of the battery is 5Ah, the light emitting diodes can be ON. dissipating for 5 hours. Besides, the lead-acid battery can sustain this service because of the enormous charge content.

$Q = A \times t_{(\text{sec})} = 5 \times 3600 = 18{,}000 Coulombs.$).

The solar panel is $9watts/12volts$ rating and it converts incident solar power into electrical energy. The $IN4001$ eliminates any reverse flow of current, especially at night and dark hours. Light emitting diodes are connected for lightening purposes at dark hours and series resistances are connected in potentiometric arrangements through a switch to either increase or decrease the speed of the DC fan. The intensity of the light emitting diodes across the DC fan indicates the speed of operation of the fan.

The Solar Power Circuits Design for Battery Charging and LED Lightening

Choice and Reason for Component Selection

For battery charging voltage, a 9-volt Solar Panel was selected. Secondly, the voltage regulator $LM317$ was chosen because its output can be adjusted within range. The $LM317$ has an output voltage range of between $1.2-37volts$. A potential divider principle using resistors R_1, R_2 and R_3 was employed and connected to the adjustable pin of the $LM317$ in order to obtain the needed varied output voltage. Using the formular below,

with R_1 = 240 ohm, R_2 = 1200 ohm and R_3 being a voltage $7.5volts$ was obtained as the output of the $LM317$ for charging the battery. This was achieved using the established formular as under

$$V_{out} = 1.25 \times \left(1 + \frac{R_2}{R_1}\right)$$

As a rule of thumb, a 6-volt lead acid battery will charge to 100% when a 7.3 volt (higher than the threshold voltage) is applied across it. Hence, considering the voltage drop in the circuit, the values of R_1 and R_2 , and by simulation were chosen to give $7.5Volts$ output at the $LM317$ output pin. Besides, D_1 ensures that only rectified current is stored in the DC battery and that no reverse DC current comes back to the panel is possible.

CIRCUIT LIGHTENING

The LEDs are rated at 3.5v/350mA. Although, the LEDs are connected through limiting resistors their total current consumption is $350 \times 10^{-3} \times 3 = 1050mA$ (since they are arranged in parallel). Now since the current rating of the battery is $5Ah$, it implies the battery can power the LEDs for

$$\frac{5000mA}{1050mA} = 4.43hrs$$

Hence, the battery can power the LEDs for $4.5hrs$ before requiring any re-charge. Nevertheless, it is good principle to leave 25% charge on a battery. Therefore, we suggest $3.30hrs$ duration for the using of the LEDs before charging the battery.

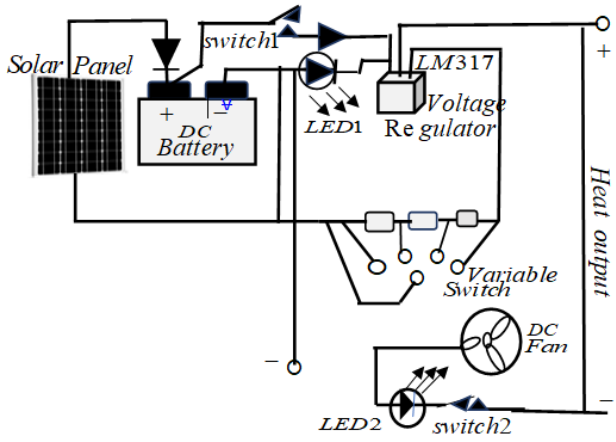

Figure 5. The complete Wiring Diagram of the Multipurpose Charcoal stove

The charcoal stove assembly

The various parts of the charcoal stove are as shown in Figure 6 the advantage of this construction is that parts are all on stand-alone and can be assembled with metal screws. Another advantage is that the stove can be easily packaged for shipping. The electronic circuit of the stove is housed in a metal casing and protected from the heat from the stove when the DC fan is functional. The LEDs indicators, the fan switch and connectors were carefully brought out from the casing through holes made on the body of the casing. Appropriate provision was made for the input cable plug connecting the solar power source to the terminals of the electronic circuit.

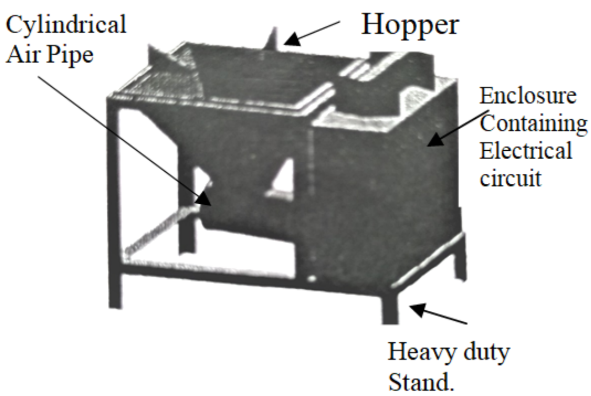

Figure 6. The Total Unit of the Multipurpose Charcoal Stove

RESULTS AND DISCUSSION

The effectiveness of the unit was tested by carefully attaching the J-type thermocouple to the cooking utensil when the unit was in use. This was to determine the heat read out as the unit was being tested. The hooper was loaded on two separate occasions with $500gm$ and $1kg$ of wood charcoal respectively. To determine what amount of heat could be generated, the quantity of charcoal is increased or decreased. Again, the voltage regulator was also adjusted to determine three different speeds of the DC fan motor. The heat of the J-type thermocouple was also taken when no dc fan motor was in use. This readout provided a reference to all the measurements taken. The result will be discussed under four headings as shown in Figure 7.

1. Without making use of the cook fan, and with $500gm$ of charcoal fuel, the stove was able to generate maximum heat of about 259^{0}C of heat in 70 minutes. In relatively about 35 minutes the stove was able to boil a medium size kettle of water at 100^{0}C. after about 70 mins, the peak heat could not be sustained, and the heat begins to depreciate. However, the maximum heat production could have been sustained or increased by adding more charcoal fuel.
2. When the stove fan was turned ON and the regulator switched to speed number 1, the level of heat produced increased. The maximum heat produced was about 380^{0}C after about 115 minutes. The medium size kettle of water reached boiling temperature in an improved time of 25 minutes. The maximum heat generated was sustained because of the activities of DC fan at speed 1 and it started dropping off after about 115 minutes.

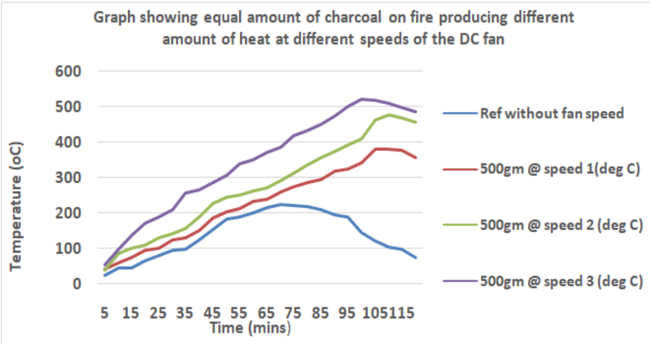

Figure 7. Showing the effect of the stove fan and the amount of heat produced against time.

3. When the cook stove fan was turned ON and regulated to speed 2, the heat produced also increased. The maximum heat produced was 460 ^{0}c after about 110 minutes. The medium size kettle of water reached boiling temperature on a much-improved time of 15 minutes. The maximum heat was sustained because of the fan up to about 110 minutes when it started to drop off.
4. At speed 3 of the fan, the charcoal stove was able to produce a maximum heat of about 523^{0}c. This heat level was produced in about 100 minutes, and thereafter it started dropping off. At this temperature, some metals like aluminum with low specific heat capacity could melt, adding to definite advantage of the cook stove. The medium size kettle of water reached boiling temperature at about 10 minutes. This was a much-improved time for boiling the water in the medium sized kettle.
5. The multipurpose charcoal stove has the added advantage of additional lighting points which could serve to light up energy bulbs for illumination during dark hours. The energy reservoir would come from the DC battery which stores up solar energy harvested by the solar panel. Nevertheless, an increase in the number of solar panels and the capacities of the battery would elongate the usage of the multipurpose charcoal stove during dark hours.

Conclusion

The design of the multipurpose charcoal stove was conceived with a view to producing a stove that could not only be affordable but could be used in remote areas for multipurpose activities. The Multi-purpose charcoal stove comes with a comparative heat advantage at temperatures above 160^0 C when compared with stoves using gas bottled in cylinder. At this temperature the pressure inside the cylinder becomes high enough and can lead to an explosion. Because of the stand-alone nature employed in the design, the cook stove is easy to assemble and use. This makes it ideal for outdoor use.

Further works

We suggest that the installation of the heat sensing element (thermocouple) be made more permanent. This is to help the user have a good guess of the cooking temperature when the stove is in use. We also recommend that for effective usage the lead-acid battery could be replaced with a deep-cycle battery. This helps the cook stove to withstand any variations in the circuit current/voltage that may result from malfunctions or wrong connections. We also recommend that the positive rail of the connection from the solar panel could be connected to the electronic circuit of the cook stove through a power diode e.g. This also saves the lives of the circuit elements from excess current/voltage, especially when increasing the number of the panels.

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